Lessons from Iowa

Development of a Bulk Energy Storage Facility in the Midwest Independent Systems Operator (MISO) Market

February 9, 2012

About ISEPA

- Iowa Stored Energy Plant Agency
  - Started by the Iowa Association of Municipal Utilities (IAMU)
  - Now an Iowa Chapter 28e organization
    - Ten individual Iowa municipal utilities
    - Three municipal power agencies
      - South Iowa Municipal Electric Cooperative Association (SIMECA)
      - Missouri River Energy Services (MRES)
      - Central Minnesota Municipal Power Agency (CMMPA)
    - Total of 57 municipal utilities represented, in four states.
  - Investment to-date in ISEP (all sources): $8.6 Million

www.isepa.com

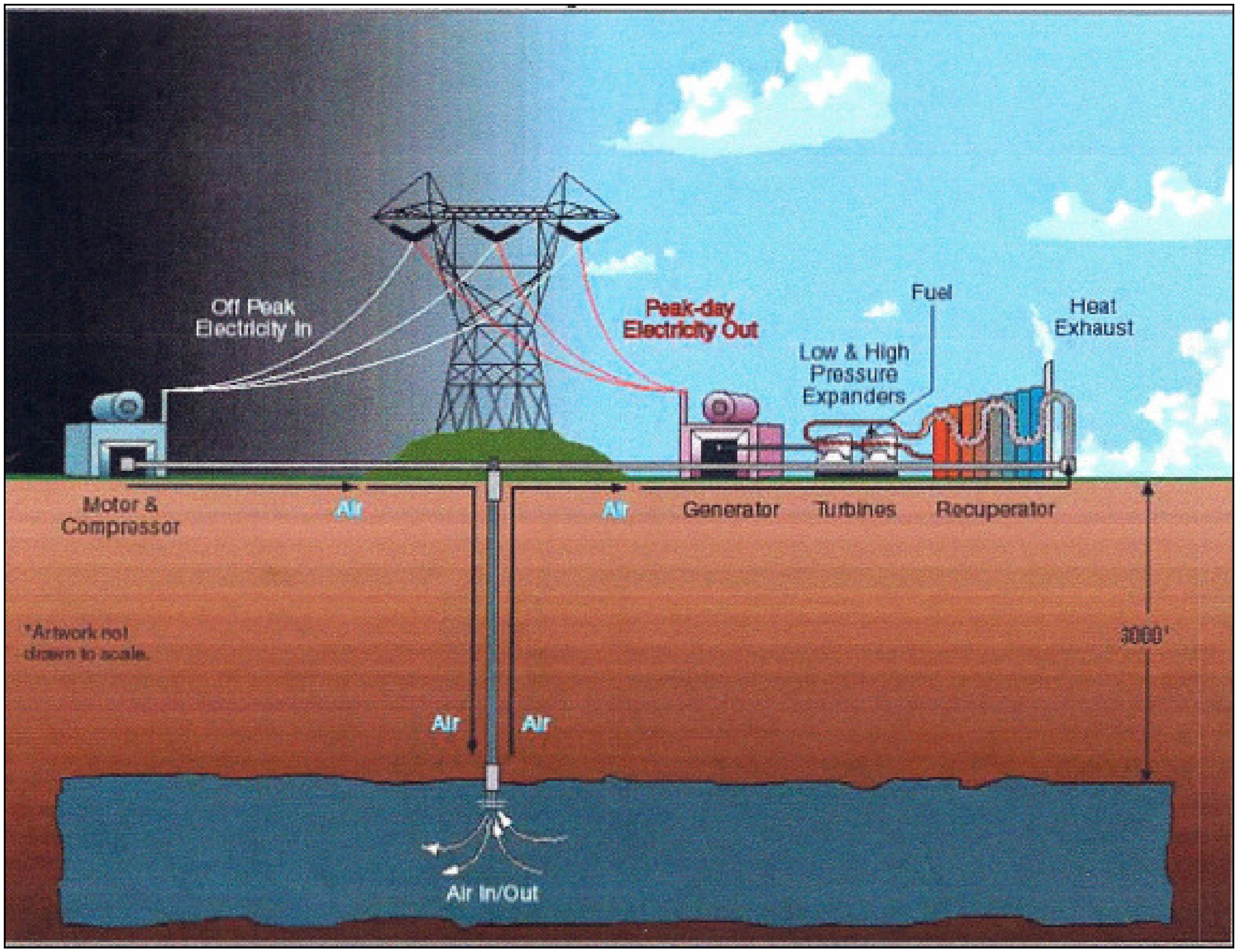
THE IOWA STORED ENERGY PARK

ISEPA Thanks:

- DOE Energy Storage Systems Program
- Sandia National Laboratories
- Iowa Power Fund
- Our colleagues and consultants:
  - Iowa Association of Municipal Utilities, R.W. Beck (now SAIC), Brulin Associates, Customized Energy Solutions, Hydrodynamics Group LLC, MHA Petroleum Consultants, Iowa State Geologists of the Department of Natural Resources, Dresser-Rand, Wind Consulting and MISO Planning Staff.

THE IOWA STORED ENERGY PARK

CAES Conceptual Layout



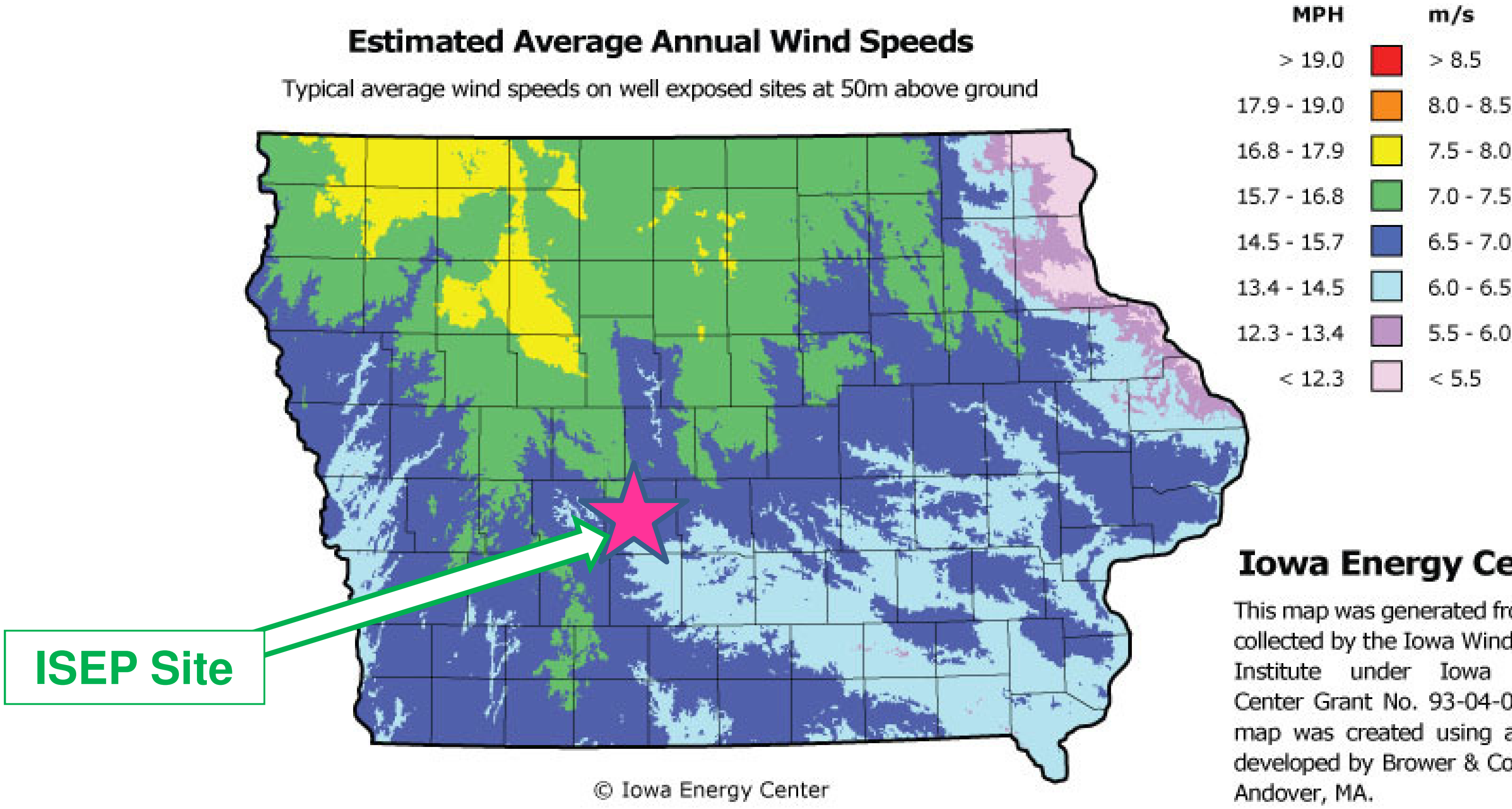
About ISEP

- Proposed 270 MW compressed air energy storage (CAES) project, 2015 in-service
- Capital cost: ~$400 million
- Site: Dallas Center, Iowa
- In daily operation, generation would look like an intermediate-duty, combined-cycle unit.
  - But heat rate only ~4400 Btu/kWh*
- Unique: Fully dispatchable load
  - Compress (220 MW): up to 12 to 16 hours, weeknights and weekends.
  - Generate (270 MW): up to 12 to 16 hours per day on weekdays.

*Excluding energy content of compressed air input to generator.

THE IOWA STORED ENERGY PARK

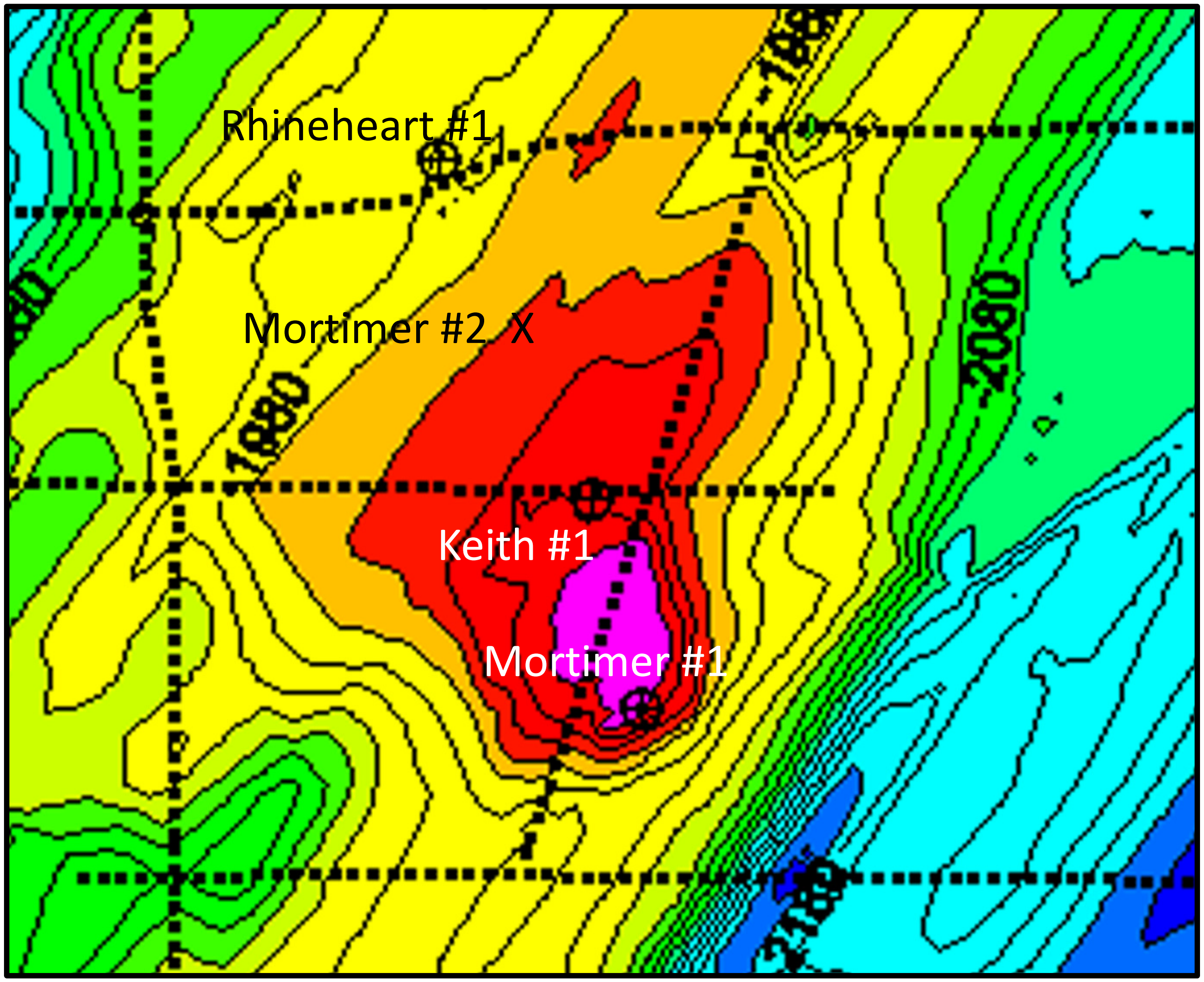
Wind Energy Country



Iowa Energy Center

This map was generated from data collected by the Iowa Wind Energy Institute under Iowa Energy Center Grant No. 93-04-02. The map was created using a model developed by Brower & Company, Andover, MA.

A Unique Underground Structure



- Not a cavern.
- Porous sandstone structure
    - ~ 1 square mile x 100 feet thick.
- 3000 feet underground.
- Originally discovered by Northern Natural Gas in the 1960s as a potential natural gas storage site.
- Northern stores natural gas in a similar structure 10 miles away.

THE IOWA STORED ENERGY PARK

Geology:
Tapping the Mt. Simon Sandstone

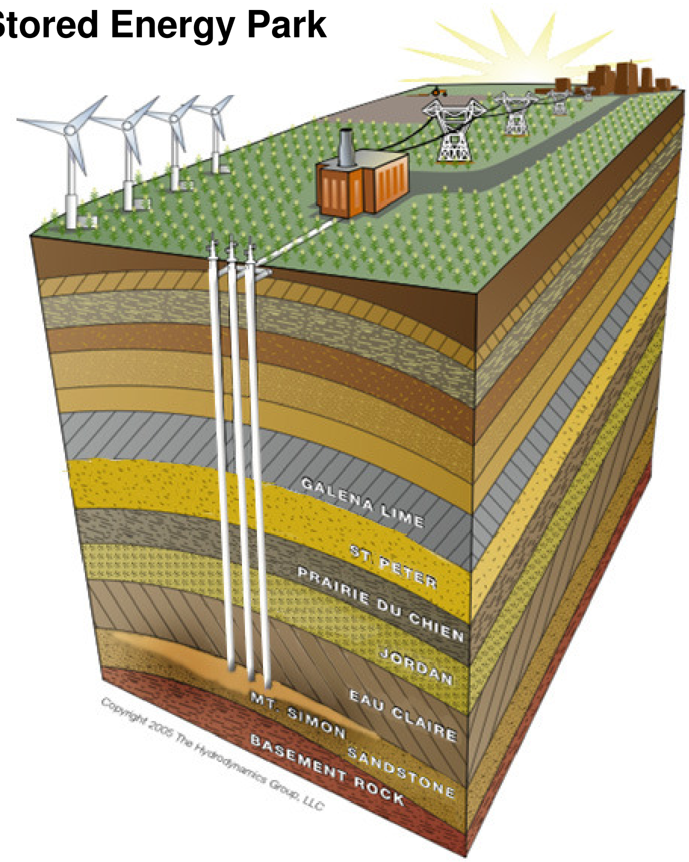
$8.6 Million Investment

Completed Work Activities

- Dallas Center Site Selected
- Geophysical Surveying
- Drilled & Cored Three Test Wells
- Economic Analysis Phase I
- Economic Analysis Phase II
- Laboratory Core Analysis
- CAES Reservoir Simulation Analysis
- Geology Peer Review

GO/NO-GO DECISION
FOR AIR INJECTION TESTING
July 2011

Iowa Stored Energy Park



Lessons from Iowa

- Project History
- Costs
- Economics
- Transmission
- Ownership Matters
- Markets and Tariffs
- Storage Policy and Legislation
- Project Management
- Siting
- Geology
- Recommendations

Questions

THE IOWA STORED ENERGY PARK

Now and the Future

- Current Conditions
  - The economy and customer electric loads are down
  - Natural gas prices are relatively low
- But, something important is happening regardless of these current conditions:

Very large amounts of intermittent, non-dispatchable wind resources are being installed in the region.

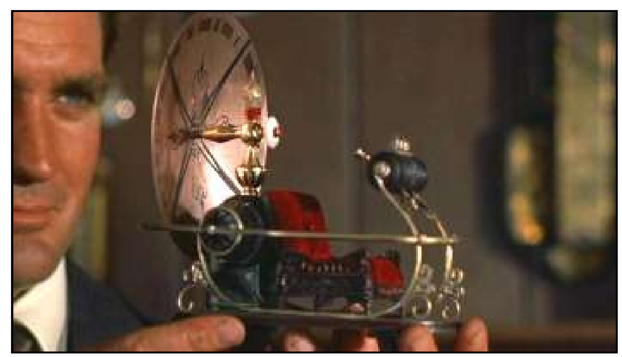
Potential Economic Benefits

- Off-peak to on-peak price arbitrage
- “Extrinsic value”
  - Option value to address hourly price volatility
- Ancillary Services (in both compression and generation modes)
  - Regulation service
    - Ramp-up and ramp-down, in both compression and generation modes
  - Quick-start reserves
  - Reactive power
- Optionality to hedge future generation costs
  - Increases in natural gas prices
  - Increased cycling wear and tear on conventional generation
  - Retirement of older, intermediate coal capacity

Economic Benefits (continued)

- A new market for wind energy generated off-peak.
  - Time-shift it to on-peak.
  - Enable wind producer to “unbundle” on-peak and off-peak wind production, and price/market them separately.
    - Sell both based on on-peak prices.
    - Reduce/eliminate off-peak price “drag” on overall average value.
  - Addresses “baseload bottoming” time periods
- Enable more wind to be installed.
  - Helps with RES/RPS compliance.
  - Reduces CO_2 footprint.

A Time Machine



THE IOWA STORED ENERGY PARK

"Phase I" Economics Study

- Primary contractor: RW Beck
- Funded by DOE Energy Storage Program
- Study timeframe: July to December 2010
- Elements:
  - Capital and O&M cost estimates for CAES and alternatives.
  - "Merchant" view of benefits and costs
  - MISO market price forecasts for various scenarios
  - Intrinsic and extrinsic (option) values.
  - 20-year planning period (2015 to 2034).
  - Compression energy from available MISO market resources. (Not wind alone)
  - Off-peak to on-peak price arbitrage.
  - Ancillary services revenues for spin and non-spin.

THE IOWA STORED ENERGY PARK

ISEP Project Characteristics

Modeled Capital Costs and Operating Characteristics
2010 $

	ISEP CAES	Generic CC
Total Capital Cost ($/kW)	1,374	1,122
Generation Cycle:		
Min Capacity (MW)	32.3	158.8
Max Capacity (MW)	264.7	264.7
Air Flow @min (lb/s)	149	-
Air Flow @max (lb/s)	800	-
Heat Rate @min (Btu/kWh HHV)	4,806	7,370
Heat Rate @max (Btu/kWh HHV)	4,395	7,000
Variable O&M ($/MWh)	2.28	2.51
Fixed O&M ($/kW-yr)	18.68	20.34
Forced Outage Rate	3.0%	2.0%
NOx Rate (lb/MMBtu)	0.0100	0.0100
SO2 Rate (lb/MMBtu)	0.0006	0.0006
CO2 Rate (lb/MMBtu)	110	110
Compression Cycle:		
Load (MW)	219.82	-
Air Flow (lb/s)	830	-
Reservoir Capacity (lb)	100,000,000	-
Variable O&M ($/MWh)	0.00	-
Fixed O&M ($/kW-yr)	0.00	-
Forced Outage Rate	3.0%	-

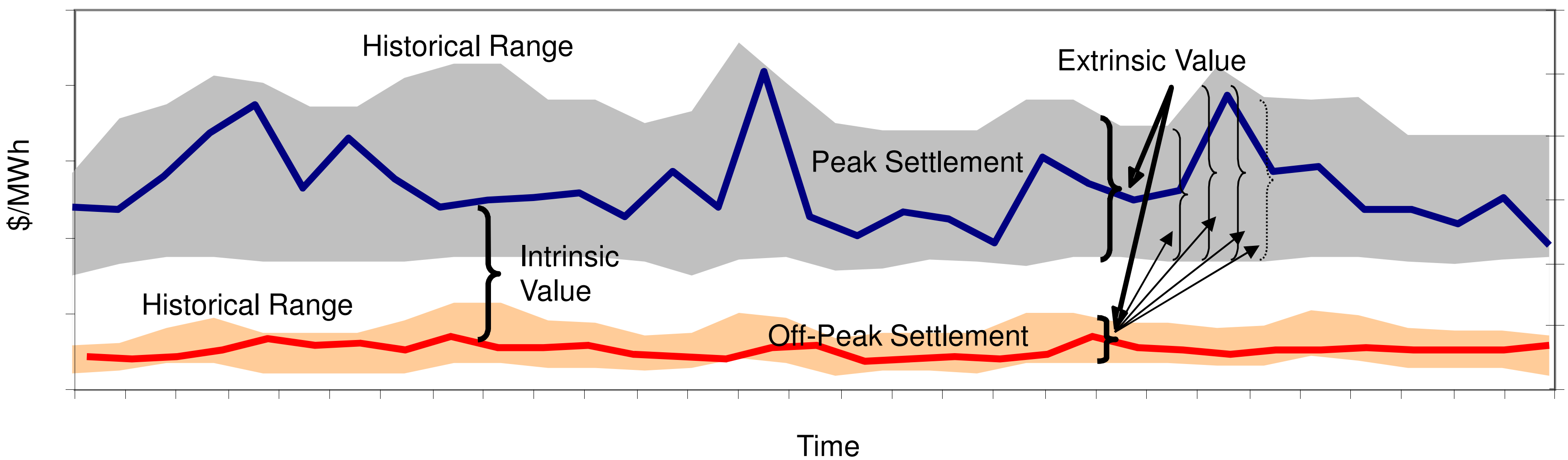
CAES: A Unique Animal

- Fast
  - 10 minutes from cold steel to full load
    - Generation and compression
- Flexible
  - Minimum output only 15% of maximum
  - Linear, 125 MW/minute ramp rate (up or down)
  - Capable of multiple starts/stops each day if needed
  - Can provide VAR support
    - Generation and compression
- And, it stores
  - Capable of 12 to 16 hour daily storage/generation cycle
  - Capable of 36 hours generation at full load, if desired

Phase I: Lessons Learned

- In normal operation, a storage facility like ISEP will look like an intermediate generating unit (generating on weekdays); not a peaking unit.
- ISEP's 220 MW compression cycle did not challenge the assumed storage capacity of the reservoir (100 million pounds).
- ISEP can pay for itself in the MISO marketplace (i.e., lifetime benefits exceed costs).
- ISEP costs would be competitive with a conventional, natural gas-fired combined-cycle alternative.

Extrinsic Value: Graphical Intuition



What We Learned:

Extrinsic value represented 20% to 30% of the total $/kW benefits for ISEP in Phase I, depending on the planning scenario.

Phase I: Lessons Learned
(continued)

- Extrinsic value was a significant portion of the benefits.
- For investor-owned utilities, investment tax credit (ITC) proposed in Congress for bulk storage* represents material benefit.

*Storage 2011 Act, sponsored by Senators Bingaman, Wyden and Collins.

Phase I: Lessons Learned (continued)

- Ownership (of the storage) matters.
  - The ideal storage owner would be:
    - a Load-Serving Entity (LSE), with:
    - large amounts of wind energy resources, located:
    - near the storage site, with:
    - conventional generation nearby, and:
    - transmission constraints (but not between the storage and the wind resources).
  - If the storage owner is not ideal:
    - You will need MISO tariff changes, bilateral contracts, a transparent electricity options market and legislation to make large-scale storage viable.
    - You need MISO to be active in enabling storage to work.

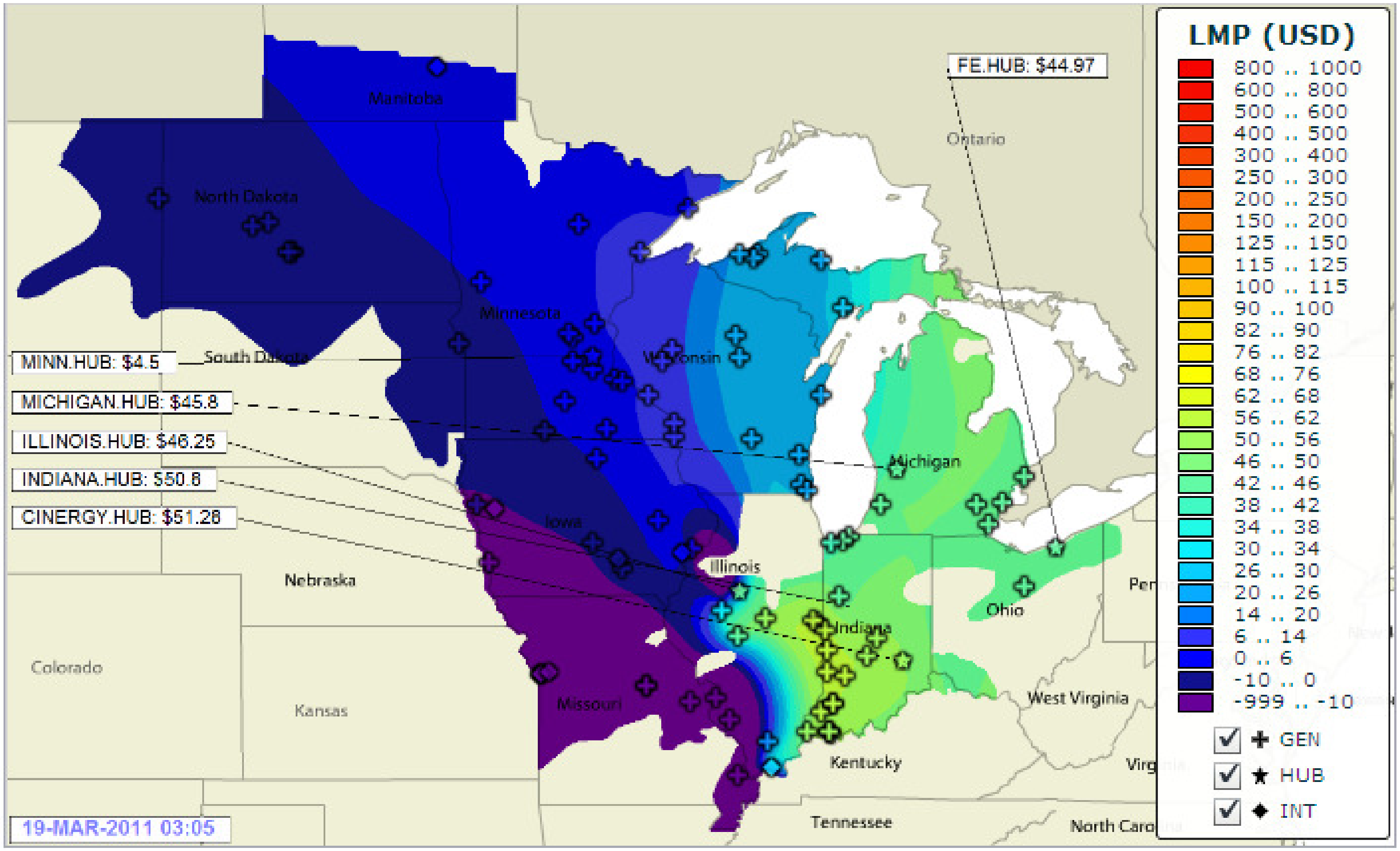
THE IOWA STORED ENERGY PARK

Questions

Phase II Economics

- Primarily about linking storage and wind:
  - What is the probability that the lowest MISO prices off-peak (for ISEP compression/storage cycle) occur when the wind is blowing?
  - How much *additional* wind generation is possible because of ISEP?
  - How much *less* curtailment of wind energy will occur because of ISEP?
  - What system savings result?
  - What transmission savings accrue?
  - What improvements in baseload utilization and reduction in conventional units' cycling result?
  - How will high penetration of renewables in MISO impact ancillary services, and how can ISEP be used to offset that?

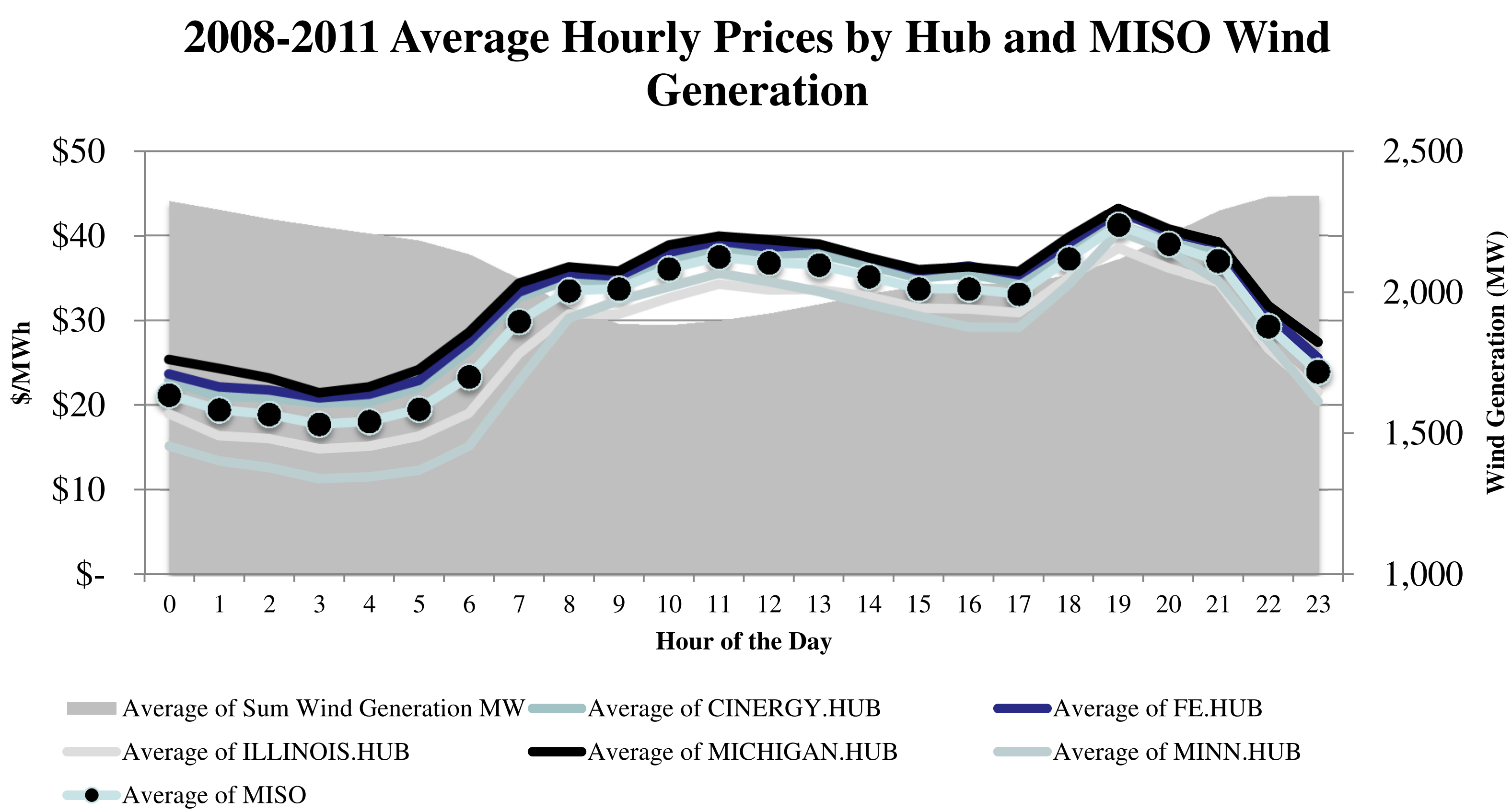
MISO Territory and Price Hubs



THE IOWA STORED ENERGY PARK

Phase II Result

MISO Wind Output Generally Inverse to Price Shape (and Load)



* Average of MISO is the simple average of the 5 selected Hubs

Phase II Result

MISO Wind Output Higher During Off-Peak and Low-Price Hours

ISEP dispatched against MISO prices will be storing when the wind is blowing.

Other Phase II Storage Benefits

- A bulk storage unit like ISEP dispatched against LMP prices in MISO would or could:
  - Result in system production cost savings.
  - Increase capacity factor of baseload generation units.
    - And thereby increase their profit margin.
  - Reduce cycling wear and tear on conventional generation units.
    - And thereby reduce their O&M costs.
  - Reduce curtailment of wind resources.
  - Qualify for state Renewable Energy Credits (RECs) or federal Clean Energy Credits itself.
    - State legislative examples: California AB 2514, Ohio, Utah.

THE IOWA STORED ENERGY PARK

Adjusted Phase I & II Values
(270 MW ISEP Project)

- Revised Phase I Base Case Values and Phase II Values create a significant advantage to ISEP at 270 MW compared to CC/CT options.

$/KW for 270 MW	ISEP	CC	CT
Intrinsic	1,713	1,696	1,281
Extrinsic	473	264	190
Original Phase I Total	**2,186**	**1,960**	**1,471**
CO_2 Penalty Removal	140		
CREB Benefit	199		
Revised Phase I Total	**2,525**		
Phase II Benefits	222		
Total I & II	**2,747**		
Cost	1,547	1,205	805
Difference	1,200	755	666

THE IOWA STORED ENERGY PARK

Lessons from Iowa

1. A bulk storage project like ISEP in coordination with renewables:
   - Can be cost-effective in MISO.
   - Can be cost-competitive with comparably-sized conventional, natural gas-fired generation options
   - But market, contract and policy innovation is required.

THE IOWA STORED ENERGY PARK

Lessons from Iowa (continued)

2. Ownership (of the storage) matters.

- An “ideal” storage owner is a vertically-integrated utility that is a Load Serving Entity (LSE), owns conventional and renewable resources near the storage and dispatches its own resources.
- If the storage owner is not “ideal”, the ISO has a role in enabling the benefits of storage.

THE IOWA STORED ENERGY PARK

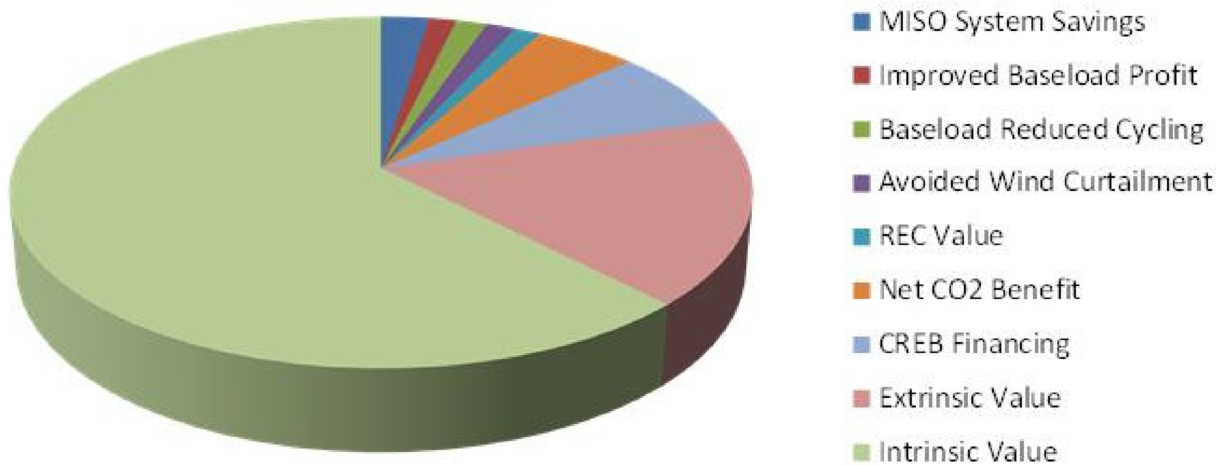
Lessons from Iowa (continued)

3. Bulk storage like ISEP would support integration of existing and additional renewable energy resources in MISO.
   – And there would not necessarily need to be a direct contract relationship between the storage and the wind machines to have this happen.

Lessons from Iowa (continued)

4. Traditional resource planning methods and models understate the value of storage.

ISEP Lifetime $/kW Benefits by Type



THE IOWA STORED ENERGY PARK

Lessons from Iowa (continued)

5. The provisions of the "Storage 2011 Act" in Congress, if passed into law, would have a material beneficial effect on the economics of storage ownership.
   - Investment tax credits (ITC) for investor-owned utilities
   - Community Renewable Energy Bond (CREB) financing for public power entities.

Lessons from Iowa (continued)

6. Most of the Lessons are independent of site geology or the storage technology being used.

THE IOWA STORED ENERGY PARK

On the Web

- The Lessons from Iowa summary report
- All 68 underlying detailed reports and references (2400 pages).
  - Organized by endnote number in the Lessons report.
  - Includes a “Resource Planner’s Toolkit”
- Contact Information for Questions and Assistance

www.lessonsfromiowa.org

THE IOWA STORED ENERGY PARK

For Further Information

LFI

Lessons from Iowa

Enabling bulk energy storage with renewables

www.lessonsfromiowa.org

or:

www.sandia.gov/ess