Final Report

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IPRO 320

The Greenhouse Project

http://www.iit.edu/~ipro320s05

Project Team

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Sponsor: IIT Collaboratory for Interprofessional Studies in collaboration with the Chicago Center for Green Technology and the Chicago Community Gardening Program

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Project Background:

The City of Chicago created the Center for Green Technology to demonstrate and promote what they termed “green” technology; it includes a solar cell manufacturing facility and several city offices. The building was rehabilitated to meet LEED standards. LEED is an accrediting program that validates that a building employs “best practices” with regard to sustainable development. As part of the design, the city designed and built a solar greenhouse. Though the greenhouse has been monitored to determine if it met the energy conservation goals, it has never been used to grow plants. Ultimately, the greenhouse, when functional, will be able to aid the surrounding community by providing free plants to its citizens.

In order to make the greenhouse run at an optimal level, many changes will need to be made to several parts of the greenhouse. These changes include but are not limited to the cold frames, the head house, the thermal mass, and ventilation system.

Project Purpose:

The goals of the teams were to evaluate the current conditions the greenhouse is in, improve the structure of the cold frames and head house for general better usage of space and to increase ventilation and air circulation inside. Another general goal was to utilize the Chicago Center for Green Technology’s solar greenhouse to its maximum potential to increase the effects of the center’s annual giveaways. The team will monitor the temperature and humidity conditions within the greenhouse and use that information to find ways to improve its efficiency and functionality. In addition to making proposals to the Center for Green Technology, the team was hoping to implement some of these ideas. The team grew plants within the greenhouse to gage its current functioning and to provide some plants for the center of Green Technology’s annual and vegetable giveaway. The overall vision for this IPRO group was to make the greenhouse fully functional and efficient. Because of multiple goals, the team split up into secondary teams with more specific goals.

There were four basic teams, one focusing on weather data and interpretation, and three looking at specific areas of redesign. Redesigning the head house for maximum storage space and usage was the focus of one team. Another focused on the cold frames, which were in need of a do over in order to function properly. The third focused on adding ventilation to the greenhouse as well as methods for air circulation.

This being the first semester the IPRO was offered, our recommendations and proposals could not be implemented due to time constraints, but it lays all the groundwork for future teams.

Constraints we had to consider were permanence of solution and the current structure of the greenhouse. Because Greencorps is run bureaucratically, permanent solutions could not be tried out and then withdrawn due to failure. Lots of people have to approve any renovation or structural changes made in regard to the greenhouse; this makes it practically impossible for any changes to occur within the time frame of the IPRO semester. We got around these constraints with the decision to make recommendations for future use in stead of taking time to go through the bureaucratic process of change.

We achieved our objectives and made solid recommendations that could be implemented within the confines of the current greenhouse design. We based all recommendations on the weather data gathered throughout the semester and offered multiple approaches to solving each of the problems until solutions were found that solved the problems addressed and were complimentary to one another. Our final recommendations can all be implemented without getting in the way of the greenhouse functionality.

Project Research Methodology

The first step in determining the functional capabilities of the greenhouse at the Chicago Center for Green Technology (CCGT) is to monitor existing conditions to see if the environment is suitable for growing plants. A greenhouse is expected to receive an adequate amount of direct sunlight and absorb heat to maintain temperatures suitable to plant growth throughout the day and night. This is especially important in passive solar greenhouses, such as that at the CCGT, which do not employ any energy-intensive means of environmental control such as active heating and cooling (i.e. air conditioners, humidifiers, etc.). The greenhouse does, however, have thermostatically controlled windows and a side-vent. The vent is open all the time; the operation of the windows is monitored for coherence with the true conditions in the greenhouse.

The goals of the weather monitoring can be summarized as the following:

- Determine thermal retention capability of the greenhouse
    - Is the environment conducive to plant growth?
- Test efficiency of existing passive cooling system
    - Is the thermostat a reliable device?
    - Do the windows open and close appropriately?
    - Is the existing passive cooling system adequate?

Monitoring the Greenhouse

Greencorps Chicago provided a weather station to aid in the monitoring of greenhouse conditions. The following tools were available for our use:

- Oregon Scientific WMR968 Wireless Weather Station including:
    - 1 Indoor temperature and humidity gauge
    - 1 Outdoor temperature and humidity gauge
    - 1 Anemometer (wind gauge)
    - 1 Rain gauge

Anticipating the need of more data points and the ability to automatically record the collected data, IPRO320’s first recommendation to Greencorps was the purchase of additional temperature gauges and the software package Virtual Weather Station by Ambient Weather.

The anemometer was modified to interface with a simple wire-contact mechanism to determine when the windows are opened and closed: the anemometer registers as north when the windows are closed and south when the windows are open. Upon obtaining the additional sensors and making the modifications to the anemometer, the weather station went on-line on March 2, 2005 and began collecting data. The sensors were implemented according to Figure 1. The inside temperature sensors are placed within the upper shelf inside the greenhouse to measure ambient temperature while being shielded from direct sunlight. The outside temperature is measured on the north side of the building, shaded from direct sunlight. The anemometer is mounted near the windows and acts as the window sensor.

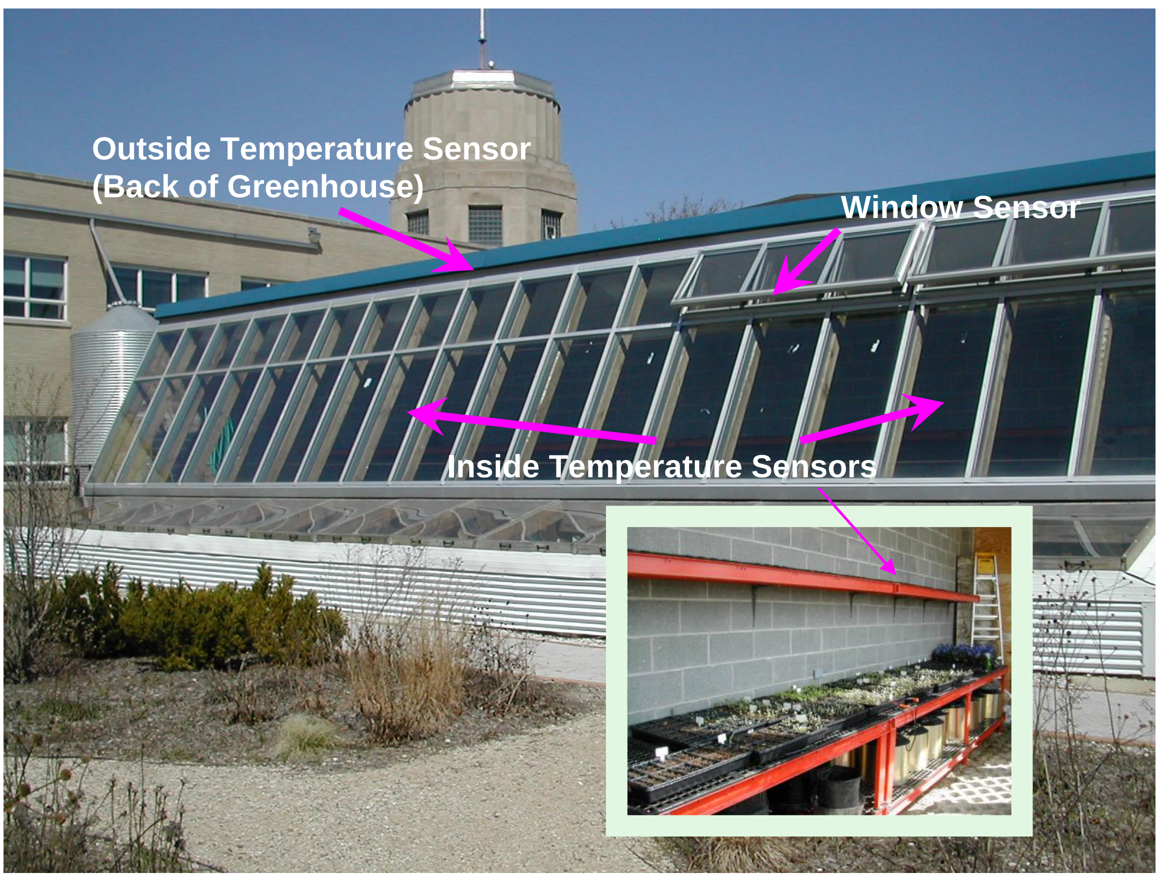

Figure 1. Sensor Placement

Assignments:

In order to most efficiently work on this project, the IPRO 320 team divided itself into eight separate sub-groups:

- **Cold Frame Redesign:** Eric Heischmidt, Aaron Teefey, and David Choi.
- **Head House Redesign:** Eric Heischmidt and Noah Smith.
- **Sensor Technology:** Chris Palmisano and Greg Waliczek.
- **Thermal Mass Modifications:** David Choi and Dan Carroll.
- **Outdoor Ventilation Redesign:** Alex Chu.
- **Seed Selection and Planting:** Megan Popielarz.
- **Team Website:** Ed Carter and Megan Popielarz.
- **IPRO Deliverables:** Dennis Bahena and Ed Carter.

Although the small groups of team members were responsible for their respective tasks, the IPRO 320 team as a whole collaborated to assist and ensure that tasks were accomplished, as well as that all information within deliverables was and is true and correct.

Barriers and Obstacles:

Thanks in large part to the much appreciated full cooperation of our sponsor, The Chicago Center for Green Technology, and due to the invaluable assistance given to us by our outside consultants, the IPRO 320 team faced relatively few obstacles.

One of the first obstacles we did face was with regards to the wood mullion system in the greenhouse. It appeared that the wood and aluminum mullion systems were redundant. Unfortunately, however, we were told that removing the wooden system was not an option. As a result, the wood frames were blocking some valuable sunlight. Therefore, the IPRO 320 team had to come up with non-traditional ideas for resolving this problem.

Another major obstacle the IPRO team faced was the Yahoo! Groups. Because the project relied heavily on architectural drawings, models, blueprints, and pictures, by the end of the semester we had many large files that needed to be shared with the rest of the group. Unfortunately, the Yahoo! Groups has a limited amount of bandwidth which we exceeded three days before IPRO day. This last minute lack of bandwidth threatened to sabotage our efforts, however, one of our team members had access to a Google Gmail account, which was then used as a group file sharing device.

Similarly, one of the other obstacles to success faced by the IPRO 320 team was from the Office of Technology Services. Since a student is unable to request IPRO web space from the Office of Technology, all requests had to go through our IPRO instructor's office. The Office of Technology required that our web space request be made from the instructor's phone. Unfortunately, our IPRO instructor does not have a phone in his office, and as a result, he had to find spare time to personally go to OTS to make our requests.

Another major obstacle facing the IPRO 320 team was simply a lack of experience on behalf of all of the team members with regards to the way solar greenhouses operate. Luckily, our IPRO team instructor was well-versed in solar heated greenhouses and other environmental aspects of the project. Moreover, one of our outside consultants, Dr. Elizabeth Britt, head horticulturist at The College of DuPage was very knowledgeable and helpful to us regarding different methods of ventilation that many greenhouses utilize. Finally, our other outside consultant, architect Roald Gundersen, has a long history involving solar greenhouses and his input was invaluable to our project.

Results and Conclusions:

Our data collection went successfully and the IPRO 320 team made several findings that would contribute to the recommended next steps.

The difference between the temperature inside the greenhouse and the temperature outside the greenhouse was due primarily to the amount and duration of sunlight. Thus the greenhouse was very warm in the mid-afternoon and much cooler in the evening hours. This was mainly due to the fact that a hollow concrete masonry wall was used in lieu of the solid rubble wall specified on the construction documents. The solid wall was designed to serve as a “tromb wall” which would store the heat from the sunny parts of the day through the night creating somewhat of a “time-released” effect that would allow the greenhouse to maintain a satisfactory temperature throughout the dark, cool hours.

Because the air rather than the mass of the structure is heating up, there was an extreme fluctuation in the temperature data from daytime to nighttime that we recorded from inside the greenhouse. Significant air leaks in the structure and insufficient insulation were also major factors in the spiking effect of the temperature data which is available on the IPRO 320 website www.iit.edu/~ipro320s05.

The air leaks also posed a problem with controlling the ventilation within the greenhouse. When there are as many significant leaks as this greenhouse currently has, all of the warm air that is collected during the day will escape by dusk. The greenhouse was equipped with an operable window system that was supposed to be regulated by a thermostat directly under that window. These windows do open occasionally, but they do not accurately react to the temperature in the greenhouse. The open windows did not contribute significantly to the cooling of the greenhouse. Moreover, the original wooden structure and the later installed aluminum curtain wall seem to be structurally redundant and are casting shadows on the plants blocking valuable sunlight and inhibiting the maximum solar energy from reaching the back wall.

Finally, the cold frame doors are inoperable due to the addition of the aluminum curtain wall above them, and there is an insufficient rodent and temperature barrier between cold frames and the inside of the greenhouse.

Recommended Next Steps:

Based largely on the findings we made from our data collection as referenced above and from consultation with our consultants and instructor, the following steps should be implemented either by The Chicago Center for Green Technology, or by a future IPRO group:

- Fill the CMU (cinder block) wall with sand so that it will act as a tromb wall which absorbs the heat of the sunlight during the day, and stores that heat until the evening hours when it will act like a large radiator and supply sufficient heat to protect the plants from thermal shock.

- Seal off all of the air gaps between the greenhouse and the exterior and storage areas.

- Have the wooden structure inside of the aluminum curtain wall analyzed by a structural engineer and remove it if possible. If it cannot be removed it should be covered in a reflective material such as reflective duct tape or paint.

- Add rigid insulation between the greenhouse and the cold frames, and bury this insulation a minimum of 18-24 inches below grade.

- Protect the insulation and the entire greenhouse including the cold frames with a buried rodent barrier. The rodent barrier should be buried a minimum of 24 inches vertically around the perimeter of the greenhouse as well as horizontally below the floor of the greenhouse. It should be installed without gaps to insure that there is no infestation.

- Redesign the head house so that it serves as a functional weather station, public entrance to the greenhouse and transition area for handling plants, seeds, etc.. In the new design we would recommend a slop sink with an adequate catch basin for washing containers and general water service, increased storage including an overhead storage loft, and a weather station via a personal computer with a network connection so that weather data can be posted on the Chicago Center for Green Technology website. We would also recommend sealing all air gaps, insulating the space, and updating the finishes with drywall and possibly CCGT graphics to make the head house more inviting to the public.

- Increase the ventilation control within the greenhouse by disconnecting the current operable windows from the system and adding a new set of fans that would do a better job of precisely controlling the ventilation. We recommend running a duct under the peak of the head house roof which would serve a 250cfm inline duct fan that would be mounted in the wall between the greenhouse and head house and serve as an exhaust fan. A larger, 3,000cfm, exhaust fan should be mounted above the operable louver at the opposite end of the greenhouse, and an intake should be created through one of the central cold frame bays and it should be controlled by an operable louver. This system will provide an ideal ventilation pattern in the greenhouse as the cold air will enter low and in the middle of the greenhouse and hot air will be exhausted near the ceiling and at either end of the greenhouse. The different sized fans will allow for accurate control of the air flow.

- Redesign and or modify the cold frames so they are useable. We recommend fixing the top panel of the cold frame which is currently the access point and creating an access point on the front panel where carts can be wheeled in and out.

Acknowledgments:

Mr. Aaron Durnbaugh, Director, Chicago Center for Green Technology, for allowing us to collect the data we needed from the greenhouse and for supporting our efforts and suggested changes.

Ms. Elizabeth K. Britt, Supervisor Horticulture, College of Dupage, for aiding us in the selection of plants for growing in the greenhouse, as well as for her assistance in learning about appropriate ventilation systems.

Mr. Roald Gundersen, Architect, for his assistance in understanding the blueprints for the greenhouse as well as for helping us to learn what is and is not necessary and optimal for the operation of a solar heated greenhouse.

Mr. Frank Wachowski, National Weather Service, for his assistance with the weather sensors.

Mr. Tie Conn, Technical Consultant, for his assistance in setting up the message board system on the IPRO 320 website.

References and Resources:

FarmTek Catalog, June 30, 2005, issue, Dyersville, IA.