EXHIBIT A
SCOPE OF SERVICES

HARNESSING SOLAR ENERGY THROUGH NOISE BARRIERS AND STRUCTURAL SNOW FENCING

BACKGROUND

MnDOT is interested in extending noise barrier and structural snow fencing to have the capacity of harvesting solar energy. MnDOT has more than hundreds noise barriers and thousand miles of snow fencing needs. Assume each solar panel is about 330W, and 1,000 panels could be integrated into 1 mile of noise barrier or snow fence. Considering the solar irradiance change throughout a year, these panels could generate up to 330 kW per mile, and could roughly generate in average 1,300 kWh energy per mile per day considering the different solar irradiance at different seasons. According to U.S. Energy Information Administration, an average of 30 kWh is used in a residential home each day. A thousand miles of solar panel integrated noise barriers or snow fences could power all the street lights along highways (assuming 8.5 kW/mile high-pressure sodium light) or 43,333 residential homes. The objectives of this project are: (1) to suggest a new integrated noise barrier and snow fencings with solar panel included; (2) to evaluate the cost-benefit of these constructions; (3) to integrate the energy generated with the power grid and investigate the acceptance of public on harvesting energy from rights-of way.

OBJECTIVE

There are vast noise barrier and snow fencing existing in Minnesota highway system. Even though they have served their purposes, they could be expanded to harvest solar energy in a cost-effective way. First, solar energy is clean; second, harvesting solar energy brings new revenue with a fraction of cost in PV panels and fixture connections; third, deployment of PV panels along noise barriers and snow fencings does not cause detrimental side effects and impact the environment if properly designed. If the project is funded, the benefits to the state are evident and lie in developing a profitable technology, reducing roadway operation and maintenance cost through providing close accessible power, and generating revenue in power production.

SCOPE

The research will be performed through literature review, surveying, and lab testing. Surveying will include surveying general public in Fargo-Moorhead area, interviewing with MnDOT maintenance, rights-of-way, and legal groups. These surveying results will be used to investigate the public acceptance and MnDOT's capacity of harvesting energy through rights-of-way and its feasibility. Lab testing will be used to investigate the new noise barrier and snow fencing system, in terms of its safety, convenience of construction and operation, and efficiency of energy harvesting. And a cost-effective analysis will be conducted to evaluate the pros and cons for integrating such a system with PV panels.

WORK PLAN

<u>Task Descriptions</u>

Task 1: Initial Memorandum on Expected Research Benefits and Potential Implementation Steps

Key benefits, such as energy harvested for roadway operations and the new technique developed, have been selected to clearly define the benefits the state will receive from the results and conclusions of this research. A benefit gain per mile of the solar energy harvesting system will be calculated along the noise barrier or the snow fencing to demonstrate the feasibility of collecting energy using rights-of way.

Task 2: Perform Literature Review and Surveys, and Provide a List of Companies Willing to Purchase the Power Energy Generated through Rights-of-Way

The research team will conduct a literature review on harvesting solar energy through existing noise barrier and snow fencing systems and summarize the results in a document. The research team will also conduct a survey on general public and power companies in integrating solar energy with the power grid and initiate contacts with utility companies in Minnesota and North Dakota region to gauge their interest in purchasing the power energy generated through rights-of-way. The survey instrumentation will include questions such as opinions on using the harvested energy for roadway operations themselves, integration of the harvested energy to a local community, accepted prices for harvested energy for public and utility companies, legal considerations in harvesting solar energy through right-of-ways, and public opinions on its potential environmental impact, such as noise generated and power lines laid, etc.

The instrumentation will be distributed to utility companies, shown in Figure 1 below, (including Xcel, Lake county power, Fritz Electric, and Moorhead City Public Services Department), MnDOT maintenance personnel, and the general public in the City of Moorhead through mailing. Farm landowners will be surveyed on the acceptance of electrical storage facility in their property as well.

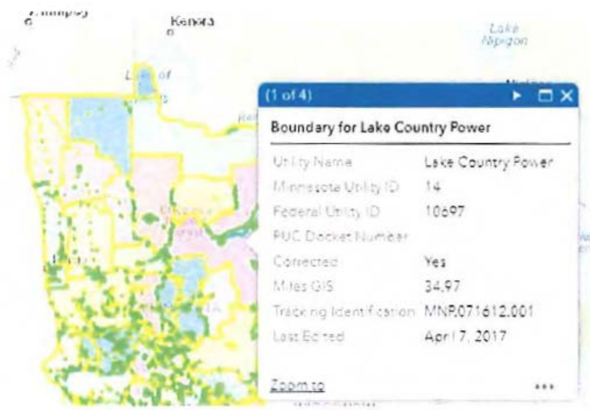
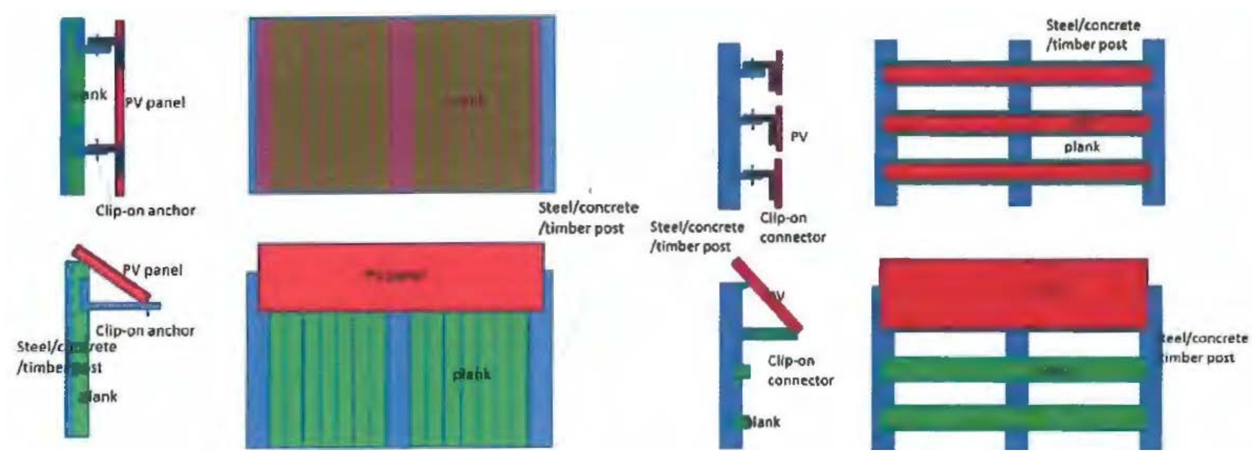


Figure 1 Utility companies in MN

Task 3: Innovative Noise Barrier and Snow Fencing Design for Solar Energy Harvesting and the Qualification of the New Design, such as Noise Reduction Level, Snow Drift Amount, and Anti-Collision Assessment

The current noise barrier and snow fencing system at MnDOT will be adopted for solar energy harvesting, which is about 6-8 feet in height for snow fencings and 15-20 feet for noise barriers. In order to make the additional mounted solar panels to work, two connections are suggested, one is on the top of the barrier and the other one is attached on the surface, as shown in Figure 2 below (but may be subject to revisions). Existing barrier systems including concrete post/wooden plank, concrete/masonry, concrete post with sound absorbing materials will be used as the main support, but additional anchors may be used to support the surcharged loads due to wind and panel weight. The current snow fencing system will be also used for collecting solar energies. Similar top mounted and clip-on connections are suggested to support solar panels. Existing posts and snow fencing blades will be tested for its capability to support or hang solar panels, as shown in Figure 3 below. In both systems (the noise barrier system and the snow fencing), the key for structural connection is the connector.



For the new system to work, a system of qualification experiments and modeling need to be conducted, including connector strength tests, lab noise reduction tests, and field noise reduction and snow drift modeling. In particular, a snow blow modeling over the fence and wind responses over the snow fence and sound barrier will be simulated through LS-DYNA. The possible extra payload over the structural system and effect on the existing snow drift effect will be evaluated.

Task 4: Lab Testing or Modeling of Side Effects caused by the New Design, such as Glaring, Distraction, and Crash Safety Analysis of the PV Noise Barrier and Snow Fencing

Three different panel surfaces (glass, polymer, roughed glass surface) are selected to test glaring and distraction of PV panels in the lab. Different orientations of light beams will be used to project onto the three different panels, a light meter (HHC230-HHC250-Series to measure the light intensity) and a refractometer will be secured at a moving cart at the same level of the light beams and used to record the light intensity when the cart passes by the solar panels. From the recorded light intensity, a glaring and refraction index could be calculated and compared with the barrier without PV panels. Shattering test of the PV panels will be conducted. Three samples of each panel will be selected. Each panel will subject to a falling weight testing in the Structural lab of NDSU. A 10lb steel ball will be dropped perpendicularly onto the panels from a 6 foot height. The flight out speeds and the sizes of shattered pieces will be recorded through a high speed camera. Impact and crash modeling of the fixed PV panels will be also conducted to simulate the effect of hail impact and vehicle crash, after validation of the modeling results through the shattering test. Three cases of hail impacts (1" ice ball with 10 mph, 20 mph, and 30 mph) and two cases of passenger car crash (2019 Ford Explorer) at a speed of 30 mph and 60 mph will be simulated. The results will be used to assess the safety of using PV panels on noise barriers and snow fencings.

Task 5: Panel Electric Connection and Safety of Electric Circuit/Avoid of Electrocution and Lab Prototyping and Testing for the Grid Integration.

To avoid electrocution and ensure safety electric connections, different solar panel connections along with the possible maximum power point tracking strategy as well as the inverter architectures for the electric grid integration will be evaluated. The desired new inverter system scaled down prototypes will be built and tested. Currently there are three different power categories for the solar panel grid integration: ~10 kW for the resident application, lO0kW-500 kW for the commercial building application, and above 1 MW for the utility scale solar farm application. Three of these solutions will be investigated and compared for the possibility of highway application due to the single line arrangement of the solar panels on the noise barriers or snow fences to ensure safer operation and avoid electrocution. For current existing photovoltaic grid connected system a voltage de bus voltage (>300V) will be normally used which is easy to design the grid-connected inverter for connection of the high ac voltage of the power grid. However, it is possible for the people to access these series connected solar panel with high voltage along the highway during the accident. Figure 4, below, shows the existing solutions utilizing micro inverter or string inverter for residential or commercial applications. The green box shows the portion that could be buried underground for safety insulation. All the solutions have the possibility for the people to access the high voltage under accident.

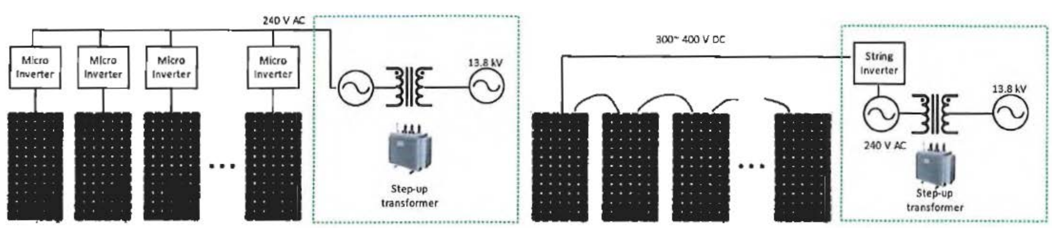


Figure 4 Existing PV panel solutions with micro-inverter or high voltage dc link enabled string inverter.

Therefore, desired solution for the solar panel grid integration along the high way should avoid the direct series connection of the solar panels, and low voltage bus is preferred, as shown in Figure 5, below. A smart wire based system utilizing the low voltage de-link and interconnected modularized inverter could help to eliminate the electrocution danger during the happening of the accident. And the bulky step-up transformer could be eliminated.

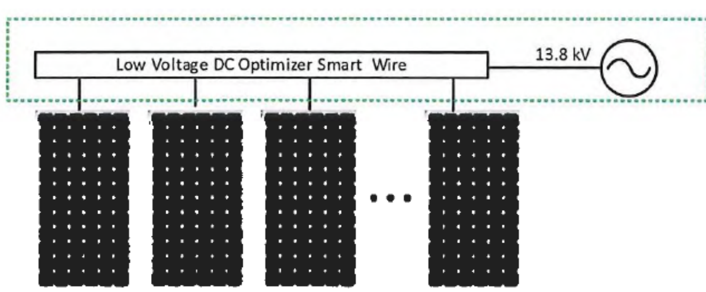


Figure 5 Proposed ideal solution.

The power scaled down prototypes interconnecting 4-6 (2 kW) solar panels will be then developed for the most desirable solution to validate the possibility to develop a modularized smart wire system with the possibility to eliminate the bulky transformer and prevent electrocution.

Task 6: Cost-Benefit Analysis for MnDOT of Installing Solar Panels on Noise Barriers and Structural Snow Fencings
A cost-benefit analysis will be conducted, which includes material, labor, maintenance, and recycling/disposal costs for the installation and use of the PV noise barriers and PV snow fencings; while the benefits include the solar energy collected, i.e., the economic benefit when the generated energy is used on MnDOT facilities with the intention of reducing the electricity bills and/or used to generate revenue for MnDOT by selling it to utility companies. The environmental benefits can be also tracked, including the reduced use of fossil fuel to generate the same amount of electrical energy as well as the associated reduction of greenhouse gas emissions, the reduction in salt usage in snow and ice control, and the reduction of operations in snow and ice removals. The possible increase of the repair and maintenance costs on the snow fencings and noise barrier walls (new or existing) due to the installation and use of solar panels on the top/side will also be evaluated.

The method consists of:
1. Determining the costs including the initial capital cost of equipment and materials, the construction/installation cost, the operating and maintenance costs, as well as the recycling/disposal cost for different PV noise barrier and snow fencing types mentioned in Task 3.
2. Determining the benefits including the economic benefits for MnDOT through comparing the amounts of electrical energy generated and the electricity MnDOT facilities may consume in order to identify the possible reduction of utility bills of the facilities, and the environmental benefits by estimating the use of fossil fuel to generate the same amount of electrical energy through PV panels and then the associated greenhouse gas emissions using the Environmental Pollution Agency (EPA) Greenhouse Gas Equivalencies Calculator (https ://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator).
3. Two models will be included in the cost-benefit analysis to identify the differences between the direct ownership of MnDOT and third-party ownership of the solar panels in terms of material, installation, operation, maintenance, and salvage/disposal costs. Additionally, the potential effects of solar guidelines, insurance, interconnection requirements of utility companies, associated codes/standards, and/or tax credits/incentives on the investment will be taken into account in the analysis.

The results (costs and benefits) will be represented based on the miles of the installed PV panels on either the noise barriers or snow fencings and on a yearly basis, i.e., $/mile/yr or CO2 tons/mile/yr.

Task 7: Final Memorandum on Research Benefits and Implementation Steps
Key benefits have been selected to clearly define the benefits the State of Minnesota will receive from the results and conclusions of this research. This task will produce a final memorandum that clarifies and documents the methodology used to calculate benefits, including any assumptions and steps required. In addition to quantitative calculations (when feasible), this task should also include a qualitative discussion of the estimated benefits. The memorandum should also include key steps that agencies could take to implement the research.

Task 8: Compile Report, Technical Advisory Panel Review, and Revisions
The University's Principal Investigator (PI) will prepare a draft final report, following MnDOT publication guidelines, to document project activities, findings and recommendations. This report will be reviewed by the Technical Advisory Panel (TAP), updated by the Pl to incorporate technical comments, and then approved by the Technical Liaison before this task is considered complete. If possible, a TAP meeting will be scheduled to facilitate the discussion of the draft report.

Task 9: Editorial Review and Publication of Final Report
During this task, the Pl will work directly with MnDOT's contract editors to address editorial comments and finalize the document in a timely manner. The contract editors will publish the report and ensure it meets publication standards.

Task Deliverables

Task:	Deliverable(s):
1:	A memorandum providing initial estimates of research benefits, documentation of the methodology, and potential benefits and implementation steps.
2:	Literature review summary, public opinions on harvesting solar energy through rights-of-way, and a list of utility companies that are willing to purchase the power energy generated through rights-of-way.
3:	Preliminary new noise barrier and snow fencing design including connector designs, and qualification experiment and modeling results.
4:	Lab testing report of glaring, distraction, and impact and shattering testing results over the three candidate solar panels.
5:	A connected solar energy harvesting system, including the integration method with power grid and the safety procedure for avoiding electrocution.
6:	A comparison of the cost-benefits of different noise barrier and snow fencing systems, with and without PV units, and with different configurations of PV units.
7:	A final technical memorandum at the end of the project that provide details of the methodology, steps and approach for evaluating benefits, benefits quantification results, and discussion of next steps for implementation.
8:	A draft final report for TAP review, and a revised report that is technically complete and approved by the TL for publication.
9:	Final Publishable Report that meets MnDOT's editorial guidelines and standards