Electric Power Resource Planning:
EGEAS Software Overview

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Today's Topics

1. Overview of Resource Planning
2. EGEAS Overview
3. Example EGEAS Analysis Completed by MISO
4. EGEAS Live Demonstration

Part 1
Resource Planning Overview

The Goal of Electric Sector Resource Planning

- To find the "best" resource expansion plan to meet projected customer demands, taking into consideration:
  1. Low-cost energy
  2. Acceptable system reliability
  3. Operating system flexibility
  4. Fuel supply security & diversity
  5. Environmental regulations
  6. Corporate financial health

Resource Planning Elements

- Low cost energy:
  - Capital costs of new plants
  - Operating costs of generation system
  - Minimize sum of capital & operating costs
- Acceptable system reliability:
  - Loss-of-Load Probability: e.g., 1 day/10years
  - Unserved or unmet energy: MWh/year
  - Percent reserve margin: e.g., 15%
- Operating system flexibility:
  - Mix of different types of resources
  - Baseload – Operates around the clock
  - Intermediate – Operates 8-12 hours per day
  - Peaking – Operates a few hours per day

Resource Planning Overview

Generation Resource Characteristics

Characteristics	Baseload	Intermediate	Peaking
Operating Hours/day	24	8 – 12	1 -2
Operating Costs	Low	Medium	High
Capital Costs	High > $2000	Medium $800-$1000	Low $600-$800
Plant Types	Coal Hydro	Gas CCs Hydro	Gas CTs Hydro
Typical Mix	50 – 70%	20 – 30%	10 – 20%

Resource Planning Overview
Fuel Supply

- Fuel security
  - Dual fuel
  - Multiple suppliers
  - Multiple sources, etc.
- Fuel diversity
  - Nuclear
  - Coal / natural gas / oil
  - Hydro, wind, solar

Environmental Regulations

- Clean Air Act Amendments of 1990 (CAAA)
  - Sulfur dioxide (SO_2)
  - Ozone (O_3)
  - Caron monoxide (CO)
  - Particulates (PM-10)
- Recent EPA regulations
  - Cooling Water Intake Structures (CWIS)
  - Coal Combustion Residuals (CCR)
  - Cross-state Air Pollution Rule (CSAPR)
  - Mercury and Air Toxics Standards (MATS)
- Greenhouse gas (GHG) emissions reductions
  - Mandatory state-based GHG reductions (e.g., CA & RGGI)
  - (e.g., EPA's proposed Clean Power Plan)

Corporate Financial Health

- Investor-Owned Utilities (IOUs) / Independent Power Producers (IPPs)
  - Financing requirements (e.g., rate base / ROE)
  - Cash-flow requirements
  - Level and quality of earnings
  - Dividends
- Municipal agencies
  - Interest & other coverages
  - In-lieu taxes

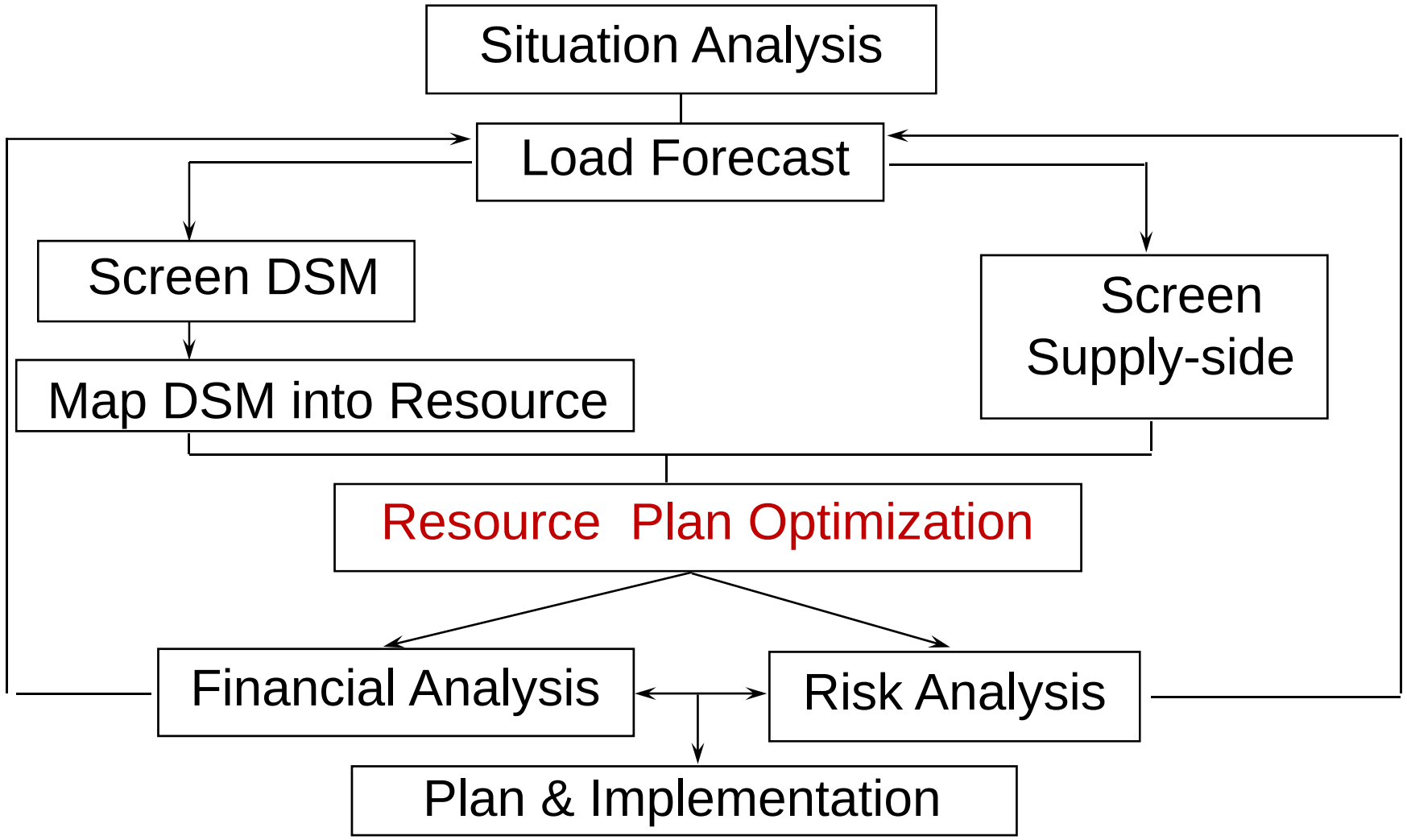
Classical Planning Method –
Using Separate Planning Models

1. A capacity or reliability model is used to determine new capacity requirements.
2. A production cost model is used to determine total system operating costs
3. Economic model is used to combine capacity and production costs on a present-worth basis
4. Iterate steps 1-3 for different expansion plans, until you reach the approximately lowest cost plan

Optimization Method –
Using an Optimization Model Like EGEAS

1. Automates the classical planning method, and evaluate all possible combinations of resources plans to reach the optimal, least-cost plan
2. Users input load forecast, costs and characteristics of existing and potential resources, purchase power contracts, and all future potential planning options.
3. Users run the optimization model, sit back, relax, enjoy a cup of coffee… and get the “right” answers.

Integrated Resources Planning Process (IRPs)



Part 2
Overview of EPRI's Electric Generation Expansion Analysis System (EGEAS) version 10.0

The Purpose of EGEAS

- Primary Purpose – To find the optimum (least-cost) integrated resource plan to meet electric system demand by expanding both supply-side and demand-side resources
- Objective Functions:
  1. Calculate present value of revenue requirements
  2. Calculate system levelized average rate

EGEAS Software Applications

- Strategic assessments
- Integrated Resource Planning (IRP) studies
- Production cost analysis
- System reliability analysis
- Emissions compliance and planning
- Renewable portfolio standards (RPS) analysis
- Plant life management analysis
- Existing plant retirement analysis
- IPP and cogeneration proposal analyses
- Sensitivity and break-even cost analyses

Example EGEAS Applications in the United States

- MISO – Regional resource forecasting, Renewable portfolio standards, EPA regulatory analysis, MISO value proposition and others.
- WPL – IRP and compliance studies, and “Certificate of Need” (CN) application
- IPL – IRP studies and CN application
- WE – IRP studies and CN application
- WPS – IRP and compliance studies, and CN application
- MGE – IRP and compliance studies, and CN application
- FPL – IRP studies and CN application
- MDU – IRP studies and CN application
- Santee Cooper – IRP studies and CN application
- SMMPA – IRP studies
- OMS / PSC’s –10 of 15 states in the Organization of MISO States (OMS) are using EGEAS for IRP and compliance studies

EGEAS also is Used Internationally

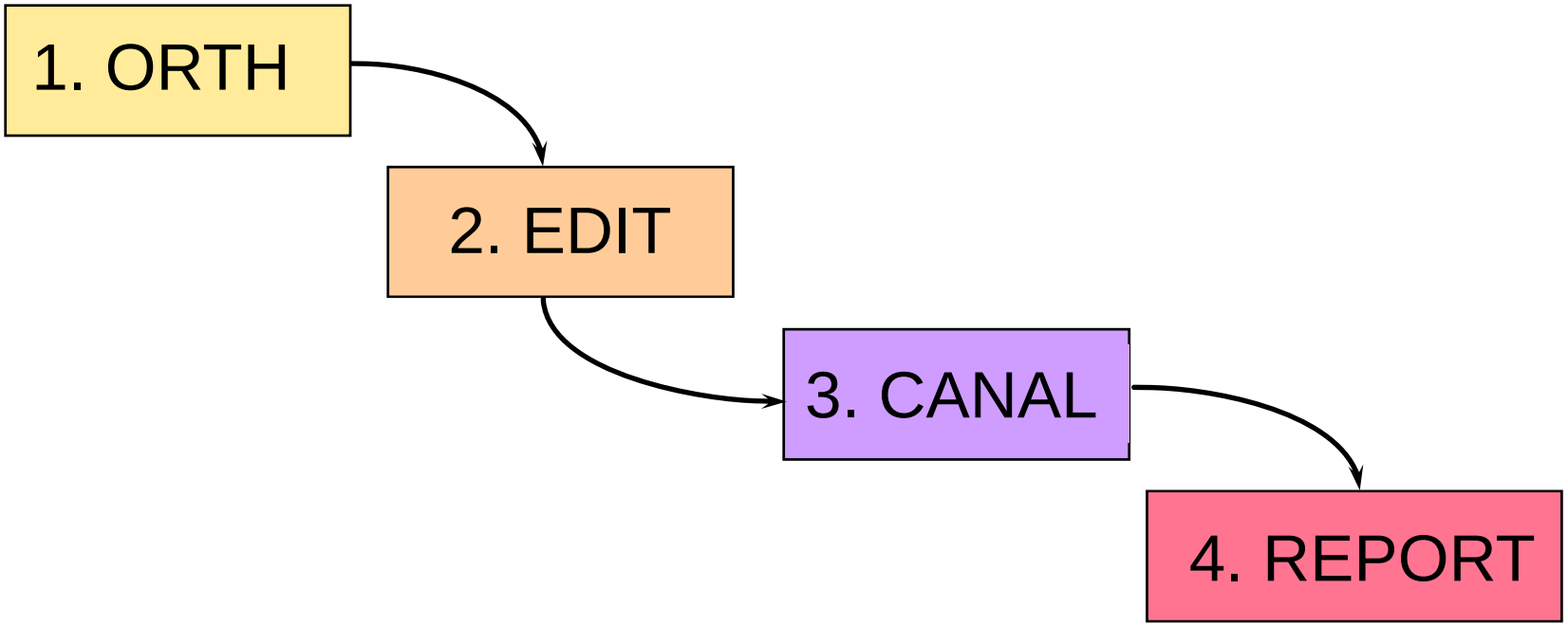
- Barbados
- Peoples Republic of China
- Egypt
- Guam
- Israel
- Malaysia
- Philippines
- Saudi Arabia
- South Africa
- South Korea
- Taiwan
- Thailand
- Qatar

EGEAS is the Foundation of Many Electric Generation Resource Optimization Models Used Today

- STRATEGIST by Ventyx
- MARKET POWER by Ventyx
- SYSTEM OPTIMIZER by Ventyx
- PLEXOS by Energy Exemplar
- AURORA by EPIS, Inc.
- UPLAN by LCG Consulting
- ENPEP (WASP) by Argonne National Labs

EGEAS Software Components (1 of 2)

- RP Workstation is the entryway to the individual EGEAS computer modules
  - DSMLink
  - EGEAS
- EGEAS is composed of four components:



EGEAS Software Components (2 of 2)

1. **ORTH** – Component that includes all data and information associated with the electric system demand & energy forecasts and future system load shapes.

2. **EDIT** – Component that includes all data and information about electric system technology costs and performance data for the existing generation system and future resources.

3. **CANAL** – Component where users define the characteristics of the model "run" they wish to execute, for example: optimization method, planning options, reliability criteria, dispatch options, tunnel constraints, etc.

4. **REPORT** – EGEAS software reporting function where users can configure the types of reports they wish to see.

EGEAS Includes Four Optimization Methods (1 of 2)

1. Dynamic Program (DP) is based on the enumeration of all possible combinations of resource additions while meeting user-specified constraints.
2. Generalized Bender's Decomposition is a non-linear technique based on an iterative interaction between a linear master problem and a non-linear probabilistic production costing sub-problem.

EGEAS Optimization Methods (2 of 2)

3. Screening Curve Option – Produces (cost by capacity factor) results for evaluating large numbers of alternatives.

4. Pre-specified Pathway Option – Provides more detailed analysis of an expansion plan than is computationally feasible within an optimization. Also allows user-defined plans to be analyzed.

Optimization Constraints (1 of 2)

- Reliability
  - Reserve margin – maximum or minimum
  - Unmet energy – maximum
  - Loss-of-Load probability – maximum
- Tunneling
  - Used to specify the upper and lower limits of the annual and/or cumulative number of resource additions available for consideration

Optimization Constraints (2 of 2)

- Environmental constraints
  - Optimize to a pollutant cap level
  - Incorporate system, site or unit limits
- Fuel use constraints
  - Limited fuel
  - Target fuel use
  - Take-or-pay fuel

Supply-Side Alternatives

- Thermal units
- Retirement of existing facilities
- Staged resources
- Life extension
- Hydro
- Storage
- Non–Dispatchable Technologies (NDT)

Demand-Side Management (DSM) Alternatives

- Conservation
- Load management
  - Peak clipping
  - Load shifting
  - Storage
  - Rate design
- Strategic marketing

EGEAS – Additional Capabilities

- Purchase and sale contracts
- Interconnections with 9 other systems
- Avoided capacity and operating costs
- Customer class revenue and sales
- Environmental tracking and emissions dispatch for up to 8 user-defined variables

Production Costing Capabilities (1 of 2)

- Production costing – performs economic dispatch to determine total system operating costs, including fuel, variable O&M, and emission costs.
- Four capacity levels
  - Rated
  - Operating
  - Emergency
  - Reserve capacities
- Change capacity levels by year and month
- Up to five loading points or blocks
  - Capacities
  - Heat rates
  - Forced outages

Production Costing Capabilities (2 of 2)

- Automatic & fixed maintenance scheduling
- Spinning reserve designations and options
- Monthly fuel pricing & target limitations
  - Minimum
  - Maximum
  - Target percentages
- Operating and maintenance costs
- Emission dispatch and costs
- Dispatch modifier costs
- Monthly limited energy data

EGEAS Version 10 – Key Features

- One-stop software licensing process (via EPRI or NG Planning LLC)
- Consolidated EGEAS, Graphic User Interface, DSMLINK, and RPWorkstation programs
- Eliminated Finance+ and Riskmin programs which are no longer supported or used
- Updated EGEAS Capabilities Manual and all other User's Guides / Manuals

EGEAS Version 11 – New Features

- Dump Energy penalty factor
  - Adding a penalty to the fuel and O&M costs for “excess” system energy that needs to be dumped
- Renewable Portfolio Standard (RPS) constraint
  - Ensure that a minimum percent of system generation is supplied by defined “renewable generation sources
- Update EGEAS user’s guides & manuals

NG Planning LLC – EGEAS Services

- EPRI license to commercialize EGEAS, including:
  - Sublicense EGEAS to new users, and
  - Provide resource planning consulting using EGEAS
- Ongoing collaboration with EPRI to upgrade EGEAS (e.g., version 11 upgrade to be completed in 2015)
- Partnering with EPRI to expand the EGEAS user base
- Provides maintenance & technical (M&T) support services for EGEAS program and users
- Provides setup and training services for EGEAS users
- Coordinates EGEAS User Group meetings

EGEAS User Group Meetings

- Annual meeting
  - **When** – Late summer / early fall
  - **Schedule** – Two half days to accommodate travel
  - **Participants** – Open to all EGEAS users
  - **Location** – MISO offices in Eagan, MN
- Purpose – The EGEAS Users Group provides a forum for EGEAS users to:
  - Exchange information on the use and application of EGEAS
  - Recommend improvements and new enhancements
  - Communicate with EPRI on current related research projects and funding availability

Part 3
Example EGEAS Strategic Analysis Performed by MISO

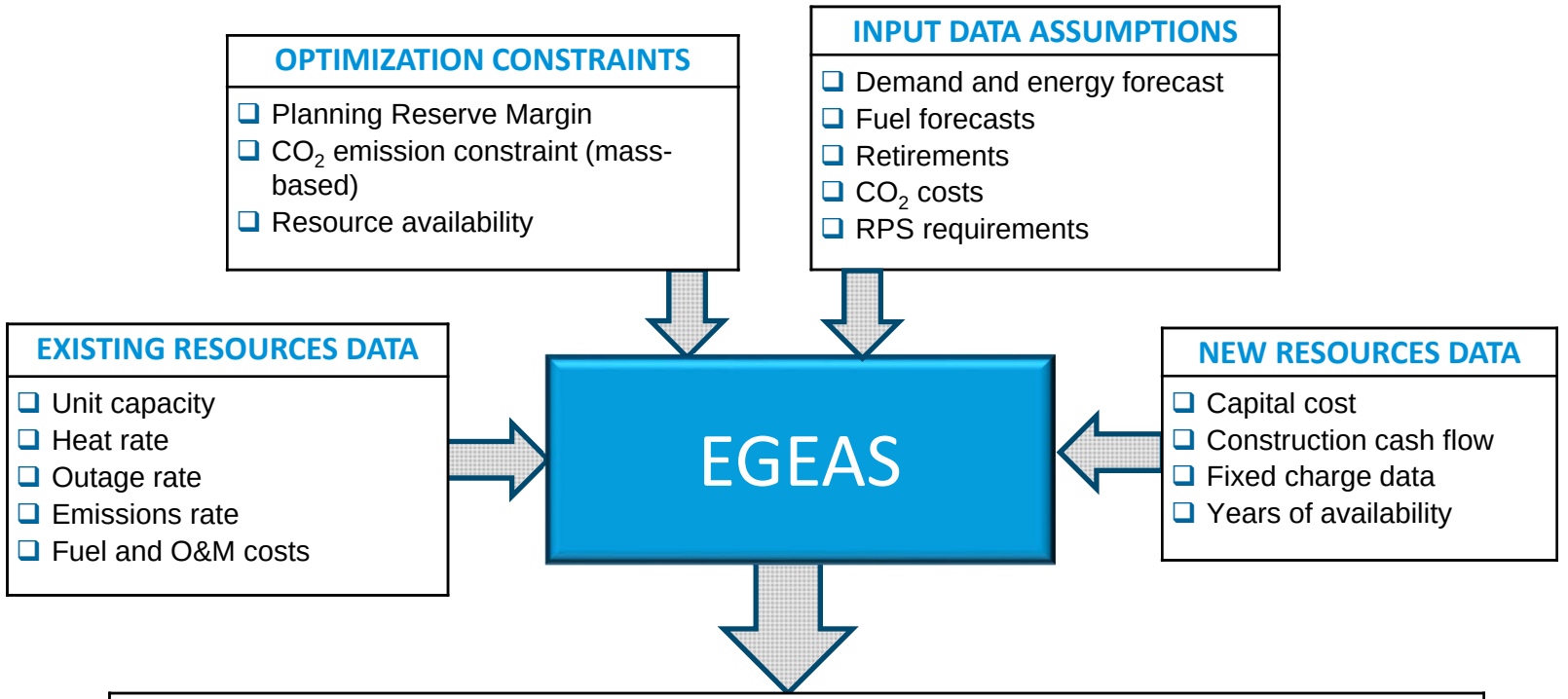
MISO Used EGEAS to Evaluate EPA's Proposed Clean Power Plan under CAA Section 111(d)

- **Purpose** – To inform stakeholders of potential impacts of EPA's proposed Clean Power Plan on the generation fleet and load resulting.

- **Key Findings**
  - Compliance costs vary based on the CO_2 reduction strategy.
    - ~$90B NPV based on EPA's Four Building Blocks
    - ~$83 B NPV based on "sub-regional" optimization
    - ~$55B NPV based on full "regional optimization"
  - "Regional compliance" is ~40% less expensive than a "sub-regional" approach, i.e., $55B (regional) vs $83B (sub-regional)

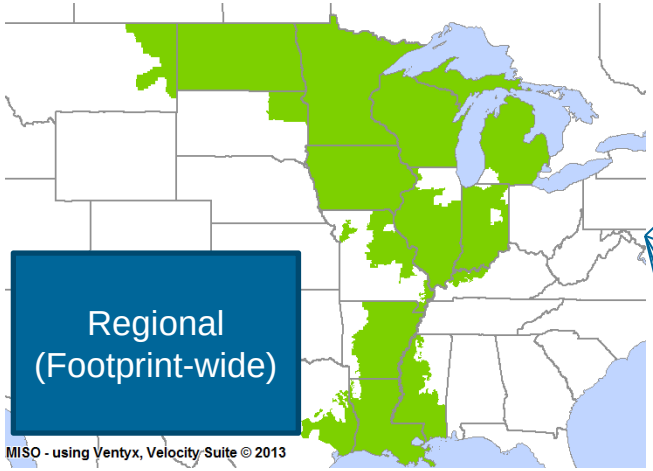
Source: Based on presentation by Mr. John Lawhorn of MISO, EPRI Program 103 Meeting, February 10, 2015, Charleston, South Carolina.

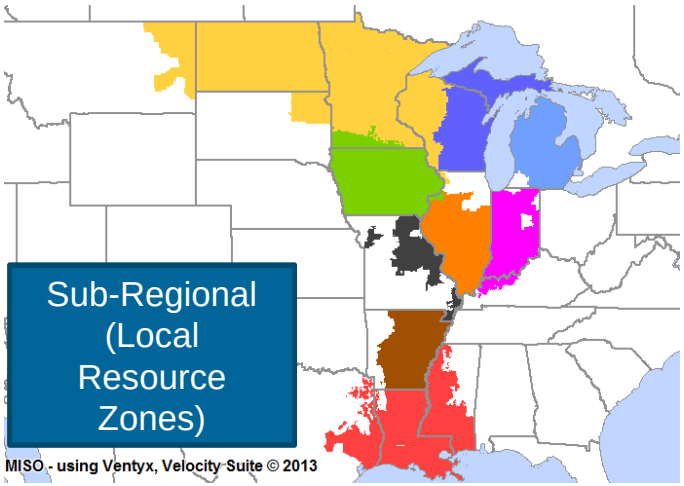
MISO Used EGEAS to Study the Potential Impacts of EPA's Proposed Clean Power Plan – 111(d)



Total System Costs = Sum of Production Cost + Fixed O&M Cost + Capital Carrying Costs.

MISO Assessed EPA's Proposed Building Blocks to Calculate Economic Costs and Emissions Reductions





- Building Block 1
  - Cost of Compliance
  - Emissions Reduction Achieved
- Building Block 2
  - Cost of Compliance
  - Emissions Reduction Achieved
- Building Block 3
  - Cost of Compliance
  - Emissions Reduction Achieved
- Building Block 4
  - Cost of Compliance
  - Emissions Reduction Achieved
- All Building Blocks
  - Cost of Compliance
  - Emissions Reduction Achieved

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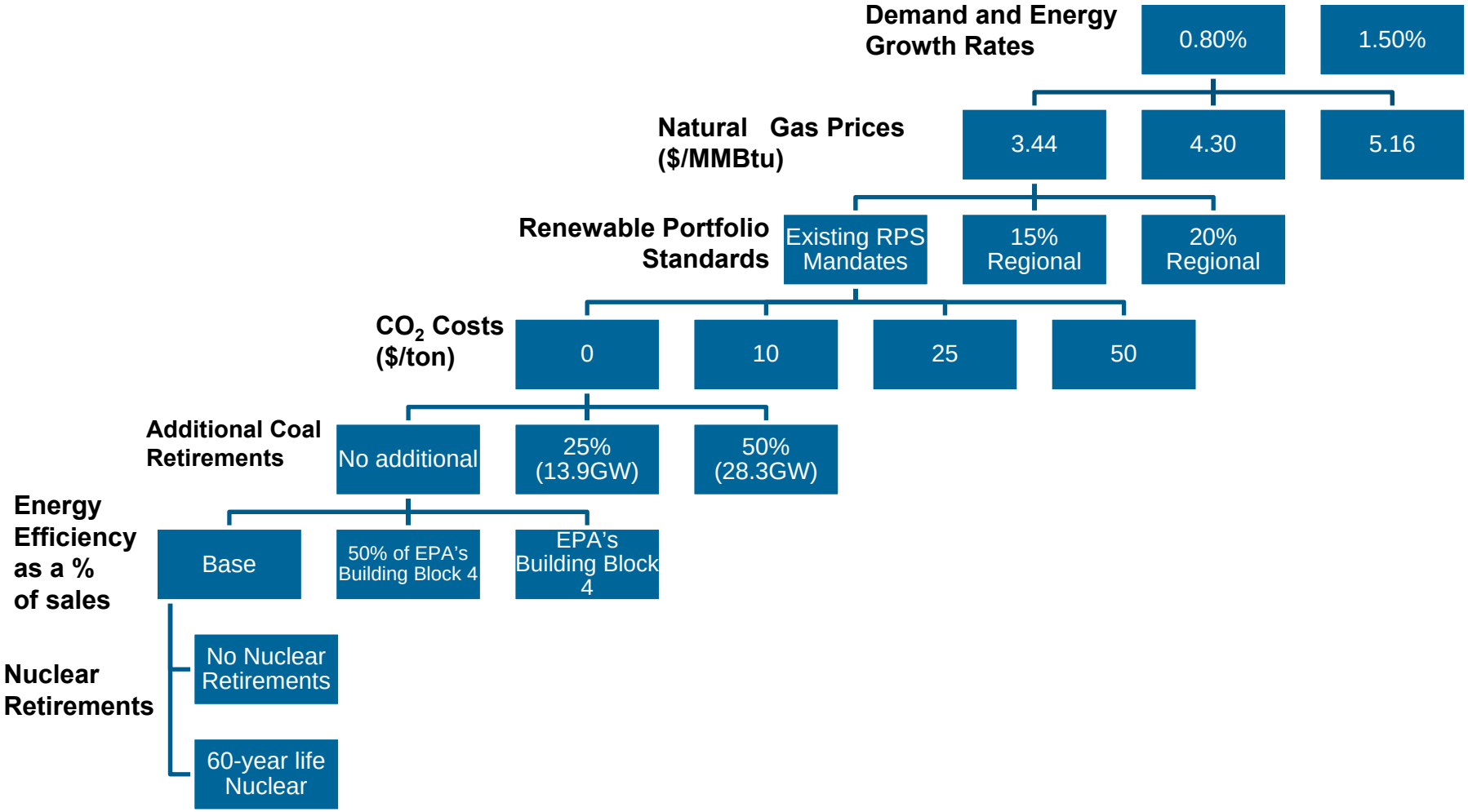
MISO Modeled Different Policy and Economic Sensitivities



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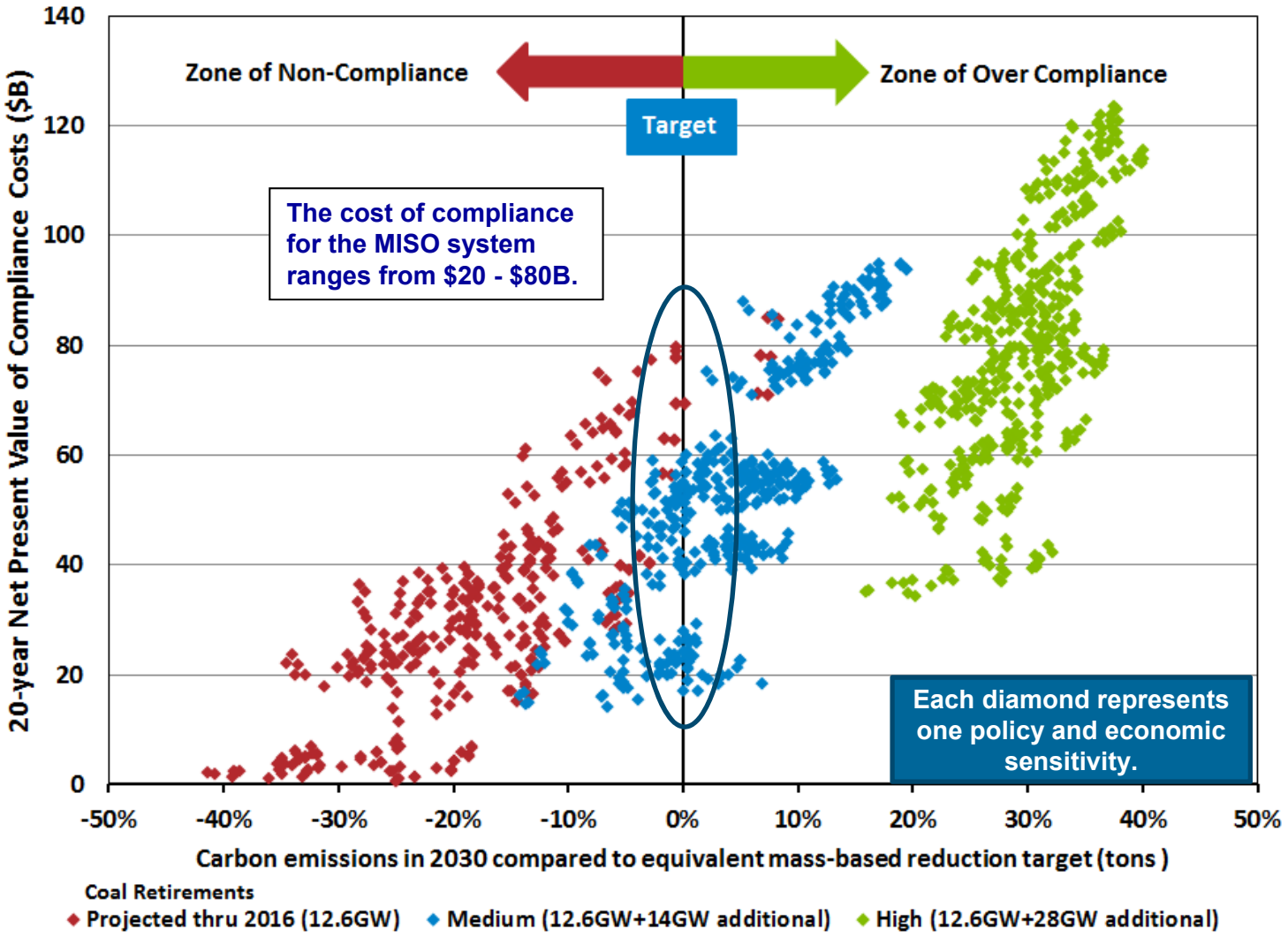
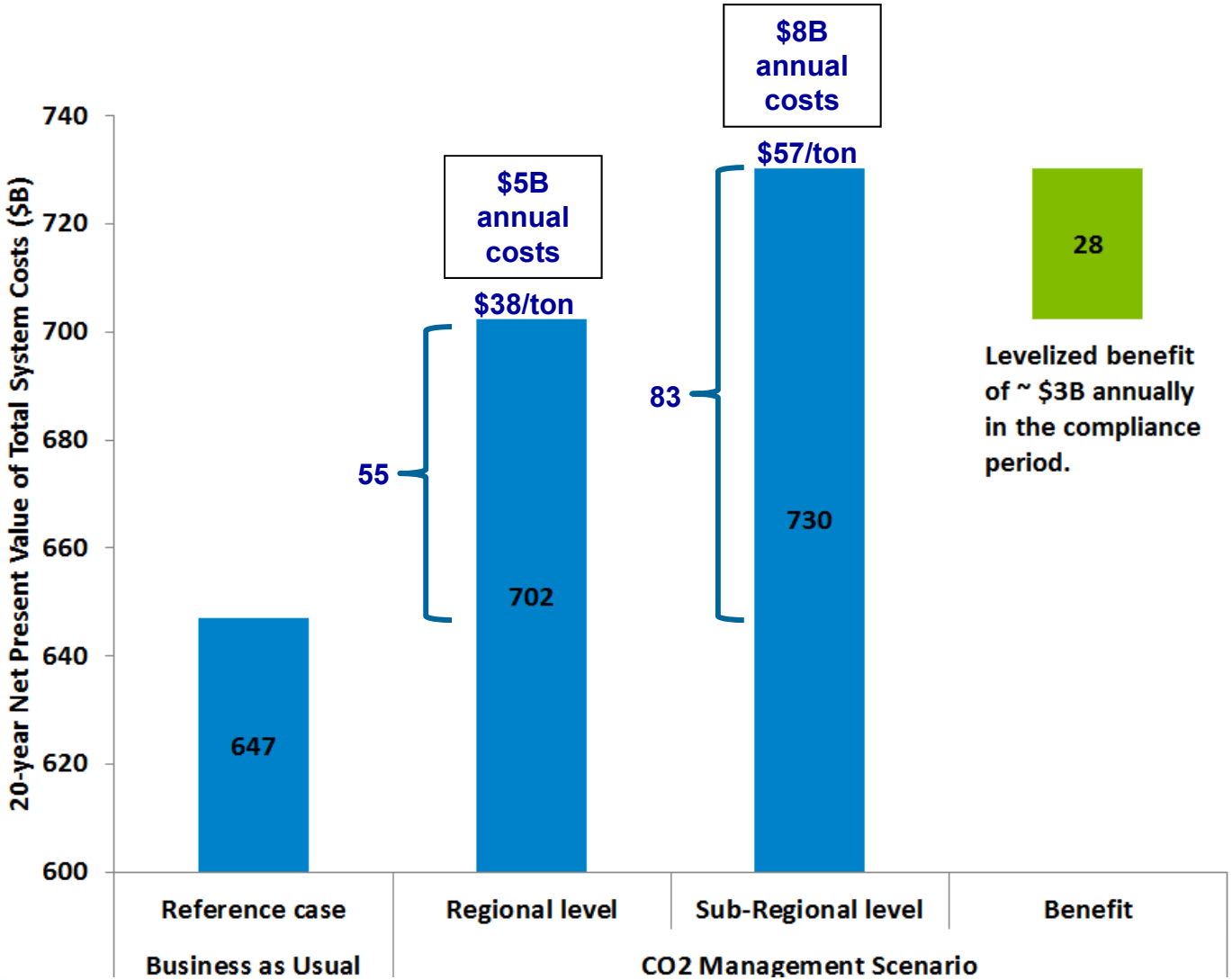
NPV of Expected Compliance Costs and Anticipated Coal Plant Retirements



"Regional" Compliance Estimated to Cost ~$3B Less Annually than "Sub-regional" Compliance



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Additional Information

- EPA Regulations webpage

  https://www.misoenergy.org/WhatWeDo/EPARegulations/Pages/EPARegulations.aspx

- Planning Advisory Committee: Study Results Presentation

  https://www.misoenergy.org/Library/Repository/Meeting%20Material/Stakeholder/PAC/2014/20140917/20140917%20PAC%20Item%2002%20GHG%20Regulation%20Impact%20Analysis%20-%20Study%20Results.pdf

- MISO One-Pager on Initial Study Results

  https://www.misoenergy.org/Library/Repository/Meeting%20Material/Stakeholder/PAC/2014/20140917/20140917%20PAC%20Item%2002%20MISO%20CO2%20Analysis%20One%20Pager.pdf

- Additional Information, please contact:

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Part 4: EGEAS Demonstration

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