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

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

Contract Number: EP3-13 Milestone Number: 7 Report Date: 1.24.2013

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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) is installing small-scale solar photovoltaic systems into several of their facilities and developing 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 additional photovoltaic capacity beyond 99 KW and the development of a renewable energy interpretive program. Wild River State Park was selected for the installation of a 10.1 KW ground mounted PV system using MN-made solar panels from tenKsolar in Bloomington, MN. These installations bring the total installed capacity to 113.3 KW. DNR was able to install 14% more generating capacity than originally planned because of cost-effective design strategies and favorable industry trends in photovoltaic module pricing.

Wild River 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
    - Approximately180,000 visitors each year
  - Park Overnight Stays: Overnight visitors are more likely to take time for interpretive activities
    - Approximately 30,000 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 near the Park entrance and Contact Station where it will be seen by all park visitors.
- Location-specific Criteria
  - Location Electricity Use: Provides opportunity to offset cost and carbon emissions
    - The entire Park uses approximately 100,000 KWh each year. The PV array should provide about 13,500 kWh each year.
  - Location Demand Charges: Provides opportunity to offset large monthly costs of high usage rates
    - The array will feed in to the Contact Station which does not get billed for 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 arrays are mounted on the ground in an open, unshaded prairie
  - 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. Wild River scored 27 points, compared to our highest site score of 35 points.

System Design: The systems consist of 53 tenKsolar 190 watt PV modules and two Sunergy 5 KW inverters to convert the direct current produced by the modules to the alternating current used on the electric grid. The tenKsolar equipment was selected for the following reasons:

- The tenK Wave™ PV System system, which combines PV modules, reflectors and racking configured in a repeating wave pattern, provides the highest density energy producing system for flat roof or ground mount systems, meaning more kWh per square foot of space.
- The entire design is internally redundant. If any part of the module production is disrupted, the rest of the module and system operates as it should.
- Conventional solar panels have a plastic backsheet, while tenK modules are sealed with a metal backsheet offering the following advantages:

    - 10,000 times the resistance to water ingress rate making it far less susceptible over time to failures due to humidity and moisture damage.
    - 200 times the thermal conductivity of plastic coverings allowing the modules to run cooler, more efficiently and more effectively distribute heat away from the system.
- A traditional solar module produces live current any time that it receives sunlight and cannot be fused. If a tenKsolar system is disconnected during an emergency event or service call, all PV modules immediately stop producing power at the module level making it safer for fire fighters and other maintenance workers.
- A traditional ground mount solar installation would use racking that extends 12 feet above the ground. The installation site at Wild River is in a beautiful restored prairie. Since the tenKsolar wave design is flat the racking extends only about 5 feet above the ground. The visual impact to the viewscape is greatly reduced.

The 10.1 KW array should produce about 13,500 KWh each year, reducing the DNR's yearly carbon emissions by over 10 metric tons. The PV array should offset about 90% of the Contact Station's electricity usage.

System Construction: There were no significant issues in the construction of any of this PV array.

System Operation: The installed system has been very reliable. The first two weeks of on-line energy monitoring showed that the 10.1 KW system was generating less energy than the 9.9 KW system mounted on the roof of the William O'Brien Visitor Center (located about 21 miles away.) tenK solar service personnel found that one of the 6 circuit breakers to the array was turned off. The breaker was turned on and new firmware was downloaded to the solar modules. The last 30 days of system monitoring show that the 10.1 KW array at Wild River using MN-made solar modules has produced 646 kWh of electricity. Over that same time the 9.9 KW array at the William O'Brien Visitor Center using Sanyo 220 watt modules has produced 606 kWh. Although the tenKsolar array is 2% larger it produced 6.6% more energy. This is particularly impressive when you consider that the tenKsolar wave system modules partially shade each other at low sun angles during winter months. Another potential factor that could help explain the difference in performance is the ability of the solar module to shed snow. The metal backsheet in the tenKsolar module should conduct heat better and melt snow faster than the plastic backsheet in the Sanyo modules. DNR has not attempted to quantify this but we will be monitoring and comparing the relative performance of these two systems for the next few years.

Wild River State Park 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 Wild River site can be found at: http://wildriver.egaug.es/. The energy monitoring portal for the William O'Brien Visitor Center site can be found at: http://wobvisctr.egaug.es/.

Renewable Energy Interpretive Program

One of our major objectives is to inform and engage the public about renewable energy in a comprehensive fashion that includes demonstrations, interpretive programming and displays. The centerpiece of DNR interpretive efforts is an interactive website. With a theme of ***Energy-Smart***, this new site will let visitors in our Parks or across the web learn about energy at DNR including

- Our renewable energy systems: where they are, how much energy they're producing and how they work
- The economic and environmental benefits of renewable energy
- DNR strategies to reduce energy usage in our buildings and fleet
- What Minnesotans can do themselves to reduce energy.

The Energy-Smart main page is located at: http://www.dnr.state.mn.us/energysmart. Figure 1 shows the main page and the wide range of energy topics available across the site. DNR has built its own energy monitoring database that is fed by renewable energy submeters across the state. The main page shows total generation and usage data for all DNR locations with renewable energy systems. Interactive charts driven by the database allow you to see how much energy these sites have generated and used on day, week, month and year timeframes. Figure 2 shows a typical solar energy page that presents information, pictures and generation/usage data for the site. These pages are table-driven so the addition of a new site requires no additional programming. Figure 3 shows the page explaining how solar energy works. Information is available at multiple levels of depth and detail to accommodate different user types and interests. Figure 4 show information on the economic benefits of renewable energy for individuals, businesses and the state of Minnesota. An interactive Solar Energy Payback Calculator is available to explore the financial benefits of renewable energy.

Interpretive signage is available at DNR sites with renewable energy and interpretive programs have been conducted at several locations. Interpretive naturalists are being trained and have presentation materials to tailor.

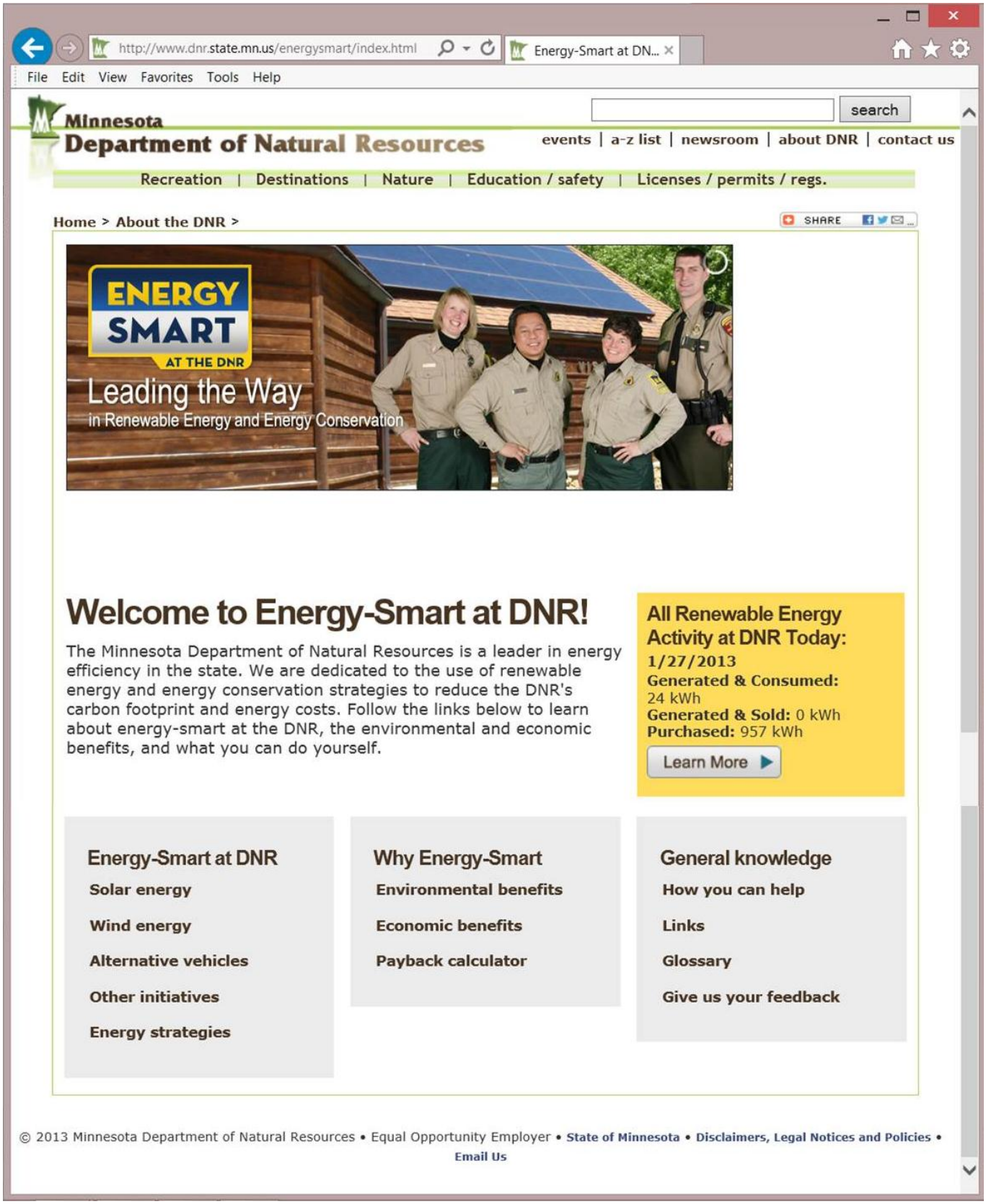


Figure 1: Energy Smart Home Page

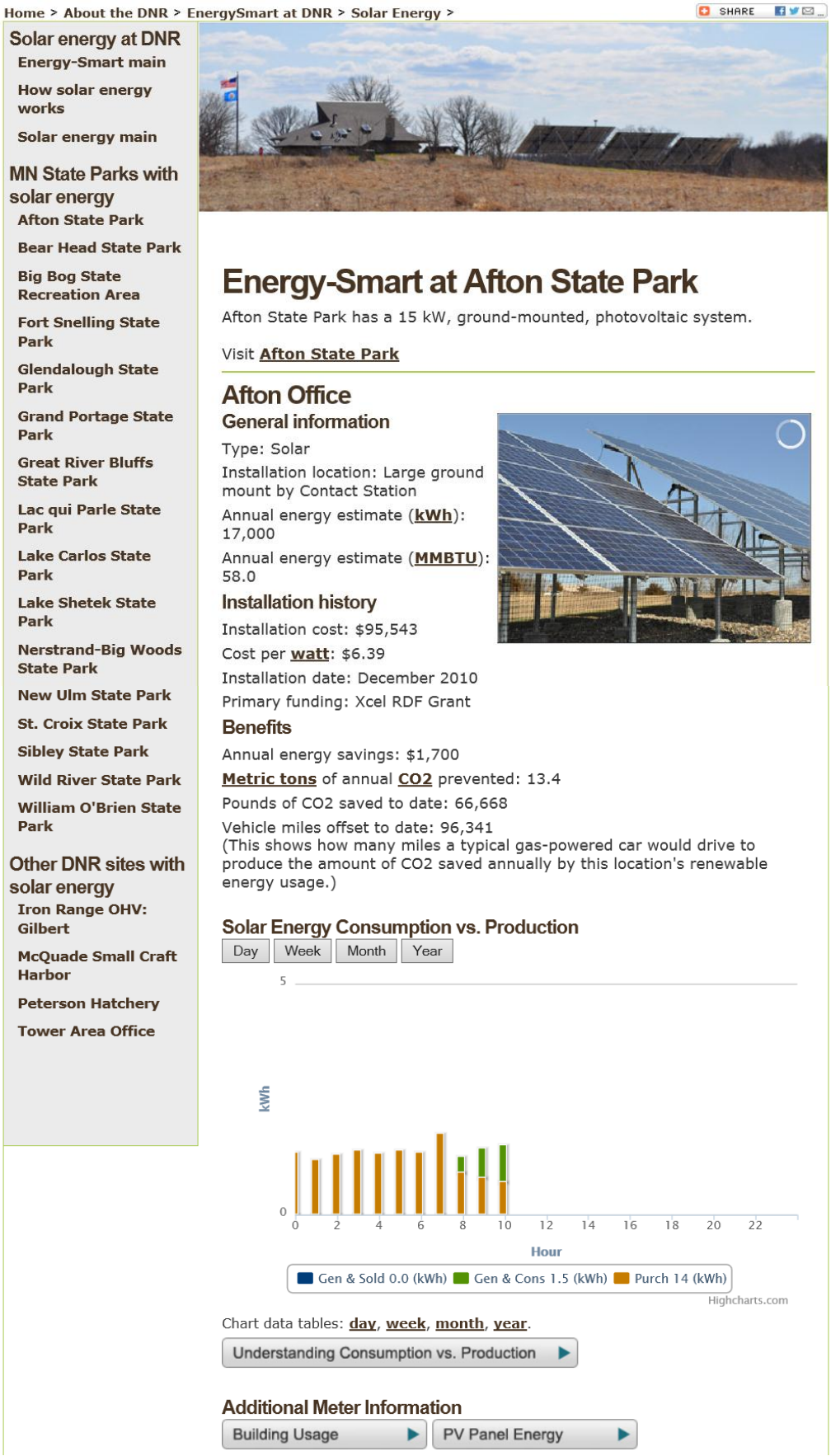


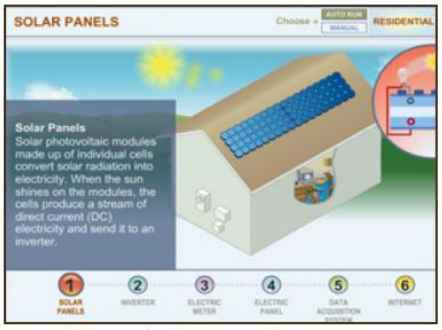
Figure 2: Solar Energy Site Page

How Solar Energy Works

How Solar Panels Produce Electricity

When light reaches a solar panel, the light energy is absorbed by the semiconductor material in the panel. This releases electrons, which can then flow in an electric current.

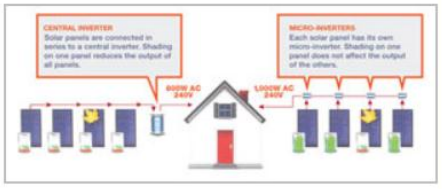
Click the image to the right to see an animated demonstration from the Fat Spaniel website showing how solar panels generate electricity. The animation also shows how solar energy systems can be monitored.



Click on the image to learn more.

Converting Solar Power to Electricity: Inverters

Solar panels produce direct current (DC) electricity. The electricity used by household lights and appliances is alternating current (AC). Inverters convert DC electricity to AC.

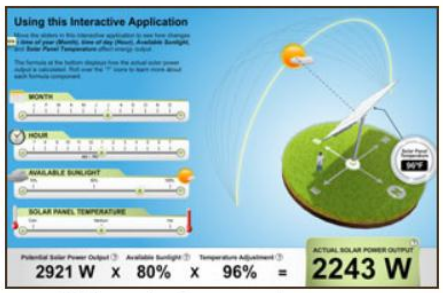


Click on the image to learn more

- **Central inverter**: Some solar energy systems connect the panels of a solar array in a series and send the combined output of the panels to a central inverter. A disadvantage of using a central inverter is that a panel with reduced output (caused by shading from vegetation or snow cover, for example) lowers the output of all the panels.
- **Micro-inverters**: In a system that uses micro-inverters, each panel in a solar array has its own small inverter. An advantage of a micro-inverter system is that reduced output from one panel doesn't affect the output of the other panels. This results in more overall power from the array, compared to a system using a central inverter.

Variables That Affect Solar Energy Output

Four main variables affect the solar energy output from a photovoltaic panel. These are time of year, time of day, available sunlight, and panel temperature.



Click on the image to learn more

- **Time of Year (Month)**: This determines the sun's angle to the horizon. The more direct the sun's angle on the solar panel, the higher the panel's energy output will be. The best angle is in summer, when the sun is higher in the sky.
- **Time of Day (Hour)**: This determines the sun's position as it rises and sets. As with time of year, the more direct the angle of the sun is on the solar panel, the higher the panel's energy output will be. The best angle is when the sun is directly overhead at noon.
- **Available Sunlight**: This determines how much sunlight reaches the solar panel, based on cloud cover, fog, rain, snow, etc.
- **Solar Panel Temperature**: This affects the efficiency of the solar panel. The higher the temperature, the lower the energy output.

Figure 3: How Solar Energy Works Site Page

Economic Benefits

Renewable energy and sustainable practices have widespread economic benefits throughout Minnesota, including reducing the economic impact of pollution and climate change on human health.

For the DNR

By generating much of the energy its facilities use, the DNR saves over $20,000 in energy costs every year.

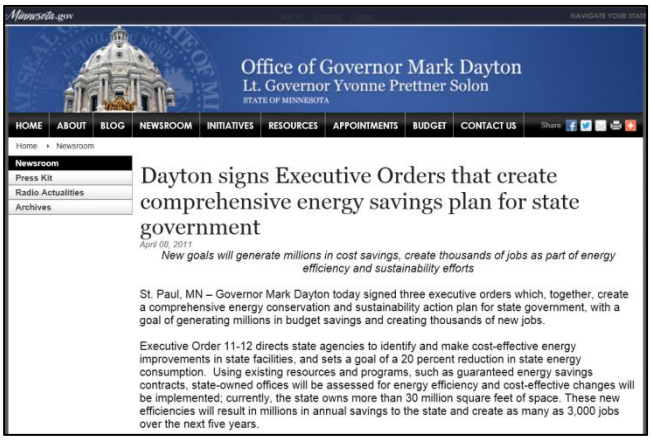
For the U.S. and Minnesota

The DNR helps create jobs by purchasing renewable-energy equipment from U.S. and Minnesota companies whenever possible.

All renewable energy equipment to be installed in 2012 will be ARRA-compliant. The American Recovery and Reinvestment Act of 2009 is often referred to as the Stimulus or Recovery act. Its main objective is to save and create jobs.

In April of 2011, Governor's Mark Dayton signed energy-related executive orders;

- Executive Order 11-12 sets a goal of reducing state government energy use by 20% from 2010 to 2015. Achieving this goal will save taxpayers millions of dollars, create jobs, and attract new investments by making the state a national leader in energy efficiency.
- Executive Order 11-13 ties together previous executive orders and instructs agencies to develop a sustainability plan to modify practices regarding resource consumption, vehicle usage, purchase of goods and services, and facility construction, operation and maintenance.



For a link to more information about these executive orders, see "Governor Dayton's Energy-related Executive Orders" on the **Links page**.

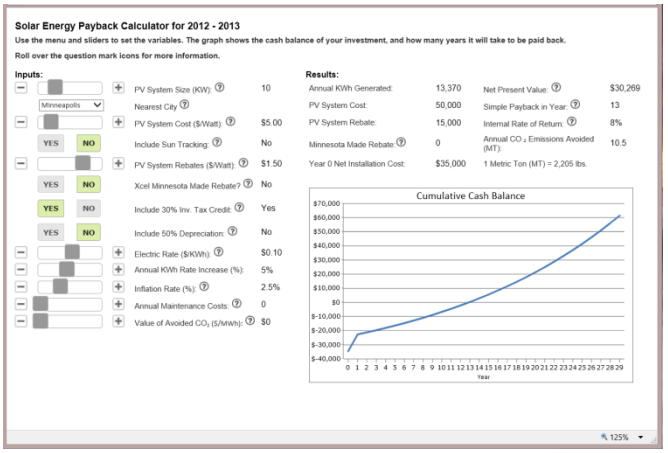
All of our coal, natural gas and nuclear fuels are imported into Minnesota. Those energy dollars are exported out of Minnesota and the vast majority of the jobs are created elsewhere. However with solar and other renewable technologies, jobs are created in Minnesota.

For Businesses

Installing a **photovoltaic** system for a business makes more sense than ever before. Rebates from electric utilities, the Federal Investment Tax Credit savings of 30% of the total system cost, and accelerated depreciation mean that renewable energy installations are typically paid for in less than 10 years.

You can calculate how many years it would take you to see a return on your investment in a photovoltaic installation with this handy **Solar Energy Payback Calculator**.

Because of the rapid increase in the use of computers and other sensitive electronic equipment, more and more homes and small businesses now require highly reliable, quality power. A renewable energy system with battery storage can provide the security of an uninterrupted power supply this kind of equipment demands.



For You

Installing a photovoltaic system can make good economic sense for individuals as well as businesses. See how rebates, tax credits and incentives would affect your potential return on investment with this **Solar Energy Payback Calculator**.

Figure 4: Economic Benefits Site Page

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.
#7: Installation of additional nameplate capacity and interpretive program; completed on December 15, 2012.

Project Status: Project is on schedule with implementation of 113 KW completed by the end of 2012. This accelerated timeline has allowed us to reduce our carbon emissions earlier and provide a more timely interpretive experience for park visitors. The modular designs of the ground mounted arrays have also supported a faster implementation.