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Contact Information

*** Salutation**	Prof.
*** First Name**	Aimee
*** Last Name**	Buccellato
*** Contact Title**	Primary Contact
*** Address**	314 Bond Hall University of Notre Dame
*** City**	Notre Dame
*** State**	Indiana
*** Zip**	46556
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*** E-mail Address**	abuccellato@nd.edu

Organization Information

*** Organization Name**	University of Notre Dame
*** Address**	940 Grace Hall
*** City**	Notre Dame
*** State**	Indiana
*** Zip**	46556
*** Telephone**	574-631-1173
Organization Website (if applicable)	http://www.nd.edu; http://greencloud.crc.nd.edu/
*** Chief Officer**	Rev. John I. Jenkins, C.S.C., President
Year Organization was established.	1842
*** Full-time Employees**	5205
*** Part-time Employees**	3207
*** Volunteers**	9000
*** Organization's Mission**	The University of Notre Dame is a Catholic academic

Statement	community of higher learning dedicated to the pursuit and sharing of truth for its own sake. One of its distinctive goals is to provide a forum where through free inquiry and open discussion the various lines of Catholic thought may intersect with all the forms of knowledge found in the arts, sciences, professions, and every other area of human scholarship and creativity. The University prides itself on being an environment of teaching and learning which fosters the development in its students of those disciplined habits of mind, body and spirit which characterize educated, skilled and free human beings. In addition, the University seeks to cultivate in its students not only an appreciation for the great achievements of human beings but also a disciplined sensibility to the poverty, injustice and oppression that burden the lives of so many. The aim is to create a sense of human solidarity and concern for the common good that will bear fruit as learning becomes service to justice. Notre Dame also has a responsibility to advance knowledge in a search for truth through original inquiry and publication. This responsibility engages the faculty and students in all areas of the University, particularly in graduate and professional education and research. The University is committed to constructive and critical engagement with the whole of human culture. Notre Dame's character as a Catholic academic community presupposes that no genuine search for the truth in the human or the cosmic order is alien to the life of faith. The University welcomes all areas of scholarly activity as consonant with its mission, subject to appropriate critical refinement.
*** Organization History**	The University of Notre Dame began in 1842 and was chartered by the Indiana legislature in 1844. It included religious novitiates; preparatory, grade, and manual labor schools; and classical collegiate curriculum. By 1940, science and graduate programs were expanded, the preparatory school was eliminated, and the law school was upgraded. Over the next 35 years, Notre Dame grew extensively in size and stature: enrollment, faculty, and degrees awarded doubled; library volumes increased five-fold; and physical facilities grew from 48 to 88. In 1967, University governance was transferred from the Congregation of the Holy Cross to a predominantly lay board of trustees. By 2005, there were over 200 endowed faculty positions, the student body was one of the 20 most selective in the US, the minority student population tripled, and the number of women significantly increased.
*** Tax Exemption Letter**	• Tax Exempt Letter.pdf (56.28 K, uploaded by Aimee Buccellato on 04/25/2012)

Finances and Board of Directors

*** Attach a copy of your most recent 990 filed with the IRS.**	• 2009 UND Form 990 Public Disclosure Copy.pdf (4.06 MB, uploaded by Aimee Buccellato on 04/25/2012)
*** Attach audited financial statements for the past two years.**	• Annual Report 2011.pdf (3.47 MB, uploaded by Aimee Buccellato on 04/25/2012)
*** 3 - 5 Year Plan**	• ND 2010 Strategic Plan.pdf (168.23 K, uploaded by Aimee Buccellato on 04/25/2012)

*** Annual Budget**	$885,000,000.00
*** Administrative Costs**	$189,000,000.00
*** Fundraising Costs**	$21,809,106.00
*** Location of Funds**	University of Notre Dame's Office of Research Sponsored Programs Accounting
*** List the five highest grant or gift amounts and sources awarded last year.**	Top five grants Department of Energy, PI William F Schneider, $2,817,926 Abbott Fund, PI Thomas G Streit, $2,600,000 Department of Energy, PI Joan F Brennecke, $2,559,562 National Science Foundation, PI Mitchell R Wayne, $2,180,000 National Science Foundation, PI Michael C Wiescher, $2,166,000 Top five gifts Abbott Fund, $750,000 Deloitte, $500,000 United Technologies, $347,308 International Business Machines, $303,600 Honeywell, Inc., $259,095
*** Organization Name: AKA or DBA**	Our organization has not operated under a different name
Explain Name	

Board of Directors Information

*** Board of Directors**	John F. Affleck-Graves, Univ. of Notre Dame José E. Ahumada F., C.S.C., St. George's College E. William Beauchamp, C.S.C., Univ. of Portland Cathleen P. Black John J. Brennan, The Vanguard Group, Inc. Stephen J. Brogan, Jones Day Thomas G. Burish, Univ. of Notre Dame John P. Calcutt, Merrill Lynch, Pierce, Fenner & Smith Inc. Robert M. Conway, Goldman, Sachs & Co. John P. Delaney Jr., Philadelphia Deputy District Attorney Drew W. DeWaltMr. James J. Dunne III, Sandler O'Neill + Partners, L.P. José Enrique Fernández, Oriental Financial Group Inc. James F. Flaherty III, HCP, Inc. W. Douglas Ford Stephanie A. Gallo, E&J Gallo Winery William M. Goodyear, Navigant Consulting, Inc.

	Nancy M. Haegel, Naval Postgraduate School
	Enrique Hernandez Jr., Inter-Con Security Systems, Inc.
	Carol Hank Hoffmann
	Douglas Tong Hsu, Far East Group
	John I. Jenkins, C.S.C., Univ. of Notre Dame
	Daniel R. Jenky, C.S.C., D.D., Catholic Diocese of Peoria
	John W. Jordan II, Jordan Industried, Inc.
	James B. King, C.S.C., Univ. of Notre Dame
	Diana Lewis, Florida 15th Judicial Circuit Court
	Kati S. Macaluso
	Patrick F. McCartan, Jones Day Foundation
	Richard C. Notebaert
	Richard A. Nussbaum II, Sopko, Nussbaum & Inabnit
	Thomas J. O'Hara, C.S.C., King's College
	Joseph I. O'Neill III, O'Neill Properties, Ltd.
	Philip J. Purcell III, Continental Investors
	J. Christopher Reyes, Reyes Holding, LLC
	James E. Rohr, PNC Financial Service Group, Inc.
	Phillip B. Rooney, Claddaugh Investment, LLC
	Shayla Keough Rumely
	John F. Sandner, Chicago Mercantile Exchange
	Timothy R. Scully, C.S.C., Univ. of Notre Dame
	William J. Shaw, Marriott International, Inc.
	Kenneth E. Stinson, Peter Kiewit Sons, Inc.
	Phyllis W. Stone
	Anne E. Thompson, NBC News
	Sara Martinez Tucker
	David T. Tyson, C.S.C., Univ. of Notre Dame
	Roderick K. West, Entergy Corp.
	Ann Claire Williams, Dirksen US Courthouse
*** Are any of the Board of Directors compensated for their services on the Board?**	No
Name(s) and amount(s) of compensation.	
*** Frequency of Board Meetings**	Quarterly
Program / Project Details	
*** Program / Project Title**	The Green Cloud: A Novel Platform for Educating Students and the Community about Innovative Pathways to Energy Conservation
*** Brief Program / Project**	We will develop an interactive learning environment and

Description	educational materials to teach students about energy and innovation through the demonstration of a novel energy conservation concept that integrates waste heat from computing equipment with buildings
*** Is this a pilot program/project?**	No
Year program/project was established.	2008
*** Program/Project Start Date**	09/01/2012
*** Program/Project End Date**	08/31/2013
*** Requested Cash Amount**	$46,000.00
*** Total Program/Project Budget**	$46,000.00
*** Usage of Funds**	The Green Cloud is an operational prototype installed at The Ella Morris/ Muessel-Ellison Botanical Conservatories in South Bend's most prominent public park. The prototype is a windowless shipping container equipped with 60 servers and is the initial test-bed for our technology. While the prototype successfully demonstrates the integration of waste heat from the computer equipment with the Conservatory, the current configuration is limited in function as an educational tool. Funding will be used to transform the current prototype into the Green Cloud Interactive Learning Environment which will visually demonstrate to students this novel energy conservation concept. Modifications to the current prototype will include the purchase and configuration of a touch-screen digital display, which will show the energy use of the servers in real time, the data from temperature sensors inside the container and Conservatory, and information about the project. Funds will also be used to enhance the current container, including paint and a small solar array to power prototype fans and expand the topical learning opportunities. In addition to physical modifications, funds will be used to create educational materials for students who visit the Conservatories on field trips. The materials will be provided to local teachers for free. Typically, a significant hurdle for this type of effort is encouraging classes to arrange field trips, but we can leverage already planned field trips in order to broaden the learning impact to include energy and technology alongside plant-life study. Finally, we will develop hand-outs that will be available for the public so they can learn more about energy conservation, energy transfer, and innovative ways to address the grand challenge of energy. This handout may also serve as a starting point for parents and children to talk about energy and science and their important roles in finding additional innovative pathways to energy conservation.
*** Budget Detail**	• 12_5-1 Green Cloud_Budget Description SUBMITTED.pdf (93.66 K, uploaded by Aimee Buccellato on 04/30/2012)
*** Income Statement**	• Annual Report 2011.pdf (3.47 MB, uploaded by Aimee Buccellato on 04/30/2012)
*** Program/Project Officer(s)**	Aimee Buccellato, Assistant Professor, School of Architecture

Paul Brenner, Associate Professor, Center for Research Computing

David Go, Assistant Professor, Department of Aerospace and Mechnical Engineering

Project Demographics

*** Number of People Served**

2900

*** Age**

Adolescents
Adults
Children
Elderly

*** Communities Served**

Initially, this project will serve communities in the vicinity of South Bend, Indiana, including northern Indiana and southwest Michigan. However, this project is the first component of the much larger vision of the Green Cloud, which is to develop viable heat integration technologies for computing equipment and buildings that can be deployed locally, regionally, nationally, and internationally. The interactive learning environment, classroom materials, and hand-outs developed with this grant can be easily adapted to any future Green Cloud installation. As such, the impact of developing quality educational components for this initial prototype can be multiplied to students on a very broad scale.

While this project provides educational opportunities for people of all ages, it is primarily aimed toward elementary school-aged children. Fourth graders in particular will be targeted in this initial work as the concepts of heat, electricity, limited natural resources, and the requirements for plants to grow are all aligned with Indiana State Academic Standards (2010) for the 4th grade.

*** Ethnicity**

25% African American / Black
1% Asian / Pacific Islander
66% Caucasian
8% Hispanic / Latino

Program / Project Narrative

*** Detailed Program / Project Description**

- 12_5-1 AHF Project Description FINAL SUBMITTED.pdf (757.93 K, uploaded by Aimee Buccellato on 05/01/2012)

*** What are your plans to recruit or attract participants for this program / project?**

There are a number of methods by which we will attract people to this project. The Green Cloud prototype is installed in a highly-visible, public location -- the Ella Morris/ Muessel-Ellison Botanical Conservatories at Potawatomi Park in South Bend. We will first target those K-12 classes that are scheduled to visit the Botanical Conservatories through organized field trips. This provides a ready audience of students and their accompanying teachers and parents. In addition, the Green Cloud project has partnered with the Center for Sustainable Energy at Notre Dame (cSEND) and will work with their Education and Outreach Coordinator, Jennifer Frech, to contact teachers and schools throughout the area to notify them of this exciting learning opportunity, encourage them to participate, and assist teachers with implementation of the classroom materials developed with this grant, including

lunchtime workshops led by the project principals. cSEND also organizes and hosts an annual Energy Week every September at Notre Dame which is targeted at both students and the community, and this project will be highlighted in advertisements for Energy Week. In addition, cSEND has a Student Advisory Board (SAB) comprised of undergraduate, graduate, and professional students. One of the goals of the SAB is volunteerism/outreach for energy education, and they will assist in the promotion of the Green Cloud project and with school field trips as needed.

*** Short-term Goals**

The short-term goals for this project are to: 1) transform the existing Green Cloud prototype into an interactive learning environment, 2) attract local and regional school groups to the Green Cloud Interactive Learning Environment, 3) develop useful curricular materials targeted toward elementary level education to expand classroom learning, and 4) develop educational handouts about the Green Cloud that will be available to all visitors. When achieved in tandem, we believe success in these four goals will lead to better education of students and the community on energy consumption, energy efficiency, and innovative ways to improve our energy utilization.

*** Long-term Goals**

The long term goal of the Green Cloud project is to develop and deploy a novel energy conservation technology that shifts the paradigm of energy use by buildings and computational equipment from an energy challenge to an energy opportunity. By using heat generated by computational equipment as a resource not an unwanted byproduct, our approach has the potential to increase energy conservation and efficiency in a substantial and measurable way while transforming sustainable building and computing practices.

Further, as educators, we are dedicated to using this technology as a launching point for inspiring the next generation of innovators to envision creative ways of solving society's grand energy, environmental, and resource conservation and management challenges. By providing interactive displays and educational materials that are connected with a physical object or building that students can visit and touch, we aim to make STEM education more accessible and exciting to students at all levels.

*** What data collection and evaluation procedures do you have in place**

We will continually measure our progress toward accomplishment of the four project goals stated above under short-term goals. We anticipate that modifications to transform the current prototype into an interactive learning environment (Goal 1) will be complete within 3 months from the project start date. To measure Goal 2, we will collect data on the number/demographics of visitors to the project, and we will compare these data with information on current visitors to the Botanical Conservatories. An increase in visitors, particularly those aged 5-18, will indicate the effectiveness of our promotion of the project. We will track these numbers monthly and adjust our advertising efforts accordingly. For Goal 3, we will track the number of classrooms that use the curricular materials, and we will also track qualitative feedback on the pre- and post-visit activities to determine if the materials are effective. Finally, for Goal 4, we will track the number of handouts distributed to the public. We will include a web link on the handout where visitors can go to provide feedback on the displays and materials. This feedback will be reviewed regularly and used to improve the displays and handout.

Sensors are already in place for collection of technical data related to the operation of the Green Cloud and the adjacent Conservatory. For the Green Cloud container, these data are transmitted electronically and displayed in

real-time on the Green Cloud website (greencloud.crc.nd.edu). This same data, in an interactive, user-friendly-format, will be displayed at the project site so that visitors can monitor the operation of the Green Cloud in real-time.

*** Top Three Pros to funding this program / project.**

The first benefit to funding this project is that a fully operational prototype already exists in a highly visible, public location. Therefore, the risk of project failure is extremely small, as it is not dependent on first ensuring that the technology will work. The second benefit is that energy is a concept that most everyone can understand on some level, and it is a topic that is a major concern in society, particularly among young people. This project involves a proven and innovative way to create a more sustainable energy future. The third benefit is the project's anticipated expansion beyond this initial implementation. While the current Green Cloud prototype is located in South Bend, we fully expect to deploy the technology to buildings throughout the region and the nation in the near-term. With successful education components already developed, additional Green Cloud installations will make immediate impact in those communities with only minimal adjustments.

*** Top Three Cons to funding this program / project.**

The first potential con to funding this project is the public access to the container that houses the computing equipment. While we have not experienced any sort of vandalism or attempted theft, this is always a possibility in a public location. The second con is that the Conservatory attached to the Green Cloud prototype is not currently a closed system. The building itself is in need of some repair, and so the real-time display of energy savings may be impacted by the variable maintenance and operating conditions of the Conservatory. However, the general trends and principles will be valid. The final potential con of this project is that it is currently limited to a relatively small geographic region. However, as indicated above, this is only a temporary limitation, as the displays and materials generated through this grant can be easily adapted and expanded to future Green Cloud installations.

*** What are your plans for expanding this program / project?**

To achieve the long-term objectives outlined in section 19 (which include expansion) we will leverage continued involvement of undergraduate students to develop the Green Cloud technology and improve its application for widespread adoption. The faculty principally involved in the project are very active in writing proposals to attract funds to further develop the technology and overcome all hurdles to implementation. These efforts will continue with support from organizations like the American Honda Foundation and the University of Notre Dame. The educational materials developed through the support of this grant, in particular, will be made available to the public and consulting will be available for peer organizations that adopt the Green Cloud technology and wish to include an educational component with their Green Cloud implementation.

The next phase of implementation that is currently being planned and developed is to implement the Green Cloud in a new, state-of-the-art ecological research facility being developed through collaboration between the St. Joseph County Parks Department and the University of Notre Dame. This research facility will be used for land-use and environmental change research and will serve as an outreach and educational hub for local school groups as well as the general community. The intention is to incorporate Green Cloud technology directly into the research facilities for the first fully-integrated Green Cloud implementation, and we will utilize similar educational tools as those supported by the American Honda Foundation for this work. Funds are currently being raised to design and

	construct these new research facilities alongside one-of-a kind constructed experimental ecosystems to be completed this summer.
Please list past results of the program/project (if applicable)	The Green Cloud is a successful prototype installation at The Ella Morris/Muessel-Ellison Botanical Conservatories. The current prototype is small, but it continuously delivers ~90-100°F heat directly into one of the large public Conservatories during the coldest months of the year -- an energy off-set which actually helped to save this valued public asset from closure due to unsustainable operating costs. For this work, the Green Cloud project received the Green Enterprise IT Award from the Uptime Institute in 2009, bringing national recognition from the data center and information technology communities. It has also been featured in both local and national media ranging from Economist magazine (March 2010 issue) to the MIT Technology Review. In addition to technological success, the Green Cloud project has mentored five undergraduate students in Aerospace and Mechanical Engineering, and Computer Science Engineering, and has been incorporated into two undergraduate architecture design studios (20 students). While these educational efforts are important at the University of Notre Dame, we have not yet had the ability to take full advantage of opportunities to teach youth in the community through the project. We see this as a critical next step in the Green Cloud project, as educating and inspiring the next generation of young people to pursue learning in science, engineering, and innovation will be essential if we are to solve many of the world's greatest challenges, including creating a more sustainable energy future.

Terms of Agreement

Terms of Agreement

*** Indicate whether you agree with all the Terms of Agreement shown.**	Yes

The information within the application is certified to be true to the best of my knowledge, information and belief.

*** Date of Signature**	05/01/2012
*** Certifying Organization (required)**	University of Notre Dame
*** Signed By**	Liz Rulli
*** Signer's Official Capacity**	Associate Vice President for Research

Need Support?

The Green Cloud:
A Novel Platform for Educating Students and the Community about
Innovative Pathways to Energy Conservation

Background

The University of Notre Dame is pioneering a renewable energy technology in response to the enormous energy expenditures and associated economic costs related to heating and cooling buildings and data centers (large colonies of consolidated computer equipment). Our approach is to harvest the energy produced by computer hardware in data centers to heat buildings. By harvesting the waste heat produced by the data centers, we can make both buildings and data centers more energy efficient. The Green Cloud is an initial prototype implementation of this concept at a large public botanical conservatory, and it is a collaborative effort by experts in buildings and architecture, computer science, and energy. We propose to expand the current impact of our Green Cloud prototype as a critical steward of energy efficiency for the Conservatory into a dynamic educational tool that we can use to inspire and teach our youth and community about innovative approaches to energy conservation.

Residential and commercial buildings account for nearly 40% of U. S. energy consumption and related carbon emissions as well as 72% of total electricity consumption.[1,2] Further, the U. S. Department of Energy (U.S. DOE) and the National Institute of Building Sciences report that nearly two-thirds of the energy/ carbon impact of buildings is tied to heating, cooling, and ventilation, with these expenditures expected to rise exponentially to $100 billion annually by 2030.[1] Meanwhile, the U. S. Environmental Protection Agency (U.S. EPA) estimated that the United States spent over $4.5 billion in 2006 to power and cool data centers,[3] and a recent study[4] revealed that this expenditure grew by 56% from 2005 to 2010, on par with the U.S. EPA,[3] The Green Grid[4], and International Data Corporation[5] predictions.

Yet we know that heat, like waste heat from industrial processes or even computer hardware, can be a useful source of energy. In fact, most power generation and chemical manufacturing processes have routine strategies for taking heat streams that are exiting one process to use as energy input for another process, a waste heat recovery concept known as heat integration. Heat integration schemes can drastically improve the energy efficiency of the overall plant, saving both valuable natural resources and money. However, one of society's biggest producers of waste heat, data centers, rarely incorporate such waste heat recovery strategies. In fact, they are typically remotely located and air-conditioned year-round in order to maintain optimal machine operating conditions. Consequently, data centers consume nearly the same amount of energy for cooling as they do for machine operation. As information technology becomes an increasingly critical and integrated aspect of modern society, the number of these data centers is only expected to increase to accommodate society's demand for computational power, speed, and access. However, ongoing pressure on traditional energy resources makes clear the need for a critical paradigm shift in the way that data centers and buildings are designed and operated. Our work seeks to find effective and efficient ways to harvest this considerable source of energy for use in adjacent or nearby buildings, making both the data centers and the associated buildings more energy efficient.

Our initial waste heat recovery prototype, the Green Cloud data center node, was developed through a 2008 partnership between the University of Notre Dame and the City of South Bend's Ella

Morris/Muessel Ellison Botanical Conservatories in an effort to use waste heat from University research computers to offset the high heating costs of the Conservatory, particularly during the cold winter months. This partnership led to the installation of the prototype Green Cloud, which is a small, container-style data center that continuously delivers ~90-100°F heat directly into the Conservatory during the coldest months of the year, an important energy off-set for a cash-strapped municipality struggling to keep the beloved facility open for the public.

Image 1: Inside the Arizona Dome at the Ella Morris/ Muessel Ellison Botanical Conservatories, South Bend, Indiana

Image 2: The Ella Morris/Muessel Ellison Botanical Conservatories, South Bend, Indiana

Since this initial partnership, our Green Cloud initiative has expanded to explore the efficacy of widespread integration of computers with buildings in order to most effectively use heating and cooling where they are already available and to use energy when and where it is most efficient and least expensive. Ultimately, we seek to shift the paradigm of energy use by buildings and computational equipment from an energy *challenge* to an energy *opportunity*, using heat generated by computational equipment as a *resource* not an *unwanted byproduct*. This approach has the potential to increase energy conservation and efficiency in a substantial and measurable way while transforming sustainable building and computing practices.

Proposed Work

Along with solving the technical challenges associated with this new type of heat integration, a fundamental goal of the Green Cloud project is to educate and inspire citizens, particularly youth, on energy challenges and new paradigms for addressing pressing issues, like energy consumption. Because the Conservatory already serves as a wonderful platform for natural systems, ecology, and environmental education, the location of the Green Cloud there only reinforces the interconnectedness of energy consumption, our natural resources, and the environment. For this project, we propose to expand the impact of our energy research by developing our existing prototype into an incubator for new science, technology, engineering, and mathematics (STEM) education initiatives while creating a new, dynamic learning environment that will expose students and our community to novel ways to address today's energy and environmental challenges. To that end, the specific goals of this project are:

(1) Develop an interactive learning environment at the Green Cloud prototype located at the public Conservatory

(2) Attract local and regional school groups to the Conservatory and Green Cloud prototype for interactive educational experiences outside the traditional classroom
(3) Develop and disseminate useful curricular materials related to the Green Cloud targeted toward elementary level education to expand classroom learning
(4) Develop an educational handout related to the Green Cloud that will be available to all community visitors to the Conservatory

By accomplishing these goals, we will positively influence STEM education in our community, particularly at the elementary school level, in areas of energy consumption, energy efficiency, and the environment, while inspiring students and the community to discover additional innovative ways to reduce society's energy consumption.

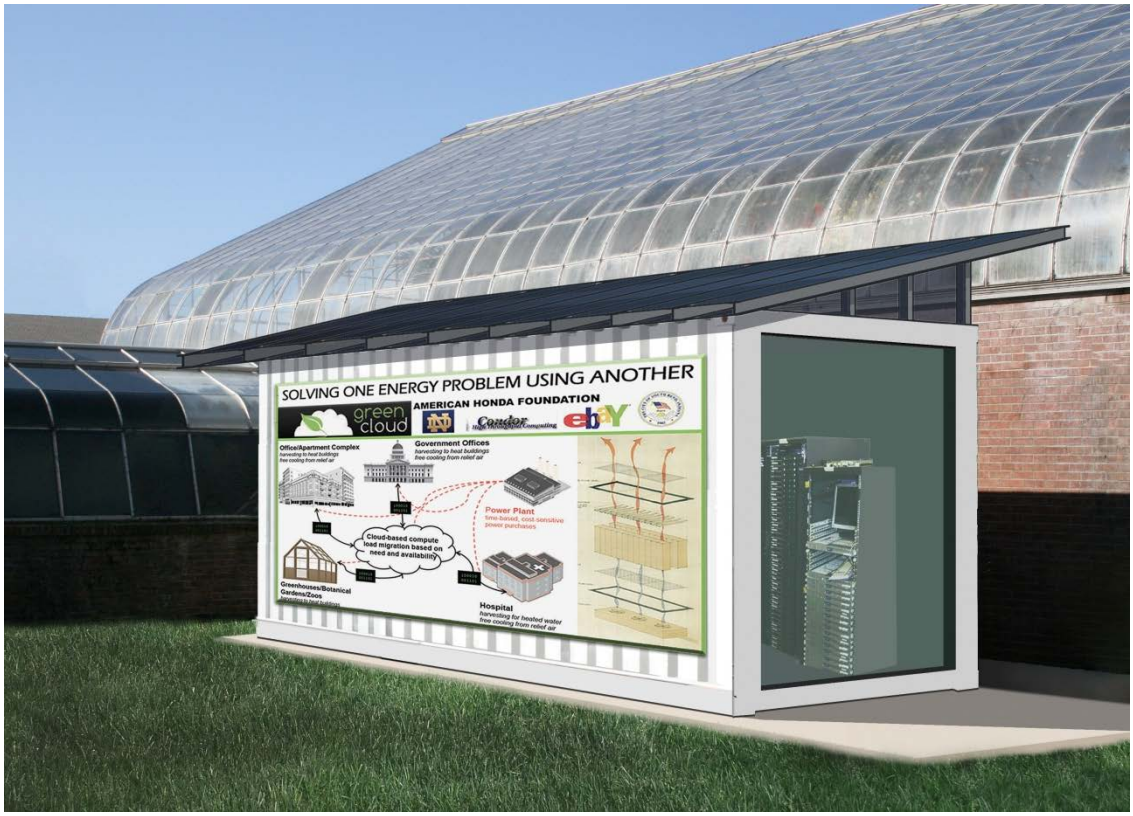

Image 3: Rendering of the proposed Green Cloud Interactive Learning Environment. This image describes the proposed modifications to the current operational prototype, shown here in its location at the Conservatory. Image credit: S. Santeramo

Goal 1: We will develop an interactive learning environment at the Conservatory prototype. While docents at the Conservatory are able to provide very general information about the Green Cloud to visitors, STEM education opportunities are currently limited. Therefore we propose the following modifications to transform the existing prototype into the Green Cloud Interactive Learning Environment.

In order to make the current prototype display-ready and enhance its functionality as an educational tool, we will paint the body of the Green Cloud container and hang a large graphic display on the outside of the prototype which will describe the energy conservation concept to visitors and students. An enhanced viewing platform will be added to the north side of the

container where students and visitors will be able to look through a new industrial-grade Plexi-glass panel to view the server and sensor equipment inside the prototype. Additional information about the Green Cloud and how the servers are working to heat the Conservatory will be located on this panel.

Inside the prototype, additional sensors and actuators will be added to encourage students to interact with system components, such as fan speeds, vent openings, and server availability, demonstrating how changes made to system inputs immediately impact the heat delivered to the Conservatory. This new interactive digital display will have buttons to press to change air flow (fan speed) which users can "feel" and subsequently observe the system dynamically adjust the compute/ heat load. This new touch-screen monitor will also show streaming data of the servers' energy usage, data from the temperature sensors installed in the Green Cloud container and inside the Conservatory, as well as general information about concepts of energy, energy conservation, and how the Green Cloud system operates. This new interactive display will be located near the inlet/outlet ductwork from the prototype. The ductwork can be seen from inside the Conservatory and will be painted red to indicate the pathway for incoming repurposed heat and blue to indicate the pathway for return air from the building (see image 4).

Image 4: Visitors to the Conservatory will be able to see the mechanics of the Green Cloud concept from inside the Conservatory and out. This image shows the ductwork that connects the Green Cloud to the Conservatory painted red and blue to indicate how heat is delivered from the servers to the building. Image credit: S. Santeramo.

An example of the type of dynamic information we will display at the Green Cloud Interactive Learning Environment can be found at our website, greencloud.crc.nd.edu/status, which shows real-time temperature measurements of the servers located in the Green Cloud. However, this new, interactive digital display will be designed so that the data and information described can be easily understood by visitors of all ages, particularly elementary-level youth. For example, we will use simple Question/Answer cartoons to teach students about how data centers work, how they produce heat, and how this heat can be used for buildings such as the Conservatory. In addition to serving school and youth groups, Conservatory docents will be able to use the display to increase the educational impact of their tours to members of our community.

Goal 2: The principle investigators will work closely with Jennifer Frech, Education and Outreach Coordinator at the Center for Sustainable Energy at Notre Dame (cSEND) to incorporate the Green Cloud into field trip experiences for school children. This serves to expand the educational value of school field trips already conducted in the Conservatory by integrating energy and waste heat recovery concepts with plant life education concepts. The Conservatory already is a frequent field trip destination for local schools, and this project provides us with an opportunity to partner with

new schools and programs to bring more children to the Conservatory and the Green Cloud prototype. Ms. Frech's role will be to facilitate these field trips, acting as a point-of-contact for schools and the Conservatory and assisting teachers with integrating the field trips into their curriculum through learning materials developed through this grant (see Goal 3). She will also play an important role in promoting access to the Green Cloud and expanding participation to schools that do not currently schedule field trips to the Conservatory. As a former high school science teacher who developed an Environmental Science Program for grades 10-12 and an Elementary Science Specialist for grades 1-4, Ms. Frech is ideally suited for this role.

The principle investigators will also be engaged in outreach education by giving talks at the Conservatory about the Green Cloud and energy conservation, and the need for new, exciting ways to address the energy challenge. Additionally, the Student Advisory Board (SAB) of Notre Dame's cSEND, comprised of undergraduate, graduate, and professional students is committed to volunteerism and outreach for energy education. We will engage this active student group in the promotion of this new learning environment, and they will also assist with school field trips as needed. Both the principle investigators and Ms. Frech will work closely with Heidi Gray, Conservatories Manager, to coordinate these various efforts.

Goal 3: The principle investigators, Ms. Gray, and Ms. Frech will work together to create curricular materials for the new Green Cloud energy field trip at the Conservatory discussed in Goal 2. The aim is to create a suite of materials (handouts, worksheets, etc.) that teachers can use before, during, and after the field trips to reinforce the energy conservation concepts that are integral to this project. The materials will include pre- and post-visit activities that will prepare students for the field trip, help them reflect on the important topics from the field trip experience, and integrate what they've learned with concepts they are already studying in the classroom. As we develop these materials, our focus will not only be on the Green Cloud, but energy in its many forms including mechanical and heat energy used in the Conservatory and energy captured from the sun and stored in plants. Additionally, some of these materials (where appropriate) will be made available to Conservatory docents to enhance community visitors' experiences as well.

Initially, these materials will be targeted to fourth graders, as the Indiana State Academic Standards[6] for energy at the fourth grade level combine well to show the interconnections of energy. In order to match the rigor of our state's educational system and reinforce critical learning milestones, we will focus on and contribute to the following core standards: (a) Physical Science (SCI 4.1.1 - 4.1.5) - provide evidence that heat and electricity are forms of energy, (b) Earth Science (SCI 4.2.5., 4.2.6) - describe how the supply of natural resources is limited and investigate ways that humans protect and harm the environment, and (c) Life Science (SCI 4.3.1)- observe, describe, and ask questions about structures of organisms and how they affect their growth and survival. While initially targeted for the fourth grade, these materials will be readily adapted for use at other elementary grade levels and flexible to include both future Green Cloud installations and other alternative energy concepts in succeeding years.

As part of our educational outreach efforts in Goal 3, we will work with principals from local public schools to arrange "Lunch and Learn" workshops with science teachers. During these workshops, the principal investigators will meet with teachers over lunch to talk about the project, distribute the curricular materials, and discuss ways that teachers can incorporate the project into their curriculum.

Goal 4: An additional educational handout will be developed for distribution to Conservatory visitors. This handout will be similar in content to the real-time display, although it will only contain sample data and trends instead of real-time data. In addition to information about the Green Cloud, it will provide suggestions for improvement of home energy efficiency, references for additional information about energy conservation initiatives, and ways that communities can get involved in reducing their energy and carbon footprints. We also expect that this handout will provide parents with interesting, conversation-starting talking points for discussions with their children on energy conservation, innovative problem solving, and the important role that the next generation will play in solving the energy challenge.

Extended Benefits

We envision that this interactive learning environment will become a special feature that helps draw additional visitors to the Conservatory. Nestled in South Bend's most prominent public park (Potawatomi Park), alongside the community zoo and pool, two large playgrounds, and an amphitheater, the Conservatory has a central role in our city's landscape (see Image 5 below and

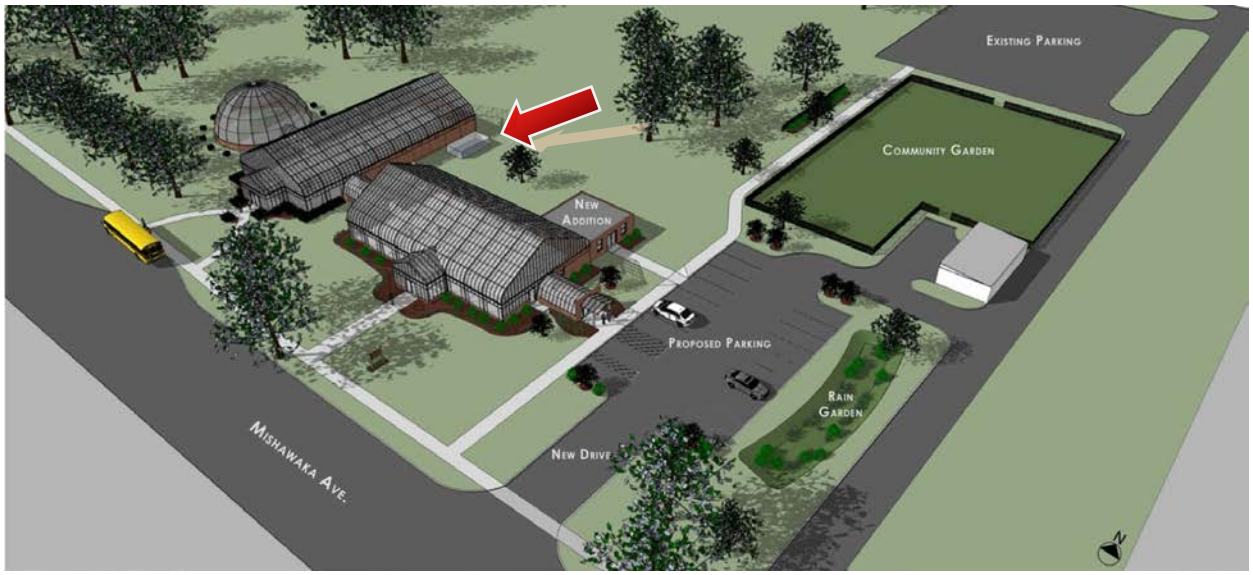

Image 5: Aerial perspective of Ella Morris/ Muessel Ellison Botanical Conservatories, including recent renovations to the complex to be completed in the summer of 2012. The red arrow indicates the current location of the Green Cloud prototype. Image courtesy of Kil Architecture and Planning in South Bend.

the map on page 7). Recently renovated (2011-2012), the timing is ideal to reinvigorate the visitor experience to the Conservatory and expand interactions with local schools. Our work related to the Green Cloud has already received significant local and national media exposure including articles in our local paper the *South Bend Tribune,*[7] national publications including the *Economist,*[8] and the principle investigators will be appearing in a local public broadcast program to promote this project. We believe that an appealing and dynamic display coupled with vigorous outreach to the community and schools will enable the Green Cloud to become a featured attraction that not only draws visitors but truly raises awareness about energy conservation and the environment and how innovative ideas can be used to overcome challenges.

In addition to the educational benefits to students and citizens of our community, the Green Cloud concept has the very real potential to improve energy efficiency and to provide financial benefit to the City of South Bend. The South Bend Municipal Energy Office is working to create a city that is more energy efficient, including retrofitting older buildings to increase energy efficiency. The Conservatory is a perfect example of the kinds of projects that the City is examining, and this is a model energy partnership between a municipality and a research institution. Beyond South Bend, we fully expect that The Green Cloud energy conservation concept we are developing will be broadly deployed, both regionally and nationally, in the coming years. Educational materials that are developed through funding from an American Honda Foundation Grant will be easily adaptable for use in other energy efficient Information Technology implementations so that those installations can have nearly immediate educational impact for local youth and communities.

As data from the existing Green Cloud prototype demonstrates, as well as the unique conservation partnership that it fosters, there is broad potential for buildings and organizations to mutually benefit from this new energy conservation concept. The Green Cloud, as an incubator for energy conservation research and education, has the potential to unleash critical innovative pathways to a more sustainable energy future while inspiring others – especially the next generation – help address the world's growing energy problem.

Image 6: Map of Potawatomi Park and surrounding context. Inset map (in blue) describes the location of the Park (in red) and Conservatory Complex (in green) relative to downtown South Bend and the University of Notre Dame campus (3 and 3.4 miles, respectively).

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