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Edward J. Bloustein School of Planning and Public Policy

Understanding Electricity, Emission and Renewable Resource Markets

New Jersey Clean Air Council

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Center for Energy, Economic and Environmental Policy

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Overview of CEEEP Research

The Center for Energy, Economic and Environmental Policy (CEEEP) integrates complex and sophisticated scientific, engineering, and economic models to inform public policy regarding the implications of major pubic policy initiatives involving the electric power sector

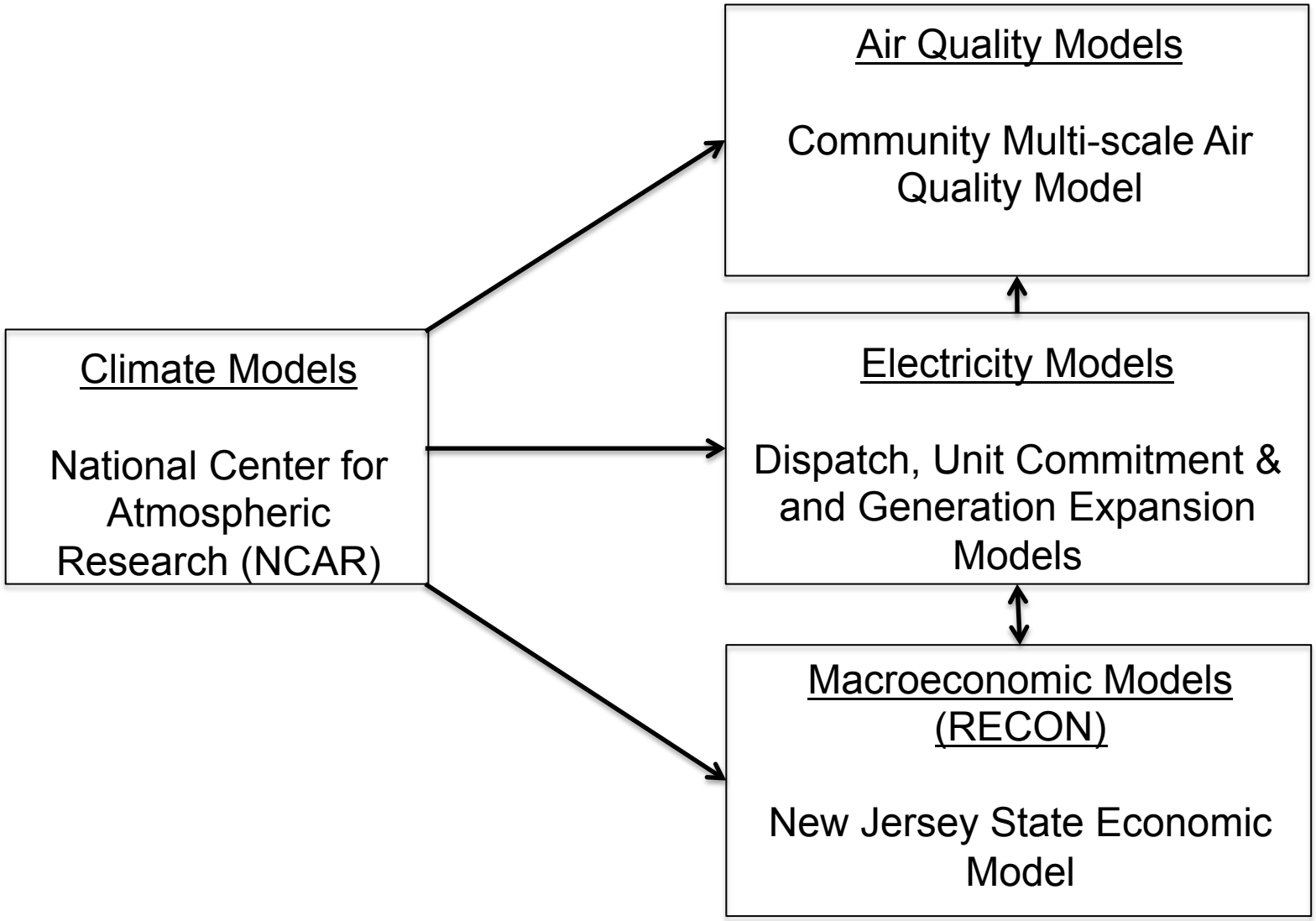
CEEEP - Founded in 2004

- Close research connections with the Departments of Industrial and Systems Engineering, Materials Sciences, Environmental Sciences), Marine and Coastal Sciences, Earth and Planetary Sciences, and the Rutgers Energy Institute
- Approximately 20 faculty and student collaborators working on active projects

CEEEP Selected On-going Projects

1. US National Science Foundation: Evaluating the reliability and resiliency and the associated costs and benefits of grid hardening in the context of power systems subject to severe weather and climate change
2. NJ Board of Public Utilities: Evaluating New Jersey Clean Energy Program
3. NJ Energy Resilience Bank: Determining the social and private costs and benefits of distributed energy resources
4. US DOE: Worked with major electric utility and its electric distribution consultants to develop cost-benefit models of increasing solar penetration on distribution feeders

Rutgers Integrated Energy Modeling



Themes

1. Getting the engineering right
2. Getting the economics right
3. Integrating environmental, energy, and economic policy
4. Cost-effectiveness is vital

Presentation Outline

1. **Power System Overview**
2. PJM Wholesale Electricity Market
3. Markets for Emissions and Renewable Resources
4. Final Thoughts
5. Discussion

Relevant Energy Legislation

- 1992 Energy Policy Act (EPAct)
  - Exempt Wholesale Generators (EWGs) established and nondiscriminatory transmission access required
- NJ Electricity Discount and Energy Competition Act
  - Enacted August 1, 1999
  - Retail electricity (and natural gas) competition
  - Renewable Portfolio Standard (RPS)
- NJ Offshore Wind Economic Development Act (OWEDA)
  - Enacted August 19, 2010
- NJ Solar Act of 2012
  - Enacted July 23, 2012

Jurisdictional Issues

	Energy	Environmental
Federal		
State		

Power System Supply Chain

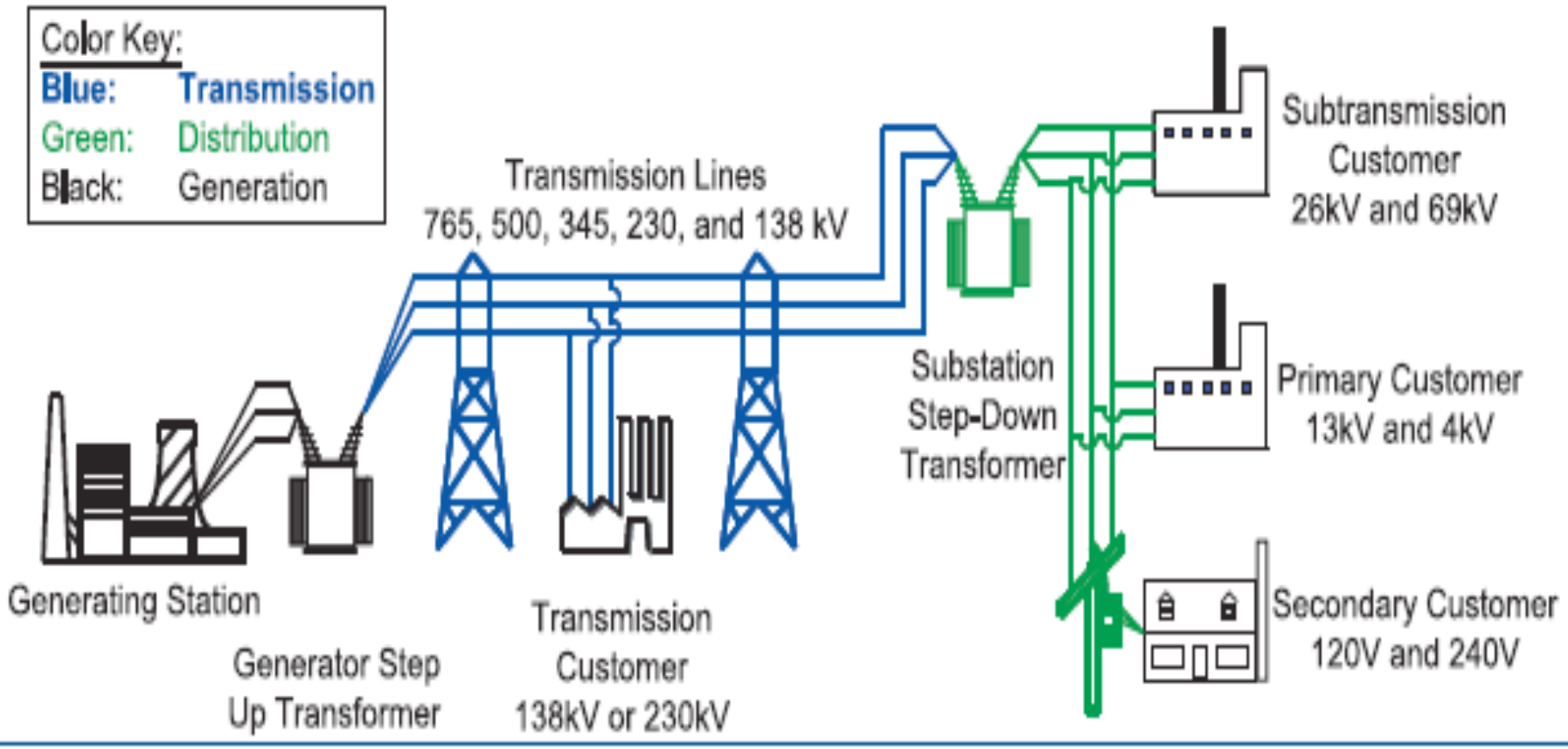
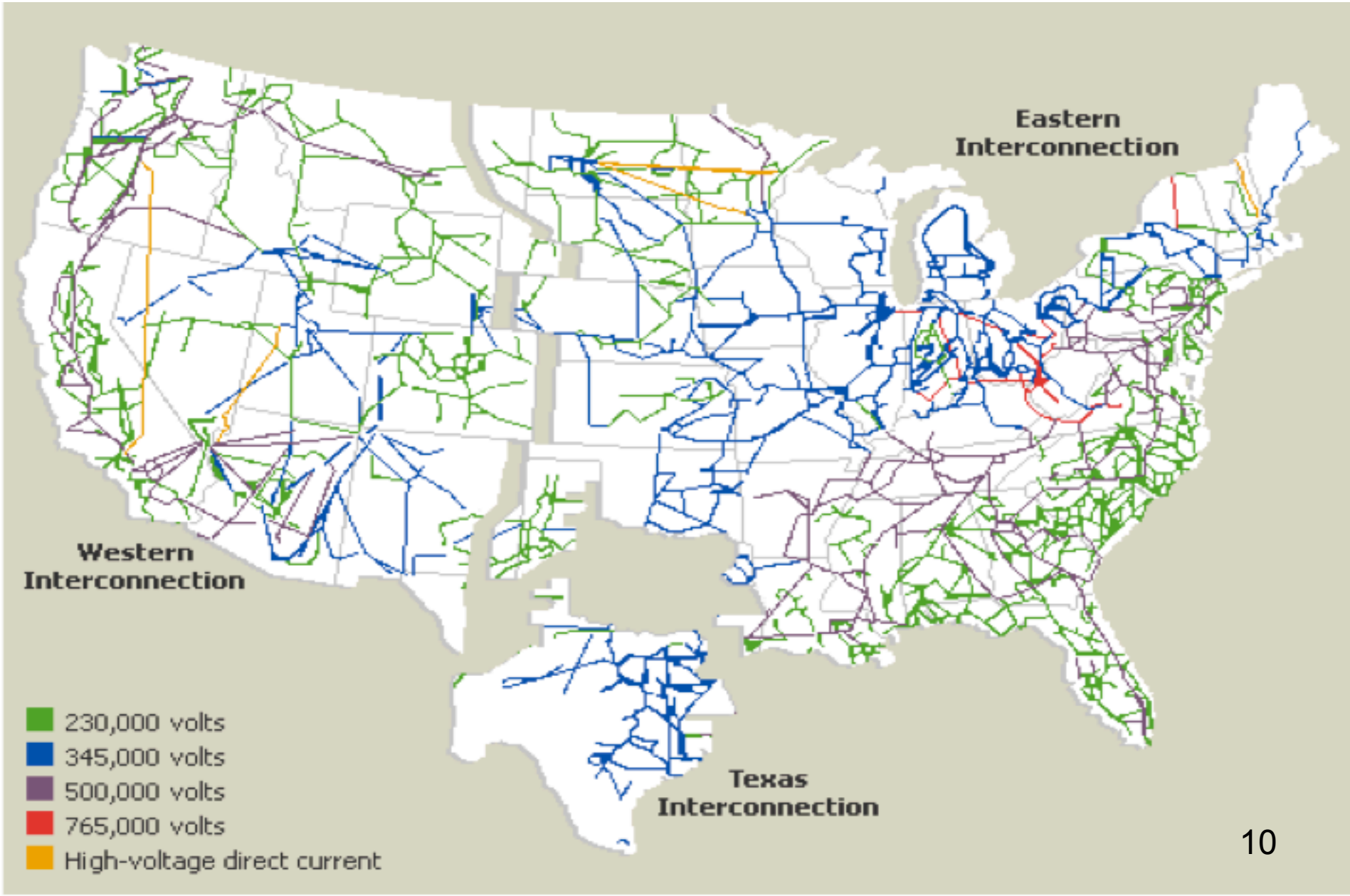


Figure from the U.S.-Canadian Power System Outage Task Force final report
On the 2003 Blackout, p. 5.

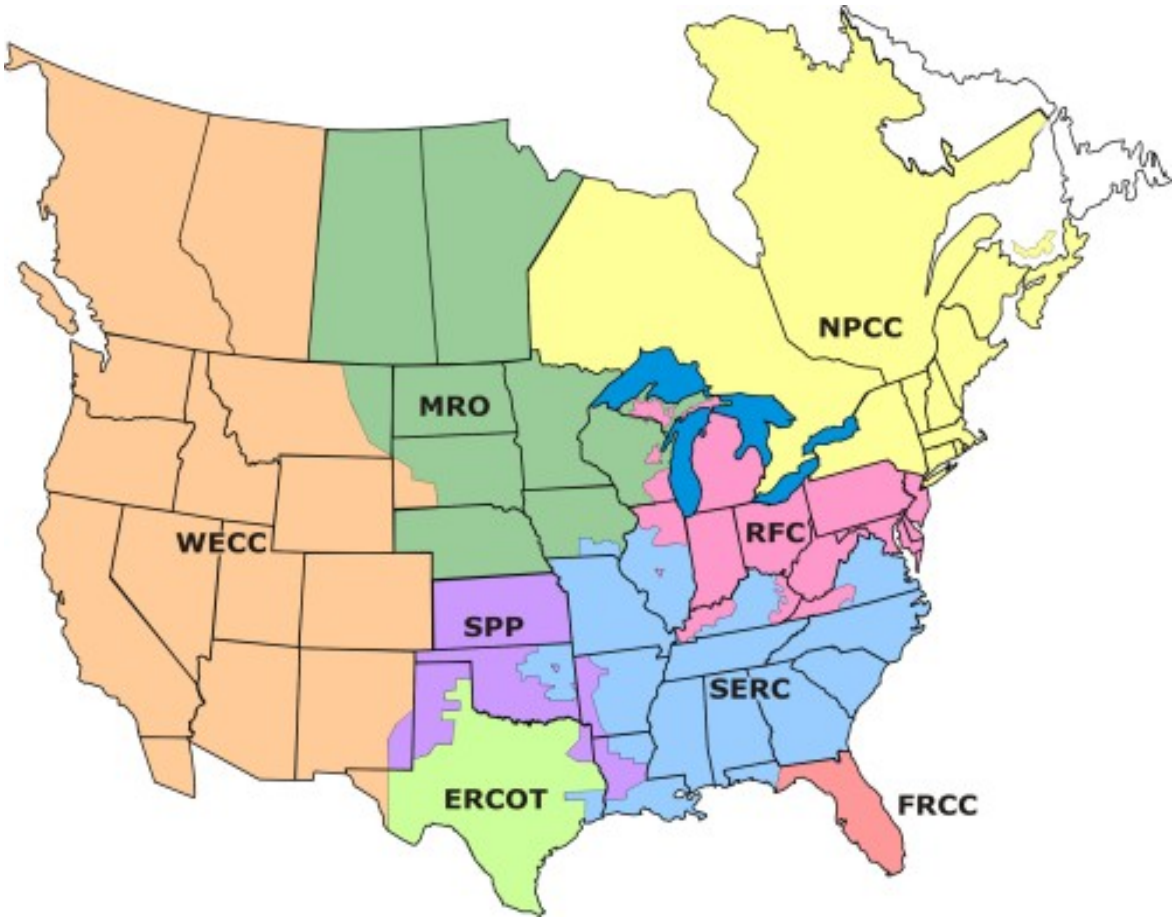
U.S. Power Grids



Complexities with Electricity

- Loop flow (aka parallel flow)
- Centralized operations
- Economies of scale
- Must balance supply and demand instantaneously and storage is expensive
- Electricity is a merit good, not just a commodity

Reliability



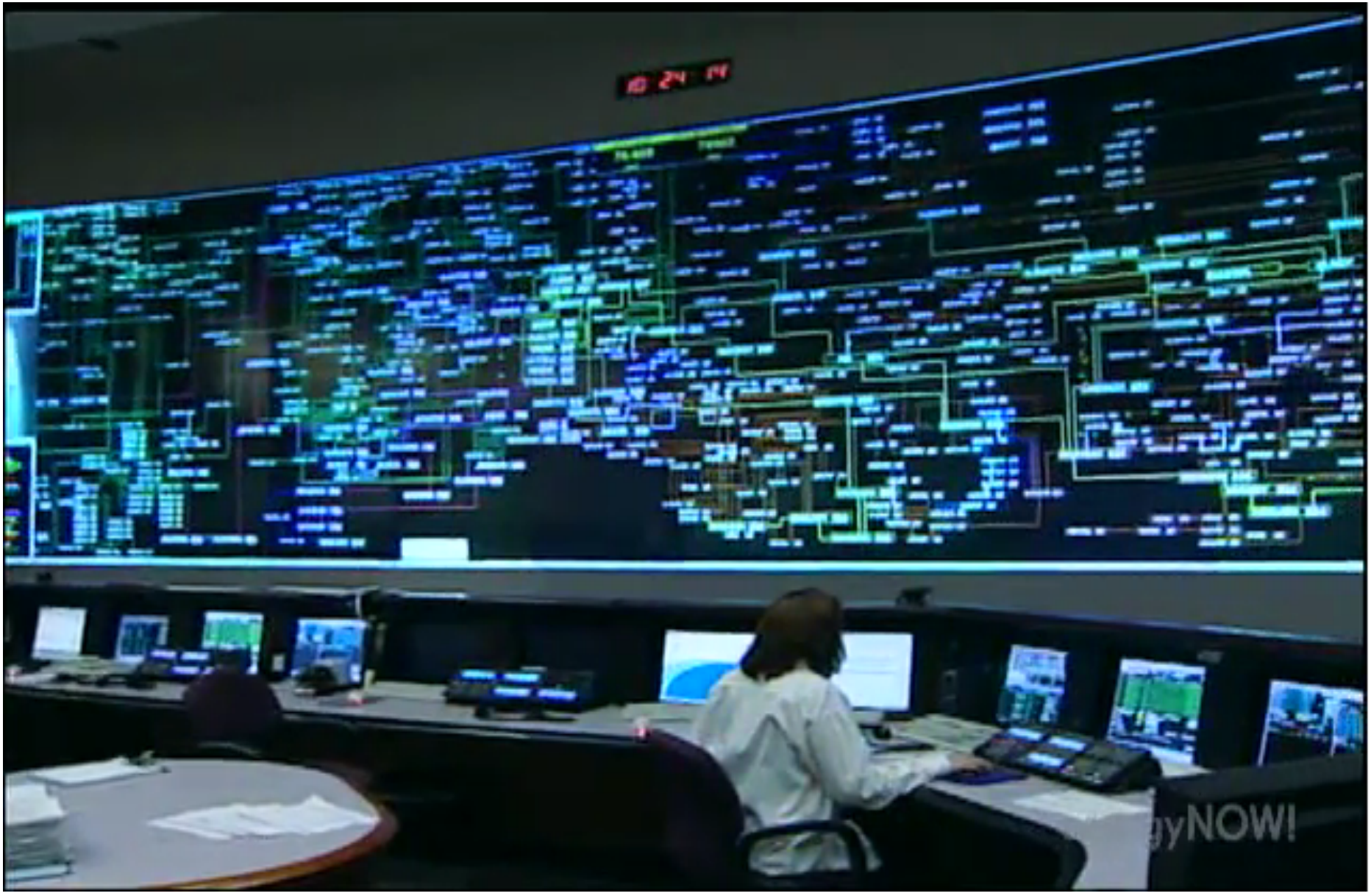
NERC (North American Electric Reliability Corporation)

Formed in 1968

Consists of 10 Regional Councils

In the past reliability policies were voluntary and enforced via peer pressure and professional norms, now are mandatory and enforceable

Centralized Operations



Efficiency

Engineering Efficiency

Heat Rate = (Btu)/kWh *Note Btu = British Thermal Unit*

Inverse measure of efficiency: the higher the heat rate the less efficient

Economic Efficiency

Private Economic Cost:

Heat Rate (Btu/kWh) * Fuel Cost ($/Btu) = Cost ($/kWh)

Social Economic Cost:

Heat Rate (Btu/kWh) * (Fuel + Environmental Cost ($/Btu)) = Cost ($/kWh)

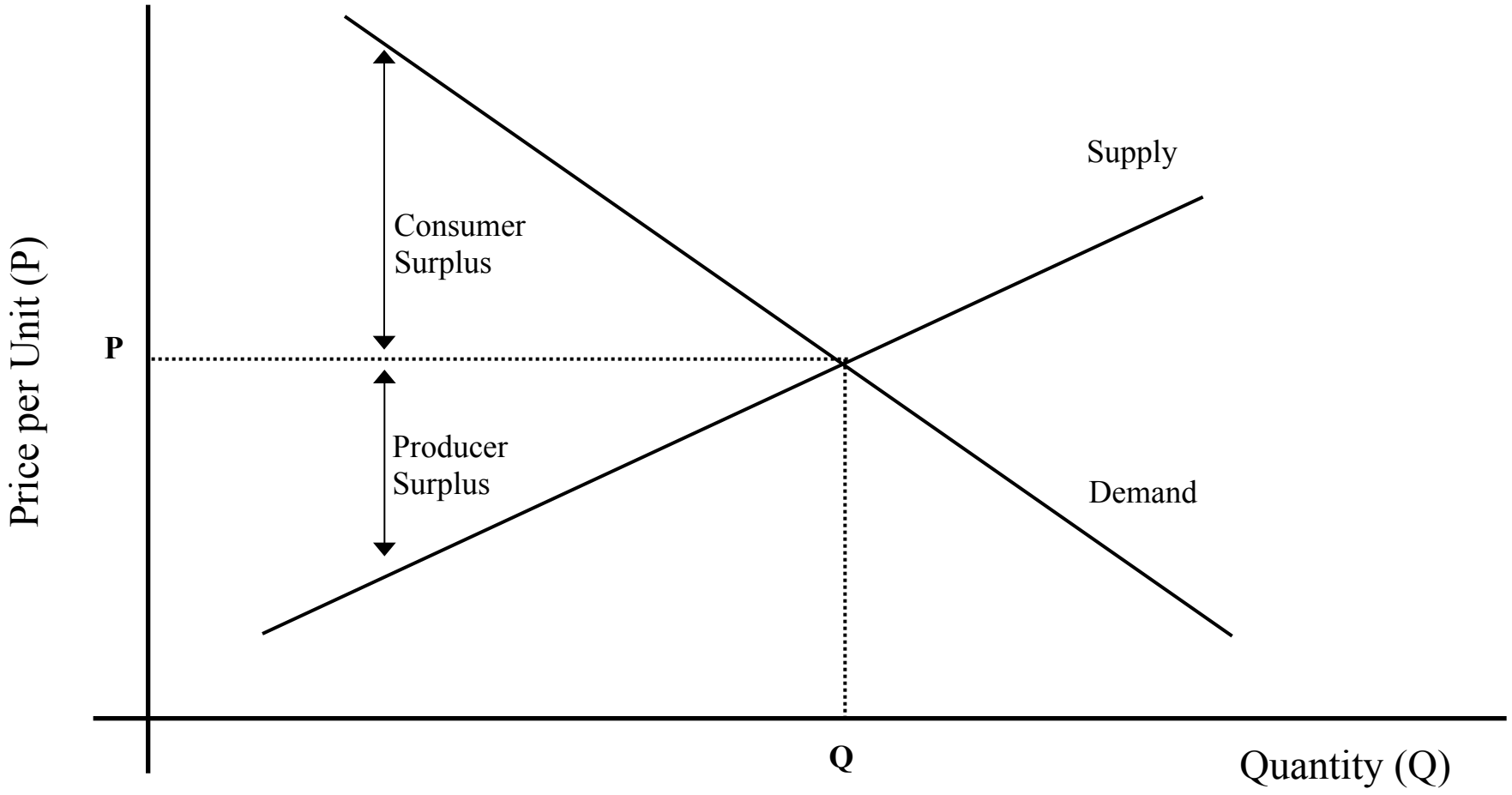
Efficiency

- Efficiency does NOT equal market economic output
- Efficiency includes ALL costs to society, not just those that are accounted for in market transactions
- Low energy prices are not necessarily efficient energy prices
- Markets are not necessarily efficient and in fact can be inefficient for many reasons

Efficiency

Total Societal Costs = Market Costs + Non-monetized Costs

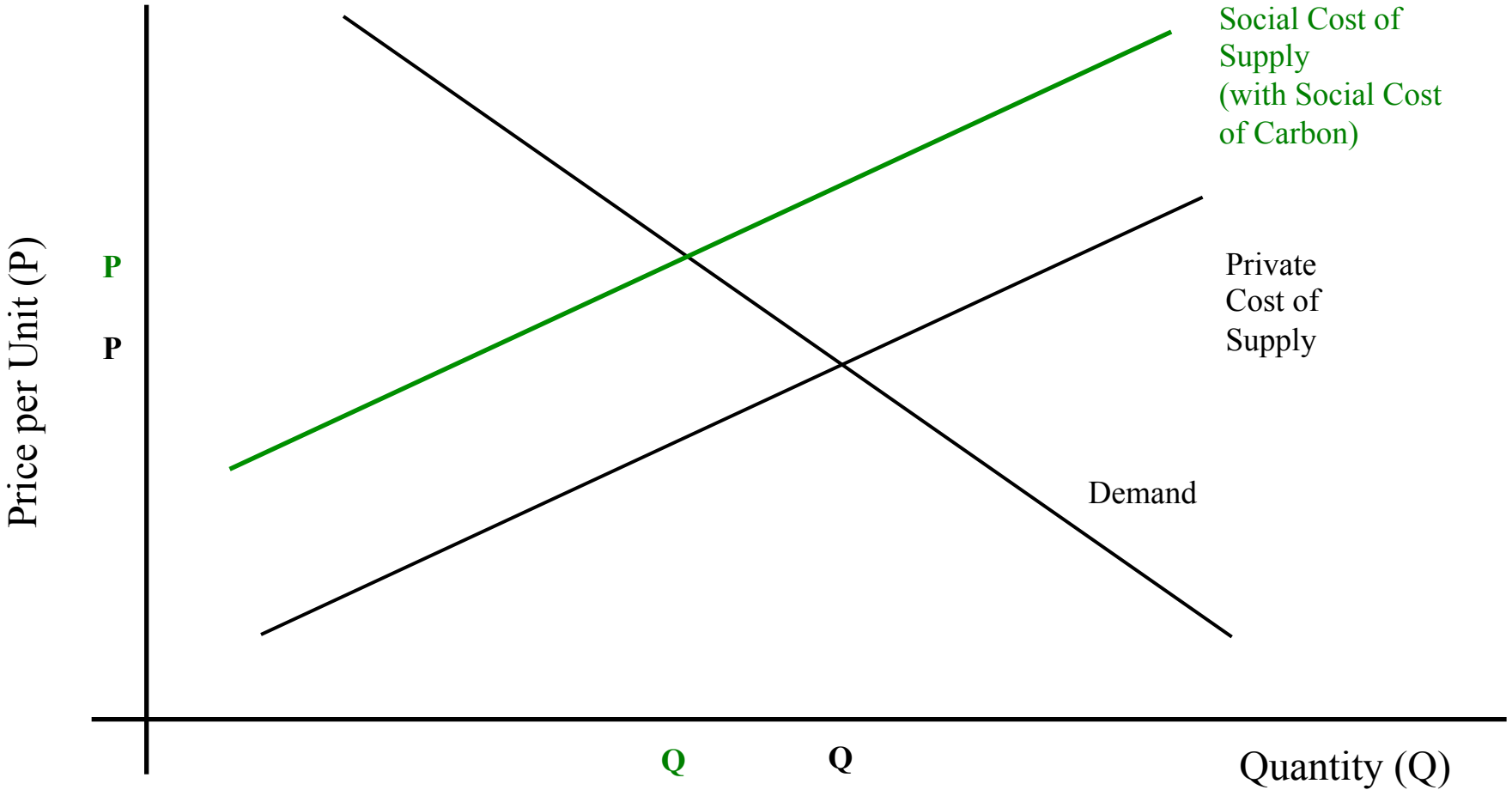
Economic Efficiency



Social Welfare = Consumer Surplus + Producer Surplus

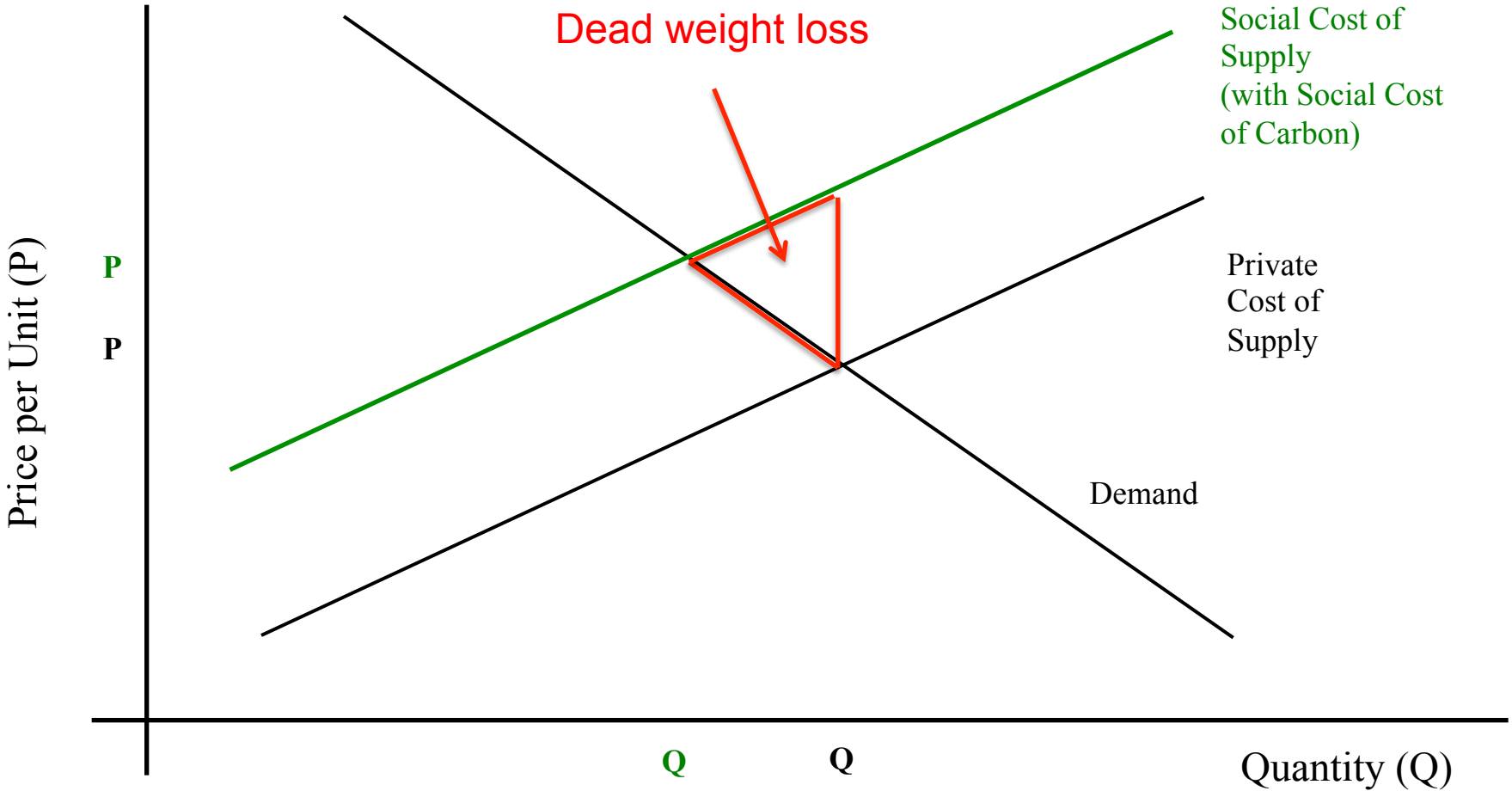
Demand and supply curves drawn as lines for simplicity

Internalizing Externalities



Demand and supply curves drawn as lines for simplicity

Internalizing Externalities



Demand and supply curves drawn as lines for simplicity

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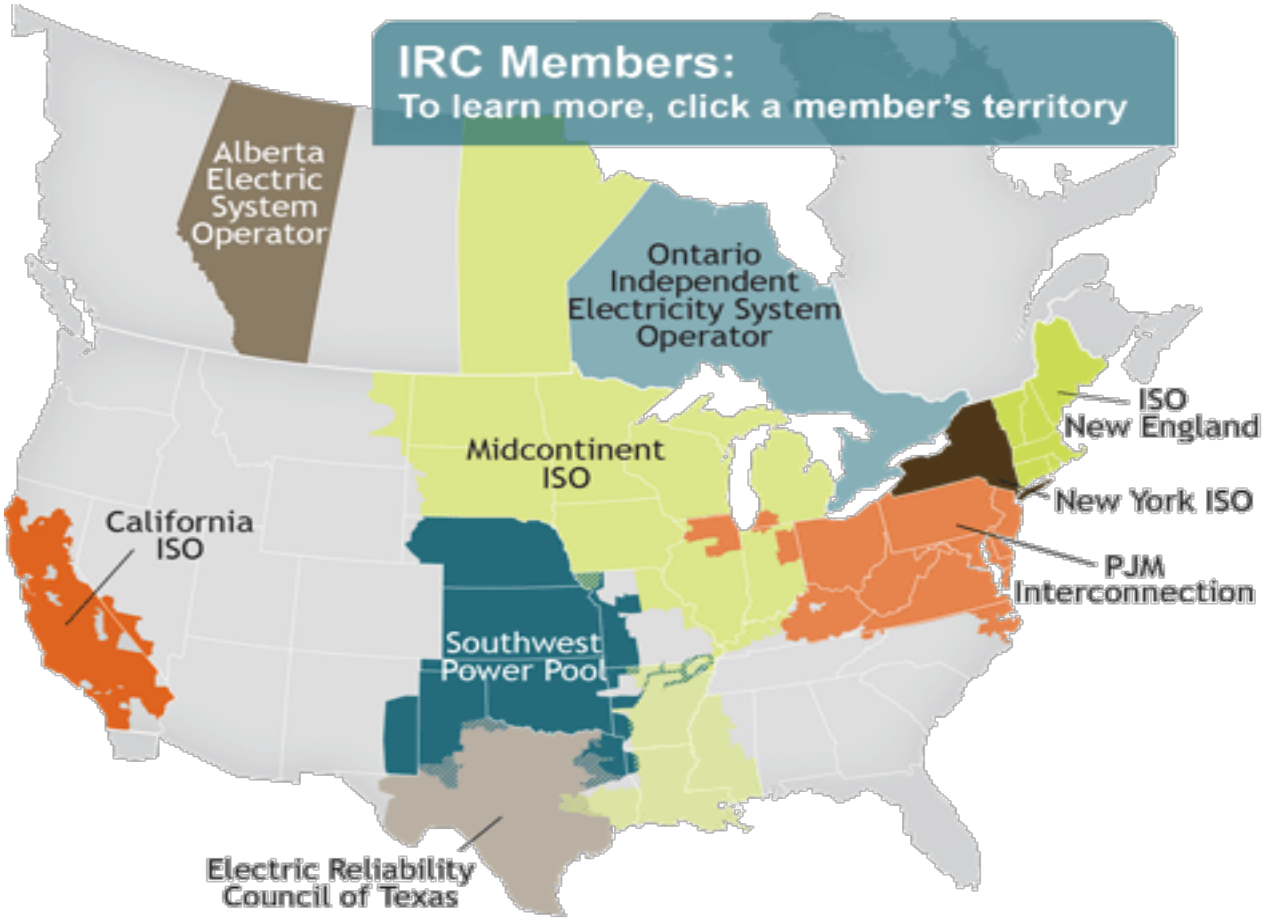
Organized Markets in the U.S.

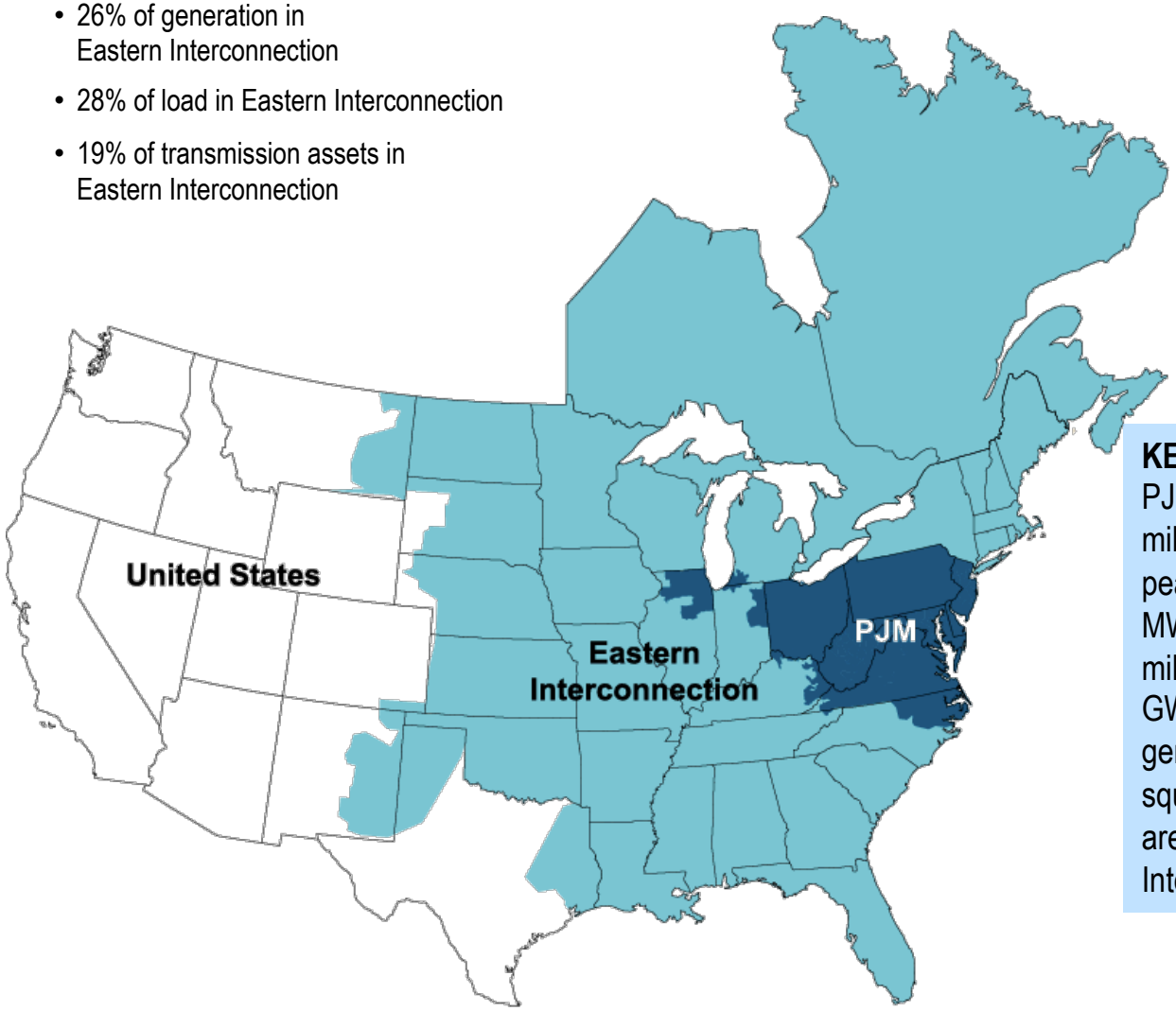


- Includes nine members
- Serves two-thirds of electricity consumers in the U.S. and more than half in Canada
- Created April 24, 2003

In the Northeast, RTOs/ISOs were formed from pre-existing "tight" power pools

PJM

- 26% of generation in Eastern Interconnection
- 28% of load in Eastern Interconnection
- 19% of transmission assets in Eastern Interconnection



KEY STATISTICS

PJM member companies	750+
millions of people served	60
peak load in megawatts	163,848
MWs of generating capacity	185,600
miles of transmission lines	65,441
GWh of annual energy	832,331
generation sources	1,365
square miles of territory	214,000
area served	13 states + DC
Internal/external tie lines	142

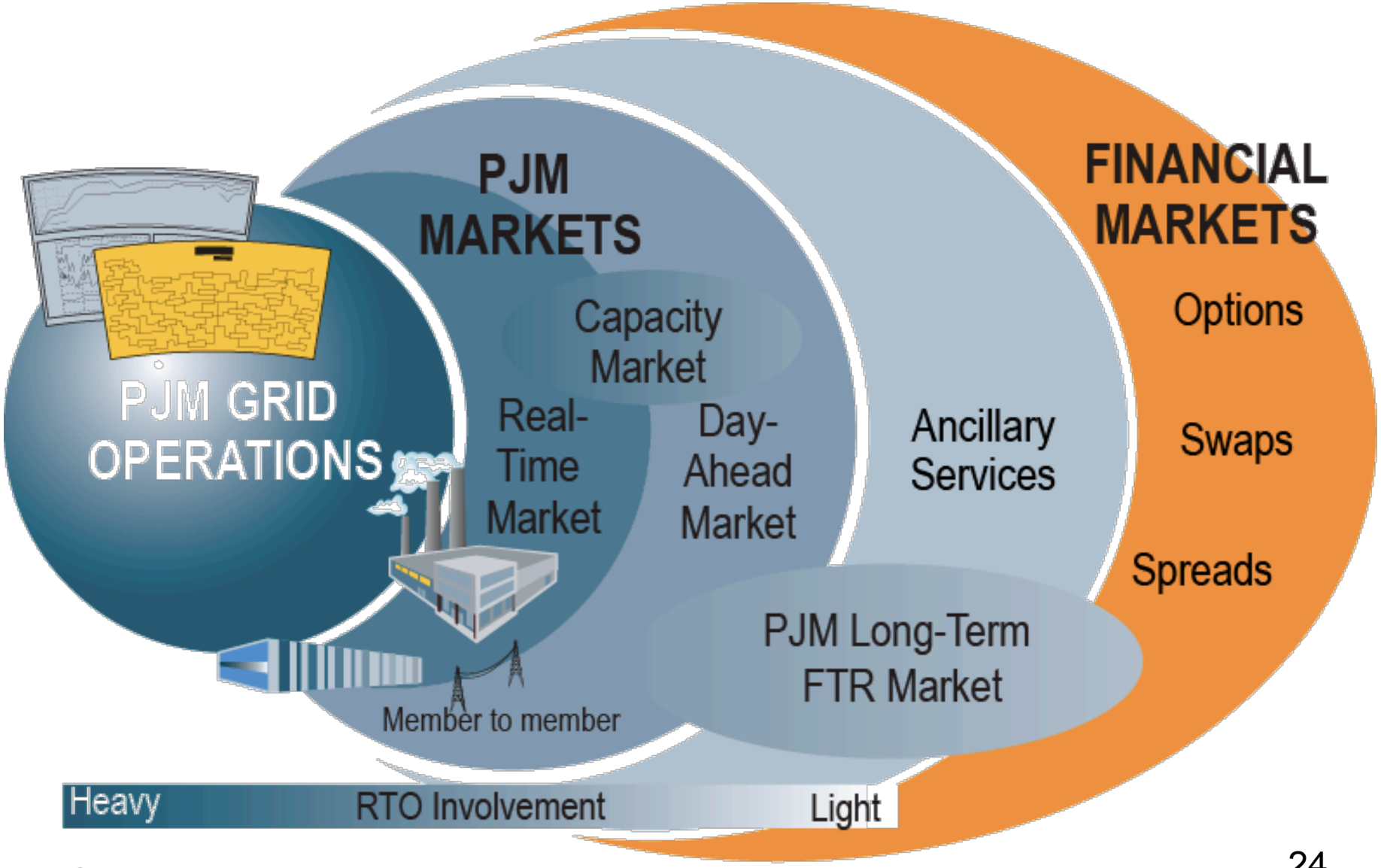
As of 1/4/2012

Source: PJM

Summary of PJM Electricity Markets

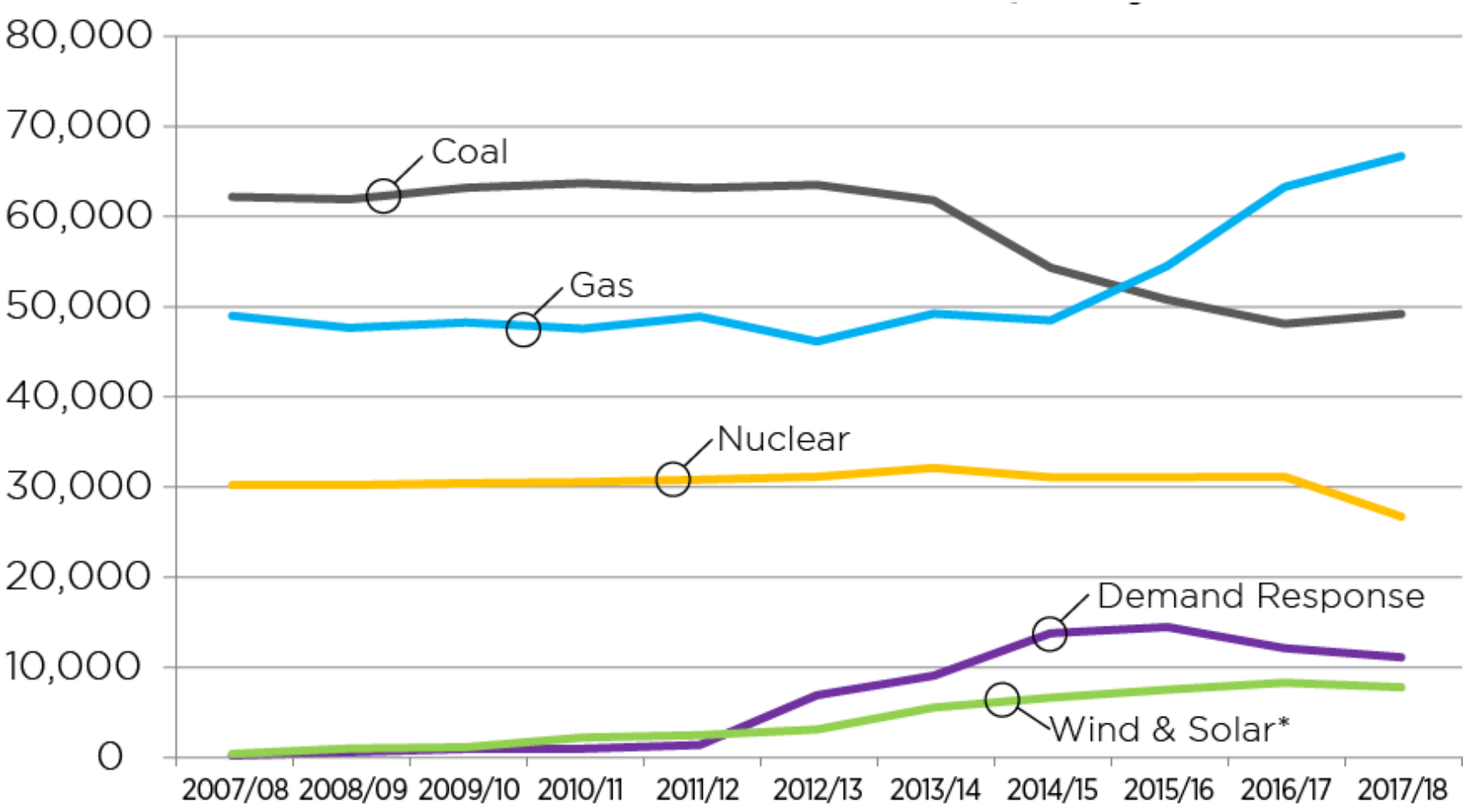
PJM Energy Market	Reason
Energy Market	**Real-time, day-ahead, and bilateral based upon locational marginal prices (LMPs)**
Congestion management	Financial Transmission Rights (FTRs)
Capacity Market	Resource adequacy (reliability)
Ancillary services markets	Operating reserves, regulation
Transmission Planning	Regional transmission planning based on cost-of-service but complements electricity markets

Summary of PJM Electricity Markets



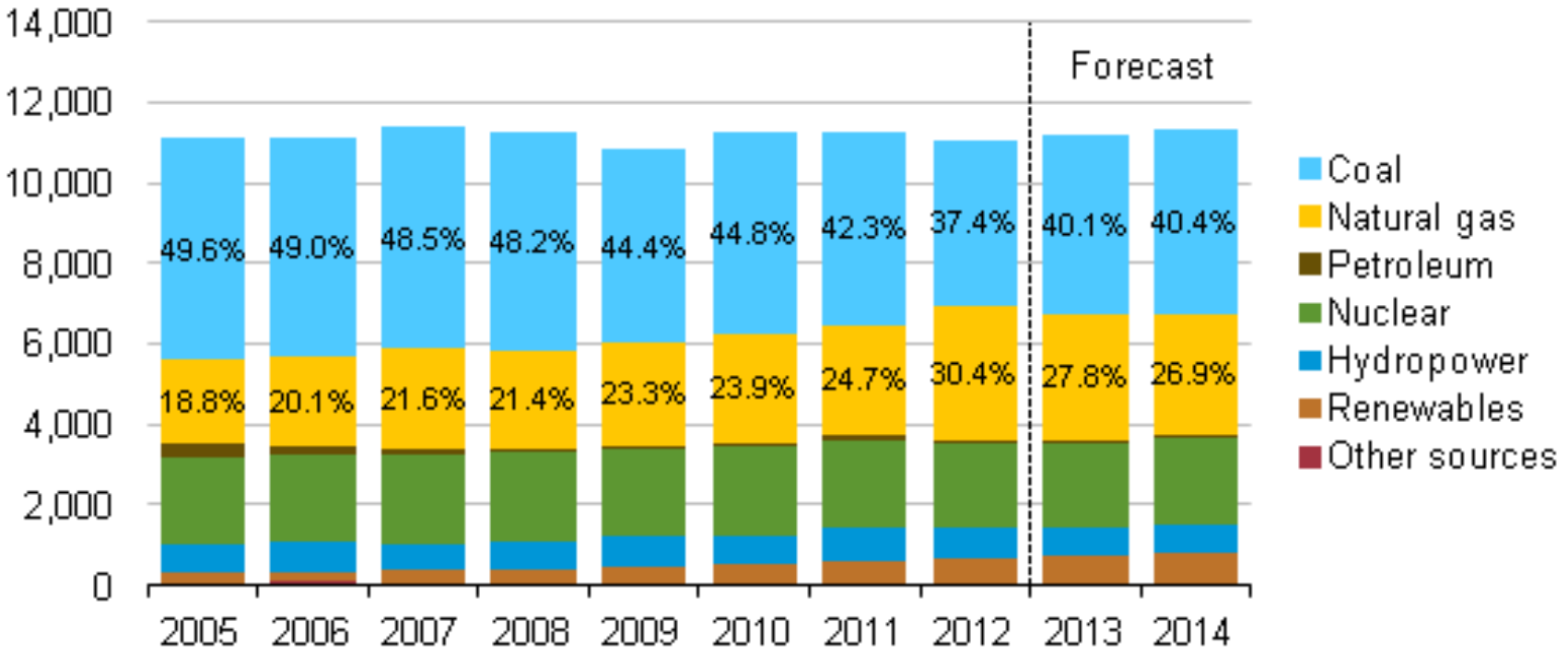
Source: PJM

PJM Capacity Mix



Source: PJM 2015

U.S. Electricity Fuel Mix



Note: Labels show percentage share of total generation provided by coal and natural gas.

Source: Short-Term Energy Outlook, May 2013

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FLOOR & TRADE

- Installed Generation Capacity: FLOOR & TRADE
  - PJM's capacity market is call the Reliability Pricing Model (RPM)
  - Load Serving Entities are required to purchase a minimum amount of capacity
  - Market participants buy and sell capacity credits, the tradable financial instrument
- Renewable Portfolio Standard (RPS): FLOOR & TRADE
  - States set the renewable portfolio standard
  - Load Serving Entities are required to purchase a minimum amount of renewables in different categories
  - Renewable energy credits (RECs) are the tradable financial instrument

Approaches to Air Emission Regulation

1. Technology-based standard
2. Performance-based standard

} Command and Control

3. Emission tax
4. Cap and trade

} Carbon Pricing

Static and dynamic efficiency

Aldy, Joseph E., and Robert N. Stavins. "The promise and problems of pricing carbon: theory and experience." The Journal of Environment & Development (2012)

Brief History of Cap and Trade

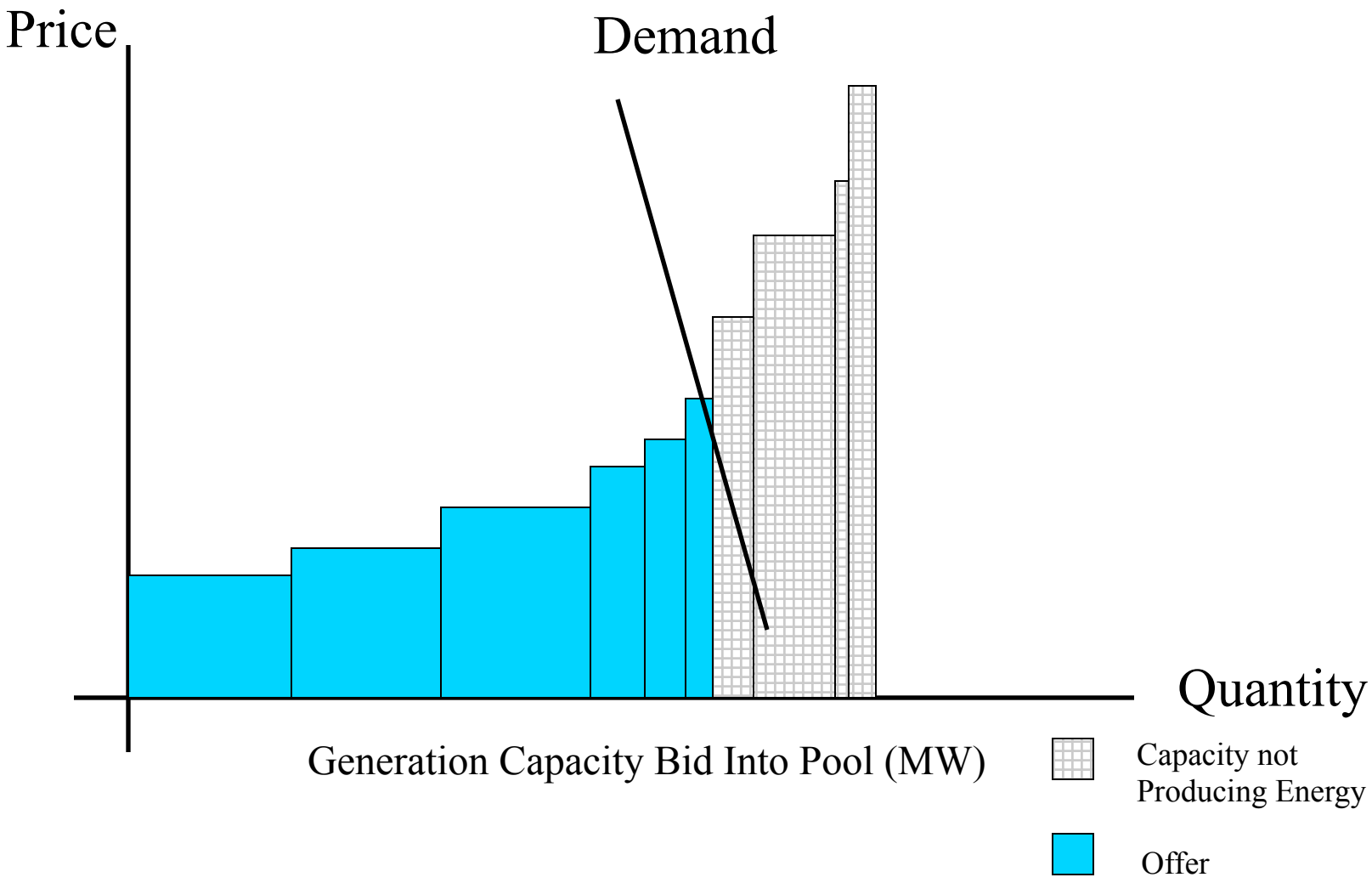
'Market-based, cost-effective policy innovation in environmental regulation — in particular, cap-and-trade — was championed and implemented by Republican administrations from that of President Ronald Reagan to that of President George W Bush.

…

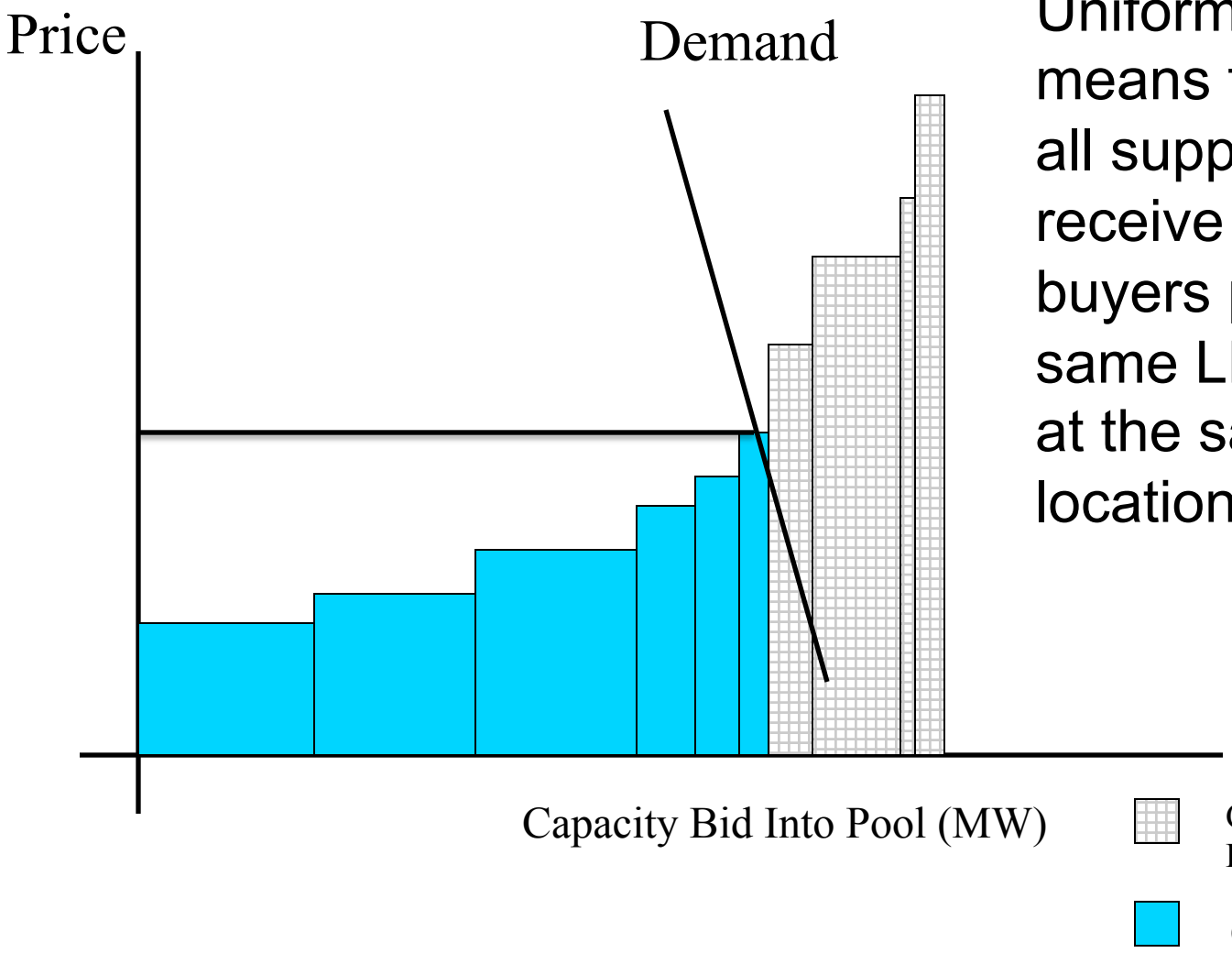
In the 1980s, President Ronald Reagan's Environmental Protection Agency put in place a trading program to phase out leaded gasoline. It produced a more rapid elimination of leaded gasoline from the marketplace than had been anticipated, and at a saving of some $250 million per year, compared with a conventional no-trade, command-and-control approach. Not only did President George HW Bush successfully propose the use of cap-and-trade to cut US SO_2 emissions, his administration advocated in international forums the use of emissions trading to cut global CO_2 emissions, a proposal initially resisted but ultimately adopted by the European Union. In 2005, President George W Bush's Environmental Protection Agency issued the Clean Air Interstate Rule, aimed at reducing SO_2 emissions by a further 70% from their 2003 levels. Cap-and-trade was again the policy instrument of choice.'

Schmalensee, Richard and Robert N. Stavins. "The Sordid History of Congressional Acceptance and Rejection of Cap-and-Trade: Implications for Climate Policy." Vox, March 7, 2013.

Economic Efficiency and Dispatch

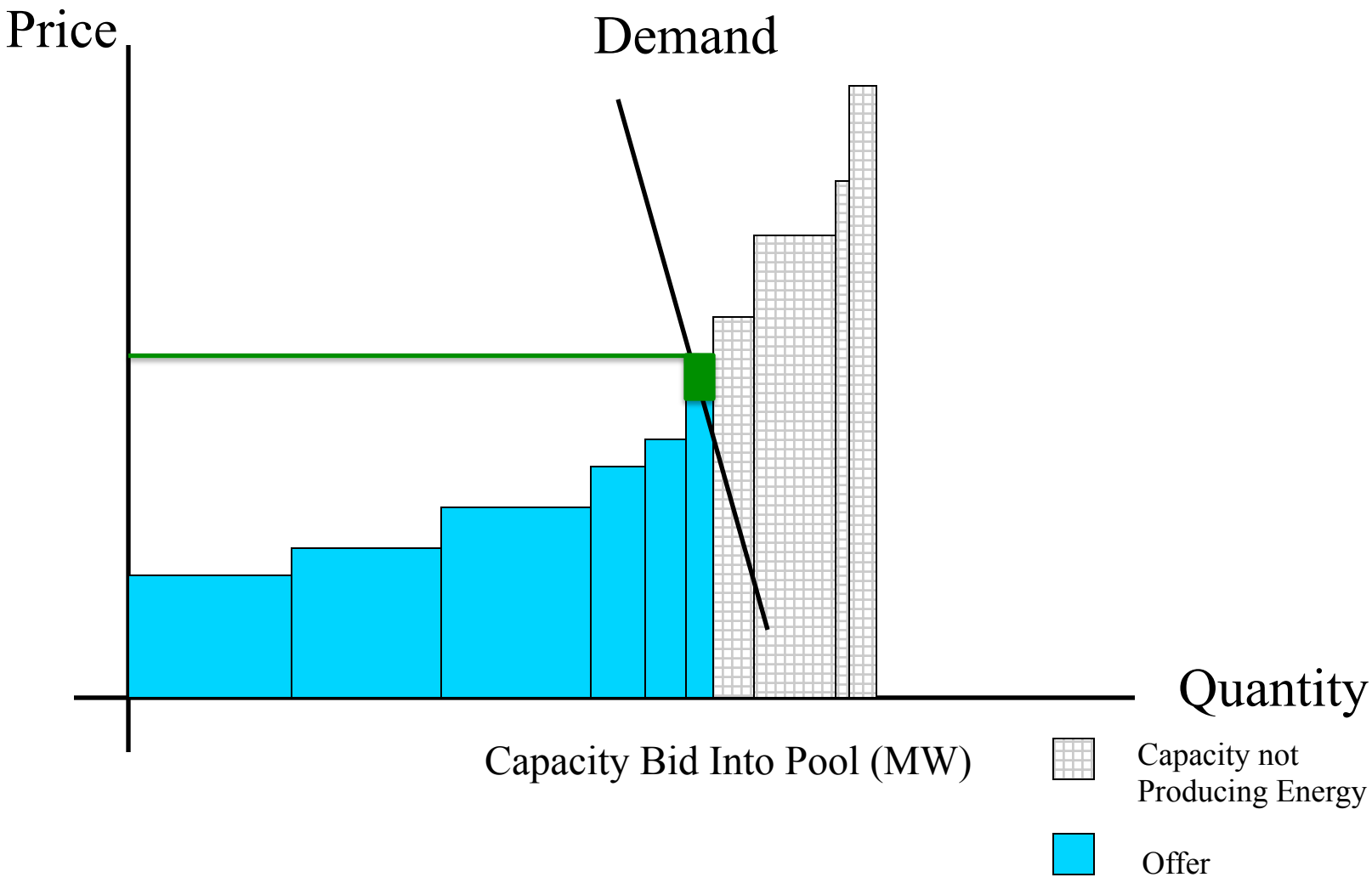


Economic Efficiency and Dispatch



Uniform auction means that all suppliers receive and all buyers pay the same LMP at the same location and time

Economic Efficiency and Dispatch



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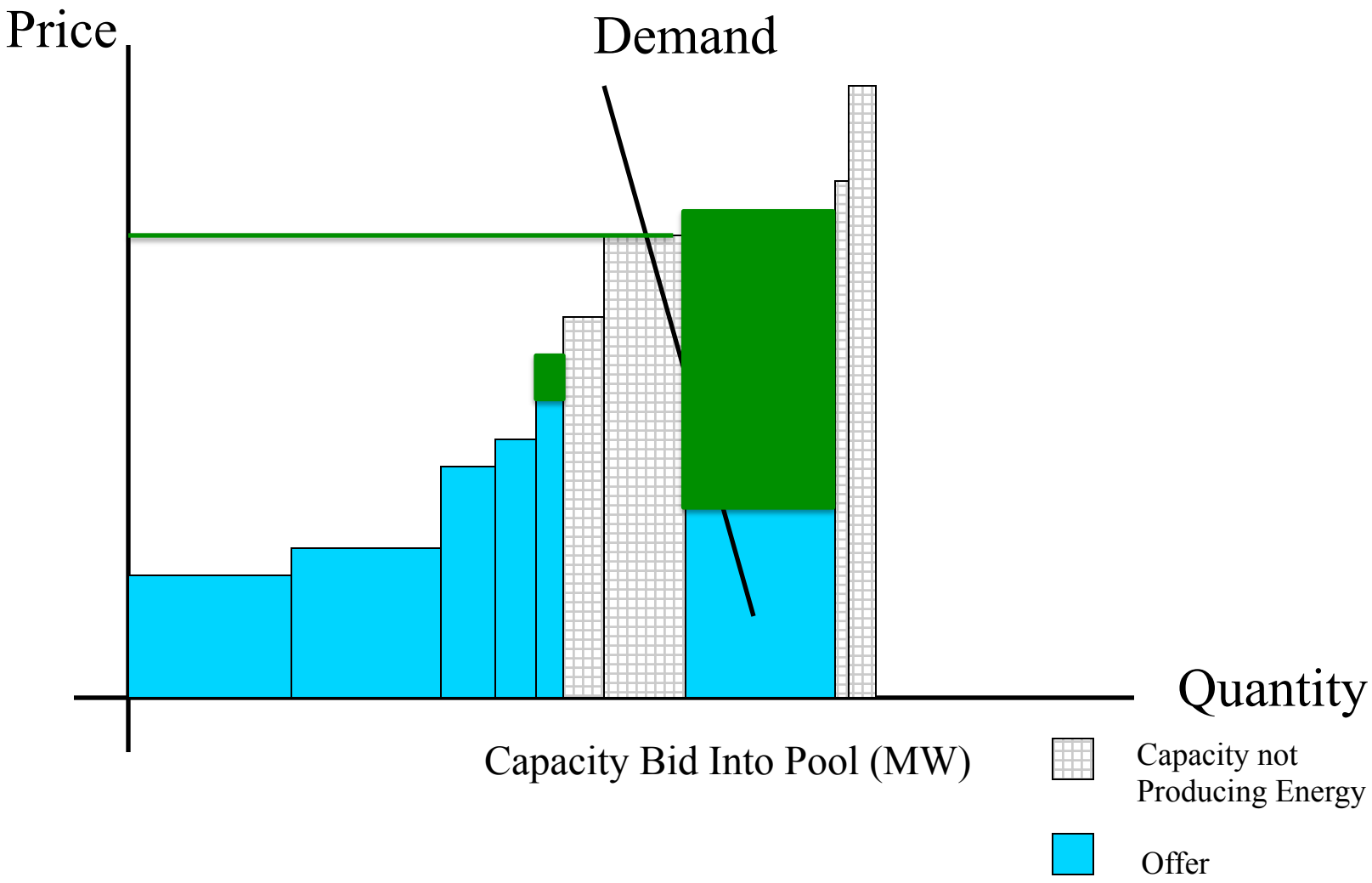
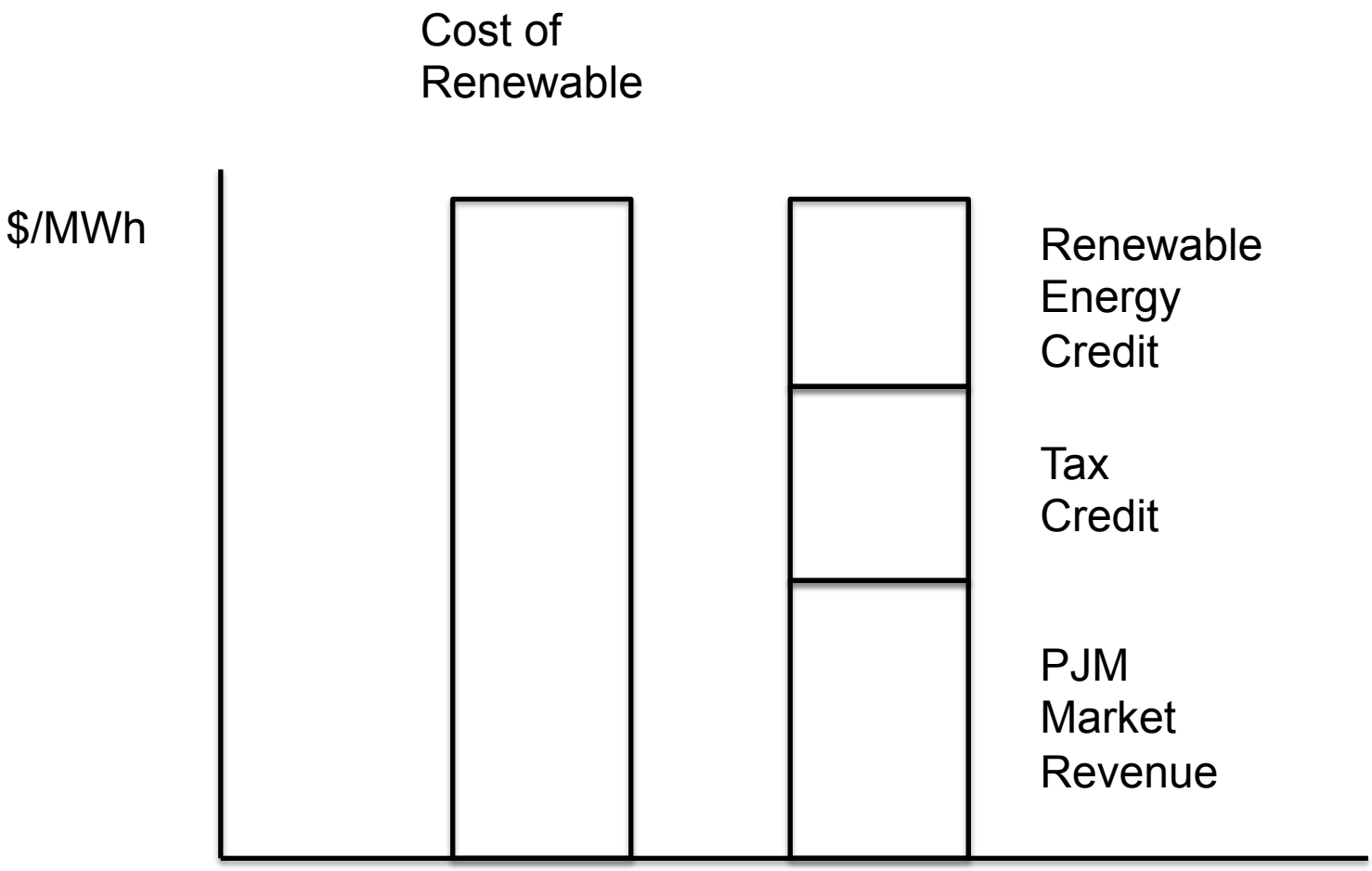


Market Interactions



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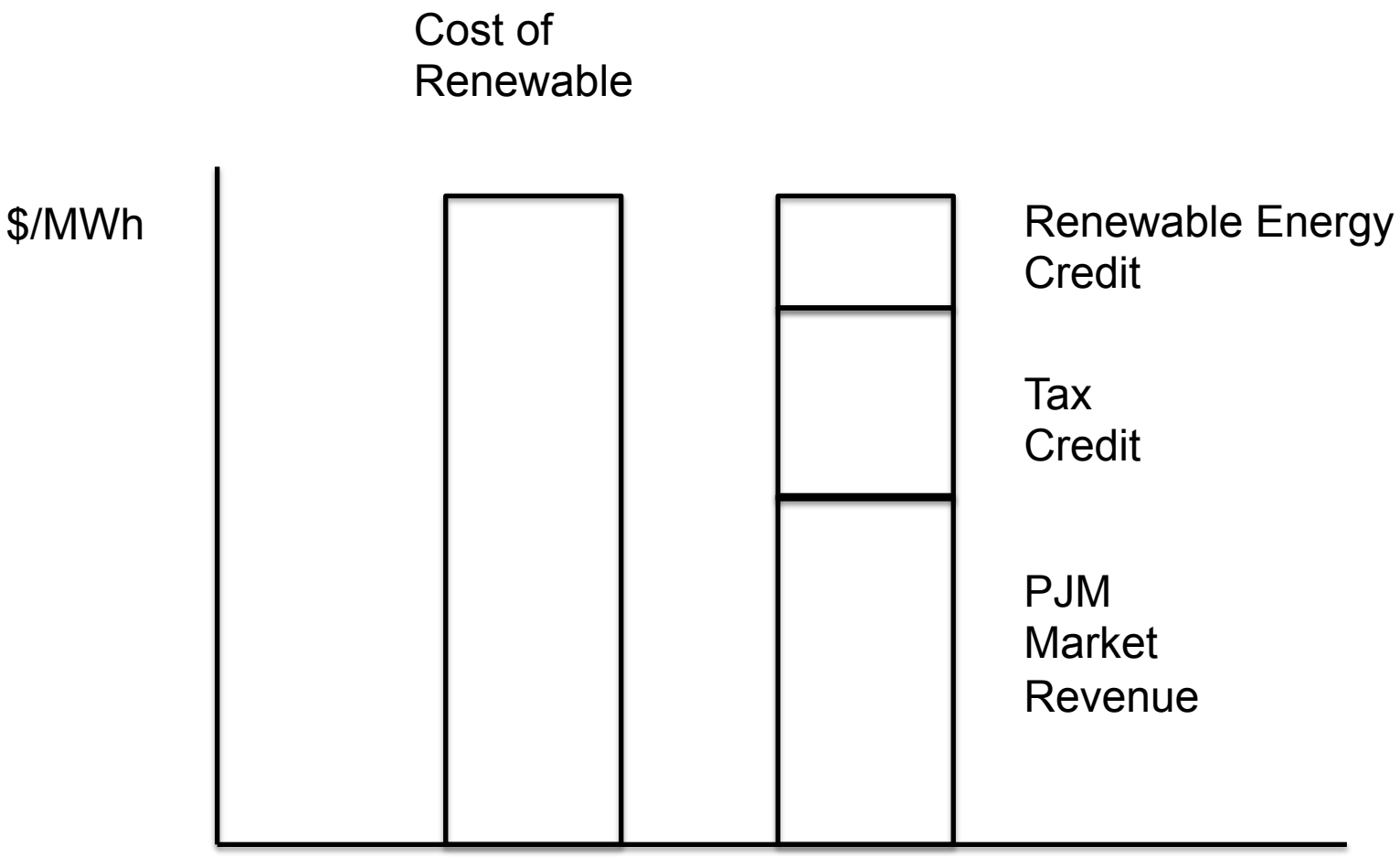
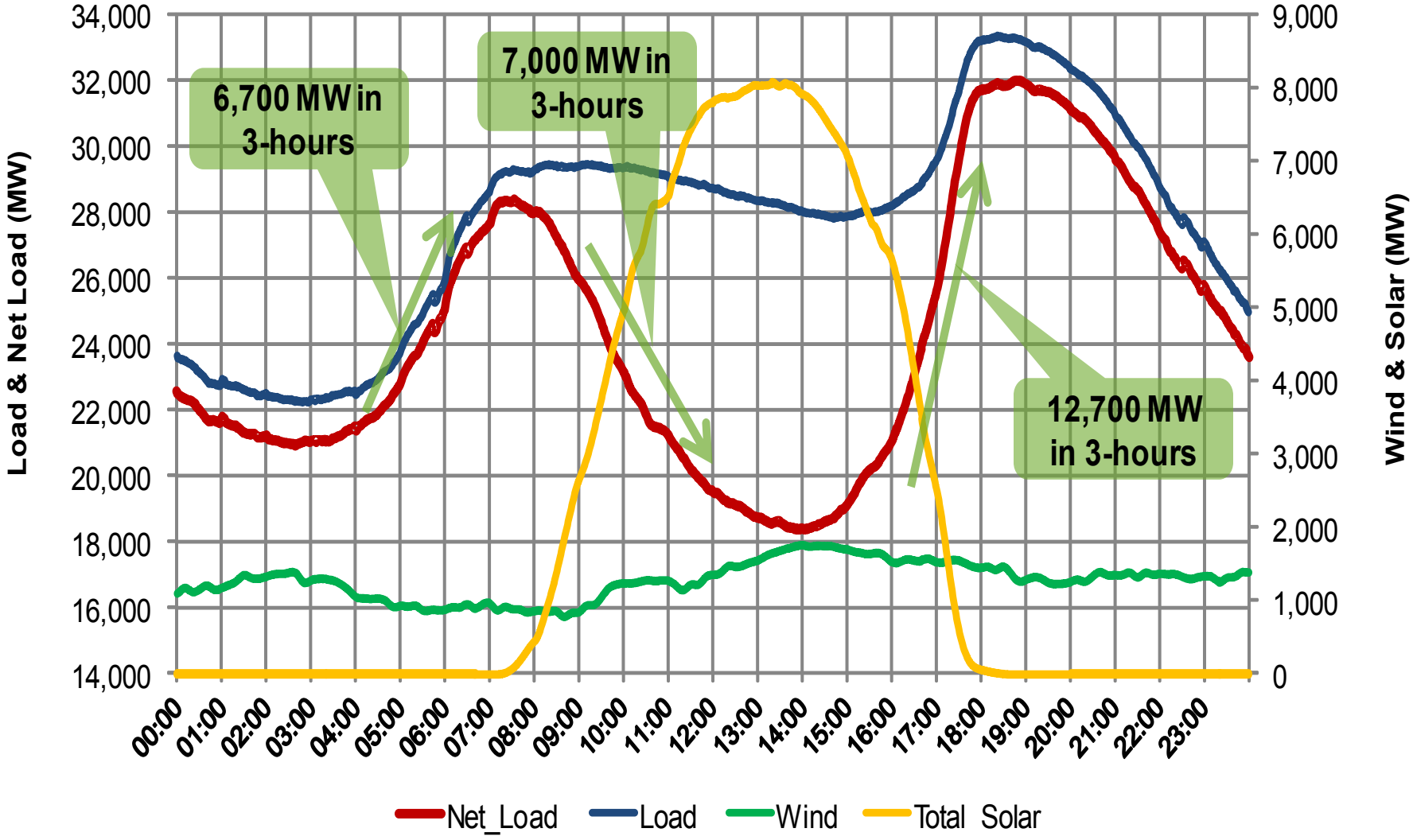


Managing Renewables



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Summary

1. If the reduction of greenhouses is to be achieved cost effectively, there needs to be a price on greenhouse gases

2. Wholesale electricity markets would treat a price on greenhouse gases as part of their fuel costs

3. Need to consider market dynamics and interactions

4. Reliability is always a concern, but with sufficient planning should not present a major problem in implementing meaningful greenhouse gas policies

5. Equity issues can and should be addressed are easier to do so if the policy is cost effective

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Frank Felder is an expert on wholesale and retail electricity markets. He is the Director of the Center for Energy, Economic and Environmental Policy (CEEEP) and Associate Research Professor at the Bloustein School of Planning and Public Policy, Rutgers University in New Jersey.

He consults to a wide range of clients on market design, market power and market manipulation, electricity price forecasting, and risk management. He has testified before the Federal Energy Regulatory Commission (FERC) and several state public utility commissions.

He holds a Ph.D. in Technology, Management and Policy from the Engineering Systems Division of M.I.T.

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