Project Title: Showcasing Carbon-Neutral, Energy-Positive Transformation of an Occupied House

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

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

Total Project Budget: $ 66,532

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

Summary:
Showcase carbon-neutral and energy-positive transformation of an occupied house that becomes a model for the entire state, where utility pays homeowners for electricity while they significantly reduce their carbon footprint.

Name: Ned Mohan

Sponsoring Organization: U of MN

Title: Professor - UMN

Department: Electrical and Computer Engineering / CSE

Address: Keller Hall, 200 Union St SE

Minneapolis MN 55455

Telephone Number: (612) 625-3362

Email: mohan@umn.edu

Web Address: http://z.umn.edu/nedmohan

Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:
A typical Minnesota house with energy audit, rooftop PVs, weatherization/insulation, replacement of all older and inefficient appliances and lightbulbs, the meter running backwards, zero-carbon footprint, indoor vegetable cultivation using LEDs.

<table>
<thead>
<tr>
<th>Funding Priorities</th>
<th>Multiple Benefits</th>
<th>Outcomes</th>
<th>Knowledge Base</th>
<th>Extent of Impact</th>
<th>Innovation</th>
<th>Scientific/Tech Basis</th>
<th>Urgency</th>
<th>Capacity</th>
<th>Readiness</th>
<th>Leverage</th>
<th>TOTAL</th>
<th>%</th>
</tr>
</thead>
</table>

If under $200,000, waive presentation?
PROJECT TITLE: – Showcasing Carbon-Neutral, Energy-Positive Transformation of an Occupied House

I. PROJECT STATEMENT
Residential homes and buildings have a large carbon footprint. This project will showcase the process (not just the end-results) of transforming a typical house - modest and older - into a highly energy-efficient and a carbon-neutral home, while it remains occupied by a family. It will be done in such a way that it becomes energy-positive by generating more electricity than it consumes (i.e., the utility pays the homeowner) in order to payback the investments made for this transformation.

This project will be unique in many ways: 1) A modest house typical of Minnesota homes, preferably in a low-income neighborhood, will be selected while it remains occupied, 2) The project website will showcase the transformation process for everyone to follow along, 3) The electricity consumption of all the improvements will be carefully monitored to calculate the payback and hence the economic feasibility of every energy improvement, 4) The use of natural gas will be TOTALLY eliminated to make this house carbon-neutral, 5) The electricity will be purchased through, for example, the WindSource program of XCEL where 100 percent of the electricity is generated from Minnesota wind farms, 6) To make it an energy-positive house, a photovoltaic (PV) system will be installed that can generate 120 percent of the electricity needs of the homeowner per year, thus qualifying for net-metering where the rate of purchasing electricity is the same as of selling, 7) In this project, leafy green vegetables will be grown for nutrition and food security using LEDs, 8) It will look into possible innovations, such as automatic opening of windows and shades to reduce space heating/cooling needs and the benefits of adding edible leafy greens production to air quality in a home and improving access to healthy, nutritional foods, and 9) It will be very useful for students in courses being taught at the University of Minnesota and promoted into Minnesota high schools through College-in the Schools (CIS) and Post-Secondary Education Option (PSEO) programs.

Climate change due to our emission of CO₂ is the greatest threat facing humanity. The amount of energy that we use in homes is an important source of this emission. The transformation proposed here can reduce the emission of greenhouse gases by nearly 2 metric tons per capita per year that as a percentage of nearly 16 metric tons per capita of the total emission in the U.S. is 1/8th – a very significant portion. For comparison, this reduction is more than the total per capita annual emission in India and four times that in Bangladesh.

We will deploy all the technologies in a house while it remains occupied by a family, and showcase this process through a website for everyone to follow along. The improvements proposed are as follows: 1) an energy audit will be performed through XCEL for home weatherization to plug-in leaks through windows and doors, 2) possible addition of attic insulation, 3) changing of all lights bulbs to LEDs, 4) installation of a state-of-the-art thermostat, 5) installing tank-less on-demand water heaters, 6) removal of the gas furnace and air-conditioner and their replacement by mini-split heat-pumps, 7) replacement of older energy-inefficient appliances and the entertainment system by highly-efficient Energy Star counterparts, 8) installation of an estimated 5 kW (peak) photovoltaic system, 9) signing up for Xcel’s WindSource program and Xcel’s time-of-use pricing when it becomes available in Minnesota, and 10) installation of indoor vegetable-growing system using LEDs.

II. PROJECT ACTIVITIES AND OUTCOMES
Activity 1: Selecting a house, Creating a Website, PV Installation & Growing Vegetables with LEDs
ENRTF BUDGET: $ 39,277

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Select the house to start the project*</td>
<td>August 2019</td>
</tr>
<tr>
<td>2. Start the website to showcase the results to the rest of the state</td>
<td>September 2019</td>
</tr>
<tr>
<td>3. Energy audit, weatherization and insulation</td>
<td>October 2019</td>
</tr>
<tr>
<td>4. Install LED based vegetation indoors for growing food throughout the year</td>
<td>December 2019</td>
</tr>
<tr>
<td>5. Install Roof-top PV panels</td>
<td>December 2019</td>
</tr>
</tbody>
</table>
* The selection of an appropriate house is extremely important. Such a house should have an unobstructed and preferably south-facing roof for installing PVs. The homeowner should allow these improvements and allow researchers to collect data and take pictures for the website.

Activity 2: Replacing inefficient old appliances, and conduct workshops

ENRTF BUDGET: $27,255

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Replacing existing inefficient old appliances to improve energy efficiency</td>
<td>August 2020</td>
</tr>
<tr>
<td>2. On-going monitoring and updating the results on the website</td>
<td>June 2021</td>
</tr>
<tr>
<td>3. Nutritional analysis of vegetables grown indoors</td>
<td>June 2021</td>
</tr>
</tbody>
</table>

III. PROJECT PARTNERS:

A. Partners receiving ENRTF funding

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Affiliation</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prof. Ned Mohan</td>
<td>Prof. of Electrical &amp; Computer Engineering</td>
<td>University of Minnesota</td>
<td>Lead-PI</td>
</tr>
<tr>
<td>Prof. John Erwin</td>
<td>Prof. of Horticultural Sciences</td>
<td>University of Minnesota</td>
<td>Co-PI</td>
</tr>
<tr>
<td>Dr. Narayan P. Dhakal</td>
<td>Board of Director</td>
<td>Member of MIPL</td>
<td>Project Manager</td>
</tr>
<tr>
<td>Dr. Mouli Vaidyanthan</td>
<td>Proprietor</td>
<td>Mouli Engineering, Inc.</td>
<td>Supply and Install PV</td>
</tr>
</tbody>
</table>

B. Partners NOT receiving ENRTF funding

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Affiliation</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>John Golle</td>
<td>CEO</td>
<td>GrowFilm, LLC</td>
<td>LEDs for Vegetables</td>
</tr>
</tbody>
</table>

IV. LONG-TERM IMPLEMENTATION AND FUNDING:

This project is sure to succeed and its impact will be transformational - imagine that such transformed houses statewide (and nationwide) will pay homeowners, rather than the other way around, while significantly reducing their carbon footprints and improving nutrition. This project will teach all of us a great deal and will be extremely educational by showcasing the transformation process from the very beginning. The results of this project will be highlighted at the workshops that the PI regularly organizes, each attended by over 100 participants. These results will be included in the courses that the PI has been teaching at the University of Minnesota, which are also being taught in high schools through the College in the Schools (CIS) program.

For the long-term impact, the homeowner must agree to allow the data collection and to maintain the plants for at least three years beyond the project completion date. Researchers collecting the data and maintaining the website after the project completion date will be paid by the Oscar A. Schott Professorship that the PI has at the University of Minnesota. Other homeowners will be encouraged to follow suit. Providing free consulting to homeowners will become an outreach activity of the University of Minnesota Center for Electric Energy (UMCEE) that is supported by six regional utilities.

V. TIME LINE REQUIREMENTS:

Year 1:
1. Find a “typical” occupied house with a roof having an unobstructed exposure, preferably facing south.
2. Create an ongoing website to document the project progress.
3. Monitor initial energy consumption including some summer and winter months.
4. Conduct energy audit to add insulation, prevent thermal leaks through windows and doors, etc.
5. Install 5 kW (peak) rooftop PV panels
6. Install the indoor vegetable system using LEDs.

Year 2:
1. Replace existing inefficient appliances such as refrigerators, washers, dryers, etc; lamps by LEDs.
2. Replace gas furnace and air-conditioners by heat pumps; install tank-less on-demand water heaters.
3. Hold workshops to disseminate the results. Use this information in high schools and university courses.
### Personnel: Research Assistant (1)
- **Name:** TBD
- **Time:** 10.5% time for 9 months
- **Salary:** $3,823 (Year 1), $3,899 (Year 2)
- **Fringe Benefits and Tuition:** $3,769 (Year 1), $3,781 (Year 2)
- **Responsibilities:** Manage growlight setup, and measure plant growths and yields

### Personnel: Undergraduate Student
- **Name:** TBD
- **Time:** 25% time for 9 months
- **Salary:** $4,485 (Year 1), $4,575 (Year 2)
- **Benefits:** None
- **Responsibilities:** Data collection, deploying data to website and assisting with preparation of educational material.

### Professional/Technical/Service Contracts: Manager, Hourly Subcontract (1)
- **Name:** Dr. Narayan Dhakal
- **Time:** 200 hours in Year 1 and 100 hours in Year 2 at $50/hr
- **Benefits:** None
- **Responsibility:** Overseeing day-to-day operations; liaison with home owner & project team

### Professional/Technical/Service Contracts: Mouli Engineering, Contractor
- **Description:** 5 KW peak Rooftop Solar PV system installation including reroofing
- **AMOUNT:** $13,200

### Equipment/Tools/Supplies: Website, Data Collection Tools and Posters etc.
- **AMOUNT:** $3,000

### Equipment/Tools/Supplies: Insulation and Weatherization
- **AMOUNT:** $1,000

### Equipment/Tools/Supplies: Energy efficient appliances and installation
- **AMOUNT:** $5,000

### Acquisition (Fee Title or Permanent Easements):
- **AMOUNT:** $5,000

### Travel:
- **AMOUNT:** $-

### Additional Budget Items:
- **AMOUNT:** $-

### TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =
- **AMOUNT:** $66,532

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**Note:**
1. Base salaries listed are for the current University appointment. Calculation of the amount of salary requested in each budget period includes inflation of 2% effective July 1 of each fiscal year, prorated to the budget period, and adjusted if appointment is less than 100%. If this award is reduced, effort obligations will be reduced proportionately.
2. The current fringe benefit rate for faculty at the University of Minnesota is 33.5% of salary.
3. The current fringe benefit rate for Postdoctoral Fellow at the University of Minnesota is 21.4% of salary.
4. Maximum GRA appointment is 12-month 50% appointment (20 hours per week). Salary is $26.65 per hour, fringe benefits include health insurance for the full 12 months and tuition reimbursement benefits for the nine month academic year only. Fringe is calculated 15% of salary, plus tuition reimbursement of $19.51 per hour worked (academic year = 780 hrs; summer = 260 hrs.).

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

<table>
<thead>
<tr>
<th>SOURCE OF FUNDS</th>
<th>AMOUNT</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other Non-State $ To Be Applied To Project During Project Period:</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Other State $ To Be Applied To Project During Project Period:</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>In-kind services To Be Applied To Project During Project Period:</td>
<td>$30,470</td>
<td>Secured</td>
</tr>
<tr>
<td>PI time donated - Prof. Ned Mohan (0.5 month each summer)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salary + Fringe: $15,084 (Year 1) $15,386 (Year 2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-kind services To Be Applied To Project During Project Period:</td>
<td>$2,536</td>
<td>Secured</td>
</tr>
<tr>
<td>PI time donated - Prof. John Erwin (1% time)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salary + Fringe: $1,256 (Year 1) $1,281 (Year 2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-kind services To Be Applied To Project During Project Period:</td>
<td>$50,000</td>
<td>Secured</td>
</tr>
<tr>
<td>Use of LI-6400 portable photosynthesis meter available with Prof. John Erwin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-kind services To Be Applied To Project During Project Period:</td>
<td>$5,000</td>
<td>Committed</td>
</tr>
<tr>
<td>LED Panels to be donated by GrowFilm, LLC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-kind services To Be Applied To Project During Project Period:</td>
<td>$5,800</td>
<td>Committed</td>
</tr>
<tr>
<td>Discount on PV System cost by Mouli Engineering, Inc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Past and Current ENRTF Appropriation:</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Other Funding History:</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Showcasing Carbon-Neutral, Energy-Positive Transformation of an Occupied House

1. Select a MN House

2. Conduct Energy Audit
   - Measure energy consumption patterns
   - Find insulation leaks
   - Identify inefficient appliances

3. Install Rooftop PV System

4a. Weatherization and Insulation

4b. Replace inefficient appliances with efficient ones
   (Central AC, Gas furnace, Incandescent lamps)

(Mini-Split ACs, Energy Star Certified Appliances, LED Lamps)

Meter runs backwards!
Utility pays for surplus solar energy

Carbon Neutral Home!
Home has a net zero carbon footprint

Fresh home grown food!
LED-powered indoor cultivation
Professor Ned Mohan (Project Lead PI) has been teaching and doing research at the University of Minnesota for the past 42 years where he is Oscar A. Schott Professor of Power Electronic Systems and Morse-Alumni Distinguished Teaching Professor. He did his PhD in Electrical Engineering and Master’s in Nuclear Engineering, both from the University of Wisconsin – Madison. He has written 5 textbooks and cumulatively they have been translated into 8 languages including Chinese and Spanish. He has graduated 46 PhD students who have gone on to work in iconic companies such as GE, GM, Ford, Tesla, Apple, etc; many of his students are professors at universities such as the University of Wisconsin – Madison, the Arizona State University, Oregon State University, Marquette, etc.

Prof. Mohan’s research is focused on increasing the penetration of renewables into the utility grid. He is the Director of the University of Minnesota Center for Electric Energy (UMCEE) which he helped establish in 1981 and that is supported by 6 major utilities in the region including Xcel, GRE and Minnesota Power.

He is passionate about combating climate change and has developed courses that are some of the most popular courses in the Department of Electrical and Computer Engineering. One of these courses is being taught in high schools as well through the College in the Schools (CIS) program at the University of Minnesota.

For his teaching and research, he has received many research and educational awards. Prof. Mohan is a Fellow of the IEEE and in 2014, for his achievements in research and teaching, he was elected to the National Academy of Engineering.

Professor John Erwin has been a faculty member in the Department of Horticultural Science at the University of Minnesota since 1989. His research responsibilities revolve around the physiology of plants grown in controlled environments and greenhouses, statewide controlled environment agriculture, and he teaches three courses on crop production.

He was elected to the Minneapolis Park and Recreation Board as a Citywide Commissioner and served as its’ President for four years. He is a national agriculture crop consultant helping to grow crops that are sold nationally including at Whole Foods, Trader Joes, Home Depot and many other retail outlets in our community. John developed techniques that are used worldwide to reduce energy and chemical inputs, including neonics, in ornamental (indoor and outdoor) and food crop production (indoor). His recent research focuses on a) improving stress tolerance of plants, b) improving the nutritional value of crops grown in controlled environments, and c) new crop introduction to meet the needs of our changing communities.

Narayan P. Dhakal (Manager) has PhD in Conservation Biology from the University of Minnesota. Narayan’s research was in social, economic and environment wellbeing of voluntary resettlement program. He is a board of director of the Minnesota Interfaith Power and Light (MNIPL). He was a board adviser (2015 – 2017) for Association of Nepalese in Minnesota (ANMN). He was a member of the Board of Directors (2012-2015) for College of Food, Agriculture and Natural Sciences (CFANS) Alumni Board. He was a president (2013 -2015) Religion and Conservation Biology group of the Society of Conservation Biology (SCB). Between 2011 and 2013 and was a developer of Experiential Learning Semester Program with CFANS/UMN. I was instrumental in generating Earthquake relief funds during 2015 devastated Earthquake in Nepal.

GrowFilm, LLC (Donating LED panels) is one of a family of lighting companies owned by common investors that first started in the lighting business in 2001. The Company’s GrowFilm™ light sheet is unique because it uses a flexible circuit board. That board is manufactured using proprietary techniques that help minimize cost. The flexibility and minimal weight (1.2 oz/ft2) of the board also enable the creation of unique applications.