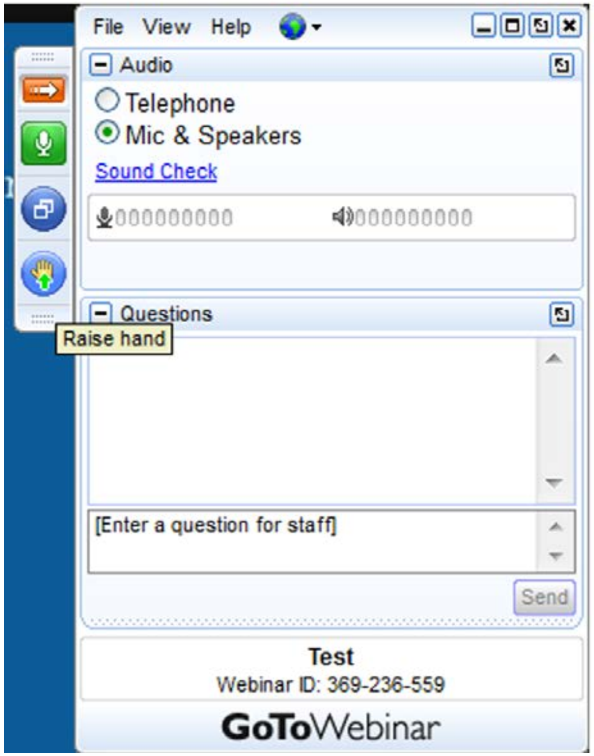
Introduction to Regional Transmission Organizations for State Air Regulators

Briefing for State Air Quality Regulators
by the Regulatory Assistance Project and the Great Plains Institute

September 11, 2015

Housekeeping

Please send questions through the Questions pane.



Our Experts

David Littell,
Regulatory Assistance Project

Doug Scott,
Great Plains Institute

Our RTO Experts

Paul Sotkiewicz, PJM

Kari Evans Bennett, MISO

Presentation Overview

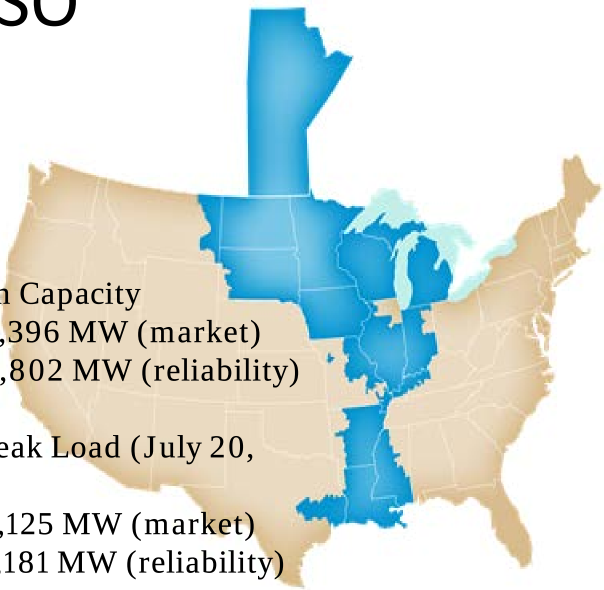
- Nature and Purpose of Regional Transmission Organizations (RTOs)
- Key RTO Functions and Benefits
- Evolution of the Electricity Grid
- Overview of Least-cost Generation Dispatch and the Formation of Market Clearing Prices
- Economic Benefits of RTOs
- Emissions Effects of Least-cost Dispatch and Interconnected Systems like of RTOs
- Implications for Clean Power Plan (CPP) Planning
- Recommendations

Nature and Purpose of RTOs

- What is a Regional Transmission Organization (RTO)?
- What do we have RTOs do?
- How can RTOs assist with CPP planning, reliability assessments, etc.?

MISO & PJM Generation Dispatch and Reliability Regions

MISO

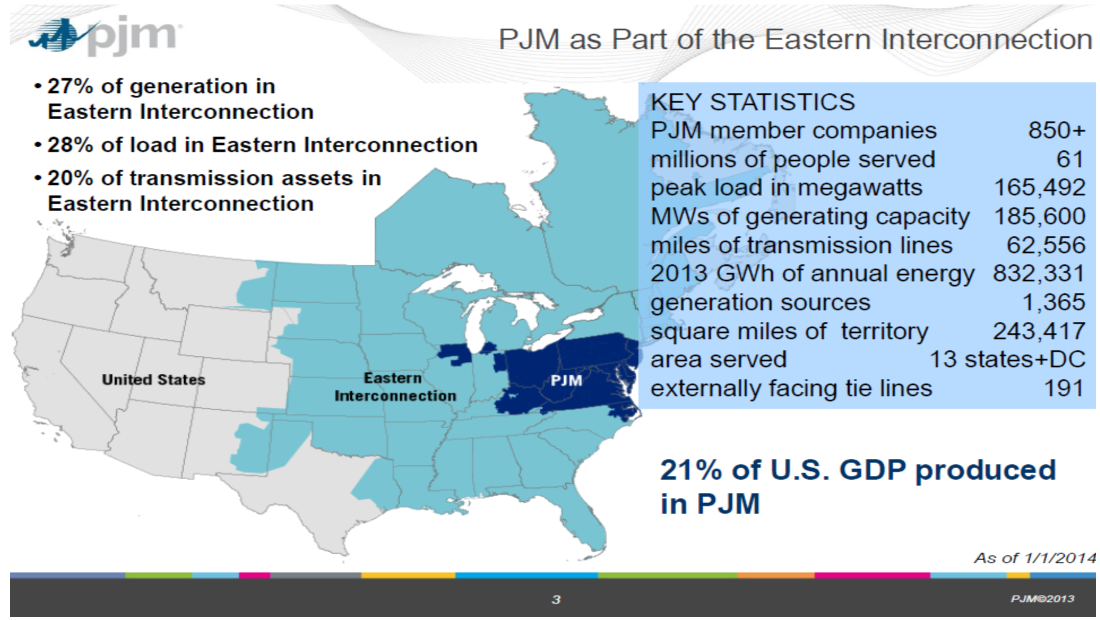


Generation Capacity
178,396 MW (market)
192,802 MW (reliability)

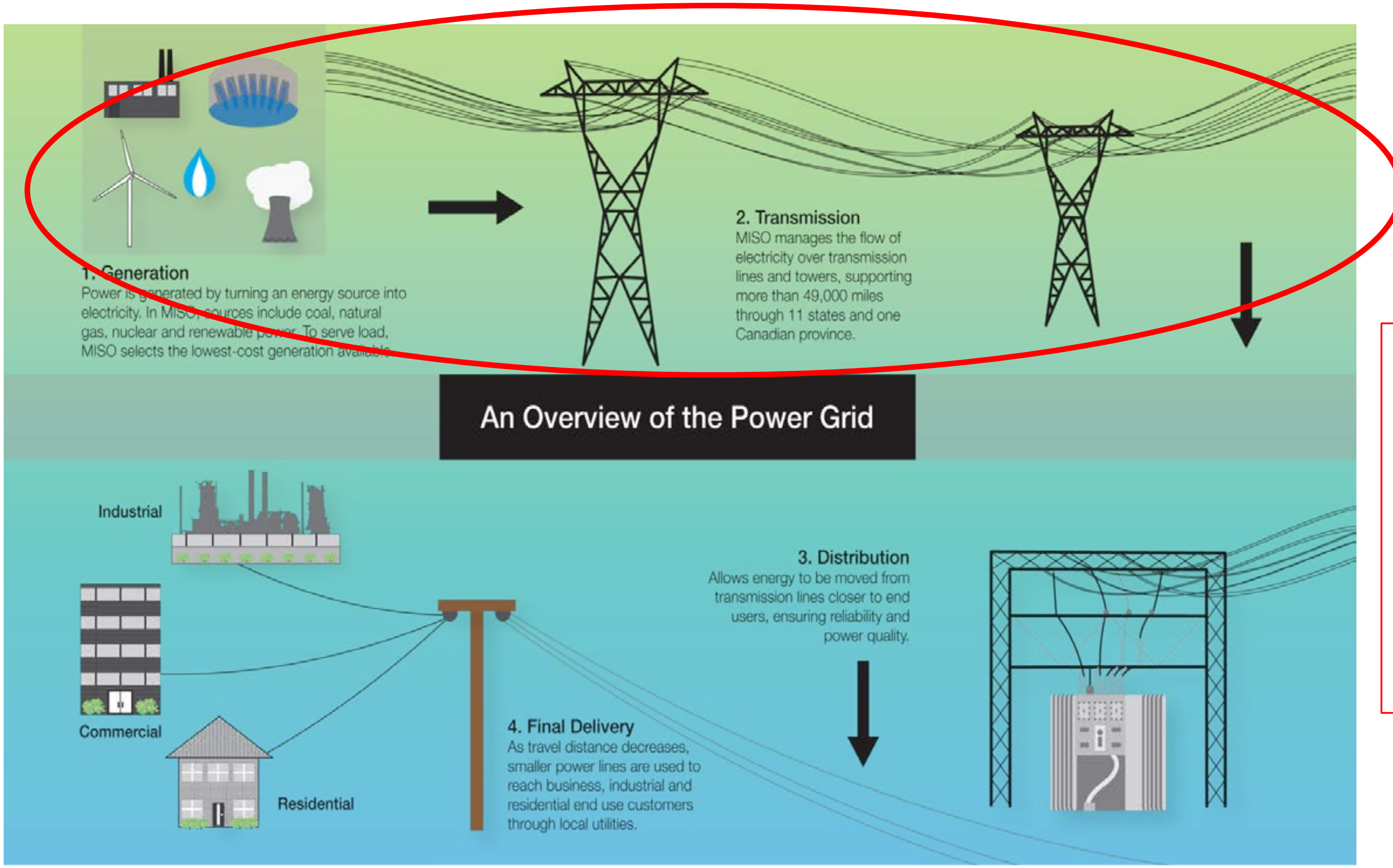
Historic Peak Load (July 20, 2011)
127,125 MW (market)
131,181 MW (reliability)

65,800 miles of transmission
15 States
1 Canadian Province
City of New Orleans

PJM

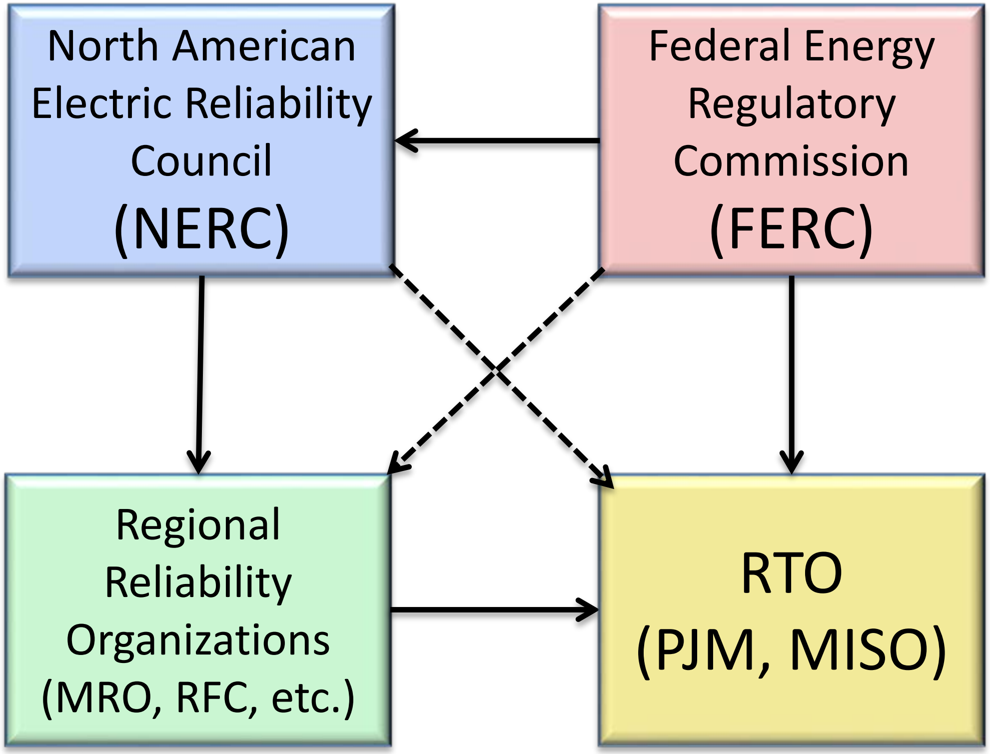


The RTO's Role in the Electricity System



Managing flows on the transmission system by directing generator output

Who Oversees RTOs?

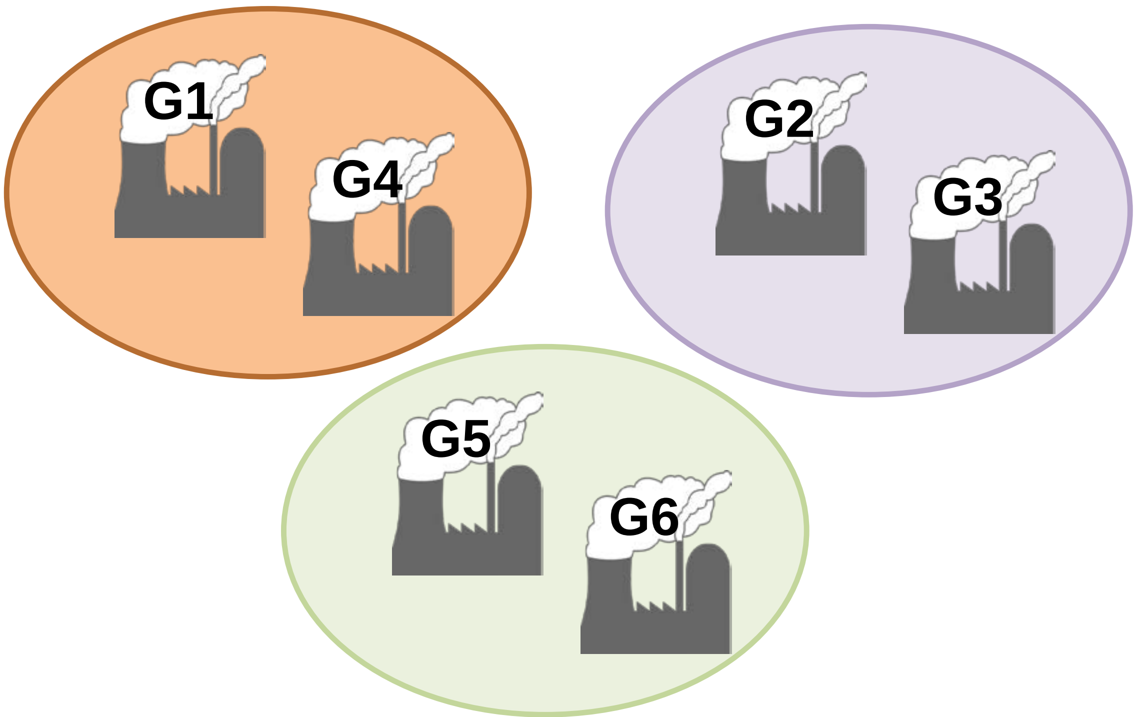


Key RTO Functions and Benefits

What RTOs Do	Implications
Provide non-discriminatory open access transmission service	Facilitates competition between generation resources
Platform for wholesale energy and capacity markets	Incentivizes efficient and cost-effect generation dispatch, and new generation investment
Perform system operations through energy markets	Least-cost dispatch that accounts for reliability needs
Long-term transmission planning, resource adequacy constructs	Enhanced long-term reliability

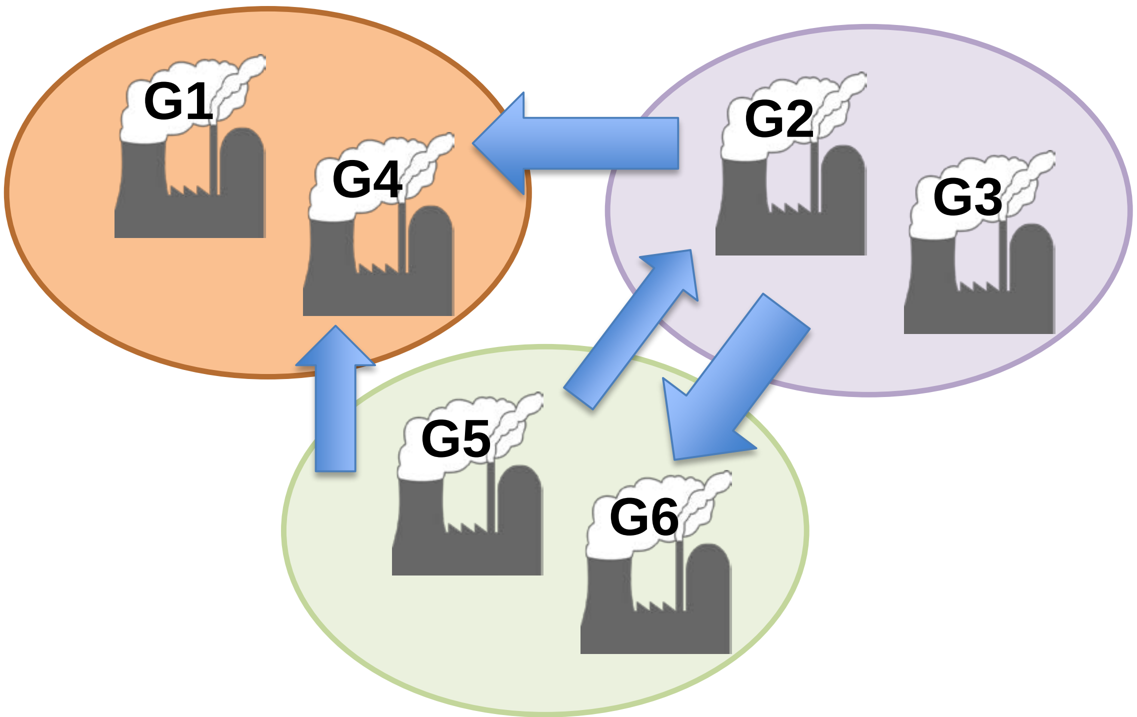
Evolution of the Grid: In the Beginning…

Each utility system serves its own geography and generates to meet its own load as if it were an island



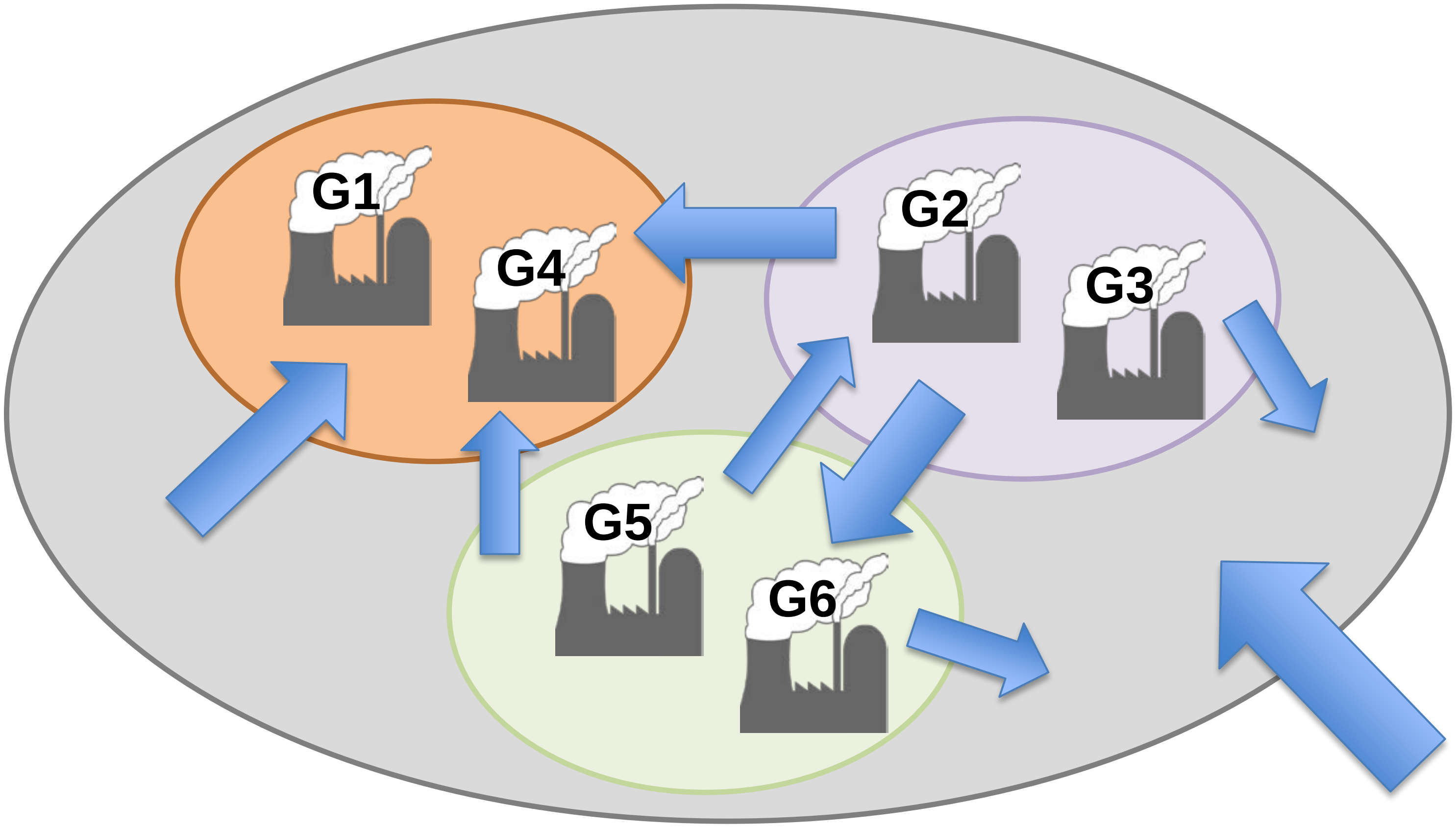
Evolution of the Grid: Systems Began to Share

Interconnecting of systems making bilateral power sharing arrangements to reduce costs and enhance reliability…but operated as separate systems



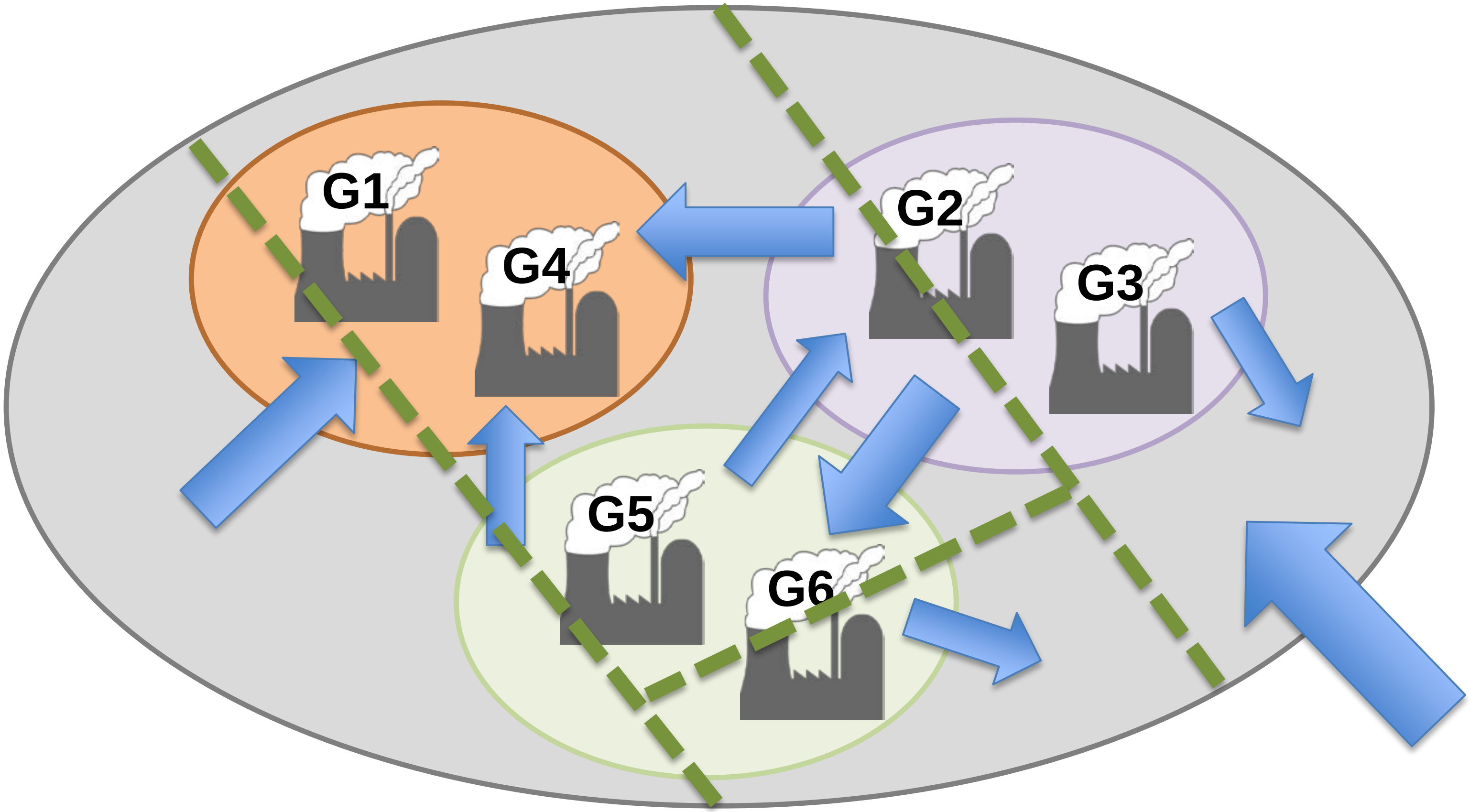
Evolution of the Grid: Systems Formed a Pool

Utility systems enter into power-pooling arrangements to be operated as one system

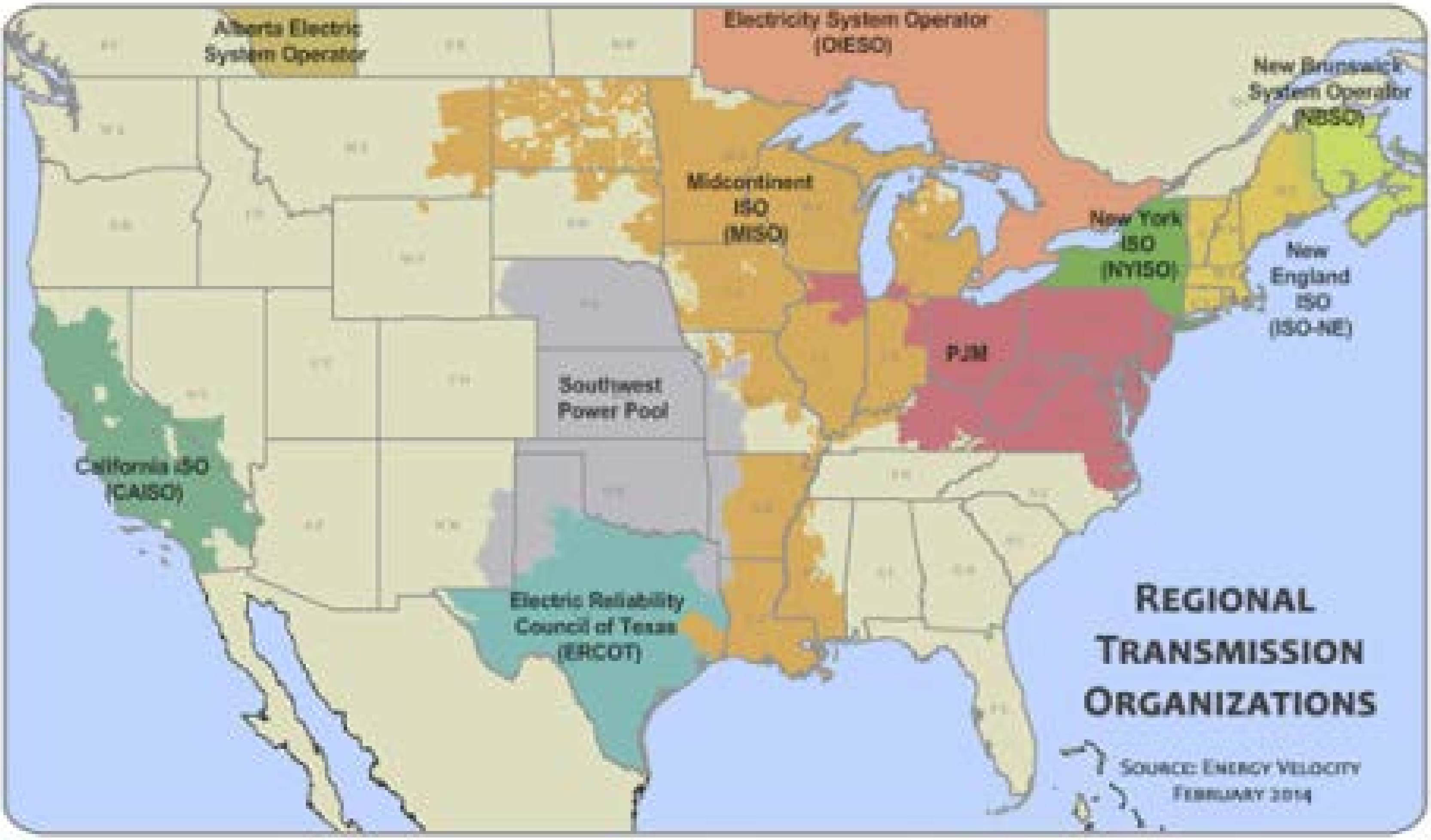


Evolution of the Grid: Pools to ISOs/RTOs

Even though state boundaries exist, even tighter coordination of operations to the benefit of all

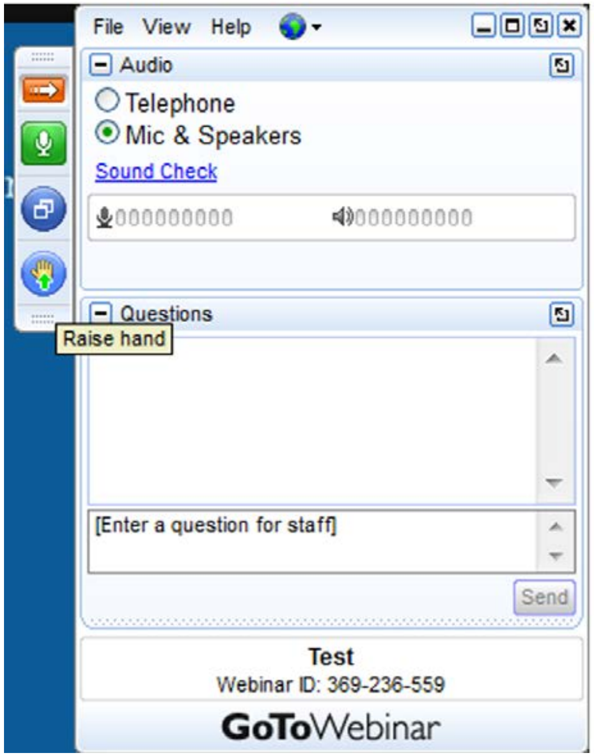


Map of U.S. RTOs Today



Questions?

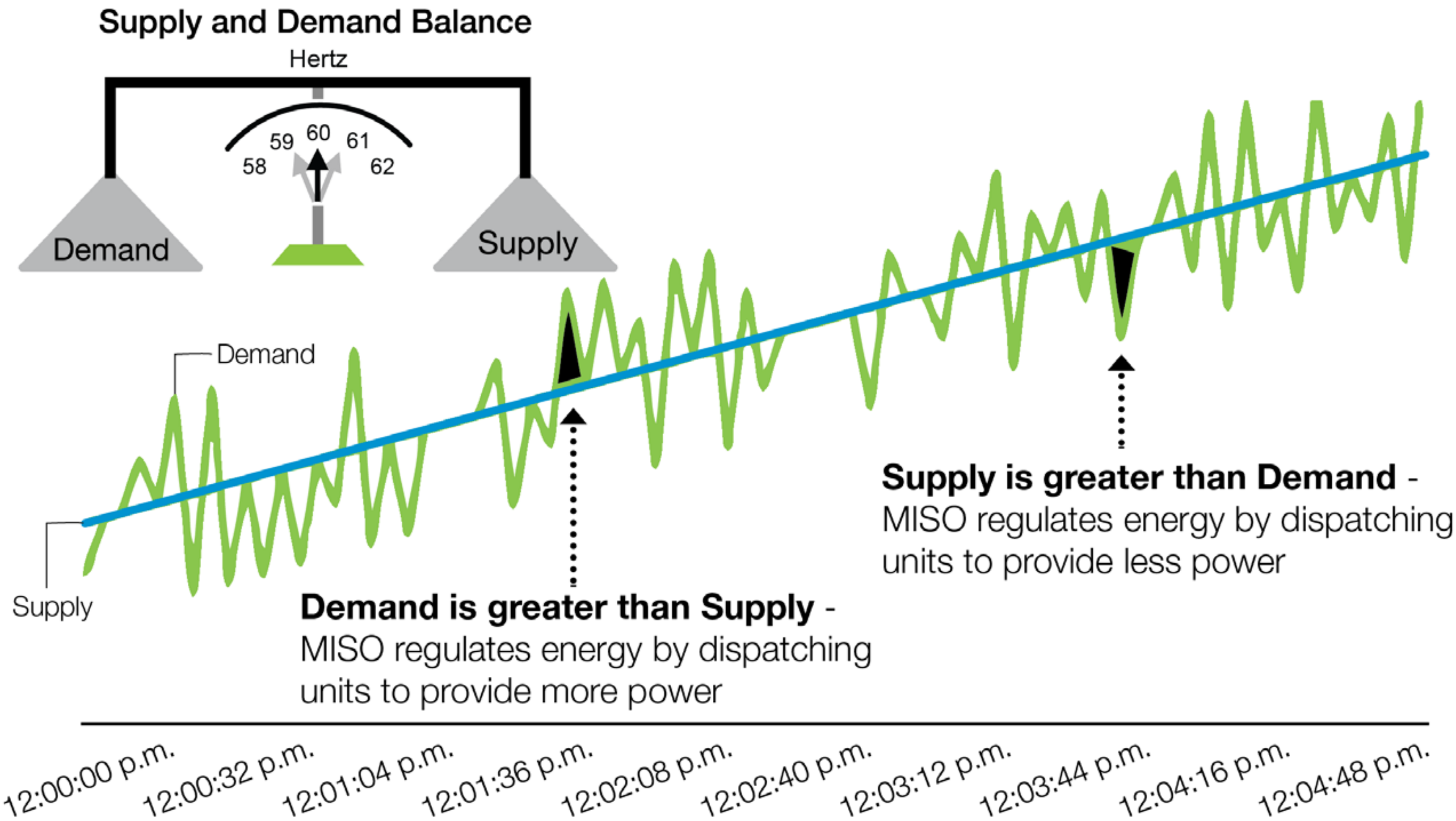
Please send questions through the Questions pane



System Operations through Least-Cost Dispatch while Respecting Generation, Transmission, or Regulatory Constraints

- System operations conducted through dispatch of generation that minimizes bid production cost while respecting generator and transmission or regulatory constraints:
  - Balance supply and demand
  - Physical limits of transmission facilities
  - Reserves and other reliability requirements
  - Power quality requirements (e.g., voltage levels, frequency)
  - Generators' schedules (e.g., maintenance outages)
  - Emissions limitations or hours-of-operation constraints
  - Other physical, regulatory, or market requirements

Balancing Electricity Supply and Demand Moment to Moment



Offers to Supply from Generators Facilitate Least Cost Dispatch and System Operation

10MW @$30

40MW @$80

20MW @$10

15MW @$40

25MW @$50

- Utilities seek to dispatch their systems at least cost
- Applies to vertically integrated utilities as well as organized markets

What goes into generators' bid?

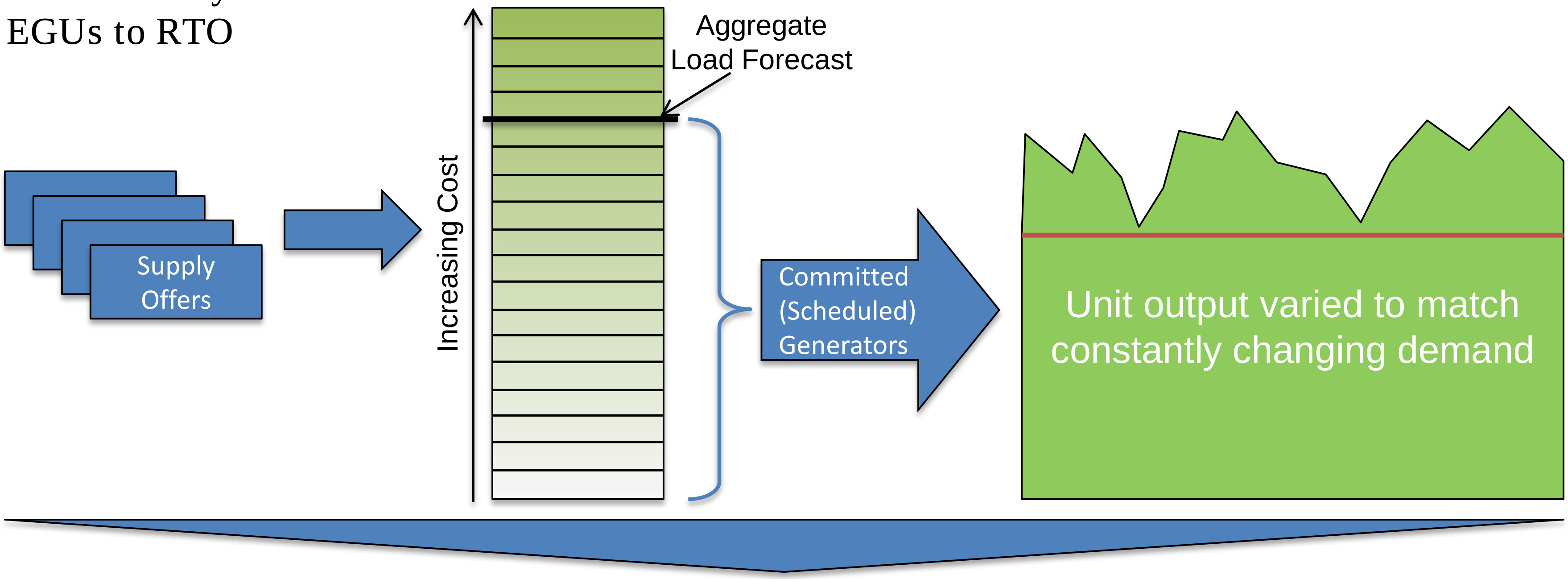
- Fuel
- Variable O&M
- Emissions Costs

Overview of Generation Dispatch

Supply offers submitted by EGUs to RTO

Offers stacked by cost; cheapest units scheduled based on expected demand and constraints

Units dispatched in real time by the RTO



- EGU availability (limits, retirement) affects the amount of supply offered to meet demand
- Changing EGU costs (and thus offers) affect frequency and magnitude of utilization in RTO
- Utilization of EGUs directly impacts fuel usage, and thus emissions produced by each EGU

Least-Cost Dispatch (i.e., "Dispatch Stack")…Minimize Bid Production Cost

Load: 499 MWs

Generator C
Capacity:
200 MWs
Bid: $20/MWh

Not Dispatched

Generator B
Capacity:
200 MWs
Bid: $15/MWh

199 MWs @ $15

Generator A
Capacity:
300 MWs
Bid: $10/MWh

300 MWs @ $10

Production cost = ((300x$10) + (199x$15)) = *$5,985*

Using Gen C would only increase production cost since its bid is higher than Gen A or B.

Market Clearing Price is the Marginal Cost of Delivering One More MW to the System

Load: 499 MWs

Generator C **Capacity: 200 MWs** **Bid: $20/MWh**	**Not Dispatched**
Generator B **Capacity: 200 MWs** **Bid: $15/MWh**	**199 MWs** **@ $15**
Generator A **Capacity: 300 MWs** **Bid: $10/MWh**	**300 MWs** **@ $10**

Cost (Bid) of Marginal Unit = $15/MWh, and it is the last unit dispatched so…

Market Clearing Price = $15/MWh, so…

Energy Market Cost = (499 MWh x $15/MWh) = *$7,485*

Production cost = ((300x$10) + (199x$15)) = *$5,985*

Payments by Load to Generation

Load: 499 MWs

Generator C
Capacity:
200 MWs
Bid: $20/MWh

Not Dispatched

Generator B
Capacity:
200 MWs
Bid: $15/MWh

199 MWs
@ $15

Generator A
Capacity:
300 MWs
Bid: $10/MWh

300 MWs
@ $10

All energy is transacted at the market clearing price, so…

Load energy payment = (499 MWh x $15/MWh) = *$7,485*

Gen A revenue = ((300x$15) = $4500

Gen B revenue = (199x$15)) =$2985

Load Increases by 2 MW…Requires Higher Cost Generation to Serve Load

Production cost = ((300x$10)+(200x$15)+(1x$20)) = <u>*$6,020 (only marginally higher)*</u>

<u>*Only need one MW from Gen C after running out of capacity from lower cost units*</u>

Cost (Bid) of Marginal Unit = $20/MWh, so…

Market Clearing Price = $20/MWh

Generator C **Capacity: 200 MWs** **Bid: $20/MWh**	**1 MW** **@ $20**
Generator B **Capacity: 200 MWs** **Bid: $15/MWh**	**200 MWs** **@ $15**
Generator A **Capacity: 300 MWs** **Bid: $10/MWh**	**300 MWs** **@ $10**

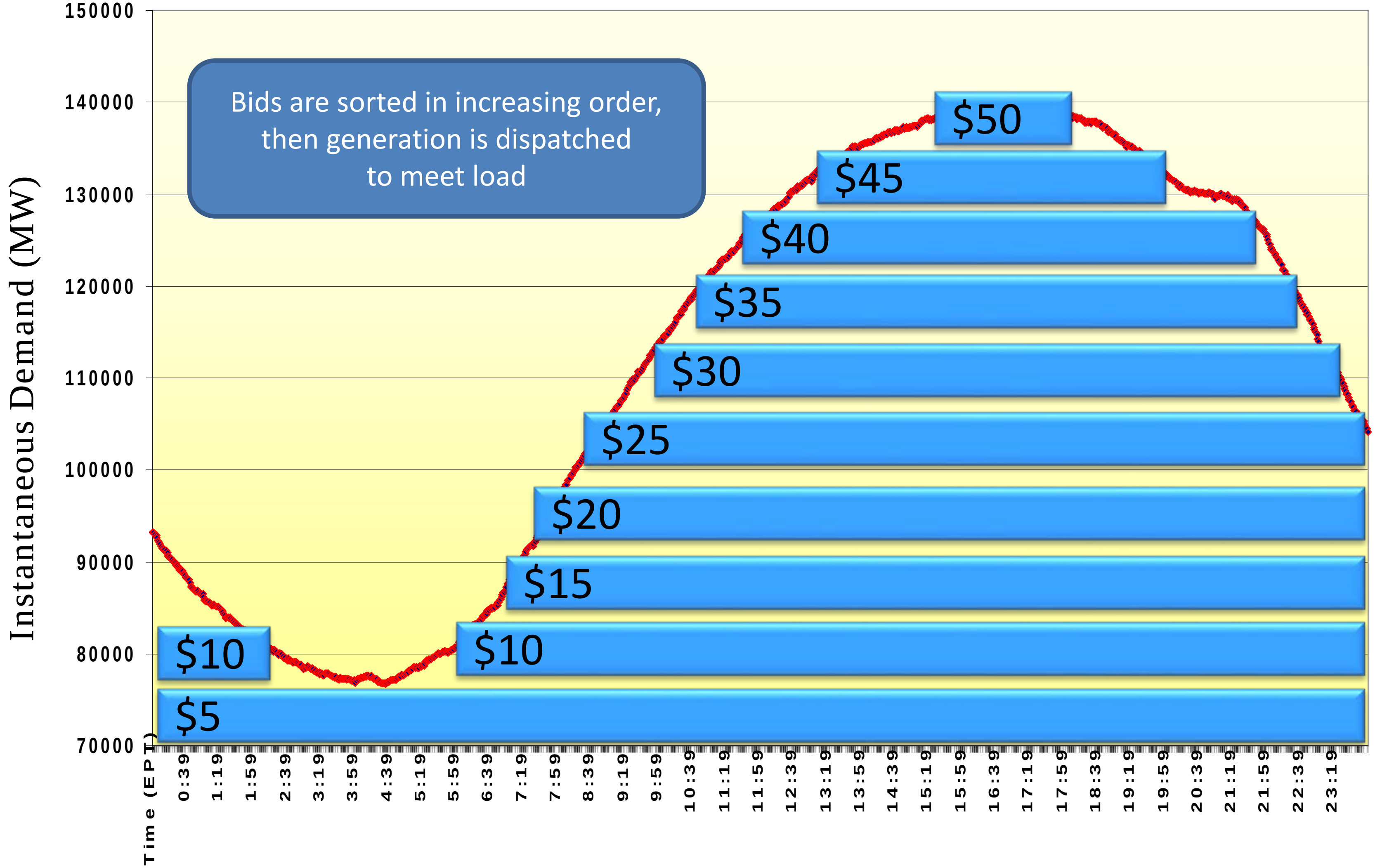
Load energy payment = (501 MWh x $20/MWh) = <u>*$10,020*</u>

Gen A Revenue = 300 MWh * $20/MWh = $6000

Gen B Revenue = 200 MWh * $20/MWh = $4000

Gen C Revenue = 1 MWh * $20/MWh = $20.

Matching Supply to Demand Over the Day

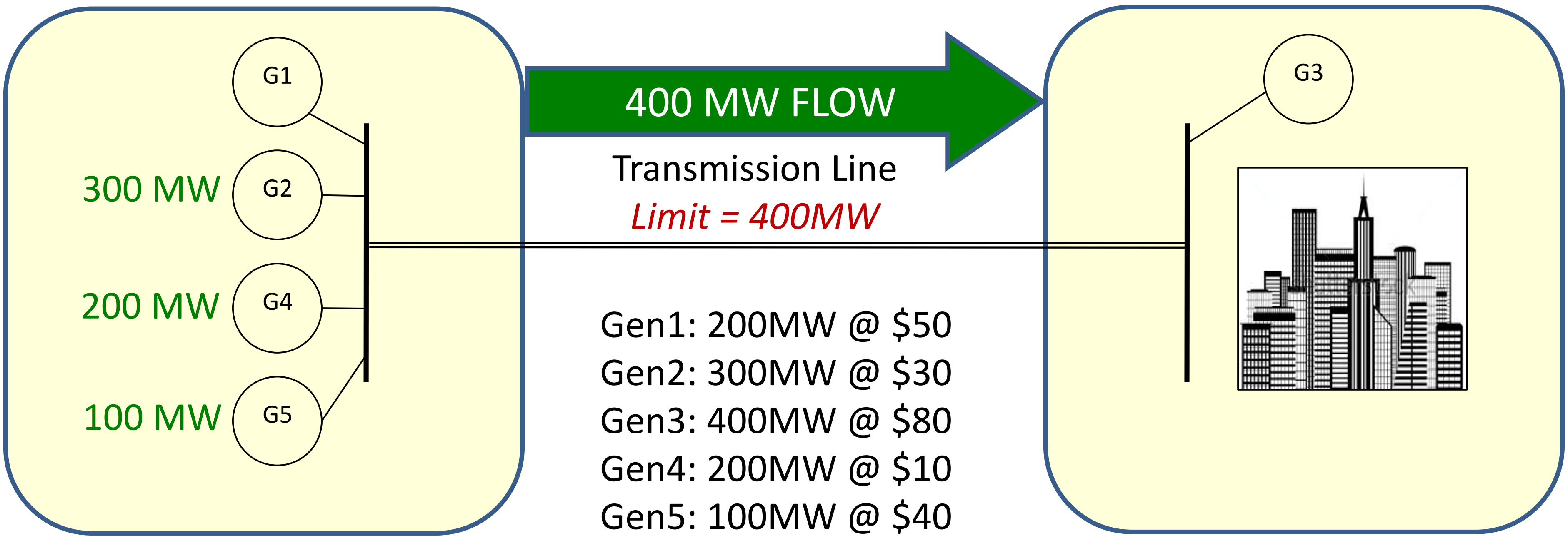


Generation Dispatch Over Multiple Areas (1)

(e.g., This could be two states in an RTO)

Area 1: Load = 200 MW

Area 2: Load = 400 MW



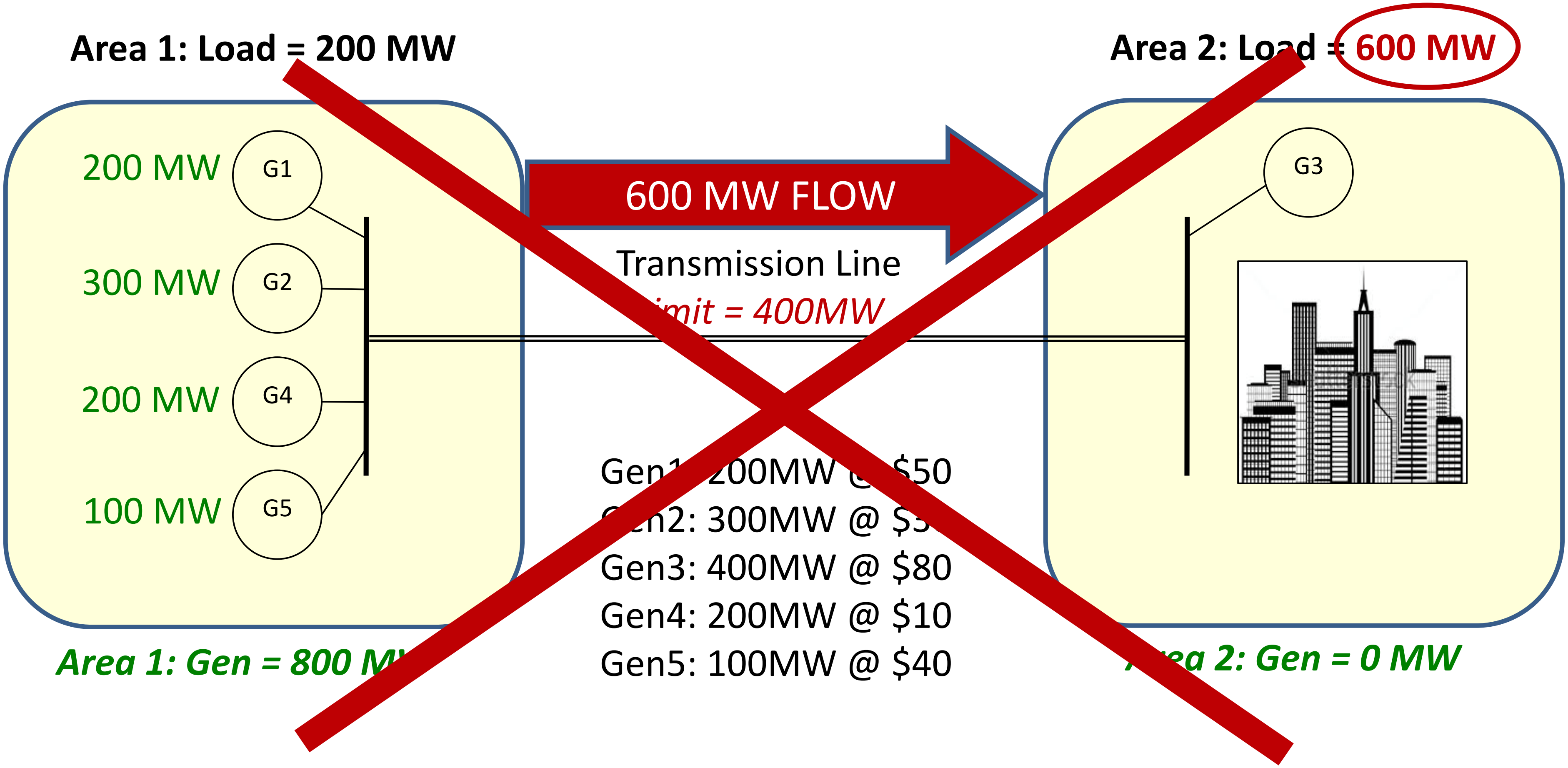
Area 1: Gen = 600 MW

Area 2: Gen = 0 MW @ $100

Market Clearing Price in both areas is $40/MWh
Load Payment in Area 1 = $8000
Load Payment in Area 2 = $16000

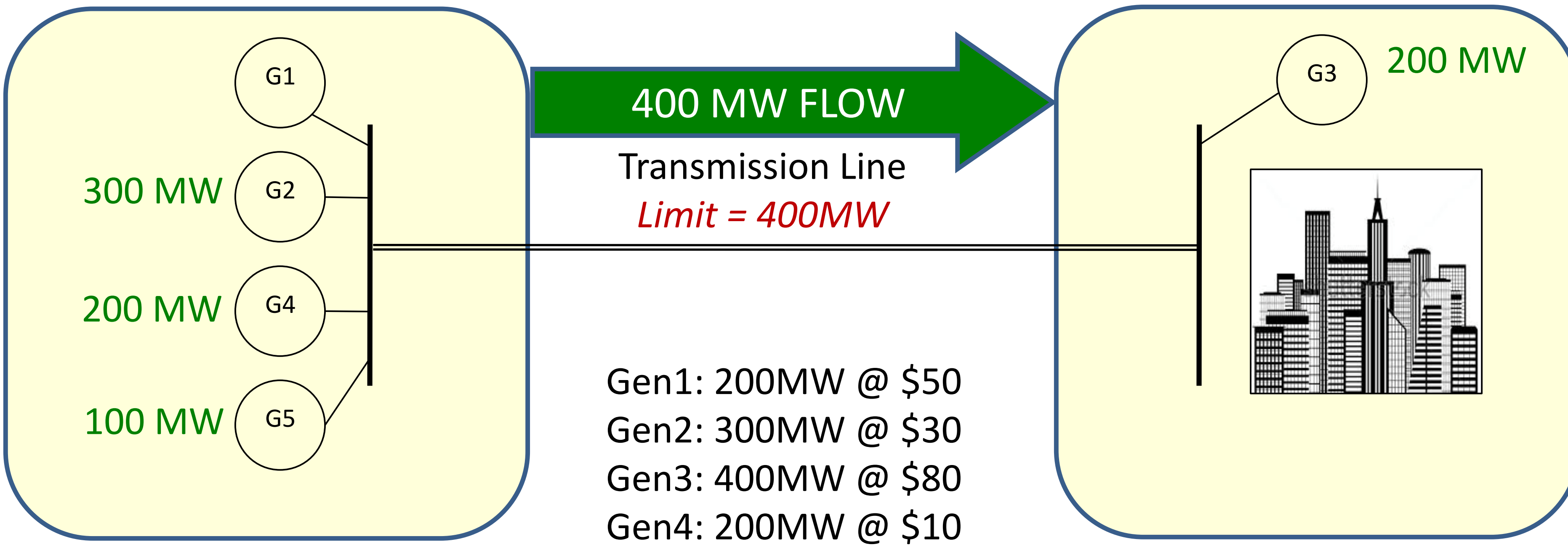
Gen 2 paid $12000
Gen 4 paid $8000
Gen 5 paid $4000

Generation Dispatch Over Multiple Areas (2)



Generation Dispatch Over Multiple Areas (3)

Area 1: Load = 200 MW **Area 2: Load = 600 MW**



Gen1: 200MW @ $50
Gen2: 300MW @ $30
Gen3: 400MW @ $80
Gen4: 200MW @ $10
Gen5: 100MW @ $40

Area 1: Gen = 600 MW

Area 2: Gen = 200 MW @ 100

Market Clearing Price Area 1 = $40/MWh
Market Clearing Price Area 2 = $80/MWh
Load Payment in Area 1 = $8000, Area 2 = $48000

Gen 2 paid $12000
Gen 4 paid $8000
Gen 5 paid $4000

Area 2 Gen
Paid $20000

Economic Benefit RTO Interconnection (1)

Isolated Systems

System 1

Load: 500 MWs

System 1 Clearing Price = $15/MWh…

Production Cost = (300*$10) + (200*$15) = $6000

Generator C Capacity: 200 MWs Bid: $18/MWh	0 MW @ $18
Generator B Capacity: 200 MWs Bid: $15/MWh	200 MWs @ $15
Generator A Capacity: 300 MWs Bid: $10/MWh	300 MWs @ $10

System 2

Load: 500 MWs

Generator F Capacity: 200 MWs Bid: $40/MWh	0 MW @ $40
Generator E Capacity: 300 MWs Bid: $25/MWh	200 MWs @ $25
Generator D Capacity: 300 MWs Bid: $12/MWh	300 MWs @ $12

System 2 Clearing Price = $25/MWh…

Production Cost = (300*$12) + ($200*$25) = $8600

Total Energy Load Payment for Both Systems: $20,000

Economic Benefit RTO Interconnection (2)

Interconnected Systems

System 1

Load: 500 MWs

Interconnected Clearing Price = $18/MWh… Production Cost 1 = (300MWh x $10/MWh) + (200 MWh x $15/MWh) + (200 MWh x $18/MWh) = *$9,600*

System 1 Generator	Dispatch	System 2 Generator	Dispatch
Generator C Capacity: 200 MWs Bid: $18/MWh	200 MW @ $18	**Generator F** Capacity: 200 MWs Bid: $40/MWh	0 MW @ $40
Generator B Capacity: 200 MWs Bid: $15/MWh	200 MWs @ $15	**Generator E** Capacity: 300 MWs Bid: $25/MWh	0 MWs @ $25
Generator A Capacity: 300 MWs Bid: $10/MWh	300 MWs @ $10	**Generator D** Capacity: 300 MWs Bid: $12/MWh	300 MWs @ $12

200 MW

System 2

Load: 500 MWs

Interconnected Clearing Price = $18/MWh…

Production Cost 2 = (300 MWh x $12/MWh) = *$3600*

Total Energy Load Payment for Both Systems: $18,000 (saving $2,000 or 10%)

Economic Benefit RTO Interconnection (3)

Interconnected with Reserve Capacity Sharing (10%)

Joint Coincident Peak Load: 1,000 MWs

System 1

Non-Coincident Peak Load: 560 MWs

Generator C
Capacity:
200 MWs
Bid: $18/MWh

200 MW @ $18

Generator B
Capacity:
200 MWs
Bid: $15/MWh

200 MWs @ $15

Generator A
Capacity:
300 MWs
Bid: $10/MWh

300 MWs @ $10

System 1 NC Peak Clearing Price = $18/MWh

System 1 C Peak Clearing Price = $25/MWh

System 2

Non-Coincident Peak Load: 560 MWs

~~**Generator F**~~
~~Capacity:~~
~~200 MWs~~
~~Bid: $40/MWh~~

0 MW @ $40

Generator E
Capacity:
300 MWs
Bid: $25/MWh

100 MWs @ $25

Generator D
Capacity:
300 MWs
Bid: $12/MWh

300 MWs @ $12

System 2 NC Peak Clearing Price = $40/MWh

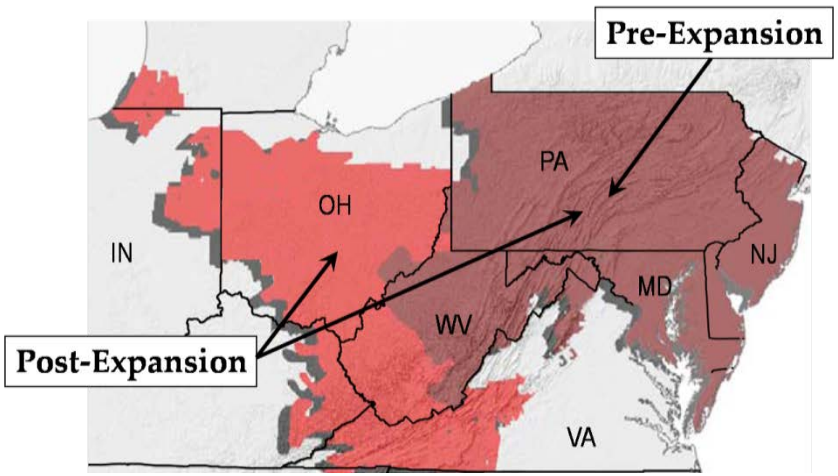
System 2 C Peak Clearing Price = $25/MWh

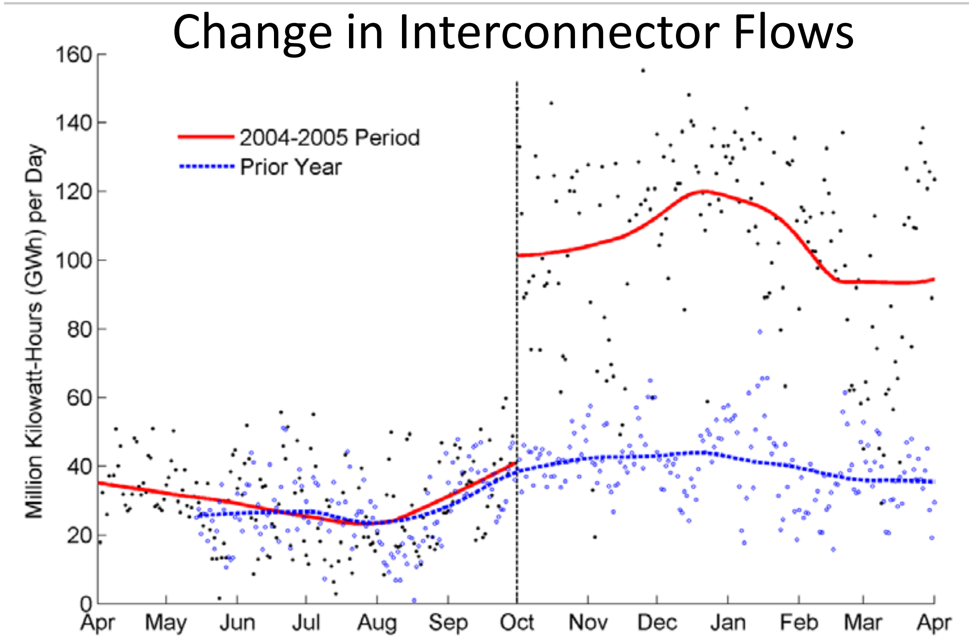
Reserve Sharing avoids Need for Gen F.

Peak + 10% = 1,100 MWs

Example: PJM Market Expansion

Integration of AEP, Dayton, and ComEd into the PJM Market





Key Conclusions:

- ***Incremental benefit = $180 Million annually; Net Present Value of $1.5B over 20 years***
- ***Bilateral trading could only achieve 40% of the efficiency gains of centralized dispatch***

Source: Erin T. Mansur and Matthew W. White, "Market Organization and Efficiency in Electricity Markets," March 31, 2009, Figure 2, pg 50, discussion draft, (available at http://bpp.wharton.upenn.edu/mawhite/).

Emissions Impacts of RTO Interconnection (1)

Individual States

State 1

Load: 500 MWs

State 1 CO_2 emissions:

(270 + 150 + 0) =

420 tons

Generator	Dispatch	Emissions
Generator C Capacity: 200 MWs Bid: \$18/MWh CO_2: 1200 #/MWh	0 MWs @ \$18	0 tons CO_2
Generator B Capacity: 200 MWs Bid: \$15/MWh CO_2: 1500 #/MWh	200 MWs @ \$15	150 tons CO_2
Generator A Capacity: 300 MWs Bid: \$10/MWh CO_2: 1800 #/MWh	300 MWs @ \$10	270 tons CO_2

State 2

Load: 500 MWs

State 2 CO_2 emissions:

(225 + 110 + 0) =

335 tons

Generator	Dispatch	Emissions
Generator F Capacity: 200 MWs Bid: \$40/MWh CO_2: 900 #/MWh	0 MWs @ \$40	0 tons CO_2
Generator E Capacity: 300 MWs Bid: \$25/MWh CO_2: 1100 #/MWh	200 MWs @ \$25	110 tons CO_2
Generator D Capacity: 300 MWs Bid: \$12/MWh CO_2: 1500 #/MWh	300 MWs @ \$12	225 tons CO_2

Total Emissions for Both States: 755 tons

Emissions Impacts of RTO Interconnection (2)

States Interconnected in an RTO

State 1

Load: 500 MWs

System 1 CO_2 emissions:

(270 +150 +120) =

540 tons

Generator	Dispatch	Emissions
Generator C Capacity: 200 MWs Bid: \$18/MWh CO_2: 1200 #/MWh	200 MWs @ \$18	120 tons CO_2
Generator B Capacity: 200 MWs Bid: \$15/MWh CO_2: 1500 #/MWh	200 MWs @ \$15	150 tons CO_2
Generator A Capacity: 300 MWs Bid: \$10/MWh CO_2: 1800 #/MWh	300 MWs @ \$10	270 tons CO_2

200 MW

State 2

Load: 500 MWs

Generator	Dispatch	Emissions
Generator F Capacity: 200 MWs Bid: \$40/MWh CO_2: 900 #/MWh	0 MWs @ \$40	0 tons CO_2
Generator E Capacity: 300 MWs Bid: \$25/MWh CO_2: 1100 #/MWh	0 MWs @ \$25	0 tons CO_2
Generator D Capacity: 300 MWs Bid: \$12/MWh CO_2: 1500 #/MWh	300 MWs @ \$12	225 tons CO_2

System 2 CO_2 emissions:

(225 + 0 + 0) =

225 tons

Total Emissions for Both States: 765 tons (10 tons more), higher in State 1, lower in State 2

Emissions Impacts of RTO Interconnection (3)

States Interconnected in an RTO

State 1

Load: 500 MWs

System 1 CO_2 emissions:

(270 +150 +80) =

500 tons

Generator C
Capacity: 200 MWs
Bid: $18/MWh
CO_2: 800 #/MWh

200 MWs @ $18
80 tons CO_2

Generator B
Capacity: 200 MWs
Bid: $15/MWh
CO_2: 1500 #/MWh

200 MWs @ $15
150 tons CO_2

Generator A
Capacity: 300 MWs
Bid: $10/MWh
CO_2: 1800 #/MWh

300 MWs @ $10
270 tons CO_2

200 MW

Generator F
Capacity: 200 MWs
Bid: $40/MWh
CO_2: 900 #/MWh

0 MWs @ $40
0 tons CO_2

Generator E
Capacity: 300 MWs
Bid: $25/MWh
CO_2: 1100 #/MWh

0 MWs @ $25
0 tons CO_2

Generator D
Capacity: 300 MWs
Bid: $12/MWh
CO_2: 1500 #/MWh

300 MWs @ $12
225 tons CO_2

State 2

Load: 500 MWs

System 2 CO_2 emissions:

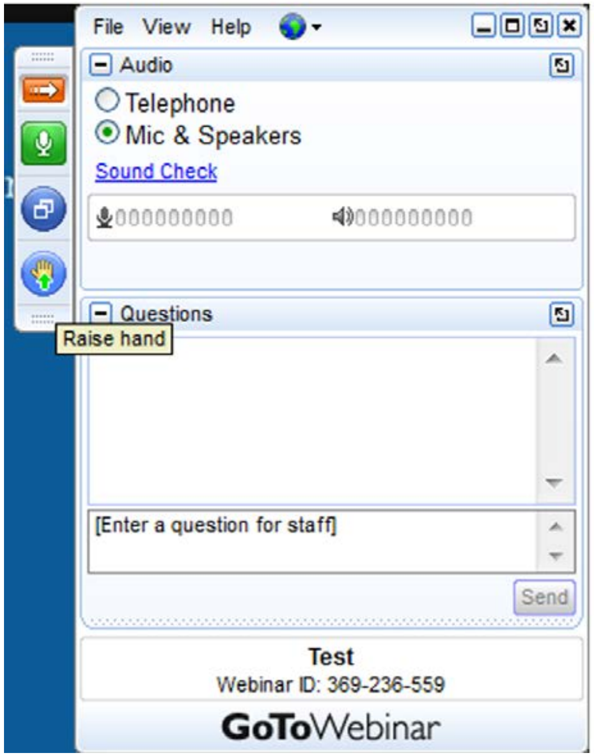
(225 + 0 + 0) =

225 tons

Total Emissions for Both States: 725 tons (40 tons less overall)

Questions?

Please send questions through the Questions pane



Implications for CPP Planning

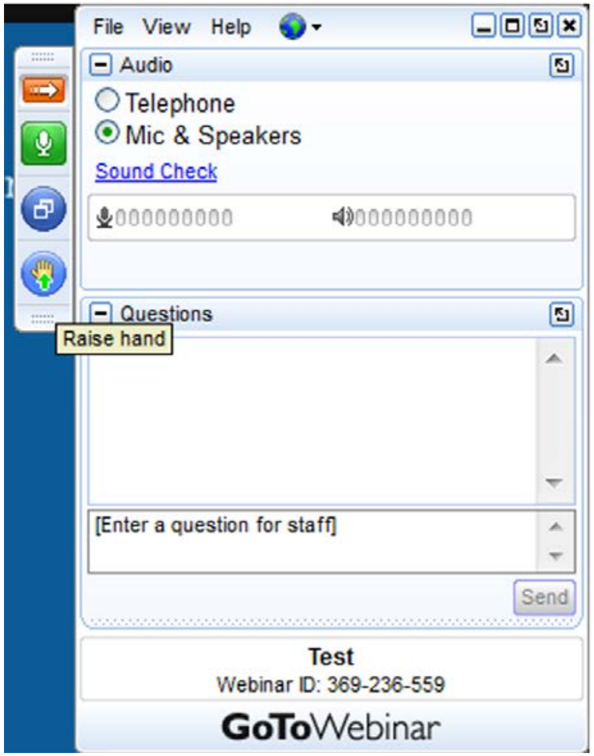
- Regional markets dispatch EGUs on the basis of cost, providing economic and reliability benefits
- The Clean Power Plan will internalize carbon costs; this will affect a regional market's "economic merit order" (EGU dispatch order):
  - Generally, EGUs with higher emissions will be more costly to use
- Modifications to dispatch order may cause electricity generation and emissions to:
  - Occur in different amounts
  - Occur in different geographic locations (sometimes in different states)
- Decision-makers will need to determine:
  - Relative advantage of compliance plan structure & path (mass or rate)
  - Benefits of coordinating compliance plans with neighboring states
  - Multi-pollutant ramifications

Recommendations

- Communicate closely with RTO staff and other states in your RTO in developing your CPP plan
- States with multiple RTOs: additional burden, but planning dialogue still necessary
- Recognize and try to preserve economic and reliability benefits of regional coordination
- Fashion carbon policy that best preserves these attributes
- System modeling will likely be required
  - Can do state-only with spreadsheets, but system modeling likely necessary for regions

Questions?

Please send questions through the Questions pane



Conclusions

- RTOs run their respective regional grids to provide reliability and efficient system operations,
- RTOs provide and manage regional energy markets to minimize energy production costs,
- RTOs perform long-term transmission systems and market planning to ensure energy resource adequacy, and
- The regional coordination by RTOs suggests that both reliability and economic costs associated with CPP compliance may well be most effectively addressed regionally.

Thank You for Your Time and Attention

About RAP

The Regulatory Assistance Project (RAP) is a global, non-profit team of experts focused on the long-term economic and environmental sustainability of the power and natural gas sectors. RAP has deep expertise in regulatory and market policies to:

- Promote economic efficiency
- Protect the environment
- Ensure system reliability
- Allocate system benefits fairly among all consumers

Learn more about RAP at www.raponline.org

David Littell: dlittell@raponline.org
Doug Scott: dscott@gpisd.net
Ken Colburn: kcolburn@raponline.org