STUDENT SUSTAINABILITY COMMITTEE

Funding Application – Step 2

Please submit this completed application, the supplemental budget spreadsheet, and any relevant supporting documentation by the deadline indicated in your Step 1 notification letter to Sustainability-Committee@Illinois.edu. The Working Group Chairs will be in contact with you regarding any questions about the application. If you have any questions about the application process, please contact the SSC Program Advisor, Micah Kenfield, at kenfield@illinois.edu

General Information

Project Name: High Resolution Temperature Profiling and Thermal Analysis for Geothermal Energy Alternatives

Total Amount Requested from SSC: Total Project Cost

Project Topic Area(s): ☒Energy ☒Education ☐Food & Waste
☒Land ☒Water ☐Transportation

Contact Information

Project Lead

Applicant Name: Yu-Feng Forrest Lin
Unit/Department: Illinois State Geological Survey (ISGS), Prairie Research Institute (PRI)
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Financial Contact *(Must be Full-time University of Illinois Staff Member)*

Contact Name: Yu-Feng Forrest Lin
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Facilities Management Contact *(If Applicable)*

Contact Name: Timothy Mies, University of Illinois Energy Farm
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Primary Project Team

Name	Department	Email
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Project Description

Please provide a brief background of the project, the goals, and the desired outcomes:
In the proposed project, we plan to collect baseline subsurface thermal data, which are needed to evaluate geothermal exchange alternatives. Typically, these data are collected by contractors for a limited time (a week or less) during the design phase of geothermal projects. However, in this project, we plan to collect data over an entire calendar year to identify the impacts of seasonal heating and cooling on the subsurface. We are also proposing this study because an ongoing geothermal study in central Illinois funded by the National Science Foundation, Lin et al. (2015a,b) found a different subsurface thermal profile in the upper 100 m than was predicted from the standard thermal transport model (Banks, 2012). Discovering this phenomenon could have a significant impact on the design of geothermal systems on the University of Illinois at Urbana-Champaign (UIUC) campus. We intend to use the same fiber-optic distributed temperature sensing (FO-DTS) system used in that study to perform a geothermal test on campus. For the proposed project, temperature data will be collected in high spatiotemporal resolutions (1-m and 0.1°C) with the FO-DTS system. At present, PI Lin is leading a research team from the ISGS that is using an FO-DTS system to investigate temperature variations at the surface and in the subsurface in Illinois and internationally. We expect that the analysis conducted by coupling an FO-DTS system with a heat exchanger will provide greater insight into the feasibility of using geothermal energy on campus, compared with conducting a standard thermal conductivity test. The industry-standard thermal response test uses only a subsurface heat exchanger to provide the average initial temperature and the average ground conductivity for the entire length of one U-bend heat exchanger installed at the depth we are requesting (100 m, in this case). When we consulted with Facilities and Services at the UIUC, it was recommended that we avoid locating the test site near the steam tunnel system, but rather place it somewhere where the technology would be cost effective. Therefore, the UIUC Energy Farm on south campus was proposed as the test site. The University of Wisconsin at Madison (UW-M) collaborator will use his expertise in operating a ground heat exchanger with FO-DTS and conducting thermal property measurements to work with the team from UIUC to perform *in-situ* thermal response tests on campus and to determine the thermal properties of the glacial material from the Energy Farm. Thermal properties will be measured by using the guarded-comparative-longitudinal heat flow apparatus (or a similar column apparatus) at the UW-M laboratory.

In addition to obtaining a high-resolution temperature profile with depth, we will analyze the costs of drilling mobilization and installation (per foot of depth) of closed vertical geothermal loop. Therefore, we will be able to determine the optimal depth of the vertical loop with respect to the cost of installation [objective to maximize: delta T/(total well cost/well depth), or equivalently to state, minimize: cost per ft/delta T]. This will allow us to accurately configure a single well or well field and determine whether a larger number of shallower wells might be more cost effective than a smaller number of deeper wells to achieve the same amount of heat transfer based on seasonal heat capacity. Note, that if the subsurface geologic materials are saturated with flowing groundwater, the efficiency of a heat sink is significantly increased. Therefore, the optimal depth is controlled by the saturated depth. On the UIUC campus, the shallow geology (above100 m depth) includes mainly hard, clayey glacial till (Burch et al., 1999) that lies below the water table and is saturated. These conditions are ideal for utilizing the earth's geothermal properties, which can provide very highly efficient thermal conductivity, as is being done in many other areas of the glaciated U.S. Midwest (Cartwright, 1968; Walker et al., 2015). Therefore, we expect to: (1) obtain a comprehensive thermal property measurements of the subsurface geologic materials; (2) obtain a subsurface temperature profile in high spatiotemporal resolutions; and (3) determine through analysis the optimal cost of a vertical closed-loop system for ground-source heat pumps, which can be used to evaluate the contribution of geothermal exchange for future energy planning on campus.

How will the project improve the sustainability of the Illinois campus and how will the project go above and beyond campus standards?

The U.S. Department of Energy (USDOE) estimated that more than two-thirds of the nation's electrical energy and more than 40% of natural gas is consumed in a building's utilities (USDOE, 2012). In residential and commercial buildings, space heating and cooling and water heating consume more than 40% of the electrical power. Within the building sector, space heating and cooling are the predominant demands, accounting for 47% of site-delivered energy, and water heating accounts for an additional 12% (USDOE, 2012). The U.S. Environmental Protection Agency (USEPA) estimated that geothermal heat pumps could reduce energy consumption by up to 44% compared with air-source heat pumps and up to 72% compared with conventional electrical heating and air conditioning (USEPA, 1997). For most areas of the United States, geothermal heat pumps are the most efficient means of heating and cooling buildings (U.S. Government Accountability Office, 1994). A recent study by the Indiana Geological Survey (Ellett and Naylor, 2016) showed that the total design length of atypical, commercial-scale vertical ground heat-exchange installation could be reduced by 17% by drilling a set of borehole that make the best use of the subsurface variability in thermal conductivity arising from changes in lithology and porosity. Despite the superior energy efficiency of geothermal heat pump systems, widespread adoption of the technology has been hindered by the higher initial capital cost relative to installation of conventional heating and cooling systems.

In numerous studies (e.g., Walker et al., 2015; Ellett and Naylor, 2016) it was found that improving the characterization of salient subsurface properties is an important methodology for achieving reduced costs through optimal design of the ground heat-exchange component of geothermal heat pump systems. Subsurface heat-exchange research in a low-temperature district-scale geothermal bore field is a demanding application of FO-DTS (McDaniel et al., 2016). The temperature profiles from fiber-optic cables placed within ground heat exchangers and sentry boreholes provide valuable knowledge on subsurface heat flow, which will assist us in detecting bore field overheating, comparing the performance of individual ground heat exchangers, and optimizing the design of future bore fields.

Where will the project be located? Will special permissions be required to enact the project on this site? If so, please explain and submit any relevant letters of support with the application.

The monitoring station will be located near the UIUC Energy Farm headquarters (4110 S. Race Street, Urbana, IL 61802). No additional permission is necessary because of the involvement of the UIUC Energy Farm.

Other than the project team, who will have a stake in the project? Please list other individuals, groups, or departments affiliated directly or indirectly by the project. This includes any entity providing funding (immediate, future, ongoing, matching, in-kind, etc.) and any entities that will be benefitting from this project. Please attach letters of commitment or support at the end of the application.

The entire University will benefit from our evaluation of green energy alternatives based on the efficiency of ground heat exchange for ground-source heat pump systems. Educational institutions in the community, such as the Champaign Unit 4 School District and University Laboratory High School, will also benefit from our operating the current systems and designing future systems. Additional staff from the ISGS and UIUC Energy Farm will be needed to complete the study. Their FTE salaries will be provided in kind.

Please indicate how this project will involve or impact students. What role will students play in the project?

During the installation process, we will provide live demonstrations of drilling, coring and geologic characterization, borehole geophysics logging, and installation of the geothermal heat exchanger with the FO-DTS cable for the benefit of students in the Department of Geology, Department of Civil and Environmental Engineering, Department of Natural Resources and Environmental Sciences, and University Laboratory High School. Data on the 100-m vertical distributed temperature profile will be collected automatically once every 4 hours for at least one year through student participation. The FO-DTS system will transmit data via a wireless network and will be supported by various energy sources, including solar panels. This project will support one UIUC student enrolled full time on campus to assist with (1) the field work on installations and the *in-situ* thermal response tests, (2) FO-DTS data processing and calibration, (3) thermal property measurements, (4) the development of a webpage or mobile apps to monitor the temperature difference between the surface and subsurface in real time, and (5) a sensitivity analysis of the optimal installation depth and cost for a potential vertical closed-loop system. The proposed project is a collaborative effort between UIUC and UW-M because the expertise from the UW-M is required to install and operate the ground heat exchangers with FO-DTS and they have the laboratory equipment required to measure the thermal properties or geologic materials. Drs. Tinjum and Hart, and one graduate student from UW-M will work with the UIUC student and scientists from ISGS to perform *in-situ* thermal response tests and determine the thermal material properties to transfer this knowledge. Thermal conductivity measurements will be conducted with a guarded-comparative-longitudinal heat flow apparatus (ASTM E1225, 2009) at UW-M.

Financial Information

In addition to the below questions, please submit the supplemental budget spreadsheet available on the Student Sustainability Committee website. Submission of both documents by the submission deadline is required for consideration of your project.

Have you applied for funding from SSC before? If so, for what project?
No.

If this project is implemented, will there be any ongoing funding required? What is the strategy for supporting the project in order to cover replacement, operation, or renewal costs?

Please note that SSC provides funding on a case by case basis annually and should not be considered as an ongoing source of funding.
No ongoing funding is required. The ISGS and UIUC Energy Farm will maintain the station after the end of the SSC funding cycle.

Please include any other sources of funding that have been obtained or applied for. Please attach any relevant letters of support as needed in a separate document.
None.

Environmental, Economic, and Awareness Impacts

In addition to the below questions, please indicate specific measurable impacts as applicable on the supplemental budget spreadsheet.

Which aspects of sustainability does your project address, and how? Does the project fit within any of the iCAP goals? If so, how does the project go beyond the university status quo standards and policies?

In the proposed project, we will provide critical information on thermal properties, the subsurface temperature profile, and the optimal cost of construction, which will allow us to evaluate the efficiency of energy consumption from current sources and the reduction in energy from utilizing ground-source heat pump systems. If the UIUC administration utilize geothermal exchange in their sustainable energy portfolio, their consultants can use our integrated analysis. The proposed study will contribute significantly to reaching the following four iCAP goals:

* Energy Utilization: 30% improvement from the FY08 baseline
* Energy Emissions: 30% reduction from the FY08 baseline
* Water Conservation: 30% reduction from the FY08 baseline
* Education & Outreach: provide immersive sustainability learning opportunities

How will the environmental impacts of your project be measured in the near and long term? What specific monitoring and evaluation processes will you be using to track outcomes and progress?

We will develop a webpage or mobile apps to help campus monitor the temperature difference between the surface and subsurface in real time. This will provide an awareness of the potential energy saved if a heat pump is installed on campus. The near-term project impact will be evaluated by data trends obtained from the proposed yearlong monitoring. We will calculate the energy saving rate from one or more potential ground-source heat pumps by comparing previous energy consumption. This information will be available to the broader campus community. The long-term impact of the project will be evaluated by initiating the use of and progressively utilizing ground-source heat pump systems.

What is the plan for publicizing the project on campus? In addition to SSC, where will information about this project be reported?

The progress and outcomes of the proposed project will be (1) updated on the ISGS and iSEE websites or the proposed mobile apps, (2) published in the form of peer-review journal papers and an ISGS report, (3) presented at scientific conferences in Sustainable Energy, (4) submitted to UIUC Facilities and Services for future energy planning on campus, and (5) presented to community groups interested in sustainability, such as the Urbana Sustainability Advisory Commission and the Champaign Unit 4 School District.

What are your specific, measurable outreach goals? How will these be measured?

We will tabulate the number of visits to our monitoring webpage or the number of downloads of mobile apps and analyze the effectiveness of this program. Follow-up communications with campus units and community groups that utilize our analysis will be considered to enrich our outreach program.

Do you have any additional comments or relevant information to aid in evaluation of this application?

References

ASTM International, 2009, Standard E1225: Standard test method of thermal conductivity of solids by means of the guarded-comparative-longitudinal heat flow technique: West Conshohocken, ASTM International, doi:10.1520/E1225-09.

Banks, D., 2012, An Introduction to Thermogeology: Ground Source Heating and Cooling, 2nd Edition: New York, John Wiley & Sons, 526 p.

Burch, S.L., R.D. Olson, and A.P. Visocky, 1999, Ground-Water Investigation for the University of Illinois: Illinois State Water Survey, Contract Report 636, 53 p.

Ellett, K.M., and S. Naylor, 2016, Utility of geological and pedological models in the design of geothermal heat pump systems, *in* C.B. Dowling, K. Neumann, and L.J. Florea, eds., Geothermal Energy: An Important Resource: Geological Society of America, Special Paper 519, p. 1–17, doi:10.1130/2016.2519(01).

Lin, Y.F., A. Stumpf, Y. Luo, and P. Kumar, 2015a, Integrating distributed temperature sensing and geological characterization to quantify spatiotemporal variability in subsurface heat transport within the Critical Zone [conference abstract]: American Geophysical Union Fall Meeting 2015, December 14–18, San Francisco, California.

Lin, Y.F., A. Stumpf, Y. Luo, and P. Kumar, 2015b, Using distributed temperature sensing to monitor potential subsurface temperature changes in an intensively managed landscape [conference abstract and oral presentation]: Geological Society of America 2015 Annual Meeting, November 1–4, Baltimore, Maryland.

McDaniel, A., M. Harper, D. Fratta, J. Tinjum, C. Choi, and D. Hart, 2016, Dynamic calibration of a fiber-optic distributed temperature sensing network at a district-scale geothermal exchange borefield [conference abstract]: American Society of Civil Engineers Geo-Chicago 2016: Sustainability, Energy, and the Geoenvironment, August 14–18, Chicago, Illinois (accepted).

U.S. Department of Energy, 2012, 2011 Buildings Energy Data Book: Washington, DC, U.S. Department of Energy, http://buildingsdatabook.eren.doe.gov (accessed March 15, 2016).

U.S. Environmental Protection Agency, 1997, A short primer and environmental guidance for geothermal heat pumps: Washington, DC, U.S. Environmental Protection Agency, Office of Air and Radiation, EPA 430-K-97-007, 9 p.

U.S. Government Accountability Office, 1994, Geothermal energy: Outlook limited for some uses but promising for geothermal heat pumps: Washington, DC, U.S. Government Accountability Office, RCED-94-84, 88 p.

Walker, M.D., L.L. Meyer, J.M. Tinjum, and D.J. Hart, 2015, Thermal property measurements of stratigraphic units with modeled implications for expected performance of vertical ground source heat pumps: Geotechnical and Geological Engineering, v. 33, no. 2, p. 223–238.

Attached Support Letters

Intensively Managed Landscapes-Critical Zone Observatory (IML-CZO)
University Laboratory High School
Urbana Sustainability Advisory Commission