Re: Campus as a Living Lab Grant Program – Final Report

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Project Title: Radiant Cooling in Diurnal Shift Climate Environment

This report is compiled for the California State University (CSU) Chancellors Office on the basis of the grant proposal that was submitted on August 12, 2013. Color-coding of the font is expressing the following:

Required: Wording in these paragraphs were taken directly from the Request for Proposal (RFP) and evaluation criteria as published by the CSU Chancellors office.

Proposed: Wording is taken from the Campus-as-a-living-Lab Grant proposal and reflects the intent of the prime investigators to meet requirements of the RFP.

Achieved: Describes what was realized to meet grant requirements and proposed goals.

INTRODUCTION

Required: Applicants may submit a proposal for either course development/redesign or the creation of a learning community. Explain the proposed program.

Proposed: The California State University (CSU) is the largest university system in the United States. Providing a safe, operational, and sustainable environment for its campus locations certainly represents a challenge. However, the large number of
facilities in various regions throughout California also offers a unique opportunity to examine sustainable technology in different climatic environments.

The vision behind this proposal is to leverage this asset by transforming selected rooms into laboratories that serve the CSU and local communities as prototypes for evaluating the effectiveness of sustainable strategies in their environment.

This entry proposes the development of a new experimental course that involves undergraduate students in the design and implementation of such a laboratory on Campus.

For the Academic Year (AY) 2013/14, the proposal suggests researching the use of commercial off-the-shelf construction products to create an inexpensive, zero-energy cooling system for climate zones with diurnal temperature shift. By using conventional radiant heating components in combination with solar collector panels, the proposed system will leverage the diurnal temperature shift to control the inside temperature of buildings and thus lower the campus greenhouse gas emissions.

Achieved: This Campus-as-a-living-Lab Grant project accomplished the following:

- It created a laboratory by retrofitting room 314 of the Cal Poly Architecture building with an off-the-self radiant floor system and installing roof collectors for night sky cooling on the adjacent roof.
- It implemented an experimental course that focused on night sky cooling and engaged the students in the design and assessment of the built system.

During execution of the project the investigators discover that the existing floor construction contained in a layer underneath the carpet asbestos. This contamination remained undetected during an initial check in Winter quarter that had cleared the room and confirmed suitability for the purpose of the grant. As a result of the identified hazard situation, the proposed room selection and construction methods were examined again. After agreement to move forward, demolition and abatement of the existing floor construction were delayed through procedural hurdles. The prime investigators requested consideration of these unforeseen circumstances and received a three-month extension with a new target to expend the funds and submit the final report by October 31, 2014.

A. PURPOSE

1. Program Objectives

Required: Explain the proposed program and program objectives and how it will contribute to delivering courses and programs that better engage students and increase their learning in the area of sustainability through the "campus as a living lab" model.

Proposed: The objective of the proposed course is to engage students by actively involving them in developing and implementing changes to the build environment. In particular, students enrolled in this class will design, plan, and witness construction of a passive solar retrofit of an existing space in a selected Campus facility. After completion of the retrofit, the room will serve as a laboratory for the selected passive solar design strategy. For the Academic Year (AY) 2013/14, the course will focus on a radiant cooling system.

Achieved: The experimental class taught in Spring Quarter 2014 attracted students from 2nd, 3rd, and 4th year of the Architecture curriculum. Students worked in a hands-on collaborative learning environment and addressed over the...
course of the quarter in focus groups various aspects of the project and prepared the construction that will be completed by the end of Fall Quarter. Upon completion, the College has access to a research facility that allows exploring the potential of the diurnal temperature shift for thermal mass cooling.

2 Anticipated Outcomes

Required: Describe the anticipated outcomes of the project, including how the campus community will benefit from this project and any additional partnerships that will benefit (i.e., CA community college campus, surrounding community [as appropriate to your proposed program]).

Proposed: The outcome of the proposed course is intended as follows:

• Students enrolling in this class will gain insight into sustainable design strategies and focus on designing and implementing a selected sustainable technology. For AY2013/14 [funded through the Campus-as-a-Living-Lab Grant Program and other sources], the experimental course will focus on the use of collector-fed radiant cooling panels for internal load dominated spaces.

• After completion of the course and the resulting retrofit, the Campus community will have a laboratory that allow faculty and student researchers to monitor and evaluate effectiveness of selected sustainable design strategies. For AY2013/14, the result will be a space that is cooled with collector-fed panels.

• The course and the retrofitted space can be used as a laboratory for research and additional course offerings outside the undergraduate programs, including but not limited to:
  o Course offerings, senior, and/or thesis projects in related graduate studies,
  o Courses offering for professional credits through Cal Poly's Continuing Education (CE) Department.

• Lessons learned from the realization of the laboratory may help to implement comparable systems in other campus facilities and hence help to reduce the carbon footprint and costs of Campus operation. Ultimately, resulting expertise could be applied to retrofit of other CSU campus locations as well.

Achieved:

• Enrolled Students were actively involved in designing the sustainable technology that was selected for the quarter [i.e., the use of collector-fed radiant cooling panels for cooling a class room]. Throughout the quarter, students researched the technology, resulting construction aspects, and scientific methods to monitor and evaluate the system.

• Due to the late detection of the asbestos contamination of the floor construction completion of the classroom retrofit was delayed. Completion is expected by the end of fall quarter 2014. The outfitted classroom will be outfitted with sensors that allow monitoring of the radiant floor and other room surfaces in comparison to outside temperatures.

• Due to the construction delay, alternative courses as described in the proposal were not offered by the beginning of AY14-15. The suggested classes were:
  o Course offerings, senior, and/or thesis projects in related graduate studies,
Courses offering for professional credits through Cal Poly’s Continuing Education (CE) Department.

- Lessons learned from the realization of the laboratory set up revealed the following challenges for implementing comparable systems in other rooms and/or campus facilities:
  - Floor construction of buildings with comparable year-built may contain asbestos. In the case of the laboratory classroom in room 314 of building #5, asbestos abatement consumed 20% of the overall construction cost.
  - Radiant floor tubing must be secured and fixed to the floor. The selected method (i.e., clip profiles and pipe straps) required a fairly large number of screws and hence extensive drilling. This resulted in construction noise and impacted instruction in adjacent classrooms.
  - For reducing system complexity, it is recommended to design an open system with a storage tank below the collector level. This allows easy drainage of the roof collector and reduces the risk of system damage under extreme temperature conditions. However, a suitable mechanical room may not always be available. In the case of the grant project, a mechanical room was conveniently located below the selected room and close to the adjacent roof area.
  - Construction cost per square feet radiant floor (excluding demolition) was $26.19. Outfitting a larger area will likely provide synergies for the executing contractor[s] and may lower the price by 15 – 20%.

3 Outcome Assessment and Communication

**Required:** Describe how the outcomes of the course[s]/learning community will be assessed and communicated to the university community. Explain your plans to institutionalize course[s]/program within the academic program.

**Proposed:** The resulting laboratory will be outfitted with sensory technology to monitor the performance of the applied sustainable technology. It is anticipated that the monitoring of the test space can be simultaneously monitored with an equal space without the proposed retrofit and hence would allow comparing the effectiveness of new sustainable technology with legacy technology.

Results will be communicated to the current class as part of a focus lecture at the end of the quarter. Results will also be published to the wider Campus community through a publication volume that documents planning, construction, and evaluation of the selected sustainable design strategy (deliverable for enrolled students).

Furthermore, students of subsequent years will be able to experience, monitor, and study the applied technology. Aspects of research include but are not limited to system performance monitoring, surveys on human perception in respect to the selected technology, and maintenance and durability evaluation.

It is planned to institutionalize the class by selecting each academic year a new sustainable technology. Due to their repetitive floor plan layout, Campus facilities provide rooms that are similar to each other; therefore, are particularly suitable for comparing emerging sustainable technologies with legacy systems.

**Achieved:** As part of the ARCH-480 class, students developed test cases for evaluating the implemented technology under different use profiles and climatic
conditions by using surface-mounted sensors to capture thermal behavior of the enclosing building parts and the room temperature in comparison with the microclimate captured close to the collectors. A copy of the artifacts provided by the student researchers is attached in the Appendix of this report.

Initial communication will be achieved through print media and the dedicated Campus-as-a-living-Lab website that was created as part of the ARCH-480 class in Spring 2014. This website is currently updated and will be published at the beginning of Winter quarter 2015. Flyers that inform the campus community about the project were prepared as part of the ARCH-480 class and are attached in the Appendix to this report.

For Spring Quarter 2015, it is planned to offer a follow-up class that will intensify monitoring and evaluation of the implemented system. Since the room continues to be accessible as a gallery space, different occupancy scenarios can be monitored and recorded. Furthermore, this class will collect documentation regarding construction details, material specifications, and other project parameters to be compiled in a publication volume. This volume was initially planned to be a result of the Spring 2014 class but was postponed due to project delay (please see introduction for details).

B. METHODOLOGY AND RELEVANCE TO PROGRAM GOALS

1  Sustainability

Required: Describe how the proposed new or redesigned undergraduate course[s] will incorporate sustainability.
Proposed: The proposed experimental course is suggested to be based on the Environmental Control System (ECS) curriculum and focus on applied sustainable design strategies. The Architecture Department supports a revision of the existing ARCH-477 Advanced Topics in Environmental Architecture course. A proposed course design is attached to this proposal.

Achieved: The proposed undergraduate course was taught with a strong emphasis on technology research. Student worked with industry partners, faculty, and external consultants on system layout, dimensions, and component specifications. Facility Services the representatives of the owner of the space, i.e. the University engaged with the class and aided them in preparing the proper documents required for their review. Generated artifacts of the respective student assignments are attached in the Appendix of this report.

2 Anticipated Time Frame

Required: What is the anticipated time frame for incorporating the proposed course[s] into the curriculum? For redesigned courses: What term will the course be taught?

Proposed: For the proposed course design the suggested time frame is intended as follows:

- **Fall Quarter 2013**: Selection of a sustainable design strategy, obtain consent from involved administrative parties, pursue industry partnerships.

- **Winter Quarter 2014**: Prepare course materials and syllabus; obtain necessary permits for facility alteration; complete teaching and space assignment, post course offering.

- **Spring Quarter 2014**: ARCH-477X [experimental] course taught, simulation and/or modeling [or prototype building] to precede construction phase starting at the end of the quarter.

- **Summer Quarter 2014**: Construction phase overflow (if required), provide final grant narrative and expense report by July 31, 2014.

- **AY 2014/15**: Revised course ARCH-477 incorporated into existing curriculum.

Achieved: The anticipated time frame for the experimental course during AY2013-14 was accomplished as proposed. The construction overflow could not be limited to the Summer Quarter 2014: Abatement was of the asbestos floor construction was completed by mid-September, pushing system installation and concrete pouring to the month of October 2014.

3 Proposed Delivery Method

Required: Describe the proposed delivery method of the course.

Proposed: The course will be offered initially [i.e. AY2013-14] as an experimental deviation of the existing ARCH-477 course. The class will be taught in a seminar setting with approximately 20 students per class. Course duration and frequency is suggested to match the current ARCH-477 offering [i.e., four seminar sessions per week].

Achieved: During AY2013-14, the proposed program was realized as a 2-credit unit experimental class under the ARCH-480 series in the Architecture Department. The number of enrolled students was 18. A class roster is attached in the Appendix of this report.
4 High Impact Practices

Required: Which High Impact Practices if any, will be incorporated into the course?

The new course is design is aligned with the following High Impact Practices:

• Collaborative Assignments and Projects:

  Required: “Collaborative learning combines two key goals: Learning to work and solve problems in the company of others, and sharpening one’s own understanding by listening seriously to the insights of others, especially those with different backgrounds and life experiences. Approaches range from study groups within a course, to team-based assignments and writing, to cooperative projects and research.”

  Proposed: Academic collaborative projects especially when dealing with problems of the built environment provide the student with the closest proximity to how problems are solved in the professional world of the built environment. Every associated academic major has an important focus that they bring to the problem. It is the collective solution that usually engages the appropriate solution. This course will bring to light the importance of the selected majors to work with other majors, to be involved in a dialogue where each person understands their own role in the scheme of the whole and as importantly the role of their fellow students with a different focus on the same problem. This course will strive to have all participating students understand the full complexity of the problem and thus understand the importance of their role in the appropriate solution. In addition, meetings with Cal Poly’s Facility Services Representatives, local engineers, and industry partners will engage individuals with different backgrounds and life experiences.

  Achieved: The course encourages group learning by assembling 4 focus area teams. Each team performed on team assignments, but also had to collaborate across team boundaries to address dependencies. Students agreed on group-internal task delegation and formulated information requirements to their peers in other teams. To enhance the learning experience, team affiliation was shuffled after the midterm presentation. A student-group affiliation matrix is provided in the Appendix of this report.

• Undergraduate Research:

  Required: “Many colleges and universities are now providing research experiences for students in all disciplines. Undergraduate research, however, has been most prominently used in science disciplines. With strong support from the National Science Foundation and the research community, scientists are reshaping their courses to connect key concepts and questions with students’ early and active involvement in systematic investigation and research. The goal is to involve students with actively contested questions, empirical observation, cutting-edge technologies, and the sense of excitement that comes from working to answer important questions.”

  Proposed: The proposed course fosters undergraduate research by including undergraduate students in the laboratory set-up and data gathering. Results and findings from the experimental set-up are not predefined. Moreover, they emerge during the course and encourage the students to derive conclusions from their observations. This methodology will allow the students to feel that they contribute to the body of new knowledge rather than processing existing knowledge. The involvement of campus officials and industry partners will
communicate that the outcome of the conducted research is relevant to current challenges and answers important questions.

**Achieved:** The student group excelled in undergraduate research. System components, monitoring technology, and support software tools were researched independently by the focus groups. Students reached out to a component manufacturer and were able to attract system component donations with a total value of over $4,000. Student experienced first-hand that partners outside of the university are interested in the students’ research and are willing to invest money. This notion emphasized the perception that the course content and findings have relevance to the industry.

5 **Collaboration with other Departments**

**Required:** Preference will be given to collaborative proposals that partner faculty and/or staff from more than one department or discipline, recognizing that sustainability is inherently multi-disciplinary.

**Proposed:** The course and the resulting laboratory will foster interdisciplinary collaboration between departments. It is suggested to engage the following Departments in interdisciplinary collaboration:

- **Architecture Department (ARCH) Department:** Primary researchers facilitate preparation and coordination of the program. The resulting ARCH-477 course will be offered, hosted, and taught through the Architecture Department.

- **Mechanical Engineering (ME) Department:** Suggested collaboration areas include: (1) planning changes to the existing Heating Ventilation Air Conditioning (HVAC); (2) monitor the thermal performance of the laboratory; and, (3) optimize system efficiency, including software design and support.

- **Construction Management (CM) Department:** Suggested collaboration areas include: (1) Supporting construction phase planning, scheduling, and management; (2) Senior projects in CM department on researching and documenting materials and methods of construction; and, (3) Detailed specifications and construction cost analysis.

**Achieved:** Collaboration with other departments was pursued after the award of the grant. The prime investigators reached out to colleagues in the Mechanical Engineering Department at Cal Poly. In particular:

- **E-mail to Professor Glen Thorncroft** on December 10, 2013, requesting assistance in the design of the alteration of the legacy heating and ventilation unit.

- **E-mail to Professor Jesse Maddren** on August 12, 2013 and April 09, 2014, proposing collaboration with Mechanical Engineering students for design, set-up, and operation of sensor technology in the laboratory room.

The lack of construction progress during Spring Quarter (caused by asbestos finding in the floor construction) rendered the proposed collaboration scope with both the Mechanical Engineering Department and the Construction Management Department not applicable at the time when the class was taught.

6 **Connect to CA Community College**

**Required:** Proposals that connect the CSU and CA Community Colleges are also encouraged.
Proposed: Even though not specifically included in this proposal, the program is suitable to be shared with community colleges in the area. Cuesta College (San Luis Obispo) and Allan Hancock College (Santa Maria, CA) both maintain an architectural program that frequently sends transfer students to Cal Poly.

Achieved: Collaboration with the local community colleges is pending. The prime investigators will work with community college faculty to explore opportunities to share/present the laboratory facility. Point of Contact at the colleges that were identified in the proposal are:

- **Cuesta College (San Luis Obispo):** Stacey White, Professor at the Engineering and Architecture Department, (805)546-3264, stacey_white1@cuesta.edu
- **Allan Hancock College (Santa Maria):** Saad Sadig, Professor at the Industrial Technology Department, (805)922-3488, ssadig@hancockcollege.edu

7 Essential Learning Outcomes

Required: Extra consideration will be given to courses, which address one or more ‘Essential Learning Outcomes’ as defined by the Association of American Colleges and Universities Liberal Education and America’s Promise (LEAP).

Proposed: The new course is design aligned with the Essential Learning Outcomes defined by the Liberal Education and America's Promise (LEAP) by focusing on the following:

- **Knowledge of Human Cultures and the Physical and Natural World** is emphasized through the scientific research on sustainable technologies, including but not limited to thermal performance of buildings, heating and cooling systems, and research on historic strategies to heat and cool buildings.
- **Intellectual and Practical Skills** is addressed through extensive teamwork and analysis of scientific data in collaboration with students and faculty from other departments.
- **Personal and Social Responsibility** is integrated by addressing the real world problem of global warming and the ethical use of the world’s energy resources in the 21 century.
- **Integrative and Applied Learning** is fostered through leveraging general knowledge acquired in the ECS curriculum of second and third year (i.e. ARCH-207 and ARCH-307) and applying it to a specific real world problem (i.e., apply an acquired sustainable strategy to an existing space in a campus facility).

Achieved: The newly designed class addressed essential learning outcomes as defined by the Association of American Colleges and Universities Liberal Education and America’s Promise (LEAP). In particular:

- **Knowledge of Human Cultures and the Physical and Natural World:** The course content is emphasizing the importance of knowledge on human cultures [present in research of historic strategies on sustainable design] and understanding of physical and natural dependencies [fostered in meeting with domain experts ad consultants of related engineering fields].
- **Intellectual and Practical Skills:** Due to the evolving nature of the project, students also had to deal with aspect of uncertainty in research. During group discussions, the instructors took a mentoring role to facilitate critical
dialogue and problem solving processes among the team members. After decisions were communicated, the instructors reflected with the group members the practical validity of the outcome and proposed adjustments when applicable.

- **Personal and Social Responsibility**: Students worked in teams and were encouraged to assume responsibility for tasks related to their assignment. Throughout the course, the prime investigators/instructors considered the enrolled students as peer researchers:
  - Instructor-level access to the online learning platform ‘Poly Learn’ was granted to the students to facilitate efficient dissemination of and access to course resources such as documents, templates, and data.
  - During thermal performance recordings, student teams had full access to the facility and were responsible for the managing the room key.

- **Integrative and Applied Learning**: Students that enrolled in the newly designed class were challenged to interact with campus institutions [e.g., college administration, facility services department] and off-campus parties [e.g., consultants, industry representatives]. As such, content of the class was not limited to architectural problem solving, but required a comprehensive strategy to address system requirements and aesthetical considerations simultaneously.

C. **BUDGET**

1. **Budget Summary**

   Please refer to the attached Budget form for further detail. Please note that the College has indicated the willingness to support this initiative with additional funds from the Evelyn and Harold Hay Foundation.

2. **Additional Funding Sources**
Proposed: It is suggested to proactively pursue additional funding from public and private sources to ensure long-term sustainment of the research and teaching initiative.

- **State Funding:** AY2014/15: Research, Development, Demonstration and Deployment (RD&D) Plan under the California Solar Initiative (CSI) Program: This program intends to build a sustainable and self-supporting industry for customer-sited solar in California. The fifth solicitation for this program is expected to be published in June 2014. For further information please visit: [http://calsolarresearch.ca.gov](http://calsolarresearch.ca.gov)

- **University Funding:** The Evelyn and Harold Hay Fund was established at Cal Poly, San Luis Obispo in the early 1990s to support research and teaching related activities of students and faculty in the areas of passive solar building design and water in architecture. For further information please visit: [http://www.caed.calpoly.edu/content/centers/ehhf](http://www.caed.calpoly.edu/content/centers/ehhf)

- **Industry Funding:** It is planned to include technology manufacturers in the planning, realization, and evaluation of the project. Industry partners would be acknowledged in publications and may use research results to market their sustainable technology offerings. In exchange, industry partners are expected to provide support in the form of one or more the following:
  - **Engineering Support** [e.g., calculations, system design, specifications, drawings for permit process, system documentation for facility records];
  - **Materials Donations** [e.g., system components such as panels, tubing, manifolds, roof collector panels, piping, other installation hardware and construction materials]; and
  - **Installation Support** [e.g., labor necessary to execute and/or supervise installation of system components].

The following industry partners have been identified and were briefed during the proposal preparation phase. The primary researchers will pursue teaming agreements with the following industry partners once the grant is awarded:

- **Solarponics Solar Energy Company** [Atascadero, CA] was founded in 1975 by a Cal Poly engineering graduate and specializes in renewable energy products such as solar electric, solar hot water systems, and wind energy. **Point of Contact:** Kristian Emrich, Vice President (805) 466-5595

- **Pacific Energy Co.** [San Luis Obispo, CA] was founded in 1980 by a Cal Poly graduate and specializes in planning and installation of grid independent utility technology. **Point of Contact:** John Ewan, President

Achieved: In addition to the funding that was provided though the Campus-as-a-living lab grant, the research team successfully secured additional sources of funding with a total value of **$18,638.19**. In particular:

- **University Funding:** $12,000 through the Evelyn and Harold Hay Foundation,
- **Industry Funding:**
  - **Engineering Support:** Viega, LLC: System design, component specifications, system documentation for facility records Viega, LLC
  - **Materials Discount /Donations:** (1) Viega LLC: **$4,366.98** (Radiant floor system components such tubing, manifolds, piping, other installation hardware, and construction materials, Gift agreement in the Appendix of
this report; (2) Solarponics: $255.88 (15% Discount on roof collectors and pumps); and (3) Hydroflex: $1,198.80 (various discounts on thermal storage tank and supplies).

- **Installation Support** Solarponics: $816.53 (15% Discount on labor for installing and connecting radiant floor system).

Donations and discounts from involved industry partners accounted for $6,638.18 and, thereby, offset the unexpected cost for asbestos abatement, which accounted for comparable portion of the overall construction cost. A Budget summary with cost allocation to the funding sources is included in the Appendix of this report.

**D. EVALUATION SUPPORT**

1 **Feasibility and Administrative Support**

Proposed: To document feasibility within campus administrative frameworks for course development and approval the proposal has attached the following documents:

- Letter of support from Facility Services documenting support for the general concept and the suggested class, including the construction in Spring 2014.
- Letter of support from the dean of the College of Architecture and Environmental Design (CAED) documenting college-level support and availability of support through the Harold Hay foundation.
- Letter of Support from the Architecture Department Head documenting support for the experimental course ARCH207x, including but not limited to curriculum support, facility related accommodation, and faculty schedule adjustments.

Achieved: The experimental class and the construction project received support from the following CSU entities in the described project aspects:

- **CSU Chancellors Office**: Grant award and administrative support in response to the unexpected construction delay. Point of Contact: Meaghan Smith, Grants Coordinator.
- **Facility Services**: Project management, abatement, demolition, and project management support, including but not limited to weekly meetings with student teams. Points of contact: Mark Hunter (Associate Vice President for Facilities), Joel Neel (Director Facilities Planning and Capital Projects), Curtis McNally (Project Manager).
- **Grants Development Office**: Grant processing. Point of contact: Susanne Gartner (Grants Analyst).
- **College of Architecture and Environmental Design (CAED)**: Access to Evelyn and Harold Hay Foundation support, midterm review, project approval process. Points of contact: Christine Theodoropoulos (Dean) and Kevin Dong (Associate Dean), and
- **Architecture Department**: Scheduling, access to Evelyn and Harold Hay Foundation support, midterm review, project approval process. Points of contact: Margot McDonald (Department Head), Kristina van Wert (Administrative Assistant).
2 Scholarly Dissemination

Proposed: Results of the course are suggested to be presented at relevant conferences, future course[s], or other scholarly dissemination venues [suggested AY2014/15].

Achieved: The investigators are currently working with students through independent study classes or paid research to prepare a scholarly dissemination to document:

• Course design, instruction and lessons-learned
• System design, specifications, and construction cost, and
• System performance and projected operational savings.