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Reliability Program Goals and Status; Purpose of the Workshop

2007 Wind Turbine Reliability Workshop

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Reliability Program Guiding Principles

The mission is to:

- ***Lead the nation's efforts to improve wind energy technology***
- ***Work through public/private partnerships that enhance domestic economic benefit from wind power development, and***
- ***Coordinate with stakeholders on activities that address barriers to wind energy use.***

Reliability is Important

Recognized Need for Improved Reliability

- **Industry and others have acknowledged the importance of reliability in the continued growth and expansion of markets for wind turbine technology**
- **Critical for hostile environments and the impacts are broad, ranging from economics to advancement of designs.**
- **Increased efforts in reliability research and resultant R&D improvements will lead back to wind turbine design, operations, and maintenance**

The value comes in having the opportunity to do something to prevent the failure from occurring…Thus prediction becomes part of the process of "designing the future"

Introduction of Staff and Other Resources/Partners

- **Staff/Contract Resources Obtained in 2006**
  - **Jennifer Stinebaugh**
  - **Dan Briand**
  - **ARES corporation**
  - **Global Energy Concepts**
- **Other Sandia Personnel**
  - **Wind Energy Technology, Dept. 6333**
  - **Energy and Infrastructures Futures Center**
- **DOE/National Renewable Energy Laboratory**

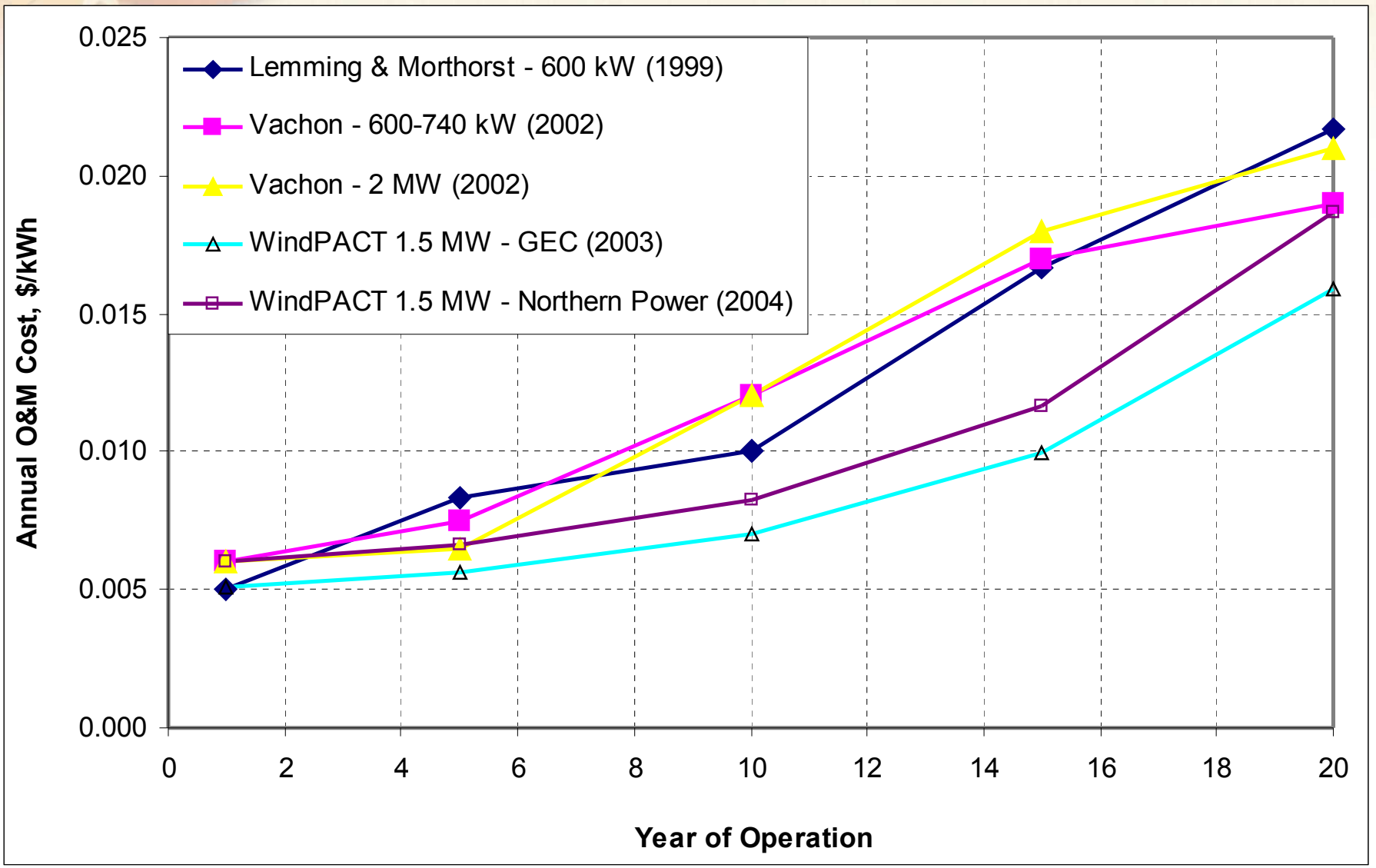
Objectives

- Establish industry benchmarks for reliability performance
- Identify failure trends
- Identify industry reliability improvements over time
- Provide high quality information to support operational and maintenance practices
- Improve system performance of wind assets through better asset management practices

Wind Turbine Reliability Analysis Status

- Current effort started in FY 2006
- Hosted the 2006 Wind Turbine Reliability Workshop
- Published *Wind Turbine Reliability: Understanding and Minimizing Wind Turbine Operation and maintenance costs Sand2006-1100*
- Participated in interviews, site visits, meetings, etc.— of special note:
  - AWEA O&M Working Group
  - UWIG O&M working Group
- Data Plan
- Sought Data Partners
- Database Design
- Initial Modeling results
- Publish Report on Wind Systems Reliability Analysis

Relative Cost of O&M?



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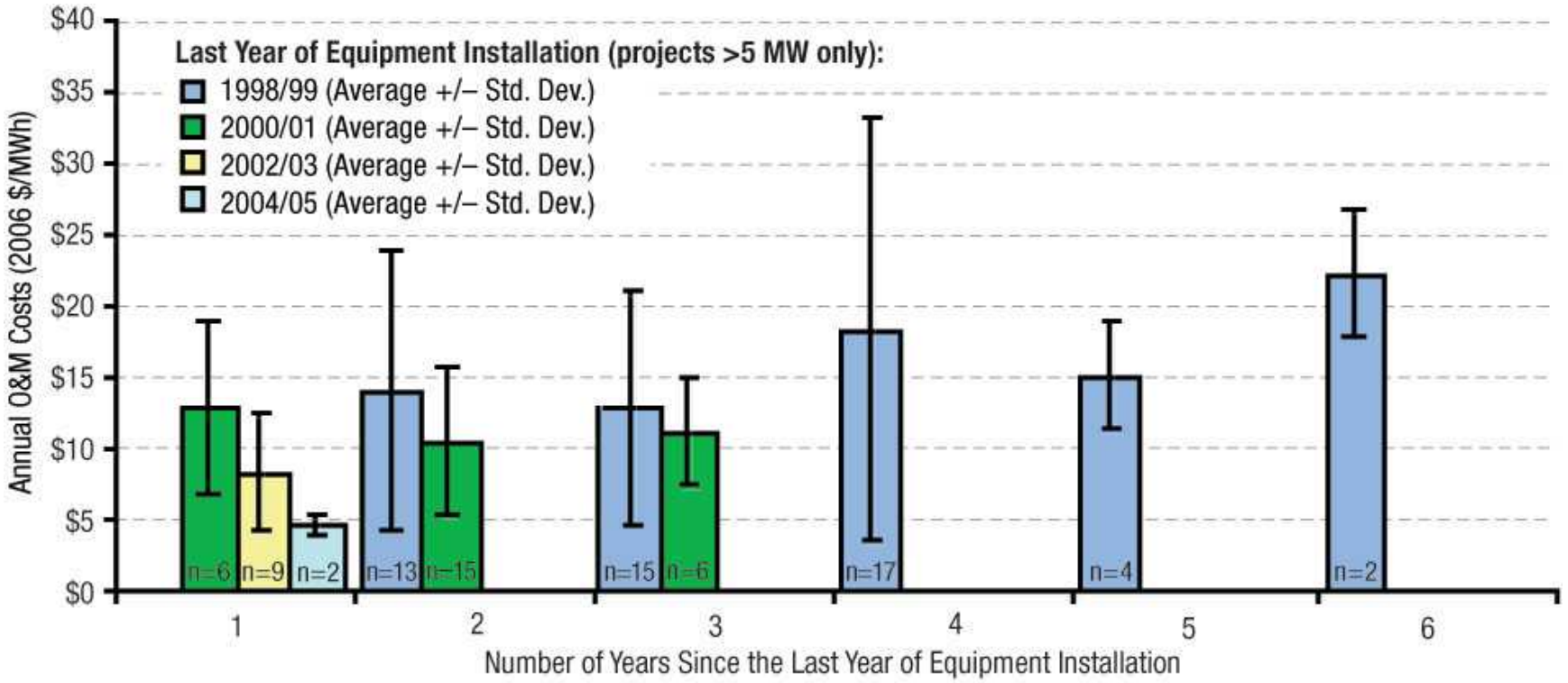
Annual Average O&M costs, by Project Age and last Year of Equipment Installation



Source: Berkeley Lab database; averages shown only for groups of two or more projects.

Note: Sample is extremely limited; figure only includes projects over 5 MW in size and built from 1998-2005

United States Wind Power Rankings: The Top 20 States

Table 2. United States Wind Power Rankings: The Top 20 States

Cumulative Capacity (end of 2006, MW)		Incremental Capacity (2006, MW)		Approximate Percentage of Retail Sales*	
Texas	2,739	Texas	774	New Mexico	7.3%
California	2,376	Washington	428	Iowa	6.0%
Iowa	931	California	212	North Dakota	5.1%
Minnesota	895	New York	185	Wyoming	5.1%
Washington	818	Minnesota	150	Minnesota	3.8%
Oklahoma	535	Oregon	101	Oklahoma	3.5%
New Mexico	496	Kansas	101	Montana	3.3%
Oregon	438	Iowa	99	Kansas	3.1%
New York	370	New Mexico	90	Oregon	2.4%
Kansas	364	North Dakota	80	Texas	2.3%
Colorado	291	Oklahoma	60	Washington	2.3%
Wyoming	288	Colorado	60	California	2.1%
Pennsylvania	179	Pennsylvania	50	Colorado	1.7%
North Dakota	178	Hawaii	41	South Dakota	1.5%
Montana	146	Montana	9	Nebraska	1.0%
Illinois	107	Maine	9	Hawaii	1.0%
Idaho	75	Massachusetts	2	Idaho	0.7%
Nebraska	73	New Hampshire	1	New York	0.6%
West Virginia	66	Rhode Island	0.7	West Virginia	0.6%
Wisconsin	53	Ohio	0.2	Pennsylvania	0.3%
Rest of U.S.	156	Rest of U.S.	0.3	Rest of U.S.	0.02%
TOTAL	**11,575**	**TOTAL**	**2,454**	**TOTAL**	**0.85%**

*Assumes that wind installed in a state serves that state's electrical load; ignores transmission losses.

Source: AWEA/GEC database and Berkeley Lab estimates.

New Mexico leads the Country in the approximate percentage of retail sales

About 1/3 of the way to 20% wind penetration!

Source: LBL

Reliability definitions

Reliability $R(t) = e(-t/MTBF)$

Where reliability is a function of the failure rate (the reciprocal of the mean time between failures (MTBF)

MTBF MTBF=Operational Time/# of failures

A principle system performance measure is system MTBF. The MTBF can be calculated as the total operational hours accumulated for a given component divided by the number of component failures

MTTR MTTR=Total repair time/# of failures

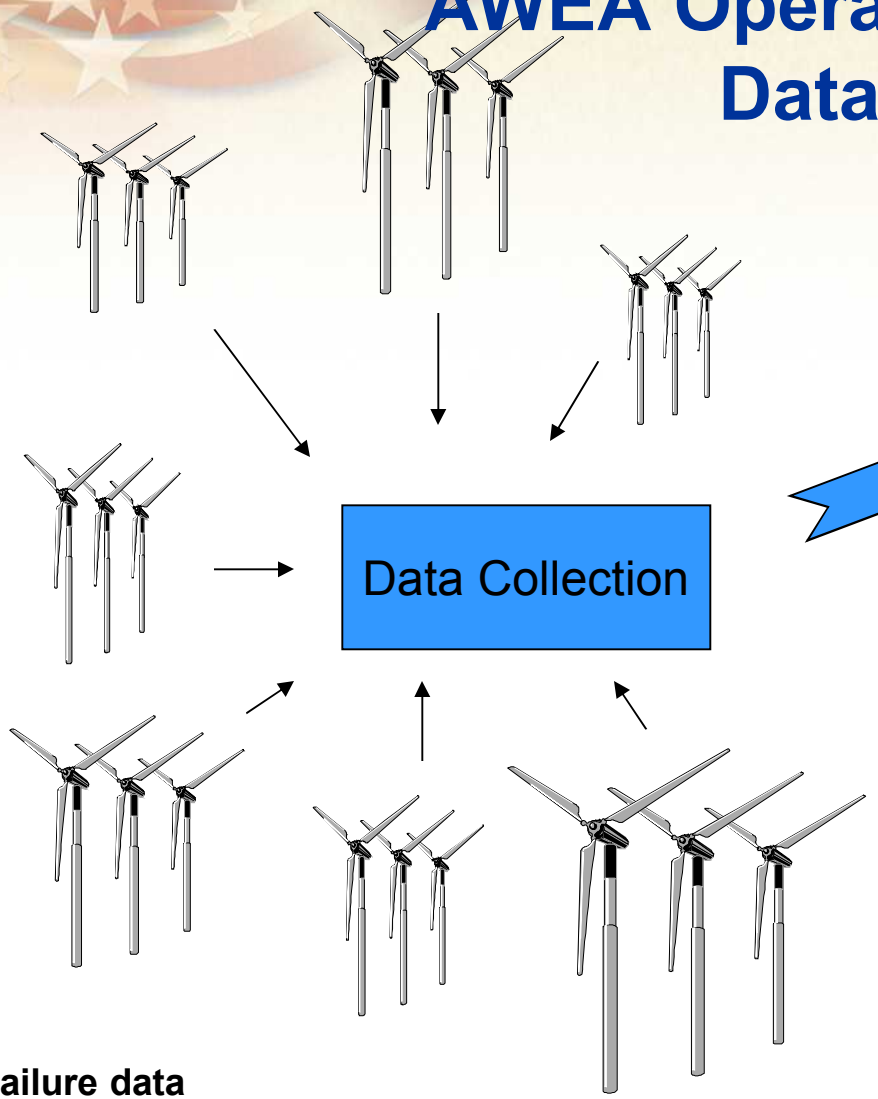
The mean time to repair metric is the average time for a repair or replacement to be made divided by the number of failures for a given component.

Availability Availability (A)= MTBF / MTBF + MTTR

However, it is Availability that is the reliability metric that is most significant in the operations of wind plants. Availability is often expressed as a percentage and it is the amount of time that a system or component is available for use divided by that total amount of time in the period of operation.

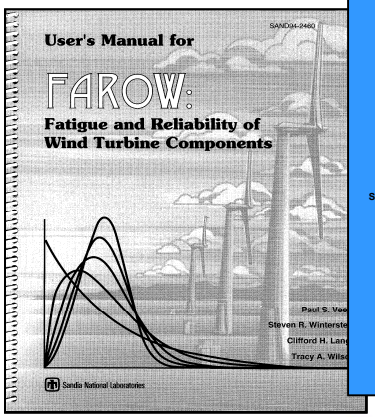
Availability is most closely related to energy production and revenues so it is of paramount importance in the operation of a wind farm.

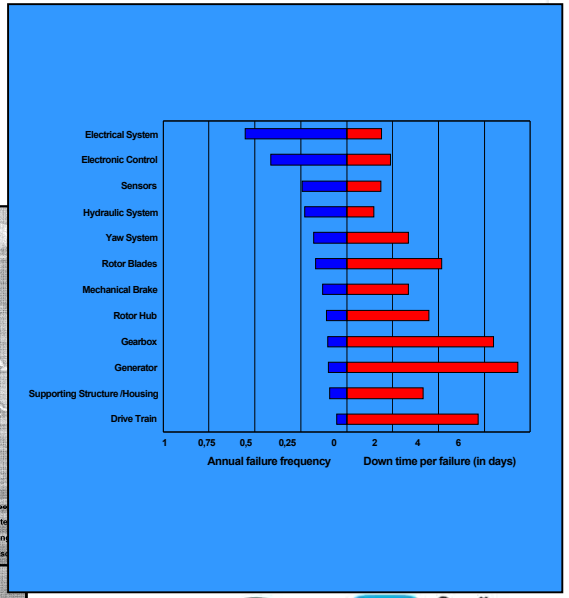
AWEA Operators O&M Working Group
Data Collection and Reporting



Data Collection

Database, Analysis





Failure data
Repair / Replacement data
Performance data
Power/loads
Condition monitoring

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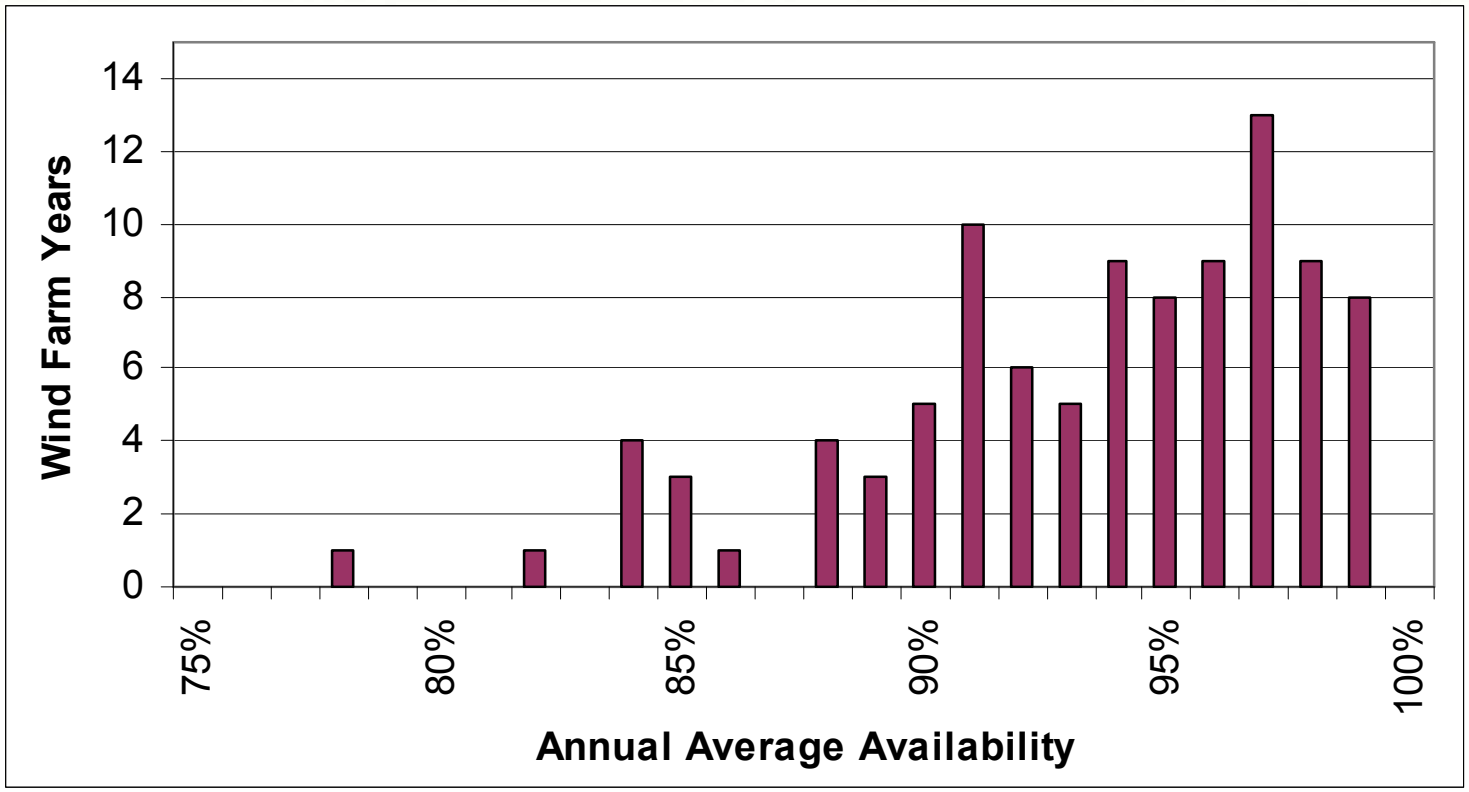
Failure Rates

- IEEE Goldbook
  - Component
  - Unit-Years
  - Failures
  - Failure rate (failures/year)
  - MTBF
  - MTTR
- Barringer
- Global Energy Concepts
- Industry Discussions

Survey Results: Availability



Source: GEC

Our Objective is to Create a National Reliability Database (NRD)

Wind Farm 1 | Wind Farm 2 | Wind Farm 3 . . . Wind Farm n

SCADA - A | SCADA - B | SCADA - B | SCADA - Z

Maintenance records

Central Data Storage

- Multiple wind farm support
- Multiple SCADA vendor support
- Electronic data transfer capability
- Paper repair history capability
- Anonymous industry reporting

Reliability
Farm 1 vs. Avg.

Reliability
Farm 2 vs. Avg.

Reliability
Farm 3 vs. Avg.

Reliability
Farm n vs. Avg.

NNSA National Nuclear Security Administration

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Looking Ahead for System Reliability
Analysis, Performance, and Validation

- Gearbox Reliability Collaborative
- Bearing Rating and Design Standards
- Blade Reliability Collaborative
- Operations and Safety Research
- Reliability database and System Analysis
- Generator Reliability Collaborative
- Reliability Centered Wind Plant Health Monitoring