Project Title: **ENRTF ID:** 103-E

Housing Clusters Consuming Less Electricity Than They Generate

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

Total Project Budget: $ 195,000

Proposed Project Time Period for the Funding Requested: 2 years, July 2015 - June 2017

Summary:

Housing clusters use renewable energy (solar photovoltaic/thermal, ground source heat, waste cooking oil and sewage effluent) to provide space heating and cooling and generate more electricity than they consume.

Name: Louise Goldberg

Sponsoring Organization: U of MN

Address: 322B Kaufert Laboratory, 2004 Folwell Ave
St. Paul MN 55108

Telephone Number: (612) 624 2492

Email goldb001@umn.edu

Web Address www.buildingphysics.umn.edu

Location

Region: Metro

County Name: Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, Washington

City / Township:

Alternate Text for Visual:

Schematic design of a residential combined heating, cooling and electrical power cluster

_____ Funding Priorities _____ Multiple Benefits _____ Outcomes _____ Knowledge Base

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

_____ Capacity Readiness _____ Leverage _______ TOTAL

PROJECT TITLE: Housing clusters consuming less electricity than they generate

I. PROJECT STATEMENT

Clusters of single and multifamily dwellings in the metro area and in small towns across Minnesota can be connected into combined heating, cooling and electrical power renewable energy systems (a similar system is currently active in downtown St. Paul for commercial buildings). Each cluster energy system independently uses solar thermal and photovoltaic energy; energy from biomass (waste cooking oil from nearby restaurants, sewage effluent, garden waste) and thermal energy stored in the near-surface earth (wells and aquifers) in combination to provide the cluster with heating, cooling and electricity. The level of insulation and air-tightness of the buildings in the cluster are optimized to match the renewable energy resources of the cluster. Previous research (see ,http://www.buildingphysics.umn.edu/PDF/UMorePublic.pdf) has shown that such systems can generate twice as much electricity as they consume on an annual basis. This system can be implemented within the existing Utility statutes by invoking the net-metering residential rate structure. It is envisaged that the combined energy cluster will be organized as a cooperative in which the homeowners are the investors with rights being transferred with the title deed. The energy system would be managed and operated by private industry and financed by the sale of heating and cooling energy, excess electricity sold back to the grid as well as passive energy savings from upgrading the energy performance of individual homes in the cluster (homeowners pay no capital costs, but are charged for the amount of energy saved or "negawatts"). Over time, this will decouple the cluster from utility energy cost increases, provide long-term energy price stability and higher occupant comfort for the homeowner that, together, will result in property value appreciation.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Evaluate residential housing stock for siting housing energy clusters **Budget: $82,000**

The initial survey of residential housing blocks suitable for renewable energy clusters will be conducted using public-domain satellite imagery of a wide swath of the 7-county metro area including some small towns such as Hastings and Stillwater. Collected information will encompass: ●housing density; ●no. of contiguous blocks that could be included in the cluster; ●available shadowed and non-shadowed south facing roof area; ●existence of an alley for siting energy cluster infrastructure (buried pipes); ●depth of water table and regional aquifers (from Geological Survey data), and, ●availability of open lots for siting the cluster energy plant. About 20 suitable sites will be visited to verify the satellite imagery and assess the residents' willingness to participate in an energy cluster. The houses in 6 to 10 of the sites with willing participants will be characterized using available data from Community Development Corporations (for example) in terms of enclosure insulation levels, air tightness and numbers and types of windows.

Outcome	**Completion Date**
1. Map of 7-county metro showing suitable energy cluster sites coded by the selection criteria in the Twin Cities and surrounding small towns.	*month 11/yr 1*
2. Report on residents' attitudes towards / acceptance of energy clusters (20 sites)	*month 1/yr 2*
3. Report on individual house thermal characteristics (6-10 sites)	*month 3/yr 2*
4. Selection of 2-3 average blocks that can be simulated in Activity 2, Task 3 including development of all the necessary house metrics.	*month 3/yr 2*

Activity 2: Computer model of a combined heating, cooling and power energy cluster **Budget: $78,000**

The Mathlab/Simulink modeling tool will be used to develop a computer simulation model of an energy cluster that can be exercised for a full year using measured weather data. The model will include state-space analytic and/or Dept. of Energy EnergyPlus simulation models of all the houses in the cluster (including combined photovoltaic-thermal solar collectors and other plant necessary for using district heating and cooling energy in each house.) Also included will be a model of the central plant (pumps, storage tanks, ground source wells) and a globally optimizing control system for operating the equipment on an annual basis to achieve net-zero or better energy performance. The model will be used to parametrically evaluate various design choices to optimize the net-zero energy performance of the energy cluster, such as, the effect of solar collector area and the minimum level of house enclosure thermal energy efficiency. Finally, the optimized model will be used to model residential energy cluster blocks selected in Activity 1.

Outcome	**Completion Date**
1. Develop a working Mathlab/Simulink model of an energy cluster including an energy simulation of all the houses in the cluster.	*month 12/yr 1*
2. Optimize the design of the energy cluster by assessing the impact of the salient design parameters	*month 3/yr 2*
3. Run the model for a full calendar year on the energy clusters selected in Activity 1, Task 4	*month 6/yr 2*

Activity 3: Evaluate economic viability and Final Report **Budget: $35,000**

A simple economic model spreadsheet will be developed to evaluate the financial viability of the energy clusters modeled in Activity 2 Task 3. Simulated energy flows will be converted to costs and the initial investment to build the energy cluster will be computed. Annualized cash flows, plant amortization and long term operating profitability will be evaluated.

Outcome	**Completion Date**
1. Develop a spreadsheet economic model	*month 9/yr 2*
2. Using the energy data from Activity 2 task 3, compute the annual operating cost budget	*month 10/yr 2*
3. Estimate the investment cost to build the energy cluster and calculate amortization and long-term profitability.	*month 11/yr 2*
4. Final report and publication of simulation model on-line	*month 12/yr 2*

III. PROJECT STRATEGY

A. Project Team/Partners

Principal Investigator: Louise F. Goldberg, Energy Systems Design Program, Univ. of Minnesota. **Co-Principal Investigator**: Patrick H. Huelman, Cold Climate Housing Program, Univ. of Minnesota. PI will be responsible for tasks 2 and 3 and co-PI will be responsible for task 1. The PI and co-PI will receive the funding from the ENRTF Fund. It is anticipated that outside partners will be sought to assist in implementing Activity 1.

Project Impact and Long-Term Strategy

A successful demonstration that a renewable energy residential energy cluster works and is cost-effective on a design basis will be transformative in achieving a massive conversion of the State's residential energy infrastructure to renewable energy without creating political conflicts with electrical utilities. The simulation and financial models developed will be published on-line in the public domain so that any interested party will be able to use them to assess the viability of particular residential blocks as renewable energy clusters. These tools will be promoted to private industry to entice them to build prototype systems owing to the anticipated demonstration of financial viability and profitability. On an aggregated basis, large scale deployment of this renewable residential energy cluster approach across MN will yield an order of magnitude increase in the deployment of renewable energy with a decrease in greenhouse gas emissions and reduction in solid organic waste disposal.

C. Timeline Requirements

It is anticipated that this project can be completed in 2 years as Activity 1 can proceed in parallel with Activities 2 and 3.

2015 Detailed Project Budget

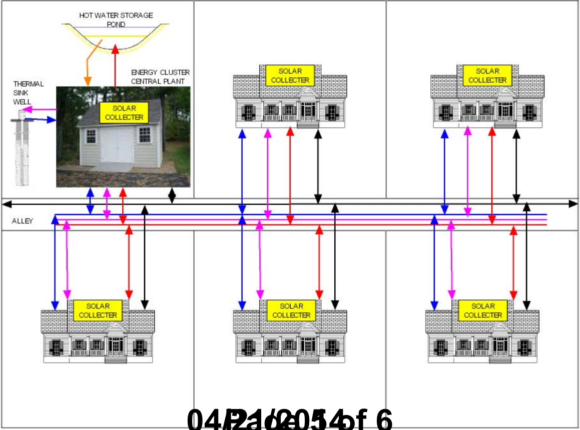
Project Title: Housing clusters consuming less electricity than they generate

IV. TOTAL ENRTF REQUEST BUDGET 2 years

BUDGET ITEM	AMOUNT
Personnel: Louise Goldberg; Principal Investigator; Activities 2 and 3; 2 years; 19% full time; 100% soft money funded appointment Salary: 74.7% of total; Fringe benefits: 25.3% of total; 1 person	$ 70,020
Personnel: Patrick Huelman; co-Principal Investigator; Activity 1; 2 years; 8% full time; 10% soft money funded appointment Salary: 74.7% of total; Fringe benefits: 25.3% of total; 1 person	$ 28,474
Personnel: Tom Schirber; Fellow; Activity 1; 2 years; 17% full time; 100% soft money funded appointment Salary: 74.7% of total; Fringe benefits: 25.3% of total; 1 person	$ 37,898
Personnel: Graduate Student (MS); Activities 1, 2 and 3; 1 years; 50% full time; 100% soft money funded appointment Salary: 56.1% of total; Fringe benefits: 43.9% of total; 1 person	$ 42,823
Equipment/Tools/Supplies: Computer for developing/exercising simulations; GIS mapping software and small tools and supplies to conduct housing survey	$ 11,473
Travel: In-state travel by vehicle in the 7-county metro area to visit and evaluate locations suitable for location of a renewable energy clusters(77 daily round trips of 100 miles each).	$ 4,312
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 195,000

V. OTHER FUNDS *(This entire section must be filled out. Do not delete rows. Indicate "N/A" if row is not applicable.)*

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: Non-recovery of University facilities and administration charges.	$ 101,400	
Funding History:	N/A	
Remaining $ From Current ENRTF Appropriation:	N/A	



(red)	very hot water
(orange)	hot water
(magenta)	warm water
(blue)	cold water
(black)	electricity

SCHEMATIC DESIGN OF RENEWABLE ENERGY RESIDENTIAL HOUSING CLUSTER

Project Manager Qualifications and Organizational Description

Project Manager: 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 in Mech. Eng., Univ. of the Witwatersrand, Johannesburg, South Africa, 1987

Dr Goldberg has had over thirty years of experience conducting sponsored research in the field of active and passive energy systems for a broad spectrum of sponsors including the US Dept. of Energy, State of MN and numerous private and public corporations. She has issued US patents and numerous refereed publications in the field. Her research is focused on the theoretical and experimental continuum mechanics and modern control theory of renewable and sustainable energy systems.

Dr. Goldberg will be responsible for the overall management supervision of the project and will be directly responsible for completing Activities 2 and 3 that focus on developing a computer simulation model of the proposed hybrid energy system and evaluation of its economic viability.

Organization: Energy Systems Design Program (ESDP), Dept. of Bioproducts and Biosystems Engineering, 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 ESDP is focused on developing the physics and engineering theory and application of integrating active (solar, biomass, geothermal, etc) and passive (energy conservation, thermal insulation, etc) energy systems into hybrid configurations with globally optimizing controls based on second law thermodynamic principles (the minimization of entropy generation).