LCCMR ID: 148-F3+4

Project Title: Cost-Effective, Efficient Geothermal Heat Pump Systems

Category: F3+4. Renewable Energy

Total Project Budget: $ $850,895

Proposed Project Time Period for the Funding Requested: 3 yrs, July 2011 - June 2014

Other Non-State Funds: $ 0

Summary:

Development and testing of a cost-effective, high-efficiency, self-regulating geothermal energy system that can be used for heating and cooling of dwellings on either a district scale or as standalone.

Name: Otto Strack

Sponsoring Organization: U of MN

Address: 500 Pillsbury Dr SE
Minneapolis MN 55455

Telephone Number: 612-625-3009

Email strac001@umn.edu

Web Address

Location

Region: Statewide

Ecological Section: Statewide

County Name: Statewide

City / Township:

_____ Funding Priorities _____ Multiple Benefits _____ Outcomes _____ Knowledge Base

_____ Extent of Impact _____ Innovation _____ Scientific/Tech Basis _____ Urgency

_____ Capacity Readiness _____ Leverage _____ Employment _______ TOTAL ______%

2011-2012 MAIN PROPOSAL

PROJECT TITLE: COST-EFFECTIVE, EFFICIENT GEOTHERMAL HEAT PUMP SYSTEMS

I. PROJECT STATEMENT

Minnesota has high energy demands for space heating and cooling. Using geothermal energy in shallow water bearing layers reduces this demand, in particular in the hot summers of Minnesota. The system is based on injecting cold fluid in winter and retrieving it in summer, as well as injecting warm fluid in summer and retrieving it in winter. This is commonly done using so-called ground heat exchange loops, which do not take advantage of the groundwater flow, but retrieve and store heat using a suitable fluid flowing through tubing installed in wells. This system requires many wells to be drilled per building with very high first costs. We propose to reduce these costs by a factor of 10 by optimal use of the groundwater flow and with only a few carefully and widely spaced wells.

The natural variation of the groundwater flow has a major impact on the efficiency of the system. A common variation in direction of flow of about 15 degrees, for example, reduces the efficiency of the system by a factor of 2; half of the cool water injected in winter will be lost, with an adverse effect on the environment. We have developed an extremely efficient new method for modeling combined heat flow and groundwater flow that permits us to adjust the flow rates of the wells so quickly that losses can be reduced significantly. This may reduce the costs well beyond the noted factor of 10, with the expected result of widespread adoption.

Our goal is to produce a prototype of an advanced field-tested system. Industry is very likely to take advantage of the new system, creating jobs and producing a major increase in the energy efficiency of buildings in the State, while reducing adverse effects on the environment (thermal pollution). The system will likely be patentable, leading to sustained income for continued system development.

The prototype system will consist of:

1. A design tool that will be easy to use and will lead to optimum use of available aquifer energy resources, rather than the current approach of installing systems and hoping for the best.
2. A working prototype system that will be available for public demonstration. The system can be applied either on a district scale or on a standalone basis.
3. The system is independent of the heat flow map update currently underway in Minnesota, since it will create its own heat pattern that is contained, by design, to local areas.

Activities. 1) Prototype design, development of the well system design tool and algorithm control technology. 2) Build and instrument the prototype system at UMore Park to complement the University's sustainability and energy efficiency goals for the property. 3) Operate the prototype system for 1 year; collect data; validate the design tool and control technology. 4) Optimize the design tool based on data collected in activity 4, optimize for commercial use, write documentation, write a project report, and demonstrate a prototype system to facilitate commercialization by the University's Office for Technology Commercialization.

II. DESCRIPTION OF PROJECT ACTIVITIES

Activity 1 **Budget: $ 218,410**

Development of the well-design tool, based on new analytical solutions of coupled heat and mass flow in aquifers to make possible timely adjustment of the system to varying conditions using temperature data. The tool will be used to design the prototype of an optimized well system for the UMore Park hydrology. The baseline control system and algorithm will be developed and tested.

Outcome	Completion Date
1. Develop coupled heat and mass aquifer analytical solution	April 30, 2012
2. Design prototype system	May 31, 2012

3. Incorporate solution into design tool and embedded control algorithm	October 31, 2012
4. Develop control system software including embedded well system algorithm	November 30, 2012

Activity 2 Budget: $ 288,217

A suitable site will be selected at UMore Park. Wells will be drilled and connected to a central research building. The system will be instrumented and tested.

Outcome	Completion Date
1. Choose prototype system site & purchase plant and data acquisition equipment	July 31,2012
2. Complete construction of the prototype system	September 30, 2012
3. Complete system instrumentation	November 30, 2012
4. Complete commissioning and begin data collection	December 31, 2012.

Activity 3 Budget: $ 126,390

The system will be operated continuously for one calendar year and transient data will be collected automatically. The data will be analyzed and used to validate the design software and optimize the control system. The design software will be refined and tested on user groups to optimize the user interface.

Outcome	Completion Date
1. Continuously collect data	December 31, 2013
2. Validate design tool and optimize control algorithm	December 31, 2013
3. Optimize design tool user interface	December 31, 2013

Activity 4 Budget: $ 115,707

Optimize design tool based on data from activity 3, create a commercial version, write manual, write project report and journal papers and demonstrate prototype system to facilitate commercialization.

Outcome	**Completion Date**
1. Finalized commercial version of design tool and user documentation	June 30, 2014
2. Project report and journal papers	June 30, 2014
3.Conduct at least 4 tours of prototype system at UMore Park	June 30, 2014

III. PROJECT STRATEGY

A. Project Team/Partners (all from the University of Minnesota)

Louise Goldberg: Director, Energy Systems Design Program and Senior Research Associate, College of Design, Martin Saar: Assistant Professor and Gibson Chair of Hydrogeology and Geofluids, Dept. of Geology and Geophysics. Otto Strack: Professor, Civil Engineering Department,

B. Timeline Requirements

Activity 1: 1 year. Activity 2: 6 months. Activity 3 1 year. Activity 4: 6 months. Total project: 3 years. Elements of activities 1 and 2 will be conducted concurrently.

C. Long-Term Strategy and Future Funding Needs

It is intended that the prototype system will be commercially deployed under license to the University of Minnesota. The license royalties and additional Federal research support will fund the continued development and refinement of the system and its applicability to more complex renewable energy systems at larger scales and potentially at smaller scales (e.g., individual residence systems).

2011-2012 Detailed Project Budget

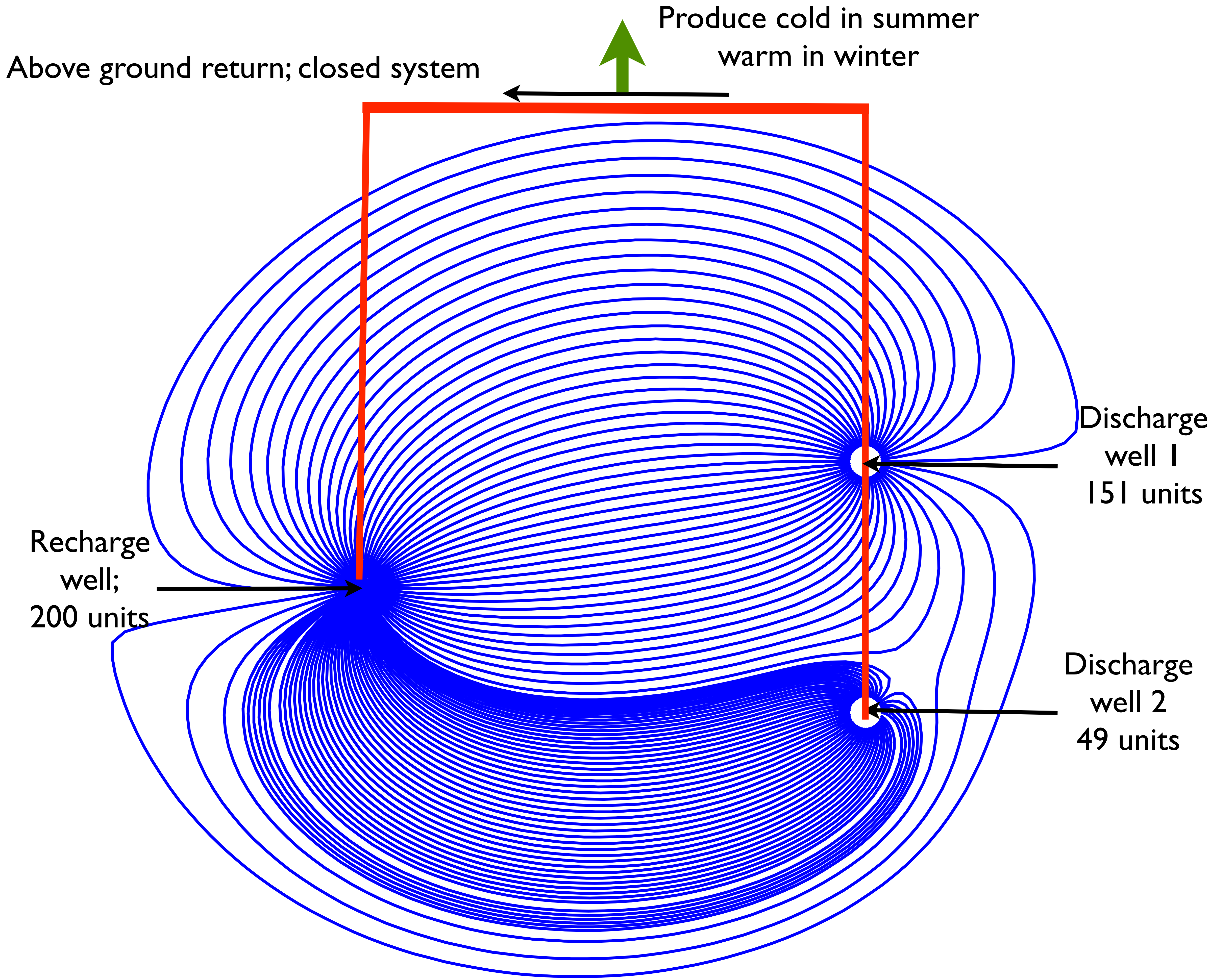
INSTRUCTIONS AND TEMPLATE (1 PAGE LIMIT)

Attach budget, in MS-EXCEL format, to your "2011-2012 LCCMR Proposal Submit Form".

(1-page limit, single-sided, 10 pt. font minimum. Retain bold text and DELETE all instructions typed in italics. ADD OR DELETE ROWS AS NECESSARY. If a category is not applicable write "N/A", leave it blank, or delete the row.)

IV. TOTAL TRUST FUND REQUEST BUDGET 3 years

BUDGET ITEM (See list of Eligible & Non-Eligible Costs, p. 13)	AMOUNT
Personnel: 1. Otto D.L. Strack, Professor. Development of the analytic solutions to be used for real-time adjustment of the pumping rates of the wells in the system, implementation of these solutions in an efficient computer program and guidance of the student who will working on the implementation and optimization of the software. 22% time, $104,012 Salary, $34,318 Fringe for 7/1/2010-6/30/2013	$ 138,330
Martin Saar, CO-PI, Professor 12% time, $24,727 Salary, $7,987 Fringe for 7/1/2010-6/30/2013	$ 32,714
Louise Goldberg, CO-PI, Senior Research Associate, 29% time, $92,858 Salary, $29,993 Fringe	$ 122,851
Personnel: 2 Research Assistant: will assist in the analysis and computer program development. 50 % time. $169,728 Salary, $123,092 Fringe and Tuition Benefits for 7/1/2010-6/30/2013	$ 292,820
Personnel: Undergrad Research Assistant $9,000 Salary for 7/1/2010-6/30/2013	$ 9,000
Personnel: Civil Service Personnel, $15,000 Salary, $5550 Fringe for 7/1/2010-6/30/2013	$ 20,550
Personnel: Administrative Assistant, $9,273 Salary for 7/1/2011-6/30/2014	$ 9,273
Equipment/Tools/Supplies: Apple computer, including software; estimated at current cost. This computer will be essential in developing the software necessary for controlling the system. Response of the system depends highly on the speed of the computations; therefore a high-end Apple computer is chosen, along with two monitors required for program development. This includes $500 (estimated) for software.	$ 9,757
Equipment/Tools/Supplies: Project specific computing hard and software for TOUGH2 and other simulations of coupled groundwater and heat transfer to test analytical method and to use heat as a groudwater flow tracer.	$ 5,000
Equipment/Tools/Supplies: Lab Supplies	$ 3,000
Equipment/Tools/Supplies: Supplies to build and and maintain prototype plant	$ 32,500
Equipment/Tools/Supplies: Software for control and system design	$ 5,000
Equipment/Tools/Supplies. Well drilling costs	$ 40,000
Equipment/Tools/Supplies. Trenching, piping and related costs.	$ 15,000
Equipment/Tools/Supplies: Prefabricated research building	$ 15,000
Equipment/Tools/Supplies: Pilot plant equipment	$ 50,000
Equipment/Tools/Supplies: Instrumentation	$ 10,000
Equipment/Tools/Supplies: Permitting fees	$ 5,500
Equipment/Tools/Supplies: Electricity	$ 3,000
Travel: travel to and from UMores site; $3,000 per year for PI, CO-PI's	$ 24,600
Additional Budget Items: Professional services, publication of sponsored journal articles, and general supplies	$ 7,000
TOTAL ENVIRONMENT & NATURAL RESOURCES TRUST FUND $ REQUEST	$ 850,895


Produce cold in summer
warm in winter
Above ground return; closed system
Discharge
well 1
151 units
Recharge
well;
200 units
Discharge
well 2
49 units

Project Manager Qualifications and Organizational Description

Dr. Otto D. L. Strack

Professor, Department of Civil Engineering, University of Minnesota
Masters (Ingenieurs (Ir)), 1969, Technical University of Delft, The Netherlands
Ph.D. Civil Engineering 1973, Technical University of Delft, The Netherlands

Dr. Strack will be the overall coordinator of the project. His research is focused on the analytical modeling of groundwater flow, heat flow, and transport in porous media.

Dr. Louise F. Goldberg

Director, Energy Systems Design Program and Senior Research Associate

B.Sc (Eng) in Mech. Eng., Univ. of the Witwatersrand, Johannesburg, South Africa, 1976
M.Sc (Eng) in Mech. Eng., Univ. of the Witwatersrand, Johannesburg, South Africa, 1979
Ph.D (Eng) in Mech. Eng., Univ. of the Witwatersrand, Johannesburg, South Africa, 1987

Dr Goldberg will be responsible for the prototype plant design, fabrication and instrumentation including the control system development. Her research is focused on the theoretical and experimental continuum mechanics and modern control theory of renewable and sustainable energy systems.

Dr. Martin O. Saar

Assistant Professor and Gibson Chair of Hydrogeology and Geofluids, Department of Geology and Geophysics, University of Minnesota

M.Sc in Geology, Univ. of Oregon, Eugene, OR, USA, 1998
Ph.D. in Earth and Planetary Sciences, Univ. of California–Berkeley, Berkeley, CA, USA, 2003

Dr. Saar will be responsible for measurements of temperature-depth profiles throughout project implementation, testing, and validation, for modeling heat as a groundwater flow tracer at the site, and for numerical simulations (using for example TOUGH2 and/or other codes) to test the analytical methods developed by Dr. Strack.

University of Minnesota

The University of Minnesota is one of the top research universities in the nation with extensive resources and experience in computations, analysis, and experimental research on renewable and sustainable energy systems. The project will be undertaken at the University of Minnesota's UMore Park site which is the planned location of a new residential community based on the overall goals of resource and energy sustainability and usage efficiency.