*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):** [x] Energy [x] Education [ ] Food & Waste

 [x] Land [x] Water [ ] Transportation

# Contact Information

### Project Lead

Applicant Name: Yu-Feng Forrest Lin

Unit/Department: Illinois State Geological Survey - Prairie Research Institute

Email Address: yflin@illinois.edu

Phone Number: 217-333-0235

### Financial Contact *(Must be Full-time University of Illinois Staff Member)*

Contact Name: Yu-Feng Forrest Lin

Unit/Department: Illinois State Geological Survey - Prairie Research Institute

Email Address: syflin@illinois.edu

Phone Number: 217-333-0235

Organization Code: 547005

### Facilities Management Contact *(If Applicable)*

Contact Name: Timothy Mies, U of I Energy Farm

Email Address: tmies@illinois.edu

**Primary Project Team**

|  |  |  |
| --- | --- | --- |
| **Name** | **Department** | **Email** |
| Andrew Anderson | ISGS, PRI | acandrsn@illinois.edu |
| Timothy Young | ISGS, PRI | young@illinois.edu |
| James Tinjum | Geological Eng, UW-Madison | jmtinjum@wisc.edu |
| David Hart | WGNHS, UW-Extension | dave.hart@wgnhs.uwex.edu |

# Project Description

**Please provide a brief background of the project, the goals, and the desired outcomes:**

The proposed project will collect baseline subsurface thermal data that is required for evaluating geothermal exchange alternatives. Typically, this data is collected by contractors for a limited time during the design phase of geothermal projects (a week or less). This project will collect data over an entire calendar year to identify impacts of seasonal heating and cooling on the subsurface. In a current geothermal study in the Champaign-Urbana, Lin et al (2015a, b) have found a different thermal profile in the upper 100 m than predicted from the standard thermal transport model (Banks, 2012). We intend to use the same fiber-optic distributed temperature sensing (FO-DTS) system to perform a geothermal test on campus. This project will collect temperature data in high spatiotemporal resolutions (1-m and 0.1°C) using a fiber-optic distributed temperature sensing (FO-DTS) system. Currently, PI Lin is leading a research team from the ISGS that is employing FO-DTS to investigate temperature variations at the surface and in the subsurface in Illinois, and internationally. On-going work for an NSF-funded project in east-central Illinois has demonstrated subsurface temperature is more variable than previously thought (Lin et al., 2015 a;b). Therefore, the analysis conducted by coupling FO-DTS with the heat exchanger is expected to provide greater insight into the feasibility of geothermal energy on campus compared with the current 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). After consulting the University of Illinois Facilities and Services, it was recommended the test site should not be located near the steam tunnel system and somewhere where the technology could be cost effective. Therefore, the University of Illinois Energy Farm on south campus was proposed for the test site. Based on existing expertise on operating a ground heat exchanger and thermal property measurements at UW-Madison, the Wisconsin collaborator will work with the Illinois team on performing heat exchange testing on campus and determining the thermal conductivity of the glacial material from the Energy Farm by using the guarded-comparative-longitudinal heat flow apparatus (or similar column apparatus) in the laboratory at UW.

In addition to a high-resolution temperature profile with depth, we can analyze the drilling mobilization cost and the cost of construction per foot of depth of the installed vertical loop. Therefore, we would be able to determine the optimal depth for the installed vertical loop with respect to the cost of installation (maximize: delta T/(Total well cost/well depth)) or equivalently to state, minimize: cost per ft/delta T. This will allow us to select the optimum depth for a single well or well field and determine if a larger number of shorter wells is more cost effective than a fewer number of deep wells to achieve the same amount of heat transfer based on seasonal heat capacity. Note, if a geologic profile is highly saturated with transient water, the efficiency of heat sink is significantly increased. Therefore, the optimization depth may be controlled by the saturated depth. The shallow geology (to 100 m depth) on campus is mainly clayey, hard glacial till (Burch et al. 1999), which lies below the water table and is saturated. These conditions are ideal for utilizing the earth’s geothermal property, which can provide very high efficient on thermal conductivity like many other areas in Midwest region (Walker et al., 2015; Cartwright 1968). Therefore, the expected outcomes including (1) the comprehensive thermal property measurements, (2) subsurface temperature profile in high spatiotemporal resolutions, and (3) optimal cost analysis of vertical closed loop installation for ground source heat pumps, which can be used to evaluate geothermal energy contribution 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 estimated that over two-thirds of the nation’s electrical energy and greater than 40% of natural gas consumption is used inside buildings (USDOE, 2012). In residential and commercial buildings, space heating and cooling and water heating consume greater than 40% of electrical power. Within the buildings sector, space heating and cooling are the dominant demands, accounting for 47% of site-delivered energy, with water heating second at 12% (USDOE, 2012). The U.S. Environmental Protection Agency estimated that geothermal heat pumps can reduce energy consumption by up to 44% compared to air-source heat pumps and up to 72% compared to conventional electrical heating and air conditioning (USEPA, 1997). For most areas of the U.S., geothermal heat pumps are the most energy efficient means of heating and cooling buildings (USGAO, 1994). A recent study by the Indiana Geological Survey (Ellett and Naylor, 2016) has shown that the total design length of a conceptual, commercial-scale vertical ground heat exchange installation could be reduced by 17% by implementing the set of bores that makes 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 is hindered by the higher initial capital cost relative to conventional heating and cooling systems.

Many studies (Ellett and Naylor, 2016; Walker et al., 2015) suggested that better characterization of salient subsurface properties is a promising avenue for achieving reduced costs through optimal designs of the ground heat exchange component of geothermal heat pump systems. Subsurface heat exchange research in a low-temperature district-scale geothermal borefield is a demanding application for FO-DTS (McDaniel et al., 2016). The temperature profiles from fiber-optic cables placed within ground heat exchangers and sentry boreholes provide valuable knowledge of subsurface heat flow which assists in detection of borefield overheating, comparison of individual ground heat exchanger performance, and design optimization of future borefields.

**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 Energy Farm headquarter (4110 S Race St, Urbana, IL 61802). No additional permission is necessary because of the involvement of the 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 whole University will have the benefit of evaluating the green energy alternatives based on the efficiency of ground heat exchange for ground source heat pump systems. The community will also benefit on operating the current systems and designing the future systems, such as Champaign Unit 4 School District and University Laboratory High School. The service time of the team members at the ISGS and the Energy Farm, and Professor Tinjum at UW will be in-kind. Professor Tinjum will also provide the fiber-optic cable without any charge. This particular model of cable has been proven to be efficient for the proposed work based on UW team’s previous experience.

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

During the installation process, we could provide live demonstrations with drilling, core recovery/description, downhole geophysics, and the installation of geothermal heat exchanger with FO-DTS cable to the students in the Department of Geology, Department of Civil and Environmental Engineering, Department of Natural Resources and Environmental Sciences, and University Laboratory High School. The 100 m vertical distributed temperature profile will be automatically collected data once every 4 hours for at least one year with students’ participation. The students will learn from the field installation, thermal conductivity analysis, temperature data processing and calibration. The FO-DTS system will transmit data by a wireless network and supported by various energy sources including solar panels. This project will support two U of I students enrolled full time on campus to assist (1) the field work on installations and heat exchange test, (2) FO-DTS data processing and calibration, (3) thermal property measurements, (4) developing a webpage or mobile apps to monitor the temperature difference between surface and subsurface in real-time, and (5) sensitivity analysis of optimal installation depth and cost for potential vertical closed loop system. The proposed project is a collaboration between University of Illinois (U of I) and University of Wisconsin (UW). Based on UW’s expertise on operating ground heat exchangers and thermal property measurements at UW-Madison, one graduate student, Professor Tinjum and Dr. Hart from UW will work with the students and scientists from U of I on performing heat exchange test on campus and determining the thermal conductivity of the unsaturated rock specimens from the site by using the guarded-comparative-longitudinal heat flow apparatus (ASTM E1225) in the laboratory at UW.

# 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 required. The ISGS and Energy Farm will maintain the station after 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.**

The proposed project will provide critical information on thermal property, subsurface temperature profile and optimal cost analysis to evaluate the efficiency of reducing energy consumption from current sources by considering ground source heat pump systems. If the university decides to change the current plan and start utilizing geothermal exchange based on our integrated analysis, this project will contribute significantly on reaching the following four iCAP goals:

\* Energy Utilization: 30% improvement from FY08 baseline

\* Energy Emissions: 30% reduction from FY08 baseline

\* Water Conservation: 30% reduction from 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?**

The development of a webpage or mobile apps to monitor the temperature difference between surface and subsurface in real-time will provide the awareness on potential energy saved if one heat pump was installed on campus. This data trend of proposed one year of monitoring will be the near-term evaluation of project impact. By comparing with the current energy consumption, any campus unit can use this information to calculate the energy saving rate from one or more potential ground source heat pumps. The initiation, progress of utilizing geothermal energy will be the long-term impact from the project.

**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 outcome of the proposed project will be (1) updated on the ISGS and iSEE websites and proposed mobile apps, (2) published in the form of peer-review journal paper and ISGS report, (3) presented in scientific conferences, (4) submitted to University of Illinois Facilities and Services for future energy planning on campus, and (5) interested community groups on sustainability, such as Urbana Sustainability Advisory Commission and Champaign Unit 4 School District.

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

We will periodically receive the visit number +on our monitoring webpage or the download number of mobile apps for the temperature difference monitoring system. The follow-up communication with campus units and community groups for utilizing our analysis will be another measurable goal.

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

References:

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

Banks D., 2012. An Introduction to Thermogeology: Ground Source Heating and Cooling, 2nd Edition, John Wiley & Sons, Inc., 526p.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 Dowling, C.B., Neumann, K., and Florea, L.J., 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, 2015, San Francisco, CA.

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, Geological Society of America - 2015 Annual Meeting, Conference Abstract and Oral Presentation, November 1-4, 2015, Baltimore, MD

McDaniel, A., Harper, M., Fratta, D., Tinjum, J., Choi, C., and Hart, D. 2016. “Dynamic Calibration of a Fiber-Optic Distributed Temperature Sensing Network at a District-Scale Geothermal Exchange Borefield.” ASCE Geo-Chicago. Accepted.

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 33(2): 223-238.

USDOE, 2012. 2011 Buildings Energy Data Book: http://buildingsdatabook.eren.doe.gov

USEPA, 1997. A short primer and environmental guidance for geothermal heat pumps, U.S.

Environmental Protection Agency, EPA 430-K-97-007, 9 p.

USGAO, 1994. Geothermal energy: outlook limited for some uses but promising for geothermal

heat pumps, U.S. General Accounting Office RECD-94-84.

Attached Support Letters:

University of Illinois Facilities and Services

Intensively Managed Landscapes-Critical Zone Observatory (IML-CZO)

University Laboratory High School

Champaign Unit 4 School District

Urbana Sustainability Advisory Commission