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Multi-regional Market Modeling

Europe and Eurasia Initiative on Enhancing Market Performance

Technical Workshop

Douglas Gotham

February 27, 2020

Information Sources

- Sources of information include the notes and recollections of the presenter, the EISPC Archive on the NARUC website, and the EIPC DOE Project Overview website.
  - https://www.naruc.org/cpi/eispc-archive/
  - https://eipconline.com/doe-project-overview

Phase 2

- Phase 2 began with the 3 scenarios selected in Task 6 of Phase 1. For each scenario,
  - identify transmission options needed to reliably operate the system
  - evaluate the costs and benefits associated with the 3 scenarios
  - identify sensitivities for the cost analysis

Develop Transmission Options (Phase 2, Task 7)

- EIPC formed the Transmission Options Task Force to develop transmission expansion options needed to reliably integrate the new resources identified by the capacity expansion model in Phase 1.
  - led by planning authorities in collaboration with EISPC and other stakeholders
  - focused on the extra high voltage network (230kV and above)
- This relied on load flow analyses for those hours during the year when the system would be the most stressed.
  - peak load and/or off-peak load with high wind output

Transmission Build-out Approach

- For the load flow model:
  - 1: choose modeling tools, cases to run, system tests to perform, develop model inputs
  - 2: test the models to ensure they will solve
  - 3: run the models to identify constraints on the system
  - 4: identify potential solutions for the constraints
  - 5: test the solutions in the model
  - 6: repeat steps 3 through 5 until all constraints are solved

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Determining Model Inputs

- Since a load flow model is based on highly detailed transmission information, the location of loads and generators were very important.
- The planning authorities assigned locations to new generators (beyond the SSI) based on location of brownfield sites, generation interconnection requests, and previous studies.
- For generator deactivation, MRN-NEEM only identified specific units for large coal and nuclear units; for other units only the NEEM region was specified.
  - units were selected based on age, lack of pollution controls, and size

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Example Results for Scenario 1 Task 7

- By way of example, the process for Scenario 1: Nationally-Implemented Federal Carbon Constraint with Increased Energy Efficiency and Demand Response is illustrated in the following slides.
  - process was used for other 2 scenarios, but not shown here
- 365 new components were added to facilitate the interconnection of new generation.
- 6 iterative passes of the load flow analysis were performed to alleviate resulting constraints.
- 415 constraint relief projects were required.
- 6 high voltage direct current (HVDC) lines were added.

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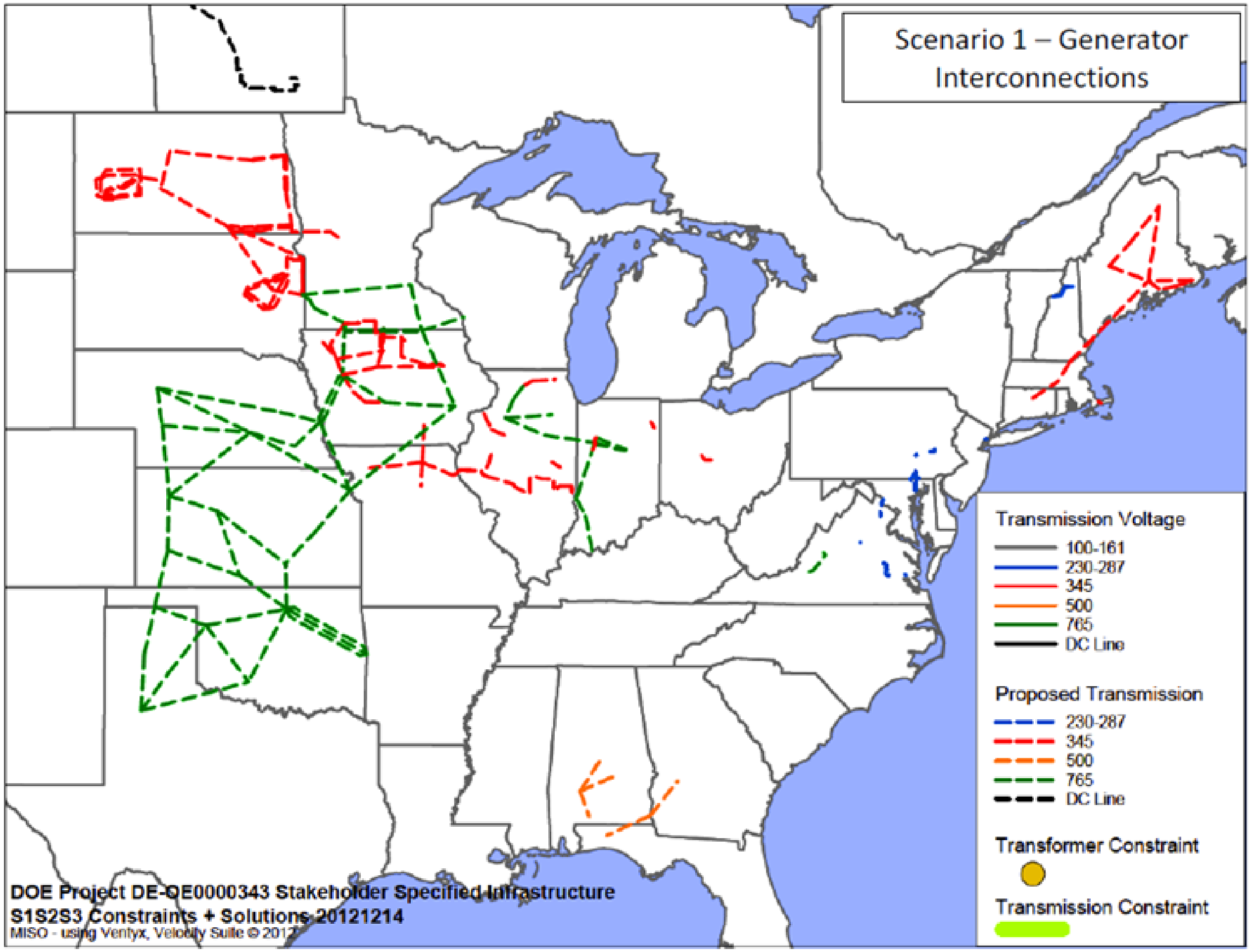
Scenario 1 Task 7 Generation Interconnections



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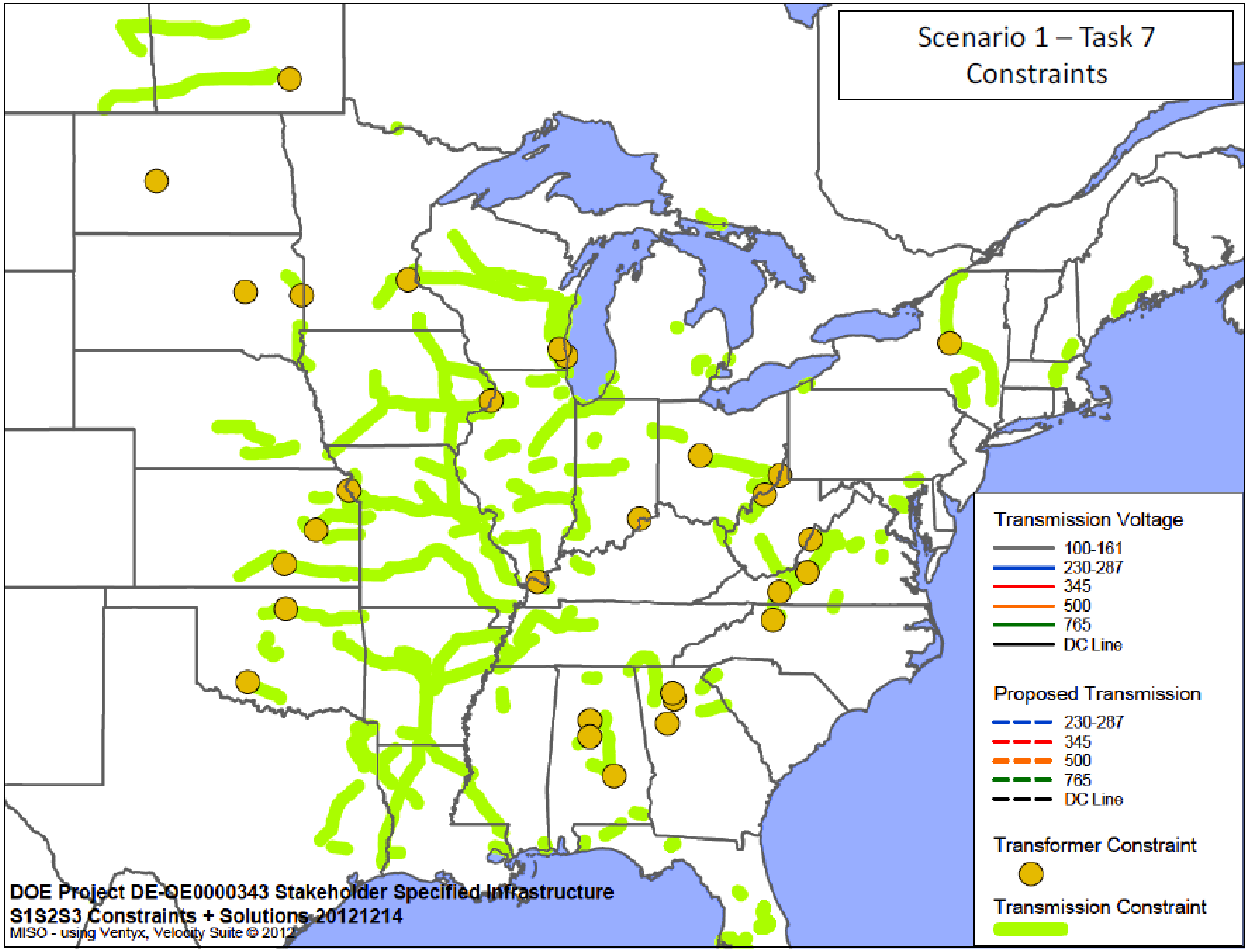
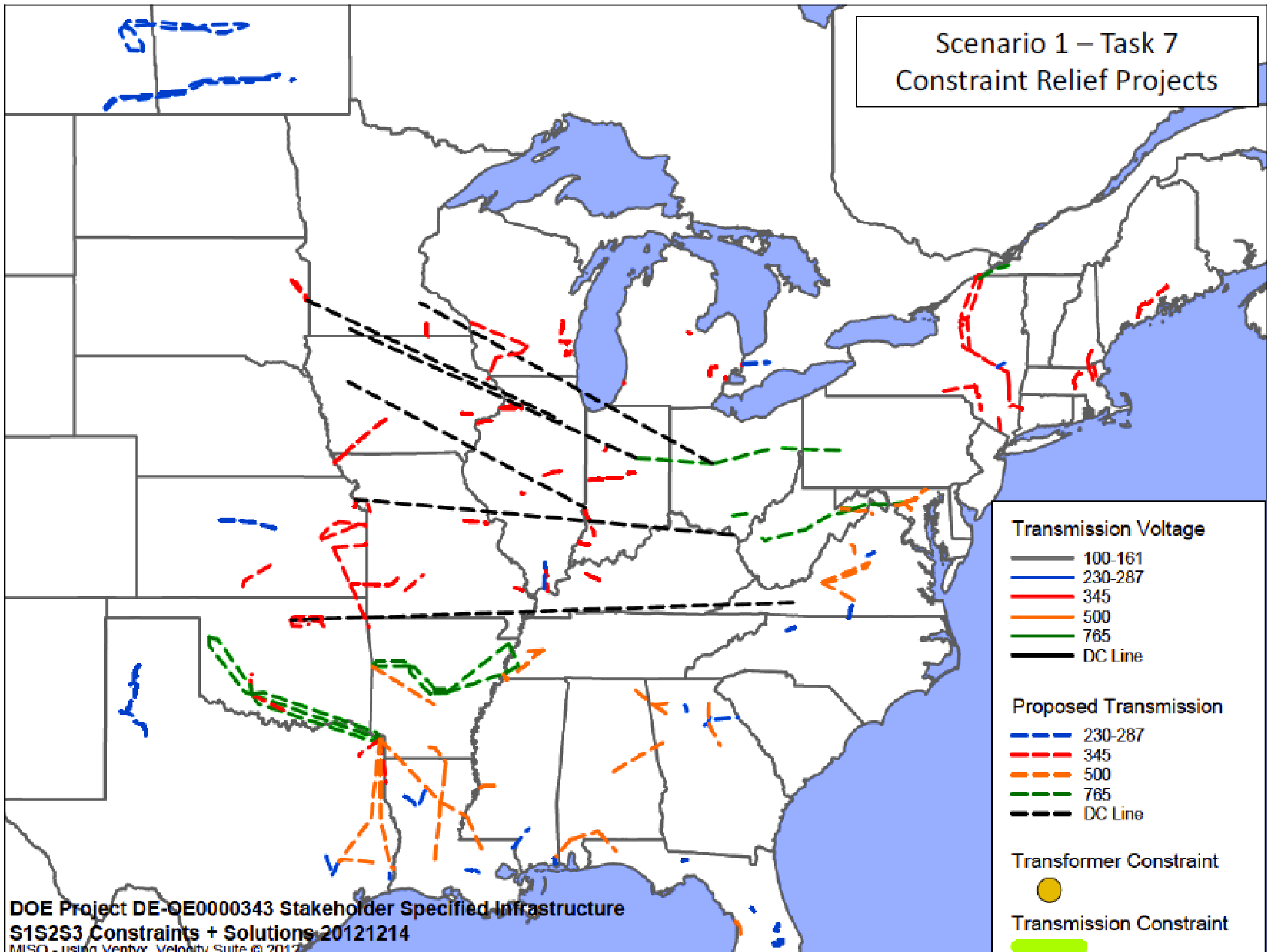
Scenario 1 Task 7 Constraints



Scenario 1 Task 7 Constraint Relief



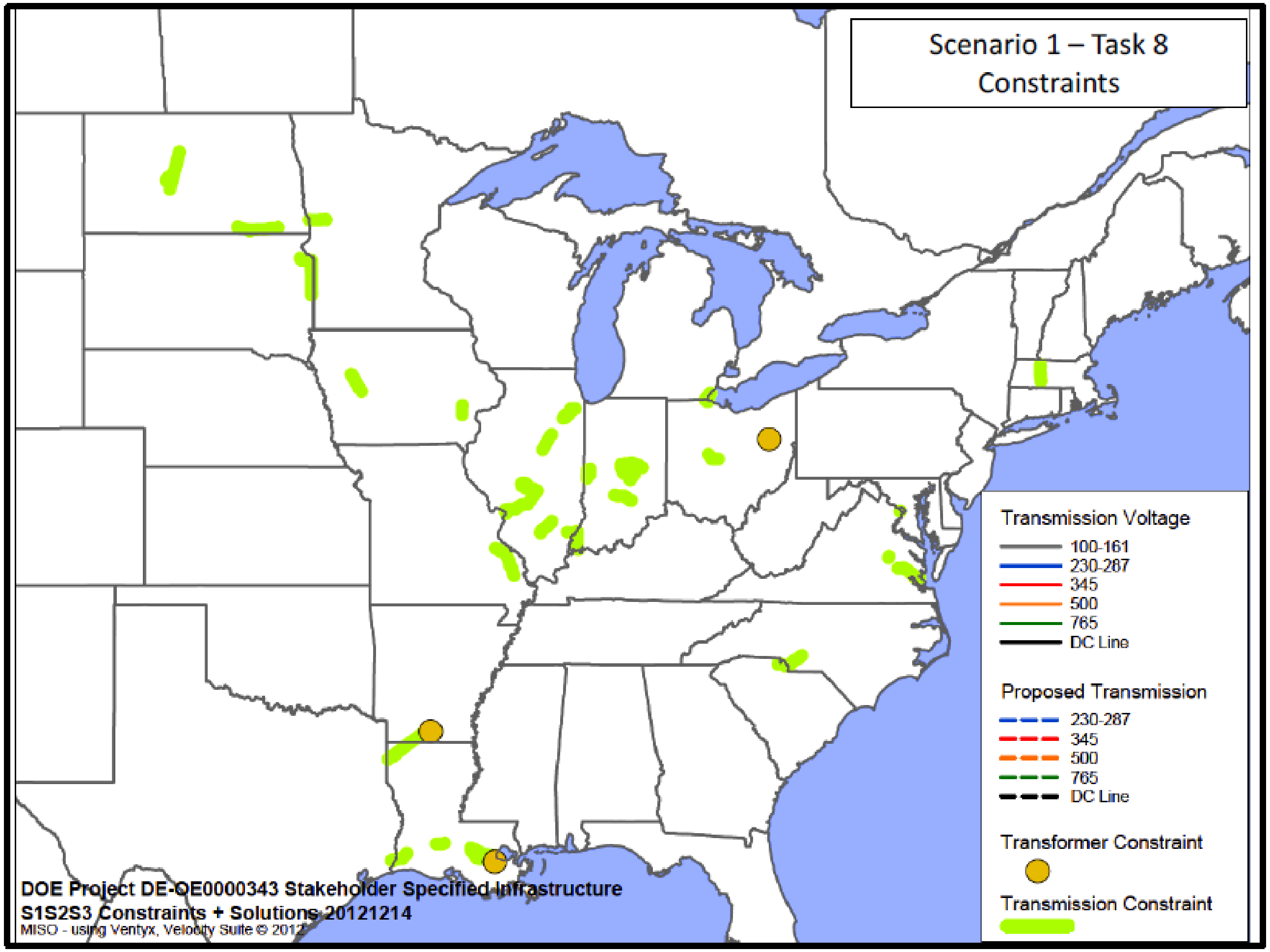
Reliability Tests (Phase 2, Task 8)

- Contingency tests were run on the new system to ensure they could meet reliability criteria.
- Five tests were applied.
  - T1, system performance with all elements in service
  - T2, system performance following the loss of a single element
  - T3, system performance following the loss of a single element under generator out scenario
  - T4, system performance following the loss of multiple transmission lines sharing common towers/structures
  - T5, system performance following the loss of multiple elements as a result of a bus section fault on buses 300 kV and above

Example Results for Scenario 1 Task 8

- Additional components were added beyond the SSI and those identified in Task 7.
- 85 constraint relief projects were required.
- 40 voltage support projects were required.

Scenario 1 Task 8 Constraints



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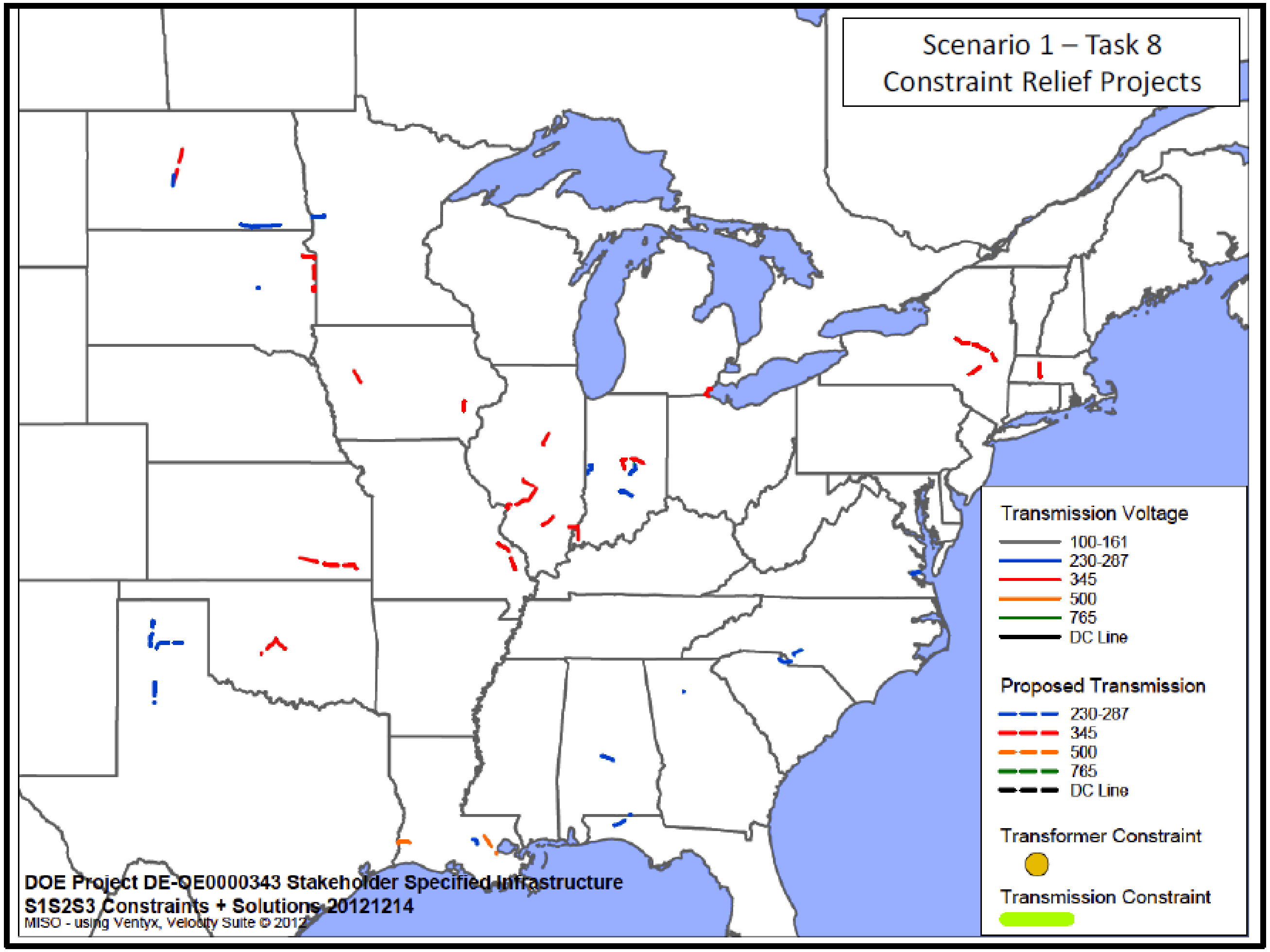
Scenario 1 Task 8 Constraint Relief



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Flowgate Identification

- Prior to moving on to production costing analysis in Task 9, it was necessary to identify the critical interconnections (flow gates) between NEEM regions.
  - It would be impractical for the production costing model, GE MAPS, to include all transmission components, so only those that had a material impact on the solution were included.
  - Linear transfer analyses between neighboring regions were performed to the load flow studies to identify candidate flow gates.
  - Planning authorities reviewed candidates and removed invalid or duplicate ones and added others
- Scenario 1 had over 1000 flow gates.

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Production Cost Analysis (Phase 2, Task 9)

- The next steps were to evaluate the costs and benefits associated with the 3 scenarios.
- The GE MAPS model was run for every hour of a single year (2030) to assess:
  - energy production costs
  - interregional transactions
  - emissions
  - renewable energy production

Production Costing Models

- Production costing models simulate network operation over a year to determine costs, emissions, and impacts of congestion.
  - optimized to find the least cost solution
- They include very detailed information on generation infrastructure (both existing and future).
- Transmission infrastructure information is generally more detailed than in capacity expansion models, but may be less detailed than load flow models.
- Examples: ANTARES, GE MAPS, GRIDVIEW, PROMOD, UPLAN

Production Costing Model Inputs

- Many of the inputs were taken directly or derived from the inputs and outputs of the NEEM model in Phase 1.
  - load, generating capacity, generating unit characteristics, supply from external regions, seams charges between regions, operating reserves, fuel & emission prices, hourly wind generation profile
- Other inputs were developed collaboratively among EISPC, the planning authorities, and stakeholders.
  - transmission flow gates, supply curve for the variable cost of demand response resources

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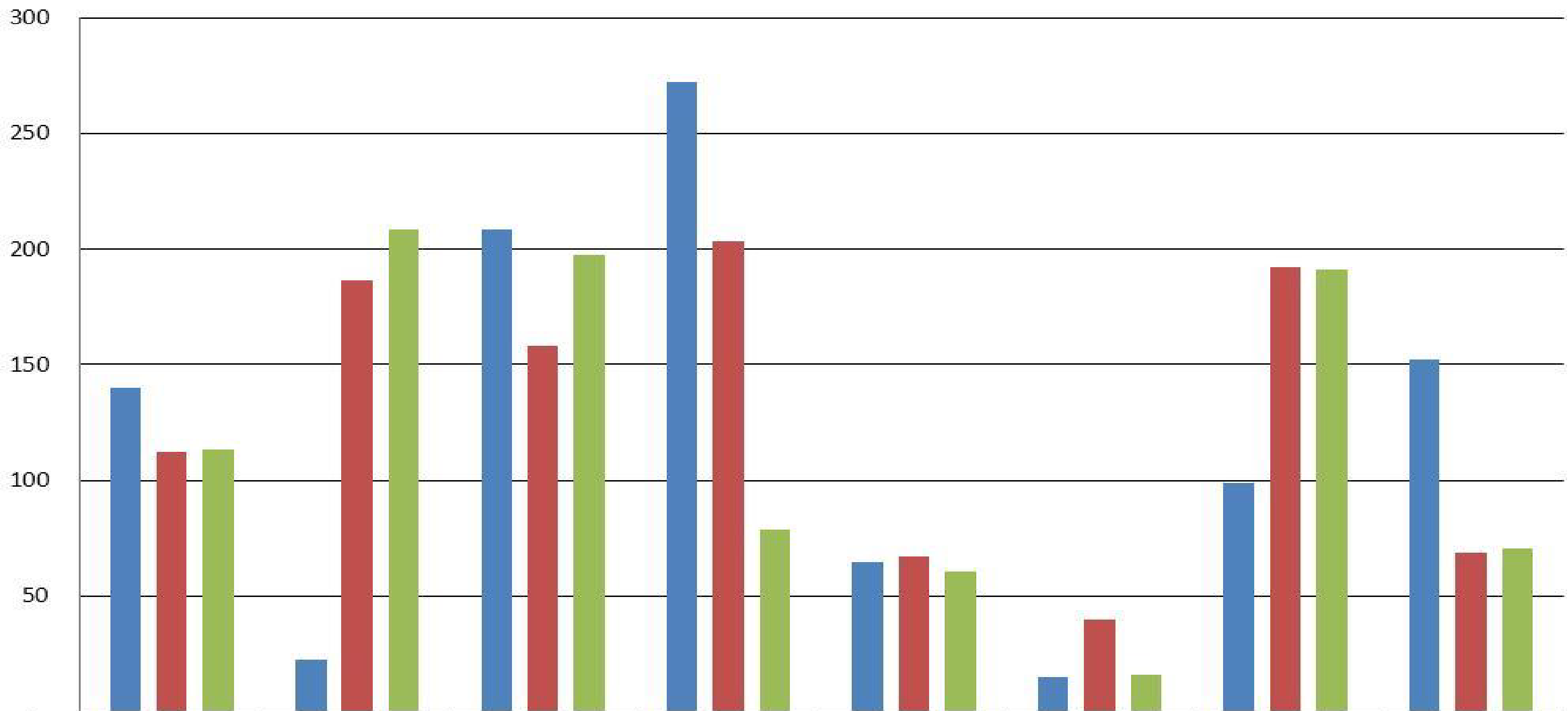
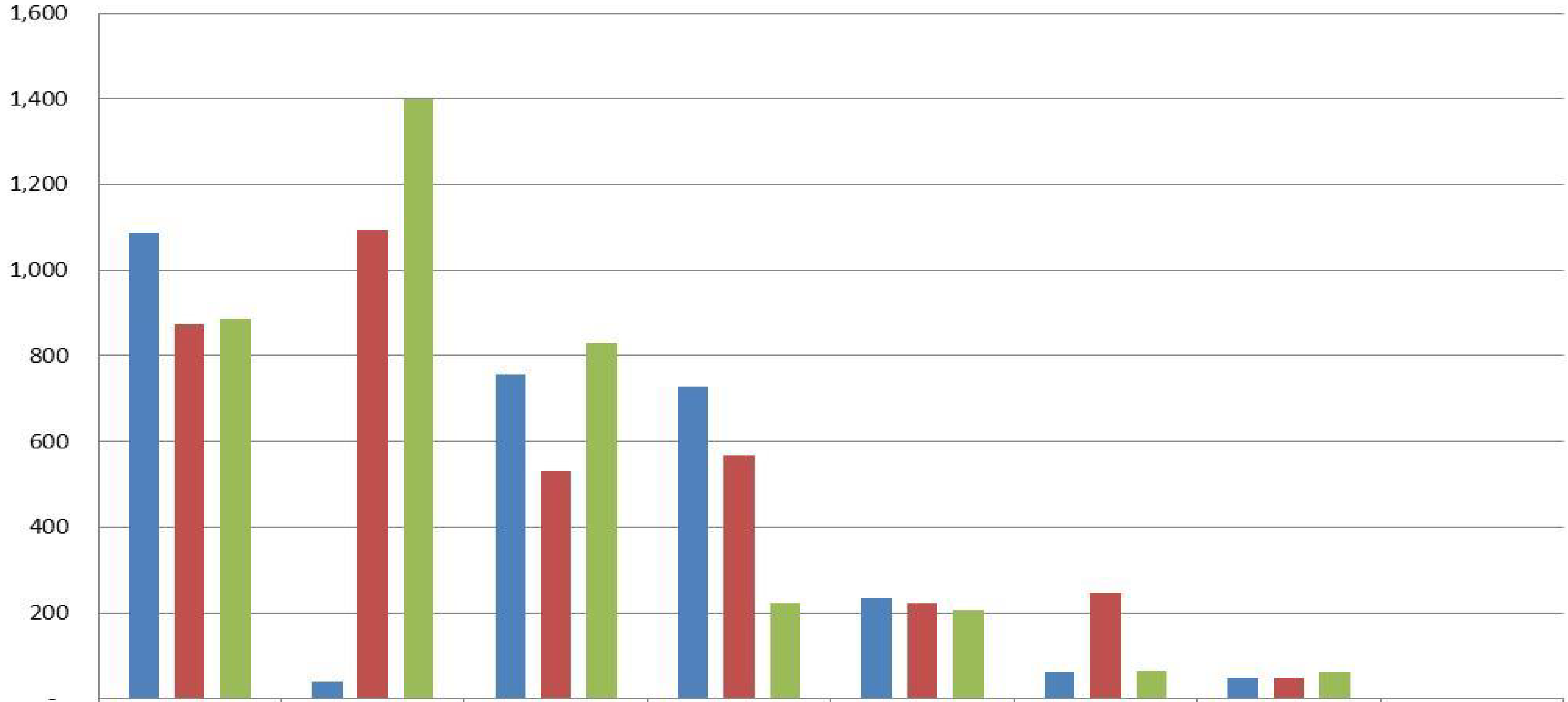
Eastern Interconnect Capacity by Type (GW)



	Nuclear	Coal	Combined Cycle	Wind	Hydro	Other Renewable	Peakers	Demand Response
Scenario 1	140	23	208	272	65	15	99	152
Scenario 2	112	186	158	203	67	40	192	69
Scenario 3	113	208	197	79	61	16	191	71

Eastern Interconnect Generation by Type (TWh)



	Nuclear	Coal	Combined Cycle	Wind	Hydro	Other Renewable	Peakers	Demand Response
Scenario 1	1,087	40	755	728	235	61	50	4
Scenario 2	875	1,095	532	568	222	248	50	0
Scenario 3	886	1,399	831	223	205	63	60	1

Observations

- Scenario 1
  - largest capacity sources are wind, combined cycle, and demand response with very little coal
  - nuclear, combined cycle, and wind are the major energy sources
- Scenario 2
  - largest capacity sources are wind, peaking units, and coal with the highest amount of other renewables
  - coal, nuclear and wind are the major energy sources
- Scenario 3
  - largest capacity sources are fossil-fueled
  - coal, nuclear, and combined cycle are the major energy sources

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Annual Costs, Emissions, Demand, and Energy

	Scenario 1 Base - Combined Policies	Scenario 2 Base - RPS Implemented Regionally	Scenario 3 Base - Business as Usual
Annual Production Costs ($M)			
Fuel	40,802	73,789	85,057
Variable O&M	6,430	15,502	18,411
Total Production Costs ($M)	47,231	89,291	103,469
CO_2 Costs ($M)	45,340	126	154
Total w/CO_2	92,571	89,416	103,622
Emissions (short tons)			
SO_2 (000)	93	873	1,122
NOx (000)	21	1,300	1,771
CO_2 (millions)	358	1,391	1,792
Peak Demand (MW)	565,012	673,108	690,492
Energy (TWh)	2,979	3,621	3,687

Note: Costs do not include capital costs of new resources

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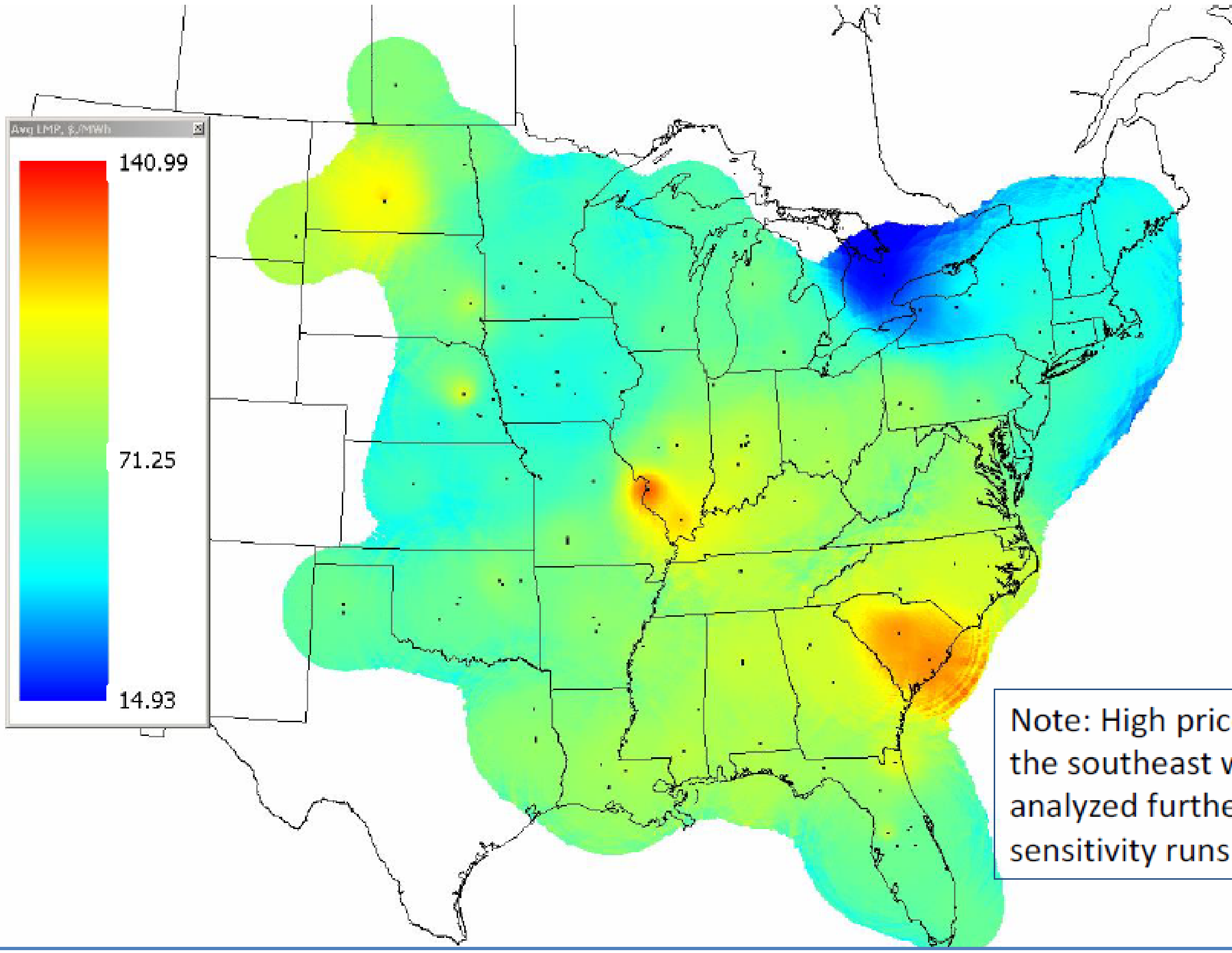
Observations

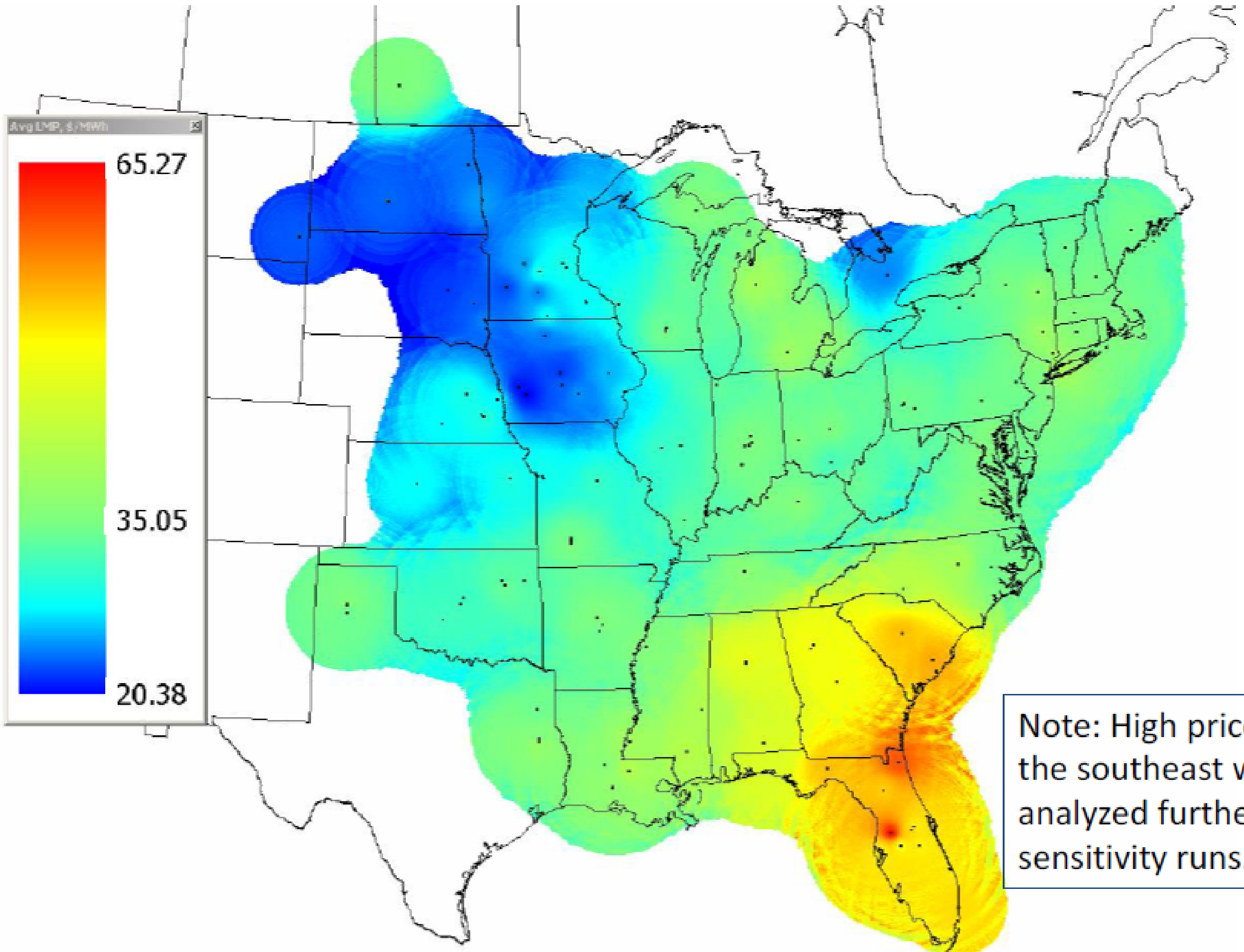
- Almost half of the annual cost in Scenario 1 comes from the cost of carbon emissions.
- While a national carbon policy (Scenario 1) significantly reduces CO2 emissions, a national renewable standard (Scenario 2) does not.
- Scenario 1 includes aggressive energy efficiency, which reduce energy demand.

Scenario 1 – Average Annual LMP in $/MWh



Note: High prices in the southeast were analyzed further in sensitivity runs.

Scenario 2 – Average Annual LMP in $/MWh



Note: High prices in the southeast were analyzed further in sensitivity runs.

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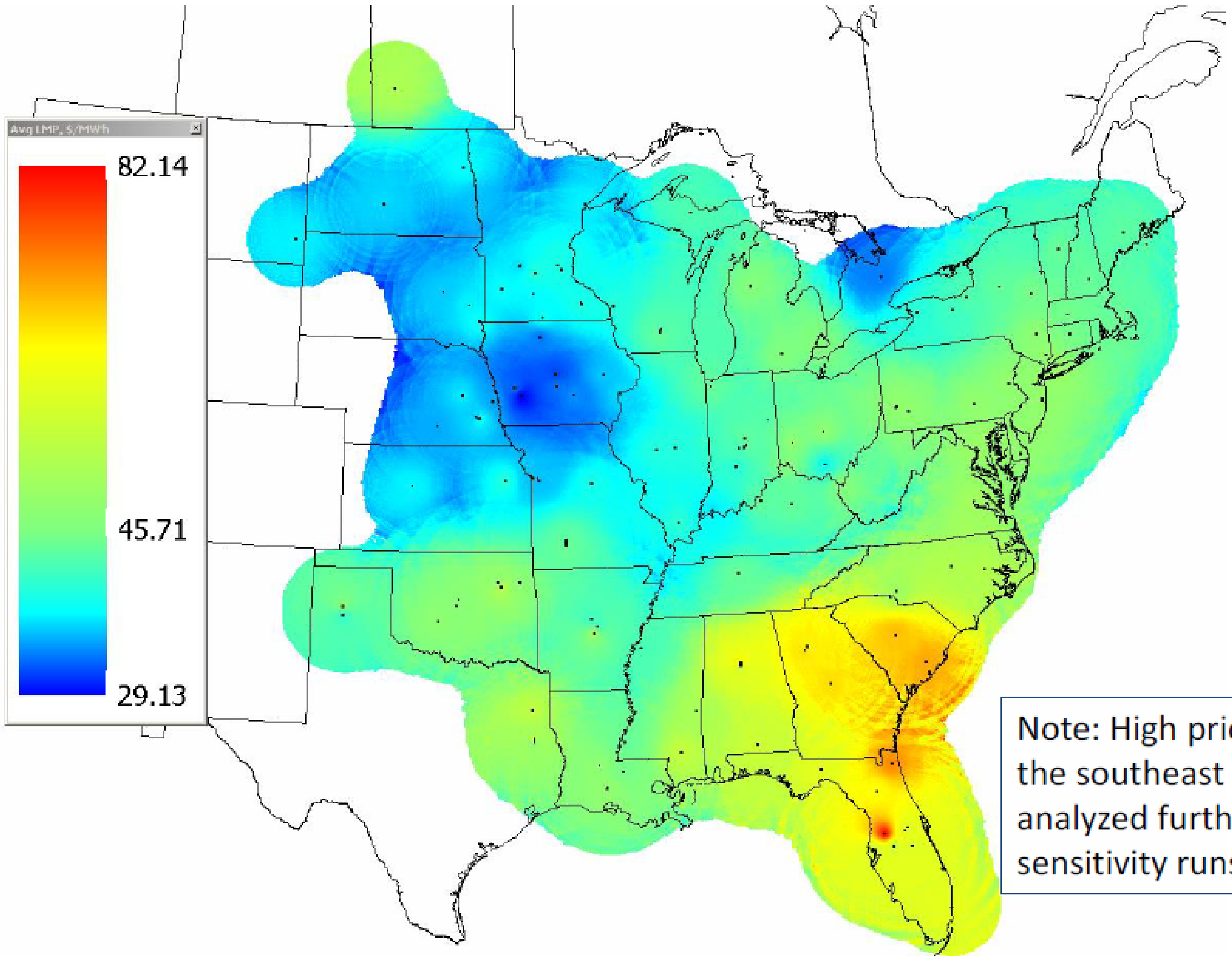
Scenario 3 – Average Annual LMP in $/MWh



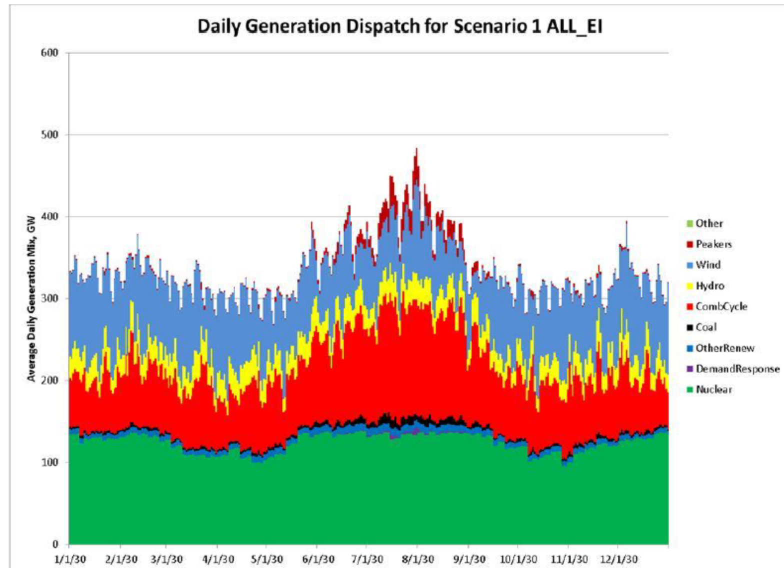
Note: High prices in the southeast were analyzed further in sensitivity runs.

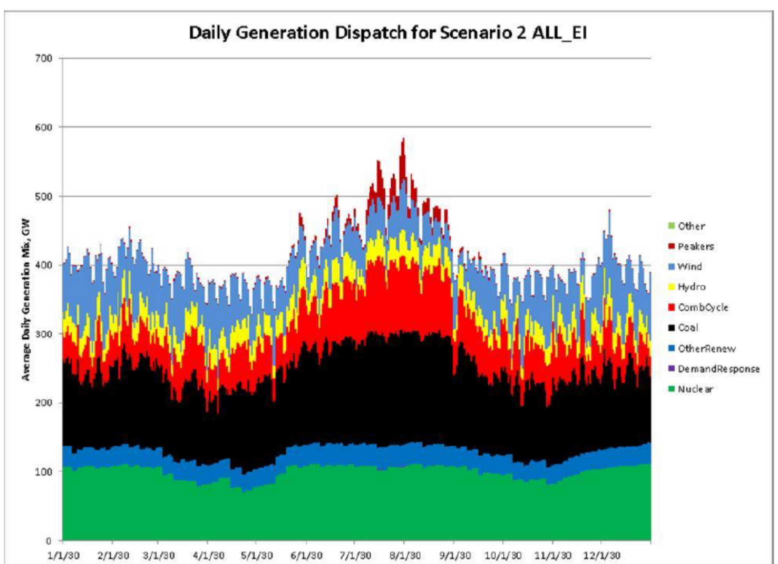
Observations

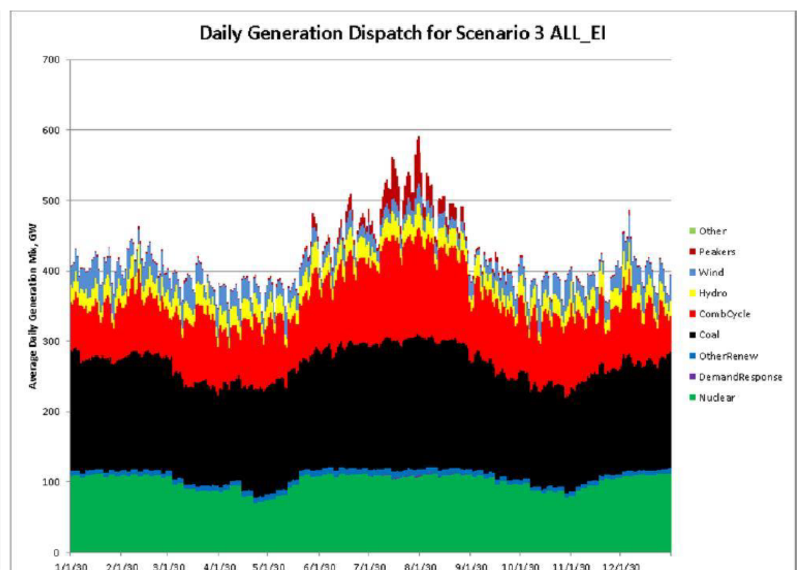
- Lower prices generally occur in areas with significant wind resources, particularly in the west region. This may indicate that transmission limitations prevent further export to the east region.
- There are pockets of higher prices, especially in the southeast region.
- Additional sensitivities would be performed to try to gain a better understanding.

Dispatch

- Comparing the daily dispatch shows the differences in nuclear (green), coal (black), combined cycle (red), and wind (blue) across scenarios.







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Transmission and Generation Costs (Phase 2, Task 10)

- This task involved the estimation of costs associated with future generation and transmission elements.
- For transmission costs, estimates were developed for
  - new or reconductored lines, according to voltage, MW capability, length, and region
  - new or upgraded substations according to voltage and region
  - transformers and capacitor banks by voltage
  - HVDC lines were modeled as a single option (500 kV, 3500 MW) with costs determined by line length

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Transmission Costs in Task 10 by Scenario

- Scenarios 1 and 2 had significantly higher transmission build costs due to the larger wind generation capacity.

	All Costs in $2010 Billions											
	Total Scenario Costs		Generation Interconnection Project Costs		Constraint Relief Project Costs						Voltage Support Project Costs	
					Total		Task 7		Task 8			
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Scenario 1	$81.75	$115.16	$38.95	$60.16	$42.41	$54.41	$39.35	$50.76	$3.06	$3.65	$0.38	$0.59
Scenario 2	$55.06	$79.67	$44.68	$63.98	$10.33	$15.59	$9.26	$14.22	$1.07	$1.38	$0.06	$0.10
Scenario 3	$12.27	$18.50	$5.18	$9.50	$6.95	$8.81	$5.84	$7.39	$1.11	$1.42	$0.13	$0.18

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Generation Capital Costs in Task 10

Fuel Type	Total Cost (2010$ B)	Total Cost (2010$ B)	Total Cost (2010$ B)
	S1	S2	S3
Biomass	$5.8	$72.2	$9.1
CC	$105.5	$31.5	$61.6
CT	$4.0	$15.4	$10.0
Coal	$0.0	$0.2	$0.0
Geo-Thermal	$0.0	$0.0	$0.0
Hydro	$15.3	$20.2	$2.2
LFG	$7.0	$7.0	$6.4
Nuclear	$143.8	$11.8	$11.4
Pumped Storage	$0.0	$0.0	$0.0
PV	$23.2	$25.7	$25.2
Solar	$0.2	$0.2	$0.2
STOG	$0.3	$0.8	$0.8
Steam Wood	$1.3	$1.3	$0.4
Wind	$554.0	$321.0	$107.3
IGCC	$0.0	$0.0	$0.0
Wind OFFS	$7.6	$172.0	$7.6
Total EI	$ 868.1	$ 679.4	$ 242.3

- Scenarios 1 and 2 have higher generation capital costs as well.

Other Costs

- Estimates of other costs were developed in Phase I by the Modeling Working Group.
  - energy efficiency costs
  - demand response costs
  - distributed generation costs
  - nuclear uprate costs
  - variable energy resource integration costs
  - pollution control retrofit costs
- Differences in these costs across scenarios were generally small.

Costs Not Captured

- It was not practical to incorporate all potential costs.
  - lower voltage transmission projects
  - SSI projects (these were common to all scenarios)
  - some generation interconnection costs
  - generator deactivation costs
  - capital costs for existing units
  - transmission system operation and maintenance costs

Sensitivities for the Production Cost Analysis

- Based on issues identified during the process (amount of wind power being curtailed, impact of load and natural gas price forecasts, high levels of demand response and high prices in the southeast region), six sensitivities were chosen by the SSC.
  - Scenario 1, higher loads
  - Scenario 1, increased spinning reserve availability
  - Scenario 1, reduced wind build-out in high wind areas
  - Scenario 1, increased transmission capacity on selected flow gates
  - Scenario 3, higher loads
  - Scenario 3, higher natural gas prices

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Natural Gas-Electric System Interface Study

- After the multi-regional electricity system model started, it became apparent that the extraction of natural gas from unconventional sources would result in significant changes to natural gas production, prices, and transportation.
- The US Department of Energy gave an extension to the EIPC work to conduct a study of how the natural gas and electricity systems interact and how those might change in the future.
- Levitan & Associates was chosen to do the modeling work.

Follow-up Analyses

- Given the huge amount of information produced in the various tasks, EISPC decided to commission a series of studies to try to gain additional insights.
- Five high priority topics were chosen for the first analysis, followed by four medium priority and four low priority.
  - one additional topic was added later.
- The work was performed by Oak Ridge National Laboratory, Purdue University, and Navigant.

- https://info.ornl.gov/sites/publications/files/Pub52176.pdf

High Priority Topics

- How do Phase 2 results compare to Phase 1?
- Were there significant changes in earlier years within various regions?
- When all costs are integrated, how do the results compare between scenarios?
- Do some regions face over-reliance on certain fuels or technologies?
- What are the gas sector inter-relationships in the different regions?

Medium Priority Topics

- How did regional operating and planning reserves definitions affect the results?
- Why were there so much wind curtailment in Scenarios 1 and 2?
- How much did demand response as defined in the models affect results?
- What transmission lines were of value in all scenarios?

Low Priority and Supplemental Topics

- How did regional vs. national implementation of policies differ?
- What were the impacts of load growth sensitivities on resource mix and cost?
- What impacts were noticed from the environmental policy sensitivities?
- What impacts were noticed from the technology sensitivities?
- Supplemental – What changes in key inputs and expected results occurred since the study began?

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Conclusions

- The lessons learned in the process and the interactions with diverse groups of stakeholders were much more valuable than specific results.
- The organizational structure of both EISPC and the SSC led to consensus-based decisions. This fostered greater understanding of the concerns of others and the development of more creative solutions.
- The level of trust and spirit of collaboration grew significantly over the course of the project.

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Activities After the Study

- EISPC merged into the National Council on Electricity Policy, which continues to bring regulators, government officials, and consumer advocates together.
  - http://electricitypolicy.org/
- EIPC continues to bring multiple planning authorities together to build upon regional transmission plans and provide interregional analysis of the Eastern Interconnection.
  - https://eipconline.com/

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Thank You

Douglas Gotham

Director

State Utility Forecasting Group

Purdue University

gotham@purdue.edu

https://www.purdue.edu/discoverypark/sufg/