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Integration of Renewable Generation
Impact of EPA Regulations

Presented at the Dogwood Plant Tour Educational Session

August 31, 2011

Agenda

- Renewables Integration
  - Impact on merit order
  - Potential short and long-term implications
- Potential impacts of new EPA regulations
  - Potential impacts on coal fired and other generation
  - Potential impacts on SPP
  - The La Cygne Case

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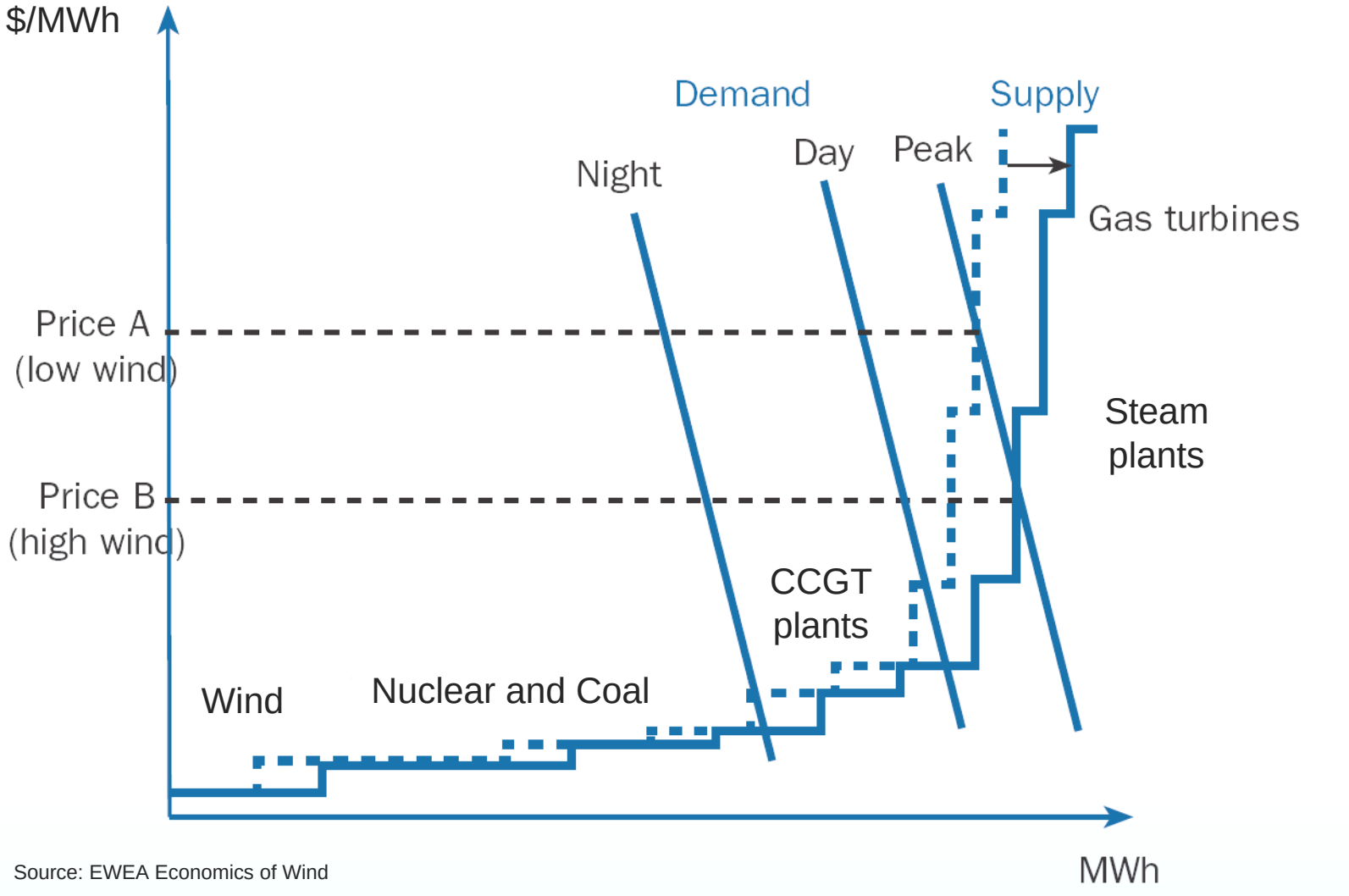
Issues in the integration of renewable generation

Wind generation can lower power spot prices

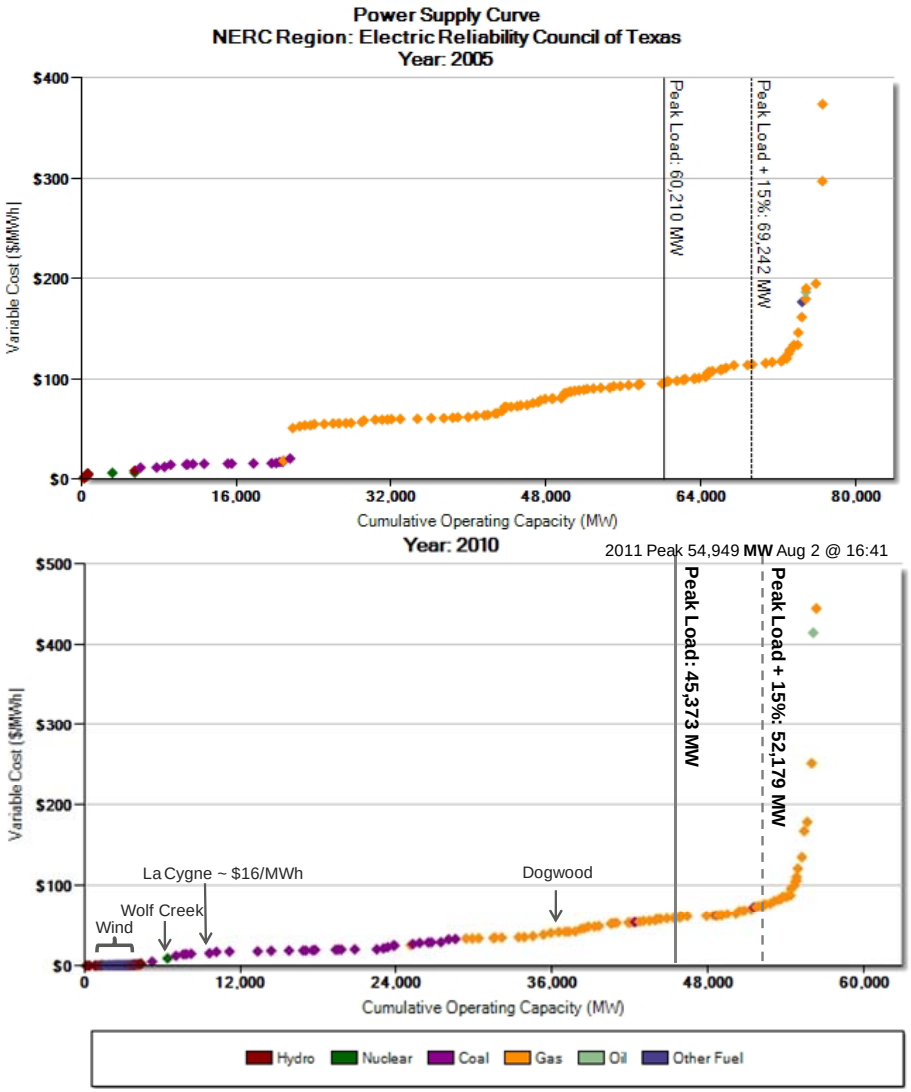


Source: EWEA Economics of Wind

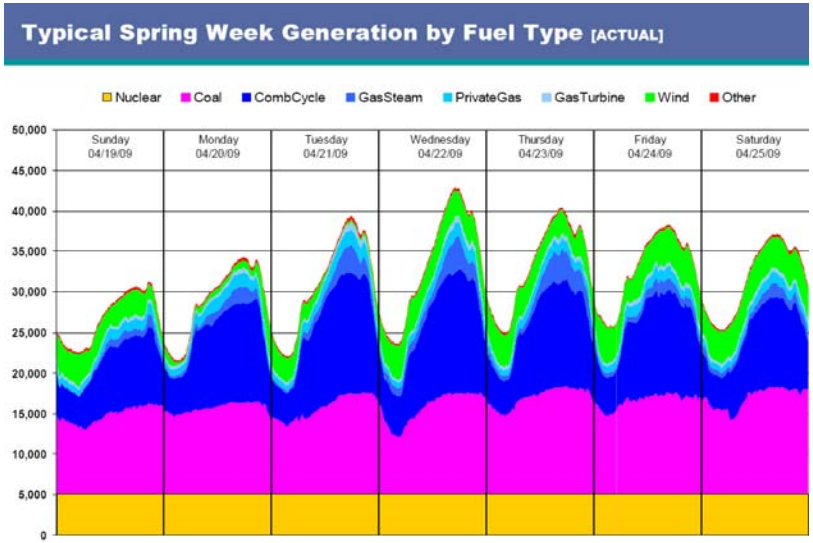
Merit order effect of wind on the spot price of electricity

- In general, in the short-term, spot prices decrease at lower wind penetration levels
  - Marginal and least flexible plants will initially be impacted the most
  - In the long term, a higher peak load plant share will be required to cope with the increased volatility of the residual demand and result in an “adaptive” merit order curve.
  - This steeper merit order curve will intersect with the more volatile residual demand curve leading to higher price volatility
  - The larger impact of wind on conventional generation is the result of the inability of base load plants to react to wind variability
  - Larger price impacts during the peak periods – larger impact on base load plants during the off peak hours

The impact of wind on merit order over 5-years is fairly apparent



In ERCOT, older gas-steam units which set market clearing prices are the most affected plants followed by coal units located on the same side of transmission constraints as the wind capacity.



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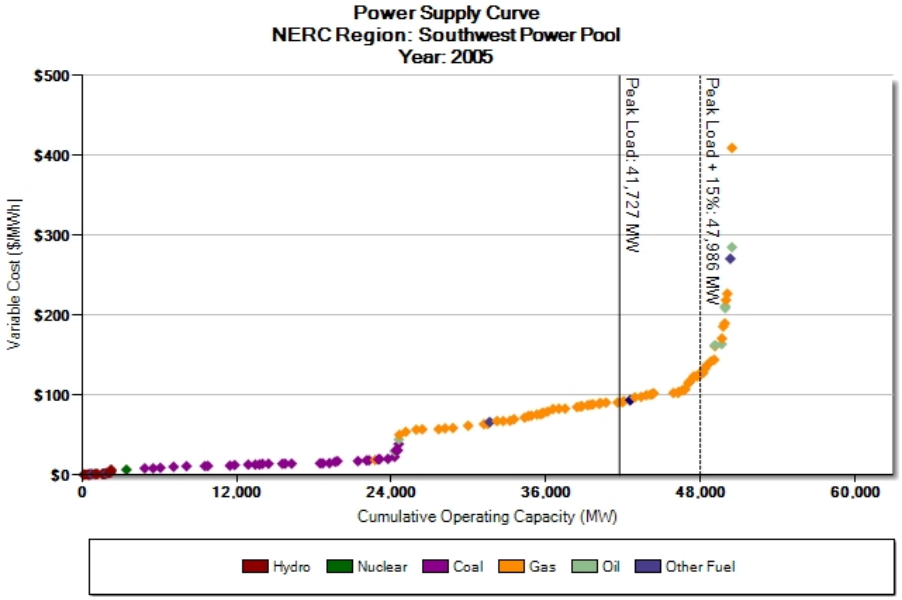
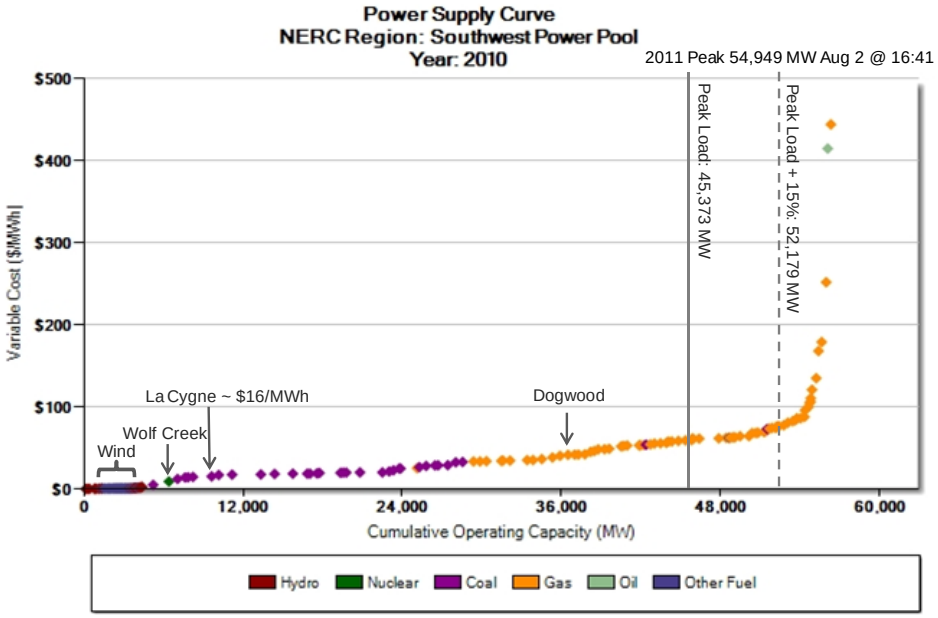
The impact of wind in SPP will be felt in similar ways





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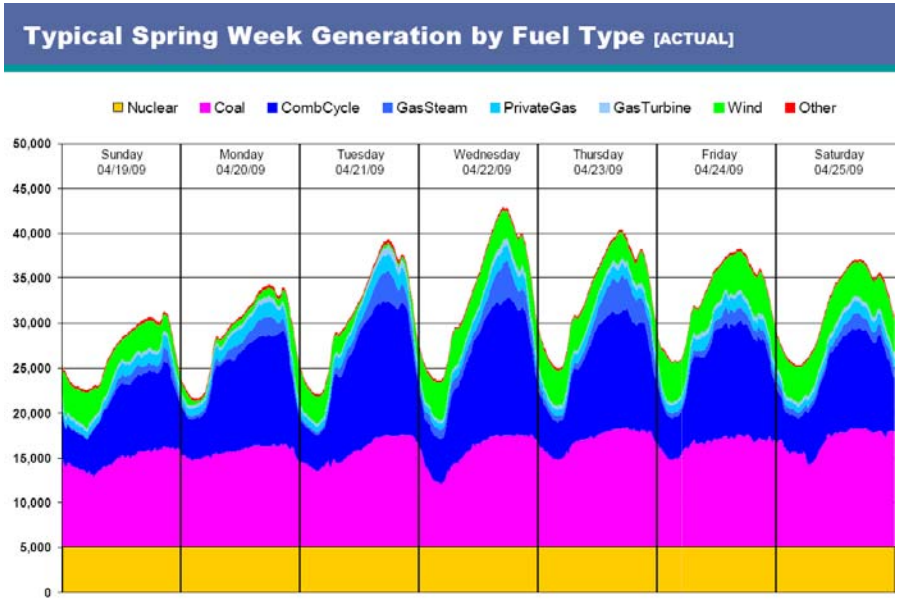
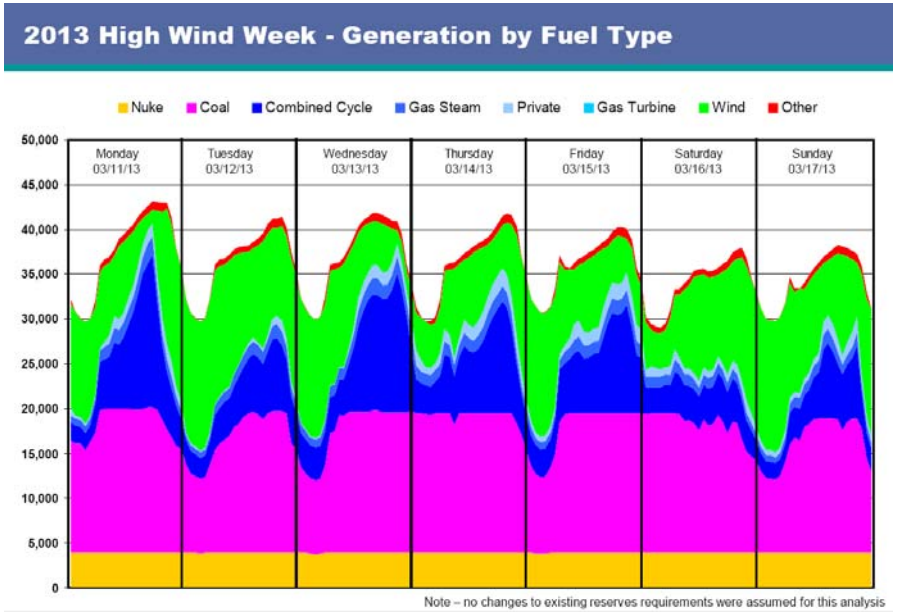
Wind generation can change the economics of base load plants

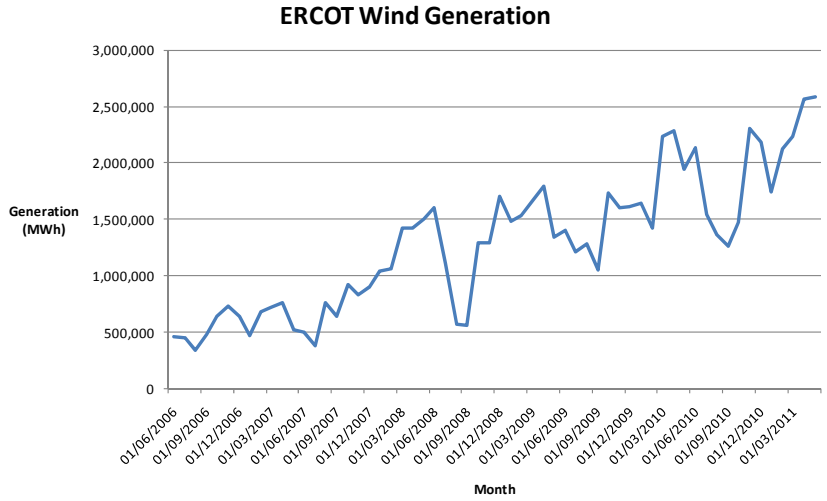
- In electricity markets with transmission constrained economic dispatch and unit commitment, as growing wind generation capacity comes on line, marginal generators experience less run time and increased cycling with the associated loss of revenue and increase in operating costs

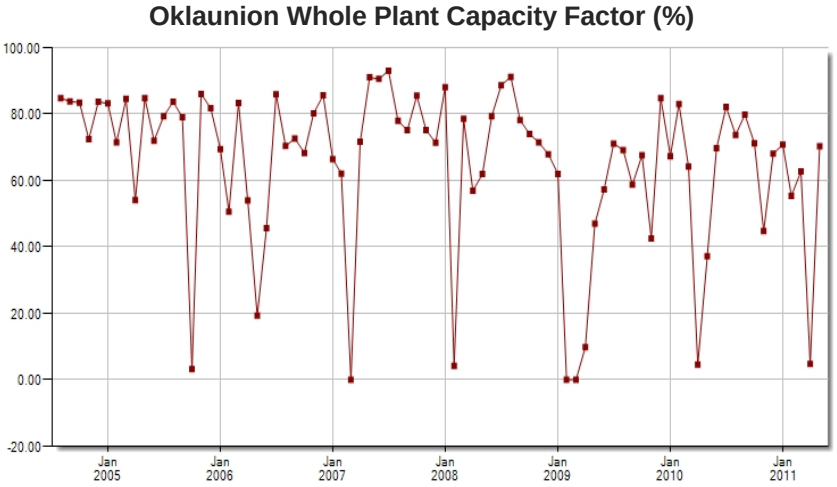




Effect of wind on coal generation plant capacity factors

Coal plants in West Texas are experiencing lower capacity factors and more frequent shutdowns when the net of wind load falls below the plant's minimum operating limits.





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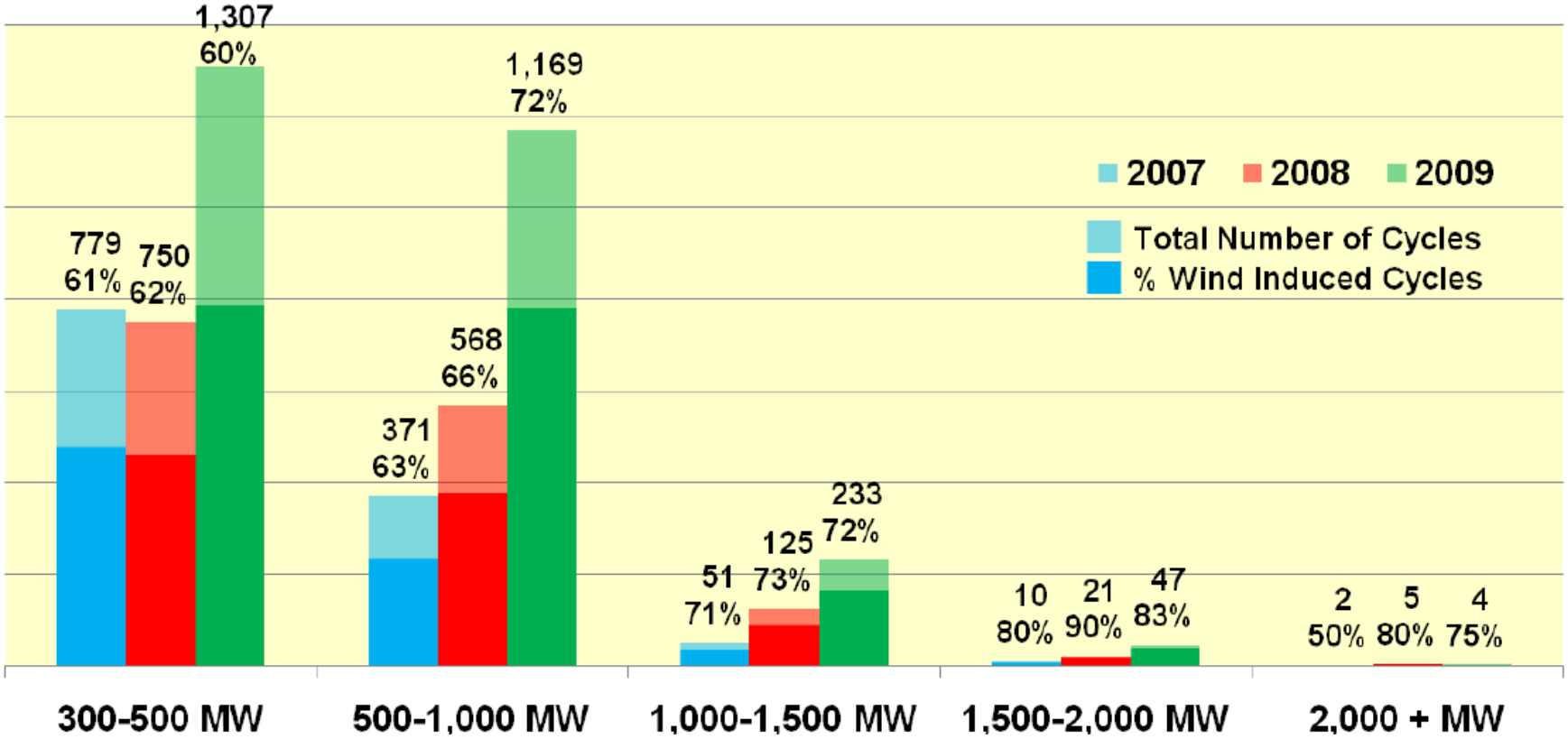
ERCOT coal plant cycling instances – Hour-over-hour change

- A recent analysis of 15-min interval generation data by fuel type for ERCOT for the years 2007, 2008, and 2009, established the increase of coal plant cycling attributable to wind generation. The analysis identified the number of instances where coal-fired power plants cycled down by 300-500 MW, 500-1,000 MW, and more than 1,000 MW during the same time periods when wind generation increased by at least a like amount.



Source: Bentek Energy and CEMS

The cost of increased cycling of coal plants

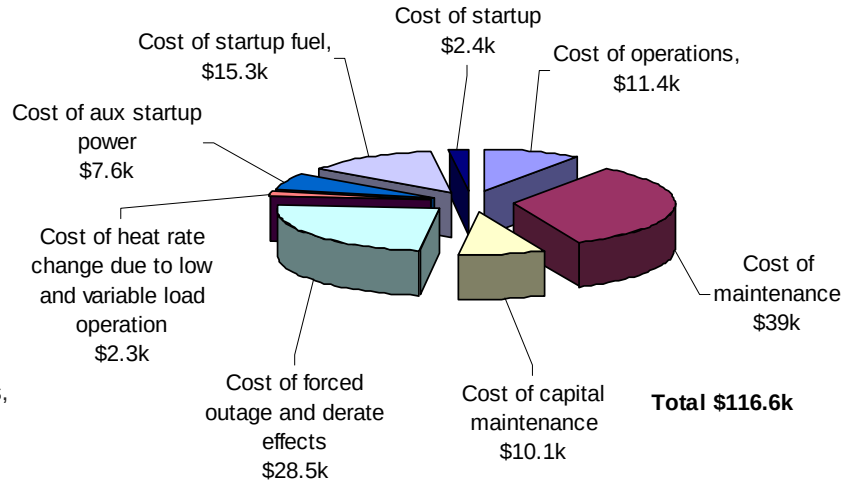
- Most coal-fired generating plants have been designed to operate at relatively constant (slow changing) load levels, with infrequent cycling, and minimum operating levels of 35-50% of their design capacities.
- Cycling of older coal plants can result in significantly increased costs (O&M, forced outage replacement energy and capacity, increased unit heat rate, plant startup costs, and the long-term capacity costs of a shortened unit life).
- Newer coal plants (< 20 yrs old) have better ramping capabilities and may be better suited to follow load and provide additional regulation, but still do not have the flexibility to match wind's real time variability, and are subject to minimum operating levels of 35% or higher.

Typical Generating Plant Shutdown-Start Per Cycle Cost

Unit Type	Potential Cost
Small drum	$3k - $100k
Large Supercritical	$15k - $500k
Gas Turbine	$.3k - $80k

Source: Lefton, Steven, et al., The Cost of Cycling Coal Fired Power Plants, Coal Power Magazine, Winter 2006.

Illustrative Shutdown-Start Per Cycle Cost of a 30-yr old 500 MW Coal-Fired Steam Plant



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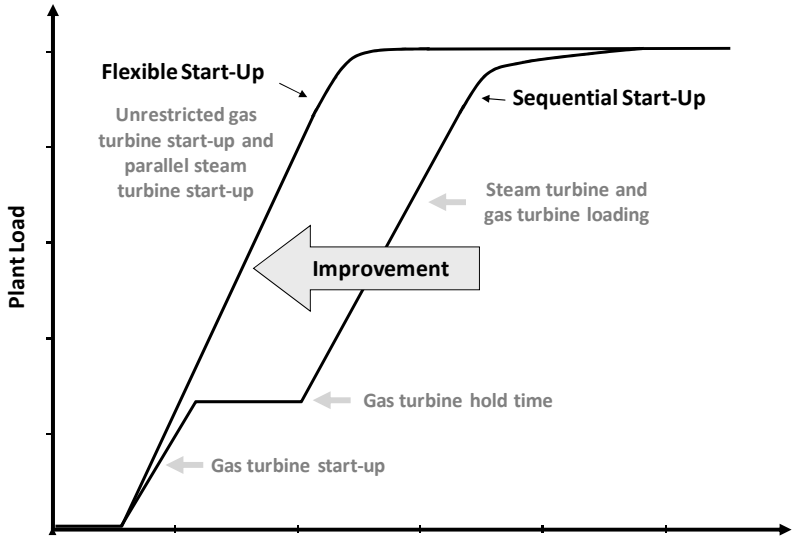
Combined cycle plants are more adaptable to cycling

- Recent vintage natural gas-fired combined cycle gas turbine plants (CCGT) can be ramped up or down more rapidly and cycled more frequently than coal with less impact on the long term economic viability of the plant.
- Older CCGT plants, built during the 1990s and earlier, were designed to operate at maximum efficiency in base load operation and to have slower sequential start-up times, but can be retrofitted for cycling duty and faster up and down-ramping while reducing the impact of cycling on O&M costs and plant operating life.
- The key factors limiting a CCGT plant's ability to rapidly vary its output are: the allowed pressure and temperature transients of the steam turbine, the waiting times of the heat recovery steam generator (HRSG) to reach proper steam chemistry conditions, and the warm-up times for the main piping system and other plant.
- These limitations of the steam side of the plant limit, in-turn, the fast start-up and ramp-up capabilities of the gas turbine. New CCGT plant designs addressed each of these factors.
- Existing CCGT plants can be upgraded to enable plant operators to start their plants faster and operate them with increased flexibility and lower NOx and CO emissions.
- While CCGT plants already provide a significant share of the load following service across all US electricity markets, CCGT plants retrofitted for additional flexibility could satisfy the need for additional load following and regulation capability created by the integration of large amounts of wind powered generation.

Siemens' "hot-start on the fly" concept (right):

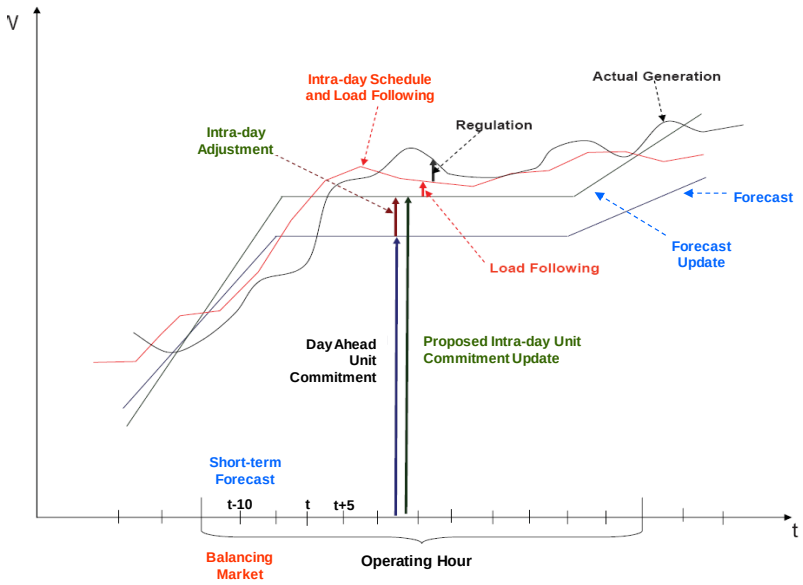
- Modified high pressure/hot reheat steam temperature control
- New high pressure and hot reheat bypass control
- Modifications to the steam turbine controller
- New balance of plant system signals.



Source: Siemens AG 2008

Successful integration of expected wind capacity in SPP

- The SPP Integrated Marketplace, to be launched in 2014, will consolidate the current Balancing Authorities within the SPP to form a Consolidated Balancing Authority.
- As the CBA, SPP will balance supply and demand for the region, maintain frequency, and maintain electricity flows between adjacent BAs.
- SPP will also maintain frequency control and scheduled energy flows to other BAAs to which it is connected, by balancing power supply with power demand over two distinct time scales:
  - Fast random variations in supply-demand balance taking place over a few seconds to a minute (regulation) and,
  - Slower variations over the longer time frame between the unit-commitment time horizon and the real-time dispatch time horizons (load following).



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Rx for successful integration of expected wind capacity in SPP

- At SPP's current wind penetration levels, one-third to one-half of all coal units may not be needed to supply power during minimum load hours.
- The introduction of additional wind will require many coal units to cycle, especially during low load hours. During the winter peak hours, combined cycle units will become the marginal generators. This will lead to less generation by those CCGT units showing the least flexibility.
- The impact of reduced output by coal and CCGT units due to additional wind will further reduce the supply of ancillary services, such as spinning reserves and regulation.

Rx

- State policy makers and regulators will have to make sure that sufficient fast up and down-ramping generation resources are available as operating reserves to the grid operator during periods of low load and high wind generation.
- SPP's Future Market Design would eventually incorporate energy and operating reserve markets, including week-ahead and day-ahead reliability unit commitment of must-run units. Depending on its implementation, these markets could solve the problem.
- In the meantime, some form of long-term contractual commitment may be necessary to cover the fixed operating costs of the flexible CCGT units during oversupply periods.
- Alternatively, electric utilities could be required to develop integrated resource plans (IRPs) that focus on acquiring fossil-fired resources with sufficient flexibility to functionally accommodate RPS-mandated wind and solar resource levels in their generation portfolios.
- Or, wind generation could simply be curtailed during periods of very high generation. However, this would increase overall supply costs

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Impact of new EPA rules on the economic viability of coal fired generation

Impact of New EPA Regulations on Coal Plant Retirements

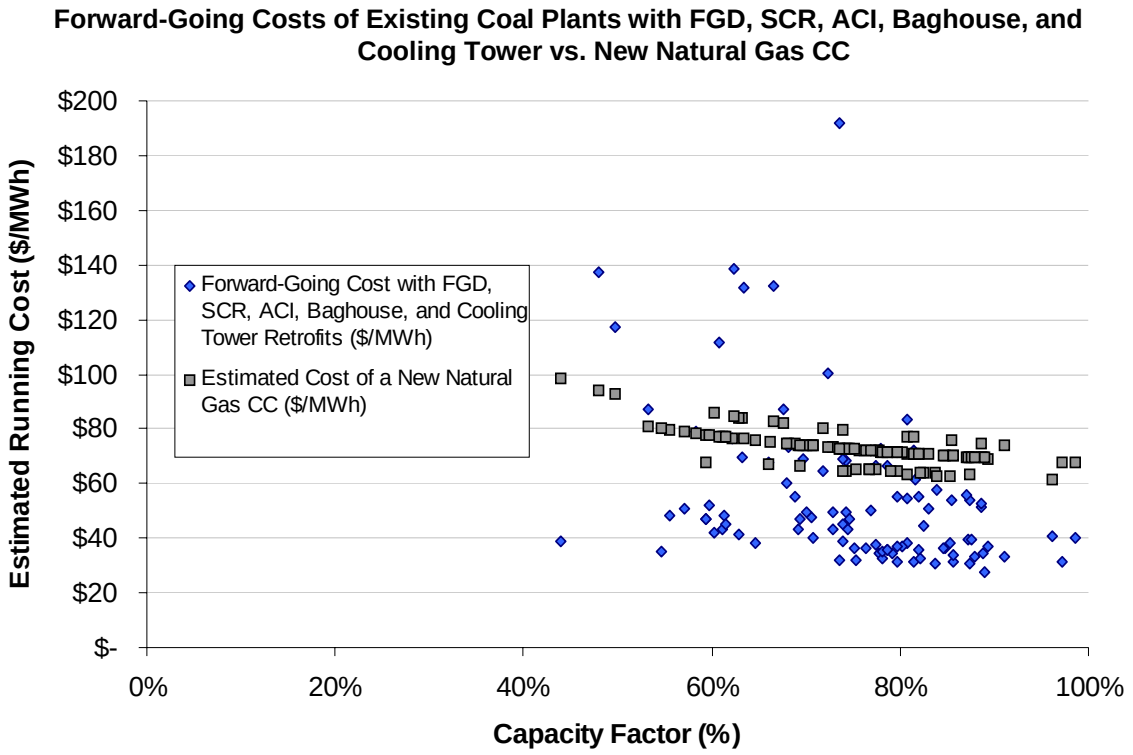
- Some coal-fired power plants will become uneconomic as a result of the promulgation of current and pending EPA rules
  - Regional Haze Rule
  - Clean Air Transport Rule (CATR)
  - Mercury and Air Toxics Standards (MACT)
  - Clean Water Act – Sect 316(b), Cooling Water Intake Structures
  - Potential coal combustion residual (CCR) regulations

- Various estimates of the coal generating capacity forced to retire as a result of these rules range from ~ 30 – 70 GW

Source: Various

New coal fired generation economics

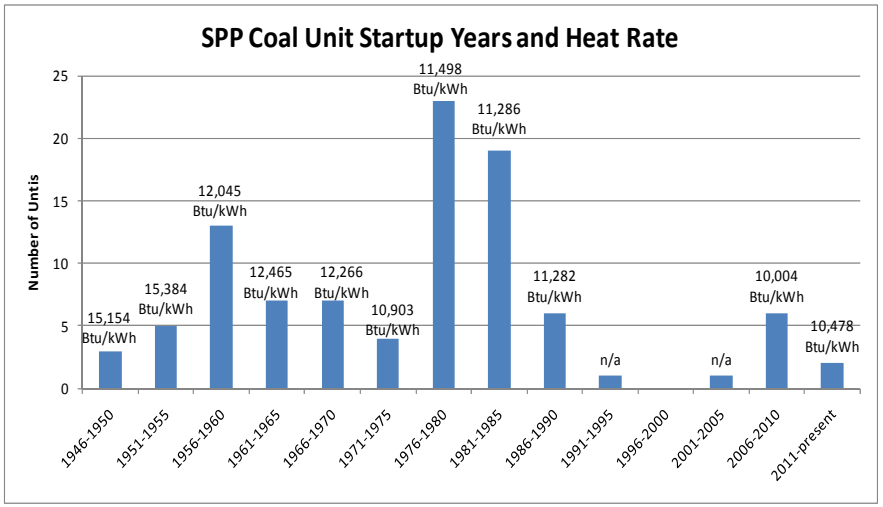
- Because of comparatively low fuel cost, plants that burn sub-bituminous coal have a greater margin to accommodate environmental compliance costs
  - For example, in the Midwest, sub-bituminous coal is currently around $1.60/mmBtu, delivered, while bituminous coal is around $2.40/mmBtu (+50%)

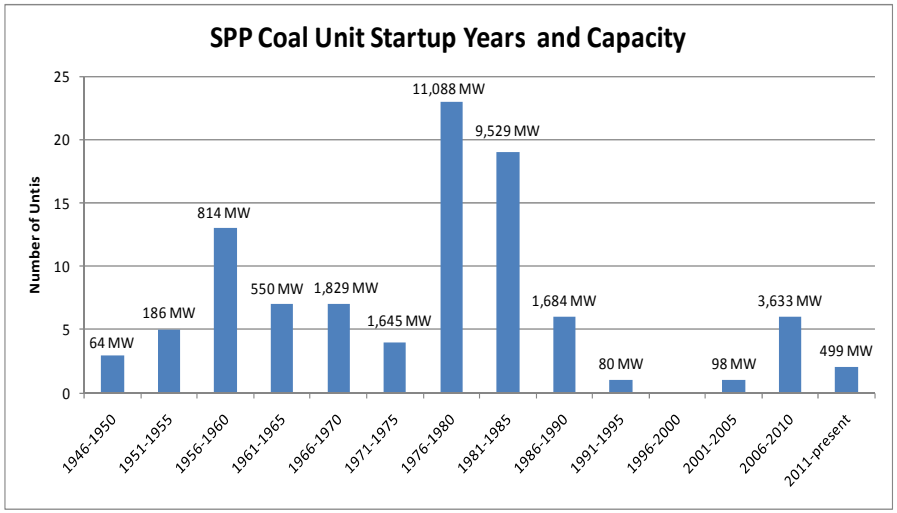


Source: WECC Coal Plant Retirement Based On Forward-Going Economic Merit, Western Grid Group, January 10, 2011.

New coal fired generation economics

- However, the older and least efficient of these sub-bituminous plants may still be at risk
  - Coal-fired plants facing very high environmental retrofit and life extension expenditures may not be economic, even with sub-bituminous fuel cost

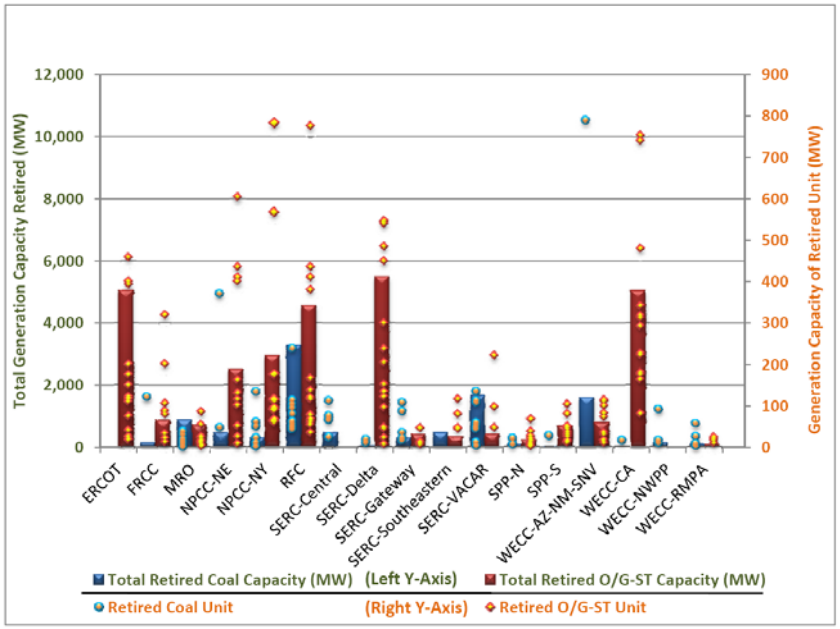




New coal fired generation economics

- Persistent, low natural gas prices resulting from increased shale gas production would put additional pressure on coal-fired plants
- Potential CO2 pricing would make even relatively efficient plants burning sub-bituminous coal at risk
  - CO2 prices based on EIA's assessment of Waxman-Markey (the American Clean Energy and Security Act of 2009) could more than double the variable cost of plants burning sub-bituminous coal

Impacts of proposed EPA Regulations on SPP Generating Capacity (2018)



Source: 2010 Special Reliability Scenario Assessment: Resource Adequacy Impacts of Potential U.S. Environmental Regulations, North American Electric Reliability Corporation, October 2010.

- By 2018, the NERC study predicts combined deratings of coal and oil/gas steam generating units of between 271 MW and 428 MW and retirements of between 972 MW and 2,149 MW across SPP.
- The capacity derated or retired would vary depending on how strictly the new rules are enforced and the higher costs associated with stricter enforcement.
- In the figure, each retired unit is plotted by unit size. Some units may be hidden behind other units of similar size. The bars show the total capacity retired.
- All retired units in SPP are below 200 MW

Economics of the La Cygne generating facility

- A Bates White study of the competitiveness of KCP&L'sLa Cygne generating station, retrofitted to meet Kansas State and EPA environmental regulations, modeled SPP and adjacent markets in the Eastern Interconnect using PROMOD IV based on the following assumptions:
  - Analysis horizon: 2015 – 2034
  - Natural gas prices based on the 2011 EIA AEO projection for Henry Hub prices: $5.25/MMBtu (2015) to $11/MMBtu (2034)
  - Model coal prices were based on confidential KCP&L information. As reference, 2009 FERC Form 1 delivered prices for La Cygne were reported as $1.45/MMBtu (LC1) and 1.31/MMBtu (LC2). Projected long term prices (2034) were not inconsistent with EIA's AEO implied projection for sub-bituminous coal prices
  - Carbon prices were modeled after EIA's assessment of Waxman-Markey: $20.23/ton (2015) to $106/ton (2034)

- The study showed that due to its size, efficiency, and relatively low cost PBR fuel, La Cygne, even with significant life extension investment, is expected to effectively compete with existing and new natural gas fired capacity, even with significant carbon costs before becoming uneconomic.

For additional information about this presentation

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