FINAL TECHNICAL REPORT

Minnesota Photovoltaic System Case Study

Residential Application

Prepared for

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BLACK & VEATCH

11401 Lamar Avenue
Overland Park, Kansas 66211
Tel: (913) 458-2000
www.bv.com

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Principal Investigators:
Anand Pattani, Project Manager
Nate Lindstrom
Jason Abiecunas
Chris Helberg

Acknowledgments:
Innovative Power Systems: Mr. Ralph Jacobson, Ms. Mia Devine
Ms. Suzannah Ciernia

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Introduction and Executive Summary

The Iowa Department of Natural Resources (DNR) has awarded a contract to Black & Veatch to develop technical case studies for four photovoltaic (PV) applications installed since 1999 in six Midwestern states - Iowa, Illinois, Minnesota, Wisconsin, Missouri and Nebraska. The purpose of these case studies is to independently demonstrate and verify the reliability and viability of photovoltaic systems.

Efforts were made to develop case studies offering diversity in applications and geographic locations. Black & Veatch prepared a questionnaire (Appendix A) and contacted various manufacturers, installers and final owners of photovoltaic systems. In-depth project information and production data were priorities when choosing final case study subjects, which include:

- Crandon, Pulaski and Oshkosh-West Public Schools - Wisconsin
- Sac and Fox Indian Settlement Pond Circulator - Iowa
- Ciernia Home - Minnesota
- Kreitman Ranch Water Pumping - Nebraska

This document presents the Minnesota case study. Suzannah and Bob Ciernia of Northfield, Minnesota, decided to install a solar PV system while constructing a new home. The system is comprised of solar shingles that replace roof shingles and provide an unobstructed view of the roof-top. The local utility offered to install and then lease the system without any upfront cost to the homeowners. The installation cost to the utility was $29,500, which then leased the system to the Ciernias for a five-year period for $50/month. The Ciernia's home in Minnesota is a unique net-metering application that is capable of exporting any excess generation of electricity to the electric grid. The system resulted in cost and emissions savings for the Ciernias.

Black & Veatch collected information on the project's timeline and history, design, procurement and installation process, operation and maintenance costs, production data, and conducted an analysis on energy and emission savings. The results are presented in the next section.

Ciernia Home – Minnesota Photovoltaic System Case Study

Project History

The Suzannah and Bob Ciernia decided to build a new home in Northfield, Minnesota in fall 1998. After learning of the potential of solar power, the family explored the possibility of installing a PV system on their home's roof with Innovative Power Systems (IPS), a full-service designer and installer of commercial and residential renewable energy systems.

IPS worked together with the Ciernias and home architects early on in the project to ensure the home was designed appropriately to support a PV system. The home design included a high efficiency furnace and air-conditioning system. In view of aesthetics and despite higher costs, the Ciernias decided to install solar PV shingles. Solar shingles replace typical roof shingles and are built into the roof, thus providing an unobstructed view of the roof-top.

Because Minnesota has net-metering laws, IPS and the Ciernias approached Xcel Energy (previously Northern States Power), the local utility company, during fall 1998 to inquire about available funds and donations for the PV system. The marketing department of Xcel Energy decided to pay for the entire system under the company's Solar Advantage Program. Through the program, the utility would own, install, maintain and pay for the PV system installation. The system would then be leased to the homeowner for a five-year period for a fee of $50/month. At the end of this time, a customer has three options: (1) sign another five-year contract, at the end of which they would purchase the system for $1, (2) purchase the system for $3,000, (3) or have the utility remove the system.

As part of this program, Xcel Energy paid for the system and its installation and leased the system to the Ciernias. Since the utility owns the system, the Ciernias were not offered any net-metering benefits. The family received credit for the electricity produced and the system helped offset about 31 percent of their monthly electric bills (see Figure 1).

Because the utility owned the PV system, no negotiations for grid connections were necessary. Additionally, the Ciernas did not face any zoning issues, although they were required to have the system inspected by a local electrical inspector.

Design and Procurement Process

The Ciernias improved the potential success of their project by choosing PV very early in the home-building process. The homebuilder was able to accommodate the procurement process into his schedule.

The Ciernia home was designed to be energy efficient from an early home-building stage. The solar PV system and a high efficiency furnace and air-conditioner system were part of the plan. IPS and the Ciernias decided not to use batteries for storing electricity generated by the solar PV system, due to high maintenance costs.

The size of the PV system was based on the maximum available rectangular area on the south side of the roof. After taking the layout and arrangement factors into consideration, IPS recommended the optimum design would allow space of 180 solar PV shingles. IPS selected Unisolar SHR 17 model photovoltaic shingles. These shingles are thin-film, amorphous cells as shown in the adjacent picture. Each shingle was rated for 17 Watts (58 BTU/hr), thus giving a system output of about 3.1 kW (52,700 BTU/hr). The next step was selecting the right inverter to convert DC power to AC power, as it had the longest lead time for procurement.

IPS, however, faced two unexpected problems during the procurement process. The California company supplying the PV shingles was suffering from cash flow problems. The other problem was that the shingles supplied were not UL-certified. This would prevent the local electrical inspector from certifying that the system was safe. However, with considerable help from Xcel Energy, IPS managed to resolve the problem by having the suppliers re-ship UL-certified shingles.

Installation Process

The installation was coordinated between the Ciernias, IPS and the builder. IPS told the builder before the home was built that 540 square ft. (50.2 m^2) of asphalt shingles on the roof would be replaced by solar shingles. The average weight of the solar shingles per unit area of

the roof was one lb/square ft. (4.88 kg/m^2). The actual installation of the shingles was 10 degrees east of South.

Procurement problems, discussed in the previous section, delayed the installation process by about one month. IPS completed the installation in about four to five days during the winter of 1999. Besides IPS engineers and local electricians, a representative of Xcel Energy helped direct the interconnection of shingles. The Cernias visited their home on a daily basis during the installation period.

IPS technicians hooked up the PV shingles in a series connection with 18 shingles in a single row. During installation, the technicians tested every shingle for current output. Since the shingles were made of thin-film, technicians took utmost care during installation to prevent any damage. The complete system included the solar shingles, inverter, combiner box (where the series connections were tied together), two meters for monitoring system performance, one meter for data acquisition and two disconnect switches on either side of the inverter.

Most of the system components were located in the home attic and connections to the solar shingles were made with #10 AWG wire run through a flexible conduit. Licensed electricians were hired locally to complete the installation after a briefing on system design.

Timeline

IPS became involved about 15 months before the home's completion to assist in home design along with the architects.

Once the design was finalized and orders were placed for the inverters, it took about 10-12 weeks to receive all the equipment, including the inverters and the shingles. Various off-shelf items such as conduits, electric wires and flex-tubes were available from local hardware stores. The actual installation took about 4-5 days to complete.

Table 1: Minnesota - Installation Timeline

Event	Time
Meetings with home builder and system engineer	Fall 1998
Meetings with utility	Winter 1998 and Spring 1999
System Ordered	Summer 1999
System Procurement	Fall 1999 (10-12 weeks)
Installation	Winter 1999
Installation Period	4-5 days

The entire project was conceived in fall 1998 and installation and start-up was completed in winter 1999.

Production Data

The Ciernia home has an area of 4,284 sq. ft. (398 m^2) including a finished basement. On average, the solar PV system has helped offset about 31 percent of their total electricity costs in years 2000 and 2001. The production decreased in the winter months due to snow cover.

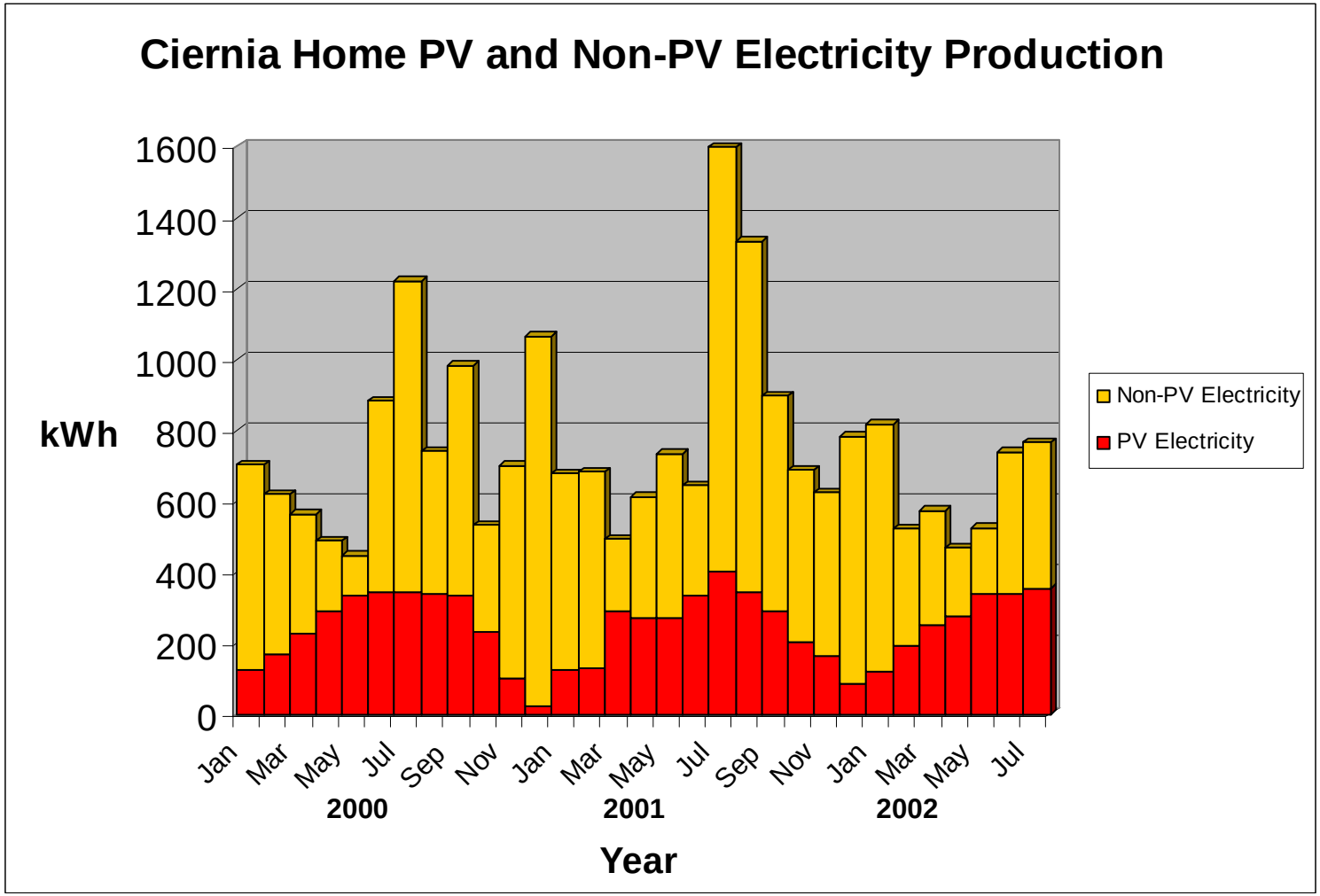
Table 2 indicates the amount of electricity consumption for the Ciernia home and the contribution from the solar PV system.

Table 2 Minnesota: Production Data for the Ciernia Residence

Month	2000 (Electricity in kWh)		2001 (Electricity in kWh)		2002 (Electricity in kWh)	
	PV System Production	Total Home Consumption	PV System Production	Total Home Consumption	PV System Production	Total Home Consumption
Jan	126	703	124	678	118	817
Feb	171	620	130	683	192	522
Mar	227	565	289	495	251	574
Apr	289	490	271	613	275	470
May	336	448	270	735	340	525
June	344	882	332	645	338	740
July	346	1220	401	1596	355	767
Aug	341	741	346	1332		
Sept	332	983	289	896		
Oct	231	532	204	688		
Nov	103	700	164	626		
Dec	21	1065	84	783		

Figure 1 highlights the ratio of electricity at the Ciernia home produced by the solar PV system to non-solar PV electricity from the utility, as it appeared in their electricity bill statements from January 2000 to July 2002.

Figure 1: Minnesota – Percentage of Electricity Produced by Solar PV System



Financial Incentives

The biggest financial incentive for the Ciernias was that the local utility, Xcel Energy, paid for the entire system, its installation and maintenance. In turn, Xcel Energy leased this system to the Ciernias. There were no property or tax ramifications due to installation of the system.

In addition, the following financial incentives would have been considered for the system if the Ciernias had incurred the system cost.

- Rebate program by State Department of Commerce- buy down for $2/Watt for a PV system up to 4 kW.
- Federal Tax Credit of 10 percent of installed cost for qualifying solar energy property.

Project Costs

IPS received $29,500 for the entire project. This included design, procurement, installation and any other associated costs. According to IPS, the equipment made up 80 percent of the total, and labor costs were about 20 percent. The current operating and maintenance costs to the Ciernias are negligible (<$100) and would be incurred only once every two years as the utility pays for any major maintenance costs since it owns the system. No major maintenance has been required so far.

Every solar PV shingle costs $95 and has a warranty of two years.

Energy and Emission Savings

Emission savings are based on the size of the system. Table 3 illustrates the estimated emission and energy savings from the Ciernia home based on the following:

- According to U.S. Environmental Protection Agency (EPA), a 1 kW solar PV system installed in Minnesota results in annual emissions savings of 2,500 pounds (1,136 kg) of carbon dioxide, 8 pounds (3.63 kg) of nitrogen oxides, and 8 pounds (3.63 kg) of sulfur dioxide.
- The average cost of electricity for the Ciernia home is 7 cents/kWh

Table 3: Minnesota – Energy and Emission Savings for 3.1 kW System

System Size (kW)	Average Annual Emission Savings (lbs)			Cost Savings ($)
	CO_2	NO_x	SO_x	
3.1	7,750	24.8	24.8	$217

The cost savings is a simplistic and conservative estimate based on amount of electricity generated by the solar PV systems. Actual savings potential will depend on the time value of electricity. Typically, a solar PV system generates and exports excess electricity to the grid through net metering during day-time hours when demand is also at its peak and the cost of electricity is the highest. However, this rule does not apply in the case of the Ciernia home because the system is owned by the utility.

Lessons Learned

The following lessons were learned during system installation:

- Planning for a PV system should be done early in the home building process so design and construction of the home and PV system installation can proceed simultaneously.
- Close coordination with the homebuilders is imperative to incorporating a system in the home building design and schedule. Since the solar PV system was installed on the southern roof, the northern side of the roof was made available for plumbing vents and other equipment.
- Solar shingles, although more expensive, are more pleasing aesthetically as there are no protruding structures on the roof.
- Some concerns and uncertainties exist if a future merger of the local utility were to create ownership problems. This should be resolved upfront.
- Most solar PV systems are installed facing the South direction for maximum capacity. However, in case of grid-connected systems, the cost of electricity is highest between 1:00 p.m. and 8:00 p.m. Under time-of-day pricing, a PV system facing the West or South-West direction may offer higher savings.
- It is important to ensure that all solar equipment purchase is UL-certified as this is required by local electrical inspectors.

Appendix A: PV Questionnaire

We are pleased to inform you that Black & Veatch has been selected by Iowa Department of Natural Resources to conduct a case study of solar PV applications installed since 1999 in the Midwest. Please provide the following information as part of the study. We thank you for your cooperation. This report will be distributed widely to engineers, at technical workshops and published over the Internet to promote solar PV systems.

Project History

- Project Name, Size and type of PV cell, and Owner or final end user with contact information.
- Reason for choice of photovoltaic system as energy source.
- Negotiations conducted with regulatory authorities and utilities.
- Permitting, zoning and all other applications that were filed.
- Other activities preceding project construction.

Design and Procurement Process

- Selection of type of photovoltaic system among various alternatives.
- System (PV and inverter) sizing procedure, one-line electrical wiring diagram and instrumentation details.
- Who was responsible for sizing the system?
- Procurement process and system delivery time-table including major milestones.

Installation Process

- Installation schedule.
- Capital costs.
- Major hardware components including any tracking system used for installation.
- Ease of finding qualified contractors to do the installation.
- Could the end-user have assembled (direction, azimuth, elevation, wiring, mechanical assembly, etc?) the system by themselves with adequate instructions?
- Lessons learned during construction that can be applied to future projects.

Timeline

- Process time-line from initial vision, system engineering, procurement, installation and start-up.

Operations Costs

- Annual cost of operating and maintaining the system.
- System reliability and major problems faced with operation and maintenance.
- How many times was routine maintenance required annually and is routine maintenance possible by the owner themselves?

Production Data

- Please provide electric production (or water pumping) data or performance summary for any consecutive 12-month period since 1999 to verify system reliability.

Electrical Consumption

- What is the ratio of electricity consumption for the load served by the photovoltaic system against the total electricity produced by the system?
- Applications for which PV-produced electricity was used.

Financial Incentives / Energy and Cost Savings / Economic Analysis

- Financial incentives considered while undertaking project development and other activities preceding project construction.
- Summary of annual energy, monetary and emission savings.
- Tax ramifications/benefits.

Environmental Issues

Environmental issues surrounding operation and maintenance of the photovoltaic system.