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Energy & Environmental Research Center

UNIVERSITY OF NORTH DAKOTA

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December 30, 2011

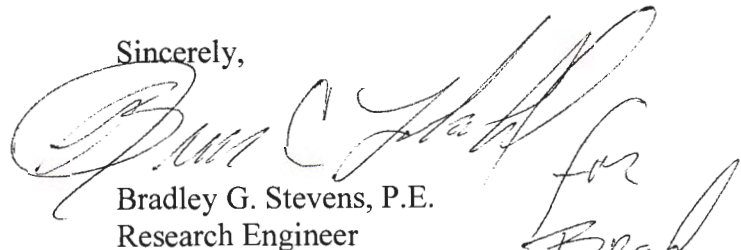
Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
State Capitol, 14th Floor
600 East Boulevard Avenue
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: Final Report; Small Wind Turbine Training Center; Contract No. R002-005; EERC
Fund 9961

Enclosed is the final report summarizing the project activities for the contract period. If you have any questions, please contact me by phone at (701) 777-5293 or by e-mail at bstevens@undeerc.org.

Sincerely,



Bradley G. Stevens, P.E.
Research Engineer

for
Brad
Stevens

BGS/cs

c: Andrea Holl Pfennig, North Dakota Department of Commerce



SMALL WIND TURBINE TRAINING CENTER

Final Report

(for the period of November 7, 2008, through December 31, 2011)

Prepared for:

Karlene Fine

North Dakota Industrial Commission
State Capitol, 14th Floor
600 East Boulevard Avenue
Bismarck, ND 58505-0840

Contract No. R002-005

Prepared by:

Brad G. Stevens, P.E.

Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

2011-EERC-12-19

December 2011

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ACKNOWLEDGMENTS

This report was prepared with the support of the U.S. Department of Energy (DOE) National Energy Technology Laboratory Cooperative Agreement No. DE-FG36-05GO85037. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the authors(s) and do not necessarily reflect the views of DOE.

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SMALL WIND TURBINE TRAINING CENTER

INTRODUCTION

Based on conversations with personnel from the U.S. Department of Energy (DOE) and the continued need to educate the public about wind energy, the Energy & Environmental Research Center (EERC) proposed to modify the original Task 1 scope of activities in DOE Award No. DE-FG36-05GO85037 to establish a small wind turbine training center (SWTTC).

The establishment of an SWTTC allowed EERC personnel to provide educational opportunities to a wide range of participants including grade school- through college-level students and the general public. In addition, the facility allowed the EERC to provide technical training workshops related to the installation, operation, and maintenance of small wind turbines.

As summarized below, the proposed activities involved 1) the selection and development of a suitable wind turbine site, 2) procurement and installation of equipment, and 3) an educational component. Conceptually, the EERC was to install up to three small wind turbines ranging in size from 1.8 to 20 kW (due to budgetary constraints the number of turbines was reduced to one 5-kW turbine) at the site and host up to two technical workshops.

Scope of Activities

Task 1 – Site Selection and Development

- Identify and prioritize potential sites for development of the SWTTC.
- Select a site based on land ownership, site access, electrical interconnection access, proximity to Grand Forks, availability of wind resource (i.e., openness, absence of obstructions), and other characteristics.
- Submit necessary permits and secure site development approval from appropriate governing bodies, including the following:
 - City of Grand Forks
 - North Dakota Historical Society
 - Nodak Electric Power Cooperative
 - Federal Aviation Administration
 - Grand Forks Airport Authority

Task 2 – Equipment Procurement and Installation

- Identify up to three potential small wind turbines to be installed at the SWTTC.
- Identify and procure necessary electrical infrastructure to interconnect the wind turbines.
- Negotiate with vendors for the purchase and delivery of a single small wind turbine.
- Negotiate with local contractors for the installation of electrical infrastructure.

- Negotiate with local contractors for the installation of the necessary wind turbine foundation.
- Install foundation, wind turbine, and associated electrical infrastructure at the site.

Task 3 – Education and Outreach

- Host up to two technical workshops related to the installation, operation, and maintenance of small wind turbine applications targeting parties throughout the region interested in installing their own small wind turbines.

PROJECT ACTIVITIES

Site Description

Based on input from representatives of the city of Grand Forks during several meetings, the EERC and the city of Grand Forks have agreed to install the wind turbine on the grounds of the Grand Forks Public Safety Center west of Grand Forks in the Grand Forks Industrial Park (Figure 1). The legal description is Township 151 North, Range 50 West, Section 7, Southwest ¼. Several other sites were considered during the evaluation process including the following:

- Adjacent to the city of Grand Forks clearwell facility
- On the grounds of the proposed Wellness Center
- The new city of Grand Forks solid waste landfill site in Rye township
- The area near a city of Grand Forks water tower adjacent to I-29 and north of Gateway Avenue
- City of Grand Forks lift station locations on the edge of town

Some permitting work had been completed by the EERC for siting the wind turbine at the clearwell facility when the turbine location was moved to the Public Safety Center location.

Wind Energy Systems

Two wind turbines were identified as potential turbines to install at the SWTTC, the Endurance Wind Power, Inc. (Endurance), S-250 and the Southwest Windpower, Inc., Skystream. Due to budgetary constraints, only one turbine was selected, and that was the Endurance S-250.



Figure 1. Small wind turbine training center wind turbine location.

Endurance S-250

The S-250, manufactured by Endurance, is a three-bladed, upwind, horizontal-axis wind turbine with a maximum electrical output of 5.0 kW at 14 m/s hub-height wind speed. Endurance S-250 specifications are shown in Table 1.

Similar to utility-scale wind turbines, the S-250 utilizes an induction generator to produce grid-quality AC power without the use of an inverter. Typical small wind turbines use a permanent magnet configuration. To improve electrical production efficiency, the S-250 employs a dual-voltage switching system that allows the generator to produce 120 volts AC at low wind speeds and 240 volts AC at higher wind speeds. Voltage switching is accomplished with the control system and software, which also prevents excessive voltage switching in variable winds. The S-250 wind turbine features dual, redundant braking systems that can be activated either by the system controls or by the operator in any wind conditions. Several tower heights are available, ranging from 63 to 126 feet. The tower height to be utilized at the SWTTC was a 105-foot guyed tilt-up tower.

SITE CONSTRUCTION

All site construction activities were coordinated and supervised by the EERC. Activities included but were not limited to the following:

- Securing all necessary permits and approvals
- Locating utilities prior to on-site construction
- Coordination with city of Grand Forks personnel
- Coordination and supervision of foundation installation
- Coordination and supervision of wind turbine installation
- Coordination and supervision of electrical infrastructure installation

Table 1. Endurance S-250 Specifications

Description	SI Units	English Units
Blade Length	2.56 m	8.67 ft
Rotor Diameter	5.5 m	18 ft
Swept Area	23.8 m ²	256 ft ²
Cut-in Speed	4.2 m/s	9.4 mph
Cutout Speed	24 m/s	54 mph
Rated Speed	10.7 m/s	24 mph
Rated Power (at rated speed)	4.25 kW	4.25 kW
Estimated Annual Production	11,000 kWh	11,000 kWh

Permitting

U.S. Department of Energy

Since funding from DOE was used in the project, the EERC was required to submit necessary documentation to secure approval under the National Environmental Policy Act of 1969.

City of Grand Forks

The city of Grand Forks required several documents including the following:

- Site construction document
- Site access agreement
- Building permit
- Electrical inspection certificate

Electric Utility

The proposed location of the wind energy facility is served by Nodak Electric Cooperative (Nodak), which obtains its electricity from Minnkota Power Cooperative. At the direction of Nodak, the wind turbine was connected on the load side of the utility meter. This allowed the city's Public Safety Center to consume any electricity produced by the wind turbine instead of putting the electricity directly on the electrical grid. Nodak required an interconnection application.

Air Traffic

Since the clearwell facility was the original site of choice, EERC personnel had several conversations with entities and agencies responsible for the safety of airspace and control of flight operations in the proposed site, including the Federal Aviation Administration (FAA), the Grand Forks International Airport, and the University of North Dakota John D. Odegard School of Aerospace Sciences.

Although it was not required, the EERC submitted to the FAA a "Notice of Proposed Construction or Alteration" (Form 7460-1). On July 20, 2008, the EERC received a "Determination of No Hazard to Air Navigation" from the FAA regarding the three proposed structures (two wind turbines and one meteorological tower).

Based on several conversations with representatives from the Grand Forks International Airport and the University of North Dakota, no objection to the proposed wind turbine installations were posed.

Upon moving the location of the wind turbine to the location described above, the EERC did not resubmit the FAA forms (as it is not required). The EERC did discuss the new location with the Grand Forks International Airport and the University of North Dakota John D. Odegard

School of Aerospace Sciences, but since this site is even further from the airport, no objections are expected.

Other

In addition, approval was required from the State Historical Society of North Dakota and the Grand Forks Historical Preservation Committee to verify that the project did not impact any historically sensitive areas.

Foundation

The S-250 required a fairly substantial foundation. Figures 2, 3, and 4 show the foundation for the tower base, winch anchor point, and guy anchor point, respectively.



Figure 2. Tower base foundation.



Figure 3. Winch anchor foundation.



Figure 4. Guy anchor foundation.

Electrical

Since Nodak desired to have the wind turbine electrically connected on the load side of the meter, EERC personnel coordinated with city of Grand Forks personnel to obtain and review the electrical configuration of the Public Safety Center and determine the necessary electrical infrastructure to interconnect the wind turbine. The S-250 was electrically connected to an existing service at the Public Safety Center. Although convenient, this interconnection point posed some challenges. Most significant was the fact that the service was a single-phase service fed from a three-phase system at the main building. For this reason, the voltage at the connection panel was 208 volts (actually measured to be 213 volts). To get the voltage, both directions, within allowable ranges, required a transformer be installed between the interconnection point and turbine control panel. Because of the long lead time required for an isolation transformer, the use of a different type of transformer known as a buck/boost transformer was attempted.

Wind Turbine Installation

On December 20, 2011, Endurance personnel arrived at the EERC to perform several upgrades to the wind turbine prior to installation. These upgrades took 1 day to perform. On December 21, 2011, personnel from Endurance, the EERC, and Enterprise Sales Company (turbine maintenance provider) performed the assembly (Figure 5) and erection of the wind turbine tower without the turbine mounted on the tower (Figures 6 and 7). This lift was done to perform proper guy wire tensioning and allow for tower straightening.



Figure 5. Tower and gin pole assembled.



Figure 6. Tower being lifted into place (without turbine mounted).



Figure 7. Tower fully erected and guy wires tensioned.

On December 22, 2011, the tower was lowered, and the wind turbine was mounted on the tower top (Figure 8). The electrical cabling was installed in the tower, and the tower (with turbine mounted) was lifted for the final time. Figures 9 and 10 show the wind turbine fully assembled, being lifted into place, and ready for commissioning.

Wind Turbine Commissioning

Once the wind turbine was erected, the tower straightened, and the electrical wiring completed, the commissioning process began. Unfortunately, only at this stage of the installation were we able to determine that the buck/boost transformers were not able to regulate the voltage to within an allowable range for the wind turbine control panel.

At the time of this writing (and the end of the contract period), an isolation transformer has been ordered and should be installed during the first week of January 2012. After the transformer is installed, the final commissioning will be completed, and the wind turbine will be put into service. The remaining work will be performed with supplemental funding from the North Dakota Division of Community Services.



Figure 8. Mounting the turbine, blades, and tail.



Figure 9. Fully assembled wind turbine being erected.



Figure 10. Wind turbine installation complete.

EDUCATION AND OUTREACH

As indicated in the introduction section, Subtask 3 involved hosting up to two workshops to educate individuals regarding small wind turbine technology.

The first workshop was held on May 18, 2010, at the EERC in Grand Forks, North Dakota. During the half-day workshop, 40 attendees from North Dakota and Minnesota heard presentations discussing the following topics as well as a question and answer session:

- Introduction, programs, incentives, and wind resource
- Wind turbine installation and maintenance
- Utility interconnection

The second workshop, also at the EERC, was held on March 8, 2011. Again this workshop was a half-day and was attended by 27 people from North Dakota and Minnesota. The same topics were presented in the second workshop. Final demographics for each workshop are provided in Appendix A.

*Energy & Environmental
Research Center*

APPENDIX A
FINAL DEMOGRAPHICS



EVALUATION SUMMARY

18 Evaluations Returned – 66%

1. Please rate the following workshop presentations:

Programs, Incentives, and Wind Resource					
Excellent (5)	Good (9)	Fair (4)	Poor (0)	N/A (0)	
Wind Turbine Installation and Maintenance					
Excellent (3)	Good (9)	Fair (5)	Poor (1)	N/A (0)	
Utility Interconnection					
Excellent (5)	Good (9)	Fair (2)	Poor (0)	N/A (2)	

2. Please rate the workshop overall:

Needs Improvement										Excellent	
1 (0)	2 (0)	3 (0)	4 (1)	5 (1)	6 (2)	7 (6)	8 (3)	9 (1)	10 (3)	N/A (1)	

Comments:

- Only commented on feeding the grid and how to make money. No discussion on how to stay off the grid and do a whole system off-grid, e.g., what type of turbine, storage, solar combo.

3. What information was most useful to you and why?

- What systems are in use.
- Would have been good to include city regulations and more of a step-by-step how to and who to see. Feel it addressed commercial or larger systems more than residential.
- Good overview.
- Blain Rekken from Nodak.
- Networking.
- Cost and how it affects me.
- Tax incentives and granting.
- Provided a good overall explanation of this process.
- Programs and Incentives helps with feasibility determination.
- General overall information.
- Utility interconnection.

4. What topics would you like to see added/deleted from the Small Wind Turbine Workshop?

- Suppliers that have systems to show their systems.
- I would like to see the “small wind” address more “in town” systems rather than just farms. Installation and Maintenance section was poor – rambling...
- None.
- More on type and workings of different types of turbine, more on the side of cost and technology in producing electricity in a system of self-sustainability. What new technology or improvements in wind.
- Add more economics.
- Property tax issues.
- Specifics on small/individual use turbines.
- Some update on legislative changes – maybe someone from the U.S. Department of Energy or the Department of Commerce.
- More detail or costs of small wind and solar systems and maintenance and operation systems.
- How to install wind generators yourself.
- No recommendations.

5. Overall, the level of information presented was:

Too Technical (0) Challenging (2) Appropriate (12) Too General (4) N/A (0)

Comments:

6. Please rate the quality of the workshop materials packet:

Excellent (3) Good (15) Fair (0) Poor (0) N/A (0)

Comments:

7. Please rate the workshop registration process:

Excellent (9) Good (7) Fair (0) Poor (0) N/A (2)

Comments:

- Very efficient – good use of name tags.

8. Please rate the on-site workshop staff assistance:

Excellent (9) Good (6) Fair (0) Poor (0) N/A (3)

Comments:

9. Please rate the following items regarding workshop facilities:

A. Refreshment Break Excellent (9) Good (5) Fair (1) Poor (0) N/A (3)

B. Meeting Room Excellent (9) Good (6) Fair (0) Poor (0) N/A (3)

- Beautiful facility!

10. How did you first learn about this workshop?

- (5) Postcard from the EERC
- (6) E-mail from the EERC
- (2) Colleague
- (0) Web site
- (3) Newspaper
- (2) N/A
- (2) Other (please list):
 - County Extension Rep.
 - Wife works for the EERC.
 - Was on your list for years and finally got to attend.

11. Do you have any other suggestions for how we could improve this workshop?

- If possible, a vendor show.
- None.
- Have vendors on-site.
- I felt Jack Hanson's remarks, from time-to-time, needed some upgrading for a group presentation.
- No. I enjoyed the workshop very much. I appreciate the networking opportunity also. Thank you!

Thank you for taking the time to complete this form; your comments are appreciated. Please turn in your form at the workshop registration desk.

Note: If completing the form following the workshop, please fax it to (701) 777-5181.



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SMALL WIND TURBINE
WORKSHOP

Final Demographic Report

Distributed by LaRae Foerster
Outreach and Communications Data Coordinator

Small Wind Turbine Workshop Registrants/Attendees

#

Total Registrations Received: 44

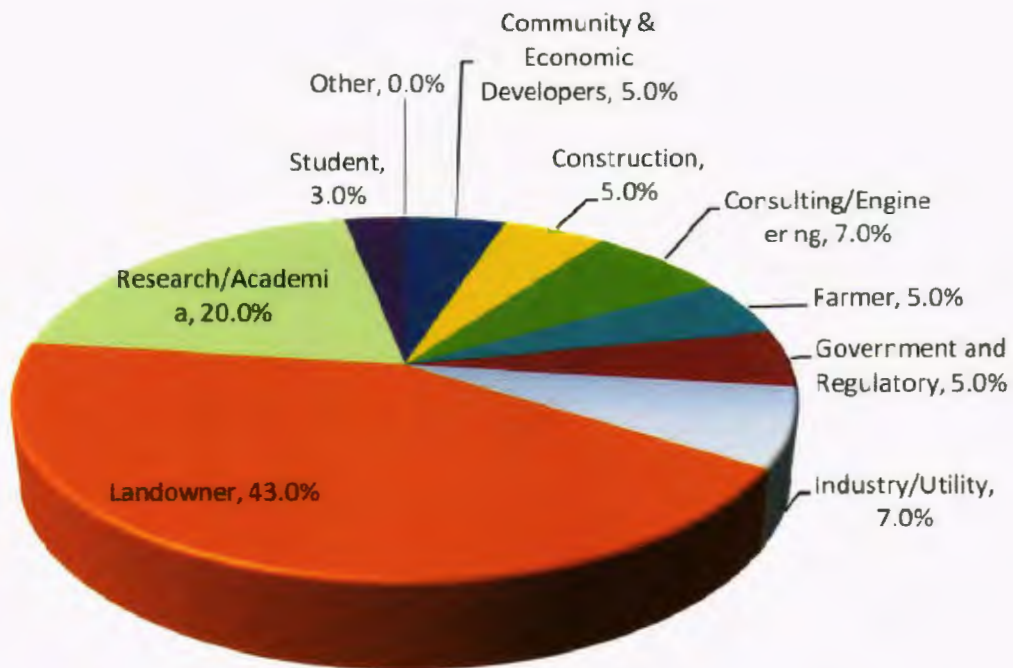
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










Participating Organizations: 23

Number of States: 2

"

Attendee Affiliations



	Community & Economic Developers	5.0%	2
	Construction	5.0%	2
	Consulting/Engineering	7.0%	3
	Equipment Vendor	0.0%	0
	Farmer	5.0%	2
	Government and Regulatory	5.0%	2
	Industry/Utility	7.0%	3
	Landowner	43.0%	17
	Research/Academia	20.0%	8
	Student	3.0%	1
	Other	0.0%	0
	Total	100%	40

States

North Dakota – 25

Minnesota - 15

Participating Organizations

23 Organizations

AquaGen, Inc.
Arvig Communications Systems
Bemidji State University
City of Grand Forks
CSMS Camp Ripley
EERC
Flying S Ranch
Giziibii RC&D
IBEW Local Union 1426
ICS (dba Industrial Contract Services), Inc.
IDA Corporation
Job Service North Dakota
Minnesota Department of Health
New Horizon Resort
Nodak Electric Power Cooperative, Inc.
Northwest Minnesota Foundation
Red River Valley Co-op Power
Sanford
sf(x) Engineering, Inc.
SFM Group
UND Aerospace
University of Minnesota
University of North Dakota



2 0 1 1
SMALL WIND TURBINE
WORKSHOP

Final Demographic Report

Distributed by Kari Gagner
Communications Specialist and Event Coordinator

Small Wind Turbine Workshop Registrants/Attendees

Total Registrations Received: 28

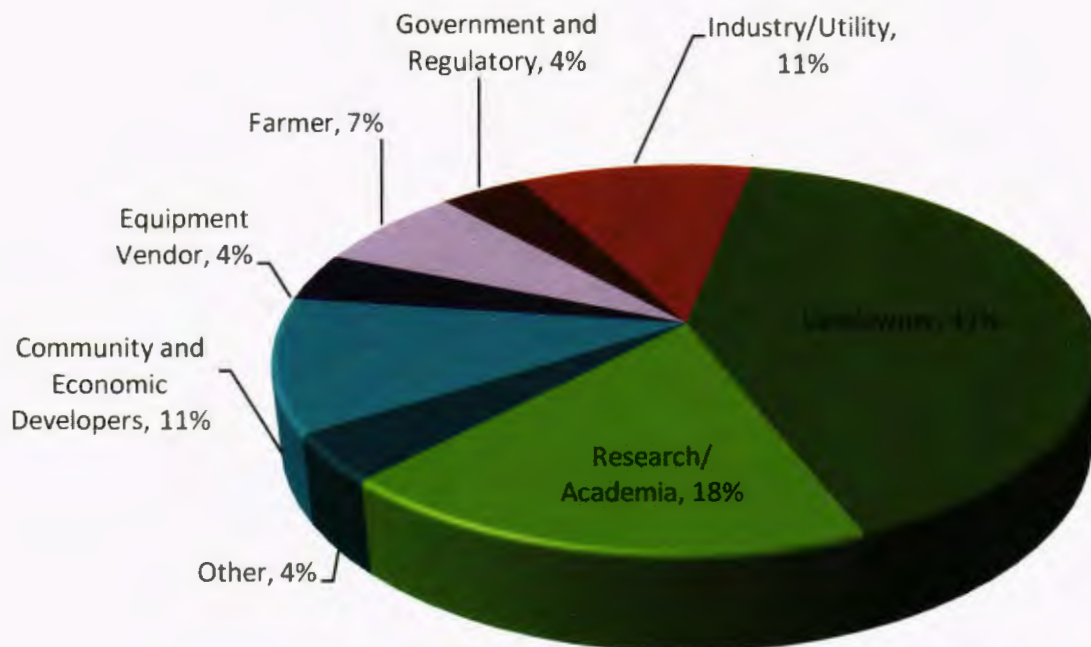
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










Total Attendees: 27

Participating Organizations: 16

Number of States: 2

Attendee Affiliations



	Community and Economic Developers	11%	3
	Construction	0%	0
	Consulting/Engineering	0%	0
	Equipment Vendor	4%	1
	Farmer	7%	2
	Government and Regulatory	4%	1
	Industry/Utility	11%	3
	Landowner	41%	11
	Research/Academia	18%	5
	Student	0%	0
	Other	4%	1
	Total	100%	27

States

North Dakota – 21

Minnesota – 6

Participating Organizations

16 Organizations

Bemidji State University
Center For Innovation
Dahlgren & Company Inc.
Dakota Turbines Inc.
EERC
Heinle Industries
Minnesota State University Moorhead
North Dakota State University Extension Service
Nodak Electric Power Cooperative, Inc.
North Dakota Department of Commerce
Rolla Job Development Authority
Serkland Law Firm
Solar and Wind Energy Consultants, LLC
University of Minnesota Extension
University of North Dakota Department of Technology
Yellow Dart Industries

List of Workshop Participants

27 Participants

David Bahr, Bemidji State University
Ray Bauer
Neal Buttke
Jay Fisher, Yellow Dart Industries
Gordon Graetz
Lonnie Greenlee, Dahlgren & Company Inc.
Jack Hanson, Solar and Wind Energy Consultants, LLC
Ron Haugen, North Dakota State University Extension Service
Lyle Heinle, Heinle Industries
Yong Hou, University of North Dakota
Keith A. Jacobson
Alex Johnson, University of North Dakota
Jerry Kaml
Frank Lewandowski
Keith Monson, Dakota Turbines Inc.
Joe Murphy, North Dakota Department of Commerce
Art Nash, University of Minnesota Extension Service
Jill Olson
Jason Rayner
Blaine Rekken, Nodak Electric Power Cooperative, Inc.
Mark D. Sanderson, Minnesota State University Moorhead
Marilyn Schlosser
Bradley Stevens, EERC
Richard Sutcliffe
Jib Wilson, EERC
George Youngerman, Rolla Job Development Authority



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June 18, 2013

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
600 East Boulevard Avenue
State Capitol, 14th Floor
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: Final Report Addendum Entitled “Small Wind Turbine Training Center”
Contract No. R002-005; EERC Fund 9961

Enclosed is the technical addendum to the final report submitted on December 30, 2011. The technical addendum is intended to provide updated operational data and summarize the project activities and wind turbine performance after the original contract period. In addition to the technical addendum, a one-page summary has been included. If you have any questions, please contact me by phone at (701) 777-5293 or by e-mail at bstevens@undeerc.org.

Sincerely,

Bradley G. Stevens, P.E.
Research Engineer

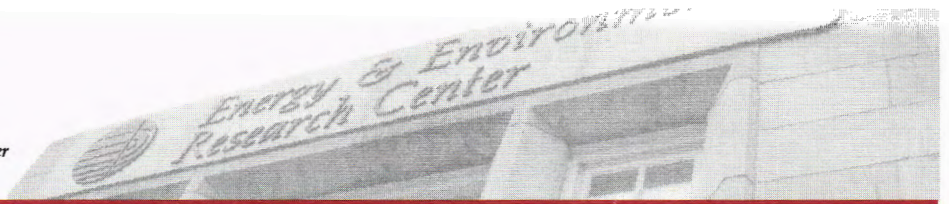
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Enclosure

c/enc: Andrea Holl-Pfennig, North Dakota Department of Commerce



EERC
Energy & Environmental Research Center



SMALL WIND TURBINE TRAINING CENTER

Final Report – Technical Addendum

Prepared for:

Ms. Karlene Fine

North Dakota Industrial Commission
600 East Boulevard Avenue
State Capitol, 14th Floor
Bismarck, ND 58505-0840

Contract No. R002-005

Prepared by:

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15 North 23rd Street, Stop 9018
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2013-EERC-06-04

June 2013

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ACKNOWLEDGMENTS

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SMALL WIND TURBINE TRAINING CENTER

EXECUTIVE SUMMARY

This project involved establishment of the Energy & Environmental Research Center (EERC) Small Wind Turbine Training Center (SWTTC). The SWTTC was funded by the U.S. Department of Energy, the North Dakota Industrial Commission (NDIC) (Renewable Energy Program), and the North Dakota Department of Commerce Division of Community Services and was established to provide a facility to educate people about small wind turbine technology as well as make available a wind energy platform for student research.

The EERC permitted and supervised the installation of an Endurance S-250 5-kW wind turbine at the city of Grand Forks Public Safety Center (GFPSC). Electricity generated is directly used to offset utility-provided electricity for the GFPSC building and operations.

The construction of footings, installation of electrical infrastructure, and installation of the wind turbine took place during the fourth quarter of 2011. The turbine was commissioned and put into service on January 5, 2012.

From January 5, 2012, through November 23, 2012, the wind turbine produced a total of 6346 kWh. The monthly production ranged from a low of 174 kWh in July 2012 to a high of 908 kWh in April 2012. Forward extrapolation of the electrical production data indicates that the wind turbine would have produced approximately 7200 kWh during 2012 had it not gone off-line.

Based on event logs recorded by the wind turbine software, the turbine stopped operating on November 23, 2012. After some troubleshooting, the cause of the shutdown was determined to be a mechanical failure. The turbine remained off-line for the remainder of 2012 and will be repaired as soon as site access allows for the lowering of the turbine (likely early summer 2013).

In addition to the installation and operation of the wind turbine, this project involved the facilitation of three educational events related to wind energy technology and the SWTTC.

The first workshop was held on May 18, 2010, at the EERC in Grand Forks, North Dakota. During the half-day workshop, 40 attendees from North Dakota and Minnesota heard presentations discussing the following topics as well as a question and answer session:

- Introduction, programs, incentives, and wind resource
- Wind turbine installation and maintenance
- Utility interconnection

The second workshop, also at the EERC, was held on March 8, 2011. Again this workshop was a half-day and was attended by 27 people from North Dakota and Minnesota. The same topics were presented in the second workshop.

A third educational event, held on July 17, 2012, was facilitated by the EERC for personnel from the City of Grand Forks. Attendees included personnel from the facility where the turbine is located as well as personnel from the Mayor's Office and Grand Forks Planning and Zoning Department.

SMALL WIND TURBINE TRAINING CENTER

INTRODUCTION

The small wind turbine training center (SWTTC) was established as part of a broader goal to provide educational opportunities to a wide range of participants, including grade school-through college-level students and the general public. In addition, the facility would allow the Energy & Environmental Research Center (EERC) to provide technical training workshops related to the installation, operation, and maintenance of small wind turbines.

The project was executed with funding from the U.S. Department of Energy (DOE), the North Dakota Industrial Commission (NDIC) (Renewable Energy Program), and the North Dakota Department of Commerce Division of Community Services.

This document represents an addendum to that report summarizing the first year of wind turbine operation. A detailed description of the site development and turbine installation was provide previously in a report titled “Small Wind Turbine Training Center – Final Report” dated December 2011, but in summary, the EERC permitted and supervised the installation of an Endurance S-250 5-kW wind turbine at Grand Forks Public Safety Center (GFPSC). The electricity generated by the wind turbine is directly used to offset utility-provided electricity for the GFPSC building and operations. The construction of footings, installation of electrical infrastructure, and installation of the wind turbine took place during the fourth quarter of 2011. The turbine was commissioned and put into service on January 5, 2012.

SITE DESCRIPTION

The wind turbine was installed on the grounds of the GFPSC west of Grand Forks in the Grand Forks Industrial Park (Figure 1). The legal description is Township 151 North, Range 50 West, Section 7, Southwest ¼.

WIND TURBINE DESCRIPTION

The S-250, manufactured by Endurance Wind Power, is a three-bladed, upwind, horizontal-axis wind turbine with a maximum electrical output of 5.0 kW at 14 m/s hub height wind speed. Endurance S-250 specifications are shown in Table 1.

Similar to utility-scale wind turbines, the S-250 utilizes an induction generator to produce grid-quality AC power without the use of an inverter. Typical small wind turbines use a permanent magnet configuration. To improve electrical production efficiency, the S-250 employs a Dual Voltage Switching system that allows the generator to produce 120 volts AC at low wind speeds and 240 volts AC at higher wind speeds. Voltage switching is accomplished with the control system and software, which also prevents excessive voltage switching in variable winds.



Figure 1. Small Wind Turbine Training Center wind turbine location.

Table 1. Endurance S-250 Specifications

Description	SI Units	English Units
Blade Length	2.56 m	8.67 ft
Rotor Diameter	5.5 m	18 ft
Swept Area	23.8 m ²	256 ft ²
Cut-In Speed	4.2 m/s	9.4 mph
Cut-Out Speed	24 m/s	54 mph
Rated Speed	10.7 m/s	24 mph
Rated Power (at rated speed)	4.25 kW	4.25 kW
Estimated Annual Production	11,000 kWh	11,000 kWh

The S-250 wind turbine features dual, redundant braking systems that can be activated either by the system controls or by the operator in any wind conditions. The wind turbine was installed on a 105-foot guyed tilt-up tower. Prior to installation, the S-250 was upgraded with some additional features which essentially made it current with the Endurance Model S-343 (which replaced the S-250 after our original purchase).

WIND TURBINE COMMISSIONING

Once the wind turbine was erected, the tower straightened, and the electrical wiring completed, the commissioning process was performed. During commissioning, it was discovered that a different electrical transformer would be needed for the wind turbine to operate properly, and a delay of approximately 2 weeks occurred until the correct equipment could be installed.

WIND TURBINE PERFORMANCE

The wind turbine was officially put into service on January 5, 2012, without issue. The turbine operated flawlessly from January 5, 2012, until November 23, 2012, at which time the turbine shut down because of a mechanical issue.

From January 5, 2012, through November 23, 2012, the wind turbine produced a total of 6346 kWh. The monthly production ranged from a low of 174 kWh in July 2012 to a high of 908 kWh in April 2012. Table 2 summarizes the monthly electrical production, and Figure 2 shows these data graphically.

Forward extrapolation of the electrical production data indicate that the wind turbine would have produced approximately 7200 kWh during 2012 had it not gone off-line. This is shown in Figure 3, which displays the daily electrical production and the cumulative electrical production of the wind turbine.

Table 2. Endurance S-250 Electrical Production

Month of Operation	Electrical Production, kWh
January	721
February	441
March	871
April	908
May	829
June	452
July	174
August	264
September	546
October	842
November	292
December	0
2012 Total	6340

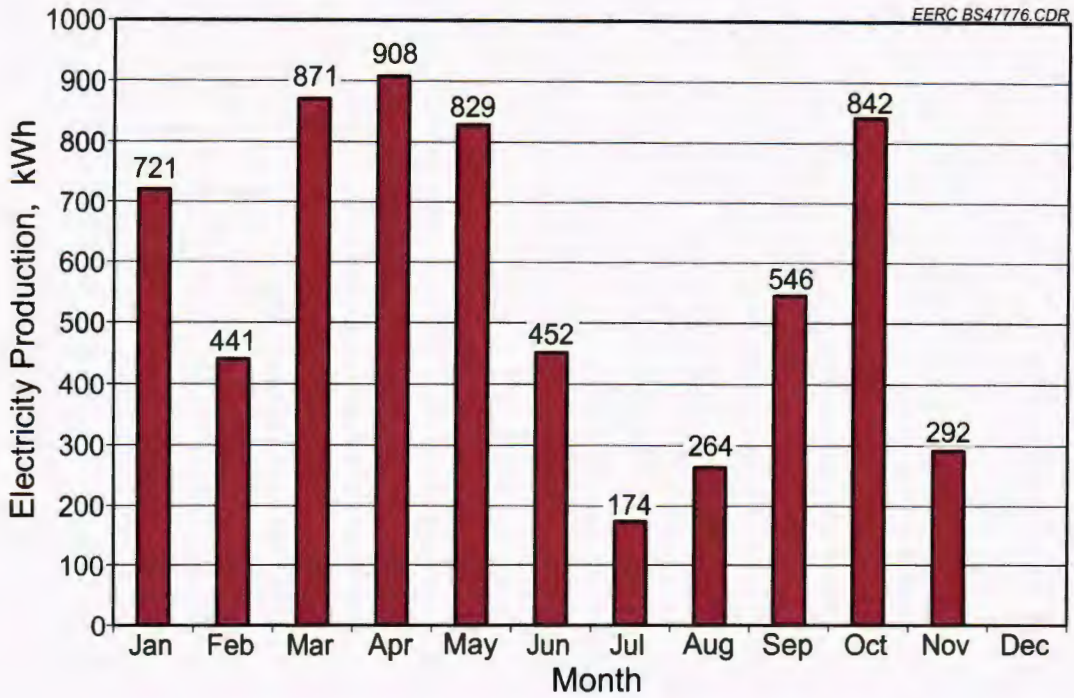


Figure 2. Monthly wind turbine electrical production.

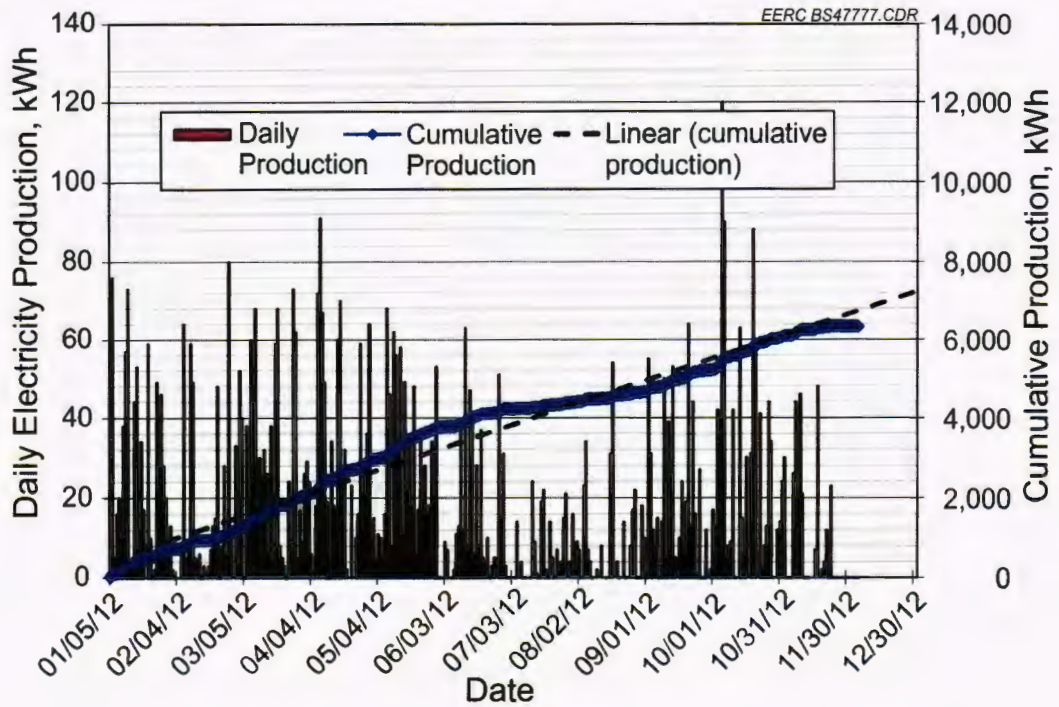


Figure 3. Daily and cumulative wind turbine electrical production.

From December through February, several attempts were made to troubleshoot the problem and restart the wind turbine; none of which was successful. The maintenance contractor was then contacted to schedule a site visit which would involve lowering the turbine, troubleshooting the problem, and taking corrective actions.

Site conditions did not allow for the access to lower the wind turbine until the early summer of 2013; troubleshooting will take place in June 2013. Once the failure has been identified, necessary action will be taken to get the wind turbine running and back online as soon as possible.

EDUCATION AND OUTREACH

Three educational events were held as part of this project to educate individuals regarding small wind turbine technology.

The first workshop was held on May 18, 2010, at the EERC in Grand Forks, North Dakota. During the half-day workshop, 40 attendees from North Dakota and Minnesota heard presentations discussing the following topics as well as a question and answer session:

- Introduction, programs, incentives, and wind resource
- Wind turbine installation and maintenance
- Utility interconnection

The second workshop, also at the EERC, was held on March 8, 2011. Again this workshop was a half-day and was attended by 27 people from North Dakota and Minnesota. The same topics were presented in the second workshop. Final demographic reports for each of the workshops held at the EERC were provided in the previously submitted final report.

A third educational event, held on July 17, 2012, was facilitated by the EERC for personnel from the City of Grand Forks. Attendees included personnel from the facility where the turbine is located as well as personnel from the Mayor’s Office and Grand Forks Planning and Zoning Department.

FINANCIAL PROJECT SUMMARY

Funding Source	Budget	Expended	Difference
NDIC	\$50,000.00	\$49,995.34	\$4.66
DOE	\$50,000.00	\$51,116.00	(\$1,116.00)
Total	\$100,000.00	\$101,111.34	(\$1,111.34)