**Minnesota Department of Natural Resources**
**500 Lafayette Road, St Paul, MN 55155**

Project Title: ***Development of Renewable Energy Strategies***

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Congressional District (RDF Awardee): Fourth

Congressional District (PV Installations): TBD

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# MILESTONE REPORT

Executive Summary: The Department of Natural Resources (DNR) will be installing small-scale solar photovoltaic systems into several of their facilities and develop a renewable energy interpretive program. This is in preparation for large-scale implementation of renewable energy resources into new and existing DNR facilities. DNR is interested in doing renewable energy in a way that is not only in keeping with its mission and the Governor's Executive Order 05-16, but in a way that will inform and encourage other renewable energy applications. Installations included in this Project are rooftop solar photovoltaic systems connected to the grid and freestanding photovoltaic systems at locations where a building is well shaded but open sunlight is close; these systems will be installed at selected area offices, interpretive centers, visitor centers, and hatcheries. The Project will form the framework for establishing renewable energy design and specification standards for future photovoltaic installations at the DNR.

This project will provide DNR with a process and the tools for determining the feasibility of various renewable energy systems, the development of standard designs and specifications for photovoltaic systems, a number of grid-connected and customer-sited installations, a monitoring process, and a renewable energy interpretive program. The DNR has over 2,500 buildings ranging from vault toilets to visitor centers at 182 sites throughout the state. Within these facilities opportunities exist for solar photovoltaic systems. The DNR will use flat plate photovoltaic arrays mounted on sloped roofs at State Park sites, flat plate photovoltaic arrays mounted in series on flat roofs at larger buildings such as Regional offices, and flat plate photovoltaic arrays mounted on the ground at historic sites. All systems are anticipated to be fixed and will be connected to the grid.

The goals of this project are to develop a series of renewable solar energy strategies, prototypes, and specifications that will become part of all future new and renovated DNR facilities and to install at least 99kW of photovoltaic systems, both grid-connected and customer-sited. Specific objectives include:

- The development of assessment tools for building site selection, both to select sites for this project as well as for use by DNR to assess sites for future renewable energy installations
- Assessment and selection of sites serviced by Xcel electricity for inclusion in this project
- Design, construction documents, and construction administration for a minimum of 99kW of solar array collection systems for electricity generation at 7 DNR state parks, regional and area offices
- The development of an interpretive program about the solar energy installations at the above referenced sites.

Technical Progress: This milestone required the installation of the third 33 KW of photovoltaic capacity. The actual installations were a 13.8 KW roof mounted PV system at Lake Shetek State Park, a 3.6 KW roof mounted PV system at Fort Snelling State Park, a 9.9 KW roof mounted PV system at the Visitor Center in William O'Brien State Park and a 7.2 KW ground mounted PV system at Nerstrand Big Woods State Park. These installations bring the total installed capacity to 103.5 KW.

Lake Shetek State Park was selected based on the following criteria:

- Overall Site Criteria
  - Park Level: Good overall proxy for park attractiveness, amenities, prominence, etc.
    - Level 3 of 5 levels. Itasca State Park is the DNR's only Level 5 park.
  - Park Annual Visitors: More visitors means more opportunities for interpretation
    - Approximately120,000 visitors each year
  - Park Overnight Stays: Overnight visitors are more likely to take time for interpretive activities
    - Approximately 15,000 overnight stays each year
  - Park Focal Point: A natural point of congregation like a Visitor Center, amphitheater, park store, etc. provides a good venue for interpretive activity
    - The array is located in two picnic shelters in the new "RV friendly" Sunrise campground.
- Location-specific Criteria
  - Location Electricity Use: Provides opportunity to offset cost and carbon emissions
    - The entire Park uses approximately 56,000 KWh each year. The PV array should provide about 19,000 kWh each year.
  - Location Demand Charges: Provides opportunity to offset large monthly costs of high usage rates
    - The array should reduce any demand charges that result from large RV's
  - Location Solar Access: This was the result of a site assessment exercise, and included all related factors like roof slope/orientation/condition, shading, etc.
    - The arrays are mounted on a roof in an open, unshaded field
  - Location Interpretive Space: Space near the PV array that can be used for interpretive displays
    - The Contact Station will have signage and an interactive terminal for interpretation

Fort Snelling State Park was selected based on the following criteria:

- Overall Site Criteria
  - Park Level: Good overall proxy for park attractiveness, amenities, prominence, etc.
    - Level 4 of 5 levels. Itasca State Park is the DNR's only Level 5 park.
  - Park Annual Visitors: More visitors means more opportunities for interpretation
    - Approximately 650,000 visitors each year, the most of any State Park
  - Park Overnight Stays: Overnight visitors are more likely to take time for interpretive activities
    - No overnight stays in this urban location
  - Park Focal Point: A natural point of congregation like a Visitor Center, amphitheater, park store, etc. provides a good venue for interpretive activity
    - The array is located at the Visitor Center, the most visited building in the Park
- Location-specific Criteria
  - Location Electricity Use: Provides opportunity to offset cost and carbon emissions

        - The Visitor Center uses approximately 70,000 KWh each year. The PV array should provide about 3,800 kWh each year.
    - Location Demand Charges: Provides opportunity to offset large monthly costs of high usage rates
        - About $3,000 in demand charges each year
    - Location Solar Access: This was the result of a site assessment exercise, and included all related factors like roof slope/orientation/condition, shading, etc.
        - The array is roof mounted and is 83% unshaded in this heavily visited area of the park.
    - Location Interpretive Space: Space near the PV array that can be used for interpretive displays
        - The Visitor Center will have signage and an interactive terminal for interpretation

William O'Brien State Park Visitor Center was selected based on the following criteria:

- Overall Site Criteria
    - Park Level: Good overall proxy for park attractiveness, amenities, prominence, etc.
        - Level 4 of 5 levels. Itasca State Park is the DNR's only Level 5 park.
    - Park Annual Visitors: More visitors means more opportunities for interpretation
        - Approximately 220,000 visitors each year
    - Park Overnight Stays: Overnight visitors are more likely to take time for interpretive activities
        - Approximately 36,000 each year
    - Park Focal Point: A natural point of congregation like a Visitor Center, amphitheater, park store, etc. provides a good venue for interpretive activity
        - The array is located at the Visitor Center, the most visited building in the Park
- Location-specific Criteria
    - Location Electricity Use: Provides opportunity to offset cost and carbon emissions
        - The Park uses approximately 100,000 KWh each year. The PV array should provide about 13,000 kWh each year.
    - Location Demand Charges: Provides opportunity to offset large monthly costs of high usage rates
        - About $1,600 in demand charges each year
    - Location Solar Access: This was the result of a site assessment exercise, and included all related factors like roof slope/orientation/condition, shading, etc.
        - The array is roof mounted and is 95% unshaded
    - Location Interpretive Space: Space near the PV array that can be used for interpretive displays
        - The Visitor Center will have signage and an interactive terminal for interpretation

Nerstrand Big Woods State Park was selected based on the following criteria:

- Overall Site Criteria
    - Park Level: Good overall proxy for park attractiveness, amenities, prominence, etc.
        - Level 2 of 5 levels. Itasca State Park is the DNR's only Level 5 park.
    - Park Annual Visitors: More visitors means more opportunities for interpretation
        - Approximately 75,000 visitors each year
    - Park Overnight Stays: Overnight visitors are more likely to take time for interpretive activities
        - Approximately 12,000 each year
    - Park Focal Point: A natural point of congregation like a Visitor Center, amphitheater, park store, etc. provides a good venue for interpretive activity

        - The array is located next to the Contact Station, where vehicles stop for information, permits, etc.
- Location-specific Criteria
    - Location Electricity Use: Provides opportunity to offset cost and carbon emissions
        - The Park uses approximately 50,000 KWh each year. The PV array should provide about 9,500 kWh each year.
    - Location Demand Charges: Provides opportunity to offset large monthly costs of high usage rates
        - No demand charges
    - Location Solar Access: This was the result of a site assessment exercise, and included all related factors like roof slope/orientation/condition, shading, etc.
        - The array is ground mounted and is 95% unshaded
    - Location Interpretive Space: Space near the PV array that can be used for interpretive displays
        - The Contact Station will have signage and an interactive terminal for interpretation

Evaluation criteria scoring metrics were defined and used to enable consistent evaluation across sites and evaluators. The criteria were weighted by a panel of experts representing DNR Parks, Regions and the Central Office. The completed selection tool spreadsheet provided a quantitative ranking for each potential location to help guide decision making. Lake Shetek scored 28 points, Fort Snelling scored 35 points, William O'Brien Visitor Center scored 34 points and Nerstrand scored 27 points, compared to our highest site score of 35 points.

System Design: The systems consist of 60 REC 230 watt PV modules (Lake Shetek), 15 SunPower 225 watt PV modules (Fort Snelling), 45 Sanyo 220 watt PV modules (WOB Visitor Center) and 30 Sharp 240 watt PV modules (Nerstrand). Each PV module is paired with an Enphase micro-inverter to convert the direct current produced by the module to the alternating current used on the electric grid. The Enphase micro-inverter was selected for the following reasons:

- Provides 10 – 15% more energy than traditional inverters. In an "apples to apples" comparison in the month of September, 2010 at our Gilbert OHV site 16 Enphase micro-inverter equipped PV modules produced 111% of the energy produced by 16 PV modules using a traditional inverter.
- No single point of system failure. Failure of a traditional inverter means loss of all energy production.
- Simpler design, installation and management.
- Safer because of low voltage DC and standard AC, instead of 600 volts DC with traditional inverters.
- Provides performance monitoring at the individual PV module level, not just at the entire array level.

The 13.8 KW array at Lake Shetek State Park should produce about 19,000 KWh each year, reducing the DNR's yearly carbon emissions by over 15 metric tons. The PV array should offset about 30% of the park's electricity usage. The 3.6 KW array at Fort Snelling should produce about 3,800 KWh each year, reducing the DNR's yearly carbon emissions by over 3 metric tons. The PV array should offset about 5% of the Visitor Center's electricity usage. The 9.9 KW array at the WOB Visitor Center should produce about 13,000 KWh each year, reducing the DNR's yearly carbon emissions by over 10 metric tons. The PV array should offset about 90% of the Visitor Center's electricity usage. The 7.2 KW array at Nerstrand should produce about 9,500 KWh each year, reducing the DNR's yearly carbon emissions by about 8 metric tons. The PV array should offset about 40% of the Visitor Center's electricity usage.

System Construction: There were no significant issues in the construction of any of these PV arrays. At Nerstrand State Park the original array footprint was found to be about 15 feet too close to the road. This resulted in a short

delay to work through the issue with Rice County. The PV array footprint was moved an additional 15 feet away from the centerline of the road, delaying the project about 3 weeks.

System Operation: The installed systems have been very reliable. There have been only two early life replacements across the 451 micro-inverters funded by this grant and no solar panels have failed. Power production has been impacted as expected by variations in sunlight intensity from clouds, rain, etc. Shading impacts from snow cover have varied widely across sites and weather events. Last winter some PV arrays were significantly impacted by ice storms and freezing snow that covered the array for 3-4 weeks. Other arrays have had snow melt off the array in 1-2 days. It's clear that the moisture content of the snow, wind direction, ambient temperature and cloud cover all combine in a unique way to determine the production impact of a particular snowfall. Here are some general observations across the entire portfolio of DNR PV arrays:

- Roof mounted arrays tend to be mounted at a flatter angle than ground mounted arrays which results in more production during summer months when the sun is higher in the sky and lower production in winter when the sun is lower and melting snow slides off more slowly.
- The tracking array the DNR has at Gilbert, MN is least effected by snow buildup. Each winter day it dips nearly vertical at the beginning and end of the day, effectively shedding any snow cover.
- DNR installed two PV arrays in December 2011 in a multi-pole configuration that can be tilted to different angles during the year. In winter they are tilted to 60 degrees to shed snow and match the lower sun angles. In summer they are tilted to 30 degrees to match the higher sun angles. DNR will be evaluating the benefits of this approach and measuring the impact on production. The only drawback to this approach is that a larger footprint is required for the array because panels can only be installed 4 high instead of the 5 high mounting used in our fixed angle ground mounted arrays.

Lake Shetek State Park PV Array

Fort Snelling PV Array


William O'Brien Visitor Center PV Array

Nerstrand PV Array


Data Monitoring: Data monitoring of the PV Array and building energy consumption is an important part of the DNR's strategy for reducing energy use and carbon emissions. Building energy monitoring allows the occupants to see the amount of energy they are using and change their behaviors to reduce consumption. Data monitoring of the PV Array allows for early problem detection and supports the DNR's interpretation efforts on solar energy. The energy monitoring portal for the Lake Shetek site can be found at: http://lshetekcmp.d.egauge.net/. The energy monitoring portal for the Fort Snelling site can be found at: http://fsvisctr.d.egauge.net/. The energy monitoring portal for the WOB Visitor Center site can be found at: http://wobvisctr.d.egauge.net/. The energy monitoring portal for the Nerstrand site can be found at: http://nerstrand.d.egauge.net/. For additional interpretative value, the Nerstrand array has sunlight and temperature sensors to predict the amount of energy that should be generated.

**Milestones:**
#1: Selection of an engineering firm; completed on June 11, 2009.
#2: Process and tool to assess buildings for renewable energy; completed on October 6, 2009.
#3: Site selection; completed on December 11, 2009.
#4: Installation of first 33 KW of nameplate capacity; completed on December 28, 2010.
#5: Installation of second 33 KW of nameplate capacity; completed on December 28, 2010.
#6: Installation of final 33 KW of nameplate capacity; completed on January 9, 2012.

**Project Status:** Project is on schedule with implementation of 99 KW completed by the end of 2011 instead of by the end of 2012. This accelerated timeline will allow us to reduce our carbon emissions earlier and provide a more timely interpretive experience for park visitors. The modular design of the ground mounted arrays will also support a faster implementation.

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