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DOE “Integrating Midwest Wind Energy into Southeast Electricity Markets” Project Findings

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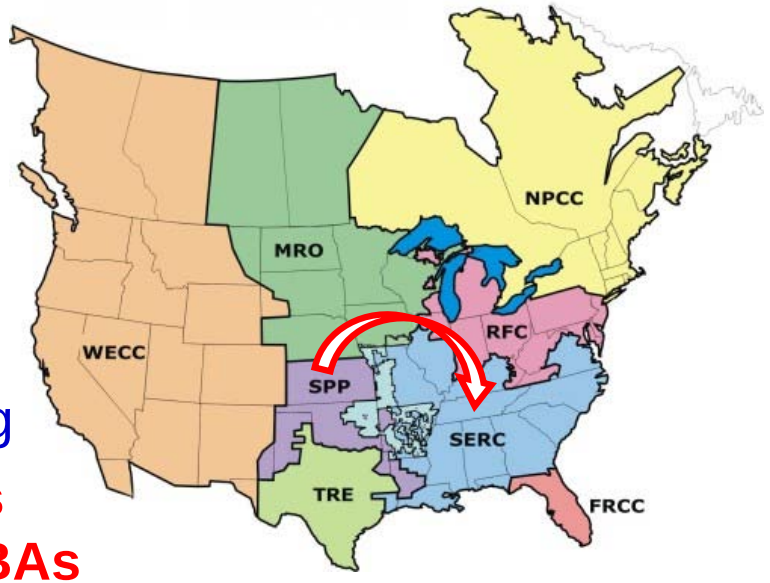
Project Background

- DOE FOA 09 [DE-PS36-09GO99009]
  - Entergy, Southern Co., SPP, TVA, and Oglethorpe active participants
- Project Team
  - EPRI, LCG Consulting
    Consultants: Brendan Kirby, Jack King
- Objective: **Scheduling/balancing needs & approaches for SPP wind → SERC BAs**



- Analysis/Modeling Scope
  - Reserve requirements based on statistical approach
  - Y2022 SPP/SERC High-Wind Transfer SCUC/SCED
    - Detail for all SPP/SERC footprint; External areas simplified
    - Wind transfers only to Entergy, Southern, and TVA
    - Evaluate scheduling/balancing challenges & collaboration benefits

High Wind Transfer Case Scenarios

1. ***Hourly Scheduling***: SPP carries all additional reserve
   A. ***Integration Proxy***: Perfect forecast & no wind reserve
2. ***Dynamic Scheduling***: Each BA carries reserve for its wind
3. ***Shared Reserve/Scheduling w/Hurdle Rates***: Reserve shared over SPP/SERC footprint w/hurdle rates maintained
4. ***Shared Reserve/Scheduling No Hurdle Rates*** : Reserve shared over SPP/SERC footprint w/hurdle rates removed

- Add'l Reserves cover intra-hr variability & HA forecast error
- All scenarios -- wind scheduled day ahead to assigned region
- VACAR constraints are kept for transportation model runs

Wind Requirements and Source Data

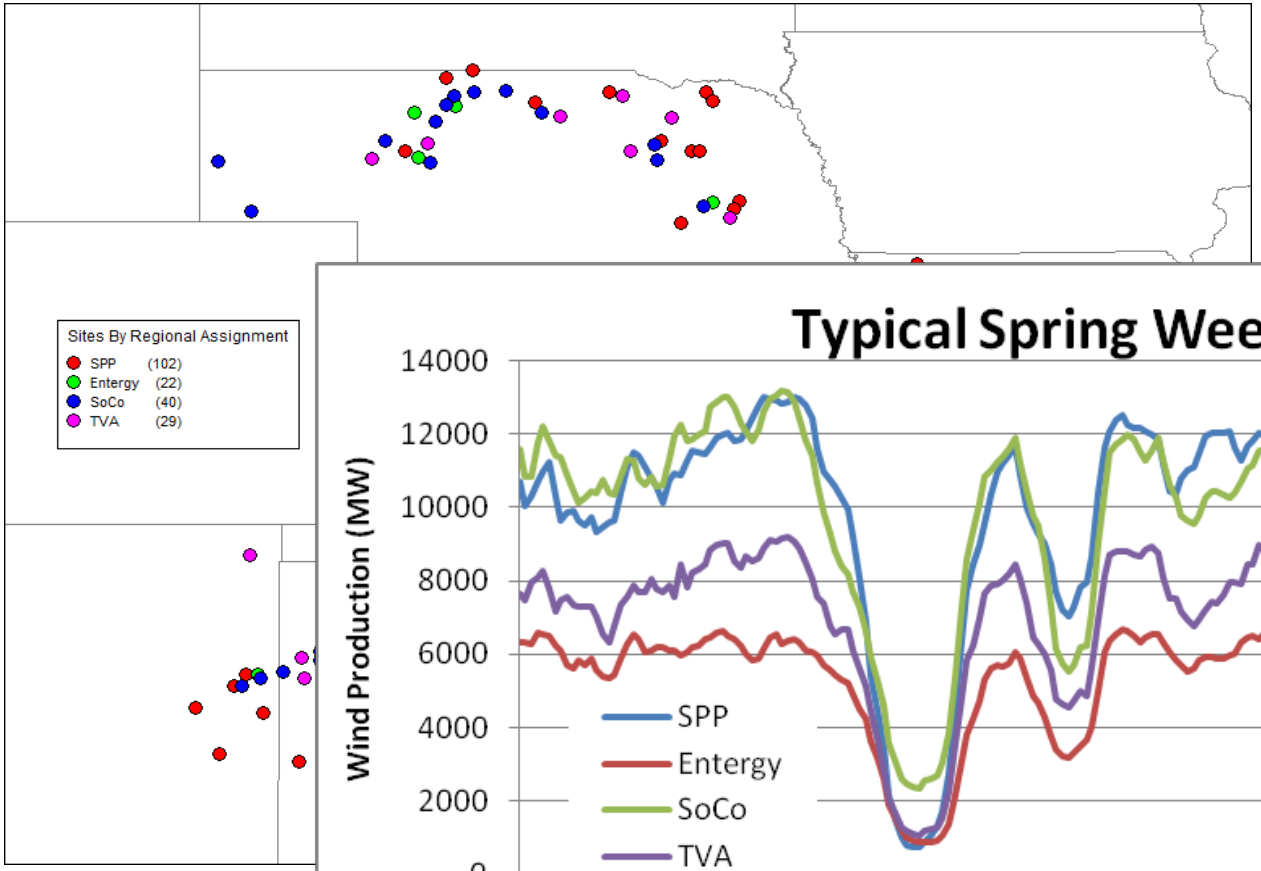
- Target 20% renewable energy across footprint in 2022
  - Randomly assigned plants until each BA target met (SPP from prior work)
  - Selected to give maximum diversity for each region

Region	Load (GWh)	Existing Renewables	Goal (GWh)	Wind Req't (GWh)	Wind Capacity (GW)
Entergy	144,457	533	28,891	28,358	7,850
SOCO	287,702	2,608	57,540	54,932	14,999
TVA	186,063	104	37,213	37,108	14,692
SPP	260,982	177	52,196	52,019	10,368
Total	879,204	3,422	175,841	172,418	47,909

- Utilized NREL Eastern Interconnect wind data set
  - 10 minute temporal, 2 km spatial
  - 190 GW of capacity in SPP: 419 plants from 10 MW to 1300 MW
- Dataset includes “forecasts” on plant level

Variability of Wind Production

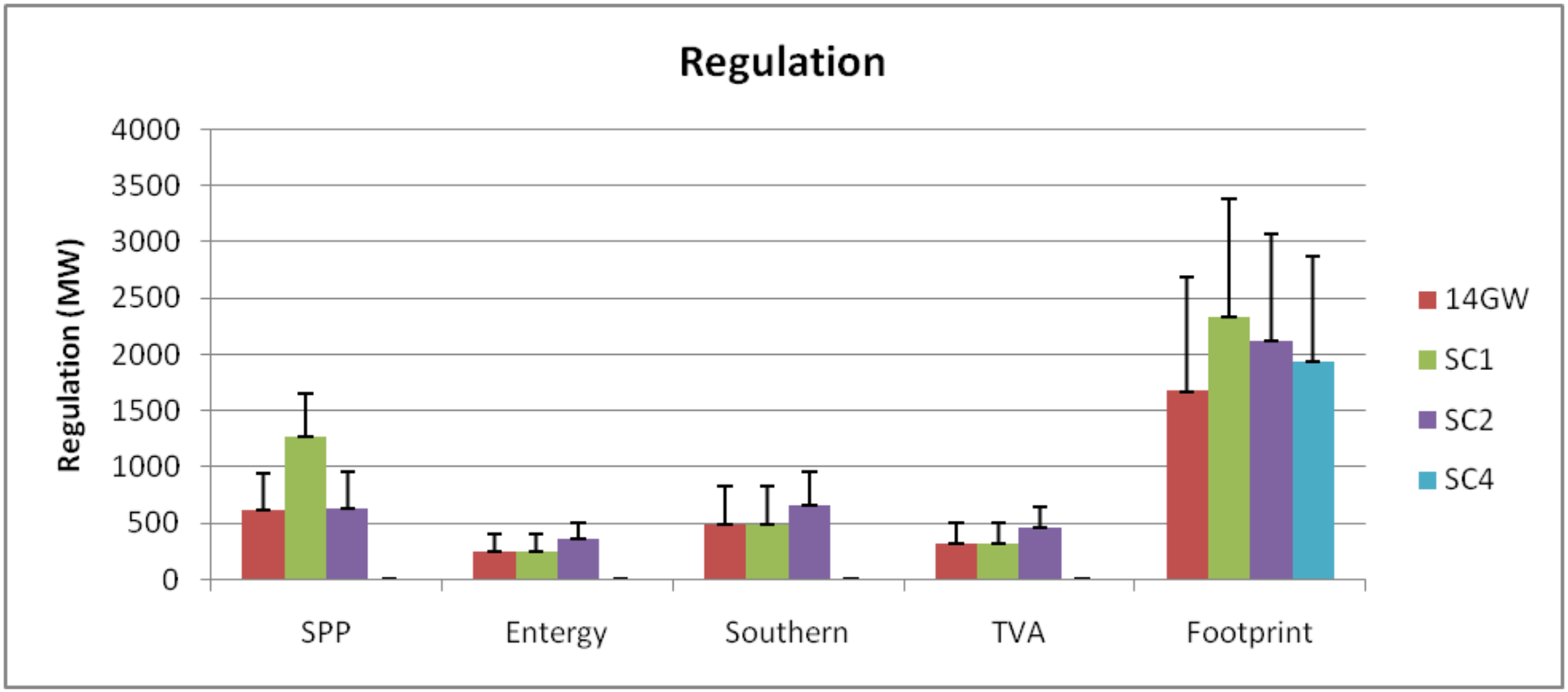
Wind Plant Allocation to BAs



Calculation of Reserve Requirements

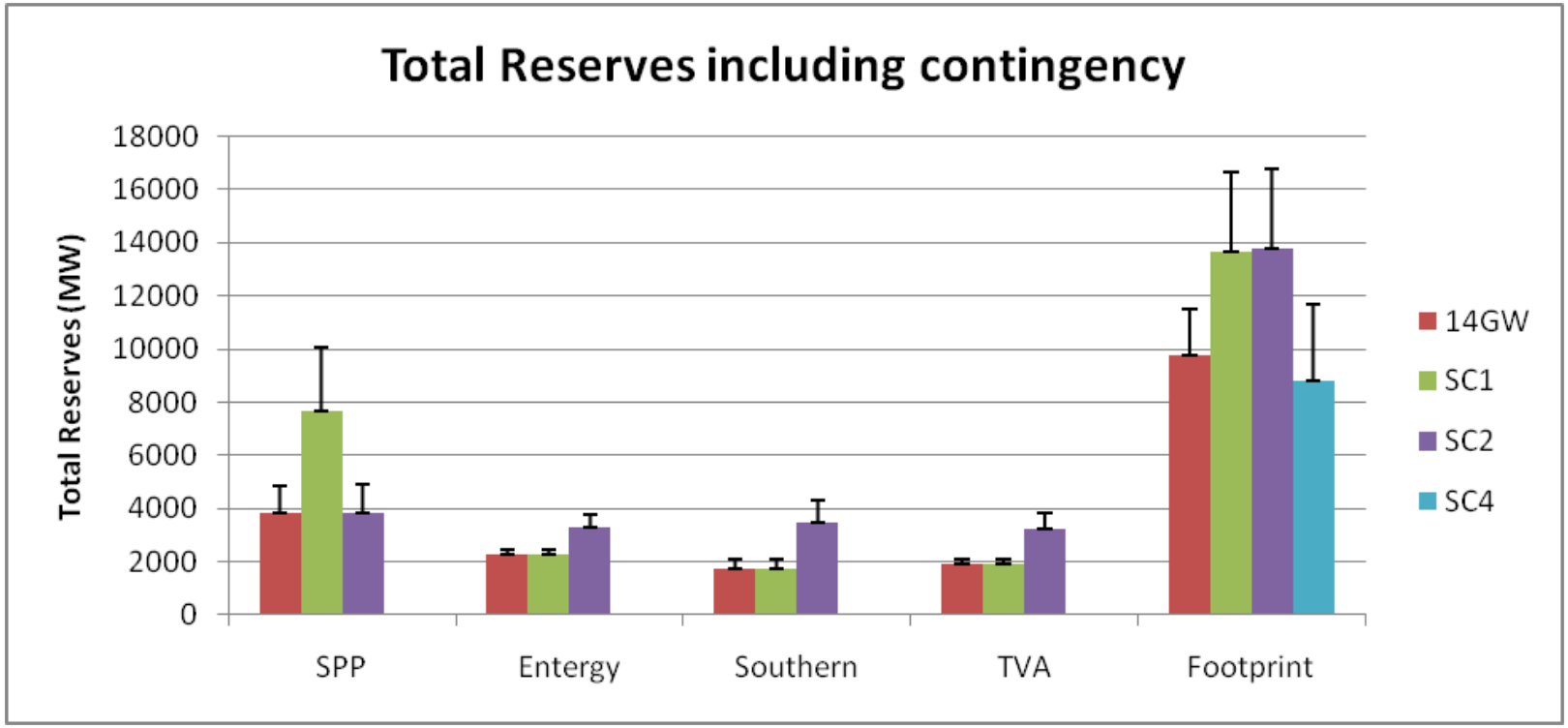
- Load regulation at 1.5% of hourly load
- Wind short-term forecast error component - Regulation
  - Based 10 minute advance error
  - Function of wind production level
  - Calculated based on wind characteristics for each area
- Load and wind regulation non-correlated
  - Combine as root-sum-squares to form total regulation
- Spin and supplemental (non-spin)
  - Hour ahead error
  - Function of production level
- Additional spin and supplemental components for contingency supplied by participants

Regulation Requirements for High Wind Cases



- Impact on aggregate footprint regulating reserve:
  - SPP carries far more in Sc. 1
  - Sc 1 → Sc 2: decrease 200 MW
  - Sc 2 → Sc 3/4: decrease 190 MW

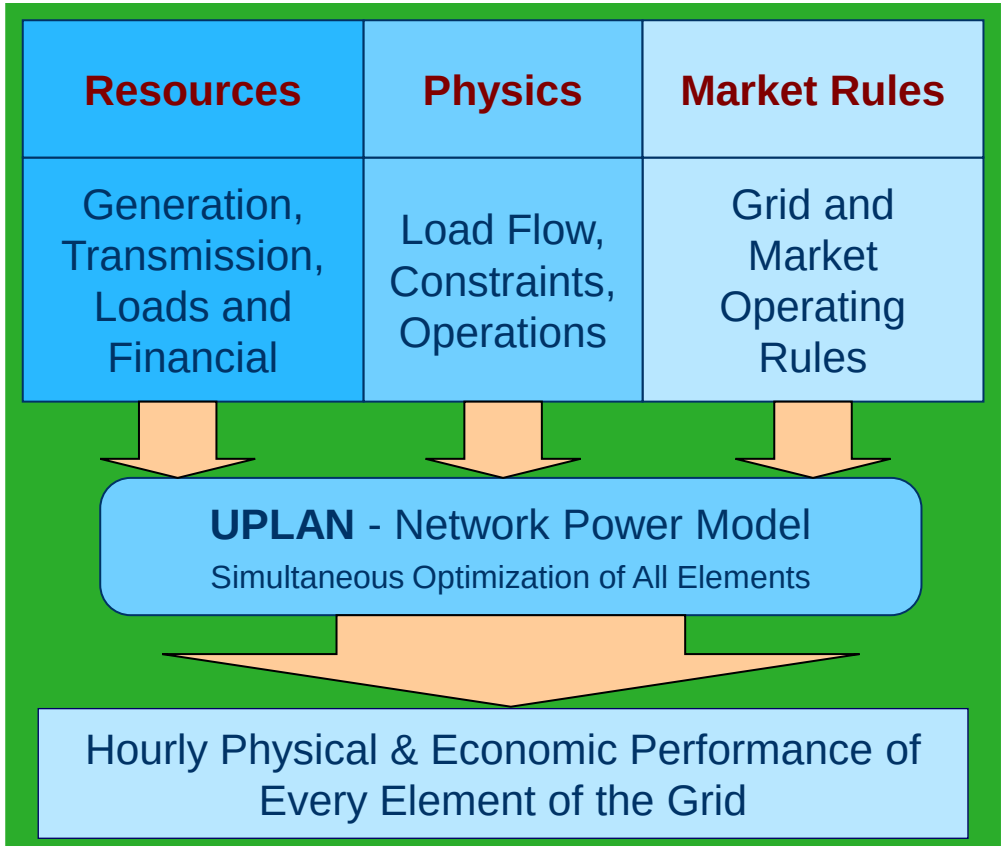
Total reserves for high wind cases



- Impact on aggregate footprint **Total** Reserve:
  - Sc 1 → Sc 2: increase 147 MW
  - Sc 2 → Sc 3/4: decrease 5000 MW (all but 550 MW from reduced contingency reserve requirements)

Production Cost Model Used

- 8760 hour production costing simulation for 2022
  - generation plans and load based on available data
  - NREL 10-min wind data
- Limiting Assumptions
  - Unconstrained transmission network
  - Gas & emission prices
  - Reserve margin & conv. generation plant mix

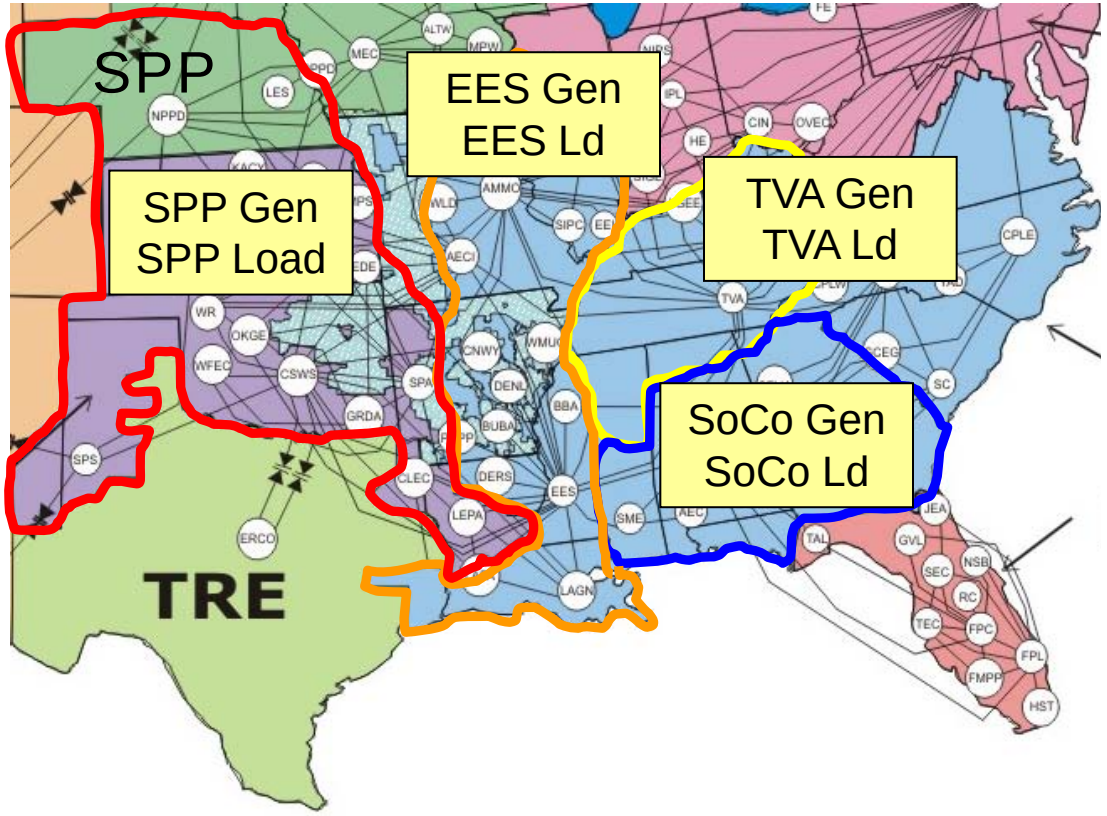


Uncertainty characterizes all future scenario PCM simulation results → Trends between Costs rather than actual Magnitudes

Scope of DA Commitment and RT Dispatch

DA Unit Commitment
BA Specific Generation & Load

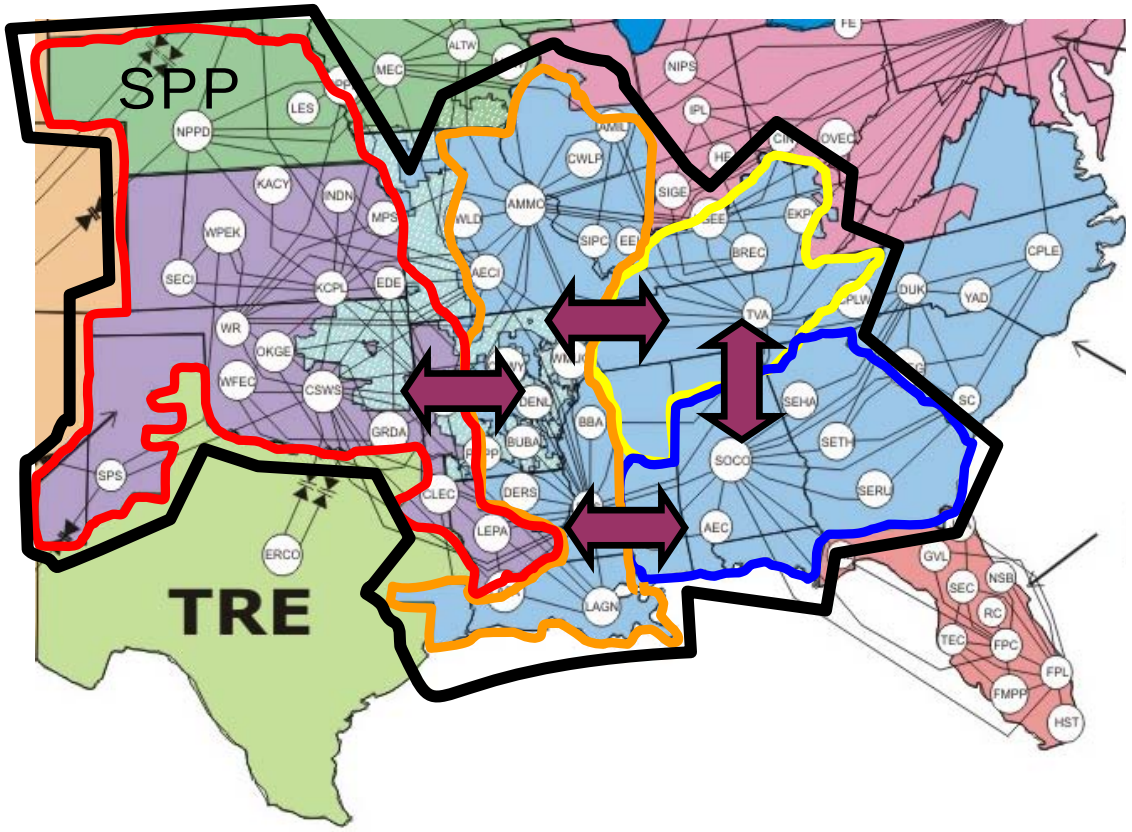
- ✓ Commits BA generation to meet BA load
- ✓ UC without regard to cost of neighboring generation
- ✓ Uses DA wind forecast for UC



Scope of DA Commitment and RT Dispatch

RT Economic Dispatch
Relative Economics Across Footprint

- ✓ Available generation transferred to surrounding BAs if economic
- ✓ Uses realized wind values with inherent error from DA forecast

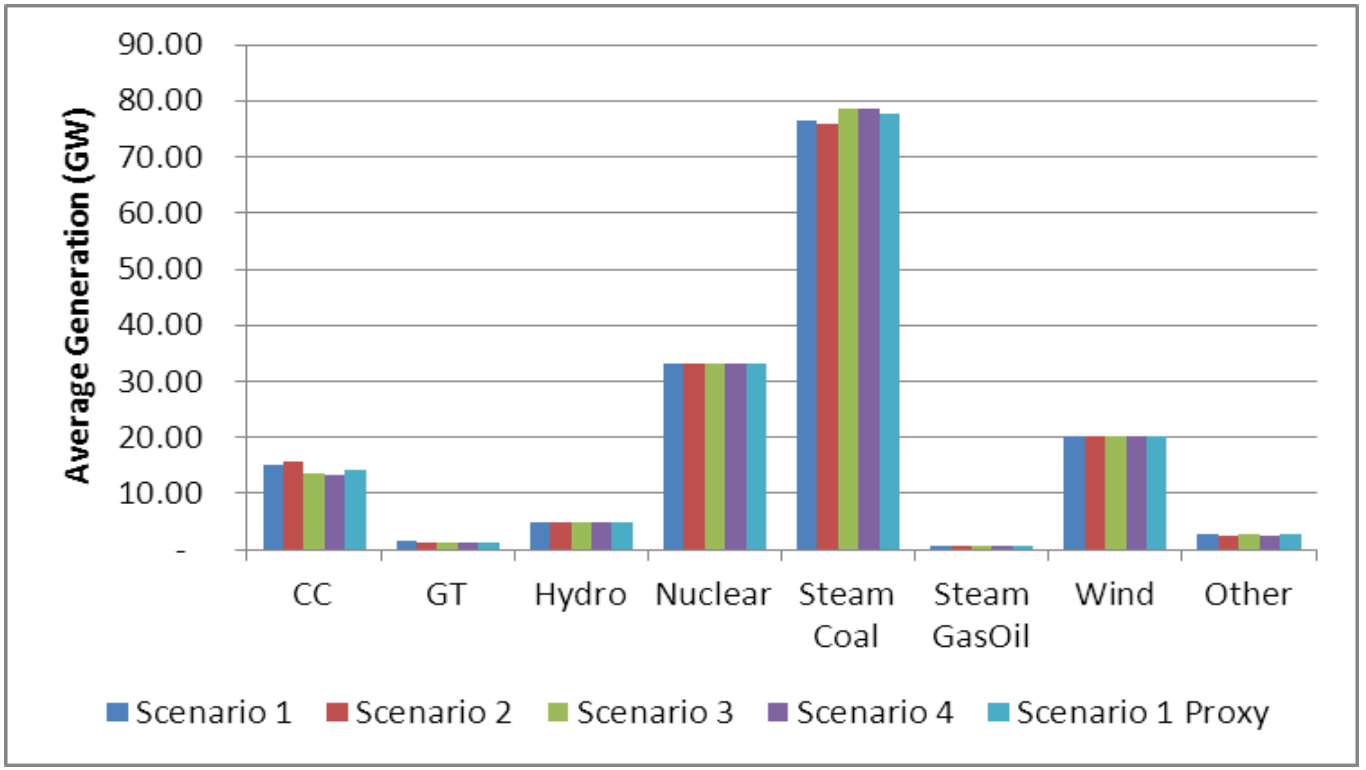


Impact of Increased Wind (14 GW → 48 GW)
Average Hourly Generation Per Class

Change in GW	EES	TVA	SBA	SPP	SERC-W	SERC-E	Total
CC	(1.19)	(0.41)	(2.18)	(0.36)	(0.36)	(0.06)	(4.56)
GT	(0.03)	(0.05)	(0.16)	0.21	(0.20)	(0.20)	(0.43)
Hydro	-	0.00	0.00	-	-	(0.00)	(0.00)
Nuclear	(0.00)	-	-	(0.00)	-	(0.00)	(0.00)
Coal	(0.09)	(0.99)	(0.92)	(2.95)	(1.58)	(0.94)	(7.48)
GasOil	(0.34)	-	(0.00)	(0.01)	-	(0.00)	(0.34)
Wind	-	-	-	13.53	-	-	13.53
Other	(0.01)	(0.03)	(0.10)	(0.06)	(0.03)	(0.10)	(0.33)
Total	(1.66)	(1.48)	(3.35)	10.36	(2.17)	(1.31)	0.39

- With transportation mode, much of the wind gets out of SPP
- Decreases coal and CC generation throughout region
- SPP carrying all reserves:
  - Transportation model assumed
  - No reduction in conventional capacity
  - Forecasted Wind committed out DA

Impact of Coordination Scenarios
Average Hourly Generation Per Class



- CC and coal most affected as modeled here:
  - Sc 1 → Sc 2: CC increases as SERC BAs carry own reserve
  - Sc 2 → Sc 3/4: Coal pushes CC off as most efficient units across footprint are utilized

Impact of Coordination (Scenario 2→3)
Average Hourly Generation Per Class

Change in GW	EES	TVA	SBA	SPP	SERC West	SERC East	Total
CC	0.03	(1.00)	(1.41)	(0.03)	0.00	0.05	(2.37)
GT	0.00	(0.26)	(0.03)	(0.02)	0.09	0.07	(0.15)
Hydro	-	-	-	-	-	-	-
Nuclear	0.00	-	-	0.00	-	(0.00)	0.00
Coal	0.03	0.50	0.47	0.62	0.50	0.32	2.45
Gasoil	(0.06)	-	(0.00)	(0.00)	-	0.00	(0.06)
Wind	-	-	-	-	-	-	-
Other	0.01	0.01	0.05	0.02	(0.01)	0.04	0.12
Total	0.01	(0.75)	(0.93)	0.60	0.58	0.48	(0.00)

- Coordination → increase usage of less expensive units
  - SPP Coal replaces TVA/SBA gas units
  - [Copper sheet assumed]

Change in generation Scenario 3 vs 2 low gas	EES	TVA	SoCo	SPP	SERC W	SERC E	Total
CC	0.10	0.01	(0.31)	0.15	0.07	0.01	0.02
GT	(0.01)	(0.22)	(0.04)	(0.08)	0.02	0.00	(0.33)
Hydro	-	(0.00)	-	-	-	-	(0.00)
Nuclear	0.00	-	-	0.00	-	(0.00)	0.00
Steam Coal	0.04	(0.07)	(0.13)	0.16	0.25	0.15	0.40
Steam GasOil	(0.10)	-	(0.00)	(0.01)	(0.00)	0.00	(0.11)
Wind	-	-	-	0.01	-	-	0.01
Other	0.00	(0.00)	0.02	(0.01)	(0.02)	0.02	0.01
Total	0.04	(0.28)	(0.47)	0.21	0.32	0.19	(0.00)

- Impact at $4 gas is far lower than $8 :
  - Less Coal replaces GT instead of CC
  - Less production cost benefit also

Impact of Coordination Scenarios
Production Costs

2010 $	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 1 proxy
Entergy	4,147	4,214	4,162	4,246	4,093
SBA	9,959	10,301	9,563	8,755	9,904
TVA	6,674	7,135	6,431	6,590	6,679
SPP	9,265	8,290	8,350	8,926	8,329
East SERC	12,303	12,273	12,480	12,505	12,391
West SERC	4,269	4,293	4,539	4,414	4,369
Total Costs	*46,618*	*46,506*	*45,524*	*45,435*	*45,765*
Total Costs/MWh	*34.37*	*34.28*	*33.56*	*33.49*	*33.74*

- Total production costs → Fuel and start costs
- Scenario 1 → 2: Insignificant difference between across footprint
- Scenario 2 → 3: **$0.7/MWh** demand benefit (~2% of total prod. costs)
  - drops to **$0.25/MWh** with $4-5/MMBtu gas prices
- 'Balancing cost' of ~$0.6/MWh demand ($5/MWh wind)

Conclusions/Next steps

- Balancing Strategy Benefits: Scen 1→Scen 2/ Scen 3→Scen 4
  - Small system benefit for each BA balancing own wind versus SPP balancing all; same for removing hurdle rates
- Balancing Strategy Benefits: Scen 2→ Scen 3
  - Reserve Reduction: 200 MW Regulation & 550 MW Spin/Non-Spin
  - **$0.7/MWh-demand** prod cost reduction ($0.25/MWh for cheaper gas)
    - (context → $4/MWh reduction when 34 GW wind added)
  - Use **cheaper units → Coal →CC (high gas)**; Coal →GT (low gas)
  - **Starts decrease** in general when balancing shared throughout region
  - **Combined Cycle units are crucial** to provide reserve and ramping

- Important Assumptions and areas for further work:
  - Unconstrained transmission → **Need network to support wind xfers**
  - Gas and emission prices → **Need more sensitivity analysis**
  - Conventional Generation mix → **Include impact of emerging regs**

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