

Electricity 101

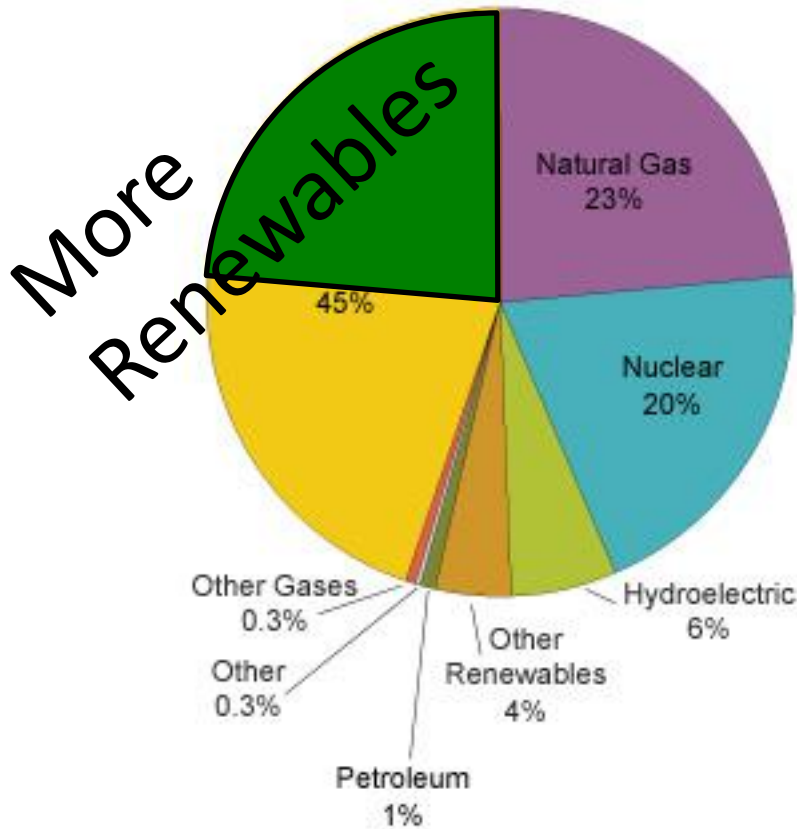
Bernie Lesieutre

University of Wisconsin-Madison

2011 UW Energy Hub Conference, November 4, 2011

Electric Energy Sources

U.S. Net Electricity Generation by Fuel, 2010



2010 Electric Energy Consumption:
3,884 billion Kilowatthours (kWh)

1.5 kW/person

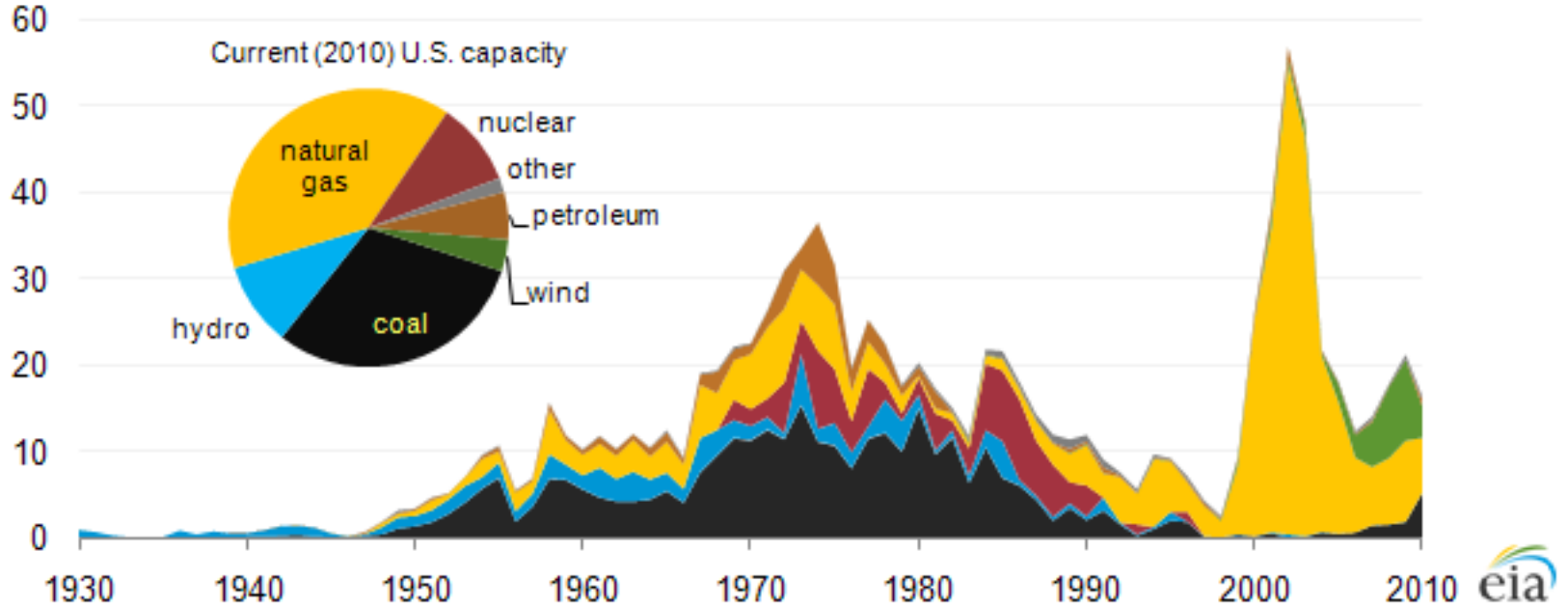
U.S. 2010 Electricity Revenues:

\$370 Billion

Source: U.S. Energy Information Administration, *Electric Power Monthly*, Table 1.1 (March 2011), preliminary data.

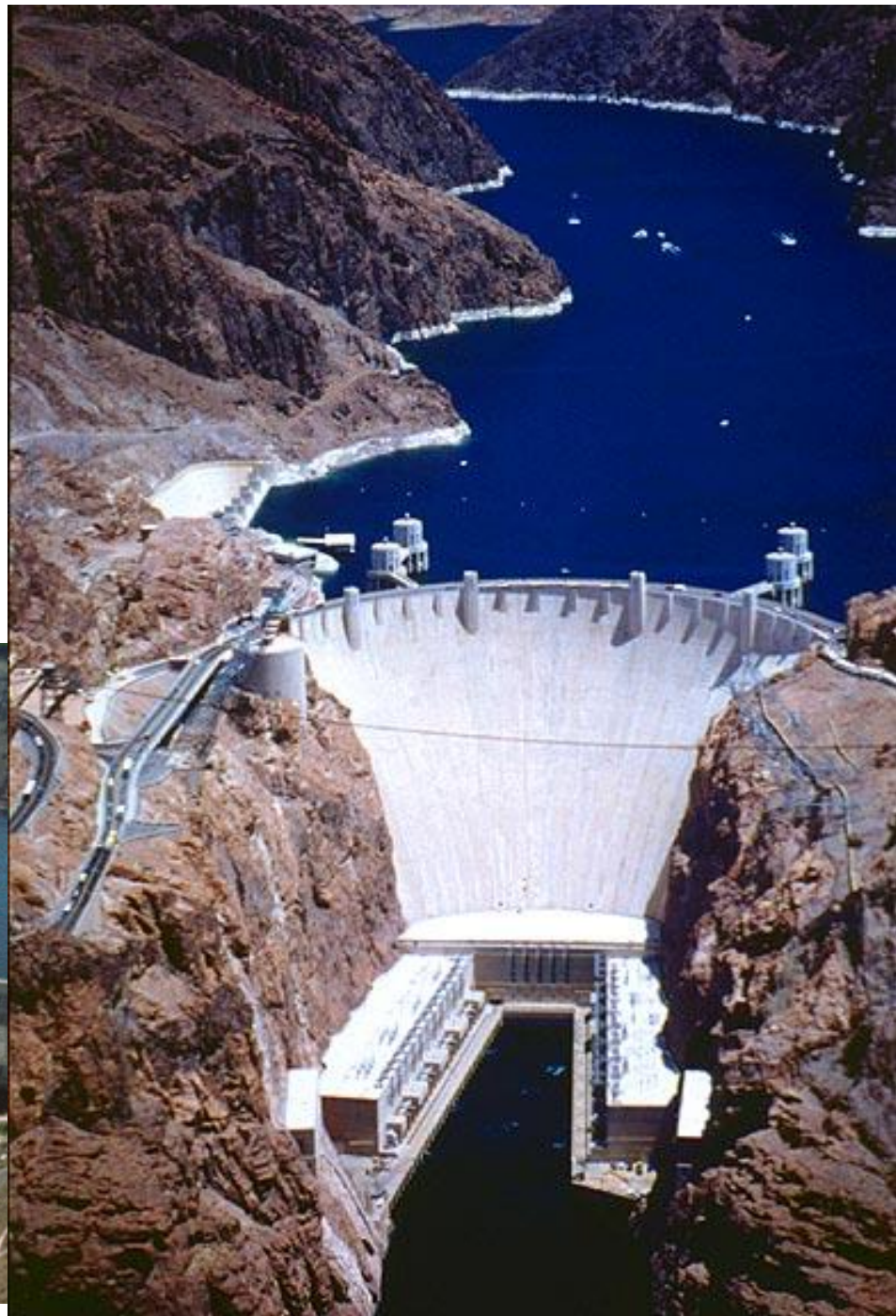
Power Plants

Current (2010) capacity by initial year of operation and fuel type
gigawatts



Source: U.S. Energy Information Administration, Energy in Brief article, How old are U.S. power plants? August 8, 2011.

Grand Coulee and Hoover Dams

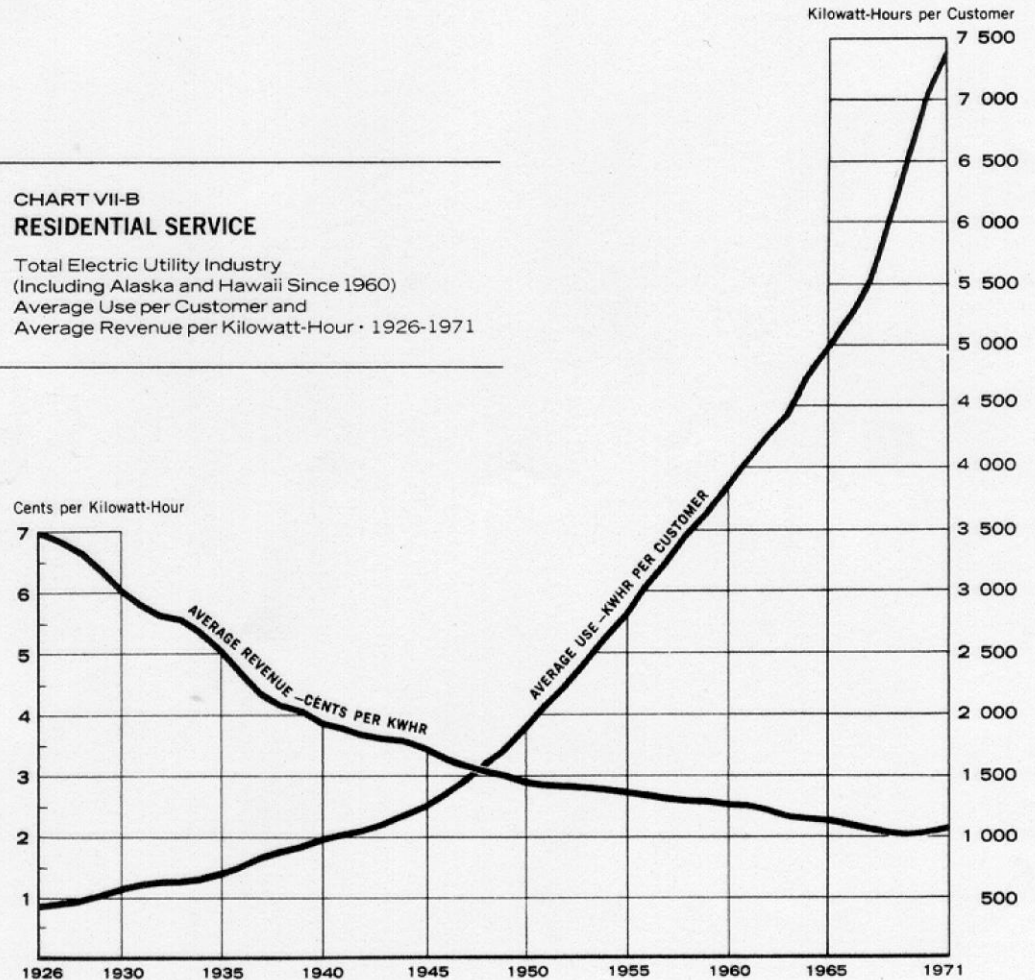


Electricity Demand and Price

Golden Era for
Electricity
increasing use
decreasing prices

CHART VII-B
RESIDENTIAL SERVICE

Total Electric Utility Industry
(Including Alaska and Hawaii Since 1960)
Average Use per Customer and
Average Revenue per Kilowatt-Hour · 1926-1971

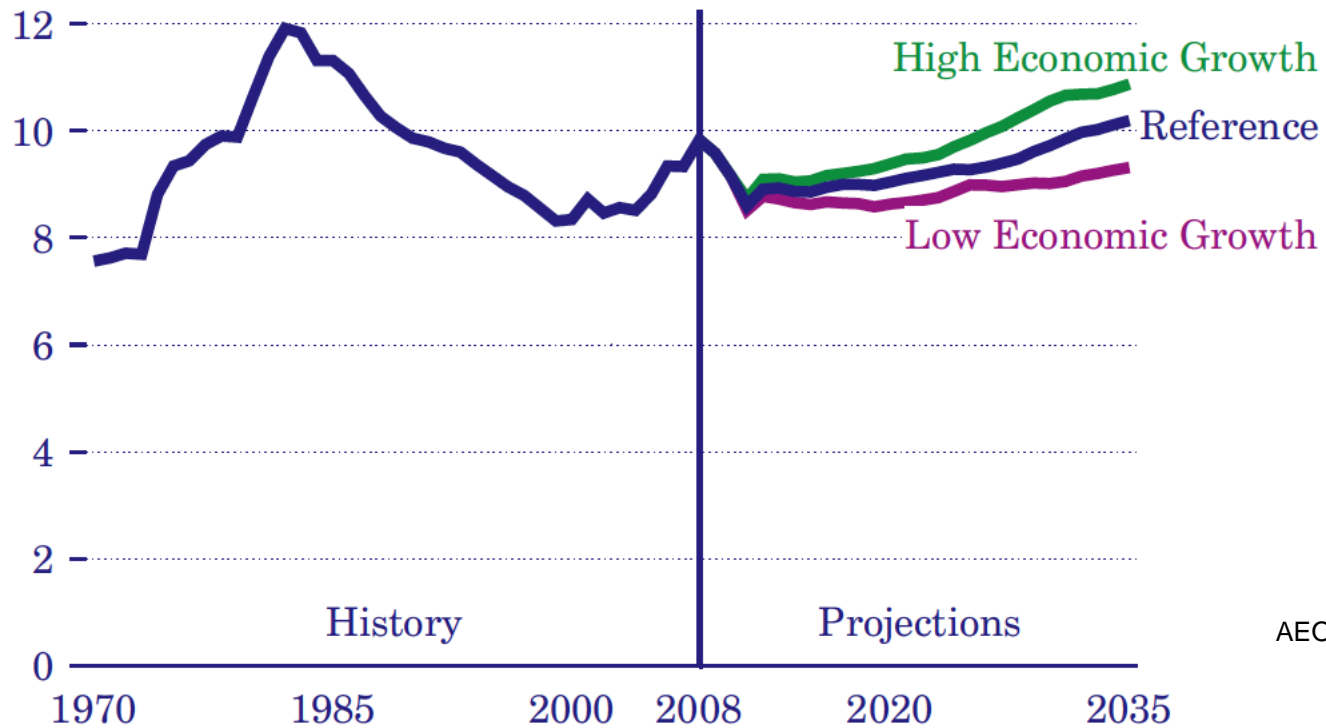


Based on Tables 44 S and 45 S, pages 52 and 53.

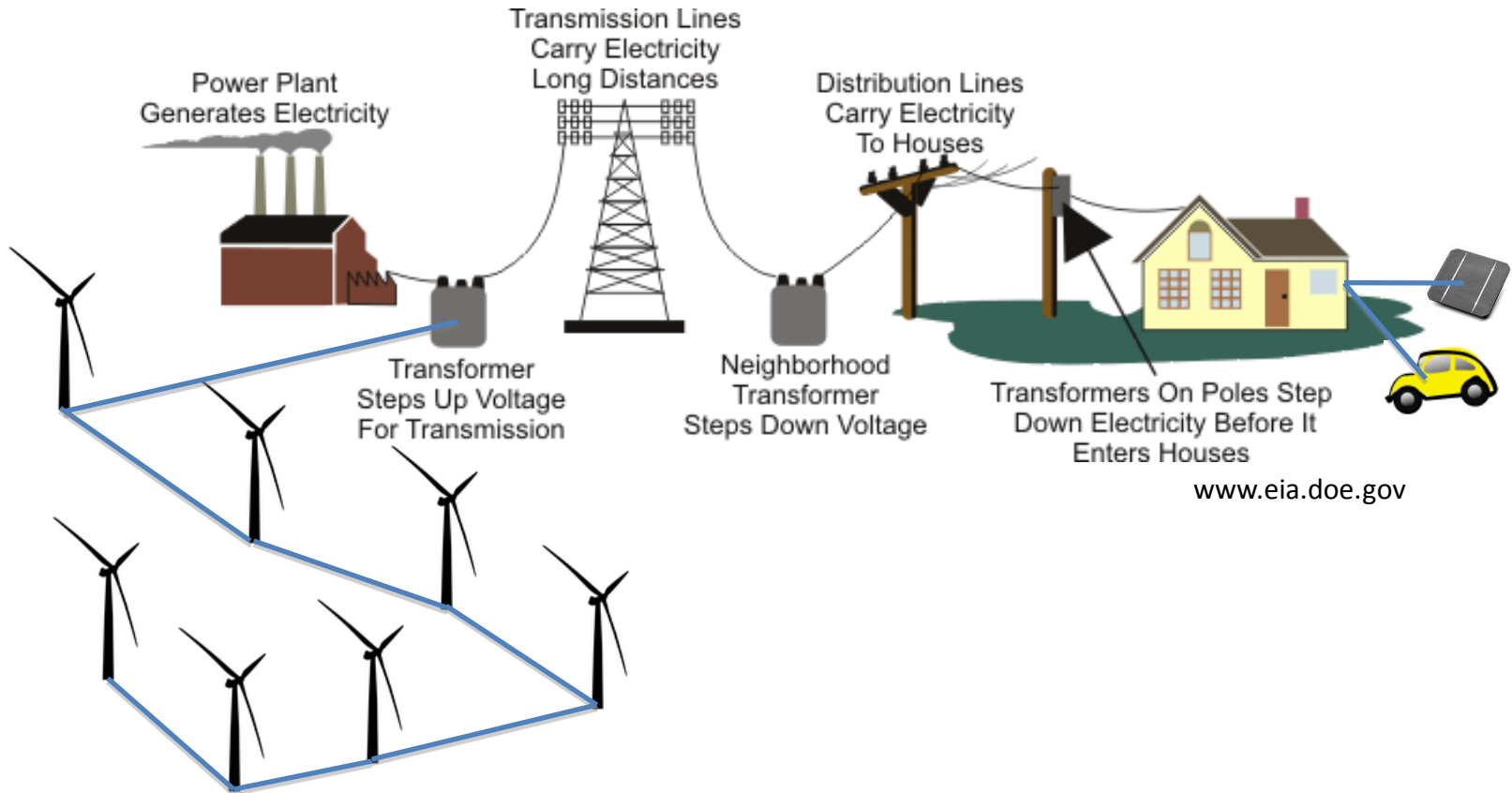
(Statistical Yearbook of the
Electric Utility Industry 1971
Edison Electric Institute)

Electricity Price

Figure 60. Average annual U.S. retail electricity prices in three cases, 1970-2035 (2008 cents per kilowatthour)

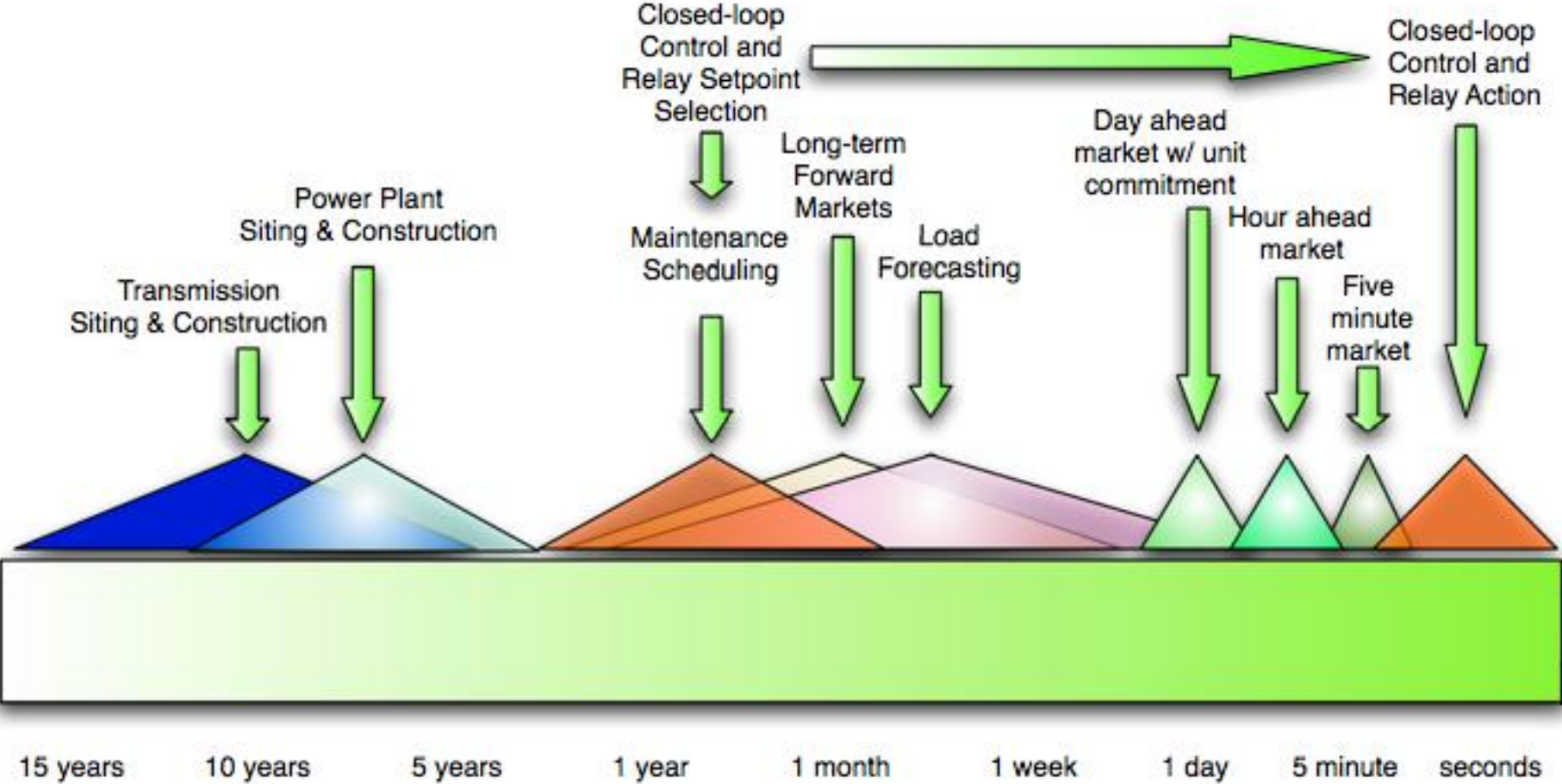


Electric Grid Overview



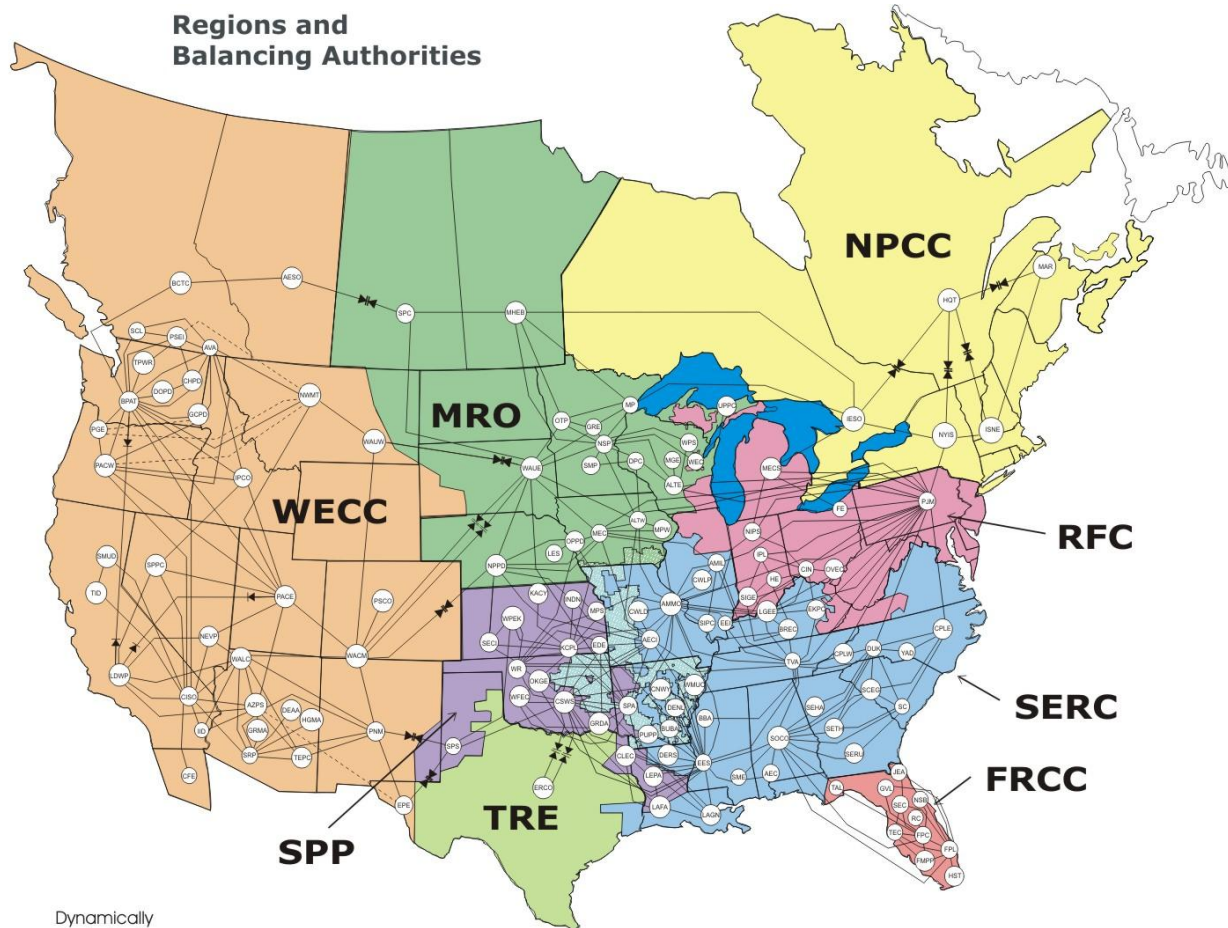
www.eia.doe.gov

Power System Decision Timescales



NERC

Regions and Balancing Authorities



www.nerc.com

----- Dynamically
Controlled
Generation

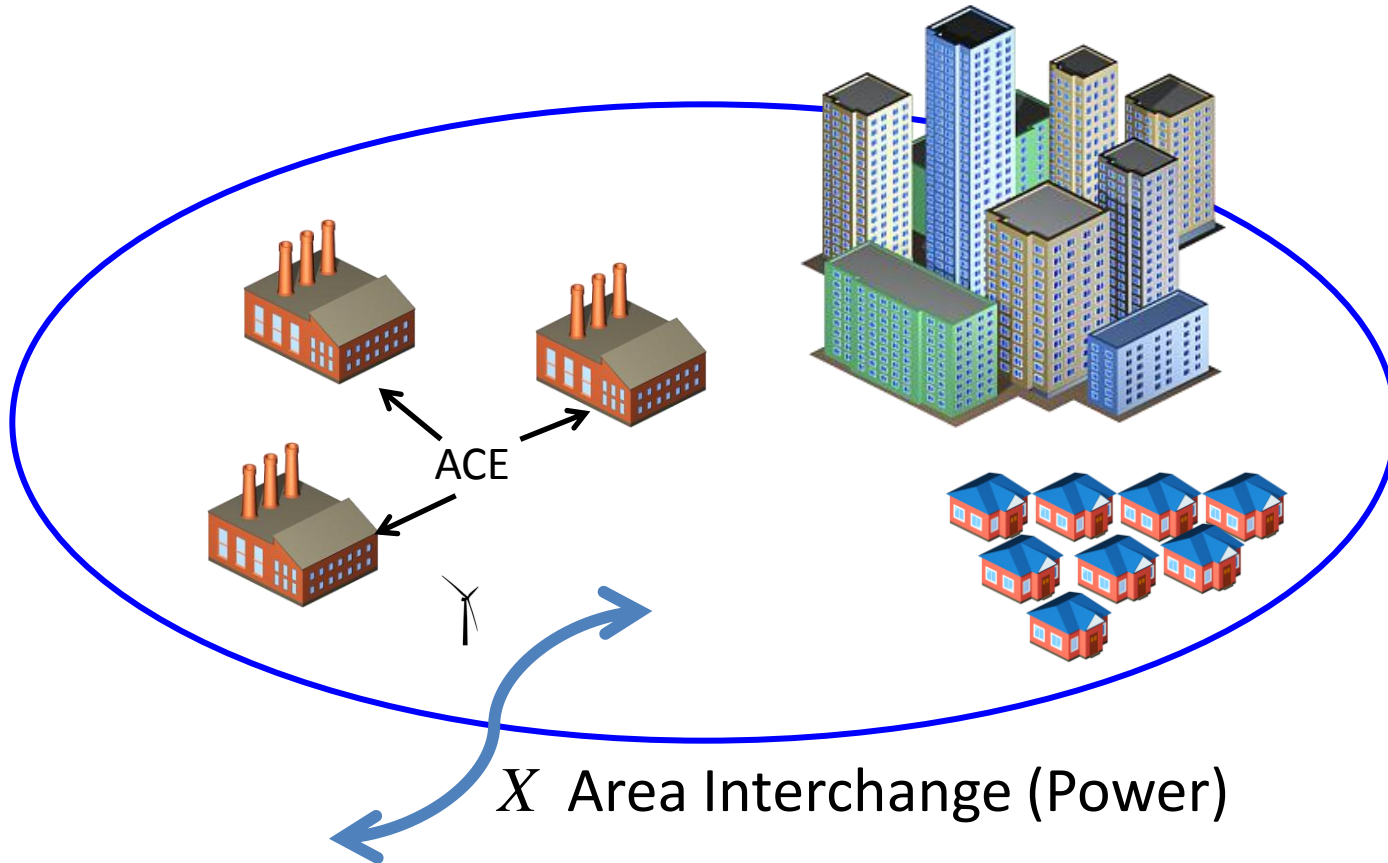
As of August 1, 2007

“The Interconnected power system shall be operated at all times so that the general system instability, uncontrolled separation, cascading outages, or voltage collapse will not occur as a result of any single contingency or multiple contingencies of sufficiently high likelihood”
WECC Operating Handbook, 2005

Balancing Generation and Load

- Measure: “ACE” – Area Control Error
- Monitored in Balancing Authorities
- Automatic Generation Control (AGC) adjusts generation every 4 seconds.
- Penalties for non-compliance.
- Generation Reserves: for tracking load, for responding to disturbances.

ACE



$$ACE = \underbrace{(X - X_S)}_{\text{local}} - 10\beta_f \underbrace{(f - f_S)}_{\text{system}}$$

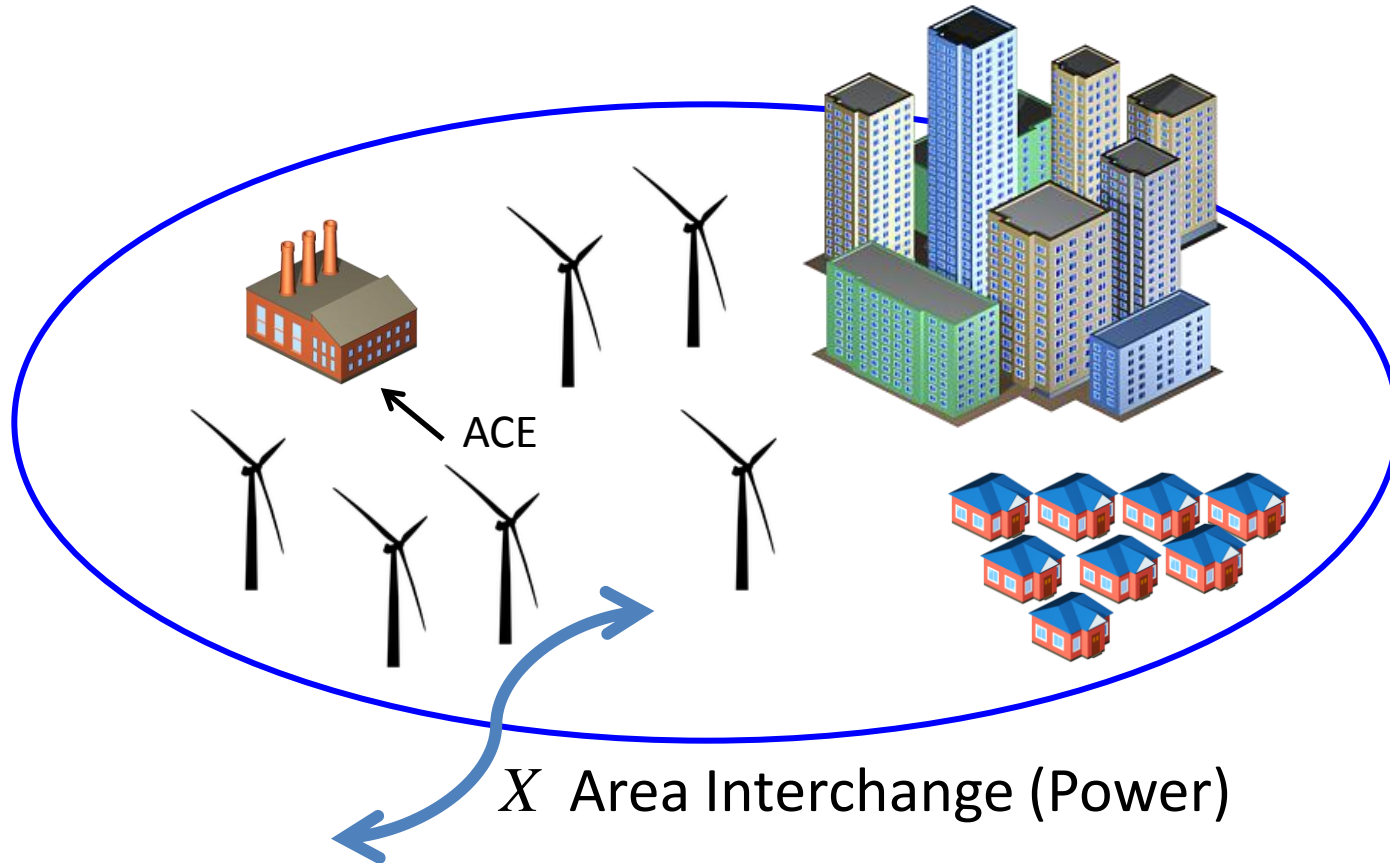
Interchange Error Frequency Error

Challenge

Intermittent Resources

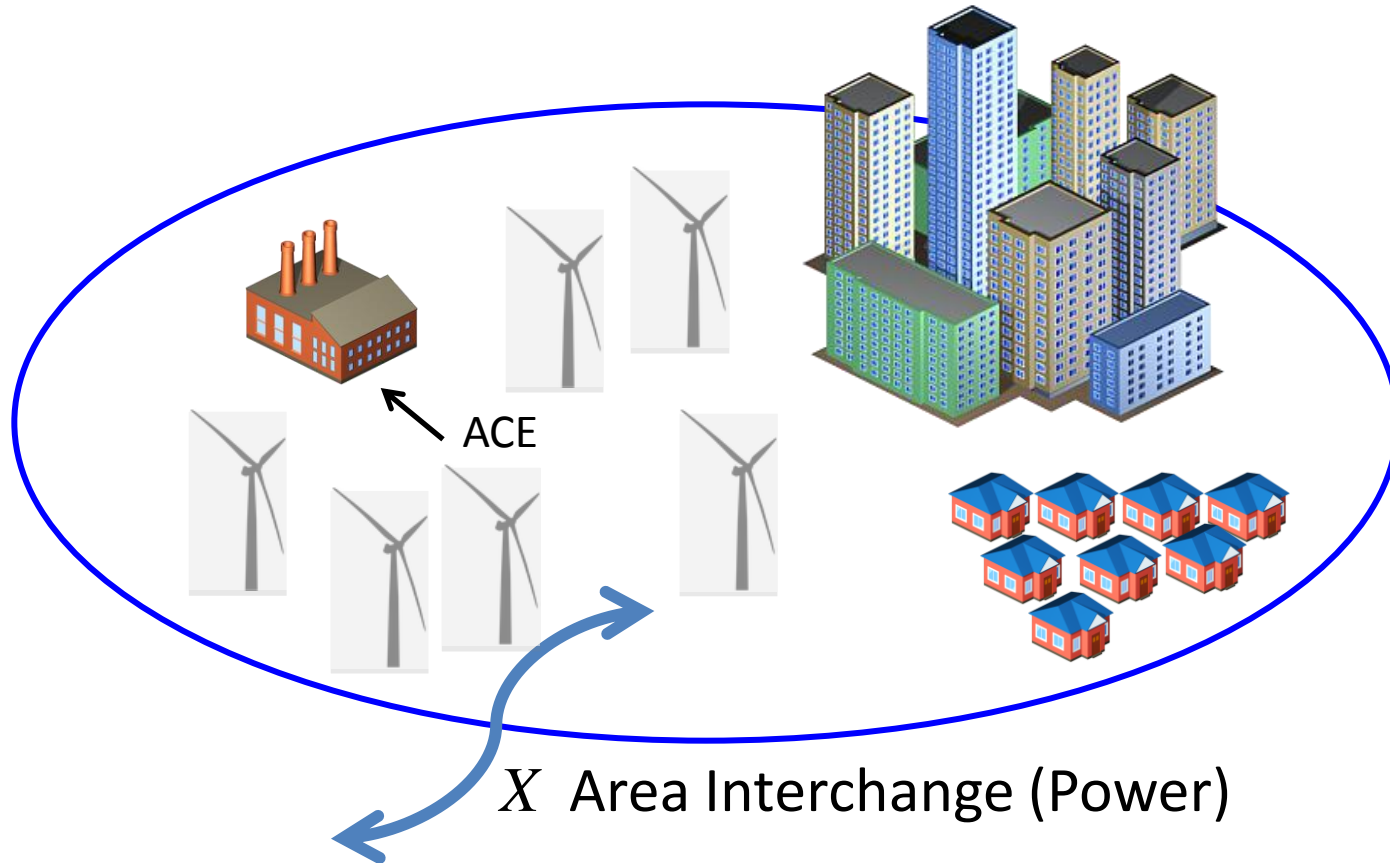
1. Replace existing resources for energy, displacing traditional controls
2. Increase the need for controls

Challenge



Need more dispatchable resources to track load and intermittent resource variability.

Challenge



Need reserves to guard against (wind) power failure.

ERCOT Feb 2008



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Loss of wind causes Texas power grid emergency

Wed Feb 27, 2008 8:11pm EST

HOUSTON (Reuters) - A drop in wind generation late on Tuesday, coupled with colder weather, triggered an electric emergency that caused the Texas grid operator to cut service to some large customers, the grid agency said on Wednesday.

Electric Reliability Council of Texas (ERCOT) said a decline in wind energy production in west Texas occurred at the same time evening electric demand was building as colder temperatures moved into the state.

The grid operator went directly to the second stage of an emergency plan at 6:41 PM CST (0041 GMT), ERCOT said in a statement.

System operators curtailed power to interruptible customers to shave 1,100 megawatts of demand within 10 minutes, ERCOT said. Interruptible customers are generally large industrial customers who are paid to reduce power use when emergencies occur.

No other customers lost power during the emergency, ERCOT said. Interruptible customers were restored in about 90 minutes and the emergency was over in three hours.

ERCOT said the grid's frequency dropped suddenly when wind production fell from more than 1,700 megawatts, before the event, to 300 MW when the emergency was declared.

Loss of 1400 MW

Dropped 1100 MW
Of "Interruptible" load.

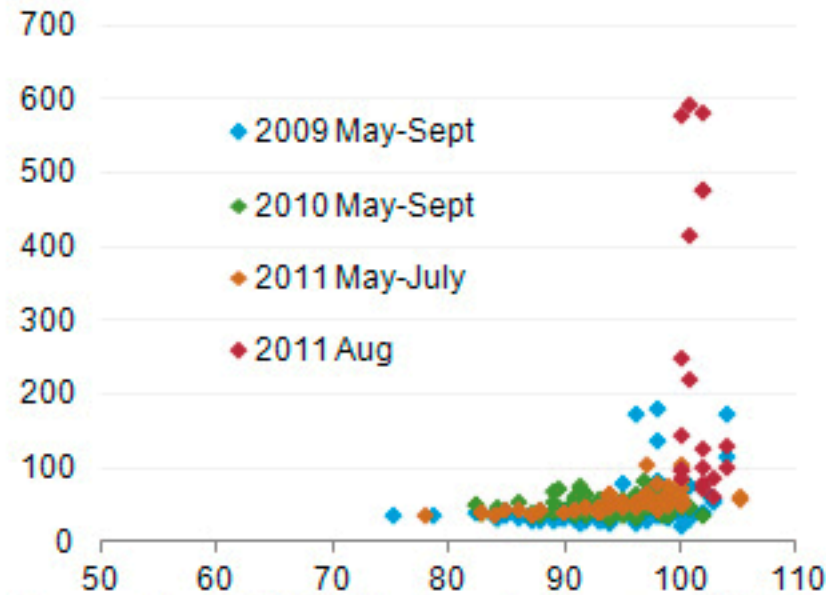
Load can be a
resource. Are there
limits?

Texas Heat Wave

leads to capacity shortage and high prices.

Capacity shortage drives high August prices in Texas

Houston daily, day-ahead, on-peak power price (\$/MWh)



Source: Electric Reliability Council of Texas and NOAA

Electricity Markets

- Allow competition of generating resources.
(Demand also)
- Markets operate over different timescales
 - 5 minutes (“real time”).
 - Hourly/Day-ahead: supports resource commitment.
 - Long term: capacity and transmission rights.

Details differ by market (ERCOT, ISONE, MISO, NYISO, PJM)

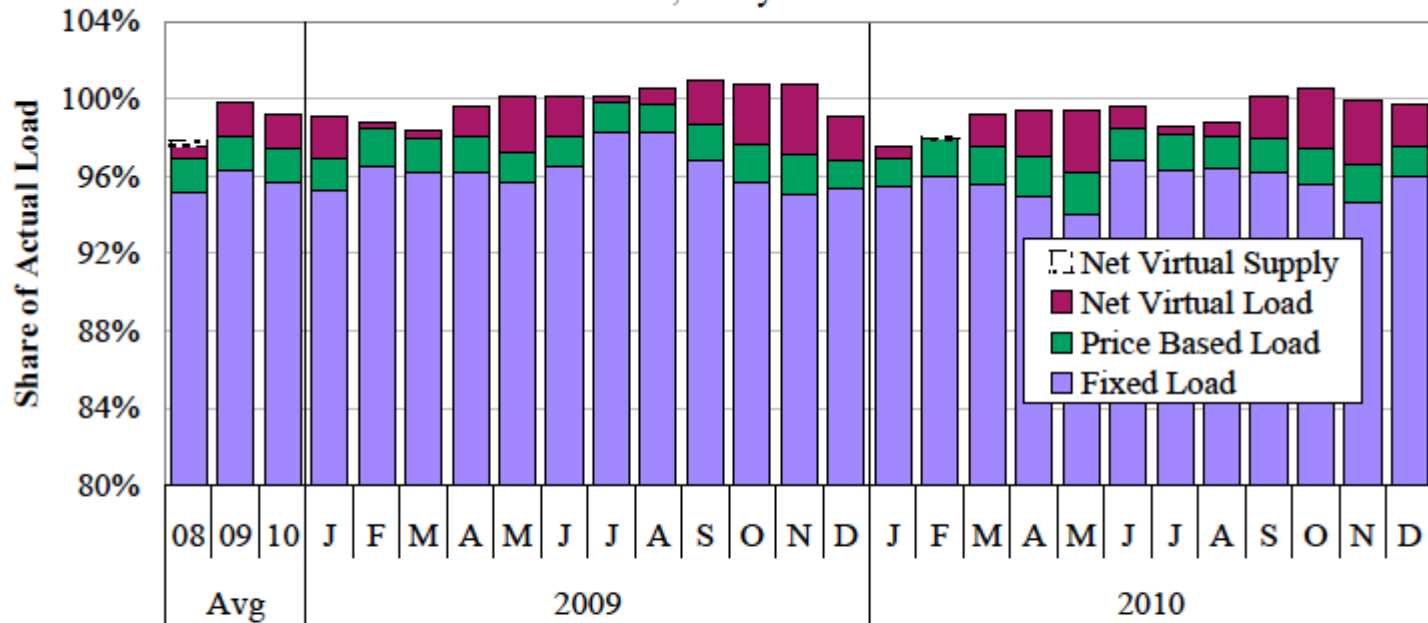
Market Challenges

Intermittent resources are challenged by and challenge market operations:

- What is the value of their “capacity”?
- How well can production be anticipated one day in advance? Under-committing wind, over-commits other resources. Over-committing wind may cause reliability concerns.
- How might uncertainty affect day-ahead and real-time markets? This could potentially skew market prices.

MISO: Load schedule

Figure 19: Day-Ahead Scheduled versus Actual Loads
2009–2010, Daily Peak Hour

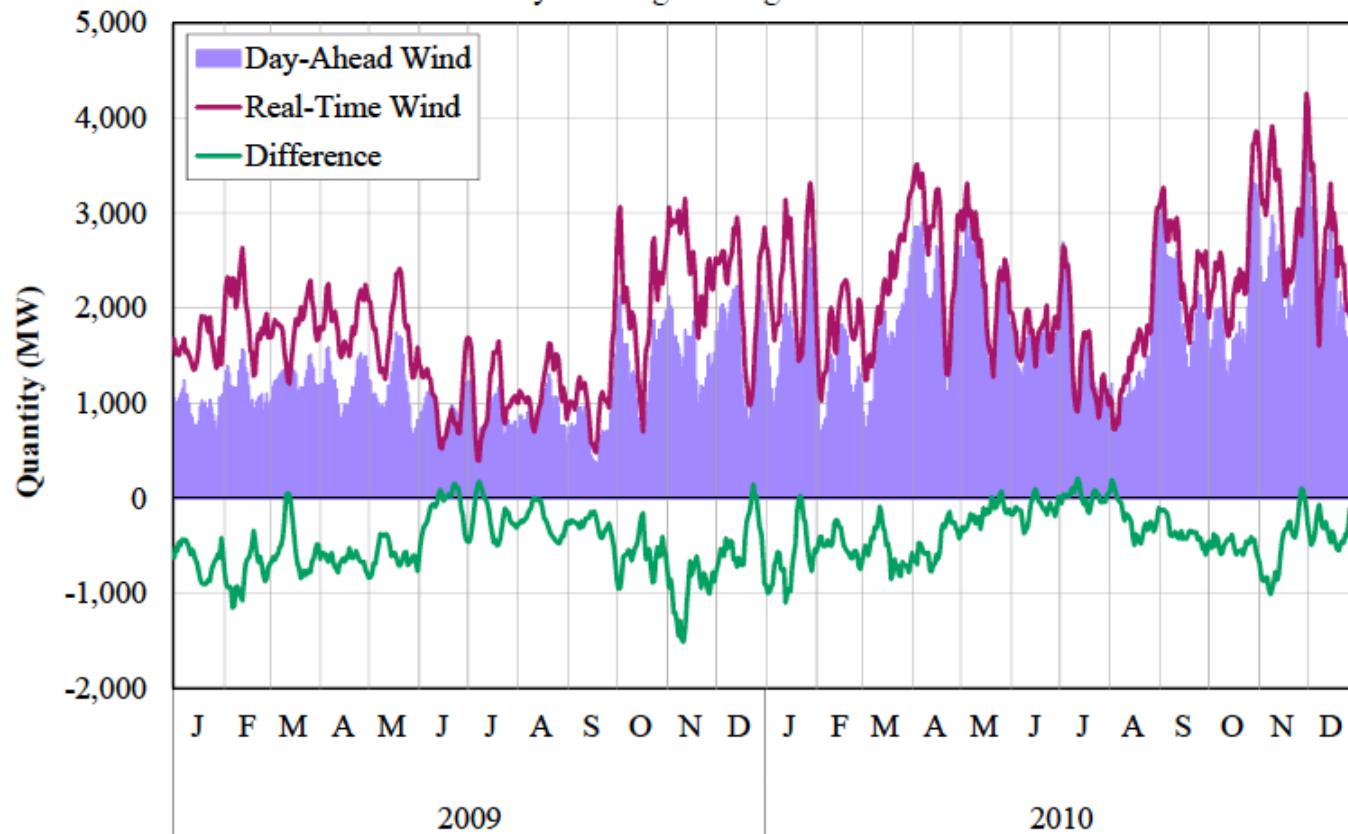


	Share of Actual Load(%)																														
All Hour	99.2	99.9	99.3	100.1	99.4	98.7	99.2	99.4	99.9	100.3	100.7	101.0	100.4	100.8	100.1	100.7	100.2	99.1	100.6	98.2	98.9	99.3	99.2	99.4	99.9	99.2	99.4	99.4	99.8	99.4	100.0
Peak Hour	97.6	99.9	99.2	99.1	98.7	98.4	99.6	100.2	100.1	100.2	100.5	101.0	100.8	100.7	100.2	99.1	100.6	97.6	97.9	99.2	99.4	99.4	99.6	98.5	98.8	100.1	100.5	99.9	99.4	100.0	

98-99% of load is scheduled in the day-ahead market.

MISO: Wind Schedule

Figure 46: Day-Ahead Scheduling versus Real-Time Wind Generation
Seven-Day Moving Average: 2009–2010



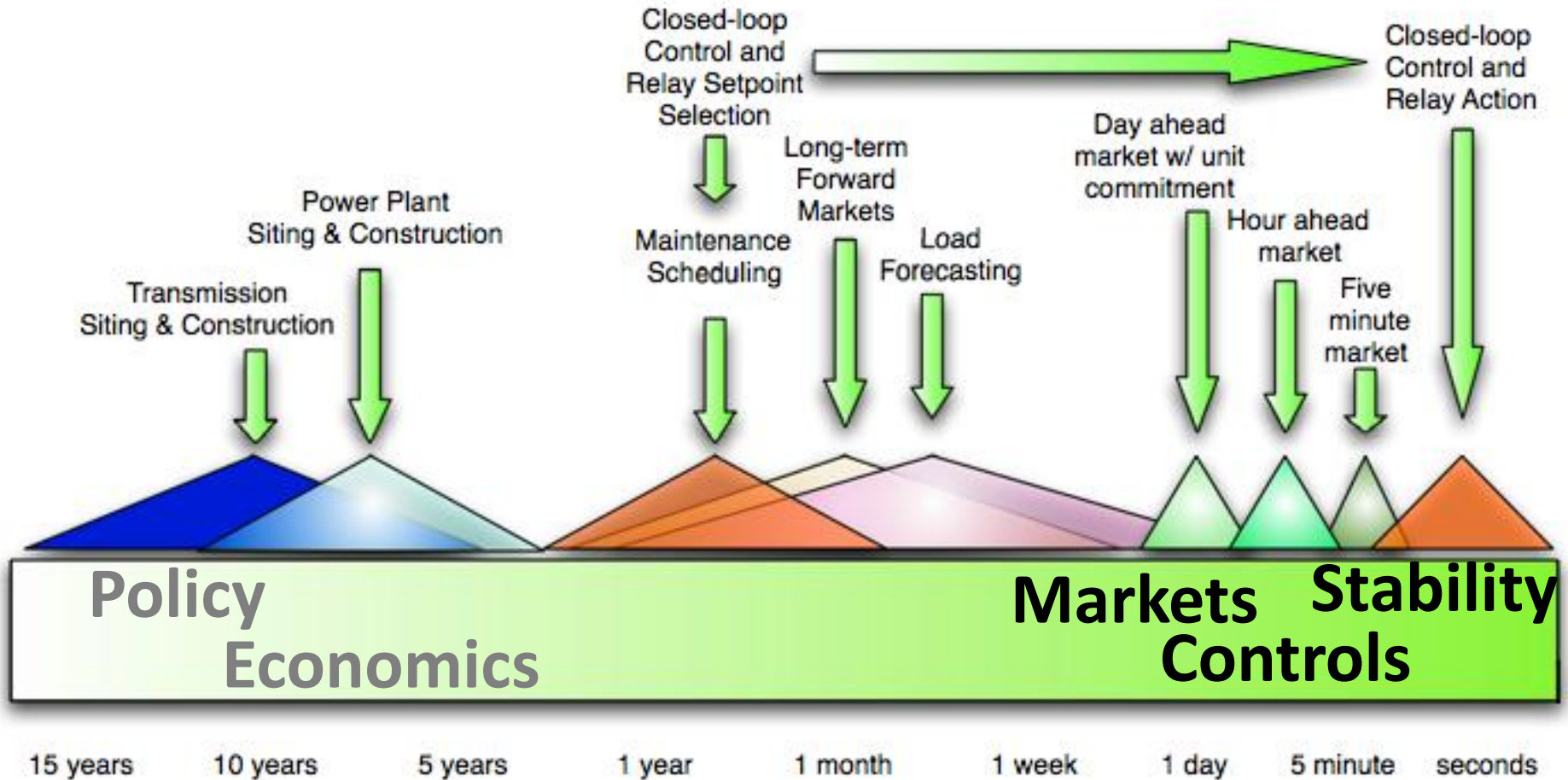
2010 State of the Market Report for the Midwest ISO, p. 71

50-100+% Wind scheduled in day-ahead market.

Summary

- Intermittent resources challenge the traditional operation of the electric grid.
- They challenge and are challenged by market dispatch.
- New approaches and technologies can help:
 - Energy storage: Central vs. Distributed
 - Load as a resource for energy reserves and market participation
 - Appropriate adjustments to reliability criteria and regulatory policies

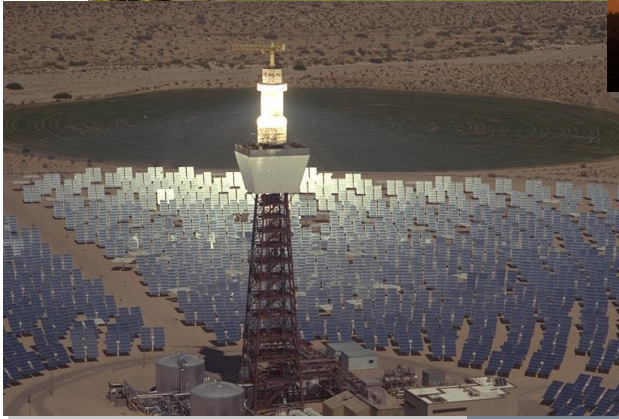
Challenges



The future...

Distributed Resources

256.com/solar



Concentrated Resources

