Environment and Natural Resources Trust Fund
2019 Request for Proposals (RFP)

Project Title: **ENRTF ID: 191-EH**

Novel Combined Solar Thermal-Geothermal Heat Pump System

Category: H. Proposals seeking $200,000 or less in funding

Sub-Category: E. Air Quality, Climate Change, and Renewable Energy

Total Project Budget: $ 168,000

Proposed Project Time Period for the Funding Requested: June 30, 2021 (2 yrs)

Summary:

The project will conduct numerical modeling and field testing of a novel combined solar-thermal geothermal heat pump system, an efficient and affordable renewable heating/cooling approach.

Name: Jimmy Randolph

Sponsoring Organization: Juneberry

Title:

Department:

Address: 4728 12th Avenue S

Minneapolis MN 55407

Telephone Number: (952) 457-8959

Email jimmy.randolph@gmail.com

Web Address

Location

Region: Metro

County Name: Hennepin

City / Township:

Alternate Text for Visual:

Sketch of a conventional geothermal heat pump system.

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%
____ If under $200,000, waive presentation?			

PROJECT TITLE: Analysis and testing of novel solar thermal-geothermal heat pump systems.

I. PROJECT STATEMENT

The proposed project will conduct numerical analysis and perform field testing of a novel approach to renewable space heating and cooling: combining ground source heat pumps (GHP's) with solar thermal systems. We also plan to use novel GHP technology that was developed at the UMN. With basic research funding provided by LCCMR, that technology was modeled and physically tested in lab settings with very promising results. Now, solar-enhanced GHP design must be formalized for real-world settings, and pre-commercial testing must be completed so that by the end of this project, the tech. will have been sufficiently demonstrated to be commercially viable.

Space/water heating/cooling comprise 48% of energy use in an average US residence, and commonly, that energy is supplied by natural gas or fossil-fuel-derived electricity. Geothermal heat pumps (GHPs) can reduce energy demands – and associated greenhouse gas (GHG) emissions – for heating/cooling by 75%. GHPs are a critical part of "electrification of everything," as they are one of the only ways to provide non-fossil heating/cooling. GHPs can be used most anywhere in the world because they use the shallow subsurface as a thermal capacitor. Traditional GHPs require numerous wells (at a high cost), are space-intensive, and difficult to size. This high initial cost and uncertainty in performance, when compared to off the shelf fossil fuels, is undesirable for building owners. Thus, despite being a proven technology, GHPs have minimal (less than 1%) market penetration in the US. However, in areas with higher energy costs, such as Sweden, GHPs are up to 75% of the HVAC market, indicating there is significant room for growth. We will investigate two novel ways to decrease GHP initial costs, bringing them close to parity with conventional HVAC systems, and test these approaches locally.

1) Conventional GHPs ignore groundwater flow, focusing on conductive heat transfer with subsurface materials. The novel GHP technology takes advantage of the thermal transport properties of groundwater flow, advectively carrying the heat to/from the ground source heat exchanger. The Advective GHP (AGHP) operates in a closed-loop fashion so that no groundwater is used and no contaminants are introduced to the subsurface. Lab tests show the AGHP drastically reduces the number of boreholes needed in an installation while improving performance, predictability and maintenance, thus decreasing costs compared to traditional GHPs.

2) Large buildings tend to have unbalanced heating/cooling loads. As such, conventional GHP's will gradually cool or heat the subsurface, requiring that such GHP's be oversized to ensure longterm (30+ year) lifespans. Oversizing increases costs and may prevent GHPs from fitting in dense urban settings. To balance loads while optimizing footprint, GHPs can be combined in a novel way with solar thermal arrays. The combination can decrease installation costs by 20-30% compared to GHP systems alone while decreasing footprint even more.

The proposed project will 1) modifying the AGHP heat exchanger design for field applications, 2) fabricating it, 3) installing a test well in the Twin Cities (a site in North Minneapolis has been identified), 4) field testing the AGHP, 5) conduct post-field-test data analysis/ numerical modeling to improve performance predictions, 6) model the AGHP together with a solar thermal system, and 7) design, install and test a small solar thermal array alongside the AGHP system. This will provide the basis for commercial development and deployment.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: AGHP Heat Exchanger Design and Fabrication

ENRTF Budget: $30,000

Here, we will modify the AGHP heat exchanger design that was developed for lab testing to ensure it is sufficiently robust for commercial applications, fabricate the unit, and develop secondary equipment to mount the exchanger in a borehole. We will also work to get the test unit permitted for field testing.

Outcome	Completion Date
1. Heat exchanger design and compliance review	08-20-2019
2. Heat exchanger fabrication and fabrication documentation	09-31-2019
3. Design and fabrication of secondary equipment for heat exchanger installation	09-31-2019
4. Permitting of heat exchanger with MN Dept. of Health and MN DNR, as needed	10-31-2019

Activity 2: Installation of Borehole to be Used to Test the AGHP, Capacity Testing
ENRTF Budget: $33,000

We are in discussions with a site in North Minneapolis to serve as the test location. There, we will install a borehole, logging it to determine optimal depth with discussions ongoing), we will test the AGHP in the field under simulated heating/cooling loads. Tests will be performed for 2 weeks to determine moderate-term performance.

Outcome	Completion Date
1. Drilling and installation of test bore in the Prairie Du Chien aquifer in Twin Cities	10/31/2019
2. Flow rate logging of bores.	11/30/2019
3. Mobile test platform testing of AGHP unit installed in Prairie Du Chien aquifer	05/15/2020

Activity 3: Numerical Model Development and Post-test Analysis
ENTRF Budget: $50,000

Numerical modeling, including modification of existing GHP subsurface and economic models to include AGHP data, and modeling to permit performance predictions over a wide range of field conditions. Additionally, field test data will be analyzed and used to inform models, then the AGHP will be compared with traditional GHPs.

Outcome	Completion Date
1. Modification of GHP hydrogeologic/economic models, development of AGHP models	06/21/2020
2. Post field test data analysis and comparison of AGHP with traditional GHPs	09/30/2020

Activity 4: Solar Thermal Analysis and Integration
Budget: $55,000

Here, we will numerically model the AGHP together with a solar thermal system, using a modeling framework provided by the U of Dayton, and design, install and test a small solar thermal array alongside the AGHP system.

Outcome	Completion Date
1. Numerical modeling of coupled solar thermal-AGHP system	12/31/2020
2. Solar equipment selection and acquisition	02/31/2021
3. Solar equipment installation and testing	06/30/2021

III. PROJECT PARTNERS:

A. Partners receiving ENRTF funding

Name	Title	Affiliation	Role
Dr. Jimmy B Randolph	Principal	Juneberry	Project management, modeling
Braun Intertec or Wenck	n.a.	Braun Intertec or Wenck	Equipment manufacturing, field installs

Braun Intertec and Wenck are MN-based consulting companies. Braun is regional leader in large-scale GHP installations and has the extensive expertise and in-kind resources required to thoroughly field-test the AGHP.

IV. LONG-TERM- IMPLEMENTATION AND FUNDING:

Although the technological risk is low, it is none-the-less too new and unproven for commercial investment but too advanced for basic research funding. This gap in traditional funding opportunities is commonly referred to as the "valley of death." While most technologies experience this period, it is particularly challenging for technologies in the energy space. Thus, LCCMR is well-positioned to help demonstrate the novel hybrid solar thermal-AGHP system, positioning MN to be a national leader in cost-effective, renewable energy technologies for building heating and cooling. Our ultimate goal is to help foster a local and national GHP industry that is an economic win for installers and building owners, which could lower MN's fuel requirements for heating/cooling by 50%,.

Non-confidential project results will be published in peer-reviewed journals and presented at conferences.

V. TIME LINE REQUIREMENTS:

The proposed project is expected to require 2 years, approx. 1 year for heat exchanger construction and field testing and 1 yr for post processing and solar analysis. Most proposed activities must be completed sequentially.

2019 Project Budget

Project Title: Analysis and testing of novel solar thermal-geothermal heat pump systems.

IV. TOTAL ENRTF REQUEST BUDGET *2* **years**

BUDGET ITEM	AMOUNT
Personnel:	$ -
Dr. Jimmy B Randolph (PI, 50% time per year for 2 years, salary 75% of cost, fringe benefits 25% of cost).	$ 75,000.00
Research Assistant (20% time per year for 2 years, salary 75% of cost, fringe benefits 25% of cost).	$ 18,000.00
Professional/Technical/Service Contracts:	$ -
Braun Intertec or Wenck: Subcontractor. Heat exchanger design and fabrication, test bore design and installation, heat exchanger capacity rate testing. Solar system installation.	$ 70,000.00
Equipment/Tools/Supplies:	$ -
Wellbore logging and monitoring equipment.	$ 3,000
Travel: In-state travel to metro heat pump test location and equipment suppliers.	$ 2,000
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST	**$ 168,000**

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period:	N/A	
Other State $ To Be Applied To Project During Project Period:	N/A	
In-kind Services To Be Applied To Project During Project Period: Ground source heat exchanger lab (Braun), including borefield and monitoring equipment. This state-of-the art field is without comparison in the Midwest US, and it will be used as a baseline against which to compare and validate the novel GHP system in the field	$ 20,880	Secured
Discounted rental rate for TC3 mobile GHP testing rig (four weeks), to be used for field testing of novel GHP and comparison systems.	$ 11,040	Secured
Computational hardware (computer workstations) and software (EM2), for numerical modeling of the GHP system.	$ 19,700	Secured
Past and Current ENRTF Appropriation:	N/A	
Other Funding History:	N/A	

Conventional Commercial-Scale Groundsource Heat Pump

The figure shows a conventional groundsource heat pump, employing vertical subsurface heat exchange loops for a large residential or commercial building. Note that the installation has multiple vertical loops that do not intersect groundwater zones. The novel Advective GHP (AGHP) technology, which will be field-tested under the proposed project, makes use of the ability of water to move large volumes of heat to decrease the required number of wells, thereby reducing costs, eliminating much of the mess of GHP installations, and improving predictability. The AGHP is also designed to allow servicing of underground equipment without requiring excavation, improving system longevity and performance.

The basic investigation of the AGHP was previously supported by the LCCMR, and the proposed project will bring the system through the new technology "valley of death." That is, the AGHP is too advanced for basic research funding but not sufficiently proven to be commercially adopted, a stage that all technologies encounter and which is the end of many. This promising renewable energy system is expected to be a win for all parties involved, including building owners, industry, and the state of MN; with the proposed project, LCCMR can help make MN a national leader in GHP technology. Figure courtesy of Braun Intertec, 2017.

2019 Project Manager Qualifications and Organization Description
Project Title: Analysis and testing of novel solar thermal-geothermal heat pump systems.

Dr. Jimmy B. Randolph
Juneberry
4728 12th Avenue South
Minneapolis, MN 55407, USA

E-mail: jimmy.randolph@gmail.com
Cell: 952-457-8959

RESEARCH AND WORK EXPERIECE:

2018-present **Juneberry**, Principal, Minneapolis, MN
2006-present **University of Minnesota – Twin Cities,** Department of Earth Sciences, Minneapolis, MN: **Senior Research Associate, Postdoctoral Research Associate, Research Assistant**
2014-present **TerraCOH, Inc.,** Minneapolis, MN: **Chief Technical Officer, Interim President, Director**
2011-2014 **Heat Mining Company, LLC,** Rapid City, SD: **Chief Technical Officer, Senior Scientist**

EDUCATION:

2006-2011 **University of Minnesota – Twin Cities**, Department of Earth Sciences, Minneapolis, MN. Ph.D., Geophysics, emphasis in Hydrogeology and Geothermal Energy.
2002-2006 **Saint Olaf College**, Northfield, MN. B.A. in Physics and Mathematics, Summa Cum Laude.

SELECTED HONORS, AWARDS, PATENTS:

2015 Saar, M.O., **J.B. Randolph**, and T.H. Kuehn (in no particular order). Carbon dioxide-based geothermal energy generation systems and methods related thereto. U.S. Patent No. 8,991,510 issued March 31, 2015.
2012-2014 Saar, M.O., **J.B. Randolph**, and T.H. Kuehn (in no particular order). Carbon dioxide-based geothermal energy generation; Systems and methods related thereto. U.S. Patent No. 8,316,955 B2 issued 2012; Canadian, Australian, and 11 European patents issued.
2012-2013 **J.B. Randolph**. Enhanced carbon dioxide-based geothermal energy generation systems and methods. U.S. Provisional Patent Application Serial No. 61/725,270 filed November 11, 2012. U.S. and International Patent Applications filed in March, 2013.
2009 UMN Dept. of Geology and Geophysics Forrest Fellowship for academic achievement.
2008 UMN Dept. of Geology and Geophysics Gibson Fellowship for academic achievement.

QUALIFICATIONS: Dr. Randolph has extensive experience investigating coupled heat and groundwater flow using field, laboratory, and computational methods. Additionally, Dr. Randolph has extensive experience developing innovative heat pump and geothermal technologies and transitioning these technologies from the University to the commercial sector. For example, together with his former advisor, Dr. Martin Saar, and a colleague from mechanical engineering, Dr. Kuehn, Randolph developed the concept of combined CO_2 sequestration and geothermal energy extraction while at the UMN, a technology that has been awarded several patents and resulted in a startup company – TerraCOH – being spun out of the UMN to commercialize the technology.

RESPONSIBILITIES: Dr. Randolph will develop numerical models and complete numerical simulations and calculations to analyze and help validate the Solar Thermal - Advective Groundsource Heat Pump (AGHP) system. He will help supervise scientists and a student in these analyses. In addition, he will coordinate with subcontractors to design and field test the system.

ORGANIZATION DESCRIPTION: GeoSys is a Minnesota-based startup company dedicated to the development and deployment of novel, cost-effective, renewable heating and cooling systems. We are in discussions with the University of Minnesota to make use of technology developed there, and previously supported by the ENRTF, regarding Advective Geothermal Heat Pump systems. Additionally, we hold internal trade secrets regarding combined solar thermal-geothermal heat pump technologies, and we have an extensive set of partners and collaborators with complementary expertise in such systems.