Atmosphere to electrons (A2e)
Overview

Wind & Water Power Technologies Office
Shreyas Ananthan
What is A2e?

1. A Research Initiative targeting Wind Plant Optimization to enable low cost wind energy

2. A Novel DOE Management Construct to engage diverse expertise and stakeholder groups
Motivation for A2e

The largest remaining opportunities to reduce LCOE will come from advances in total wind-plant system design & operation.

Consider the following challenges facing modern wind power plants:

- Wind plant energy losses of 20% or higher.¹²,³
- Major components not meeting 20-year design life.⁴,⁵
- Investment risk has inflated the cost of capital.⁶
- Inaccurate forecasts cost industry $300M+/year.⁷
Desired Goals and Objectives

**Challenges**

Wind plant energy losses of 20% or higher

Major components not meeting 20-year design life

Investment risk has inflated the cost of capital

Inaccurate forecasts cost industry $300M+/year

**Plant Optimization Objectives**

- Increase Plant capacity factors from 0.39 to 0.50
- Reduce losses from 20% to 12%
- Extend component/system design life from 20 to 30 years
- Reduce installed capital costs from 1615 to 1454 $/kW
- Reduce cost of capital (WACC) from 8.5% to 7.5% for land (larger opportunity for OSW)
- Improve day- and hour-ahead forecast accuracy by 10-20%

**A2e LCOE Impact**

$65/MWh to $42/MWh (39% reduction from 2014 to 2030)

Note: Starting points and trajectories (2014-2030) for A2e objectives and LCOE targets are from the 2014 NREL LCOE Memo to WWPTO, which builds from the Wind Vision study, the 2013 Wind Market Report, and WWPTO LCOE analysis.
Attaining these objectives will require a shift in R&D focus

**Yesterday**
(Individual Turbines)

**2015-2021 (and beyond)**
(Smart Wind Plants)

**Individual wind turbine R&D**
- Turbine and rotor scaling driving LCOE reductions
- Well defined design process and value engineering
- Mature wind turbine industry

**Wind plant optimization R&D**
- Design for operation at optimal project profitability and Internal Rate of Return (IRR)
- Develop new technologies that exploit interactions among turbines, resource, & operating environment
A shift in R&D focus requires a *Novel DOE Management Construct*

Implementing A2e will require a focused, multi-year, multi-stakeholder, R&D effort lead and supported by DOE.

**Atmosphere to Electrons (A2e)**
- DOE lead partnership with National Laboratories, Universities, Industry
- Integrated strategic research planning coordinated through lead National Labs & DOE
- Research activities conducted by most appropriate stakeholder
- Center construct with 5-7 year anticipated duration

**DOE Wind Program**
- Federal Engagement & Oversight
- Integrated Program & Project Management
- Budgetary Control

**National Labs & Universities**
- Subject Matter Expertise
  - Project Planning
  - R&D Execution

**Other Fed Agencies**
- Leverage Strategic Programs
- Access to HPC Core Competencies
- Subject Matter Expertise

**Private Industry**
- R&D Execution
- Operational Expertise
- End User Requirements
- Access to Operating Plants

**Int’l Collaboration**
- Coordinated & Collaborative Research Campaigns

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A2e management construct

Executive Management Committee (EMC)

**Director:** Mike Robinson, DOE IPA

**DOE Reps:** Mike Derby, Joel Cline, Shreyas Ananthan

**National Lab:** Veers (NREL), Shaw (PNNL), Laird (SNL)

- Provides vision & direction and coordinates integrated program planning activities
- Develops and “owns” A2e integrated, multi-year strategic plan
- Conducts formal quarterly reviews of all R&D planning and project performance
- EMC members assigned to each A2e focus area

R&D Implementation Organizations

- EMC plans and coordinates R&D, does not execute
- R&D organized around Strategic Focus Areas
- Research conducted by domain experts and expected to include a diverse group of industry stakeholders and research organizations

External Merit Review Board

- External assessment of A2e performance and impact on industry
- Constituency includes senior representatives from industry, national laboratories, academia, government agencies, and international stakeholders
- Members meet with A2e leadership on an annual basis to provide an outside perspective on strategic priorities

Continuous Implementation Process
I. Implement Formal Verification & Validation Framework (V&V)
   ➢ Must start with a systematic approach to ID physics gaps, uncertainties, and instrumentation requirements

II. Kick-off high fidelity physics modeling activities
   ➢ ID starting point, personnel, and availability of HPC resources
   ➢ Develop open HFM architecture that is scalable and relevant
   ➢ Benchmark state-of-the-art high fidelity modeling approaches
   ➢ Preliminary code comparison & validation efforts.

III. Conduct initial field experiments and instrumentation assessment
   ➢ LIDAR and instrumentation capabilities assessment project
   ➢ Launch Wind Forecasting Improvement Project II (WFIP II)

I. Conduct detailed field measurement campaigns
   ➢ Conduct experiments at SWIFT, beginning with a detailed investigation of the near-wake region and proceeding to more complex physics
   ➢ Begin data collection for WFIP2
   ➢ Continue instrumentation development and assessment

II. High fidelity modeling utilizing high performance computing
   ➢ Multi-lab, multi-stakeholder code development and model comparison
   ➢ Evaluate control strategies that enhance wind plant performance
   ➢ Evaluate plant designs and layouts

III. Define path from new physics to technology innovations
   ➢ Define linkages between model results and technology pathways for reducing LCOE

I. Partner With Industry to Develop New Technology
   ➢ Integrated wind plant level control systems with sophisticated dispatch strategies
   ➢ Advanced sensing technologies and real-time flow monitoring
   ➢ Adaptive rotor technology that mitigates loads and extends design life while reducing failure rates
   ➢ Short-term forecasting tools that ensure high reliability dispatch.
A2e Perspective on Systems Engineering

What should the SE community start thinking about in coming years?

- A validated hierarchy of models that captures critical system-level interactions for the desired application
  - A2e is not just building models, but wants to back everything with confidence levels and validation

- Development of methodologies and best practices to assess uncertainty, as well as the impact of uncertainty on design and operational decisions
  - Turbine design, plant siting, and operational processes
  - Impact of plant level objectives/constraints on turbine design process

- The appropriate role of SE for plant operations and reliability improvements
  - Potential upgrades to existing plants
  - Plant control strategies to address siting issues or resource variability

- Integrating Wind into the Grid in the most effective manner
  - Grid integration and improving the overall value of wind to the grid
Appendix


10. Internal Wind Program Analysis, DOE and NREL, 2014.

FY14 and FY15 Activities

FY14 Emphasis – Stakeholder Engagement and Strategic Plan Development

- **Focus Area Workshops**
  - High-Fidelity Modeling, Experimental Measurement Campaigns, Verification & Validation
  - Advanced Controls, Plant Reliability, & Aeroacoustics
  - Performance Risk, Uncertainty, and Finance (PRUF)
  - Data Archival and Portal

FY15 emphasis on V&V framework, initial experiments and modeling

- **V&V Framework Development**
- **Wind Forecasting Improvement Project (WFIP) II**
- **Experimental PBL Instrumentation Assessment (XPIA)**
- **Code Comparison for Meso-Micro Coupling Approaches**
- **Near-Wake Experimental Campaigns – Wind Tunnel and SWiFT Scale**

**Upcoming Workshops**
- Integrated Wind Plant Design & Analysis (Jan. 16)
- High-Fidelity Modeling Simulation Environment Workshop (Jan. 27-28)
- High-Fidelity Modeling Needs Workshop (Feb. 24-26)
Initial, High Priority Strategic Planning Areas

### Strategic Planning Areas

1. **Financial Risk, Uncertainty, and Portfolio Analysis**
   - John Meissner (DOE Contractor)

2. **High Fidelity Modeling**
   - Dr. David Womble (SNL), Dr. Steve Hammond (NREL)

3. **Experimental Measurement Campaigns**
   - Dr. Scott Schreck (NREL), Dr. Jon White (SNL)
   - Dr. Jim Wilczak (NOAA)

4. **Data Archive and Portal**
   - Chitra Sivaraman (PNNL)

5. **Integrated Wind Plant Control**
   - Dr. Kathryn Johnson (Colorado School of Mines/NREL)
   - Dr. Dave Wilson (SNL)

6. **Wind Plant Reliability**
   - Dr. Carsten Westergaard (SNL Contractor)
   - Dr. Jonathan Keller (NREL)

7. **Aeroacoustics and Propagation**
   - Dr. Pat Moriarty (NREL)

8. **Integrated Wind Plant Design and Analysis**
   - Acting Lead, Dr. Shreyas Ananthan (DOE)

- High priority R&D areas that need accelerated planning to align with A2e objectives
- Each has external Planning Group, with appointed Chair
- Cross-cutting activity planning is the key benefit of a consortia “wind plant systems” approach
- In the completed integrated strategic plan, must directly link these initial R&D thrust areas to LCOE-driven objectives and desired outcomes.
# Input from Senior Industry Leaders

**External Merit Review Board**

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<tr>
<th>Name</th>
<th>Organization</th>
<th>Role</th>
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<tbody>
<tr>
<td>Bill Mahoney</td>
<td>NCAR</td>
<td>Academic R&amp;D (Atmospheric Science)</td>
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<tr>
<td>Peter Hauge Madsen*</td>
<td>DTU</td>
<td>Academic R&amp;D (Wind Energy R&amp;D)</td>
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<tr>
<td>Jim Lyons</td>
<td>NOVUS</td>
<td>Investor</td>
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<td>Erik White</td>
<td>JPMorgan</td>
<td>Investor</td>
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<td>Mark Jonkhoff</td>
<td>GE</td>
<td>OEM</td>
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<td>Henrik Stiesdal*</td>
<td>Siemens</td>
<td>OEM</td>
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<tr>
<td>Sandy Butterfield (Chair)</td>
<td>BWP / AWEA</td>
<td>OEM, standards, AWEA</td>
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<tr>
<td>Dan Brake</td>
<td>NextEra</td>
<td>Owner/operator</td>
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<tr>
<td>Robert Poore</td>
<td>DNV</td>
<td>Service provider (Due diligence)</td>
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<tr>
<td>Bruce Bailey</td>
<td>AWS TruePower</td>
<td>Service provider (Forecasting)</td>
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<tr>
<td>Charlie Smith</td>
<td>UVIG</td>
<td>Utility integration</td>
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A2e – Integrated Execution Framework

Wind Technology Program Manager

Mike Derby, DOE HQ

A2e Executive Management Committee

Director: Mike Robinson (DOE IPA)
Atmospheric Science: Joel Cline & Will Shaw
Wind Plant Aerodynamics: Shreyas Ananthan & Daniel Laird
Technology Development: Mike Derby & Paul Veers

Lead Laboratories

Atmospheric Science: PNNL (Will Shaw)
Wind Plant Aerodynamics: SNL (Daniel Laird)
Technology Development: NREL (Paul Veers)

R&D Execution

Lead Labs coordinate the R&D, but the actual research will be conducted by appropriate stakeholders including national Labs, universities, manufacturers, gov’t agencies, owners, operators, international entities, etc.

- EERE Senior & Executive Management Reporting
- Strategic planning and fiduciary responsibility

- Multi-year strategic program planning
- Establish R&D priorities and implementation strategy
- Stakeholder coordination & leveraging
- Coordination of multiple research initiatives
- Continuous oversight and integrated management to achieve programmatic goals and objectives

- R&D activity and implementation planning
- Coordinate research across technical areas
- Ensure research is conducted by the best entity for the job

Atmospheric Science
- Foundational R&D – Modeling & Validation
- Smart Wind Plant Technology Innovations

Wind Plant Aerodynamics

Technology Development

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