TECHNOLOGY
INSIGHTS

2008 Update to the EPRI-DOE Handbook Supplement of Energy Storage for Grid Connected Wind Generation Applications

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Background/Terminology

- 2003 - EPRI-DOE Handbook of Energy Storage for Transmission & Distribution Applications, 1001834
  - **“The Handbook”**
- 2004 - EPRI-DOE Handbook Supplement of Energy Storage for Grid Connected Wind Generation 1008703
  - **“Wind Supplement 2004”**
- 2008 Update to the EPRI-DOE Handbook Supplement of Energy Storage for Grid Connected Wind Generation Applications
  - **“2008 Wind Supplement Update”**
  - **“This Update”**

2008 Wind Supplement Update

- **Major objective:**
  - Enhance the relevance of the “Handbook” and “Wind Supplement 2004” to energy storage stakeholders
- **What’s in the 2008 Wind Supplement Update?**
  - Wind Generation: Deployment Status and Growth Drivers
  - Market Structure and Energy Storage Ownership
  - Wind Integration Studies
  - Other Stakeholder Perspectives
  - Insights from 2007 California Wind Integration Assessments
  - Opportunities for Energy Storage in Wind Integration
  - Status of Major Wind-Storage Demonstration Projects
- **What’s NOT in the 2008 Wind Supplement Update?**
  - There are NO CHANGES in the energy storage technologies included, in cost and performance data, or in application cases reported the “Handbook” and “Wind Supplement 2004”

2008 Wind Supplement Update
Wind Generation:
Deployment Status and Growth Drivers

- **Wind Deployment Status: Fastest growing sector globally**
  - 30% annual growth in U.S. since 2003
  - 16.8 GW end of 2007
  - ~0.6% U.S. electrical supply
- **Growth Drivers: Social and strategic**
  - Perceived environmental and national energy security advantages
- **Long Term Prospects: Projections vary widely, e.g.:**
  - DOE-EIA projects 2.4% of U.S energy by 2030
  - DOE-EERE projects 20% by 2030

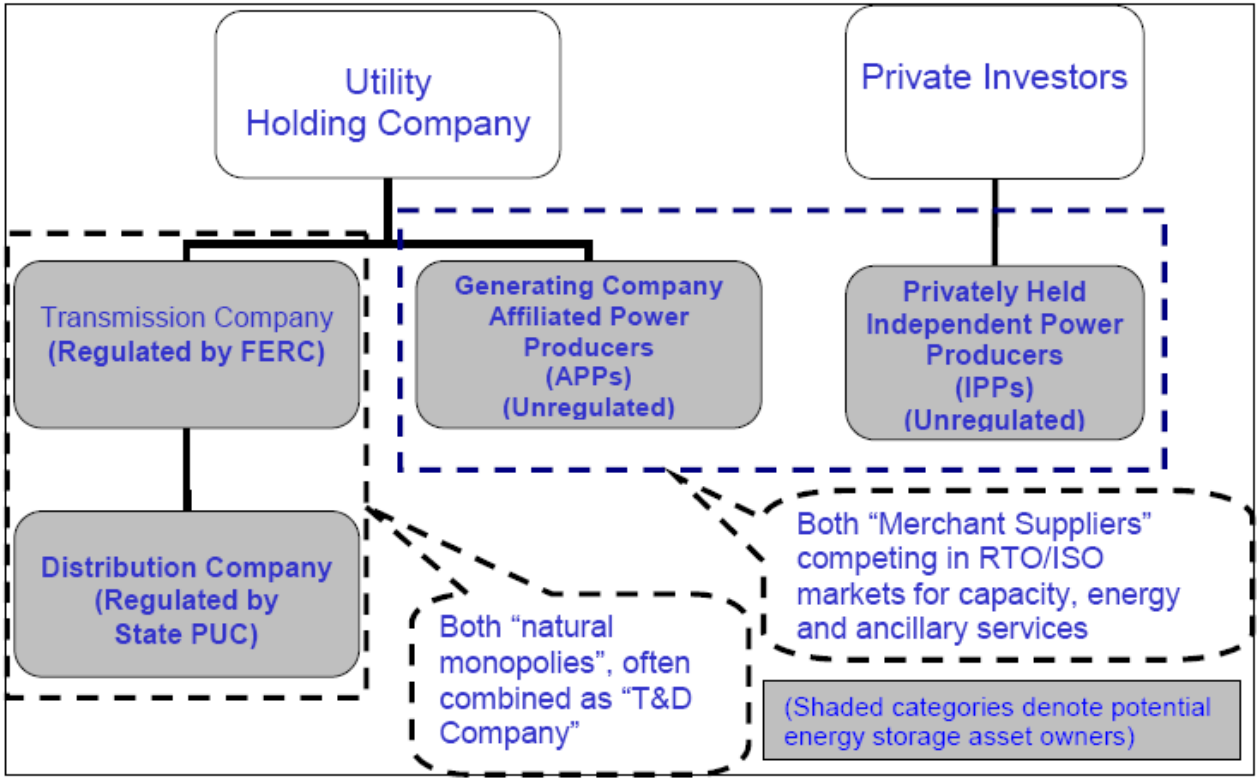
2008 Wind Supplement Update
Market Structure and Energy Storage Ownership

- **Market structure shaped by Federal Energy Regulatory Commission (FERC)**
  - Order 888 (1996) – Unbundled generation/ transmission, Required open access to transmission, Required specified ancillary services
  - Order 889 (1996) – "Chinese wall", OASIS, sets stage for Independent Power Producers (IPPs), Affiliated Power Producers (APPs)
  - Order 2000 (1999) – Framework for competitive markets, characteristics of RTOs (market independence, grid operation, reliability)
  - Order 890 (2007) – Favorable to intermittent resources, implied recognition of storage, i.e., "non-generation resources capable of providing. . .[ancillary services]"
  - FERC ruling on LEAPS* project (2008)
    - *. . ."may not be operated. . . or functionalized as transmission for rate recovery purposes."*

**Lake Elsinore Advanced Pumped Storage*

2008 Wind Supplement Update
Market Structure and Energy Storage Ownership (continued)

- **Implications of FERC policies/ rulings for storage ownership:**
  - AT THIS TIME, strongly favors storage ownership by merchant suppliers, investment recovery via services market



2008 Wind Supplement Update
Wind Integration Studies

- Wind industry has conducted integration studies in virtually every part of the country deemed to offer a potential economic resource
  - **Web accessible electronic libraries maintained by AWEA, UWIG and NREL**
- 2007 IEEE Study* provides an excellent distillation of such studies. Findings include:
  - **The cost of wind Integration is low (up to $5/MWh) for penetration up to 20% to 30%**
  - **Wind variability cannot be dealt with in isolation, net system that needs to be balanced**
  - **Deep, liquid day-ahead and hour-ahead market needed for dealing with wind variability**
  - **Capacity for reliability must be provided through market mechanisms, utility unit commitment processes**
  - **New transmission required for large amounts of remote wind**

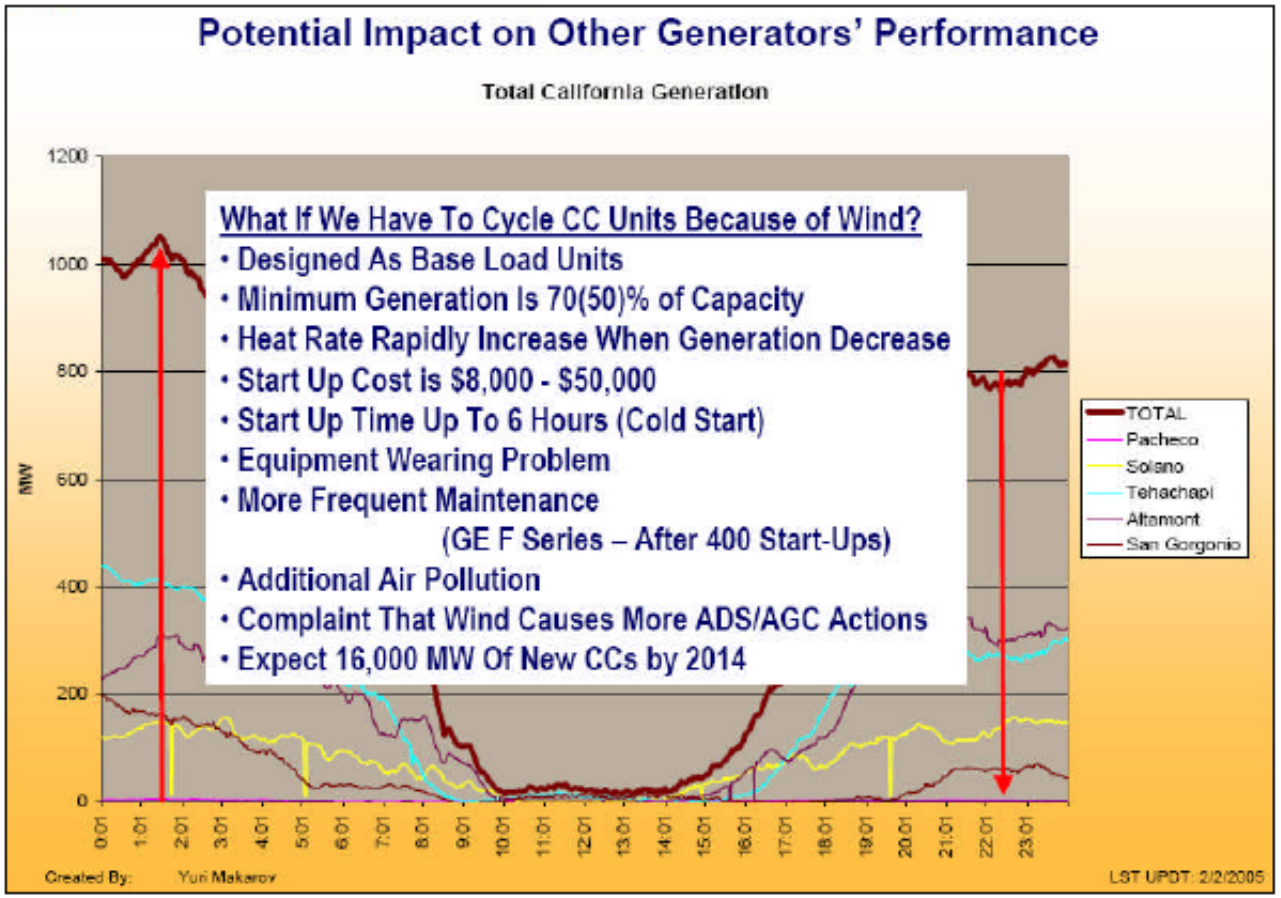
*Utility Wind Integration and Operating Impact State of the Art, IEEE Transactions On Power Systems, Vol. 22, No 3, August 2007.

2008 Wind Supplement Update
Other Stakeholder Perspectives

- **Wind industry vision would require substantial changes to**
  - The grid infrastructure (needs flexible, fast-start/stop dispatchable assets; needs to retire low-cost, high emitter, old units)
  - Market practices (automation, short duration bid intervals)
- **However, wind integration studies summarized in IEEE report include very limited stakeholder input on**
  - Industry realignment (e.g., gas turbine suppliers)
  - Impact on grid operations (e.g., ISOs) and,
  - Role of energy storage
- **Cost/performance projections may be optimistic based on**
  - Adverse operating experiences, uncertainty in underlying assumptions
- **The following slides are examples of events/conditions associated with "as yet unaccounted" costs of wind integration**

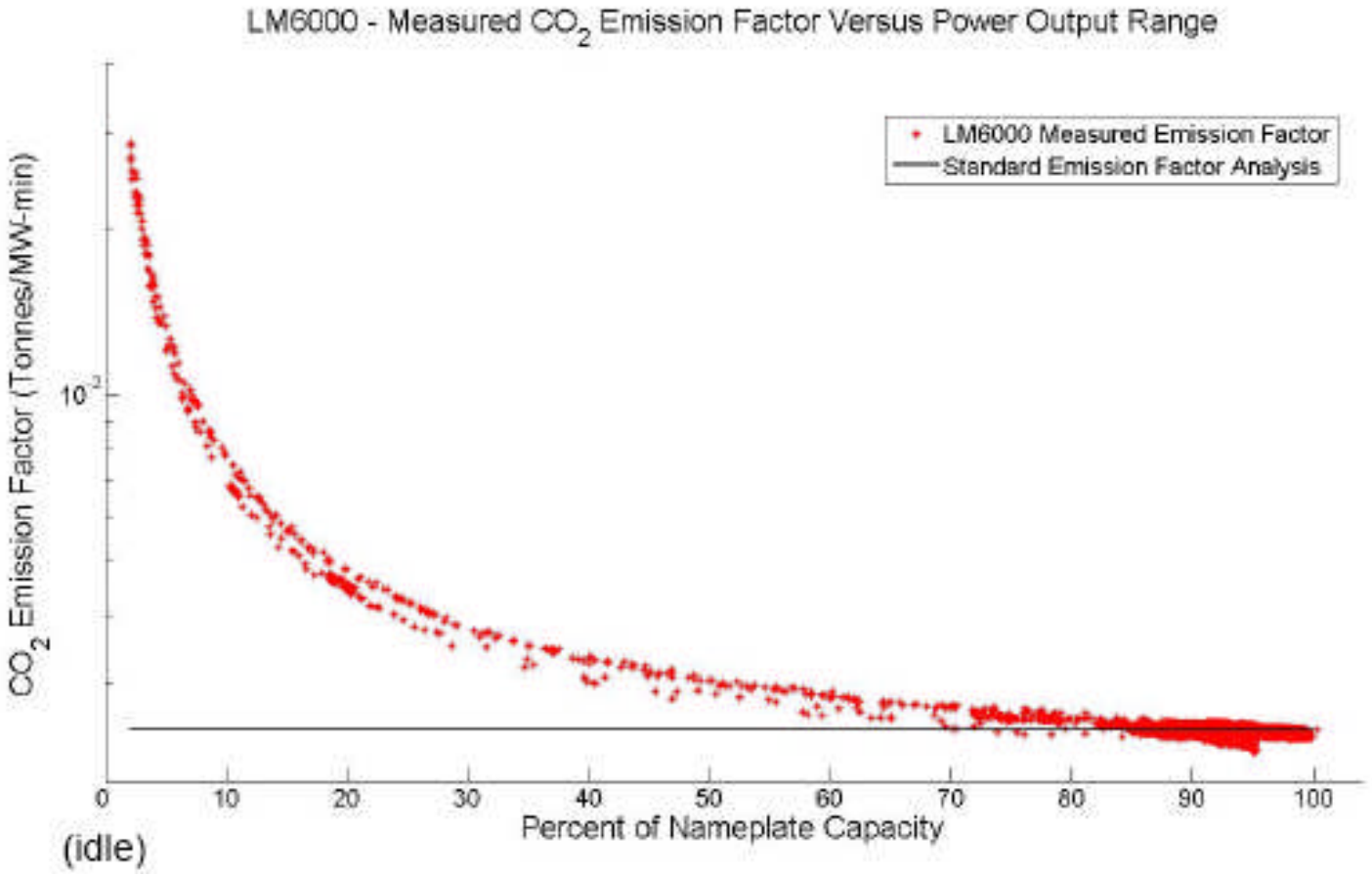
2008 Wind Supplement Update
Other Stakeholder Perspectives - Examples

- **GT supplier and grid operator (CAISO) concerns**



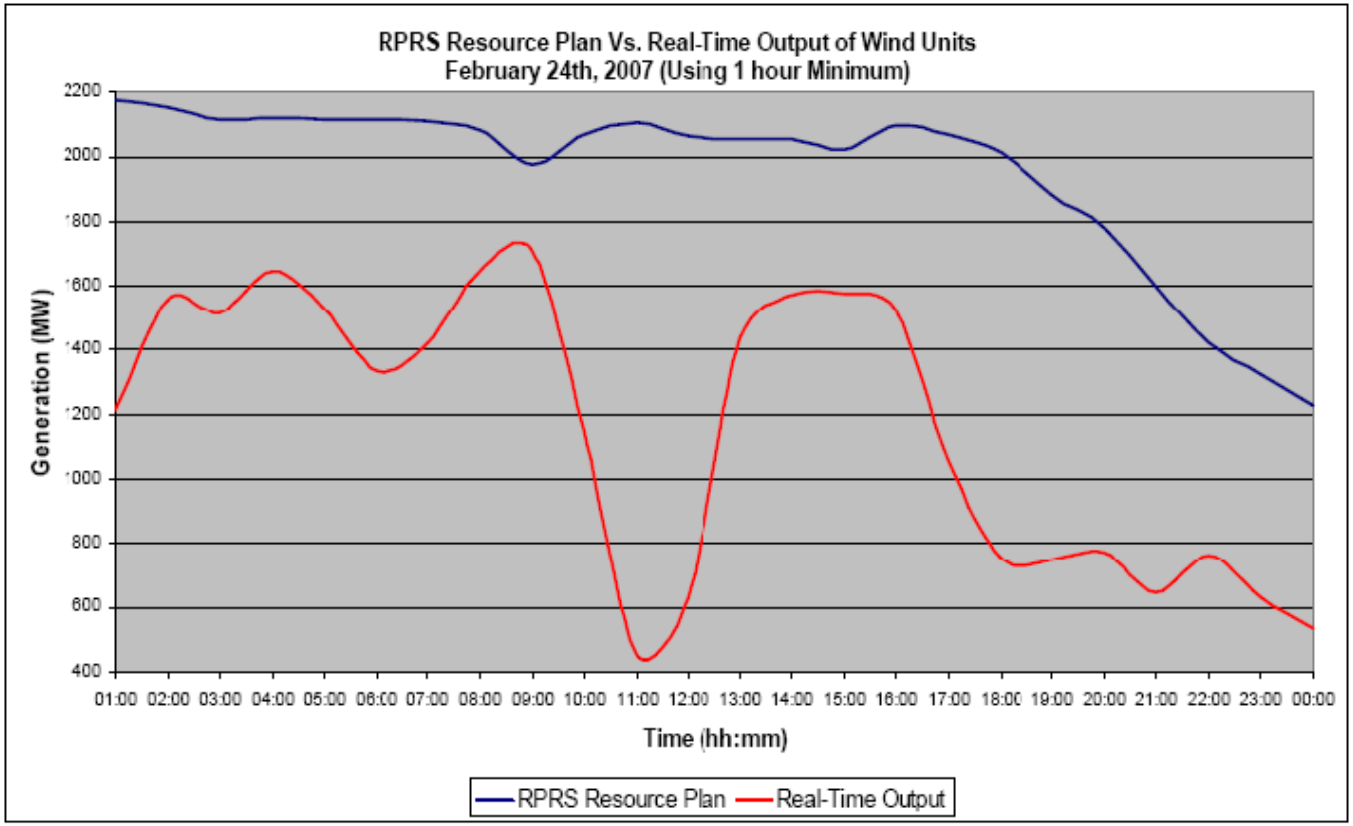
2008 Wind Supplement Update
Other Stakeholder Perspectives - Examples

- **Environmental concerns – increased emissions for cyclic part load operation**



2008 Wind Supplement Update
Other Stakeholder Perspectives - Examples

- **Operating experience – Sudden loss of wind generation ERCOT Feb 2007 (again Feb 2008)**



2008 Wind Supplement Update
2007 California Assessments

- **California Energy Commission (CEC), "Intermittency Analysis Project (IAP) Report", July 2007**
  - Consistent with studies summarized in the IEEE report
  - Provides insight to the degree of change that CA is willing to impose on its electrical system
- **California Independent System Operator (CAISO), "Integration of Renewable Resources Report" (IRRR), Draft/Final Sep/Nov 2007**
  - Presents asset-level response to IAP from ISO perspective to
  - Created a dialogue with stakeholders on issues associated with wind integration findings,
  - First industry participant report to provide a meaningful emphasis on the role energy storage

2008 Wind Supplement Update
2007 CA Assessments – CEC IAP

- **CEC IAP scenarios:**
  - 2006 – Base case, (2.1 GW wind)
  - 2010 – 20% renewables, (7.5 GW wind, ~ 8%)
  - 2020 – 33% renewables, (12.7 GW wind, ~ 12%)
- **Impact on Generation Resources : [storage opportunities]**
  - Realign dispatchable generation for fast stop/start, diurnal stop/start, low minimum operating load, regulation and load following capability, hourly/multi-hour schedule flexibility, low emissions.
  - Add ~5.8 GW gas turbine plants by 2015 (~ 36% SCCT)
- **Impact on Transmission Infrastructure: New or upgraded transmission line segments**
  - 2010 – 74, ~ $1.2 B
  - 2020 –128, ~ $5.7 B

2008 Wind Supplement Update
2007 CA Assessments – Draft CAISO IRRR

- **Sep07 draft CAISO IRRR, recommendations relevant energy storage include:**
  - Integrate real-time forecast with real-time economic dispatch at 5-minute intervals
  - Study impact of additional cycling and associated wear and tear on costs/ environmental impacts of conventional generation.
  - Encourage new energy storage technology to store off peak wind for delivery during on-peak
  - **FIRST SUCH STUDY to provide a meaningful emphasis on the role energy storage.**
    - ***Chapter 7 dedicated to energy storage options and specifically addresses pumped hydro and flywheel technology as well as hydrogen storage, flow batteries and CAES.***
- **Equally important, CAISO launched stakeholder dialectic that drew insightful comments on the role of storage**

2008 Wind Supplement Update
2007 CA Assessments – Draft CAISO IRRR

Comment Category	Stakeholders* (Interest) [*Those Posting Comments Most Relevant to Storage]
– Transmission Planning Issues – Grid Operations Issues – Forecasting Issues – Implementation Issues – Grid Operation Issues/ Storage Technology – Other Issues	AWEA – American Wind Energy Association (Wind Industry) CalWEA – California Wind Energy Association (Wind Industry) CASWP – California Department of Water Resources – State Water Project (State Agency – water resources) CPUC – California Public Utility Commission (Regulator) MWD – Metropolitan Water District of Southern California MWSF – Megawatt Storage Farms, Inc. (IPP) NAS – Sodium Sulfur Battery (NGK Insulators, ES Vendor) PG&E – Pacific Gas & Electric Company (IOU) SCE – Southern California Edison Company (IOU) SDG&E – San Diego Gas & Electric Company (IOU) VRB – Vanadium Redox Battery (VRB Power, ES Vendor)

2008 Wind Supplement Update
2007 CA Assessments – Final CAISO IRRR

- **Key points in CAISO/stakeholder exchange wrt energy storage include:**
  - CAISO receptivity of storage, encouragement of developer participation in market rules
  - Stakeholder recognition of storage attributes and proposals for valuation, e.g., location/relocation flexibility; prompt, precise power delivery
    (Many attributed to Dr. Edward G. Cazalet, MWSF (IPP))
  - Limitations of existing hydro and thermal assets
- **Stakeholder comments incorporated in the CAISO Final IRRR, Nov07**
  - CAISO follow-on program with storage stakeholder participation in-progress thru Fall 2008

2008 Wind Supplement Update
Opportunities for Storage in Wind Integration

- **Wind generation is a "positive disruptive" technology, i.e., it is bringing about**
  - Substantial upgrading of dispatchable generation assets,
  - Introduction of new technologies (e.g., storage, forecasting, ISO market methodologies, etc.).
- **Numerous opportunities for storage if wind societal/strategic benefits continue to be justified**
- **However, business/technical readiness of storage remains a major question before investors**
  - Can storage suppliers offer products/terms that support long term financing within the next few years?
- **If so, multi-gigawatt markets are at hand.**

2008 Wind Supplement Update
Opportunities for Storage in Wind Integration

- **Opportunities addressed by applications described in the Update (and Wind Supplement 2004), i.e.,**
  - Grid operational support, transmission curtailment, time shifting, forecast hedge, grid frequency support, and fluctuation suppression
- **Current application/technology leaders include:**
  - Regulation Control – Beacon Power to be commended for flywheel inroads in the ISO-NE, CAISO and MISO markets and recent 5 MW announcement
  - Time Shifting – NGK Insulators commissioned 34 MW NAS battery installation in April 2008 (Japan) for time shifting and stabilization, plan product line with Japan Wind Development Company

2008 Wind Supplement Update
Status of Major Wind-Storage Demo Projects

- **Large (300 MW) and small (15 MW) CAES – EPRI, coming soon**
- **34 MW NAS Battery Project, Rokkasho, Japan – direct wind support for wind developer, commissioned April 2008**
- **5 MW Beacon Flywheel Project, Tyngsboro, MA – NEPOOL/ISO-NE RC Program, coming soon**
- **2 MW (3MW Pulse) VRB Project, Sorne Hill, Ireland – direct wind support, under construction**
- **1 MW NAS Battery Project, Xcel Energy, Luverne, MN – demo direct wind support for wind developer plus ancillary services, under construction**

2008 Wind Supplement Update Acknowledgements

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