

Power System Engineering, Inc.

Resource Reliability in a Changing Environment

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FULL-SERVICE CONSULTANTS

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Definitions

- NERC Glossary of Terms – Reliable Operation
  - Operating the elements of the [Bulk-Power System] within equipment and electric system thermal, voltage, and stability limits so that instability, uncontrolled separation, or cascading failures of such system will not occur as a result of a sudden disturbance, including a cybersecurity incident, or unanticipated failure of system elements.
- MISO Vision
  - To be the most reliable, value-creating RTO
- MISO Mission
  - Work collaboratively and transparently with our stakeholders to enable reliable delivery of low-cost energy through efficient, innovative operations and planning

Definitions

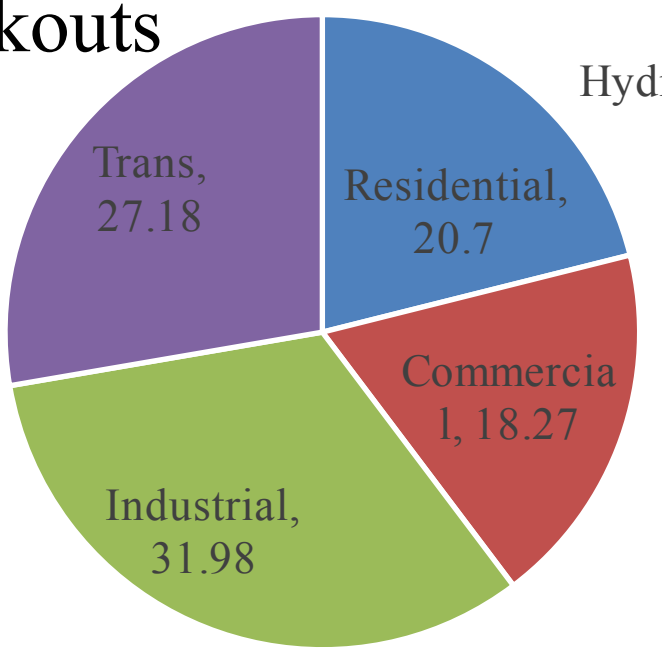
- Minnesota Resource Plans – 7843.0500 Subp 3 Par A
  - maintain or improve the adequacy and reliability of utility service;

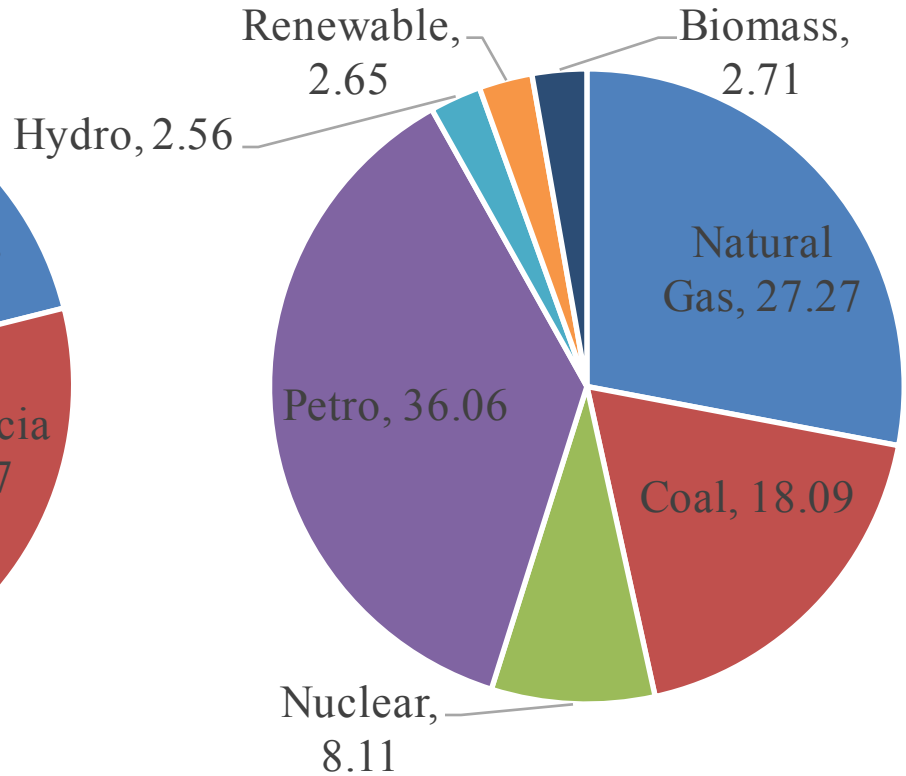
Functional Definition of Energy

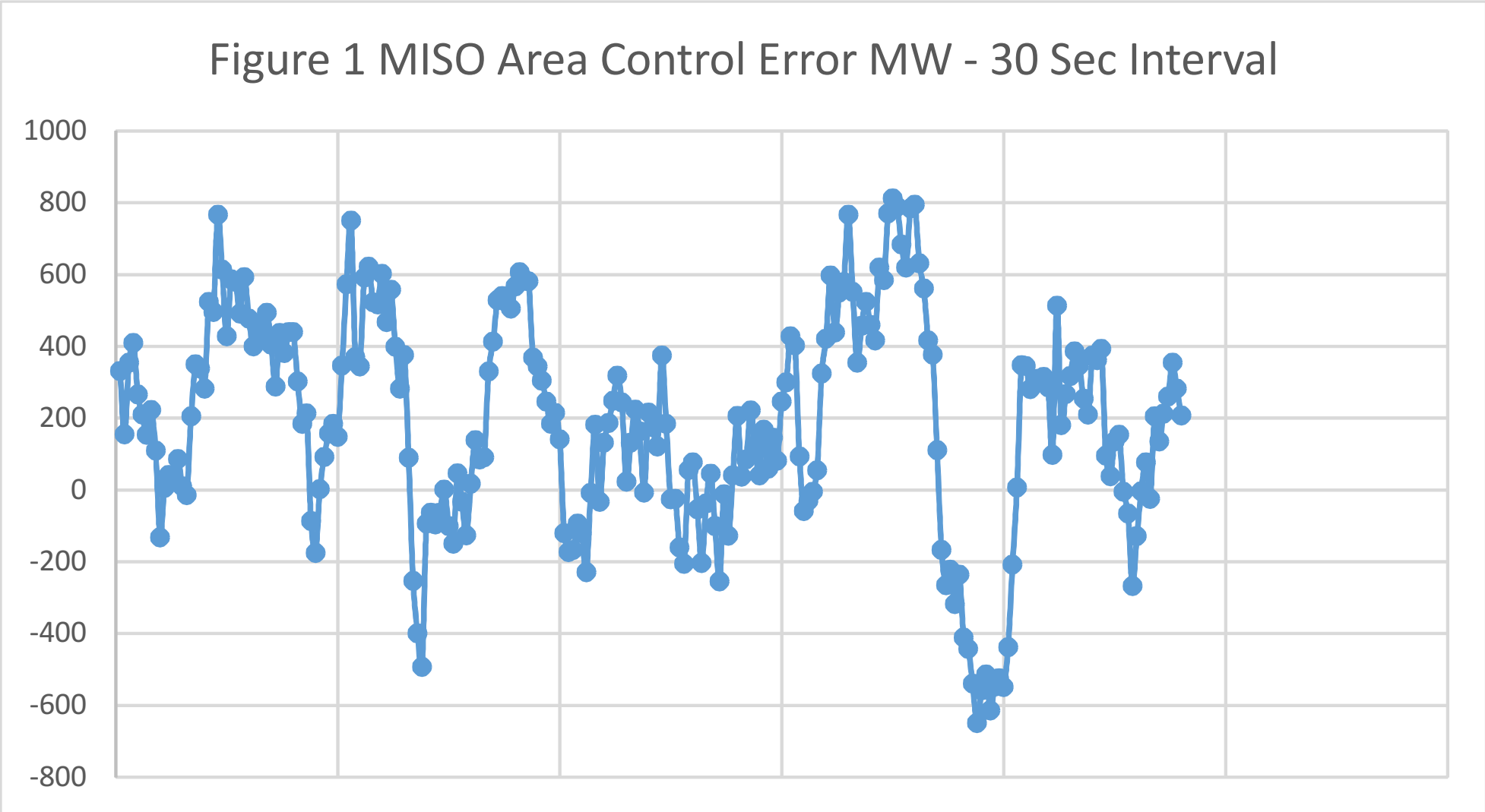
- A well developed energy infrastructure allows the leveraging of a workforce to create the greatest economic value.
  - Contrast to Primitive Camping
    - All Time Spent Simply Surviving
  - Contrast to Less Developed Countries
    - Cooking over fire
    - Walking vs. Driving
    - Labor Intensive Construction Sites
  - Significant Elements
    - Instant Mechanical Energy – (fuel and electric) Transportation
    - Food Chain – Farming, Processing, Transportation & Storage
    - Controlled Climate

How Much Energy do We Use?

- 2015 – 97.83 Quadrillion Btus (1 x 10^{15} Btu) – Quads
- What is a Quad?
  - Energy to Warm a 270 acre Lake 20 ft deep 70 F to 212 F
  - Thermal Energy in 8 billion gallons of gasoline
- Breakouts







Initial Thoughts

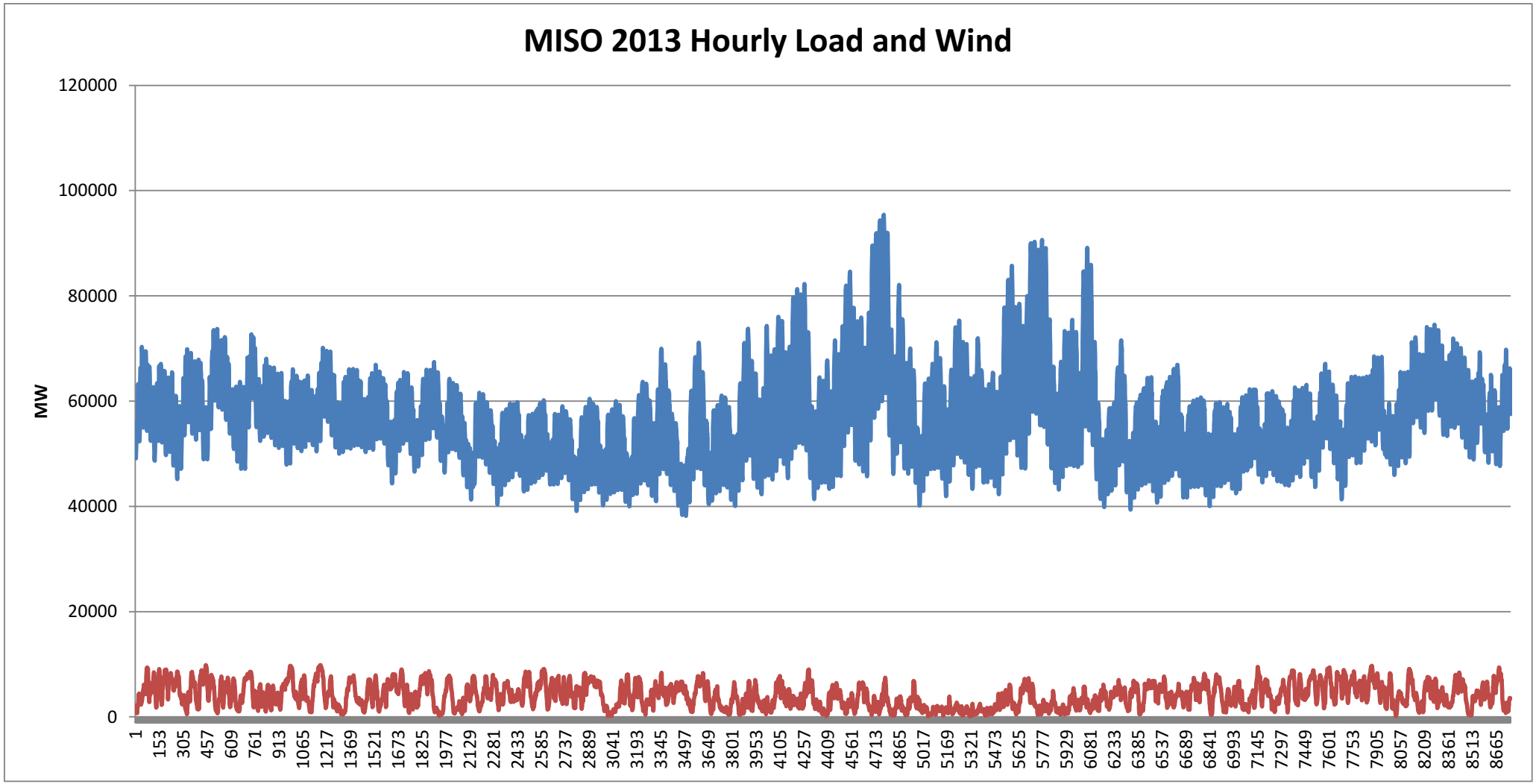
- Everyone Agrees
  - Reliability is REALLY Important
- Not as Apparent
  - Using the word "reliable" doesn't provide clarity or assurance that it is being evaluated
  - All Modeling Does not Provide Definitive Reliability Evaluation
    - Importance of Understanding Limits of Modeling
  - No Modeling Answers All Issues
  - Regulatory Framework for Resource Decisions
    - Reliability Demonstrated?
  - Impact of Unregulated Resource Decisions
    - PV and MicroGrid Installations

Typical Modeling Approaches

- PSSE Steady State Transmission Analysis
- PSSE Stability Analysis
  - Voltage/angle analysis
  - System Disturbances
- Power Production Models
  - Many types
    - Resource Optimization
    - Chronological vs. Load duration curve
    - Representative hours
    - Hourly vs. sub-hourly
    - Deterministic vs. Statistical
    - Simplified generation operation points vs. Full Operating Curve

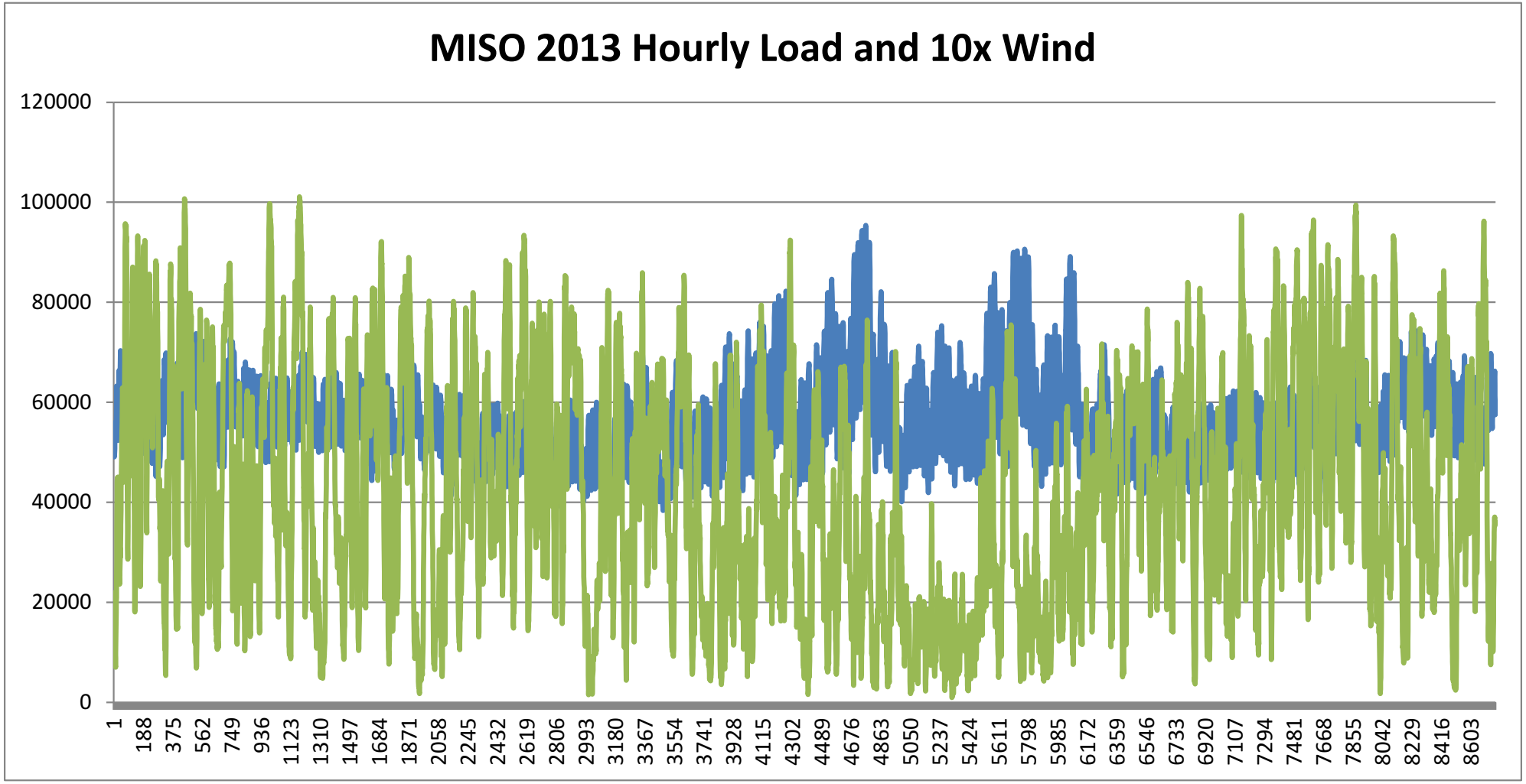
Questions that Face Us

- Is Current Resource Adequacy Approach Adequate with Expected Future Changes?
  - Does the "MW" capacity approach work to make sure system is reliable 8760 hours/year?
  - How are Planning Reserves and "system load" defined with higher levels of Micro-grid applications?
    - Who Has responsibility to Serve Load?
    - How to Integrate Grid and Micro Grid planning?
  - Do current long range planning approaches need additional metrics to evaluate reliability?
    - Operational Metrics

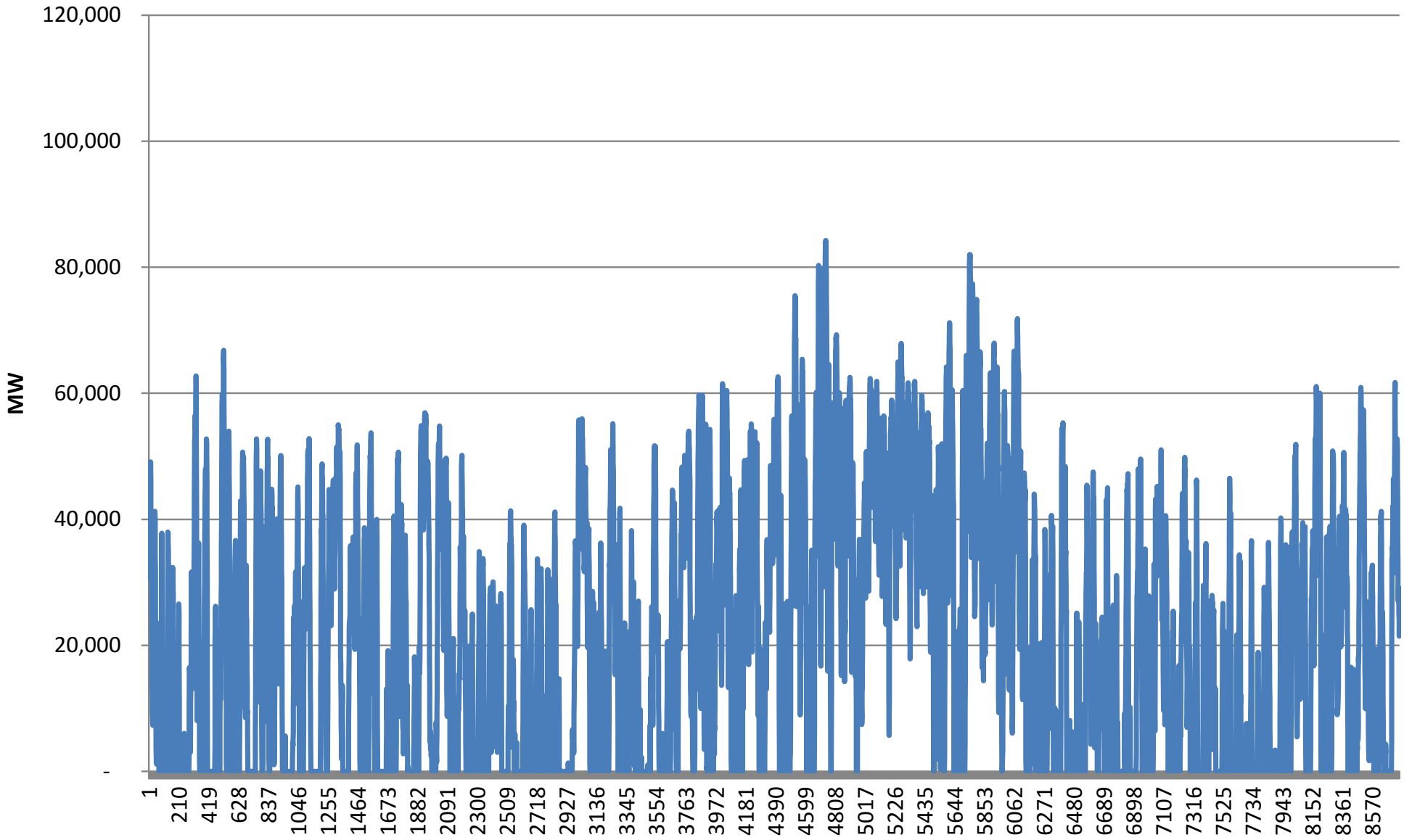


MISO 2013 – Wind Expansion Dispatch

- Evaluate Scaling Factor to Wind Shape
- Seek to Minimize both Excess energy and shortfall energy
- Excel Goal Seek -> Default Factor=1 Resulting Factor -> 10.24
- Scaled Wind Energy Summary
  - Peak – 101,098 MW
  - Energy – 362,411 GWh
  - Capacity Factor – 40.9%
  - Percent of MISO Energy – 72%



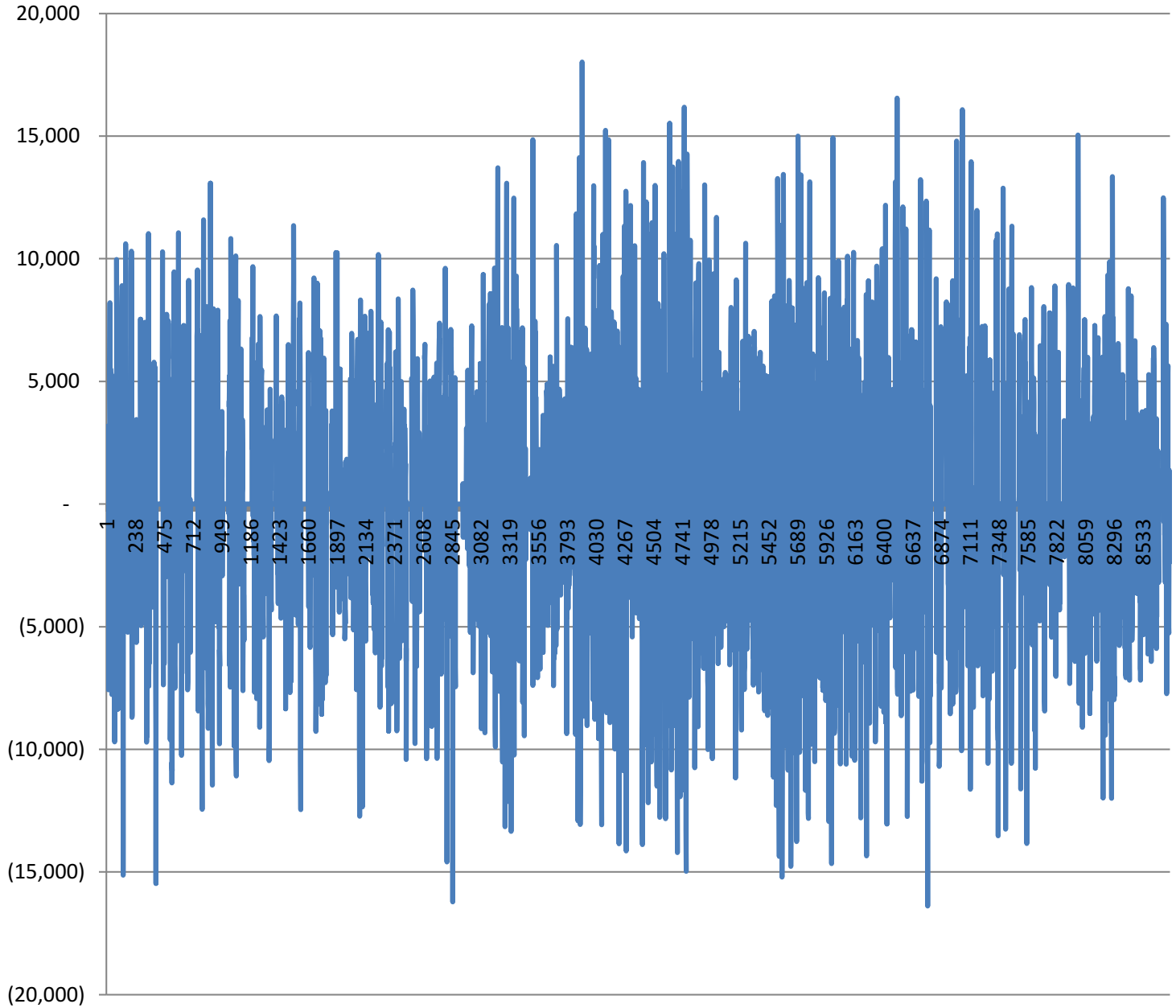
Hourly Dispatch of Energy Shortfall with 10x wind



MISO Wind Expansion Dispatch - Cont

- Excess Energy – 40,253 GWh 51,429 MW
  - Capacity Factor 8.9%
- Shortfall Energy 181,955 GWh 84,240 MW
  - Capacity Factor = 24.7 %
  - Actual installed capacity would need to be 12% higher due to planning reserves – Installation Capacity of 94,372 MW
  - Number of Starts – 188
  - Hours of Operation - 6,154 70% of all Hours

Hourly Variation in Balance of Need Resource 10x Wind



Energy Storage Analysis

- Storage considered Very Important with Higher levels of intermittent energy production
- Use MISO 2013 Load and Wind Shape
- Each Surplus energy hour placed into storage
- Each deficit energy hour withdraw from storage
- Seek annual adequate energy
  - Requires a wind scaling factor of 16 x existing wind
- Storage Requirements
  - 80,000 MW peak
  - Over 740 hours of energy storage!
    - Far beyond a daily energy storage need

Breakout of Transportation Fuel

- Transportation
  - Gasoline – 16.4 Quads (2,644 billion vehicle miles)
    - Ping – maximum electric car potential – Energy view
    - Assume 35% efficiency → 1,682,300 GWh Electric Energy
    - 480,000 MW of wind assuming 40% Capacity Factor
    - Shape of wind vs. shape of electric charging?
  - Electric Car Trends
    - Ranges expected to dramatically increase to 200 miles / charge
    - More charging Stations – Faster Charging Stations
      - Fast Charging in the range of 100-250 kW
      - Aggravates Shape of supply vs. shape of demand

Planning Timeframe vs. Operating Timeframe

- Planning Timeframe
  - Imperfect Forecasts
  - Partial
- Operating Timeframe
  - Season ahead
  - Coordinate Planned Maintenance
  - Day Ahead and Real Time Markets
  - Resources and Load Match Perfectly each Instant of Time

Operational Real World Challenges

- Starting Current Requirements
- Adequate Fault Current Levels from Generation Resources for Adequate System Protection
- Reactive Power Supply
- Inverter Self-Protection During System Disturbances
- All and many others are Challenges

What is the CPP?

- Regulating CO2 emissions from EXISTING Coal and Gas fired Power Plants – not peaking plants
- Overall Reduction
  - Approximately 32% of 2005 levels by 2030
- Specific Limit for each State
  - States Must Create Compliance Plan
- Compliance Starts in 2022
  - 2022-2029 Transition to 2030 levels
- Two Basic Approaches to Compliance
  - Mass Based & Rate Based

What is the CPP (Cont.)

- Reliability Safety Valve (RSV)
  - Allowance for 90 days of not being in compliance to the CPP
  - Final Rule: → *The corrective measures must both ensure future achievement of the CO2 emission performance rates or state CO2 emission goal and achieve additional emission reductions to offset any emission performance shortfall that occurred during a performance period. The shortfall must be made up as expeditiously as practicable.*
- Comments on the RSV
  - Reliability Issues that require additional unit availability – may not be something that could change in a 90 day timeframe
  - For Mass-based compliance, evaluating the variance expected to not meet annual goals would be challenging to perform.

Existing Generation vs. New Generation

- CPP applies to Existing Generation
- New Source requirements apply to new generation
  - Emission limits set to maximum
    - Natural Gas Combined Cycle (NGCC) CO2 limit of 1,030 lb/MWh
    - Eliminates option of adding coal generation
- CPP plans must show compliance and that compliance will not be rely on adding new NGCC generation
  - Leakage - using new NGCC to meet CPP requirements
  - Clear indication on desiring to rely more on renewable energy

Compliance Building Blocks

1. Increase Coal Plant Efficiency

2. Increase Utilization of Existing Natural Gas Plants
   - Target max of 75% Capacity Factor
3. Increase New Renewable Energy Resource
   - Emphasis on 2013 and Later Installations

- What about Energy Efficiency?
  - Removed from Building Blocks in Final Rule
  - Allowable in State Plans – M&V Required

Description of Mass-Based Approach

- Goal – Set Maximum Annual CO_2 emissions
  - Existing Coal and Existing Combined Cycle Gas
- Means of Meeting Objective
  - Reducing dispatch of both Coal and NGCC generation
    - More emphasis on reducing of Coal Generation in order to maintain adequate system energy – NGCC
  - Retirement of Coal generation – issue of retention of allowances
  - Trading

Description of Rate-Based Approach

- Limit the CO_2 Emission Rate
  - Aggregate of generation CO_2 lb / generation MWh
  - No means of removing CO_2 from flue gas
- Means of Meeting Objective
  - Redispatch System
    - Increase NGCC dispatch
    - Increase Renewable Dispatch - Only Renewable Built since 2013
  - Retirements of coal generation can lower the average
    - Especially if you have NGCC included in your baseline.

Rate vs. Mass Plans

- Each State will choose Rate vs. Mass
- Emission Trading limited to states with the same type – Mass or Rate

Resource Impacts for CPP

Typical Power Plant CO_2 Emission Rates

- Coal Fired Steam Turbine
  - 2000 lb / MWh
- Natural Gas Combined Cycle
  - 800-1200 lb / MWh
  - New Source Limit of 1,030 lb / MWh

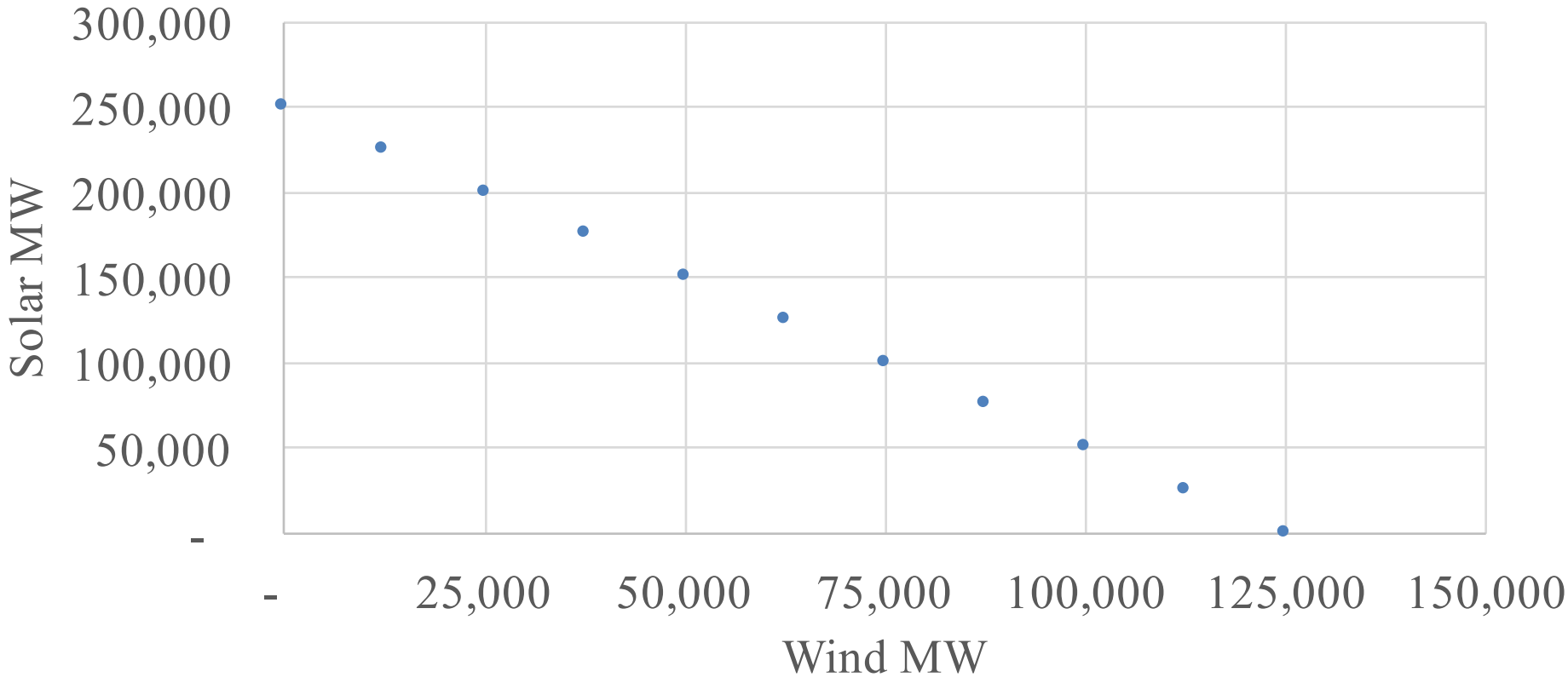
CPP Defined Best System Emission Reduction(BSER)

Region	Heat Rate Improvement	Maximum Existing NGCC Dispatch Potential	Maximum Zero Emission Dispatch Potential
Eastern Interconnection	4.3%	988,000 GWh	438,000 GWh
Western Interconnection	2.1%	306,000 GWh	161,000 GWh
Texas Interconnection	2.3%	204,000 GWh	107,000 GWh

Eastern Interconnect Renewable Potential

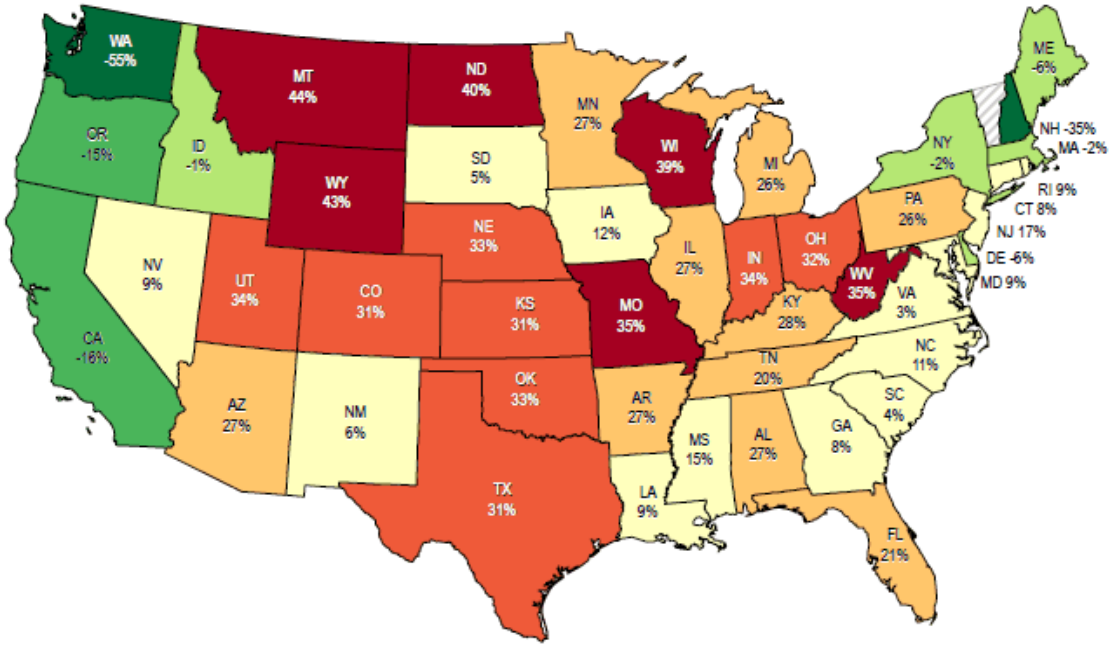
- Current Wind Nameplate Capacity
  - 55,000 MW
- CPP Renewable Potential
  - 438,000 GWh
  - Assume 40% capacity factor
  - Additional Wind Nameplate
    - 125,000 MW
- Concerns
  - Timeframe of Transmission Expansion for Renewable?
  - Balance of Load following resources required for higher saturation of wind generation?

Eastern Interconnect 438 TWh - Wind/Solar MW



EPA's required CO2 emissions rate reductions versus projected levels

Compares 2020 projections with 2030 Clean Power Plan goals



Needed % reduction in CO2 emissions rate (lbs/MWh)

-55 to -30 | -29 to -10 | -9 to 0 | 1 to 19 | 20 to 29 | 30 to 34 | 35 to 44

SNL

State	2020 emissions rate projections without CPP	Final emissions rate goal (2030)	Needed progress from 2020 projections
Alabama	1,386	1,018	27%
Arizona	1,409	1,031	27%
Arkansas	1,551	1,130	27%
California	712	828	-16%
Colorado	1,692	1,174	31%
Connecticut	858	786	8%
Delaware	861	916	-6%
Florida	1,170	919	21%
Georgia	1,135	1,049	8%
Idaho	766	771	-1%
Illinois	1,705	1,245	27%
Indiana	1,882	1,242	34%
Iowa	1,456	1,283	12%
Kansas	1,870	1,293	31%
Kentucky	1,796	1,286	28%
Louisiana	1,235	1,121	9%
Maine	736	779	-6%
Maryland	1,411	1,287	9%
Massachusetts	808	824	-2%
Michigan	1,588	1,169	26%
Minnesota	1,658	1,213	27%
Mississippi	1,107	945	15%
Missouri	1,950	1,272	35%
Montana	2,314	1,305	44%
Nebraska	1,930	1,296	33%
Nevada	944	855	9%
New Hampshire	636	858	-35%
New Jersey	981	812	17%
New Mexico	1,225	1,146	6%
New York	902	918	-2%
North Carolina	1,273	1,136	11%
North Dakota	2,184	1,305	40%
Ohio	1,742	1,190	32%
Oklahoma	1,598	1,068	33%
Oregon	760	871	-15%
Pennsylvania	1,486	1,095	26%
Rhode Island	845	771	9%
South Carolina	1,202	1,156	4%
South Dakota	1,229	1,167	5%
Tennessee	1,517	1,211	20%
Texas	1,515	1,042	31%
Utah	1,779	1,179	34%
Virginia	959	934	3%
Washington	634	983	-55%
West Virginia	2,021	1,305	35%
Wisconsin	1,940	1,176	39%
Wyoming	2,264	1,299	43%

Sources: U.S. EPA, SNL Energy
Map credit: Whit Varner

Regional Selection - State Goal Summary

Description	MN	ND	WI	IA
2012 CO_2 (Short Tons)	28,263,179	33,370,886	42,317,602	38,135,386
2012 CO_2 (lb/MWh)	2,033	2,368	1,996	2,195
2022-2029 Mass Based Goal (CO_2 Short Tons)	25,433,592	23,632,821	31,258,356	28,254,411
2022-2029 Rate Based Goal (CO_2 lb/MWh)	1,414	1,534	1,364	1,505
2030 and beyond Mass Based Goal (CO_2 Short Tons)	22,678,368	20,883,232	27,986,988	25,018,136
2030 and beyond with New Source Complement Mass Based Goal (CO_2 Short Tons)	22,931,173	21,099,677	28,308,882	25,281,881
2030 and beyond Rate Based Goal (CO_2 lb/MWh)	1,213	1,305	1,176	1,283
Rate Based % 2030/2012	40%	45%	41%	42%
Mass Based % 2030/2012	10%	11%	9%	11%

Rate Based Zero Emission Gen Levels

Description	MN	ND	WI	IA
2012 CO_2 (Short Tons)	28,263,179	33,370,886	42,317,602	38,135,386
2012 CO_2 (lb/MWh)	2,033	2,368	1,996	2,195
2030 and beyond with New Source Complement Mass Based Goal (CO_2 Short Tons)	22,931,173	21,099,677	28,308,882	25,281,881
2030 and beyond Rate Based Goal (CO_2 lb/MWh)	1,213	1,305	1,176	1,283
zero emission gen MWh	11,214,763	12,652,245	17,419,826	14,437,232
all wind gen (MW)	3,201	3,611	4,971	4,120
all solar gen (MW)	6,401	7,222	9,943	8,240

CPP Reliability Issues

- Mass Based
  - There is NO requirement to replace the energy removed from the system with energy from another source
    - Example of Reduced Dispatch but not retiring a unit
  - Unique to this regulatory requirement – peaking needs?
- Rate-Based
  - Timing of Building Adequate Infrastructure to Meet Rate Goals
    - Generation
    - Transmission
    - Energy Efficiency
  - If there isn't adequate lower emission resources, coal dispatch will be limited

Pondering Thoughts

- Bulk Transmission as Generation Outlet
  - System Costs Inversely Proportional to Generation Capacity Factor
    - 40% capacity factor generation Requires Twice as Much Transmission as 80% generation resources for energy transfer
- Three Phase 60 Cycle Power – Created vs. Simulated
  - Coordination vs. Self Protection → Reliability?
- Capital Expenditures vs. Energy Supply
  - 80% Baseload - Wind 40% CF Solar 20% CF
- Renewable Tax Credit For All Future Resources?
  - Total Dollar Impact for Higher Saturations?
  - Does Renewable Development Stall if Tax Credit is Ended?

Plans – and Actions

- Adding new Generation
  - MISO Generation Interconnection Study
  - Possible Outcomes
    - Yes, build new generation
    - No, new transmission facilities are needed before interconnection
- Retiring Generation
  - Attachment Y or Y2
  - Possible Outcomes
    - Yes, retire generation
    - No, System is not considered reliable

Plans and Actions

- Resource Adequacy
  - Is there Adequate Capacity for the next Planning Year
  - Possible Outcomes
    - Changes in Planning Reserve Margin
    - MW Capacity Required for Each Zone
    - Zonal MW Transfer Capability
- Long-Term Planning
  - MTEP Planning
  - Possible Outcomes
    - Defined Long-term Plans
    - MVP Facilities
    - Range of Resource Portfolios

Suggested MISO Changes

- Resource Adequacy
  - Extend Analysis to Additional Years
    - 5-10 Years
    - Transition from 1 Year to Multi-Year Market
  - Expand Capacity Type Definition
    - Examples→
      - Load Following Capability
      - Storage Capability
      - Peak Supply Capability
      - Energy Supply Capability
  - Quantify Optimum Resource Mix
  - Each Load Serving Entity Required to Purchase Share of Resource Adequacy

Suggested MISO Changes (Cont)

- MTEP
  - Provide LOLE Analysis
  - Include a Range of Resource Supply Datasets
    - Example – range of wind and solar annual profiles
  - Challenge of Interconnection Queue
- Generation Retirement
  - Evaluate Resource Adequacy not just Transmission Model analysis
  - Show impact on Optimal Resource Mix

Model Evaluation

- Evaluate Capabilities
- Chronological Datasets
- Full range of output variations of all resources
  - Thermal & Intermittent
- Reflect statistical nature of Variables
  - Statistical Distribution of Variables
    - Forced Outages and Costs

Modeling Approach

- Include Representative Range of variable data
  - Wind and solar resources Fuel Prices
- Resource Interaction to be Identified by Resource Type and not just a blind market interaction
  - Load following and Energy Supply
- Clearly Show Impact on Resource Mix and Load
  - Both from Energy and Capital Perspectives
- Modeling Results
  - Sanity Checked
  - Effectively Summarized
  - Explained

Example

- Proposed Retirement of Sherco 1 and 2
- Studies Performed
  - Attachment Y
  - Transmission Reliability Study
  - Blackstart Analysis
- Conclusions
  - Attachment Y raised reliability issues
    - Didn't provide guidance on Generation needed –
    - Only provided insights on transmission system deficits
  - Additional Studies Provided VERY important observations
    - Adequate Fault Current for System Protection
    - Blackstart Plan and Impact on Nuclear Generation.

Conclusions

- Reliability is Critically Important
  - Dependency on Reliability Cannot be Overstated
- Reliability Must be Maintained
  - Pace of Industry Change and Modeling Limitations are a Challenging Combination
  - Entities with Load Serving Responsibilities May Need to Push Current Regulatory Requirements
  - Define Load Serving Responsibilities
  - Define Planning Reserve Approach
  - Demonstrate the Viability of Expected Changes the in Planning Arena

Thank You:

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About PSE

- Power System Engineering, Inc. (PSE) is a **full-service consulting firm** for electric utilities.
- Our team has extensive experience in all facets of the utility industry, including communications, IT, and smart grid automation; economics, rates, and business planning; electrical engineering; planning and design; and procurement, contracts, and deployment.
- Established in 1974 to serve the engineering and technology needs of electric cooperatives.
- Have served more than 250 clients including distribution cooperatives, G&Ts, municipal utilities, and IOUs.
- 100 % employee owned and managed.
- About 84 employees with offices in Wisconsin, Ohio, Minnesota, South Dakota, Indiana, and Kansas.
- PSE is independent:
  - PSE is a 100 % independent consulting firm with no sales ties or marketing affiliations with any vendors.
  - PSE is NOT a value-added reseller (VAR) of any software, hardware or services from any supplier.
  - Our entire business model is based on being an agent, advocate, resource, and technical advisor to our clients.

PSE Services

Utility Automation

- Technology Work Plans
- Integration, Testing, Training and Support
- Cyber Security & IT Assessments
- Substation and Distribution Automation
- Strategic Planning
- Consulting and Procurement services on SCADA, AMI/AMR, OMS, GIS, CIS, and others

Economics & Research

- Load Forecasting
- Statistical Performance Measurement (Benchmarking)
- Market & Load Research
- Energy Efficiency
- Demand Side Management (DSM)
- Value of Service
- Other Economic Studies

Rates & Financial Planning

- Revenue Requirement Studies
- Class Cost of Service Studies
- Rate Design
- Key Account Services
- Rate Comparisons & Competitive Assess.
- Strategic & Financial Planning

Communications

- Strategic Comm. Planning
- Technology Assessments: Private vs. Commercial
- Land Mobile Radio Design
- Radio Path & Propagation Studies
- Fiber WAN Design & Procurement
- GIS Mapping & Integration of Communication Assets
- Microwave & Fixed Data Design & Procurement

Engineering & Design

- System Planning Studies
- Distributed Generation Strategies
- Transmission Studies
- Power Factor Correction Studies
- System Loss Evaluation
- Substation Design
- Line Design