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Sustainable Village

IPRO 301 – Fall 2005

Final Report

EXECUTIVE SUMMARY

Politicization of resources. Climate change. Social inequality. Urban pollution. Increasing health risks. Ecological instability.

There exist many problems in this world related to the misuse of natural resources and the current world reliance on the burning of fossil fuels in order to keep the economies of the world running. Although scientists and politicians will argue for decades to come over the impact of burning fossil fuels and the forecast for the depletion of these resources, there is little debate that there is an impact to burning fossil fuels, and that they are a limited resource. The great challenge to the societies of the world lies in how the people of today will provide for the people of tomorrow. Will today's society of consumption leave a world depleted of natural resources and rife with undrinkable water, dangerous air, and unstable weather and ecosystems? Can efforts to curb consumption, to maximize the efficiency of resource use, and to clean up the air and water systems of the world make a difference not only in the quality of life of this generation, but also the next?

IPRO 301: Sustainable Village at the Illinois Institute of Technology sought to answer those questions, as well as many others. In doing that, the project group analyzed the current condition of consumption at IIT, developed a plan for achieving sustainability at IIT, and designed a building to serve as the model for applying sustainability. By applying the concepts and technologies present in the House of the Future, and by following the Roadmap proposed by the team, IIT will begin the process of becoming the most sustainable campus in the most sustainable city in the world. In order to successfully start the process, the IPRO team divided into two sub-teams: the Sustainability Team and the House Team. This required intense cooperation as each team began to produce results, requiring that the concepts and recommendations be focused in a way that is meaningful and achievable. Through this, the group exemplified that achieving sustainability will require cooperation across ideological, intellectual, social and political divides, as well as the patience and courage to recognize and adopt the policies that will make a true difference.

The Illinois Institute of Technology needs to address its ecological impact and work with local agencies, university officials, and the campus community to encourage others to replicate the efforts that can be undertaken to improve the school. The school has already formed an Energy and Sustainability Institute, and currently offers a degree program in Energy/Environment/Economics that seeks to produce professionals who understand the interrelation among environmental stewardship, energy needs, and economics/affordability. Taking this a step further, the students of IPRO 301 have developed a plan for making IIT a sustainable campus. This report details the findings and makes recommendations for immediate and long-term solutions to the problem of making IIT a "Sustainable Village".

Part 3 of this report summarizes the need for sustainability, both globally and at IIT. In this discussion, key areas of concern are identified, including air, water, fuels, electricity, waste and people. Continuing this idea, part 4 looks to the vision of sustainability by defining sustainability in terms of the environmental and social impact made by people in their lives. The definition of sustainability takes shape in the form of seven sustainable philosophies; these philosophies form the foundation for decision-making and planning at IIT and offer guidance in how each and every aspect of daily life can be made sustainable. The philosophies are summarized as follows:

- Move from being a consumer to producer
- Utilize waste streams as resources
- Conserve, optimize, maintain
- Eliminate the burning of fuels
- Encourage public participation
- Treat energy as capital, not as a commodity
- Identify and develop the Green Unit

With the sustainable philosophies as a foundation, part 5 introduces the Roadmap to Sustainability, focusing on an action plan for achieving sustainability at IIT, as well as the development of infrastructure for making the process of sustainability, well, sustainable. The action items and Roadmap provide recommendations for turning the sustainable philosophies into reality. The ultimate example of this implementation is the “House of the Future”, introduced and defined in part 6. The “House of the Future” will demonstrate how the Green Unit philosophy – the idea that to make a campus sustainable, one must make each fundamental unit as sustainable as possible first – is applied successfully. The “House” will serve as an example not only to those seeking to make their own homes sustainable, but also to organizations, companies and governments who want to make a change in how they approach sustainability. IIT, through building the “House of the Future” and implementing the Roadmap, can take a leading role in making the City of Chicago, State of Illinois, and even the United States of America, sustainable – one fundamental unit at a time.

After offering conclusions in part 7, the report details possible future steps to be undertaken in order to further the implementation of the recommendations contained in the other sections of the report. Part 9 includes the acknowledgements for the report and part 12 the references, and Parts 10 and 11 include the background information that supported the teams as they researched sustainability. Part 10 has a summary of benchmarking that was done against other university programs, as well as a detailed analysis of the present state of consumption associated with the university. In part 11, one will find all of the research that went into selecting technologies and strategies available for implementation in the "House of the Future".

In addition to this report, the IPRO 301 team produced a website (www.iit.edu/~svillage) that offers a resource to those inside and outside the university who wish to make a difference.

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1 TEAM MANAGEMENT

In order to tackle the vision of how to make IIT sustainable and how to design a “House of the Future” incorporating various sustainable ideas and technologies, two major and two minor teams were created. The two major teams consisted of a Sustainability team and a House. All team members, except the group leader were placed in one of the two teams. The two minor teams consisted of a Website team and a Knowledge team. Certain individuals volunteered to be part of these teams.

1.1 Sustainability Team

The tasks assigned to the Sustainability team were to: perform fundamental research in the area of sustainability, benchmark IIT against other universities that claim to be in sustainable development, audit IIT to see where IIT is currently standing and, based on this research, create a roadmap for IIT on how to become sustainable.

The Sustainability team faced many obstacles while trying to accomplish their tasks. One of the bigger obstacles that the Sustainability team faced was communication problems and not being able to fully grasp the vision of sustainability at first. At first the team was given some direction and an end product that needed to be achieved. But since the project dealt with a lot of research, the aim in the beginning of the project was unclear until enough information was gathered to fully know the direction that needed to be followed.

Other obstacles that the team faced were that each team member had a different vision of what the end product was going to look like. Communication between the team members on this issue was not sufficient at first, but was quickly solved once this problem was identified.

A third obstacle that the Sustainability team faced was being able to gather information from the faculty body at IIT. At first considerable amount of time was required to contact and receive information from the faculty and staff body. It was underestimated how long this process would take, but once the various faculty and staff members were contacted and were responsive they were willing to provide a lot of the much needed data to help audit and benchmark IIT.

1.2 House Team

The tasks assigned to the House team were essentially to design a house that is truly sustainable and looks appealing to the general student body and population to inspire them to think in sustainable terms.

The major obstacles that this team was faced with were very similar to those faced by the Sustainability team. Provided the openness and visionary style of this project each individual team member had a different idea of how the House of the Future should look like. This partly promoted a very dynamic process throughout the semester which was hard to stay on top of things at times.

One difficultly that was faced was that at first this project should be treated as a vision and that everything was possible. When it came to choosing the site location of the house a location was chosen with that mind site. It was rather frustrating to be told shortly thereafter that the location of the House of the Future could not occur at that place but needed to be at another site. Overall the difficultly was that it would have been more efficient if this was told to the team at first. On the one hand side one is told that almost everything is possible, but when one makes a proposal, one realizes that thoughts have already gone into certain things from people outside of the team and it would be easier for the team to have known about these ideas beforehand.

A more global difficulty that arises more for the sub-team leader is how to include the advisors into the team. The advisors bring along a lot of knowledge and know-how that is crucial for the project and is greatly appreciated. The problem arises though that the team indirectly tended towards treating the advisor as the sub-team leader and therefore undermining the effectiveness of the actual sub-team leader.

1.3 Website Team

The task that was assigned to the Website team was to create a website that would accurately display the results of the project and make it intuitive and informative so that an every day user can take some useful information from it and be able to take the first steps towards sustainability in their lives.

One of the difficulties that the Website team was faced with, was that the designing and discussing of its features started too late in the semester. It would have been easier for the team to have started earlier. Another difficulty that came up was that the expectations of the website changed over time. Part of these difficulties came about due to unclear communication and was swiftly resolved by setting aside a larger portion of the regular meeting time to thoroughly discuss the matter. Another difficulty that rose out of the poor communication between the Website team and the Sustainability and the House team was that the information needed for the website was only obtained by the Website team a few days before the deadline.

During the creating of the website it was further noticed that the initial plans for the website were a little too ambitious. It was therefore necessary to postpone a few elements of the website, such as the full knowledge base and the campus map with updated statistics for the EnPRO that will be working on this project next semester.

1.4 Knowledge Team

The purpose of the Knowledge team was to collect all the information and documents created throughout the semester so they would be available to the next team that will be working on this project. Overall the major obstacle that this team faced was that besides working on the major tasks of this project it was hard to find the necessary time to compile an easily understandable and accessible database that would be intuitive enough for easy extraction of the information.

1.5 Conclusion and Future Recommendations

As a general conclusion it can be stated that from a project point of view the expectations and goals that were set forth at the beginning of the semester were very ambitious for a team of only 11 students and advisors. It might have been a better idea to split this project into two separate projects. In a first step more research could have been performed due to an increase in manpower and then in a second step the House team could have solely focused in incorporating the ideas formulated by the Sustainability team in the previous semester.

It can further be concluded that the advisors were very crucial to the success of this project as they posses information that can only be obtained through advanced knowledge and experience which the undergraduate student do not necessarily possess. Therefore, for future IPROs it would be highly recommended that the project is actively monitored and supported by a few advisors that are active in the area of research of the project.

From a team management point of view a statement can be made that the group forming and selection of the team leaders at the beginning of the project is crucial to the success of the project. It would be beneficial to the team and the project that before the project is tackled all the students perform a self-evaluation and evaluate where their strengths and weakness are relative to this project. The team members should then be grouped into areas of interest and abilities that will minimize complications and create an environment were all students in the team can work on the same task as they possess the necessary knowledge. This of course, due to the nature of the IPROs, is not always easily achieved and one needs to comprise. Ideally team leaders and sub-team leaders are selected due to their organizational talents and their knowledge in the area of the project.

2 TEAM MEMBERS

The following list shows all the team members that worked on this project and how they were distributed among the teams. For a complete list of the sponsors and project partners, please refer to Chapter 9 – Acknowledgments of this report.

Instructor:

Prof. Said Al-Hallaj

Advisors:

Anand Sathyan

Darcy Evon

Elena Savona

Joseph Clair

Kris Kiszynski

Students:

Group Leader:	Siddha Pimputkar
Sustainability Team:	Andrew Higashi
	Bez Robinson
	Jef Larson
	Tony Thomas
House Team:	Anna Ninoyu
	Evans Ogbebor
	Mike Staats
	Philip Golucki
Website Team:	Bez Robinson
	Philip Golucki
Knowledge Team:	Jef Larson
	Siddha Pimputkar
	Philip Golucki

3 WHY IS SUSTAINABILITY IMPORTANT?

3.1 The Need for Sustainability from a Global Perspective

3.1.1 Environment

The depletion of the environment has been a major concern since the latter half of 20th century. Issues dealing with contaminated air and water, increasing waste production, the use of fossil fuels for energy and electrical energy have been at the forefront of the discussion. The next section focuses on the problems that exist globally in these areas.

3.1.1.1 Air

Air Pollution is a major contributor to the global warming effect that is going on today. Air pollution causes a change in the make up of the earth's atmosphere and over the past few decades has caused an increase in carbon dioxide gas in the atmosphere. A rise in carbon dioxide gas in the atmosphere causes a warming effect on the earth and along with it causes a decrease in oxygen gas. Air pollutants that are inhaled by people are a major cause of health problems today. Some of the health issues that arise from breathing air pollutants range from respiratory problems, to lung cancer, and even death. This has become a serious problem in our world and affects all areas of environment, even the quality of water that we drink.

3.1.1.2 Water

Water is one of our most valuable resources. A human can live a little over a month without food, but can only live for approximately a week without water[1]. Currently American's look at drinking water as an unlimited resource, that will never run out, but the fact is that pure drinking water is a limited resource especially here in Chicago. The water level of Lake Michigan, Chicago's source of water, is decreasing every year which causes unwanted effects for fishermen who keep their boats at the docks, and animals living in the lake.

3.1.1.3 Waste

Landfills take a huge toll on our environment, not only because of damage they cause when they are built and operated, but because they remove products from circulation so that virgin resources have to be mined or harvested to replace

[1] Lenntech Water Treatment & Air Purification Holding B.V., "Water Facts and Trivia," 2005, <http://www.lenntech.com/water-trivia-facts.htm> (18 April 2005).

them. Landfills waste valuable resources: for every ton of paper recycled, acres of forest are saved from clear-cutting.

In some countries with rapidly developing urbanization, waste management cannot keep up with the increasing stream of waste. Landfills that were once large enough to fulfill the needs of the community are full. This leads to a need to incinerate the waste. If a proper incinerator is not created, there is a possibility of dioxins being released upon burning of the waste.

It is prohibited by law to use as landfill waste which contains hazardous chemical materials or infectious wastes. Nevertheless, in cases of illegal dumping and improper treatment, hazardous materials may leak out from waste and pollute the nearby soil, sea, and groundwater.

3.1.1.4 Fuels

The present quality of life in the developed world comes from improved sanitation, productivity, and improved ease of transportation. All of these require energy to make them happen. For the last 150 years, the fuel for this energy was petroleum, with natural gas becoming more important over the last 50 years. These fuels, combined with their predecessor, coal, have served to provide the inexpensive energy that has allowed the technological achievements of the last century to happen. These advancements have not come without a price. Economies based on these fuels, of which the nations of the West have become dependent, gives rise to a standard of life that requires these fuels. As developing nations seek the same quality of life that the West enjoys, their thirst for these fuels will increase. As consumption increases, the availability of the fuels decreases. In addition, over the last 200 years, fossil fuel based energy has increasingly stressed the environment by introducing more carbon and pollutants that the ecosystem can handle. As the world pursues improved quality of life, the environment will be stressed further. Unless a way is found to decrease dependence on finite fuel supplies, the economies of the world, the environments of the world, and the quality of life in the world will collapse.

Fossil fuels are a finite resource. No matter how long they are predicted to be available, there will be a day when they are no longer around. Scientists have predicted that the world will begin to run out of oil and natural gas (meaning that the amount of these fuels extracted will begin to drop) starting anywhere from 1995 to 2015. The United States has certainly stopped extracting more oil and natural gas, and works continually to develop new ways to extract the same amount, or less, than it has in the past. In contrast to the decline of indigenous sources for oil and natural gas, the consumption of these fuels in the United States continues to climb, far outpacing the supply. As this trend continues, the dependence of the United States on foreign sources of oil and natural gas will affect the stability of international relations as countries vie for increasingly scarce resources. Although there are people who will state that the economy will naturally influence the development of new sources and methods of obtaining these fuels, and that international interdependence can be good, there can be no sustainability if consumption exceeds supply. Although the economy of the US presently allows for the trade of capital for resources, this scenario cannot go on indefinitely.

Oil and natural gas present problems of scarcity and security as the remaining reserves become more concentrated; of equal concern is the environmental damage brought on by the emissions from the burning of fossil fuels. At present, coal does not present the same immediate concern with regard to scarcity that oil and natural gas do, however it carries an environmental burden that surpasses the others. All fossil fuels produce carbon dioxide and various amounts of NOx and SOx. “Clean-burning” fuels like natural gas produce little in the way of NOx and SOx (the primary culprit in acid rain), however they still produce significant amounts of carbon dioxide. Coal produces not only carbon dioxide, but also NOx, SOx and particulates. Particulates are a major cause of asthma and other lung-related illnesses that have become an increasing problem in health care. The continued use of fossil fuels as a source of energy will cause environmental and, subsequently, health-related issues that justify investigating other ways of transferring energy.

3.1.1.5 Electricity

At first thought, the common person does not realize how much pollution consuming electricity causes. Pollution may be a concern of many people, but the figures are not known by to make an impact on the way people live. For every megawatt-hour of electricity consumed, ComEd produces 657 pounds of CO_2. The average amount of CO_2 absorbed by the typical North American tree in its annual growth is 14.7 pounds. Pollution is not only harming nature, but it is having a direct affect on humans. For example, the Crawford and Fisk power plants in Illinois are linked to an average of 41 deaths, 550 emergency room visits, and 2800 asthma attacks annually. Some of the reasons for this health issues are because the power plants are not well maintained.

3.1.2 Social

There are numerous social problems such as poverty, disease, injustice, illiteracy, and political power struggles around the globe that plagues society. For there to be any hope for the future these issues must be attacked head-on. The previous sections have focused on the degradation of natural resources, inefficient use of energy, and the production of wastes, yet even beyond the efficient use of resources must come the well-being of human beings; these subjects are inherently intertwined. This next section will focus on what are the problems that do exist in the world today and will show the deep need for social reform through global sustainability.

3.1.2.1 Poverty

Living in an industrialized country can often lead the people there to believe that poverty and hunger is not a pressing problem around the world. Yet, a global scan of the statistics will reveal otherwise. The world today has 6.39 billion people which are split into three major categories: industrialized world, developing world, and countries in transition. Here is a table summarizing the current conditions in these categories:

	Number of Countries	**Population** [billion]	**Undernourished**
Industrialized	50	0.9	9 million (1%)
Developing	125	5	815 million (16.3%)
Transition	Baltic states, Commonwealth of Independent states, Eastern Europe	0.4	28 million (7%)
Total	World	6.39	• 852 million (13.3%) undernourished • 1.2 billion (18.8%) live in “absolute poverty” making less than $1/day • 3 billion (46.9%) live in “poverty” making less that $2/day

Table 3.1: Statistics on World Poverty[2]

A lack of nourishment affects people’s health, productivity, sense of hope, and overall well-being. Since the undernourished continually seek food, it requires more time and energy for basic survival and gives less time to work and earn a steady income. From an emotional perspective, the result of hunger is often shame and more broken relationships. Statistics show that one child dies from hunger or a related cause every five seconds. Sadly, statistics also show

[2] Bread for the World Institute, “International Facts on Hunger and Poverty,” 2005. <http://www.bread.org/hungerbasics/international.html> (13 April 2005).

that there is sufficient food in the world to feed everyone.[3] It is once again a problem of inefficient use of resources.

3.1.2.2 Disease

The problem of disease in the world is probably the most pressing issue with the HIV/AIDS epidemic occurring in many developing countries. AIDS first appeared in the early 1980s and since that time nearly 20 million people have died from the disease. The estimate is that nearly 40 million people now live with AIDS and will die from it in the next ten years. Of that 40 million, 25.4 million live in Sub-Saharan Africa.

Other health problems are tuberculosis, malaria, and maternity and birth related disease. Tuberculosis affects 40 million people in the world and 2 million people die each year from the disease. Malaria infects 300 million people a year and 1 million people die each year from it. Pregnancy and childbirth are the leading causes of death among women of childbearing age in the world today as 300 million obtain diseases during this time and 529,000 die from it each year.

3.1.2.3 Social Injustice

Beyond the problems caused by factors largely outside of much human control, such as poverty and disease, there are problems inflicted upon humanity by ourselves. Power-hungry governmental regimes, terrorism, poor labor conditions, racism, and a lack of women's rights are just a few of the many injustices. The root of many social injustices come from deeply-rooted ethnic or class discriminations that lead the abuse of power. Many problems also stem from a lack of equity in resources and economic power. The root of many of these economic inequities are the international free trade system which favors richer countries, the lack of aid relief to poorer countries, and a lack of debt relief for poorer countries.

3.2 The Need for Sustainability at IIT

3.2.1 General

Until climate change, pollution or resource depletion affect the daily lives of people, they remain relatively unaware of the footprint they leave on their world. Although IIT remains a leader in cutting edge technological development, this leadership has not translated into a commitment to reducing consumerism or the

[3] United Nations, "World Food Programme," 2005, <http://www.wfp.org/country_brief/hunger_map/map/hungermap_popup/index.swf> (13 April 2005).

ecological impact of the school. As the campus maps in Figures 3.1 and 3.2 show, IIT leaves a significant mark on the environment.

The campus uses 127 million gallons of water each year above and beyond the daily needs of the students, faculty and staff.

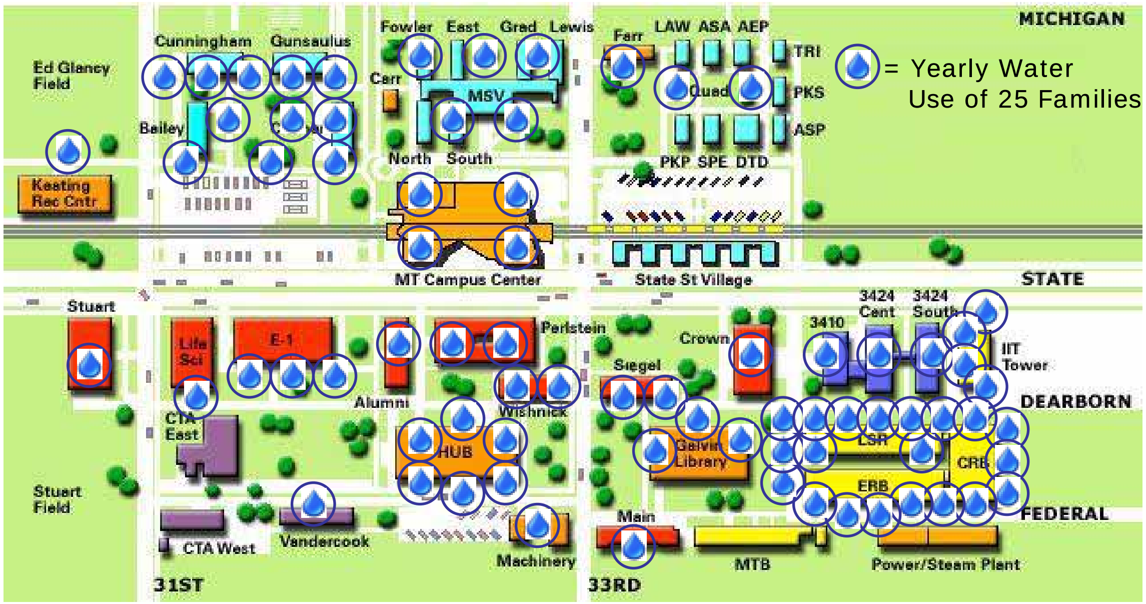

Figure 3.1: The IIT Main Campus Ecological Footprint - Water

To sequester the greenhouse gas emissions produced as a result of IIT's main campus, 1.3 million trees would have to be planted each year

Figure 3.2: The IIT Main Campus Ecological Footprint – Greenhouse Gas Emissions

Section 9 has more detailed information on the campus audit and the impact IIT has on the environment. It also contains the sources for the calculations used to determine the environmental impact.

3.2.2 Environment

3.2.2.1 Air

Air quality in universities and businesses is vitally important to sustainability. The reason is that with increased air quality and airflow, people are able to function better and productivity is increased. In casinos oxygen is purposely pumped into the rooms and air quality is an important issue, because the more oxygen that is breathed in, the livelier people feel. This works the same with lectures and classes. The better the air quality in the classrooms, the easier it will be for students to stay awake during class and the more they can learn. This will result in an increase in reputation of IIT at producing quality engineers and will therefore result in increased enrollment.

3.2.2.2 Water

Approximately three feet of rainwater is poured down on Chicago every year. The rainwater that flows through IIT, flows into the city drainage system and then gets treated and dumped in the Illinois River. This water will eventually end down south in the Gulf of Mexico leaving Chicago with less water then it started with. This leaves IIT depending on Lake Michigan, a finite constantly decreasing reservoir of water, for all of its water. IIT has no water conservation program and continues to allow gallons of fresh drinkable water to be poured out on the landscape during a thunderstorm. These problems at IIT contribute towards the problems that occur with a decrease in water and will eventually contribute to the bigger depletion of clean drinking water in Chicago.

3.2.2.3 Waste

IIT is a large contributor to landfills. The IIT laboratories produced 9,657 lbs of hazardous waste and 4,620 lbs in 2004. Sodexho throws away approximately 25, 50-70 gallon bags of food/kitchen waste daily. IIT does attempt to recycle. IIT's recycling program follows the city of Chicago's recycling efforts. The bags of recyclables collected are placed with the bags of garbage collected to be filtered out of the waste stream upon arriving to the waste plant. This process is not as successful as it should be.

3.2.2.4 Fuels

The primary direct consumer of fossil fuels on the campus is the main steam plant. Building utility costs are directly related to the steam consumed by the building, regardless of packaged HVAC equipment or cooking equipment in the building that consumes natural gas. As the primary source of heat and a source of cooling for some buildings, the steam boilers run continuously throughout the year. As natural gas becomes scarcer, and prices rise, the steam plant will come under greater pressure to perform more efficiently. At current usage of almost 170,000,000 pounds of steam for the campus, it leaves IIT with an overall energy density of 167,800 Btu/square foot for natural gas and 217,915 Btu/SF for natural gas and electricity combined[4]. According to the Energy Information Administration, for buildings of similar size and region, the campus energy density should be 34,300 Btu/square foot for natural gas and 91,300 Btu/square foot overall[5]. With window air conditioners providing a predominant source of cooling, and their installations requiring physical manipulations of the window openings, the integrity of classroom and office exterior walls are less than adequate. When accounting for the age and condition of the rest of the exterior wall structure, the older buildings require an inordinate amount of heat to maintain thermal comfort. In addition to the steam generation, the university maintains a combined heat and power plant that consumes natural gas in order to produce electricity and waste heat to offset the steam plant. This plant does not presently operate due to an agreement with the electrical utility, however when that agreement runs out, the university could choose to recommission the plant into service.

In addition to the steam plant, which is the primary fuel consumer on campus, there are package heating equipment (e.g. rooftop HVAC units) and cooking equipment. They represent a significantly smaller load, and are generally not accounted for when the utility costs are distributed by building. However, they still rely on natural gas, and their operation causes the release of carbon dioxide into the atmosphere.

In addition to the natural gas used for campus heating, gasoline used for transportation, both direct and indirect, accounts for a significant amount of fuel usage. Direct transportation relates to the fuel necessary for the staff and students of the university to commute to and from the campus, for the shuttle buses to and from the downtown campus, and for the vehicles that transport students and staff to and from university events. Indirect transportation refers to fuel required to move goods and services to and from the campus. Trucking, rail and air fuels required to bring books, food, paper, equipment, etc. to the campus represent a significant energy cost due to the existence of the university. At present, there are approximately 900 faculty and staff who commute to campus

[4] According to utility bill information from IIT’s Facilities Department
[5] “1999 Commercial Buildings Energy Consumption Survey”, Energy Information Administration, 2001

daily, for an average travel of 10 miles per commuter. In addition, the average student lives outside the Chicago metropolitan area requiring them to travel that distance an average of ten times a year. In addition, there are 20 shuttle bus trips daily between the main and downtown campuses, and in an average year, there are at least 300 trips of at least 50 miles round trip taken by university student organizations for school related events. The approximate direct transportation fuel usage for the university is summarized in the table below.

	Total Number	Commute (miles)	Trips per year	Yearly miles	Fuel used @ 20 mpg (gal)
Undergraduates	3,125	500	6	9,375,000	468,750
Graduate	1,815	400	4	2,904,000	145,200
Faculty (full-time)	325	10	10 trips per week at 42 weeks	1,365,000	68,250
Staff	600	10	10 trips per week at 42 weeks	2,520,000	126,000
Campus Total	5,865			3,885,000	808,200

Table 3.2: Approx. Transportation Fuel Usage for IIT

Indirect transportation includes the energy required to transport goods and services to the university. As an assumption, indirect transportation can account for almost 20% of the fuel necessary to operate the university.

The university consumes directly, in an average year, 498,190 million Btu of natural gas and over 800,000 gallons of gasoline, releasing over 100,000 tons of carbon into the atmosphere each year.[6] With the cost of fuels increasing, the university can expect that fuel usage will represent an increasing burden on the economic stability of the campus. In addition, the ecological damage caused by the release of carbon and pollutants into the atmosphere cannot presently be reversed. IIT alone, in a given year, produces as much carbon as can be sequestered by 1.3 million trees planted each year.

In order for IIT to become a sustainable institution, and build a model Sustainable Village, the sources of energy must be renewable. In heating, cooling, transportation and every other form of energy that now presently relies on fuels, the campus must move toward sources that are local, reliable and economically feasible.

In our area, the sun produces approximately 3.8 Btu/ square foot. Given the campus area at approximately 484,000 square yards that means that almost

[6] "Alternatives to Traditional Transportation Fuels 1994 Volume 2: Greenhouse Gas Emissions", Energy Information Administration,1994.

665,000,000 kWh of solar energy falls on the campus in a given year. Knowing that these resources are unpredictable, the university must work to develop and utilize energy transportation and storage systems that take advantage of these renewable sources when available, and allow for uninterrupted power when they are not. To facilitate a transition to renewable sources, the university structures must be improved so that they require less energy to maintain and operate.

Need for Sustainability Analysis

- Steam production consumes natural gas which is a fossil fuel
- Fossil fuel burning produces carbon dioxide which contributes to global warming
- Steam production efficiencies require analysis
    - Transmission of steam through underground piping reduces efficiency of the process due to losses in the pipes
    - Steam-to-hot water heat exchangers add another layer of efficiency loss and require maintenance and replacement
    - Steam-driven absorption chillers require the operation of the steam generation plant during the summer
- Steam pipes in the underground unnaturally heat the frost layer during the winter
- Cogeneration facility is dormant due to economic advantages
- Gasoline powered vehicles contribute to greenhouse gas emissions
- Gasoline and oil consumption reduce reserves at a rate that cannot be maintained by production and extraction as the world economy grows
- Natural gas, gasoline and oil costs will present an increasing strain on the operating budget of the university

3.2.2.5 Electricity

From looking at the ten colleges and universities which were used as benchmarks, IIT has come first in the amount of electricity consumed. IIT consumes around 40,000 MWh of electricity annually. This figure comes out to around 5,000 kWh per student/staff, or around 15 kWh per square foot. In terms of pollution, IIT is responsible for 25,716,294 pounds of CO_2 emissions per year. IIT would need 1,749,407 trees to take care of the pollution it creates.

3.2.3 Social

3.2.3.1 Leadership

"Transforming Lives. Inventing the Future". This is the vision statement at IIT and according to the current director of the Energy and Sustainability Institute, Hamid Arastoopour, is the key to sustainability at IIT as well. Sustainability requires creativity and technology which comes from science and engineering. The point then is not to predict the future, but to invest in creative and technological minds that will invent the future through sustainability.

The Energy and Sustainability Institute was developed at IIT from the vision of the IIT Energy Technology Program that started in 1985 from the efforts of Harold Linden and Hamid Arastoopour. This program eventually was renamed as Energy/Environment/Economics (E3) which continues to function as the main sustainability academic program at IIT.

The vision of the Energy and Sustainability Institute for IIT is that it will become a leading institution in energy, security, and sustainable development. The approach at IIT would be to use a "least-cost strategy to improve energy efficiency, enhance power reliability and security, minimize pollution, and continue the decarbonization of the global energy system. IIT researchers believe that the ultimate endpoint of this evolution will be electrification of most stationary energy uses with such high-tech renewables as photovoltaic, solar-thermal and wind energy, and the use of non-fossil hydrogen as the dominant transportation fuel in fuel-cell-powered electric vehicles".[7]

Part of the vision is also to make the effort interdisciplinary and collaborative amongst various programs at IIT. Also, there are plans to partner with the City of Chicago, State of Illinois, industry, national laboratories and other universities. The institute wants to continue to influence the direction of sustainability research and influence national policy and initiatives. Below represents the proposed leadership structure and interdisciplinary vision for the institute:

[7] Hamid Arastoopour and Henry R. Linden, *Illinois Institute of Technology: Energy and Sustainability Institute*, "Energy and Sustainability Activities at IIT," 2005

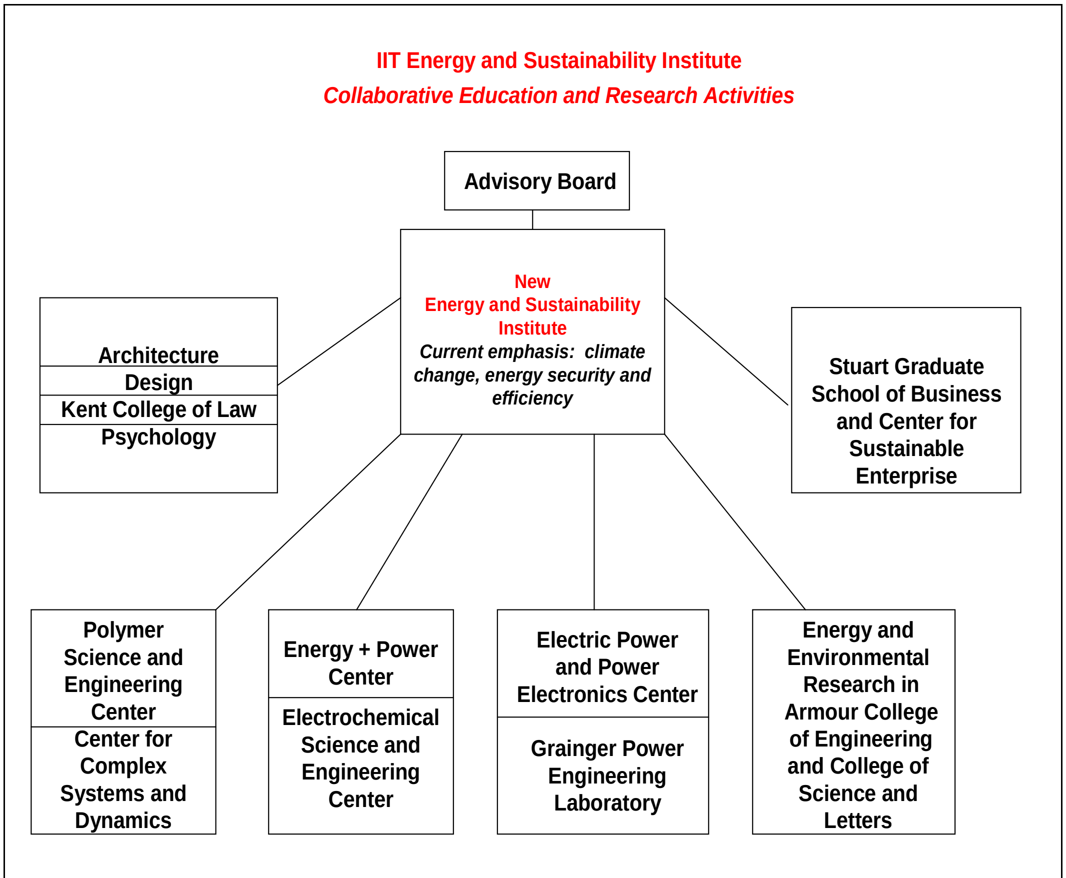

Figure 3.3: Organizational Structure for Energy and Sustainability Institute[8]

In a discussion with school administration about the topic of sustainability there were signs that they have been looking more into making IIT sustainable. The administration understands that "sustainability is good business", yet is still faced with difficult decisions that involve taking some financial risk. Currently, they see the renovation of the Chemistry Research Building (CRB), Wishnick Hall, and soon Crown Hall as the first major advances towards sustainability. One major flaw has been the lack of a policy or mission statement as it relates to sustainability for the university. Also, the new buildings that have been built on campus, the McCormick Tribune Building and the State Street Student Village, have not been made using sustainability concepts. There is legitimate concern that future buildings will follow suit. The biggest barrier that faces IIT become sustainable are the fixed costs, the time required by the process for payback, and a lack of support from enough of the IIT community.

[8] Hamid Arastoopour and Henry R. Linden, *Illinois Institute of Technology: Energy and Sustainability Institute*, "Energy and Sustainability Activities at IIT," 2005.

3.2.3.2 Education

Research

There are multiple research efforts in various disciplines at IIT in the area of sustainability. The eventual goal is that IIT could provide a living laboratory for sustainability research and have all independent researchers and projects be responsible to be practicing sustainability. Here are a few of the current sustainability research activities occurring at IIT, details can be found in the appendix:

- Energy Sources and Conversion
    - Solar Energy
    - Production of Natural Gas from New Reserves
    - Clean Coal Technology
    - Fuel Cells
    - Energy Conversion Process Modeling
- Energy Storage, Distribution, and Utilization
    - Hydrogen Storage
    - Optimal Hybridization Level for Hybrid Electic Vehicles
    - Ethanol-fueled Vehicles
    - Power and Power Electronics
    - Electric Grid Modeling
- Material and Energy Conservation
    - Recycling
- Energy Policy
    - Energy policy analysis and forecasting

Curriculum

IIT's mission statement is "to educate people from all countries for complex professional roles in a changing technological world and to advance knowledge through research and scholarship".[9] The university is broken into these main areas of academia:

[9] Illinois Institute of Technology, *IIT/About IIT*, 2004, <http://www.iit.edu/about/index.html> (13 April 2005).)

- **Armour College of Engineering**
    - Biomedical Engineering
    - Chemical & Environmental Engineering
    - Civil & Architectural Engineering
    - Electrical & Computer Engineering
    - Mechanical, Materials & Aerospace Engineering
- **College of Science & Letters**
    - Applied Mathematics
    - Biological, Chemical & Physical Sciences
    - Computer Science
    - Humanities
    - Mathematics & Science Education
    - Social Sciences
- **Other Colleges & Programs**
    - Center for Law & Financial Markets
    - Center for Professional Development
    - Center for the Study of Ethics ion the Professions
    - Chicago-Kent College of Law
    - College of Architecture
    - Distance Education
    - Engineering Management
    - Graduate College
    - Institute of Design
    - Institute of Psychology
    - Manufacturing & Industrial Technology
    - National Center for Food Safety & Technology
    - Stuart Graduate School of Business
    - Undergraduate College

The main program in place for sustainability education is Energy/Environment/Economics (E3). The goal of the program is to "respond to the rapidly changing needs of the energy industry by providing the interdisciplinary research and training required to produce a new breed of engineer—one who specializes in energy technologies and who understands the associated environmental issues and economic forces that drive technology choices".

From the standpoint of curriculum, E3 includes an undergraduate specialization, a graduate and Ph.D. program for chemical, mechanical, and electric engineering. There is an Industrial Advisory Group that maintains relevance of E3 research and education. The faculty members of E3 participate in conferences and workshops and host seminars that relate to sustainability. There is also an interdisciplinary approach to the E3 program with involvement from Chicago-Kent College of Law with its environmental and energy law program; the College of Architecture and Institute of Design with expertise in energy systems design, energy conservation, and indoor air pollution management; the Stuart School of Business with curriculum in energy economics, energy policy, and environmental management; and the Lewis College of Liberal Arts which looks at societal concerns of energy use and the environment.

The undergraduate curriculum of E3 has three main topics of courses:

1) Energy Sources and Conversion Petrochemical
2) Energy and Power Distribution
3) Energy Analysis, Economics, and Policy

There are 30 listed courses that relate to sustainability under these areas that fall under the following disciplines: Chemical Engineering (12), Electrical Engineering (6), Mechanical Engineering (4), Environmental Engineering (4), Computer Science (1), Economics (1), Law (1), Political Science (1). The undergraduate minor in E3 requires students to take 3-4 courses with at least one in each of the three areas. The graduate program offers students to take a thesis in the areas of E3 and also offers more graduate courses as well in various disciplines.

The problem that faces the university is that the E3 program is not widely publicized and only a small percentage of IIT students are actually enrolled. Sustainability is not meant to be a subject for a select few that are interested, but is to envelope everyone's thinking. The majority of IIT students will pass through their academics without having ever taken any courses that relate to sustainability. The faculty needs to receive training and support to rethink and retool courses to incorporate sustainability.

3.2.3.3 Well-being of people

Quality of Life on campus

The basic components of quality of life on the IIT campus would involve the physical environment that surrounds people and also the social well-being of people in terms of contentment and happiness. The aspects of the physical environment include indoor and outdoor air quality, well-lit rooms, comfortable temperatures, good acoustics for classrooms, comfortable furniture, quality drinking water, and various other smaller factors that play a role in each individual's physical condition while at IIT. The social aspects of quality of life deal with emotional and mental health of individuals, and also a general contentment with campus life.

More research and studies needs to be done into this area to gain an understanding of the quality of life for individuals at IIT. Currently, IIT Facilities works on any hazard reports that deal with hazardous conditions and also complaints about ventilation or heating. They deal with keeping asbestos levels down in buildings by doing periodic audits; currently, all the buildings are within the acceptable level. IIT Facilities also performs regular trainings for staff on basic procedures and hazard control. The quality of life in terms of social well-being has been reviewed by *The Princeton Review* report on "The Best 357 Colleges". It showed that some of the issues students have expressed as concerns were: problems of red tape with administration, poor dorm rooms and dorm food, an unsightly campus, and a general unhappiness on campus.[10] More survey work needs to be done to obtain more results of the social well-being on campus.

Surrounding Community

The history of IIT dates back to 1890 when Chicago minister Frank Gunsaulus and meat packer and grain merchant Philip Danforth Armour had a united vision for an educational institute where people of all backgrounds could come and influence industrial society. The Armour Institute began in 1893 and in 1940 merged with the Lewis Institute to form the Illinois Institute of Technology. The school is located in the Bronzeville community located on the mid-south side of Chicago. Bronzeville consists of two major communities: Douglass (northern) and Grand Boulevard (southern). It is marked by a deep rooted and rich history for African Americans, yet today is impoverished and faces major social issues. The boundaries of the community are 26th Street (north boundary) to 51st Street (south boundary) and the Lakefront (east boundary) to the Dan Ryan

[10] The Princeton Review, *Illinois Institute of Technology's Best 357 College Rankings*, <http://www.princetonreview.com/college/research/profiles/rankings.asp?listing=1023460&LTID=1> (13 April 2005).

Expressway (west boundary). The map below shows the community surrounding IIT:

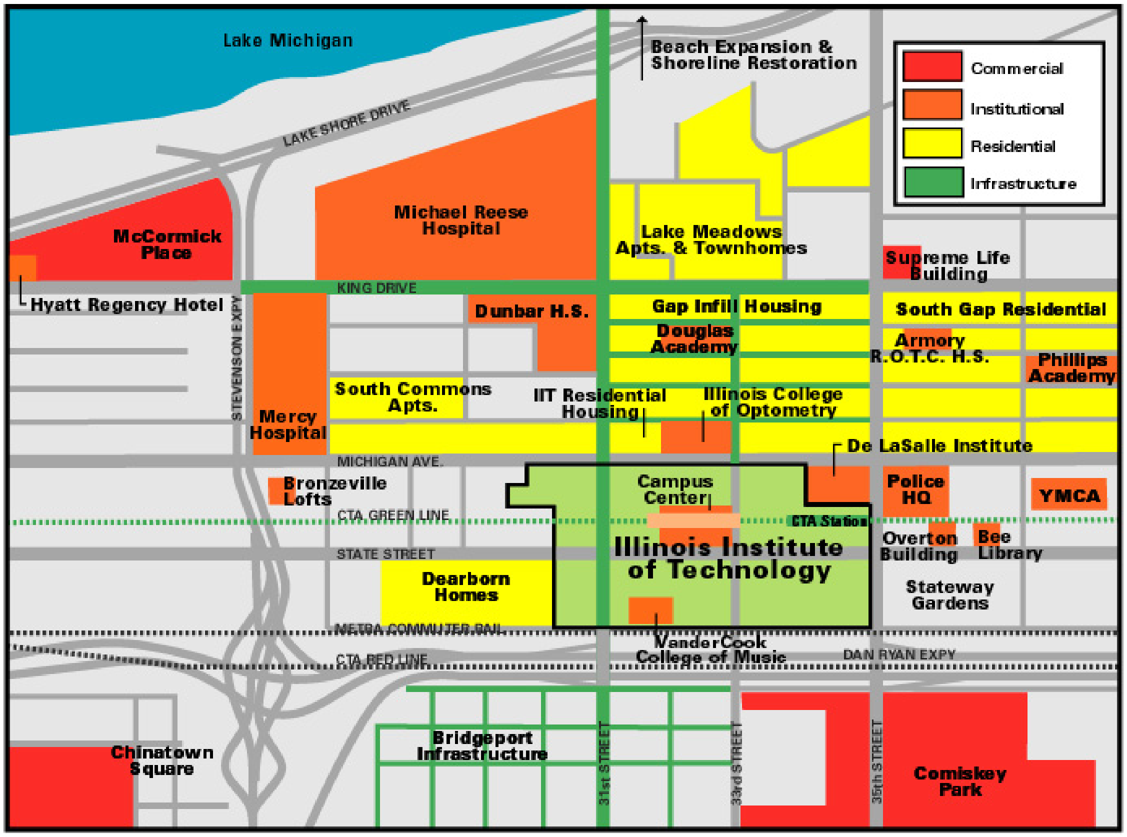

Figure 3.4: Community Surrounding IIT[11]

The Bronzeville community became populated when African-Americans flooded the area after World War I and II as they were restricted from many other areas due to exclusive laws and real estate practices. Eventually a thriving economic and social community emerged and the area became known as “Black Metropolis”. Over time as restrictions on other land were lifted, people left and the population declined leading to clearance of single-family homes and raising public housing high-rises. This led a great economic decline.[12]

Today, the community is in deep need of social reform. Census data from 1990 showed that the median salary in Chicago was $39,000. In Grand Boulevard, the median salary was $8,371, which is 65% below the poverty line. There were 32,000 housing units in the area, yet 20% are vacant. Only a small percentage, below 5%, was owner occupied. The Chicago Housing Authority owned 10,000 of the housing units. The graduation rate was 65% and 42% for

[11] Illinois Institute of Technology, *Illinois Institute of Technology and Community Development,* 10 October 1999, <http://www.iit.edu/~iitcomdev/introduction/map2.jpg> (13 April 2005).
[12] Illinois Institute of Technology, *Illinois Institute of Technology and Community Development,* 10 October 1999, <http://www.iit.edu/~iitcomdev/com_dev_tech/ccdt.html#community> (13 April 2005).

Douglass and Grand Boulevard, respectively. The report also said that two-thirds of the people were not in the labor force. These are all major social issues that face the Bronzeville community and IIT as part of that community.

IIT has taken responsibility to develop the community though “The Mid-South Development Plan”. The mission of the plan is to increase the quality of life and maintain cultural heritage of the people of Bronzeville. This is sought to be accomplished by the integration and coordination of residents, churches, community based organizations, institutions, and government. Some of the areas of focus are for school reform, welfare reform, and public housing reform.[13] At IIT, the Community Development Department is the liaison between the community and school.

[13] Illinois Institute of Technology, *Illinois Institute of Technology and Community Development,* 10 October 1999, <http://www.iit.edu/~iitcomdev/south_partners/mid-south.html#quad> (13 April 2005).

4 WHAT IS SUSTAINABILITY?

4.1 Environment

4.1.1 Air

In order for a college campus such as IIT to become sustainable in regard to air, it can be broken down into three parts indoor air quality and outdoor air pollutants. For indoor air quality there needs to be sufficient airflow through each building so that “clean air” is always being renewed. For outdoor air quality there are pollutants being released into the air in many different areas.

4.1.2 Water

For IIT to become sustainable IIT must start to look at water as a valuable resource by conservation and utilization of waste water. In order to become sustainable, conservation programs need to be started up. On each floor of the dorms, and in each building signs need to be posted in each of the bathrooms promoting water conservation. Conservation needs to take place in the landscaping as well. New water sprinklers need to be implemented that are sensitive to the amount of the moisture in the soil. Water saving shower heads need to be refitted and waterless toilets need to be implemented in order to

Utilization of waste water is another area that needs to happen in order to achieve sustainability. A dual distribution water system needs to be looked into when achieving sustainability at IIT. This system will separate water into treated wastewater (grey water) and purified clean water. The treated waste water is able to be sent through to water the landscape or to fill toilets, while the purified water is clean to drink and shower with.

4.1.3 Waste

By next year (2006) IIT should have contracted a recycling company. This recycling company will be exclusively responsible for the recycling of all the paper waste on campus. This includes all printer paper, magazines, and books. Either this same company or another should be contracted after the paper recycling has been established to be responsible for the recycling of plastics, cans, and glass. For the recycling company (companies) to receive the proper items for recycling, the custodial staff need to be educated on what items go into certain bags/containers that in-turn go to the correct dumpster for pickup. IIT’s downtown campus has already established a recycling program through contracting an outside recycling company. IIT’s main campus should look to the downtown campus as an example.

To help students put recyclables in the correct containers, distinctly labeled ‘multi-containers’ should be purchased. Once again, the downtown campus has already done this and should be looked at as an example. Concerning the living areas (Greek houses, MSV, and SSV) for the students, paper recycling containers should be in every room with containers for other items on each hallway/floor.

IIT currently does recycling for computers. This is relatively unknown to the student body.An area (if not more than one) easily accessible to the student body should be designated for computer disposal and should be checked every or every-other week. This area should be used not just for computers, but for any electronic device including, but not limited to, cell phones and video game consoles.

Batteries are another item to be recycled at IIT. With the announcement that the city of Chicago will have a funded program for disposing of used batteries at any Chicago Public Library or Walgreens store, IIT should become a drop-off point for batteries.

With all the printing that goes on at IIT, printer cartridges (laser and inkjet) should be recycled as well. A company called EnviroSmart has given IIT prepaid shipping containers for individual cartridges. These containers are being stored and not used. These should be brought out and placed in every computer lab and office on campus.

Sodexho is able to reduce the amount of food sent to the landfill by working with IIT to create a station for composting food items. This compost station would be able to provide fertilizer for the landscape on campus.

4.1.4 Fuels

For a college campus to become a Sustainable Village, the burning of hydro-carbon-based fuels must be eliminated. This cannot, and will not, happen quickly since these fuel sources form the basis of our economy, and because mature technologies have not been developed that will replace them. However, the vision of a Sustainable Village is one in which fuels will not be burned to produce energy. Instead, the heating, cooling transportation, and cooking needs are met through the following:

1) Focus research efforts on alternatives to hydro-carbon-based fuels, carbon dioxide sequestration and building envelope (the walls, roof and openings that form the barrier to the outside) improvements.

2) Improved buildings with minimized heating requirements through improving the building envelope.
3) Building heating through the implementation of distributed geothermal heating, solar-concentrated heating, and renewably-produced electric hot water heating. Use electrical heating where geothermal source is not available. Implement heat recovery to increase ventilation without increasing the heating load.
4) Provide all cooling through renewably-produced electricity and passive means.
5) All campus-based vehicular transportation through hydrogen fuel cell vehicles.
6) Campus-sponsored “I-Go”-like, vehicle sharing program that uses hybrid and electric vehicles, then eventually hydrogen fuel cell vehicles.
7) Order goods from companies within a 500-mile radius as long as they are cost competitive. For those goods that are not within the 500-mile radius, evaluate the need for the good and identify possibilities to replace the good with another that can be obtained for the same or less cost within the 500-mile radius.
8) Energy and Sustainability Institute should work with businesses in the Chicago area to develop and follow through on plans to eliminate the burning of hydro-carbon-based fuels. Also, for goods that have to be obtained from outside of the 500-mile radius, work to develop companies in the area that can provide the material at or below the cost necessary.
9) When cooking equipment is replaced, provide electric cooking equipment or equipment that makes use of fuel from food waste streams. Electricity will be provided from renewable sources.
10) Develop carbon dioxide sequestration practices that will reduce harmful emissions from processes that have not yet been decommissioned, or cannot be decommissioned because a useful, non-consuming alternative is not available.

4.1.5 Electricity

Sustainable efforts for electrical energy should consist of a couple of different initiatives. One is finding the sustainable technology to implement and the other is getting the people involved in the sustainable efforts. Finding the sustainable technology is difficult because they are not too widely used, such as wind turbines and photovoltaics. These technologies have a big premium at the beginning, but what the consumers do not realize is that they will pay itself off in a couple of years. Consumers also do not realize that there are specific grants and systems called green tags that help pay for these types of technologies. So in the long run, consumers of these products will save money. Not only is buying into these technologies important, but it is of equal significance that the people are informed about how to be sustainable with electricity. Sometimes it is too much to go and buy these technologies right away. For example, IIT is using too much electricity when compared to other colleges. Buying sustainable technology for this type of load would be very expensive. But if IIT lowered its load and then utilized the technologies, it would give a better outcome. The solution to lower the existing cost of the load right now is in the hands of all the people on campus, from the students all the way to the administration. They must be educated on methods of saving electricity. For example: turning off the lights when they are not used, turning off computers when not in use, keeping the windows closed when heating/cooling systems are on. The goal is not only to accomplish getting lower usages of electricity, but it is to continuously re-evaluate the campus and making it more and more sustainable. IIT is an outstanding technical institute, and should be a role model and leader to other institutions and organizations on how to be sustainable. In the future, IIT should not only consume less energy, but also produce the load that it consumes. IIT should utilize the existing green technology in order to use the natural resources such as wind and solar energy to power the campus. IIT should be an example for the surrounding community and especially to the students who attend this institution. Sustainability is useless if it is not practiced widely. The best way for sustainability to progress on campus is when the students are given the resources to adapt the way of sustainability into their own lives. IIT could not only make a difference in its own community, but also wherever its students go.

4.2 Social

Sustainability not only refers to the environment and the economy, but is also inherently tied to society. In the past these three entities were treated separately, but are now being understood to be connected. The economy must now take into consideration that natural resources are valuable capital to be conserved and protected while the society at-large must now adopt changes in lifestyles, attitudes, expectations, behaviors, and values.[14]

Understanding "people" as a resource within a sustainable society can be broken-down into three main areas: leadership, education, and the well-being of all people. These three components are important for producing the initiative and making decisions (leadership), creating awareness of the need for sustainability and continual improvement (education), and providing an enhanced quality of life while maintaining equality (well-being of all people).

[14] International Institute for Sustainable Development, "Our Commitments," 1996. <http://www.iisd.org/educate/learn/a4.htm> (19 March 2005).

4.2.1 Leadership

Traditional approaches to leadership are usually based on control and power. As defined in the *Global Tomorrow Coalition Sustainable Development Tool Kit*, "the process is adversarial, the goal is winning, the decision-making structure is hierarchical, the ethic is competition, the ideal is individual and institutional independence, thinking is linear, decisions are by executive prerogative, often patriarchal, and consultation is without obligation".[15] This approach is what has led to the compartmentalization of economy, environment, and society which created a clash of ideas and priorities. This system in the end lends itself to an attitude of "might is right" and the effects are seen in the depletion of natural resources, economic disparity among people, and racial inequality. In response to this traditional process, a revamped approach is necessary. The process should be exploratory where the goal is resolving problems, decisions should be inclusive and by consensus, ethics should be integrated and not competitive, the ideal would be collective well-being, thinking would be expanded, and consultation would be an integral part of the process.

One of the ways to bring forth a consensus in the community on sustainable development is through a local round table. A round table draws people from the community into a discussion of issues of the economy, environment, and their society. It is best to have an environmental audit performed before the discussion takes place to provide all parties with an understanding of the issues at hand and what policies are in place that do not comply with regulatory standards and also are not sustainable practices. Representation is an important aspect of these round table discussions and a list of important community members that could be represented is given by *Global Tomorrow Coalition Sustainable Development Tool Kit* (variations occur based on geographic location):

- agricultural authorities/farmers/ranchers
- businesses, industries, financial institutions
- conservation and planning authorities
- education officials (school boards, principals or presidents, teachers)
- environmental, wildlife, naturalist organizations
- consumer groups
- ethnic, cultural, faith communities
- fisheries, aquaculture
- forestry authorities
- government officials (local, county, state, federal)

[15] David Chernushenko, "Greening Campuses," in *Institute for Sustainable Development* 1996, <http://www.iisd.org/educate/learn/gtc6a.htm> (19 March 2005).

- health and social services professionals
- labor unions, professional associations
- mining interests
- journalists, radio and television broadcasters
- real estate developers
- native peoples' communities
- recreation and tourism interests
- researchers, scientists, engineers, technical experts
- social interests, service clubs
- utilities
- youth, students, senior citizens

Since the focus of this project is on sustainability at IIT, the leadership structure at the university level should also be understood. A structure which has been in place in many universities is an environmental management system (EMS). An effective EMS should be able to do two main tasks: (a) define the environmental and economic goals, policies and strategies of the organization, and (b) implement them.[16]

The initiative to begin such a program needs to come from the top level of the university and requires the support of all levels of people within the university for success. An EMS model that has been proposed is the Canadian Standards Association's EMS Model: CSA Z750.[17] The CSA model is comprised of four major elements and areas of action/decision-making:

[16] David Chernushenko, “Greening Campuses,” in *Institute for Sustainable Development* 1996, <http://www.iisd.org/educate/learn/campems.doc> (19 March 2005).
[17] David Chernushenko, “Greening Campuses,” in *Institute for Sustainable Development* 1996, <http://www.iisd.org/educate/learn/campems.doc> (19 March 2005).**)**.

Element	**Area of Action/Decision-Making**
Purpose	Environmental Policy Risk Assessment Environmental Objectives & Targets
Commitment	Environmental Values Alignment & Integration Accountability & Responsibility
Capability	Resources Knowledge, Skills & Training Information Management & Procedures
Learning	Measuring and Monitoring Communication & Reporting Systems Audits & Management Review

Table 4.1: Model for Environmental Management System

The management structure most effective for sustainability at the university level is one where the initiative comes from the top executives, but heavily involves all stakeholders[18]. A sample structure for the university is given below:

[18] David Chernushenko, "Greening Campuses," in *Institute for Sustainable Development* 1996, <http://www.iisd.org/educate/learn/campems.doc> (19 March 2005).

A BASIC ENVIRONMENTAL MANAGEMENT STRUCTURE

BOARD OF DIRECTORS

SENIOR MANAGEMENT (Vice-President- Environment) — ENVIRONMENT COMMITTEE -INTERNAL (Membership from cross-section of institution including students)

MIDDLE MANAGEMENT (Environmental Office or Officer)

STAFF/INSTRUCTORS

STUDENT GROUPS

Figure 4.1: Environmental Management Structure in University[19]

4.2.2 Education

Inherent in the definition of sustainability is for environmental, economic, and social concerns to be not only for the present time, but for future generations. Since the concept is so broad and still exploratory there is not a set of hard guidelines, therefore, it is of the utmost importance that education be at the forefront of sustainability. The future depends much on making better decisions about resources and their uses and for that better information is needed. Thus, research will be a key part of the educational aspect. For example, obtaining an understanding of the full cost accounting of environmental resources used will be important for making decisions about how to use resources more wisely and efficiently. In the university, having sustainability infiltrate the curriculum will be key to creating a culture of sustainability within faculty and students that will go on to be influencers in society through the policies and attitudes of the future.

[19] David Chernushenko, "Greening Campuses," in *Institute for Sustainable Development* 1996, <http://www.iisd.org/educate/learn/campems.doc> (19 March 2005)

4.2.3 Research

The concept of sustainable research is complex and far-reaching. It involves different facets which are important ideas for sustainability to continue to advance. At the University of Virginia[20] a summary of research objectives for sustainability are given that provide a framework for understanding how they relate:

- Render visible current human practices damaging to the built and natural environments and to human and ecological health, and articulate the strategies of change that celebrate the concepts and the promise of a sustaining and delightful world.
- Be a living laboratory for the incubation and testing of innovative and sustainable practices and technologies.
- Engage industry to enable ethical and prosperous commerce to be an effective agent of change.
- Create tools to make possible the successful transfer and implementation of sustainable practices and technologies.

The major goals of research then from these objectives then are to uncover what practices are not sustainable and what are, provide a grounds for testing of new sustainable practices, to be an agent of information transfer to industry, and finally create the tools for change that are practical and feasible.

4.2.4 Curriculum

Sustainability, as with any movement that seeks to be incorporated into the social fabric for any lasting period of time, must make its way into the education system. From pre-collegiate studies to the university, a case for sustainability ought to be made for a lasting impact within the culture. According to Chernushenko in *Greening Campuses*, “the educational system that supports sustainability must have the capacity to teach holistic thinking in addition to specialized knowledge. For this to be possible requires several things”:[21]

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[20] University Leaders for a Sustainable Future, “Research: Research for Sustainability at the University of Virginia,” June 1998, <http://www.ulsf.org/pub_declaration_resvol22.html> (19 March 2005).

[21] David Chernushenko, “Greening Campuses,” in *Institute for Sustainable Development* 1996, < http://www.iisd.org/educate/learn/newpara.htm> (19 March 2005).

1) Those who develop educational policy and influence curriculum must recognize the need for interdisciplinary and transdisciplinary study and the integration of sustainability thinking into all programs and courses.
2) Instructors must be encouraged to and supported in developing such curricula.
3) Students must be introduced to sustainability concepts as they relate to their course of study and, where possible, to their post-graduation lives.

This integration of sustainability into curricula is directly related to the initiative of the leaders and is thus directly tied to an effective environmental management system.

An example of what a course in sustainability would look like has been developed by Lazlo Pinter of the International Institute of Sustainable Design (IISD). The title of the course is “Sustainable Development: Tools and Methods in Practice”. The course objective is given as:

“The main objective of this course is to help apply the principles of sustainable development by understanding the possibilities, constraints and interactions of its decision-making tools and practices. Students will gain familiarity with applying tools and methodologies in a variety of multistakeholder, multi-objective environments. We will use case studies from the public and private sectors as illustration and to enhance your confidence when dealing with sustainability in real-life situations.”

The class itself consists of seminars, lectures, assigned readings, and case studies to help students better understand the concepts. Ultimately, the goal in education for sustainability is to have all of the curricula and accordingly all the disciplines incorporate sustainable ideas and practices within their frame of thinking.

4.2.5 Social Issues

As the understanding of the interplay between the environment, economics, and society grew, a greater need to meet basic human standards of living along with social equality and justice concerns arose as well. The goals of sustainability in the end ought not lose sight of basic human rights and principles, rather they must uphold and protect them. One of the groups that has concerned itself with issues of social policy, which can be summed up as the “well-being of all people”, is The World Conservation Union (IUCN). They have come up with ten major categories where sustainability and social policy tie together:[22]

[22] The World Conservation Union, “Social Policy,” 2003. <http://www.iucn.org/themes/spg/themes.html> (19 March 2005).

1) **Social Equity in Conservation**
"Social equity refers to the right of everyone to enjoy a rewarding quality of life, as well as to the expectation for fair and equitable distribution of the benefits and costs among different social groups and individuals for conserving natural systems."

2) **Gender Equity in Conservation**
"Adopting a gender perspective means focusing on both women and men and their relationships with each other and natural resources."

3) **People and Protected Areas: Tenure and Participation**
"Sustainable use of natural resources cannot be achieved unless fair access and control to natural resources are available to local people, without discrimination based on gender, class, ethnicity, age or other social variables. There is a need to empower communities and local users, recognizing their rights and responsibilities, ensuring their means to sustainable livelihoods and human development."

4) **Indigenous Peoples and Conservation**
"These resolutions stress the need to enhance participation of indigenous peoples in all conservation initiatives and policy developments that affect them. Furthermore, they recognize that indigenous peoples possess a unique body of knowledge relevant for the conservation and sustainable use of natural resources."

5) **Cultural Diversity and Traditional Knowledge in Relation to Biodiversity Conservation**
"Support conservation of the world's cultural diversity and of traditional ecological knowledge of indigenous and traditional peoples."

6) **Poverty Alleviation, Rights, Human Wellbeing and Livelihood Security**
"IUCN wants to make sure that all its programms are responsive to the need for addressing poverty issues; hence poverty and livelihood security concern the whole organization. Social elements of IUCN's poverty-related work worldwide include community empowerment, participatory approaches to promoting change in governance, rights and cultural identity, and strengthening the role of women in decision making."

7) **Social Aspects of Environmental Security and Vulnerability**
"There are a wide range of issues related to environmental security and vulnerability. IUCN is concerned with the promotion of peace and human rights, and empowerment of vulnerable communities such as indigenous peoples, as these are fundamental conditions addressing environmental security."

8) **Human Rights and the Environment**
"Full respect for human rights, is connected with the right to a decent quality of life and to other related rights recognized in the International Covenant on Economic, Social, and Cultural Rights."

9) **Social Aspects of Environmental Governance**
"'Good' environmental governance should be based on the principles of":

- Transparency - openness in decision making
- Access to information and justice - accurate and open communication, and effective exercising of environmental justice
- Public participation - genuine involvement in decision making
- Coherence - a consistent approach within a complex system
- Subsidiarity - decisions taken as closely as possible to the citizen
- Respect for human rights - civil, political, developmental and environmental rights
- Accountability - for economic, social and environmental performance

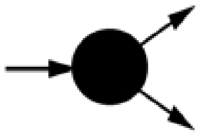
10) **Population Dynamics and the Environment**
"Develop strategies that inter-relate population control, production and consumption policies and sustainable use to conservation of the environment".

The complexities of social policy issues are just as great, if not greater, than the issues of limited resources and the scientific aspects of sustainability. Yet, it will take an interdisciplinary approach and a mutual respect for all parties involved to reach decisions. If in the search for a sustainable future people have lost basic rights and been marginalized, it would be considered a failure by the very definition of sustainability—which is to bring forth social equity.

4.3 Sustainable Philosophies

After researching the need for a sustainable future and grasping a vision for what sustainability looks like, some simple "sustainable philosophies" can be derived. These seven philosophies below offer overriding principles that can be applied directly for organizations to have sustainable development. As policies are set, especially at IIT, these philosophies should be the guide for decisions made.

4.3.1 Consumer to Producer



At present, communities are net consumers of water, energy and materials. Either directly through grid-based electricity consumption or the use of fuels for heating, or indirectly through the items we purchase, our society's focus remains on the individual as consumer. Yearly, our homes, communities, cities receive energy from the sun and wind, water in the form of rain, and air to sustain our existence. A sustainable village will not only support itself from these resources, but will provide energy, clean water and clean air in a usable form for other communities. Through this the sustainable village moves society from net consumers to net producers.

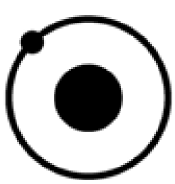
4.3.2 Waste Stream Utilization

A community operates through many different processes. Each process has inputs that are required, and waste products that remain. The focus of a sustainable village is on maximizing the redistribution of waste products of one process so that they become the inputs to another. This means, also, that any waste that cannot be reused in the community is processed to a form that is usable by another community, and that as processes are planned and built, they are built with an eye toward how they will be disassembled.

4.3.3 Conserve, Optimize, Maintain

In order to become net producers of energy, and utilizers of waste, the sustainable village must conserve energy, optimize the processes that support the population, and maintain those processes so that they work as effectively as possible. Without constant vigilance to conservation, optimization and maintenance, there can be little hope of increasing the quality of life without sacrificing the resources available to the next generation.

4.3.4 Eliminate burning of fuels



The present quality of life established in the developed world has as its foundation inexpensive energy. At present, the most inexpensive ways to produce electricity, heat buildings or power transportation is through sources that require the burning of hydro-carbon based, or fossil, fuels. This practice has caused the release of carbon dioxide, nitrous oxides and sulfur dioxide, as well as other compounds, into the atmosphere at a rate which the environment cannot process. These compounds contribute to climate change, acid rain and health issues. A sustainable village will not produce any more pollutants, either directly or indirectly, than its environment can process.

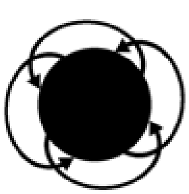
4.3.5 Public Participation

The most important part of any village is the people. Without the support of its individual members, no community can survive. This is even truer for a sustainable village. Especially in the early phases of development, the cooperation among the members of the community must be present at all levels. Just as leaders cannot set policies that contradict the will of the community, and cannot expect only the lowest members of the community to do all the work, so those who are not in leadership cannot sit back and wait for the leaders to act. Each individual must make their own choices, and do so in the interest of the village.

4.3.6 Treat Energy as Capital, not a Commodity

Energy always appears as an expense on the financial statement of any process. It is a commodity that is purchased at a certain price, and the idea is to fetch the best price for the commodity so that you can afford it when you need it. In a sustainable village, energy is treated like capital, like a resource to be wisely invested, saved, and used when needed to meet the needs of the village. With this mindset, projects and processes that require energy must have a return on that investment. When energy is a resource, then it is not "spent" in ways that waste the resource. If a process is losing energy, then the process is revisited to understand why; in the present circumstance, as long as the energy is cheap, or the process profitable, the energy losses are ignored. A sustainable village treats its energy as a resource that is used only when needed, and invests its energy for the progress of the village.

4.3.7 Green Unit



As a philosophy governing the application of philosophies, the Green Unit offers a vision of how a village becomes sustainable. Dreams offer us the hope that we can make a change; however, only when dreams become reality does change really occur. In order for the vision of the sustainable village to be realized, through the application of the sustainable philosophies, a practical method for implementing the philosophies is needed. In the Green Unit philosophy, the village is broken down into its essential units – for a university campus, those units are the classroom, dorm and office. Efforts are focused on making each unit as sustainable as it can be. Only when the unit cannot make a part of its process sustainable, is the process escalated to the next level of unit. By working this way, sustainability can be implemented in pieces, not requiring enormous capital and energy investment, but rather a series of significant investments leading to the larger goal.

5 ROADMAP TO SUSTAINABILITY AT IIT

The end goal of the research on sustainability and environmental auditing at IIT was to obtain a “Roadmap to Sustainability” that IIT could implement to become a sustainable campus. The following steps are built around the seven sustainable philosophies. They are described below in chronological order with a brief description of each action. At the end of the brief descriptions a summarizing graphical representation of the roadmap will be provided.

5.1 Student Organization for Sustainability

Start: Fall 2005
Description:

- Bi-weekly meetings
- Discuss issues of sustainability
- Invite speakers, coordinate campus-wide speakers
- Work with Recycling Program
- Focus Group Study, Campus Survey
- Dialogue with administration
- Community Service
- Field Trips
- Work with “Energy and Sustainability Institute” to begin developing “Sustainability Committtee”
- Plan “Sustainability Kick-Off Day” in Spring 2006

Goals:

- To mobilize the student body to become educated and excited about sustainability and influence the university as a whole

Sustainable Philosophies:

- Public Participation
- Green Unit

5.2 EnPro: "Sustainable Village" Business Proposal

Start: Fall 2005
Description:

- Do economics behind roadmap for sustainability from IPRO301
- Propose to administration for support
- Get funding from sponsors
- Work with "Energy and Sustainability Institute" to begin developing "Sustainability Committtee"

Goals:

- To provide an economic proposal to the administration and sponsors to show the economic viability of sustainability

Sustainable Philosophies:

- Public Participation
- Treat Energy as Capital, not a Commodity

5.3 Development of a "Sustainability Committee"

Start: Spring 2006
Description:

- Under direction of Energy and Sustainability Institute
- Members:
    - Director of Energy and Sustainability Institute
    - At least one member of administration
    - 2 Faculty
    - 3 Students
    - 2 Staff
    - 1 Business advisor
    - 2 Community members
- Discuss future vision
- Discuss funding issues
- Set school policy towards sustainability

- Create various arms: Curriculum, Faculty Development, Research, Operations, Student Activities, Community Outreach
- Do planning for “Sustainability Kick-Off” for Fall 2006

Goals:

- To provide a consensus leadership structure for sustainability at IIT by obtaining support and creating school policies

Sustainable Philosophies:

- Public Participation
- Green Unit

5.4 “Sustainability Kick-Off”

Start: Fall 2006
Description:

- Vision-casting to university
- “Sustainability Kick-Off Day” during O-Week activities
    - “Community Cup” Program
        - Each university member receives “Community Cup” which is reusable to reduce water bottle waste and wasting cups
        - Cup is attractive, durable and has website and info for Sustainable Village group
    - Community Service
    - Speaker and “Sustainable Party” for O-Week

Goals:

- To provide a consensus leadership structure for sustainability at IIT by obtaining support and creating school policies

Sustainable Philosophies:

- Public Participation
- Conserve, Optimize, Maintain

5.5 Energy Usage Reduction

Start: 2006
End: 2010
Description:

- Educate the students and faculties of why energy reduction is vital in helping the environment
- Teach ways on how to reduce energy usage.

Goals:

- To reduce the energy consumed by the campus and indirectly helping sustain the environment.

Sustainable Philosophies:

- Conserve, Optimize, Maintain

5.6 IIT as a battery collection site

End: 2006
Description:

- As of 4/24/2005, Walgreens and Chicago public libraries will be designated battery drop-off points.
- IIT should involve itself in this project and become a battery drop-off as well.

Goals:

- To provide the surrounding IIT community with an easily accessible battery drop-off.

Sustainable philosophies:

- Waste Stream Utilization

5.7 Recycling company contracted

End: 2006
Description:

- The city's recycling plan isn't successful enough and the custodial service does not take responsibility for the custodians throwing recycled goods in with the normal physical waste

- A company should be contracted to take care of IIT's recycling needs

Goals:

- The company contracted should be able to take care of IIT's paper and glass/plastic/can recycling and train the custodians to place waste items in their correct place.

Sustainable philosophies:

- Waste Stream Utilization
- Public Participation

5.8 Paper recycling established

Start: 2006 [when recycling company is contracted]
End: 2007
Description:

- The contracted company will first deal with IIT's largest waste stream (paper).

Goals:

- Once the paper recycling is established, smaller waste streams will be easier to undertake.

Sustainable philosophies:

- Waste stream utilization

5.9 Sustainability Conference

Start: Spring 2007
Description:

- Bring major sustainability conference to be hosted at IIT

Goals:

- To provide education and excitement about sustainability to IIT and show our commitment to it

Sustainable Philosophies:

- Public Participation

5.10 *"Greening the Curriculum"*

Start: Fall 2007
End: Fall 2025
Description:

- "Greening the Curriculum" is defined by integrating sustainable philosophies as the framework of thinking as students are taught about their specific discipline (i.e. "how does what I learn here relate to having a sustainable future?")
- ITP teaches sustainability for all departments (Fall 2007)
- Provide faculty training (Fall 2007)
- 15% Green Curriculum by Fall 2010
- One course directly related to sustainability in each department by Fall 2010
- 50% Green Curriculum by Fall 2015
- 75% Green Curriculum by Fall 2020
- 100% Green Curriculum by Fall 2025

Goals:

- To provide courses directly related to sustainability in each discipline
- Create a culture of sustainability within the future leaders of the world

Sustainable Philosophies:

- Public Participation

5.11 *Green Energy*

Start: 2007
End: 2010
Description:

- Invest in large-scale, Green Energy producers such as Wind Farms.

Goals:

- Reduce the amount of energy produced by fossil-fuel burning power plants by buying into Green Energy.
- Decrease the pollution that would have been produced.

Sustainable Philosophies:

- Eliminate the Burning of Fuels

- Treat Energy as Capital, not a Commodity

5.12 Energy Star Showcase Dorm Room

Start: 2007
End: 2008
Description:

- Create a showcase dorm room that features all Energy Star products that a student would need.

Goals:

- Introduce students to Energy Star products that will do the same function as other products but will also save on energy costs.

Sustainable Philosophies:

- Conserve, Optimize, Maintain

5.13 Plastic/glass/can recycling established

Start: 2007 [after paper recycling is under control]
End: 2008
Description:

- IIT should work with the recycling company to purchase labeled containers to separate recyclable items.
- The custodial service should be retrained to deal with these new changes.

Goals:

- To expand recycling to glass, aluminum, plastics, metals, chemicals, etc.

Sustainable philosophies:

- Waste Stream Utilization

5.14 Compost station

Start: 2007
End: 2009
Description:

- IIT should work with Sodexho to lighten the amount of food waste delivered to the waste stream.

- Recovered food waste should be placed in containment to degrade.

Goals:

- Not only lessening the food going to the waste stream, but also to provide fertilizer for campus landscape.

Sustainable philosophies:

- Waste Stream Utilization
- Consumer to Producer

5.15 Retrofit the Campus – Phase 1

Start: 2008
End: 2033
Description:

- Invest and promote technology that improves the energy performance of the campus buildings (EnergyStar Products, light bulbs, motion sensors)

Goals:

- Cut the electricity bill and energy usages.

Sustainable Philosophies:

- Conserve, Optimize, Maintain

5.16 Retrofit the Campus – Phase 2

Start: 2015
End: 2040
Description:

- As buildings are optimized and made energy efficient, implement green technology such as solar panels, photovoltaics, wind turbine)

Goals:

- Produce green energy on campus.

Sustainable Philosophies:

- Conserve, Optimize, Maintain
- Consumer to Producer

5.17 Water Conservation Program

Start: 2010
Description:

- Placing signs for education of people at IIT in bathrooms, kitchens, etc.

Goals:

- To provide education and better water utility around campus

Sustainable Philosophies:

- Green Unit
- Conserve, Optimize, Maintain
- Public Participation

5.18 Reducing transportation distance for purchasing

Start: 2010
End: 2030
Description:

- Establish purchasing practices where materials are brought from surrounding community rather than from distances further than 500 miles
- 50% of goods procured within 500 miles by 2010
- 75% of goods procured within 500 miles by 2020
- 100% of goods procured within 500 miles by 2030
- Accomplish this by working with existing vendors and suppliers to reduce transportation time for goods and services.
- For those services that cannot presently be purchased locally in a cost effect manner, work with those companies to improve their cost structure so that they become competitive and a potential supplier.
- Where a product is available from multiple sources, some of which are local and some not, evaluate the companies and products not just on the direct cost, but on the energy that is invested in those products.

Goals:

- To reduce burning fossil-fuels

Sustainable Philosophies:

- Conserve, Optimize, Maintain
- Treat Energy as Capital, not a Commodity

- Eliminate Burning of Fuels

5.19 Water Efficient Bathrooms

Start: 2010
End: 2015
Description:

- Replacing showers, faucets, toilets to be efficient and not wasteful
- Reduce sewage with waterless urinals
- System that will clean and reuse potable water

Goals:

- To provide more efficient use of water on campus

Sustainable Philosophies:

- Green Unit
- Conserve, Optimize, Maintain
- Waste Stream Utilization

5.20 All campus buildings meet ASHRAE Standard 62 for ventilation

Start: 2010
End: 2020
Description:

- The American Society of Heating Refrigerating and Air Conditioning Engineers (ASHRAE)
- Set of building ventilation standards
- Complete ventilation assessment of each building

Goals:

- To provide better ventilation for better quality of life and also greater productivity for people at IIT

Sustainable Philosophies:

- Green Unit
- Conserve, Optimize, Maintain

5.21 Outdoor Air Quality

Start: 2010
End: 2015
Description:

- Increased number of trees, and greenery planted around campus

Goals:

- Reduce Carbon Dioxide emissions

Sustainable Philosophies:

- Consumer to Producer

5.22 Campus Vehicles using hydrogen as fuel

Start: 2008
End: 2015
Description:

- Developing hydrogen as the fuel for transportation by use of hydrogen-fueled vehicles on campus
- Use the hydrogen fueling station to supply the necessary hydrogen for campus shuttles, maintenance vehicles, and local transportation vehicles.

Goals:

- To reduce burning fossil-fuels
- Use a renewable energy source

Sustainable Philosophies:

- Eliminate Burning of Fuels

5.23 Developing Energy Efficient Businesses

Start: 2015
End: 2020
Description:

- Energy and Sustainability Institute develops 10 new companies by 2015
- Decarbonizes 100 companies by 2020

- Requires IIT to help the companies that do business with IIT, or are established near IIT, to understand the benefits both economically and environmentally to eliminating the burning of fuels.
- In order to meet the demand for technologies that replace fuel burning, IIT will work to develop local companies that can serve the Chicago market.

Goals:

- Develop local businesses
- Reduce amount of fossil-fuel burning

Sustainable Philosophies:

- Eliminate Burning of Fuels
- Public Participation

5.24 Rain Guards and Flat Roofs

Start: 2015
End: 2020
Description:

- Collecting water from rain with rain guards to collect and reuse
- Less rainwater from Lake Michigan sent through sewage and sent to Gulf of Mexico

Goals:

- To provide more efficient use of water on campus
- To renew supply of water in Lake Michigan

Sustainable Philosophies:

- Conserve, Optimize, Maintain
- Waste Stream Utilization
- Consumer to Producer

5.25 Eliminate fuel-based heating in package equipment

Start: 2005
End: 2025
Description:

- Eliminate fuel-burning based heating package equipment by 2025.

Goals:

- Eliminate emissions
- Increase the energy independence of the university

Sustainable Philosophies:

- Eliminate burning of fuels

5.26 Energy Payback Cycle

Start: 2015
End: 2035
Description:

- By 2025, all buildings developed on campus will have an “energy payback cycle” of no more than 10 years.
- By 2035, all buildings developed on campus will have an “energy payback cycle” of no more than 5 years.
- The energy payback is the total energy needed to build or refurbish a building. Once the building is operational, the building will be a net producer of energy, and the net amount of energy produced will be such that the building “pays back” in the time set.

Goals:

- Reduce the amount of energy necessary to build on campus, and increase the amount of energy that a building produces
- Improve building quality so that buildings require less energy to operate.

Sustainable Philosophies:

- Treat Energy as Capital, not a Commodity

5.27 Sprinkler system and dual distribution water system

Start: 2030
End: 2030
Description:

- Filtration system that will process water into quality drinking water and grey water
- Grey water used for landscaping and with timed and rain-sensing sprinkler system

Goals:

- To provide more efficient use of water on campus
- To renew supply of water in Lake Michigan

Sustainable Philosophies:

- Conserve, Optimize, and Maintain
- Waste Stream Utilization
- Consumer to Producer

5.28 Eliminate natural gas-based cooking

Start: 2015
End: 2030
Description:

- Find alternative sources of energy for cooking in campus buildings
- Utilize waste streams where possible
- Develop technologies where none presently exist

Goals:

- To reduce burning fossil-fuels
- Use a renewable energy source

Sustainable Philosophies:

- Waste Stream Utilization
- Eliminate Burning of Fuels

5.29 Emissions

Start: 2020
End: 2030
Description:

- Sequestration of 150% of the emissions produced directly and indirectly by the presence of the university by 2030.
- Work to develop technologies that work with nature to sequester carbon dioxide, nitrous oxides and methane in a way that improves the carbon balance.
- Depends also on the reduction of campus emissions and work with companies that deal directly with the university.

Goals:

- Reduce pollution
- Become a producer of clean air

Sustainable Philosophies:

- Eliminate Burning of Fuels

5.30 Energy Production

Start: 2008
End: 2030
Description:

- IIT will be a net producer of energy for consumer, residential and commercial use.
- Through outfitting buildings with solar collectors, building-integrated photovoltaics, and implementing geothermal heating, buildings can move from net consumers to net producers of usable energy.
- This goal is linked to the goals of improving building performance and elimination of the steam plant as a source of heat.

Goals:

- Increase the energy independence of the university.
- Reach out to the community and provide an example and resources to help it meet its own needs.

Sustainable Philosophies:

- Consumer to Producer
- Eliminate Burning of Fuels
- Treat Energy as Capital, not a Commodity

5.31 Elimination of Steam Plant

Start: 2008
End: 2045
Description:

- Replace district heating system, presently accomplished through distribution of steam throughout the campus, with geothermal heating.

Step 1: Replace windows, repair exterior walls, replace roofing (start 2006, end 2020)
Step 2: Install heat recovery units and dedicated outdoor air systems on all buildings as ventilating systems are replaced. (start 2006, complete 2030)
Step 3: Begin construction of a geothermal heating system for the campus (design 2006-2007, begin construction 2010, complete construction 2030)
Step 4: Install solar-thermal hot water heating on all buildings (start 2010, complete 2020)

- This replacement must be gradual, and can only occur once individual building envelopes have been improved so that building heat loads are as small as they can be.
- As the load on the steam plant is decreased, and if electrical demand exceeds the campus capacity for renewable generation, the cogeneration plant should be used to produce steam through its waste heat. Once the supply of renewably generated electricity exceeds campus demand, then the cogeneration plant can be decommissioned also.

Goals:

- To reduce the use of heating systems that burn fossil fuels.
- To eliminate the greenhouse gas emissions that are directly related to the existence of the university.
- To improve the energy payback in new and refurbished buildings by reducing the consumption of solid-matter, natural resources for energy.

Sustainable Philosophies:

- Eliminate Burning of Fuels
- Treat Energy as Capital, not a Commodity

5.32 Recycle Equipment

Start: 2005
End: 2040
Description:

- As infrastructure is replaced, that which is removed should be recycled in the most efficient manner possible
- All systems that are installed should be designed not only for operation, but also for decommissioning

Goals:

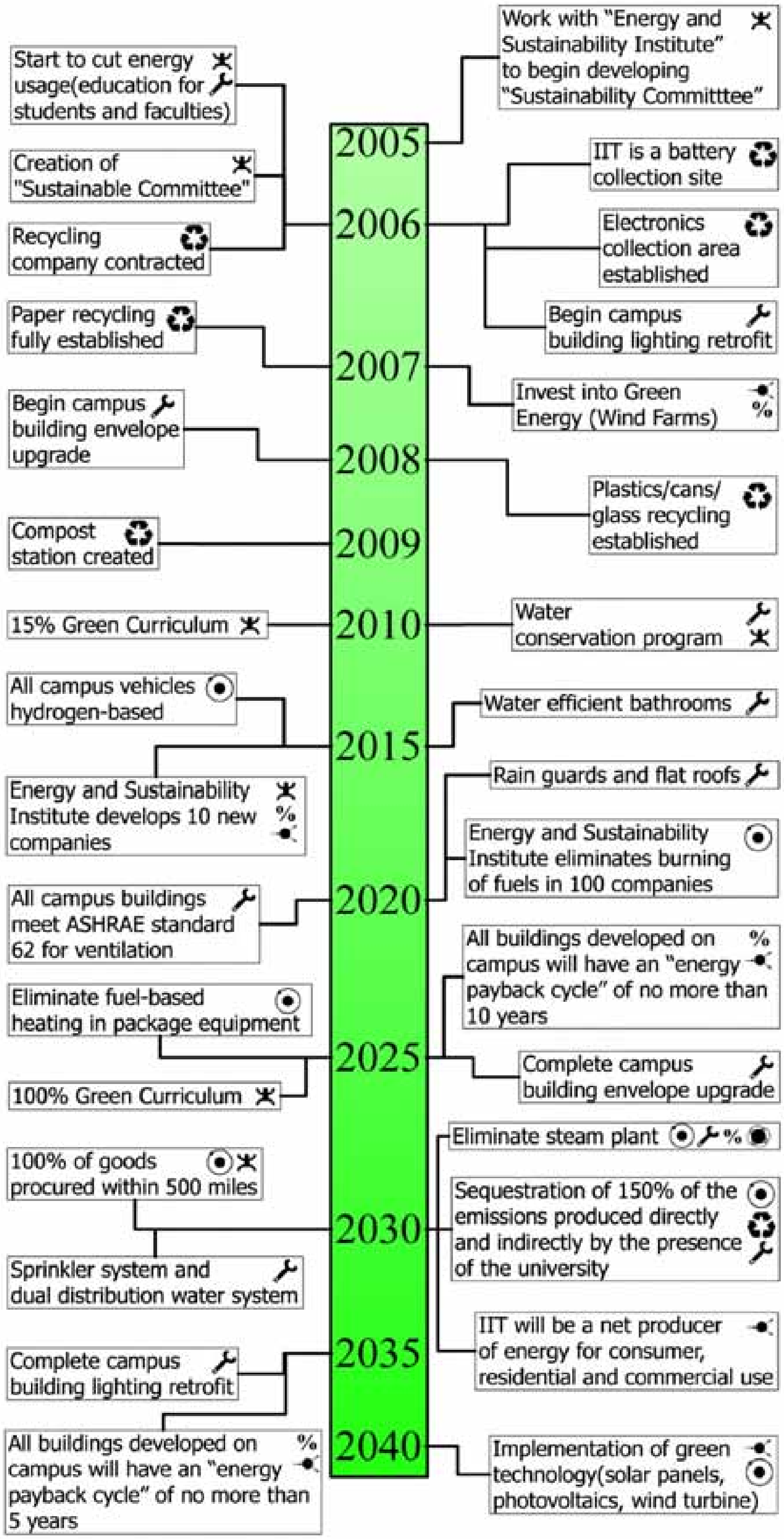
- Reduce the amount of solid waste that goes to landfill

- Maximize the useful life of materials

Sustainable Philosophies:

- Waste Stream Utilization
- Treat Energy as Capital, not a Commodity

5.33 Roadmap Summarized



6 THE "HOUSE OF THE FUTURE"

6.1 Introduction

The Green Unit philosophy, as described in the previous section, is the process that IIT needs to take in order to be sustainable. This process is not only easy to implement, but is a sustainable way of implementing sustainability at IIT. The Green Unit focuses on making each individual unit of the campus (classroom, office, or dorm room) sustainable, in order to make the entire campus sustainable. The idea is that IIT will start by making individual units sustainable, then soon will have sustainable buildings and once sustainable buildings are achieved IIT will have sustainable sectors on campus then a sustainable village.

In each of these Green Units the idea is to maximize the "free" resources that naturally occur on the IIT campus. In terms of sustainability each green unit will maximize the natural air ventilation that flows through buildings and take the naturally occurring sunlight, earth, and wind, energy and convert that into usable energy. The naturally occurring rainwater needs to be collected in order to reduce the amount of external resources that flow into the campus from the utilities. The concept is to maximize the amount of natural resources used, while minimizing the number of resources coming into the campus. The next idea of the green unit is to minimize the waste that flows out of the campus by conservation, and also to maximize the use of this waste by turning it into usable resources through different types of recycling programs.

The House of the Future is a showcase of the Green Unit philosophy that IIT needs to implement in order to become a leader of Sustainability. The house will implement different technologies to utilize the natural resources that come into each unit on campus. The House of the Future is designed to reduce the energy load. Solar energy will be deployed to produce the electricity needed and to heat the water for domestic use. The House of the Future will be water efficient: rainwater will be recycled and reused in the house after being processed in a storm water treatment system. The air quality will be continuously monitored and controlled through mechanical systems and indoor landscaping will contribute to maintain the clean air. Offering a lab and an exhibition space, the House of the Future will also contribute to educate the surrounding community on the strategies to achieve a Green Unit and ultimately a Sustainable Village.

6.2 *Explanation of the renderings*

6.2.1 Southeast View

The House of the Future is situated at the south-west corner of State and 30th Street. The public entrance is located on the east side along State Street. An exhibition space on the first floor and a lab space on the second floor will serve as educational and experimental facilities for IIT's community. In order to offer flexibility to the space and make it multifunctional, movable partitions on track systems are used. In the laboratory, new housing materials or new paints can be tested and monitored, and eventually both exhibition and lab space can be used for residential purpose.

The House consists of three structural bays: the two on the east and west sides are clad with a bare concrete panel system and are currently testing Eternit recycled panels for their 'green' qualities. In the center bay a thermal chimney contributes to heat the house in the winter. The heat gained from the sun is stored by the thermal mass of a concrete ramp that serves as a passage between half-shifted floors. In the summer natural ventilation is provided in the thermal chimney by openings at the bottom on the north side and at the top on the south side to allow cool air to circulate through the space. In the middle of the south façade, a photovoltaic (PV) system integrated into the outside layer of a double-skin façade gathers solar electricity for the house.

On the west roof solar thermal collectors and an experimental test bed are located. The solar collectors use the sun energy to heat up the water for domestic use; the test bed is used to test different roofing materials. The east side features a green roof; the central roof houses a second array of PV panels, not integrated.

All of the wood used in the house is reclaimed from the site. Saw-dust recycled material will also be used for the finishes.

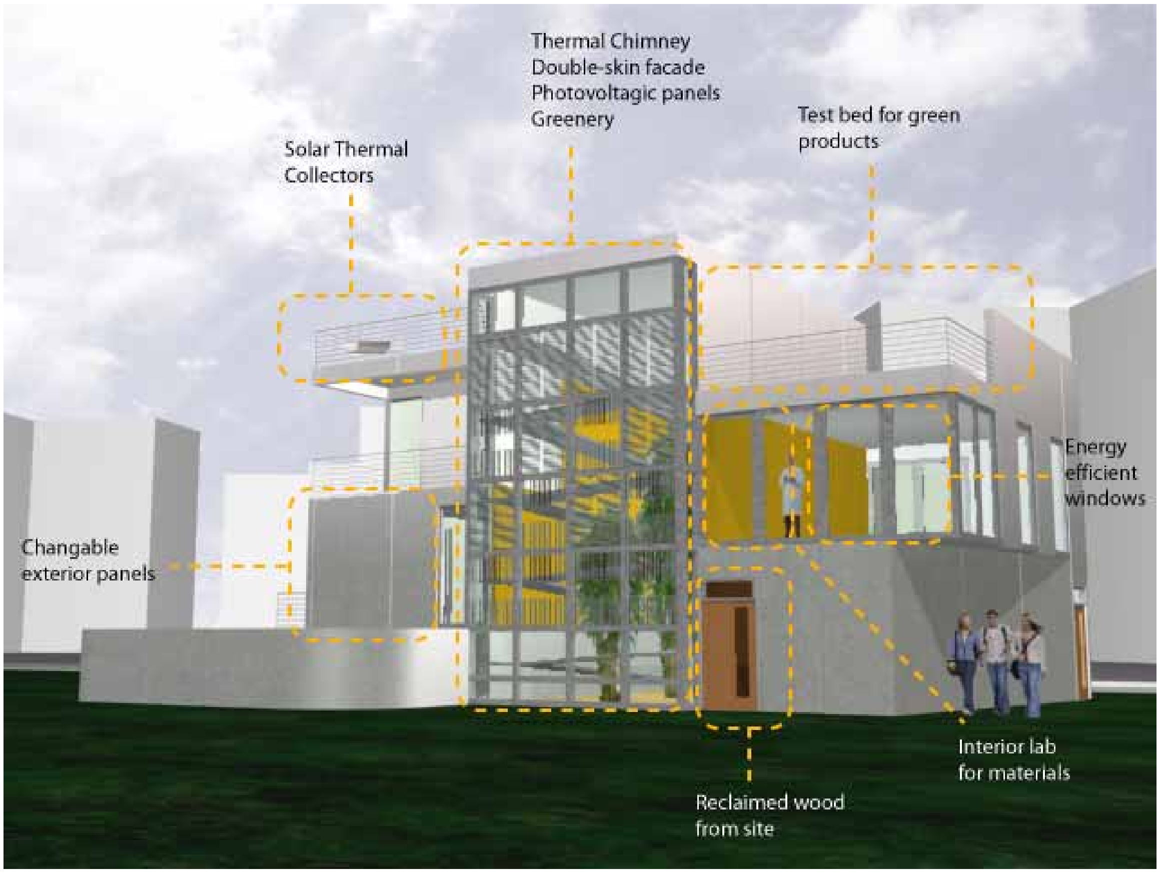


Figure 6.1: Southeast View

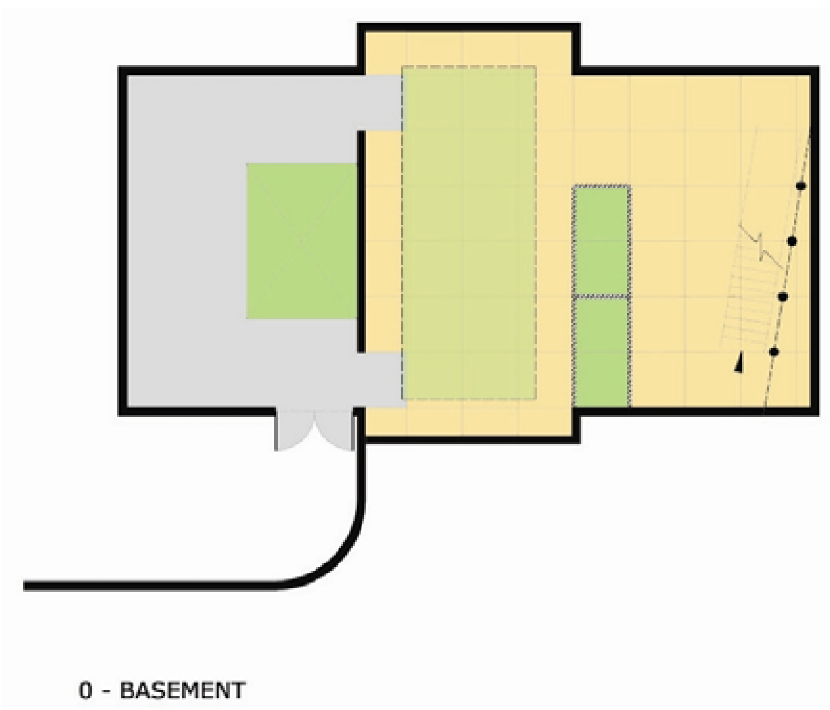
6.2.2 Northwest View

The private entrance for the residents is located on the west side of the building. The entrance leads into a kitchen/dining and living area. In the north façade there is much less glass compared to the south façade to avoid heat loss through the windows.

To provide natural ventilation in the summer, lower windows in the thermal chimney open up and allow cooler shaded air to enter the space and draw out hot air at the top of the chimney.

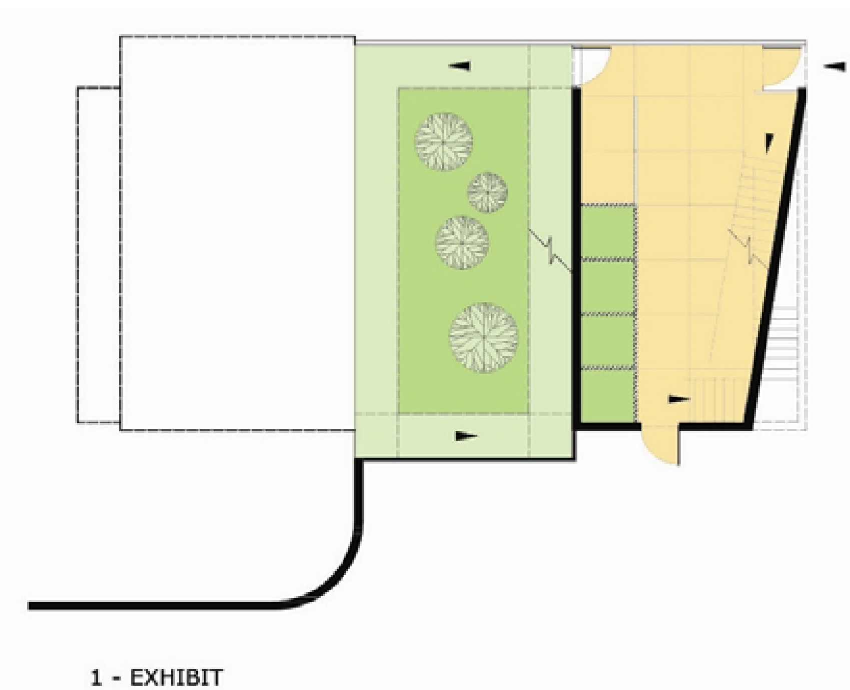
Figure 6.2: Northwest View

6.3 Plans and Spatial Distribution



Full Basement according to Residential code standards

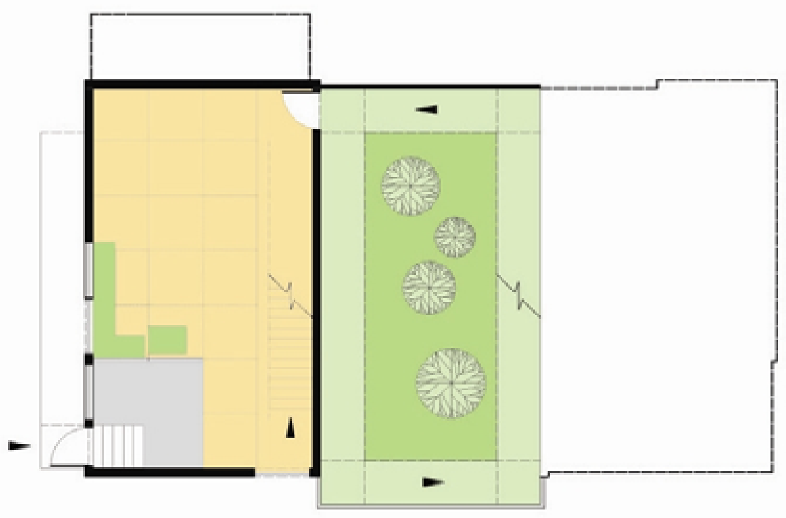
- Additional exhibit space
- Storage space for fuel cells, batteries and other electrical equipment
- Overhead natural lighting from thermal chimney
- Storm water collection and treatment system (left); Toilets with partition wall system (right)



Living space according to Residential code standards

- Partition walls on tracking system
- Information booths

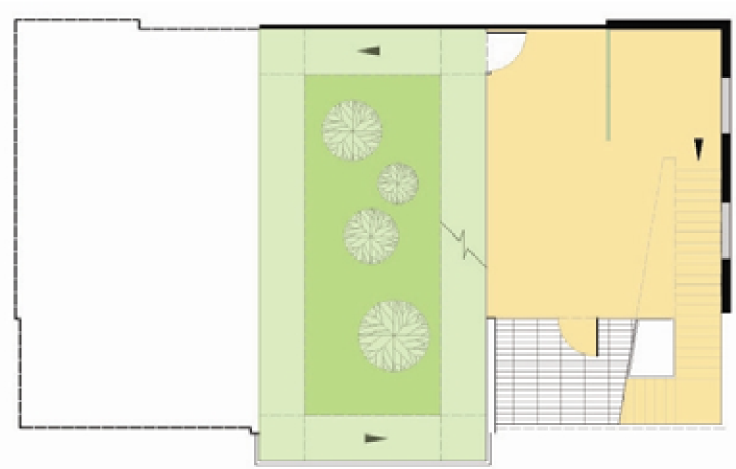
Entrance into the Thermal Chimney



1.5 - KITCHEN/LIVING

Kitchen /Dining and Living area

- Partition walls on tracking system
- Energy Star rated kitchen appliances and fixtures
- Water resistant material for entry way

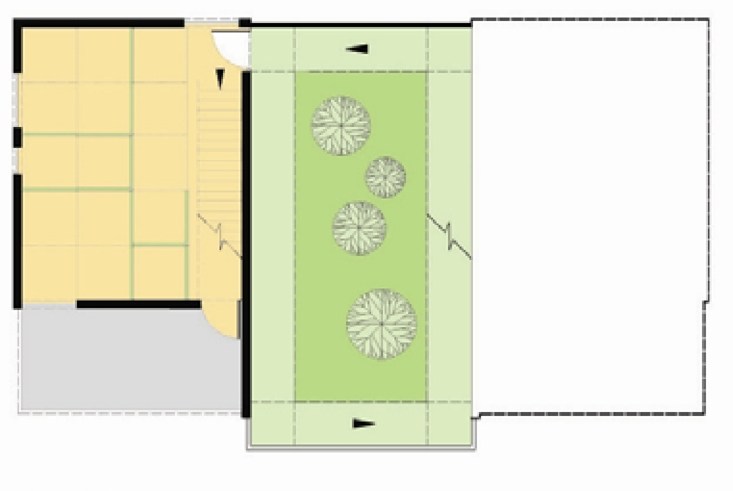


2 - COMMON/LAB

Bedroom space according to Residential code standards

- Space allocated for lab and office space for IIT educational purposes

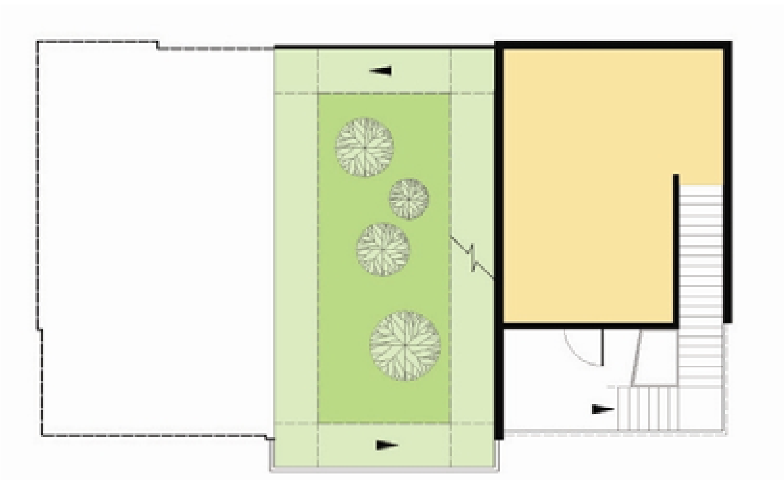
Access to green roof



2.5 - BED/BATH

Bedroom/Bath

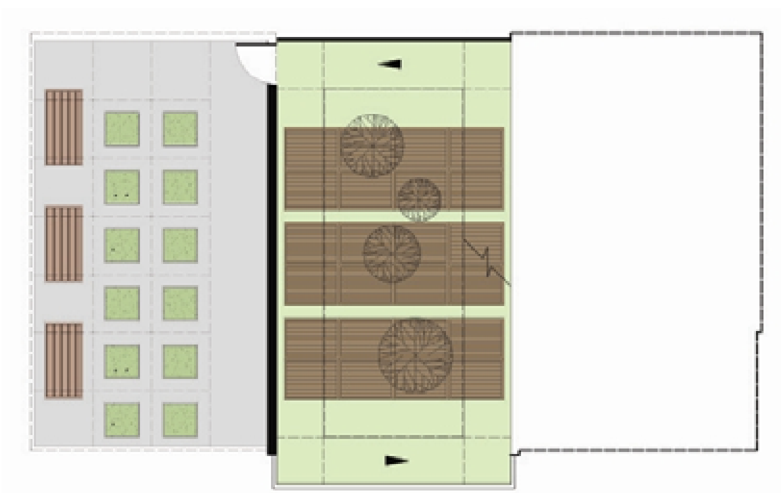
- 2 Bedrooms (10 x 10)/full bathroom/Storage
- Partition wall system



3 - ROOF/TEST SITE

Green Roof

- Green Roof



3.5 - ROOF/GREEN/ SOLAR THERMAL

Experimental Roof

- 3 Solar Collectors
- 24 Photovoltaic panels on Thermal Chimney
- 12 Roofing materials testing grounds

7 CONCLUSION

Becoming a Sustainable Village will not be easy for IIT; however the reward for succeeding brings not only economic reward, but also tremendous social and environmental payback. The process of changing engrained social norms in order to move from a society of consumers to a society of producers may require some apparent sacrifice initially. As the members of the "village" become more aware of their impact, and begin to reprioritize their actions based upon what is important to the community as a whole, as well as themselves, they will move past the desire to consume. Also, the process of achieving sustainability will require everyone in the university to look at the impact of all of their decisions, including those that indirectly affect the sustainability of the campus.

Technology will play a critical role if and when IIT attempts to improve waste stream utilization and avoid the burning of fuels for energy. As a technological leader, IIT is not only poised to accomplish this for itself, but can show the way for others to reduce the wasting of resources and the damage to the environment from the burning of fuels.

Most importantly, the path to sustainability must begin by conserving resources that are presently used, optimizing the systems that consume those resources, and maintaining the systems so that they continue to operate as efficiently as possible. Once systems are operating efficiently, then the technology and strategies necessary to make them sustainable can be implemented. By implementing these technologies and strategies in this way, and one unit at a time, the university can become sustainable through its existing means. Lastly, it is important that the "village" encourage participation by all of its members, regardless of position or station. Then, the act of becoming sustainable is itself sustainable.

By building the "House of the Future", IIT can make a bold statement about the future of sustainability. Through the incorporation of existing technology, the "House" offers a glimpse into what can be done, but also encourages research and development of systems that will improve upon the present best practices. As a tool for outreach to the local community and beyond, the "House of the Future" will serve as a mechanism by which those outside of IIT become familiar with the benefits of sustainability, learn how to accomplish it, and share their experience with others. This allows the impact of what IIT can accomplish to reach far beyond the limits of the campus.

IIT can become a "Sustainable Village". What is most needed is not technology, or even knowledge, but will. The City of Chicago as it presently exists, was founded on the spirit of a population of people who said, "I will". This spirit of Chicago must become part of the community at IIT; a community of people who collectively say, "I will do what is necessary to make this community sustainable." Once that step is taken, all others will follow.

8 FUTURE STEPS

Making IIT a sustainable village will take continual vigilance, commitment from administration, and a sincere effort by all of the members of the IIT community. The Sustainable Village project team has developed the Roadmap and initial design of the House of the Future. In order to further these projects toward reality, the following must occur:

1) The Energy and Sustainability Institute should form a sustainability committee comprised of representatives of all stakeholders in the university from staff to students to administration to alumni.
2) Perform a full and detailed building audit of each facility on the campus. The audit will record, at a minimum, the following:
   a. Electricity consumption
   b. Steam consumption
   c. Natural gas consumption
   d. Water consumption
   e. Solid waste production (by type if possible)
   f. Waste water production (separated by sanitary and storm)
   g. Exterior wall R-value
   h. Roof R-value
   i. Indoor lighting levels
   j. Air quality levels (CO2 and airborne particulates)
   k. Ventilation rates
3) Design development of the House of the Future must proceed, and a business plan be drawn up for a company to develop the designated parcel of land into the house. In design development, all of the technologies and strategies scheduled to be employed in the house should be evaluated and reconsidered.
4) Follow through on the present contract for recycling services and expand the contract to include separation of solid waste by type. Develop a waste recycling plan for food waste, and join the cities battery collection and disposal campaign.
5) Develop detailed action plans for each of the Roadmap items.
6) Establish a dialogue with the local and state government agencies to work through the barriers to implementing the Roadmap and building the House of the Future.

7) Extend the Website by updating it with a real-time information tracker of IIT’s Main Campus consumptions, create a virtual tour of the “House of the Future” and upload an extended database with the knowledge collected relating to sustainability.

These steps can be started through the Energy and Sustainability Institute, especially the interface with local governments. However, the development of the house and expansion of the recycling program should be further explored as ENPROs. The auditing and modeling of the current campus can be done as a follow-up IPRO.

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10 APPENDIX – SUSTAINABILITY

10.1 Benchmarking Information

In order to gain an understanding of the challenges to sustainability, the team researched how other universities have approached the concept, and evaluated the success of the programs and their applicability to the IIT campus. The detailed results of that benchmarking can be downloaded from the following website: **www.iit.edu/~svillage**. The process for determining which schools to benchmark involved using Internet search engines to find schools that claimed to have programs related to sustainability. Once a list of schools was found, the team selected a total of ten schools to analyze. The schools selected appeared to have more detailed information, or more recent information, than other schools.

One website found of significance is the University Leaders for a Sustainable Future at **www.ulsf.org**. The site contains a list of schools that have committed to sustainability by signing the Talloires Declaration. The declaration commits the university and its leadership to a ten-point action plan for incorporating sustainability into the campus. The Talloires Declaration is included for reference.

10.2 Talloires Declaration – 10 Point Action Plan[23]

We, the presidents, rectors, and vice chancellors of universities from all regions of the world are deeply concerned about the unprecedented scale and speed of environmental pollution and degradation, and the depletion of natural resources.

Local, regional, and global air and water pollution; accumulation and distribution of toxic wastes; destruction and depletion of forests, soil, and water; depletion of the ozone layer and emission of "green house" gases threaten the survival of humans and thousands of other living species, the integrity of the earth and its biodiversity, the security of nations, and the heritage of future generations. These environmental changes are caused by inequitable and unsustainable production and consumption patterns that aggravate poverty in many regions of the world.

We believe that urgent actions are needed to address these fundamental problems and reverse the trends. Stabilization of human population, adoption of environmentally sound industrial and agricultural technologies, reforestation, and ecological restoration are crucial elements in creating an equitable and

[23] University Leaders for a Sustainable Future, *Welcome*, <www.ulsf.org>

sustainable future for all humankind in harmony with nature.

Universities have a major role in the education, research, policy formation, and information exchange necessary to make these goals possible. Thus, university leaders must initiate and support mobilization of internal and external resources so that their institutions respond to this urgent challenge.

We, therefore, agree to take the following actions:

1) Increase Awareness of Environmentally Sustainable Development
Use every opportunity to raise public, government, industry, foundation, and university awareness by openly addressing the urgent need to move toward an environmentally sustainable future.

2) Create an Institutional Culture of Sustainability
Encourage all universities to engage in education, research, policy formation, and information exchange on population, environment, and development to move toward global sustainability.

3) Educate for Environmentally Responsible Citizenship
Establish programs to produce expertise in environmental management, sustainable economic development, population, and related fields to ensure that all university graduates are environmentally literate and have the awareness and understanding to be ecologically responsible citizens.

4) Foster Environmental Literacy For All
Create programs to develop the capability of university faculty to teach environmental literacy to all undergraduate, graduate, and professional students.

5) Practice Institutional Ecology
Set an example of environmental responsibility by establishing institutional ecology policies and practices of resource conservation, recycling, waste reduction, and environmentally sound operations.

6) Involve All Stakeholders
Encourage involvement of government, foundations, and industry in supporting interdisciplinary research, education, policy formation, and information exchange in environmentally sustainable development. Expand work with community and nongovernmental organizations to assist in finding solutions to environmental problems.

7) Collaborate for Interdisciplinary Approaches
Convene university faculty and administrators with environmental practitioners to develop interdisciplinary approaches to curricula, research initiatives, operations, and outreach activities that support an environmentally sustainable future.

8) Enhance Capacity of Primary and Secondary Schools
Establish partnerships with primary and secondary schools to help develop the capacity for interdisciplinary teaching about population, environment, and

sustainable development.

9) Broaden Service and Outreach Nationally and Internationally

Work with national and international organizations to promote a worldwide university effort toward a sustainable future.

10) Maintain the Movement
Establish a Secretariat and a steering committee to continue this momentum, and to inform and support each other's efforts in carrying out this declaration.

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10.3 Campus Audit

Following the benchmarking spreadsheets are a series of tables (Table 10.1 through 10.8.) that detail the campus energy usage as reported by the Facilities Department. The electrical, natural gas and water consumption information have been summarized, and information on general building usage is included for comparison. The information in the audit spreadsheet was used to obtain the greenhouse gas and water consumption information that is presented in the campus maps that are included in section 3 on the need for sustainability at IIT. The electricity, steam usage and water consumption come from data collected by the Facilities Department. The natural gas information is derived from the steam data, and is apportioned by the Facilities Department in that same way. For water consumption, the consumption of the steam plant is divided among the buildings based upon their use of steam.

BUILDING	Building Type	ADDRESS	YEAR	SQFT
3424 S. State	Office	3424 S. State	1965	200,088
Alpha Epsilon Pi	Lodging	3350 S. Michigan Ave	1961	15,616
Alpha Sigma Phi	Lodging	3361 S. Wabash Ave	1960	12,402
Alumni Memorial Hall	Education	3201 S. Dearborn St.	1946	36,132
ASA Sorority	Lodging	3340 S. Michigan Ave	1961	15,616
Bailey Hall	Lodging	3101 S. Wabash Ave	1955	75,316
Carman Hall	Lodging	60 E.32nd St	1953	75,316
Chemistry Research Bldg	Office	60 W. 35th Street	1957	141,328
Crown Hall	Education	3360 S. State St.	1956	52,800
Cunningham Hall	Lodging	3100 S. Michigan Ave	1955	75,316
Delta Tau Delta	Lodging	3349 S. Wabash Ave	1960	15,616
Engineering #1 Bldg.	Education	10 W. 32nd St.	1967	145,056
Engineering Research	Office	55 W. 34th St	1945	82,234
Farr Hall	Education	3300 S. Michigan	1948	24,535
Fowler Hall	Lodging	3200 S. Michigan Ave	1948	24,535
Galvin Library	Public Assembly	35 W. 33rd St	1962	92,000
Gunsaulus Hall	Lodging	3140 S. Michigan Ave.	1948	80,632
Hermann Hall	Public Assembly	3241 S. Federal St.	1960	112,640
Keating Hall	Education	3040 S. Wabash	1967	64,524
Law House	Lodging	3330 S. Michigan Ave	1961	15,616
Life Sciences	Education	3105 S. Dearborn St.	1966	107,000
Life Sciences IITRI	Office	3424 S. Dearborn St	1959	101,477
Machinery Hall	Utility	100 W. 33rd St.	1901	32,700
Main Building	Office	3300 S. Federal St	1891	62,370
Material Technology Bldg	Office	3350 S. Federal	1941-64	78,542
McCormick Village	Lodging	71 E. 32nd St	1958-66	242,313
McCormick-Tribune Student Ctr*	Public Assembly	3201 S. State St	2003	88,000
Perlstein Hall	Education	10 W.33rd St.	1947	108,000
Phi Kappa Sigma	Lodging	3366 S. Michigan Ave	1959	12,528
Pi Kappa Phi	Lodging	3333 S. Wabash Ave	1961	15,616
Research Tower	Office	10 W. 35th St	1963	382,858
Siegel Hall	Education	3301 S. Dearborn	1957	65,000
Sigma Phi Epsilon	Lodging	3341 S. Wabash Ave	1961	15,616
State Street Village 03	Lodging	3303 S. State St	2003	36,500
State Street Village 33	Lodging	3333 S. State St	2003	36,500
State Street Village 53	Lodging	3353 S. State St	2003	36,500
Stuart Building	Education	10 W. 31st St	1966	80,796
Triangle	Lodging	3360 S. Michigan	1960	13,336
Vandercook	Education	3140-62 S. Federal St	1950	31,000
Wishnick Hall	Education	3255 S. Dearborn St.	1947	65,000
Campus Totals				**2,968,970**

Table 10.1: IIT Main Campus General Building Information (from IIT Statement of Property Values)

BUILDING	Electricity 2002-2003	Electricity 2004	Variance 2003-2004
3424 S. State	1,340,181	1,070,059	-25.24%
Alpha Epsilon Pi	117,600	4,100	-2768%
Alpha Sigma Phi	124,540	127,180	2.08%
Alumni Memorial Hall	940,320	912,960	-3.00%
ASA Sorority	140,180	158,780	11.71%
Bailey Hall	547,200	494,720	-10.61%
Carman Hall	539,200	531,040	-1.54%
Chemistry Research Bldg	1,135,000	968,000	-17.25%
Crown Hall	812,144	780,428	-4.06%
Cunningham Hall	451,440	468,000	3.54%
Delta Tau Delta	169,590	158,720	-6.85%
Engineering #1 Bldg.	2,824,100	3,837,887	26.42%
Engineering Research	1,695,000	1,856,000	8.67%
Farr Hall	120,120	127,720	5.95%
Fowler Hall		162,338	100.00%
Galvin Library	1,064,291	1,004,720	-5.93%
Gunsaulus Hall	573,680	530,400	-8.16%
Hermann Hall	1,857,611	1,541,222	-20.53%
Keating Hall	978,400	1,208,400	19.03%
Law House	117,440	139,880	16.04%
Life Sciences	4,621,503	4,869,364	5.09%
Life Sciences IITRI	1,518,480	2,223,120	31.70%
Machinery Hall	174,000	207,280	16.06%
Main Building	486,480	455,680	-6.76%
Material Technology Bldg	710,300	325,000	-118.55%
McCormick Village	2,572,410	2,397,160	-7.31%
McCormick-Tribune Student Ctr.*		3,216,651	100.00%
Perlstein Hall	1,399,200	1,331,200	-5.11%
Phi Kappa Sigma	68,844	102,992	33.16%
Pi Kappa Phi	177,840	169,800	-4.73%
Research Tower	6,811,200	6,649,300	-2.43%
Siegel Hall	1,243,264	1,254,272	0.88%
Sigma Phi Epsilon	140,000	149,000	6.04%
State Street Village 03		476,939	100.00%
State Street Village 33		476,939	100.00%
State Street Village 53		476,939	100.00%
Stuart Building	1,575,000	1,325,100	-18.86%
Triangle	136,270	112,280	-21.37%
Vandercook	165,900	159,500	-4.01%
Wishnick Hall	1,180,000	874,000	-35.01%
Campus Totals	**38,528,728**	**43,335,070**	**11.09%**

Table 10.2: IIT Main Campus Building Electricity Consumption Information for Baseline

BUILDING	**Water gal**	**Electricity kWh**	**Steam lbs**	**Natural Gas MMBtu**	**Energy MMBtu**
3424 S. State	6,663,031.28	1,070,059	15,361,000	43,529	47,180
Alpha Epsilon Pi	401,282.84	117,600	55,000	156	557
Alpha Sigma Phi	430,783.64	125,860	380,000	1,077	1,506
Alumni Memorial Hall	1,140,592.62	926,640	1,136,000	3,219	6,381
ASA Sorority	451,933.44	149,480	613,000	1,737	2,247
Bailey Hall	6,542,749.24	520,960	6,692,000	18,963	20,741
Carman Hall	1,643,794.02	535,120	6,481,000	18,365	20,191
Chemistry Research Bldg	847,014.98	1,051,500	5,614,000	15,909	19,496
Crown Hall	2,201,698.62	796,286	3,791,000	10,743	13,460
Cunningham Hall	6,044,571.33	459,720	8,087,000	22,916	24,485
Delta Tau Delta	396,290.40	164,155	0	0	560
Engineering #1 Bldg.	6,537,315.69	3,837,887	6,408,000	18,159	31,253
Engineering Research	3,033,038.40	1,775,500	2,443,000	6,923	12,981
Farr Hall	1,234,682.30	123,920	1,571,000	4,452	4,875
Fowler Hall	1,005,451.52	162,338	271,000	768	1,322
Galvin Library	6,543,372.57	1,034,506	6,066,000	17,189	20,719
Gunsaulus Hall	7,732,463.63	552,040	5,958,000	16,883	18,767
Hermann Hall	12,256,232.93	1,541,222	5,884,000	16,674	21,932
Keating Hall	1,652,050.46	1,208,400	6,169,000	17,481	21,604
Law House	502,856.35	128,660	1,174,000	3,327	3,766
Life Sciences	3,247,172.42	4,745,434	11,593,000	32,851	49,043
Life Sciences IITRI	37,527,297.48	2,223,120	34,206,000	96,931	104,516
Machinery Hall	1,474,308.00	190,640	0	0	650
Main Building	1,645,066.69	471,080	4,678,000	13,256	14,864
Material Technology Bldg	15,249.64	325,000	168,000	476	1,585
McCormick Village	11,001,791.47	2,484,785	4,091,200	11,593	20,071
McCormick-Tribune Student Center*	7,119,201.94	3,216,651	10,731,131	30,409	41,384
Perlstein Hall	4,986,433.20	1,365,200	1,057,700	2,997	7,655
Phi Kappa Sigma	454,565.81	102,992	642,000	1,819	2,171
Pi Kappa Phi	477,857.46	173,820	898,596	2,546	3,139
Research Tower	10,548,833.36	6,730,250	12,435,000	35,237	58,201
Siegel Hall	3,573,365.64	1,248,768	2,371,000	6,719	10,980
Sigma Phi Epsilon	495,594.61	144,500	1,094,000	3,100	3,593
State Street Village 03	77,686.76	476,939	855,848	2,425	4,053
State Street Village 33	77,686.76	476,939	855,848	2,425	4,053
State Street Village 53	77,686.76	476,939	855,848	2,425	4,053
Stuart Building	1,666,190.00	1,325,100	3,968,000	11,244	15,766
Triangle	467,143.59	112,280	780,565	2,212	2,595
Vandercook	720,324.00	162,700	0	0	555
Wishnick Hall	5,393,105.37	874,000	371,100	1,052	4,034
Campus Totals	**158,307,767**	**43,608,989**	**175,806,836**	**498,190**	**646,984**

Table 10.3: IIT Main Campus Building Utility Consumption Baseline

BUILDING	Electricity kWh/SF	Natural Gas Btu/SF	Energy Btu/SF
3424 S. State	5.35	217,549	235,796
Alpha Epsilon Pi	7.53	9,980	35,675
Alpha Sigma Phi	10.15	86,826	121,452
Alumni Memorial Hall	25.65	89,093	176,597
ASA Sorority	9.57	111,237	143,898
Bailey Hall	6.92	251,784	275,385
Carman Hall	7.10	243,845	268,087
Chemistry Research Bldg	7.44	112,565	137,951
Crown Hall	15.08	203,460	254,917
Cunningham Hall	6.10	304,270	325,097
Delta Tau Delta	10.51	0	35,867
Engineering #1 Bldg.	26.46	125,183	215,458
Engineering Research	21.59	84,184	157,852
Farr Hall	5.05	181,447	198,680
Fowler Hall	6.62	31,300	53,876
Galvin Library	11.24	186,842	225,208
Gunsaulus Hall	6.85	209,388	232,748
Hermann Hall	13.68	148,026	194,712
Keating Hall	18.73	270,927	334,827
Law House	8.24	213,038	241,150
Life Sciences	44.35	307,023	458,345
Life Sciences IITRI	21.91	955,199	1,029,948
Machinery Hall	5.83	0	19,892
Main Building	7.55	212,541	238,312
Material Technology Bldg	4.14	6,061	20,180
McCormick Village	10.25	47,845	82,833
McCormick-Tribune Student Center*	36.55	345,559	470,277
Perlstein Hall	12.64	27,752	70,882
Phi Kappa Sigma	8.22	145,215	173,265
Pi Kappa Phi	11.13	163,062	201,041
Research Tower	17.58	92,038	152,017
Siegel Hall	19.21	103,366	168,917
Sigma Phi Epsilon	9.25	198,521	230,093
State Street Village 03	13.07	66,445	111,029
State Street Village 33	13.07	66,445	111,029
State Street Village 53	13.07	66,445	111,029
Stuart Building	16.40	139,169	195,127
Triangle	8.42	165,860	194,587
Vandercook	5.25	0	17,907
Wishnick Hall	13.45	16,178	62,057
Campus Totals	**14.69**	**167,799**	**217,915**

Table 10.4: IIT Main Campus Building Energy Density from Baseline

BUILDING	Electricity kWh/SF	Natural Gas Btu/SF	Energy Btu/SF	Electricity kWh	Natural Gas MMBtu	Energy MMBtu
3424 S. State	22.2	25,000	104,100	4,441,954	5,002	20,829
Alpha Epsilon Pi	13.1	53,100	104,200	204,570	829	1,627
Alpha Sigma Phi	13.1	53,100	104,200	162,466	659	1,292
Alumni Memorial Hall	9.1	33,800	75,700	328,801	1,221	2,735
ASA Sorority	13.1	53,100	104,200	204,570	829	1,627
Bailey Hall	13.1	53,100	104,200	986,640	3,999	7,848
Carman Hall	13.1	53,100	104,200	986,640	3,999	7,848
Chemistry Research Bldg	22.2	25,000	104,100	3,137,482	3,533	14,712
Crown Hall	9.1	33,800	75,700	480,480	1,785	3,997
Cunningham Hall	13.1	53,100	104,200	986,640	3,999	7,848
Delta Tau Delta	13.1	53,100	104,200	204,570	829	1,627
Engineering #1 Bldg.	8.3	31,900	75,800	1,203,965	4,627	10,995
Engineering Research	17.1	30,900	83,100	1,406,201	2,541	6,834
Farr Hall	9.1	33,800	75,700	223,269	829	1,857
Fowler Hall	13.1	53,100	104,200	321,409	1,303	2,557
Galvin Library	12.5	29,100	77,500	1,150,000	2,677	7,130
Gunsaulus Hall	13.1	53,100	104,200	1,056,279	4,282	8,402
Hermann Hall	17.6	21,700	103,200	1,982,464	2,444	11,624
Keating Hall	9.1	33,800	75,700	587,168	2,181	4,884
Law House	13.1	53,100	104,200	204,570	829	1,627
Life Sciences	8.3	31,900	75,800	888,100	3,413	8,111
Life Sciences IITRI	22.2	25,000	104,100	2,252,789	2,537	10,564
Machinery Hall	9.1	33,800	75,700	297,570	1,105	2,475
Main Building	17.1	30,900	83,100	1,066,527	1,927	5,183
Material Technology Bldg	17.1	30,900	83,100	1,343,068	2,427	6,527
McCormick Village	11.1	38,500	81,200	2,689,674	9,329	19,676
McCormick-Tribune Student Center*	12.5	29,100	77,500	1,100,000	2,561	6,820
Perlstein Hall	8.3	31,900	75,800	896,400	3,445	8,186
Phi Kappa Sigma	13.1	53,100	104,200	164,117	665	1,305
Pi Kappa Phi	13.1	53,100	104,200	204,570	829	1,627
Research Tower	22.2	25,000	104,100	8,499,448	9,571	39,856
Siegel Hall	9.1	33,800	75,700	591,500	2,197	4,921
Sigma Phi Epsilon	13.1	53,100	104,200	204,570	829	1,627
State Street Village 03	13.1	53,100	104,200	478,150	1,938	3,803
State Street Village 33	13.1	53,100	104,200	478,150	1,938	3,803
State Street Village 53	13.1	53,100	104,200	478,150	1,938	3,803
Stuart Building	9.1	33,800	75,700	735,244	2,731	6,116
Triangle	13.1	53,100	104,200	174,702	708	1,390
Vandercook	9.1	33,800	75,700	282,100	1,048	2,347
Wishnick Hall	9.1	33,800	75,700	591,500	2,197	4,921
Campus Totals	**14.7**	**34,266**	**91,265**	**43,676,462**	**101,734**	**270,962**

Table 10.5: IIT Main Campus Energy Density and Consumption if Buildings Performed as Typical Buildings (data from Energy Information Administration 1999 Commercial Building Energy Consumption Survey)

BUILDING	**Carbon Dioxide lbs.**	**Carbon Monoxide lbs.**	**Nitrogen Oxides lbs.**	**CO_2 (tons) Equivalent**
3424 S. State	5,640,710	1,741	5,353	3,312
Alpha Epsilon Pi	78,440	6	163	58
Alpha Sigma Phi	190,422	43	258	123
Alumni Memorial Hall	851,031	129	1,464	592
ASA Sorority	279,765	69	348	176
Bailey Hall	2,485,418	759	2,401	1,465
Carman Hall	2,422,711	735	2,364	1,432
Chemistry Research Bldg	2,399,620	636	2,788	1,481
Crown Hall	1,664,553	430	1,992	1,035
Cunningham Hall	2,916,574	917	2,688	1,701
Delta Tau Delta	84,039	0	207	67
Engineering #1 Bldg.	4,089,359	726	6,506	2,770
Engineering Research	1,718,936	277	2,874	1,184
Farr Hall	584,301	178	566	345
Fowler Hall	172,958	31	275	117
Galvin Library	2,540,779	688	2,885	1,558
Gunsaulus Hall	2,257,974	675	2,249	1,341
Hermann Hall	2,739,851	667	3,476	1,732
Keating Hall	2,663,954	699	3,131	1,649
Law House	455,104	133	468	272
Life Sciences	6,273,049	1,314	9,002	4,112
Life Sciences IITRI	12,479,022	3,877	11,719	7,310
Machinery Hall	97,598	0	240	78
Main Building	1,792,146	530	1,813	1,068
Material Technology Bldg	222,084	19	453	164
McCormick Village	2,628,511	464	4,197	1,783
McCormick-Tribune Student Center*	5,204,638	1,216	6,851	3,325
Perlstein Hall	1,049,591	120	1,996	757
Phi Kappa Sigma	265,580	73	297	162
Pi Kappa Phi	386,914	102	453	239
Research Tower	7,568,338	1,409	11,722	5,082
Siegel Hall	1,425,405	269	2,192	955
Sigma Phi Epsilon	436,689	124	467	264
State Street Village 03	527,923	97	824	355
State Street Village 33	527,923	97	824	355
State Street Village 53	527,923	97	824	355
Stuart Building	1,993,963	450	2,704	1,285
Triangle	316,276	88	345	192
Vandercook	83,294	0	205	67
Wishnick Hall	570,481	42	1,198	427
Campus Totals	**80,613,846**	**19,928**	**100,781**	**50,747**

Table 10.6: IIT Main Campus Greenhouse Gas Emissions (calculated from data supplied by ComEd and EIA Natural Gas Issues and Trends 1999)

BUILDING	Sulfur Dioxide lbs.	High Level Nuclear Waste (lbs.)	Low Level Nuclear Waste (ft^3)	Particulates lbs.
3424 S. State	1,584	5	0.11	305
Alpha Epsilon Pi	169	1	0.01	1
Alpha Sigma Phi	182	1	0.01	8
Alumni Memorial Hall	1,338	4	0.09	23
ASA Sorority	217	1	0.01	12
Bailey Hall	769	2	0.05	133
Carman Hall	789	2	0.05	129
Chemistry Research Bldg	1,530	5	0.11	111
Crown Hall	1,157	4	0.08	75
Cunningham Hall	685	2	0.05	160
Delta Tau Delta	236	1	0.02	0
Engineering #1 Bldg.	5,545	18	0.38	127
Engineering Research	2,564	8	0.18	48
Farr Hall	183	1	0.01	31
Fowler Hall	235	1	0.02	5
Galvin Library	1,507	5	0.10	120
Gunsaulus Hall	812	3	0.06	118
Hermann Hall	2,236	7	0.15	117
Keating Hall	1,758	6	0.12	122
Law House	189	1	0.01	23
Life Sciences	6,866	22	0.47	230
Life Sciences IITRI	3,298	10	0.22	679
Machinery Hall	275	1	0.02	0
Main Building	692	2	0.05	93
Material Technology Bldg	468	1	0.03	3
McCormick Village	3,590	11	0.25	81
McCormick-Tribune Student Center*	4,662	15	0.32	213
Perlstein Hall	1,969	6	0.14	21
Phi Kappa Sigma	150	0	0.01	13
Pi Kappa Phi	253	1	0.02	18
Research Tower	9,727	31	0.67	247
Siegel Hall	1,805	6	0.12	47
Sigma Phi Epsilon	211	1	0.01	22
State Street Village 03	689	2	0.05	17
State Street Village 33	689	2	0.05	17
State Street Village 53	689	2	0.05	17
Stuart Building	1,919	6	0.13	79
Triangle	164	1	0.01	15
Vandercook	234	1	0.02	0
Wishnick Hall	1,260	4	0.09	7
Campus Totals	**63,295**	**201**	**4.36**	**3,487**

Table 10.7: IIT Main Campus Other Emissions (calculated from data supplied by ComEd)

BUILDING	Min. Water Need Apportioned by SF	Water Over Needs
3424 S. State	2,113,172	4,549,859
Alpha Epsilon Pi	164,924	236,359
Alpha Sigma Phi	130,980	299,803
Alumni Memorial Hall	381,598	758,995
ASA Sorority	164,924	287,010
Bailey Hall	795,428	5,747,321
Carman Hall	795,428	848,366
Chemistry Research Bldg	1,492,595	-645,580
Crown Hall	557,632	1,644,067
Cunningham Hall	795,428	5,249,143
Delta Tau Delta	164,924	231,366
Engineering #1 Bldg.	1,531,967	5,005,348
Engineering Research	868,491	2,164,548
Farr Hall	259,119	975,563
Fowler Hall	259,119	746,332
Galvin Library	971,632	5,571,741
Gunsaulus Hall	851,572	6,880,892
Hermann Hall	1,189,615	11,066,618
Keating Hall	681,452	970,599
Law House	164,924	337,932
Life Sciences	1,130,050	2,117,123
Life Sciences IITRI	1,071,720	36,455,577
Machinery Hall	345,352	1,128,956
Main Building	658,703	986,364
Material Technology Bldg	829,499	-814,249
McCormick Village	2,559,119	8,442,672
McCormick-Tribune Student Center*	929,387	6,189,815
Perlstein Hall	1,140,611	3,845,822
Phi Kappa Sigma	132,311	322,255
Pi Kappa Phi	164,924	312,934
Research Tower	4,043,445	6,505,388
Siegel Hall	686,479	2,886,887
Sigma Phi Epsilon	164,924	330,671
State Street Village 03	385,484	-307,798
State Street Village 33	385,484	-307,798
State Street Village 53	385,484	-307,798
Stuart Building	853,304	812,886
Triangle	140,844	326,299
Vandercook	327,398	392,926
Wishnick Hall	686,479	4,706,627
Campus Totals	**31,355,925**	**126,951,842**

Table 10.8: IIT Main Campus Excess Water Usage

10.4 Greenhouse Gas to Trees Conversion

To put the energy consumption and ecological footprint into perspective, the team analyzed how much carbon is released into the atmosphere yearly directly due to the existence of the university. Determining that value relied upon information disclosed by ComEd, Energy Information Statistics for natural gas burning and gasoline usage, and the table of commuter information in section 3. Once the total weight of carbon released was calculated, a factor of 0.039 metric tons of carbon per urban tree was used to convert the tons of carbon to trees needed to sequester.[24] This calculation yielded the result of 1.3 million trees per year.

10.5 Water Overusage to Families Conversion

To arrive at a similar measurement for water wasted, the campus water consumption was compared with the quantity needed to maintain the health of the university staff, students and faculty. From the IIT website, faculty, staff and student population numbers were obtained, and water use requirements are taken from two sources.[25] [26] According to Mr. Gleick, the necessary water consumption per person is fifty (50) liters per day, while Mr. Falkenmark suggests one hundred liters per day. From this, an average of 75 liters per day or 19.75 gallons per day per person is established. To account for the fact that only the student population gets all of their water from the campus, the faculty is assumed to get only eighty percent of their required water five days a week, and the staff only sixty percent five days a week. Once this quantity was determined, it was divided among the campus buildings based upon the relative square footage of the buildings. This is the number that is subtracted from the usage information to determine the overusage. By performing a similar calculation to that from above, but this time accounting for the entire yearly consumption of a family of four, and using a very conservative 53 gallons per day per person (or 200 liters per day) in order to account for a family in the developing world that would use more water for irrigation, health, and improving quality of life than a person in the developed world.

[24] Energy Information Administration, Alternatives to Traditional Transportation Fuels 1994: Volume 2 Greenhouse Gas Emissions

[25] Gleick, P., Basic water requirements for human activities: Meeting basic needs. International Water 21(2): 83-92. 1996.

[26] Falkenmark, M. and Widstrand, C. Population and water resources: A delicate balance. Population Bulletin 47(3): 1-36. Nov. 1992. As referenced in Population Reports: Solutions for a Water-Short World Volume XXVI, Number 1 September, 1998.

10.6 Preliminary Geothermal System Calculations

As the starting point for a discussion of the size of geothermal system that would be needed for IIT, the natural gas consumption for heating was compared with that of a typical building of type. Assuming that the sustainability efforts could produce a building that is high performance, the building would consume energy at a rate that is sixty percent of a typical building. Using these numbers, a total projected campus energy consumption profile is obtained. This profile can be used to calculate the approximate size and installation cost of the geothermal system according to the following table:

Target Water Use Per SF	10.56	gal/sf/year
Target Water Use Per Student/Staff	5,346.28	gal/person/year
Target Electricity Use Per SF	8.83	kWh/sf/year
Target Electricity Use Per Student/Staff	4,468.18	kWh/person/year
Target Heating Need Per SF	0.03	MMBtu/sf/year
Target Heating Need Per Student/Staff	13.01	MMBtu/person/year
Heating Load Instantaneous	76.30	MMBtu/h
(Assume that the system must be sized to produce .1% of the yearly consumption at any given time.)		
Geothermal Installation Cost	$1,200	per ton
System size required	6358	tons
Estimated cost	$7,630,051	
Current yearly Natural Gas Costs (avoided)	$2,700,000	
Simple payback	2.8	years

Table 10.9: Approximate Size and Installation Costs of Geothermal System

The geothermal installation cost comes from estimates on the Department of Energy website. Note that the simple payback includes the building improvements. These costs cannot presently be estimated without a detailed audit, so the simple payback period will increase, however it can be anticipated that it would not increase beyond nine years.

10.7 Target Consumption and Available Renewable Resources

To determine if the campus can truly become sustainable, an analysis was performed that use the average solar energy density and average rainfall. The solar density comes from the National Renewable Energy Laboratory and the average rainfall from the National Oceanic and Atmospheric Administration. Using the totals from Table 10.10, and the information that follows the table, the potential for sustainability is calculated.

BUILDING	Water gal	Electricity kWh	Heating Load MMBtu
3424 S. State	2,113,172	2,665,172	3,752
Alpha Epsilon Pi	164,924	122,742	622
Alpha Sigma Phi	130,980	97,480	494
Alumni Memorial Hall	381,598	197,281	916
ASA Sorority	164,924	122,742	622
Bailey Hall	795,428	591,984	2,999
Carman Hall	795,428	591,984	2,999
Chemistry Research Bldg	1,492,595	1,882,489	2,650
Crown Hall	557,632	288,288	1,338
Cunningham Hall	795,428	591,984	2,999
Delta Tau Delta	164,924	122,742	622
Engineering #1 Bldg.	1,531,967	722,379	3,470
Engineering Research	868,491	843,721	1,906
Farr Hall	259,119	133,961	622
Fowler Hall	259,119	192,845	977
Galvin Library	971,632	690,000	2,008
Gunsaulus Hall	851,572	633,768	3,211
Hermann Hall	1,189,615	1,189,478	1,833
Keating Hall	681,452	352,301	1,636
Law House	164,924	122,742	622
Life Sciences	1,130,050	532,860	2,560
Life Sciences IITRI	1,071,720	1,351,674	1,903
Machinery Hall	345,352	178,542	829
Main Building	658,703	639,916	1,445
Material Technology Bldg	829,499	805,841	1,820
McCormick Village	2,559,119	1,613,805	6,997
McCormick-Tribune Student Center*	929,387	660,000	1,921
Perlstein Hall	1,140,611	537,840	2,584
Phi Kappa Sigma	132,311	98,470	499
Pi Kappa Phi	164,924	122,742	622
Research Tower	4,043,445	5,099,669	7,179
Siegel Hall	686,479	354,900	1,648
Sigma Phi Epsilon	164,924	122,742	622
State Street Village 03	385,484	286,890	1,454
State Street Village 33	385,484	286,890	1,454
State Street Village 53	385,484	286,890	1,454
Stuart Building	853,304	441,146	2,048
Triangle	140,844	104,821	531
Vandercook	327,398	169,260	786
Wishnick Hall	686,479	354,900	1,648
Campus Totals	**31,355,925**	**26,205,877**	**76,301**

Table 10.10: Target Energy Consumption for IIT Main Campus Buildings (calculated as 60% of typical buildings)

Average Solar Energy	4.5	kWh/m2/day
	3.762	kWh/yd2/day
Campus size	484,000	yd2
Potential Energy Recovery from Solar	664,594,920	kWh
Needed energy % of available	4.90%	
(Originally)	28.53%	
Average Rainfall	3	ft/sf/year
Yearly Volume of Rainfall	13,068,000	ft3
	97,748,640	gal
Needed water % of available	32.08%	
(Originally)	161.95%	

Table 10.11: Potential of Sustainability

Education				
Type	Small <10000	Medium 10000-100000	Large >100000	
Natural Gas	38.7	33.8	31.9	ft3/sf
Natural Gas	N/A	33800	31900	Btu/sf
District Heating	N/A	100600	100600	Btu/sf
Electricity	8.1	9.1	8.3	kWh/sf
Water				
Total Energy	**68**	**75.7**	**75.8**	**Mbtu/sf**

Office				
Type	Small <10000	Medium 10000-100000	Large >100000	
Natural Gas	33.9	30.9	25	ft3/sf
Natural Gas	33900	30900	25000	Btu/sf
District Heating	N/A	48500	48500	Btu/sf
Electricity	13.8	17.1	22.2	kWh/sf
Water				
Total Energy	**74.7**	**83.1**	**104.1**	**Mbtu/sf**

Lodging				
Type	Small <10000	Medium 10000-100000	Large >100000	
Natural Gas	N/A	53.1	38.5	ft3/sf
Natural Gas	N/A	53100	38500	Btu/sf
District Heating	N/A	107510	107510	Btu/sf
Electricity	17.5	13.1	11.1	kWh/sf
Water				
Total Energy	**152.4**	**104.2**	**81.2**	**Mbtu/sf**

Food Service				
Type	Small <10000	Medium 10000-100000	Large >100000	
Natural Gas	177.2	N/A	N/A	ft3/sf
Natural Gas	177200	N/A	N/A	Btu/sf
Electricity	40.5	N/A	N/A	kWh/sf
Water				
Total Energy	**281**	**N/A**	**N/A**	**Mbtu/sf**

Public Assembly				
Type	Small <10000	Medium 10000-100000	Large >100000	
Natural Gas	47.9	29.1	21.7	ft3/sf
Natural Gas	47900	29100	21700	Btu/sf
District Heating	N/A	69860	69860	Btu/sf
Electricity	8.2	12.5	17.6	kWh/sf
Water				
Total Energy	**66.5**	**77.5**	**103.2**	**Mbtu/sf**

Table 10.12: Typical Building Consumption Data from Energy Information Administration

11 APPENDIX – HOUSE OF THE FUTURE

11.1 Passive Design Principles

Passive design principles are a unique basis for building space because of its direct and sensitive concept of controlling the thermal and luminous environment within the building. There are two basic reasons why passive design strategy is imperative in sustainability. First, passive approaches have a direct effect on the design of the building envelope. Second, passive systems should be considered as primary source of energy for comfort and efficiency and mechanical and electrical systems should be secondary or a backup.

To intuit the principle nature of passive design a thorough knowledge of the principles of conduction and convection, thermal transmittance, radiation, evaporation, humidity, phase change, sensible heat, latent heat, specific heat, and enthalpy. These concepts result in a comfortable microclimate, or living condition, within the building. In addition, understanding material properties is imperative to gage how the material will act in different seasonal climates and day-to-day changes in temperature and humidity as well as what the material will do when build with other materials. For instance, thermal bridging is a term used to describe a value in heat loss usually associated with glass windows with metal frame that have negative expansion properties where the differential may cause infiltration (cold heat coming in, vice versa), or even cracking windows.

To avoid such construction problems a comprehension of the source of energy is important: the sun. From the sun the building is able to gain heat, store heat and cool off during the night. The technique has been used with sun-dried mud bricks in parts of the Middle East and Africa since civilization began, some continuing to this day. Passive design principles are intuitive and based much on common sense; the understanding of the laws of physics and application will allow for progress from sun-dried mud bricks to removable and replaceable walls.

11.1.1 Passive Solar Heating

Passive solar heating is achieved by way of radiation, conduction, and natural convection as opposed to active solar heating with air pumps and fans for forced distribution. With an active system there are apparent ventilation shafts, ducts and piping retrofitted into the building. In contrast, passive system is very intimately interconnected with the placement and replacement of specific building components that may even look bare upon completion. The great benefit of this system is that by sun angle and materials studies designers such as architects and engineers are able to predict and zone the spaces as such for maximum efficiency and comfort. In other words, builders are reproducing the “greenhouse effect” with total control without unnecessary emissions.

There are five basic methods of collecting heat according to physical configuration and sun angles.

- **Direct gain**: Consists of south-facing windows that admit winter sunshine directly unto the building into its interior where the heat is absorbed by the furniture, carpet, or other such masses.
- **Thermal storage wall**: Commonly associated with a Trombe wall, which is a south facing wall constructed of heavy masonry or a Water wall consisting of water-filled containers as a massive wall to absorb heat. A glass glazing system is constructed outside on the south-facing wall to lower heat loss during the night.
- **Sunspace**: Analogous to a greenhouse, sunroom, conservatory, or atrium located on the south side of the building. The basic concept is conduction of heat from the sunspace to the adjacent rooms, or convection if the common wall has windows and openings.
- **Convection air loop**: A solar collector or a thermal mass is placed isolated from the living spaces to store that is distributed as hot air.
- **Roof pond**: Primarily a system used for passive cooling but has attributes to maintain heat during cooler nights combined with other systems.

To maximize on the five basic components designers must consider orientation of the glazing system (window system), the distribution of solar glazing areas (where we place the windows), conservation levels (how airtight and insulated the building and the components are), and nothing has to be perpendicular to the ground. All these points must be put to equal task of accomplishing solar heat gain; however, the latter point is usually ignored due to possible installation difficulties or customization of a window. An increase of performance can be achieved by tilting the solar glazing. Optimum winter heat angle is 50-60 degrees in most all locations in the United States. During the winter the building can also benefit from the reflectance factor of snow onto the glazing increasing solar heat gain. Vertical glazing is easier to construct and install and reduces unwanted heat gains and facilitates the installation for night insulation.

11.1.2 Passive Cooling

If a room heats up because of people, afternoon heat, or electronics, opening the window and letting the heat out is the obvious thing to do. Passive cooling is the counterpart of passive solar. Passive cooling has been around longer than passive solar heating, but its use is not widely found. Whereas the sun drives passive solar heating, passive cooling is in essence, nonsolar, making heat sinks to absorb and diminish. Because both systems rely on heat flow by natural means (radiation, conduction, convection, and phase change), they share many similar principles.

The key in understanding passive cooling is to understand the workings of the natural environment. The sun directs heat to the earth, the layer of the atmosphere breaths, but maintains and allows certain rays to heat the earth, whereby the natural heat sinks in the form of water, earth (soil), and sky absorbs and evacuates the unwanted heat. This heat also insulates plant life that cleans the air and produce organic matter for other plant life and animals to live. A basic recycling system that was lost, now made complex in human evolution, will set precedent to the way humans live.

Passive cooling components can be categorized by different fields of study on heat sinks rather than actual building components and orientation as in passive solar heating. There are four basic studies on passive cooling:

- **Ventilative cooling**: The exhausting of warm building air and replacing with outside air; directing across occupant's skin to cool by evaporation and convection. This required air movement is provided by either the wind or "stack effect". Fans can be used.
- **Radiative cooling**: The transfer of warm heat to a cooler adjacent surrounding surface.
- **Evaporative cooling**: The exchange of sensible heat in air for the latent heat of water droplets of wetted surfaces (phase changes).
- **Dehumidification**: The removal of water vapor from room air by dilution with drier air, condensation, or desiccation.
- **Mass-Effect cooling**: The use of thermal storage to absorb heat during the day and release it during the night for warmth. This is where cool night air is drawn through a building to exhaust heat stored during the day called "Night Flushing".

11.1.3 Applications of Passive Design Principles of the House

11.1.3.1 The South Façade

The house is designed to take advantage of the sun along the south façade. In the center of the façade, 400 sqft of semi-transparent photovoltaic (PV) modules are integrated into the exterior glazing of a double-skin façade. The double-skin photovoltaic façade has the following multiple functions:

- **Solar electricity**: The semi-transparent PV modules produce 3,345 kWh of electricity per year;
- **Solar heat gain**: in the winter the air in the house is heated by the sun rays coming through the façade and is distributed throughout the house;
- **Natural ventilation**: in the summer operable windows at the bottom of the north facade and at the top of the south façade provide natural cooling inside the house;
- **PV ventilation and fresh air pre-heating**: in the winter, through opened louvers below the PV panels, the double-skin façade allows back ventilation of the solar cells in a 25 inches wide cavity. The fresh outside air, flowing through the cavity is preheated and can be used in the winter to contribute to the mechanical ventilation of the house
- **Reduce façade temperature**: in the summer the air, flowing through the cavity, ventilates the façade and then it is rejected outside.

11.1.3.2 The Thermal Chimney

The thermal chimney is located in the center structural bay of the House of the Future. The chimney is used in the summer to provide natural ventilation by drawing cooler air from the north side of the house. Since the air in the north side is shaded by the building it is cooler than the air in the south side. Opening the windows, cooler air is brought in and hot air is drawn outside the chimney. See Figures 11.1 and 11.2 below.

To protect from too much heat gain during the summer through the south façade, the double skin façade is opened in the exterior side. A set of louvers located at the top and bottom of the south façade provide air flow so that the heat is not brought into the house. This also provides adequate air flow behind the PV modules to avoid efficiency losses. The PV modules provide some shading in the thermal chimney to prevent an excess of heat gain. In the winter heated air is captured within the double-skin façade on the south side. Only the louvers at the bottom are opened to draw air up to feed a mechanical ventilation system for the house, the energy recovery ventilator (ERV). The energy recovery ventilator recovers up to 85% of the energy of the exhaust air from the house. See details in Figures 11.3 and 11.4 below.

The concrete ramp that serves as passage between the floors stores the heat and releases it when the indoor air becomes cooler thermal mass. Located inside the thermal chimney are bamboo trees that grow through its center. The trees will provide better air quality releasing cleaner and oxygen-rich air into the environment of the house.

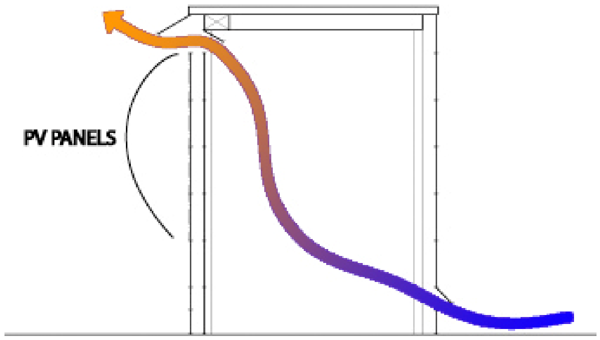

Figure 11.1: Natural ventilation

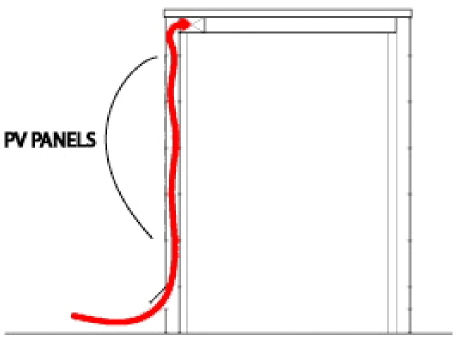

Figure 11.2: Pre-heat air in the double-skin facade

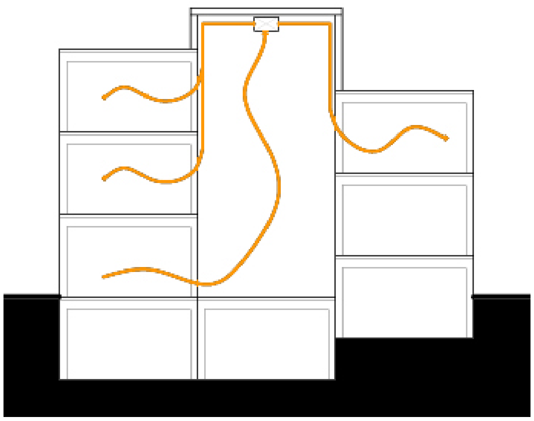

Figure 11.3: Redistribution of heat throughout the house

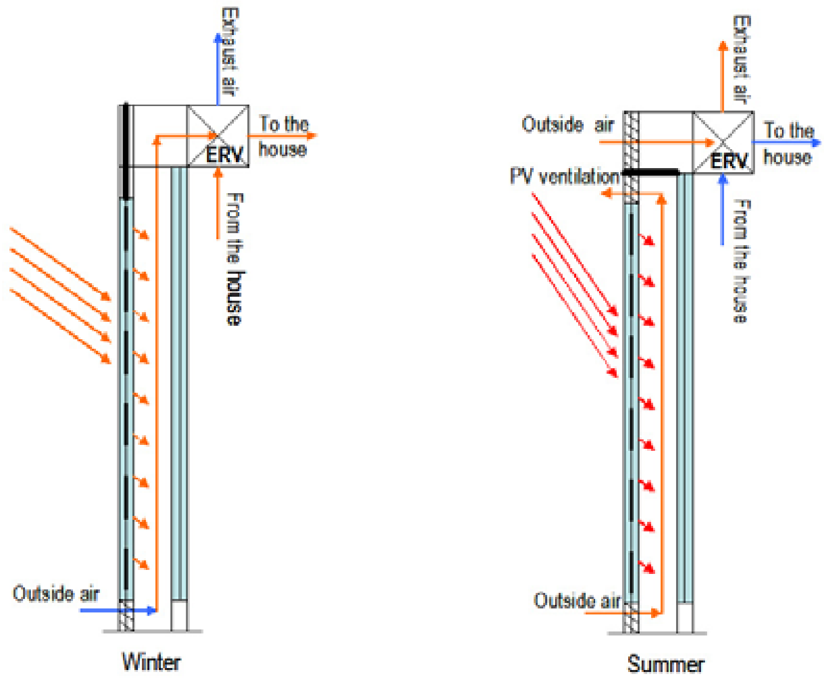

Figure 11.4: The air flowing in the back of PV is preheated and fed into the house ventilation system in the winter; the heated air is rejected outside in the summer.

11.2 Active Design

The basic concept of active design is a retrofitting of HVAC (heating, ventilation, and air condition) systems consisting of pipes, ducts, plumbing accessories, and ventilation shafts that are independently designed from the actual spatial experience. HVAC engineers require knowing the occupancy load, heat load, cooling load, openings and materials after the building was designed. In a form of numbers and codes, it is calculated to "fit" the necessary loads of the building. Aesthetically, it is not as attractive, and fire codes especially in the City of Chicago regulate heavily on exposed ducts and piping and the general fire protection of the building.

Most building in Chicago as well as the all across America relies heavily on centralized HVAC systems. The advantages of active systems are that it is on demand, easily replaceable parts, easy and quick installation, and economically feasible especially for large high rises needing mass-produced parts. The disadvantages are that once on demand, in a case of a house with multiple rooms there is no choice but to heat or cool all rooms as opposed to the one room in use. HVAC parts are cheap, disposable, and replaceable, but live shorter than the life span of the building. The source of energy comes from the municipal grid from a centralized energy plant far away from the actual daily lives of the people, losing consciousness of how energy usage and the emissions that are produced.

Using renewable energy technologies such as solar and wind is also defined as active design because mechanical systems are required. Even if passive design is a method that has succeeded in many cases, active technologies are necessary due to political and code safety measures as well as imperfections of the passive design techniques. When renewable energy technologies are used a backup systems has to be provided because of the variability of natural resources.

11.2.1 Applications of Active Design to the House

11.2.1.1 Space heating/cooling

When the passive solar design is not sufficient, the heating/cooling load of the House of the Future will be supplied by a hydronic (water-based) geothermal heat pump. Although this technology is not new (the first installation was made in 1919 in Larderello, Italy), according to a study by the Environmental Protection Agency, geothermal heat pumps are the most energy efficient, environmentally clean, and cost-effective space-conditioning systems.[27] Geothermal heat pumps take advantage of the underground temperature, typically constant at 50-55°F. In the winter a heat transfer fluid, flowing in pipes laid underground at up to 200 feet, removes the heat from underground and brings it to the house; in the summer the heat is removed from the house and transferred underground.

Geothermal heat pumps can cut the energy use by 23-44% compared to advanced air-source heat pumps, and by 63-72% compared to electric resistance heating or standard air-conditioning equipment[28]. The cost of geothermal heat pumps is approximately $3,500/ton (the house would need no more than a 3-tons system), and the lifespan is up to 50 years.

In the winter the heat will be distributed by radiant flooring that allows energy savings between 15-20% compared to other hydronic heating systems because the operation temperature is maintained between 85-140ºF instead of 130-160ºF. The disadvantage is that the installation costs for radiant flooring can be up to 40-50% more than conventional systems.

For cooling distribution individual fan coil units will be provided. Fan coils provide also dehumidification to achieve the comfort level in the summer.

[27] EPA 1993, *Space Conditioning: The Next Frontier*
[28] DOE 1998, *Environmental and Energy Benefits of Geothermal Heat Pumps,* <http://www.eere.energy.gov/geothermal/pdfs/26161b.pdf>

11.2.1.2 Domestic hot water (DHW)

The energy to heat the water for domestic use will be supplied by three solar collectors placed on the roof at a slope of 40°. The solar collectors investigated are the type compound parabolic collectors (CPC2000) by Solargenix, a manufacturing company in Chicago. With this type of collector the water can reach temperature between 105°F and 200°F that is enough for residential use (typically domestic hot water is delivered at 140°F although 120°F is sufficient). One collector by Solargenix (24 ft^2 or 2 m^2) is capable to provide 1 kW_{th} (3,410 BTU/h) of power. According to an approximate sizing, to meet the demand of the house (5.27 MBTU/yr); three solar collectors will be sufficient. It is very important to size the whole system for the house in an appropriate manner so that the system is not neither oversized nor undersized. The complete system comprises: collectors, storage tank, heat exchanger, piping, valves and temperature controllers.

In a typical residential installation in Chicago for 4 people (a demand of 70 gallons of hot water per day) the system comprises 2 collectors and 80 gallons storage tank and costs between \$6,500 and \$8,500. The water usage in the typical example is very high.

The cost of the system is \$90/ft^2 i.e. \$2,160 for the whole system including storage and one collector.

As a backup system for the solar thermal collectors, tankless electric water heaters can be used at the point of use.

11.2.1.3 Mechanical Ventilation

In addition to natural ventilation in the summer, a mechanical system supplies fresh air inside the building in very hot summer and in the winter days. The energy recovery ventilator (ERV) is able to recover up to 85% of the energy of exhaust air in order to heat or cool fresh outside air. In the winter, fresh outside air flowing in the double-skin façade will be pre-heated and fed to the ERV, while in the summer the hot air will be rejected outside.

11.2.1.4 Electricity

The electricity need of the house will be met by the Renewable Hydrogen Fueling Station next to the House of the Future. The hydrogen produced with renewable sources will be delivered to the house to feed the fuel cells located in the basement. On the roof of the house, 4.5 kW_p of PV array will produce 5,783 kWh/yr of electricity that will be used either directly by the house or by the hydrogen fueling station, according to the decisions made by a controller system. The PV array on the roof comprises 24 Kyocera modules (KC187G) of 187W each. In addition, a building-integrated photovoltaic (BIPV) array is located in the south façade. The PV modules proposed are based on a technology in development at IIT and commercialized by a spin-off company, Phocus Solar Tech (see Figure 11.5). The BIPV array, of about 400 sqft and 3.5 kW_p, will be able to produce up to 3,345 kWh of electricity per year in the specific site conditions taking into account 9% efficiency of the modules.

Figure 11.5: PV modules by Phocus Solar Tech will be integrated in the south façade.

11.2.1.5 Appliances

It is true that "The best way to live with renewable energy is to need less of it"[29] Because the design of the House of the Future involves using the energy from renewable sources such as solar, geothermal and wind, it's smart to have appliances that have low power requirements in order to reduce the energy load. When choosing appliances, it is important to look for the ENERGY STAR® logo. ENERGY STAR® is a government-backed program that looks to reduce energy usage in appliances. Any product bearing the ENERGY STAR® logo must go through a rigorous testing process, and be marked with exactly how much energy it uses. When it actually comes down to choosing which appliances will be used in the house, it will be important to make sure that anything that is chosen is not only ENERGY STAR® compliant, but also that it uses the least energy of anything in its class. To that end, detailed tables listing energy efficient appliances are shown on the website of the American Council for an Energy-Efficient Economy.[30]

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[29] Round River Allternatives, *Solar Power Systems,* <http://www.round-river.com/solarstuff.html>
[30] American Council for an Energy-Efficient Economy, *ACEE American Council for an Energy-Efficient Economy,* <http://www.aceee.org/>

Clothes Washers:

Brand	Model	Capacity (ft^3)	Modified Energy Factor (MEF)	Water Factor	kWh/yr (elec.wtr.htr)
LG Electronics	WM2077C*	3.22	2.03	3.89	195
Bosch	WFMC3200UC	3.03	2.1	5.3	186
Bosch	WFMC6400UC	3.03	2.2	4.5	178
Asko	W660	1.9	1.92	9	176
Equator	EZ 3612 CEE	1.92	1.92	5	143
Equator	EZ 1612 V	1.92	2.04	4.85	135
LG Electronics	WD-324*RHD	1.96	2.1	5.04	115

Table 11.1: Various Clothes Washers

Top Freezer, Automatic Defrost, less than 18 Cubic Feet

Brand	Model	Volume	Energy Use (kWh/yr)	Annual Energy Cost ($)*
Sun Frost	RF-16	14.3	254	21
Whirlpool	ET5WSE*K*0	14.5	372	31
Roper	RT14HD*P*0*	14.4	373	31
Frigidaire	FRT15HB2D*	14.8	376	31
Frigidaire	FRT15HB3D*	14.8	376	31

Table 11.2: Various Top Freezers with Automatic Defrost and less than 18 ft^3

11.2.1.6 Water usage

The water usage of the House of the Future, compared to traditional American single-family buildings has to be reduced. According to the American Water Works Association (AWWA) the average water usage in US is 74 gallons/person/day, with outdoor water use between 50% and 70% while houses that use water efficient fixtures are able to reduce their water usage by 30% (51.9 gallons/person/day)[31]

[31] 1999 Residential Water Use Summary, Report by the American Water Works Association (AWWA).

By deploying low flow faucets in lavatories (.5 to 1 GPM), kitchen sinks (1.5 to 2 GPM), showerheads (1 to 2 GPM), dual flush toilets (1.6 gallons per flush and 0.8 gallons per half flush), horizontal axis clothes washer will allow major water savings.

In order to take advantage of the almost 37" of rain fall annually in Chicago, a storm water collection and treatment system will be able to provide about 27,677 gallons of water per year to use in the house.

11.2.1.7 Storm water collection and treatment system

There are few systems available on the market for processing storm water due to tight regulations on the reuse of grey water. Chicago codes prohibit the reuse of grey water for domestic uses unless for outdoor irrigation. Given the abundance of fresh water supplied by Lake Michigan, there is no real need to recycle. In the last decades, concerns on the future availability of water have risen worldwide and the possibility to reuse the storm water is being considered also in Chicago since the annual rainfall rate is high.

Following are brief descriptions of the advantages and disadvantages of storm water systems investigated for the House of the Future. The storm water system proposed for the House is the Equaris system. Common components for rainwater filtration systems can be checked on the web.[32]

Aqua filter systems[33]

Advantages

- It is highly recommended by the EPA
- The company has lots of experience
- A chart on how much wastes it reduces is available[34]
- Highly durable, and easy to install

Disadvantages

- Looks bulky and too large
- It does not seem to be compact
- It seems to be another installation, and extra space needed.

Equaris water recycling system[35]

Advantages

- The very idea of sustainability

[32] Centre for Science and Environment, *Components of Rainwater Harvesting Systems*, <http://www.rainwaterharvesting.org/Urban/Components.htm>
[33] Aquashield Storm water Treatment Solutions, *Aquashield*, <http://www.aquashieldinc.com/>
[34] Environtemental Protection Agency, *Aqua-Filter™ Stormwater Filtration System*, September 2, 2004, <http://www.epa.gov/NE/assistance/ceitts/stormwater/techs/aquafiltersys.html>
[35] Equaris Corporation, *Water Recycling System – Equaris Total Household Water Recycling and Wastewater Treatment System,* <http://www.equaris.com/default.asp?Page=Disinfection>

- Take care of water wastes and water consumption
- The company is located in Minnesota
- Minimal costs for operation
- Incorporated grey water filtration in its system

Disadvantages

- Might require extra installation time

French drains

Advantages

- Very common
- Eeasy to build
- They collect the runoff and stop them from reaching the sewer
- They can be easily incorporated into buildings[36]

Disadvantages

- Water is not reused

Acorn RAINSAVA[37]

Advantages

- Recycles water
- Easy to understand
- Easy to install
- Tank is underground

Disadvantages

- Acorn is a British company. This would mean heavy use of carbon fuels in transportation of the system

Rain barrels

Advantages

- Available anywhere
- Easy to install
- Cheap
- Saves water

Disadvantages

- Water could really only be used for irrigation

Living Water Systems[38]

Advantages

- Very common

[36] Becker, Lynn,"It's not easy being Green", 2004, <http://www.lynnbecker.com/repeat/AIAhouse/beinggreen.htm>

[37] Acorn – Environtenmental Systems Limited, *Domestic and commercial style rainwater harvesting system,* <http://www.v63.net/acornsystems/pages/rainsava.html>

[38] Buckminister Fuller Institute, *Living Machine System*, <http://www.bfi.org/news/livingMachines.htm>

- Require less land
- Good for communities
- Very natural
- They can definitely be used for tours

Disadvantages

- Not for small scale
- Not energy efficient
- Not for houses. The smallest areas they were used where for places with ponds like the Lewis Center at Oberlin College.[39]

11.3 Additional Features of the House of the Future

11.3.1 Operable Walls

The House of the Future needs to offer flexibility to the public that will be visiting, and to the students that will use the facility. To respond to this need of a changing environment, the interior walls will be movable and removable. In the market there are currently track systems that allow walls to be shifted to change the space. The house will use the skeleton of a track system offered by Hufcor, Inc. The wall panels will then be inserted into this track so that they can be easily installed. The new wall materials can be applied in a controlled lab setting and then brought into the house so that the house will not have to shut down for the installation of new walls.

The flexibility in the floor plan will make the House of the Future more sustainable. This will allow the house to change without much construction costs and very little installation time. It will greatly reduce the amount of energy spent in changing according to the needs of displaying technologies in the house. There will also be less waste materials because the panels can be reusable. The walls can be used to test new paintings; even if the painted surface has to be removed, the panel frame can still be used again.

11.3.2 Flooring

Flooring is an important factor. It is something that will be seen throughout the entire house. Anyone who walks through the house will notice it. Also, since it covers such an extensive area, flooring offers a large canvas with which to work on. The research was conducted mainly on quickly renewable materials such as cork flooring and bamboo flooring. It was find out that cork flooring has some advantages over bamboo.

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[39] Oberlin College, *Adam Joseph Lewis Center for Environmental Studies*, 2004, <http://www.oberlin.edu/ajlc/ajlcHome.html>

One of the biggest benefits of cork is its environmental impact. Unlike hardwood flooring, the production of cork flooring does not involve cutting down trees. Instead, cork is harvested from the bark of cork trees every nine to fourteen years. This doesn't cause harm to the plant. Indeed, this process means that the trees rarely have to be cut down. In fact, cork trees can live over 500 years.[40] Cork flooring is completely non-toxic. When being manufactured, cork flooring is first coated with a natural resin, and then processed into panels. Cork flooring can be manufactured in two processes, one which involves mixing rubber into the cork. Based upon this, the team recommends a completely natural cork. During installation, cork is held down by a water based adhesive. This adhesive is also non-toxic, which has a low impact on the environment. Finally, it can also be sealed with a natural wax. This means that cork does not release toxic gases under combustion.

The flooring itself provides many lifestyle advantages. It provides great thermal and acoustic insulation. Since 90% of cork tissue is gaseous, cork is a very resilient material. It is less affected by impact and friction than other, hard surfaces. Cork can be compressed, and afterwards it can return to its original shape. This durability means that cork can potentially outlast hardwood or vinyl. Cork is also highly resilient against rot. Unlike carpets, cork does not absorb dust. Because of this, allergic reactions are minimized.[41] Cork flooring can be installed over radiant flooring. Properly installed cork flooring can be beneficial when installed over radiant flooring[42] Cork flooring is priced competitively against other flooring. Cork flooring can be had for as little as $2 per square foot. A local company called PCI Floor Tech offers high quality cork flooring at $8 per square foot with full installation.

Cork flooring complements the radiant heating system the team has chosen to use for the House of the Future. Installing cork flooring between 3/8 to ½ inch thickness over the Warmboard system will keep the R value to 1.5 of less. This gives the Warmboard system better heating response, while simplifying the mechanical design at the same time. This means that cork will operate in the same temperature range as tile, hardwood, or carpet.[43]

Cork has few disadvantages. Water can be damaging to cork, depending on how it is sealed. Also, because cork is soft and resilient, heavy furniture left on it over time can be damaging.

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[40] PowerHouse, *Cork Flooring*, <http://www.powerhousetv.com/stellent2/groups/public/documents/pub/phtv_yh_co_000428.hcsp>
[41] Luxury Home Products, *Cork Flooring*, 2005, < http://www.galleriacollection.com/naturalcork/>
[42] Warmboard Radiant Heating, *Installing Cork Flooring over Warmboard*, 2005, <http://www.warmboard.com/install_cork.html>
[43] Warmboard Radiant Heating, *Installing Cork Flooring over Warmboard*, 2005, <http://www.warmboard.com/install_cork.html>

Bamboo is another sustainable alternative. Bamboo provides benefits to its natural environment. It serves to control erosion in the places where it grows. It can be harvested after about three years of growth. Harvesting it will not kill the plant, as bamboo is a form of grass, and it can grow quickly which thereby makes it very sustainable.[44] It is an attractive alternative to hardwood flooring. It is also inexpensive to purchase at about $4-8 per square foot. A disadvantage of both cork and bamboo is that they tend to be grown in far away, and therefore have to be transported long distances. Bamboo is harvested from places like China, while cork is brought in from countries in Europe.

11.3.3 Exterior Facade

The exterior façade of the building will be a modular precast concrete panel system that is easy to install, remove and is recyclable. This system allows panels to be installed temporarily while providing a tight enclosure around the building. They can be removed so that other panels with different properties can be tested in the House of the Future. Since the enclosure panels can be removed it will require less energy in equipment and labor to change out.

The concrete itself will be made of recycled concrete added into the mixture. The precast panels will also have fasteners that are embedded so that other exterior panels can be attached and tested. New materials can be tested for their water shedding capabilities, UV resistance, public acceptance, durability, and maintenance requirements. The first proposed panel to be installed is made by Eternit which is a composite material made of sawdust and concrete.[45]

11.3.4 Insulation

The insulation for the House of the Future will be cast into the precast concrete panels. Recycled cellulose has been chosen because it is a 75% recycled material and provides 50% higher R-value than conventional fiberglass insulation. Since the R-value is raised to approximately 30, 25% less energy is devoted to heating the building. Cellulose will also provide a 36% tighter building envelope which will keep in heat longer and further reduce the amount of energy required for heating[46]. As additional advantage over fiberglass, cellulose is not hazardous to human health and has a lower environmental impact when disposed of since it is mostly made of recycled newspapers. To raise the thermal mass of the building a Phase Change Material (PCM) will be cast into the

[44] Graham, Christi, “Bamboo - a sustainable alternative to conventional floor”, *Healthy Home Plans*, 2005, <http://www.healthyhomeplans.com/articles/information9.php>
[45] Eternit Building Materials, *Home*, <www.eternit.co.uk>
[46] Cellulose Insulation Manufacturing Association, *Home*, <www.cellulose.org>

concrete. The PCM will store heat over the time of day and release it into the house over the night to reduce the heating load.[47]

11.3.5 Windows

Energy in the home can be lost in many ways. A large amount of energy in the home is lost through inefficient windows. During the winter, heat loss from windows can represent 10% of the heating bill, and 30% of the cooling bill during the summer[48]. Therefore, it is important to have energy efficient windows. The design of the House of the Future presents a thermal chimney with high solar heat gain south windows. The windows in the west facade should have low solar heat gain coefficient. There are many factors to consider when choosing a window. The amount of heat loss through a window is known as the U-factor. Windows can come as either single pane, double glazed, or triple glazed. Each additional glazing is another sheet of material, with either air or gas trapped between the panes. Argon gas is commonly used, and is one of the best choices for glazing. Windows are also offered with low emittance (Low-E) coatings that reduce the solar heat gain while transmitting visible light. For the Chicago conditions, the best window for both heating and cooling is a triple glazed window with Low-E coating, with moderate solar gain.[49] Another option is to use double glazed window; the team found a triple glazed window to be moderately (approx. $20) more expensive than a double glazed window.

11.3.6 Budget

An approximate budget for the building construction has been estimated at $300/sqft i.e. $1.26 million. This estimation takes into account that the cost per square foot will be approximately twice as in a typical residential construction of similar size.

A more accurate budget for the material cost of the special systems has been calculated to be around $100,000 (no installation cost). This includes BIPV panels for the façade, PV panels for the roof, solar collectors, mechanical ventilation system, geothermal heat pump, radiant flooring and storm water collection and treatment system.

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[47] Wilson Alex, 2005. Insulation: Thermal Performance is Just the Beginning, *Environmental Building News* 14, no. 1

[48] Louisiana Energy and Environmental Resource & Information Center, *Energy Efficient Windows*, <http://www.leeric.lsu.edu/energy/windows>

[49] Efficient Windows Collaborative, *Home*, 2004, <http://www.efficientwindows.org/>

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