

Expanding CREW to national fleet representation leveraging detailed technology studies

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Agenda

- Objectives for a growing CREW
- CREW in A2e context
- CREW Evaluation process and justification
- Specific work packages under CREW
- Discussion

Continuous Reliability Enhancement

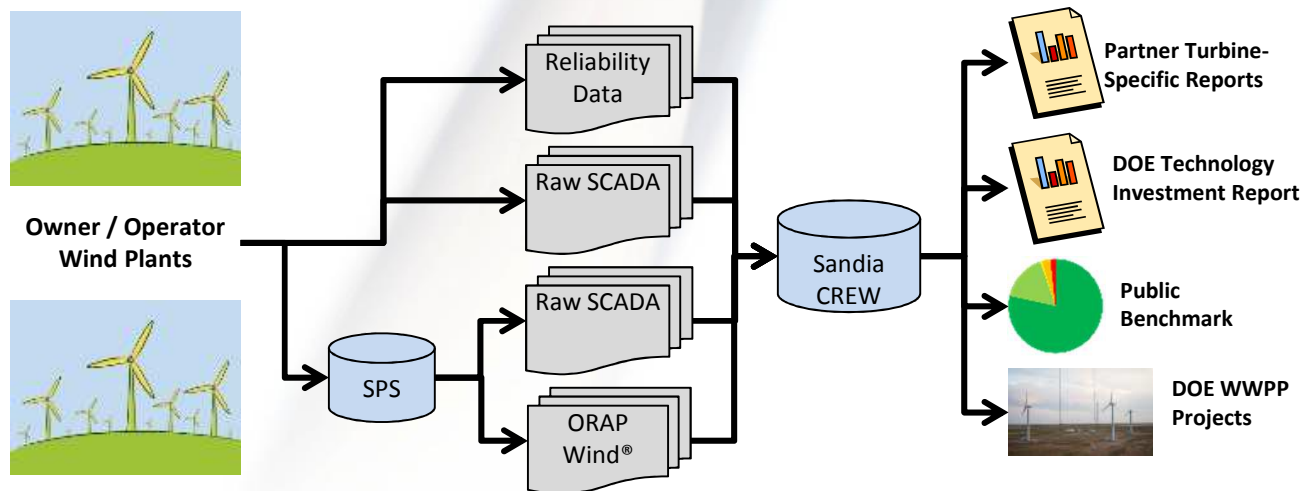
- Improve US wind fleet reliability through strategic technology improvements driven by an extensive quantitative baseline of performance and reliability
- Strategic technology improvements are accomplished by:
 - Establishing a US Wind Fleet Benchmark that can be used to drive DOE Technology Investments and as a baseline to which owner/operators can identify improvement opportunities.
 - Deep technical analysis of a few wind farms to provide performance and reliability tools and model validation, root cause analysis of failures and research on operations.

CREW Benchmark Plans (Thrust 1 of 2)

Goal 1: Decrease uncertainty and cost of wind energy (capital and operations and maintenance - O&M) through performance and reliability analysis of an elaborate national database of wind plant operating, maintenance, and cost data

Key Objectives

1. Capture and store wind plant O&M and cost data in a national database that protects proprietary information
2. Create a national benchmark of US wind reliability, cost, and O&M performance
 - a) Identify and quantify DOE technology improvement opportunities (TIOs)
 - b) Enable O&M comparisons at levels of plant, turbine and components, solutions, and cost reduction
 - c) Provide unbiased assessment to increase confidence from financial sector and policy makers



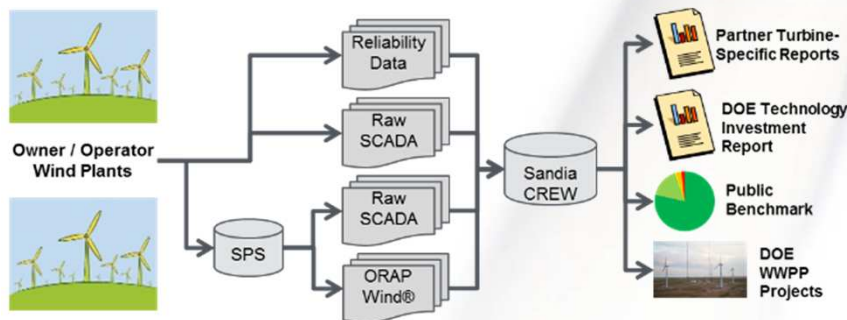
CREW Technology Plans (Thrust 2 of 2)

Goal 2: Explore methodologies and technology achievements assisted by the reliability data base

Key Objectives

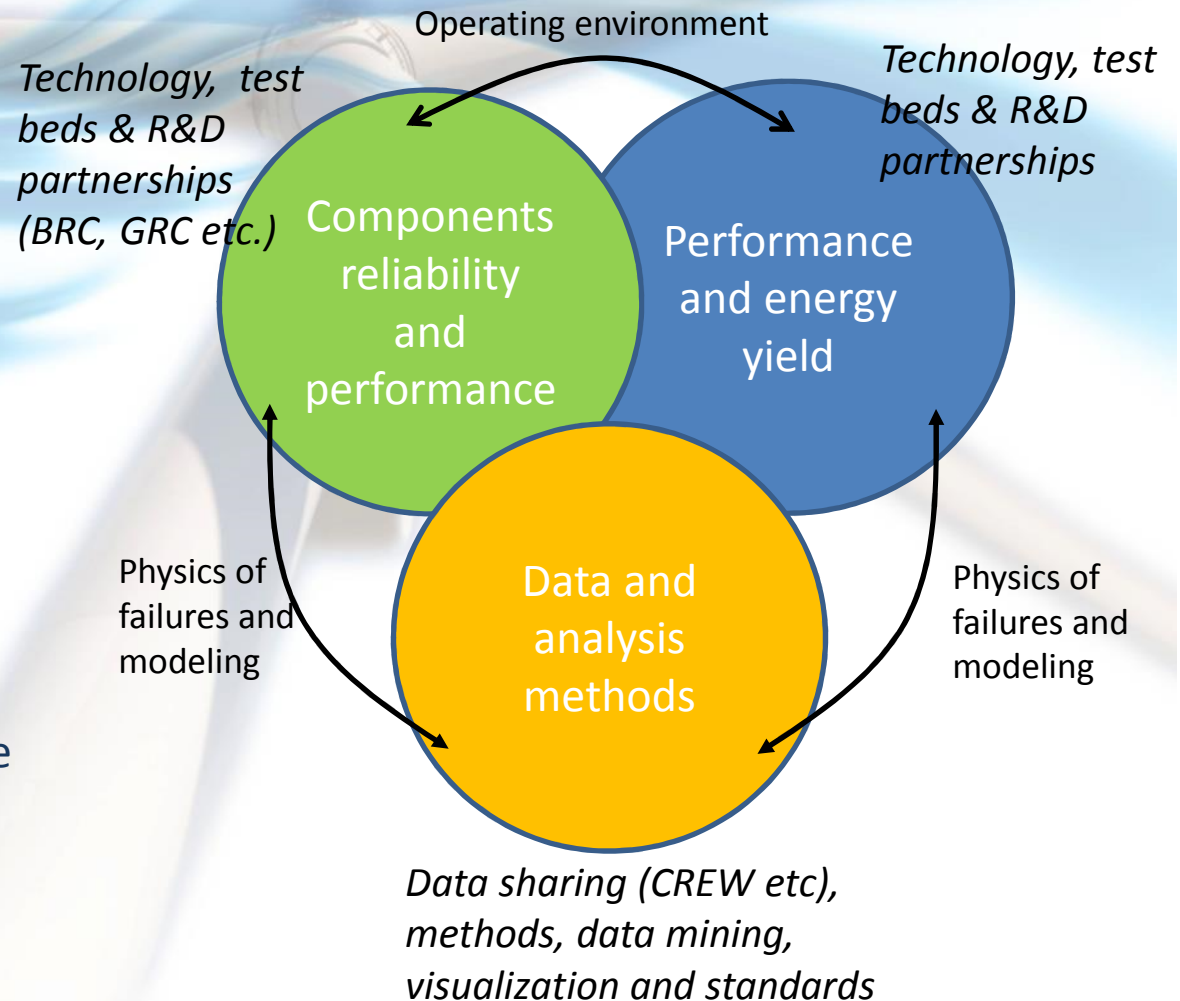
1. Fully capitalize on the CREW data through analysis of advanced wind plant performance, including turbine-to-turbine interaction and lessons learned at SWIFT transformed to full-scale
2. Combine the reliability data with advanced full-scale turbine performance measurements and simulations, uncovering technical root-causes in greater details
3. Perform Root Cause Analysis for wind turbine failures

New insight and results



Structuring CREW in a larger context under A2e

- There is an opportunity to structure reliability and performance work, extracting physical models into improving
 - Data analysis
 - Methods
 - Visualizations
 - Standards
- The physics should come from
 - NREL GRC / O&M Database
 - SNL BRC
 - SNL SWIFT
 - Etc.
- This could benefit the owners on a higher level providing more refined data analysis toolsets



CREW Evaluation Process

- Two tracks were proposed to stakeholders, emphasizing that either one, both, or neither could be done:
 - A) CREW grows as a national benchmark with increased relevance to stakeholders
 - B) CREW becomes a technology platform to develop tools with and for stakeholders
- Sandia initiated the reassessment through internal / external audit of the CREW project and collecting feedback from stakeholders
 - Early evaluation: Jon White and Carsten Westergaard
 - Meetings with 12 owner/operators, 3 OEMs and 2 industrial consultants
- NREL (Paul Veers, Shawn Sheng, Jonathan Keller) and Sandia (Josh Paquette, Jon White, Carsten Westergaard, Valerie Hines) met in November to discuss reliability projects, collaboration and future plans

Feedback Highlights

- **Owners are developing in-house reliability & cost monitoring, data mining, and in some instances condition monitoring**
 - **Main objectives are:**
 - Increasing power performance yield
 - Decreasing risk by increasing certainty in future performance (business case certainty)
 - Understanding variability across models and geographical location - just as important (if not more) than average reliability
- **Benchmarking is highly desirable** to assist the above objectives
 - Ideally with **more details** and cost data included (though it may not be uniformly available)
 - Balance of plant (BOP) components are just as important as the turbines
 - User groups, for example across turbine models, is also highly desirable
 - Two major owners offered to “pressure” others to participate, if any reluctance for participation is observed
- Majority of reliability costs can be subscribed to large events; minority is from frequent little faults that are minor in cost
- **Owners are moving away from availability towards energy availability**
- **There is a real need for technology developments (i.e. new data mining algorithms, performance optimization etc.)**
- OEMs still hard to motivate for participation. This is possibly even more difficult now, due to their increasing interest in long term service contracts (although logic should dictate interest)

Extensive CREW benchmark supports owners and DOE objectives

- An extensive benchmark can give the owner invaluable statistical insight beyond their limited number of wind farms:
 - Rare and expensive events that happen a few times a year in individual farms
 - Aging data across the US fleet, with turbine model breakout
 - Future business case certainty
 - Potential mitigation
- Business case certainty drives LCOE both from a CAPEX and OPEX perspective
- The owners' goals are identical to DOE objectives
- Positive feedback from summarized data request

CREW Stakeholder Map

	Benchmark with higher % representation	Benchmark with cost data	Technology platform, Performance, rotor, wakes	Technology platform, Reliability: BRC, GRC etc.
DOE	Indirect LCOE Fleet reliability Public advocate Technology directions	Direct LCOE mapping (CAPEX and OPEX)	Direct support of owners primary concern: yield	Direct support of owners secondary concern: future reliability Direct guidance to subsuppliers and service providers (=US jobs)
Financial	Industry confidence Factual data	Business case certainty results in better financial deals	N/a	N/a
Owner / Operators	Business case certainty Benchmark operation results Benchmark fleet User groups		Advanced tools to manage and monitor yield Better farm management Better future layout	Advanced tools to manage reduce future O&M and monitor fleet & service providers
OEMs	Future customer satisfaction as benchmarking will drive better products	Benchmark service products against others	Opportunity to advance products in CRADA's or in a proprietary context	Opportunity to support the growth of a better supplier platform and better standards
Service providers and component suppliers	Benchmark service products against others		Infrastructure to verify development of better products and services for the industry	
Research	Avoid mis-directed research projects	Quantify research	Application of advanced know-how to real(time) data	

Conclusion on evaluation

- The original plan for growing CREW has been overtaken by a fast growing fleet, a lack of robust growth in SPS' ORAPWind user base, and large fleet owners who are collecting these data themselves
- There is an opportunity to capitalize on the work done by the large owners, by collecting much more pre-summarized data **without significant budget impact** (versus direct data streaming and summarizing within CREW which is very expensive)
- Owners are very willing to participate and share if Sandia is collecting the data
 - Owners want and will support an auditing procedure to review how data is collected and processed, as this supports alignment of benchmarking
- Technology-specific results are equally important to a benchmark and collaboration with key owners could prove very synergetic for the A2e program
 - Yield performance (wakes and power analysis) and also new data mining methods

Planned Benchmark Work

- Year 0 (Q2 – Q4 FY14)
 - Transition to Summary-Data-Driven Report
 - Summarized data submission design and agreement
 - Pilot partner onboarding
 - Partner-Specific Reports with preliminary results
 - Hybrid Public Benchmark (determined on ability to reduce “Other” category)
 - Out-year scoping and Assessment of resource needs
- Year 1 (FY15)
 - Expansion of Summary-Data-Driven Report
 - Expansion to many partners and technologies (+30% wind fleet)
 - DOE Technology Investment Report
 - Partner-Specific Reports
 - Public Benchmark
- Year 2 (FY16)
 - Standardization of Summary-Data-Driven Report
 - Standardization of Benchmark (potential to represent majority of fleet)
 - DOE Technology Investment Report
 - Partner-Specific Reports
 - Public Benchmark

Summarized Reliability Data - Owner/Operator Request (work in progress)

- Key input areas:
 - Plant Overview
 - Plant Geography (from a predefined list)
 - Maintenance Provider Type
 - Turbine OEMs
 - Major Component OEMs
 - Wind Class
 - Location (latitude, longitude, elevation)
 - Etc.
 - Event Summary
 - Subsystem/Component
 - Event Type (IEC categories – scheduled, forced, out of spec, etc.)
 - Statistics on
 - Time Between Events (related to Event Count)
 - Event Duration
 - Energy Lost
 - Cost (may be “cost category” depending on info available)
- Potential partners have already reviewed and initial feedback is incorporated

Planned Technology Work

- Year 0 (Q2 – Q4 FY14)
 - Pilot Wind Plant Reliability and Performance Analysis
 - Subject: proprietary wind farm
 - Continue Normalized Power and Variability Analysis
 - Wind Speed Observer (use of correlation with surrounding wind turbines)
 - Analyze additional sensor information which may be needed
 - Evaluate higher sampling rate data (limit of 1-2 Hz)
- Year 1 (FY15)
 - A2e / NREL RFI for Study Wind Plants / Wind Plant Reliability and Performance Analysis
 - Work with A2e / NREL to hypothesize a set of ideal wind plants using IEA Wakebench breakdown
 - Use lessons learned from CREW to set requirements and improvements needed for wind plant
 - Execute RFI / RFQ to setup test case wind plants (potentially public) and long process to make them of value to researchers
 - Continue to develop methods and begin to transition to a tool with NREL
 - Field Operations Research hardware in test case wind farms (hand held tablets)
- Year 2 (FY16)
 - 2-3 Cases of Wind Plants Operations Research, Reliability and Performance Analysis
 - Test case wind plants fully operational with research quality data
 - Initiate Operations Research
 - First version of Wind Plant Performance Tool Released jointly by NREL / SNL
 - Continue to develop methods for performance and reliability

Discussion

- Feedback
- Partnership / collaboration proposals:
 1. Develop a shared database for all DOE reliability information (CREW, GRC and BRC) with direct access by DOE, NREL, SNL,...?
 2. Unified data request with preface for CREW, GRC and BRC to eliminate confusion of external entities.
 3. Collection of cost data in unified data request to support O&M cost models
 4. Work together on RFI and RFQ to select wind plants for detailed analysis.