HOW THE ELECTRIC GRID WORKS: DISPATCH, PLANNING, AND REGULATION

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MIT COURSE 11.S946 "ELECTRICITY, ECONOMICS, AND THE ENVIRONMENT"

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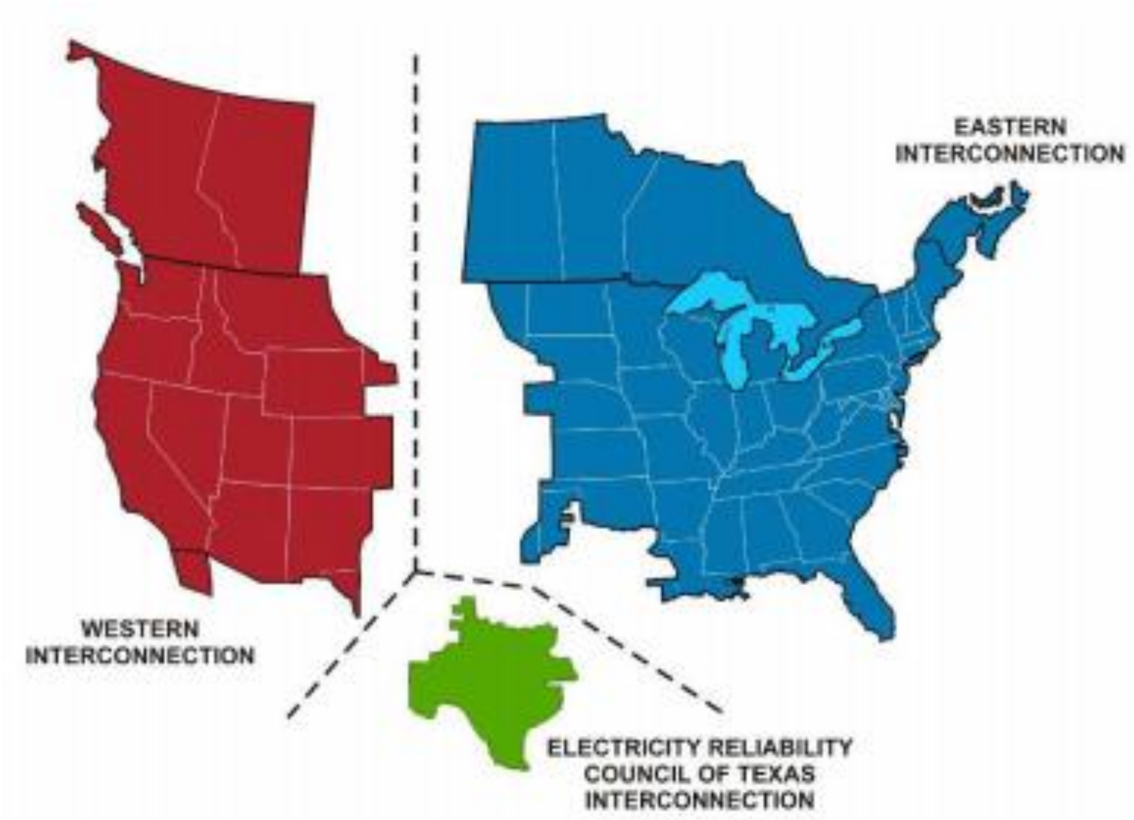
Synapse
Energy Economics, Inc.

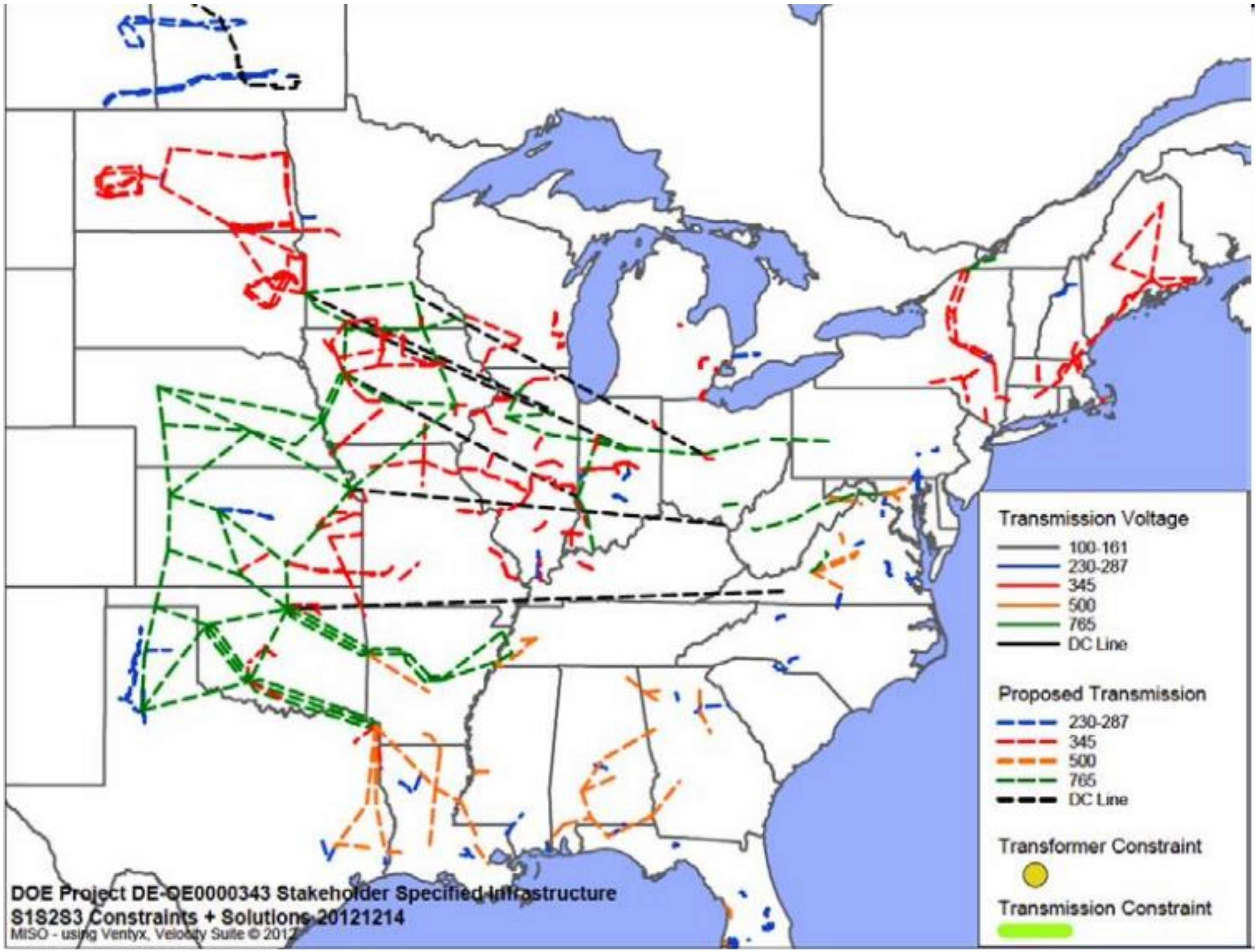
1. THE GRID

North American Electric Reliability Corporation Interconnections

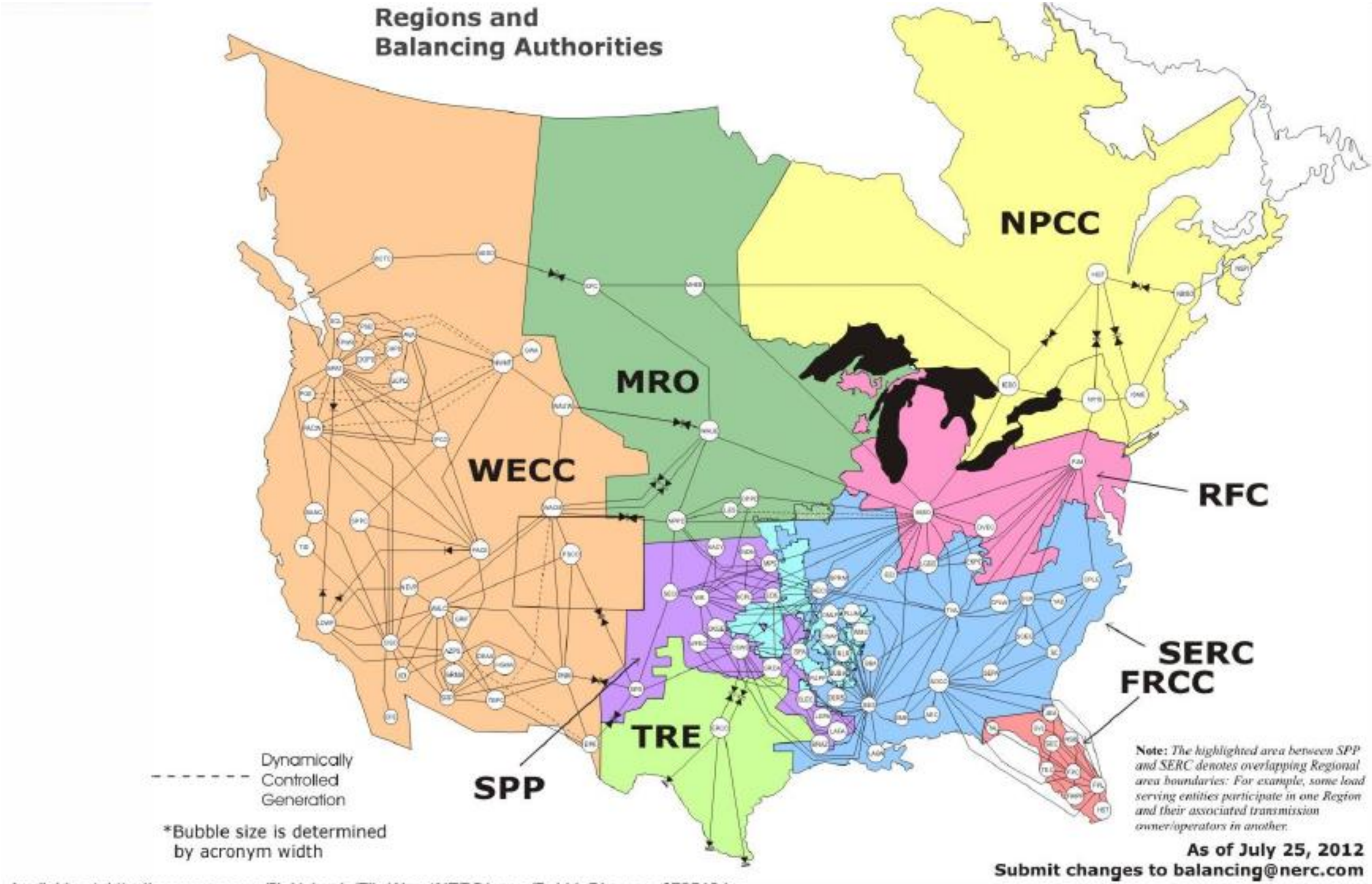


Source: Fagan, Bob, Jeremy Fisher, and Bruce Biewald, July 19, 2013, "An Expanded Analysis of the Costs and Benefits of Base Case and Carbon Reduction Scenarios in the EIPC Process: Preliminary Results," Synapse Energy Economics, Inc., prepared for The Sustainable FERC Project.

EIPC transmission build-out for wind, Scenario 1

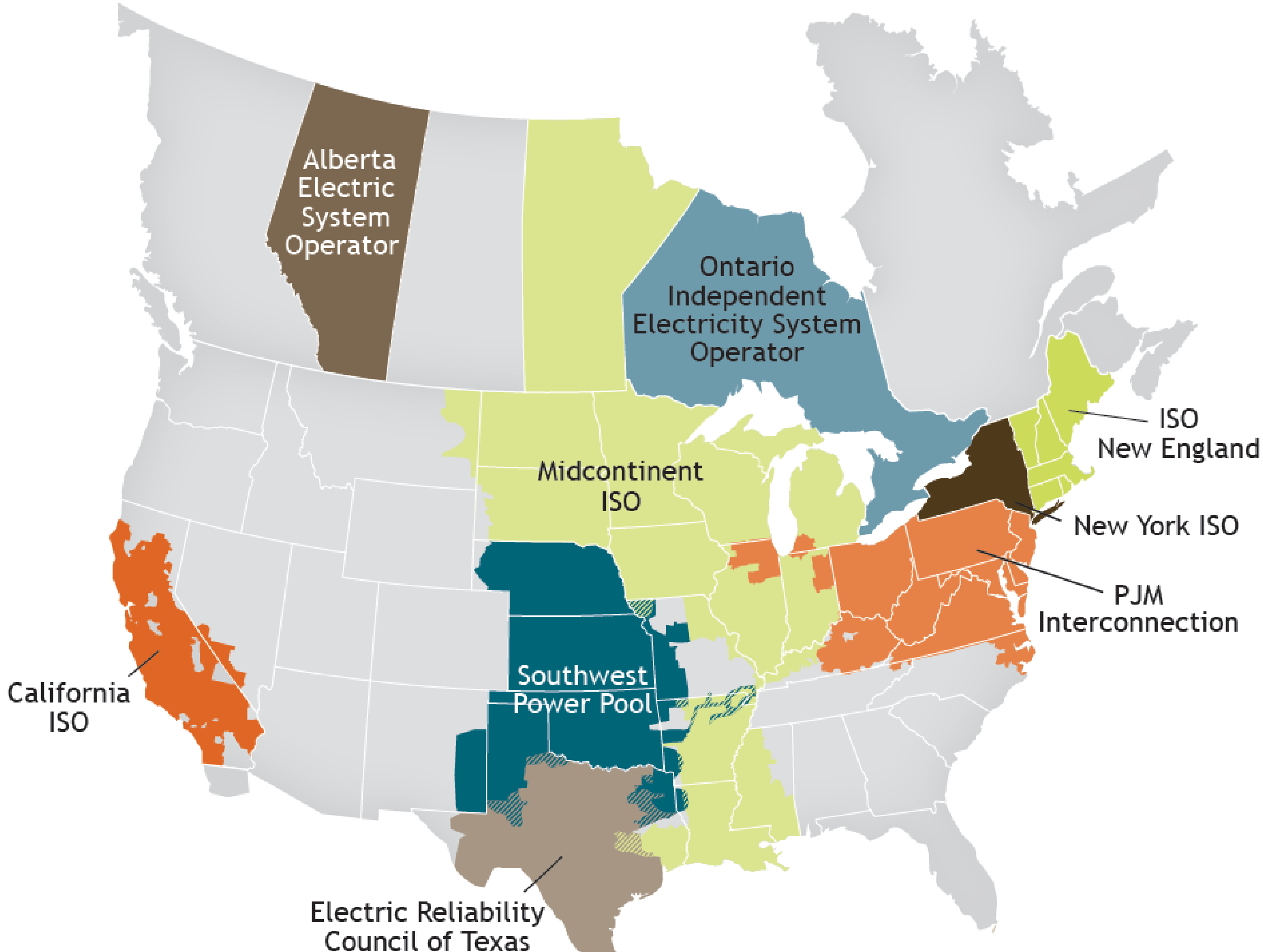


NERC regions and balancing authorities



Available at: http://www.nerc.com/fileUploads/File/AboutNERC/maps/BubbleDiagram_072512.jpg

Regional Transmission Organizations



Source: ISO/RTO Council (IRC)

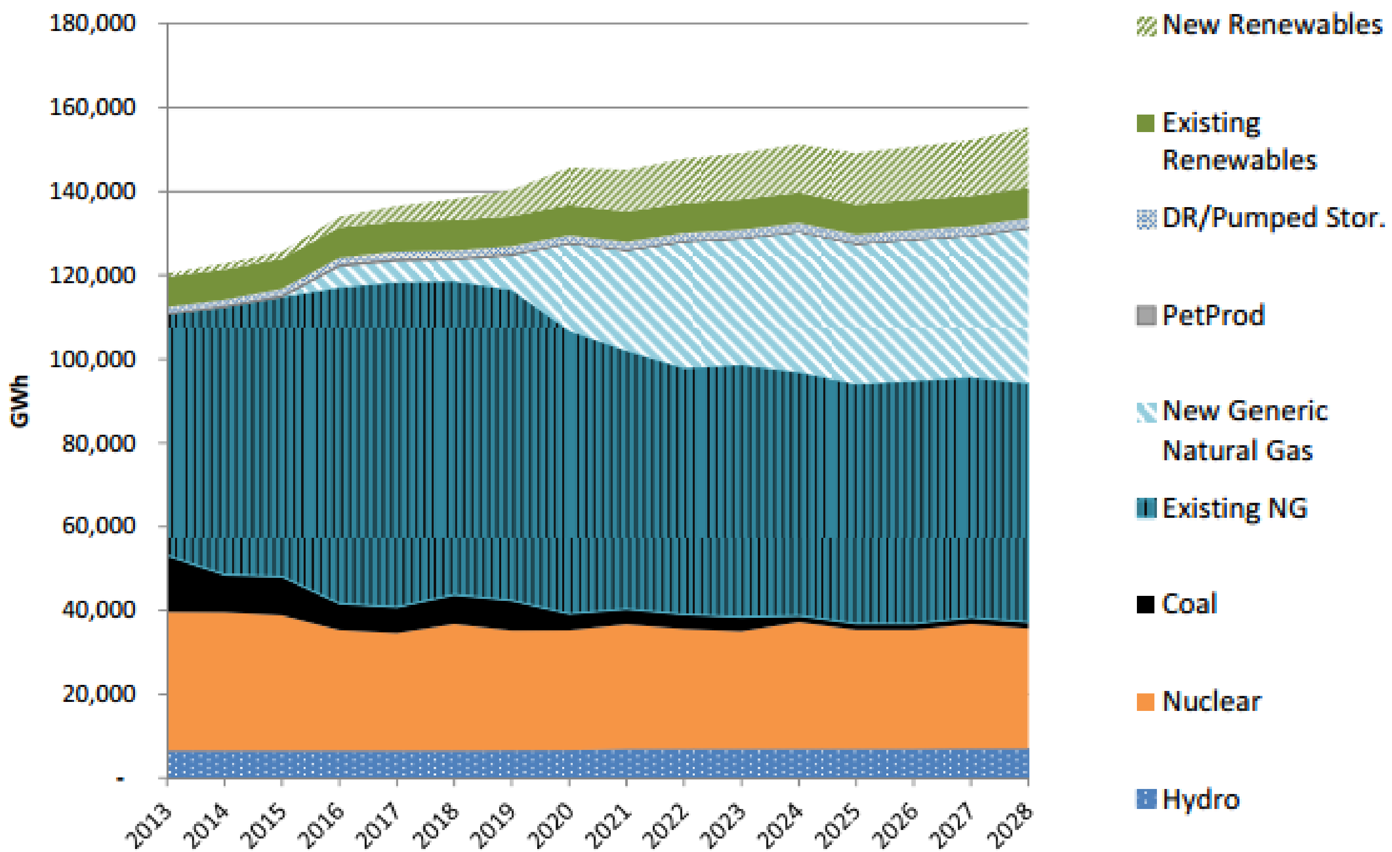
Electric industry structure

Generation	Transmission	Distribution	Retail Electric Service
Merchant	ISO/RTO		Competitive
Public Power		Local Distribution Companies	Default Service
Investor-Owned Utility	Utilities are Planning Authorities and Grid Operators		Cost-Based Utility Supply

Wholesale markets

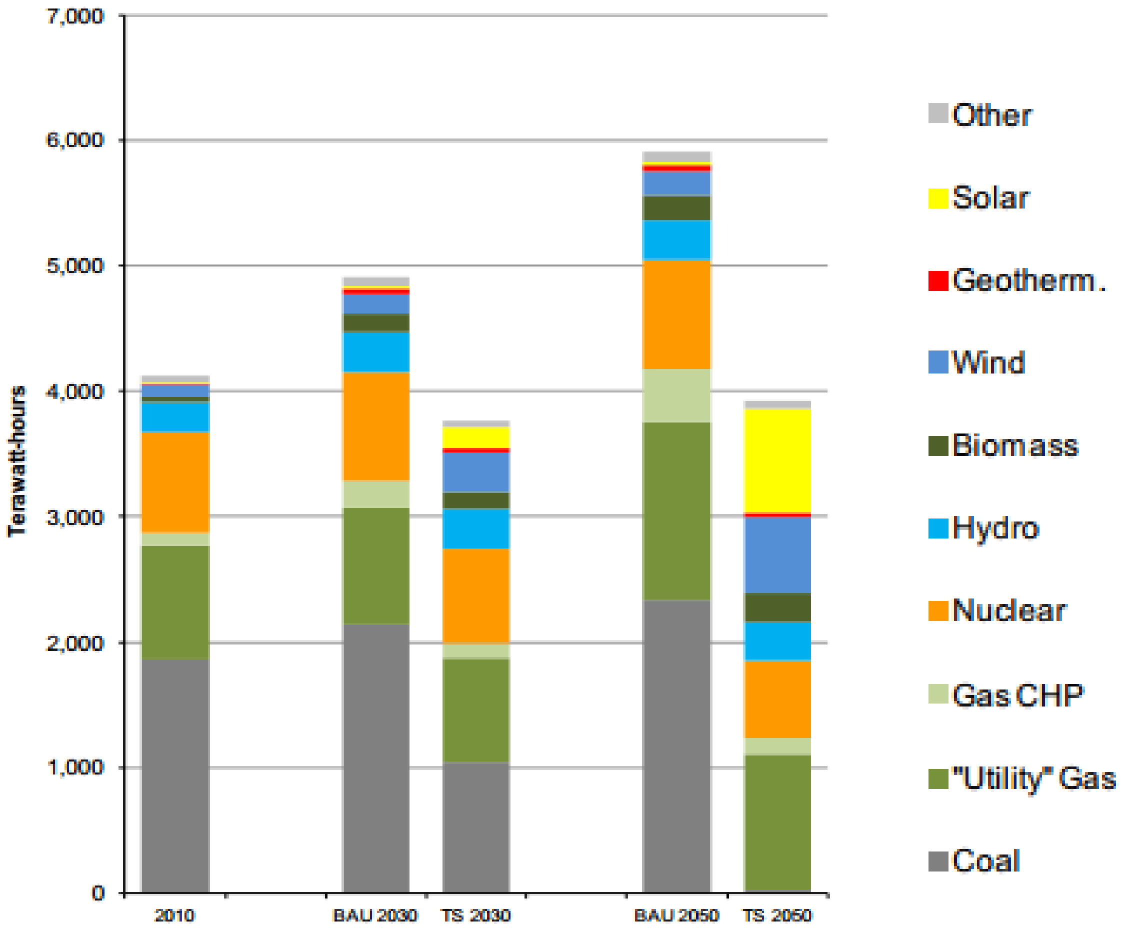
- Energy (and reserves)
  - Day ahead, hour ahead, real time
- Capacity
  - Financial hedge for both sides
- Ancillary services
  - All of the other stuff to make the grid reliable
  - Reserves, regulation, black-start, voltage support, etc.

New England Electric Generation Fuel Mix



Source: *Avoided Energy Supply Costs in New England: 2013 Report. Synapse Energy Economics for the Avoided-Energy-Supply-Component Study Group, July 2013.*

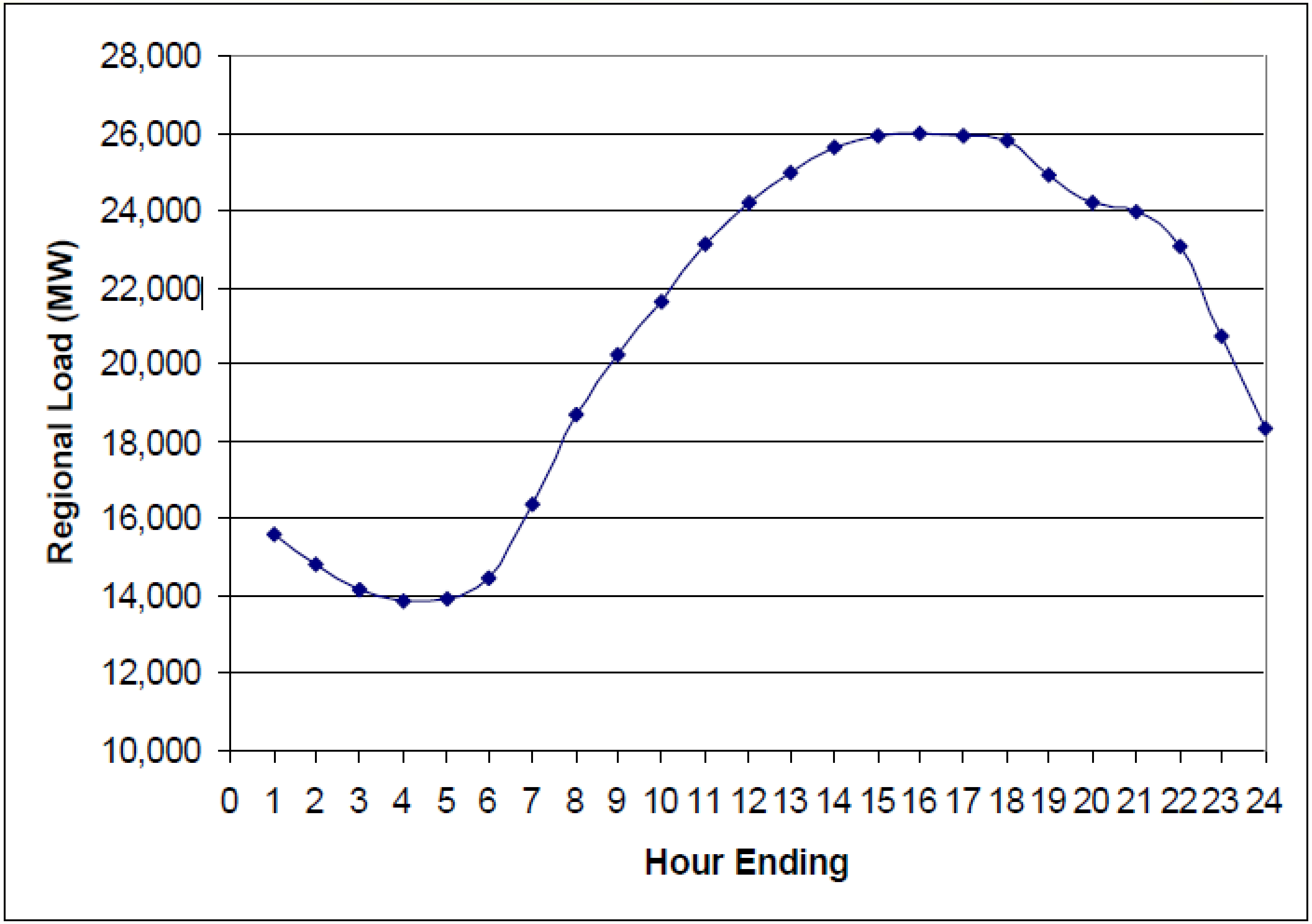
U.S. Electric Generation Fuel Mix



Source: *Toward a Sustainable Future for the U.S. Power Sector: Beyond Business as Usual 2011.* Synapse Energy Economics for the Civil Society Institute, November 2011.

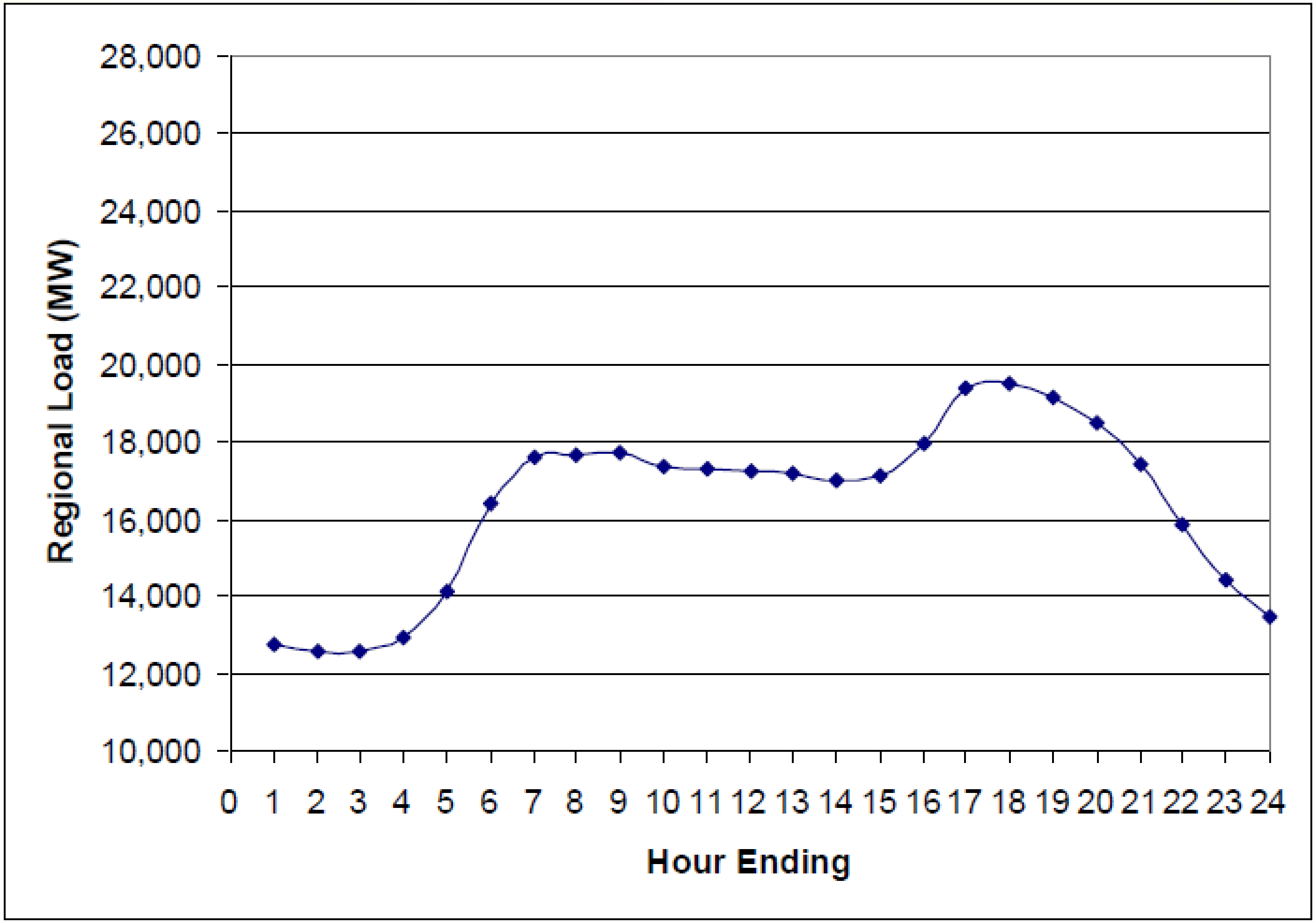
2. DISPATCH

Typical load on a summer day



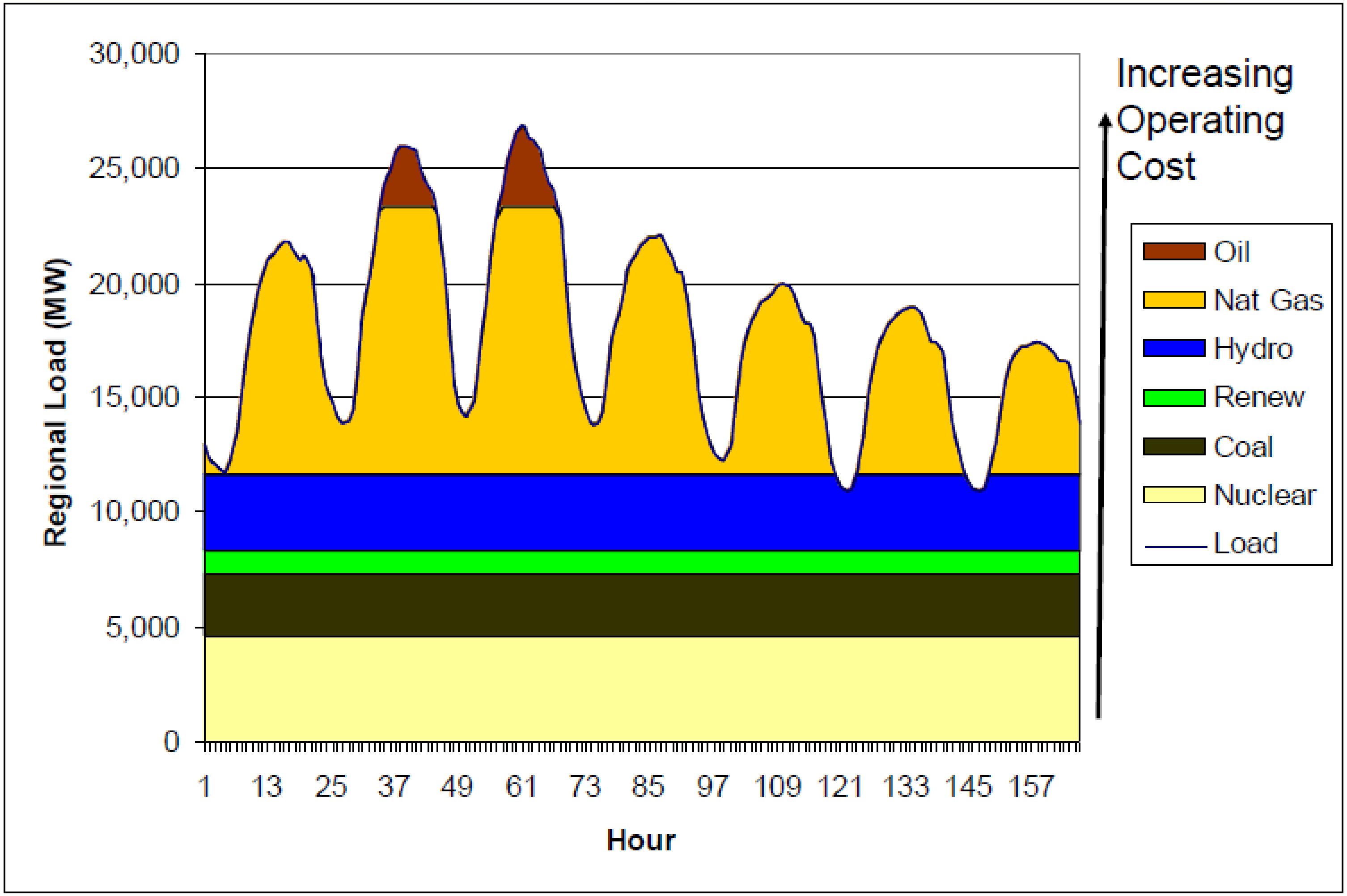
New England load on a typical summer day (9 June 2008)

Typical load on a winter day



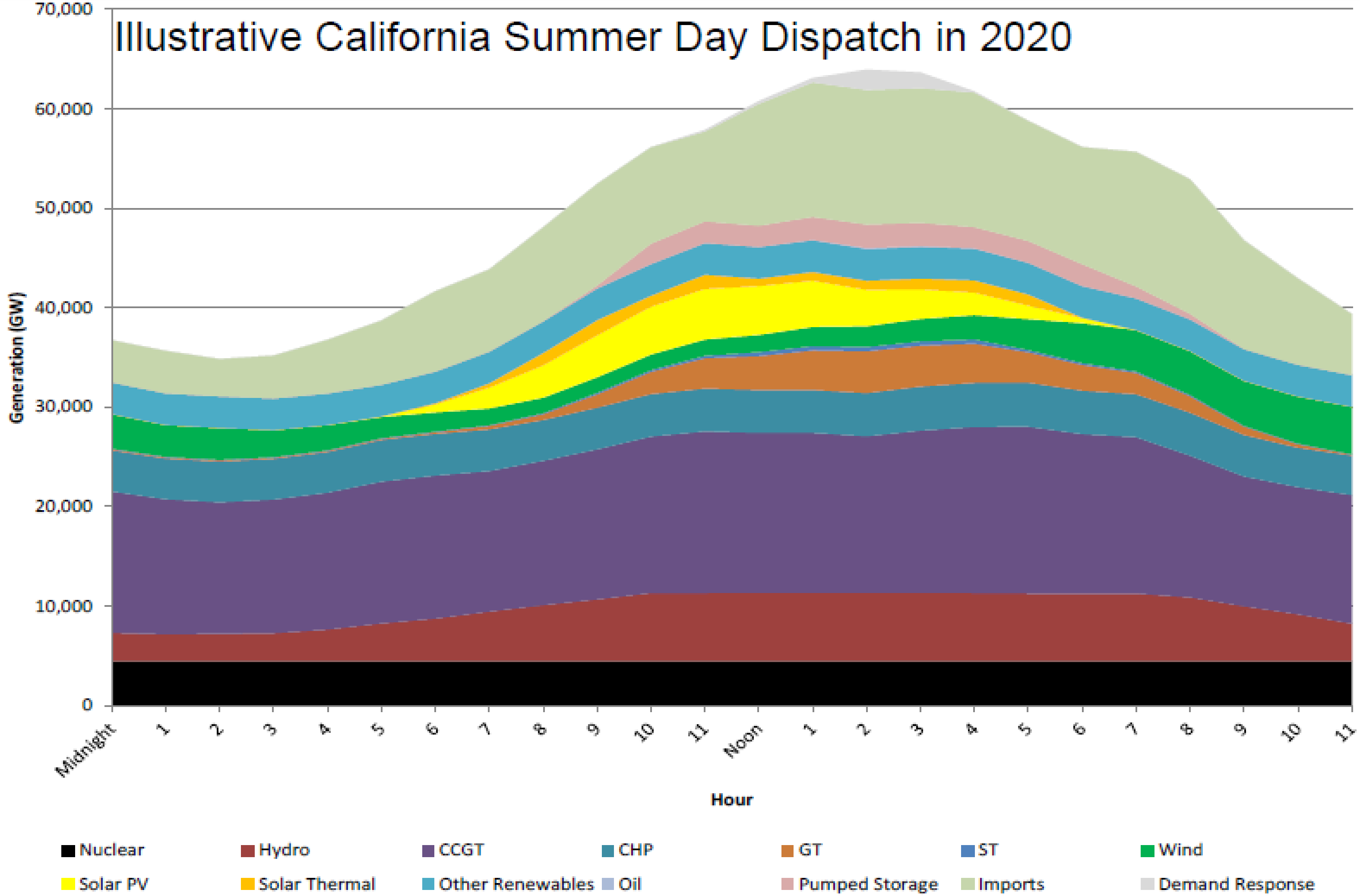
New England load on a typical winter day (23 Jan 2008)

Available resources, stacked by operating cost



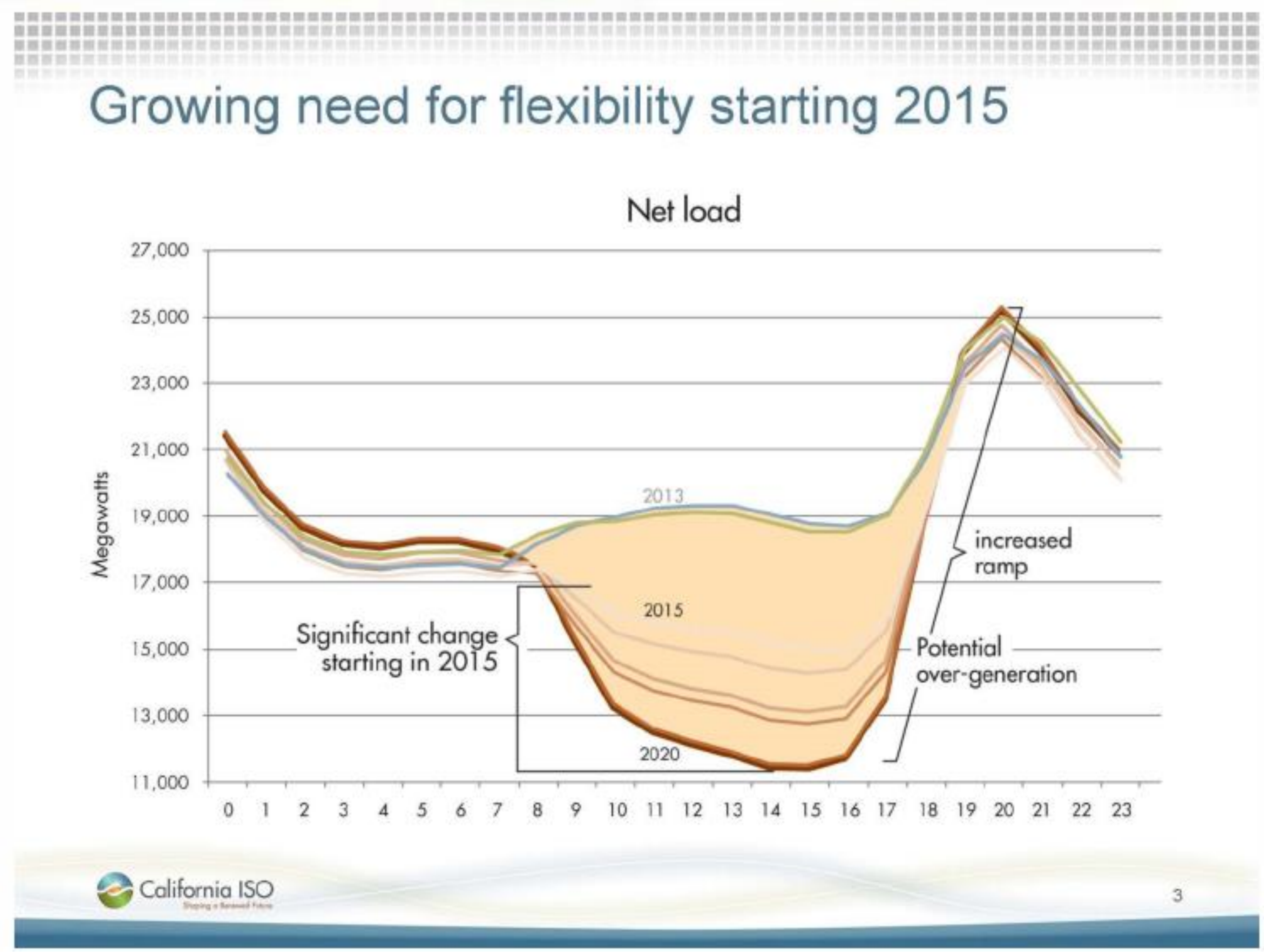
Simplified version of New England load and resources on a typical summer week (8-14 June 2008).

Understanding supply option limitations

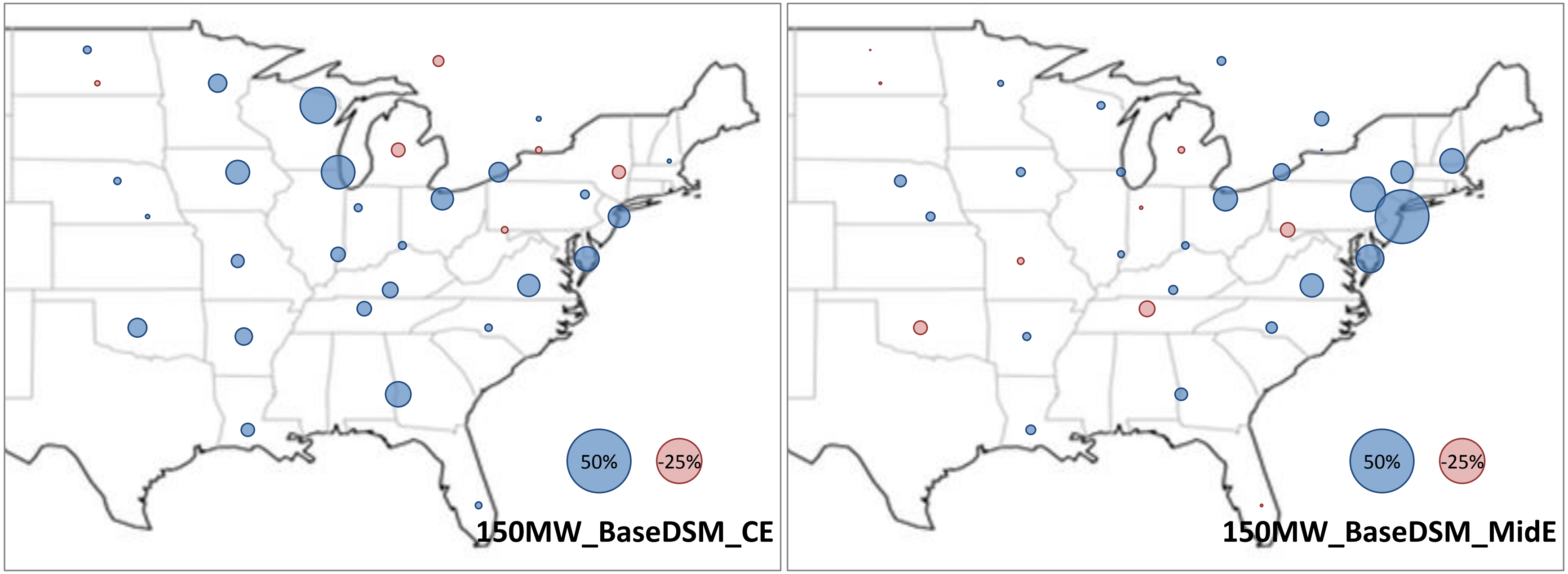


Source: Synapse Energy Economics' Plexos model results for California ISO base scenario with 33% RPS.

Understanding supply option limitations

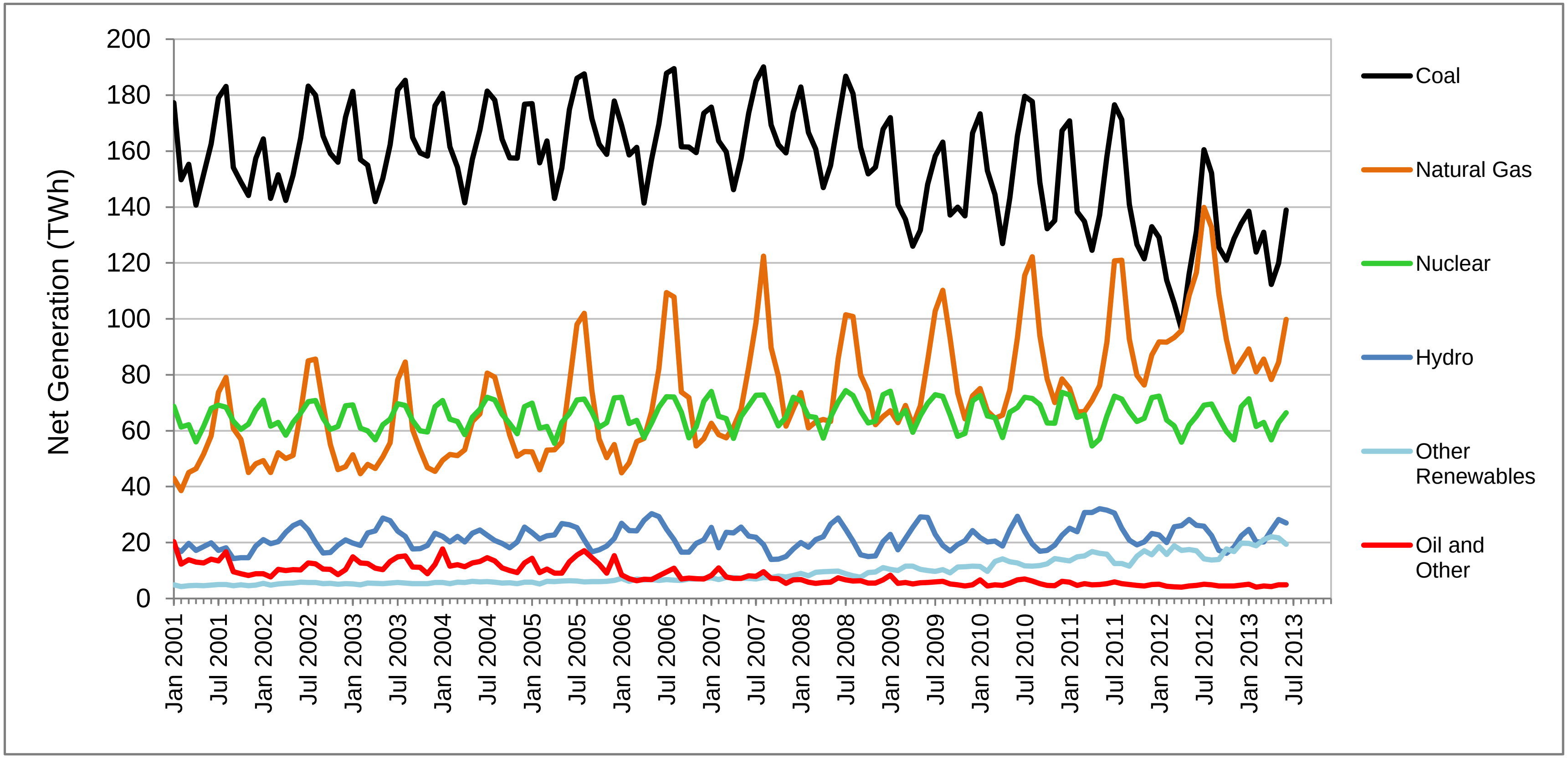


Generation displaced by EE in Chicago and New Jersey



Source: Synapse model runs based on materials from J. Buonocore, P. Luckow, G. Norris, J. Spengler, B. Biewald, J. Fisher, and J. Levy, "Public Health and Climate Impacts Offset by Energy Efficiency and Renewable Energy Measures." Unpublished.

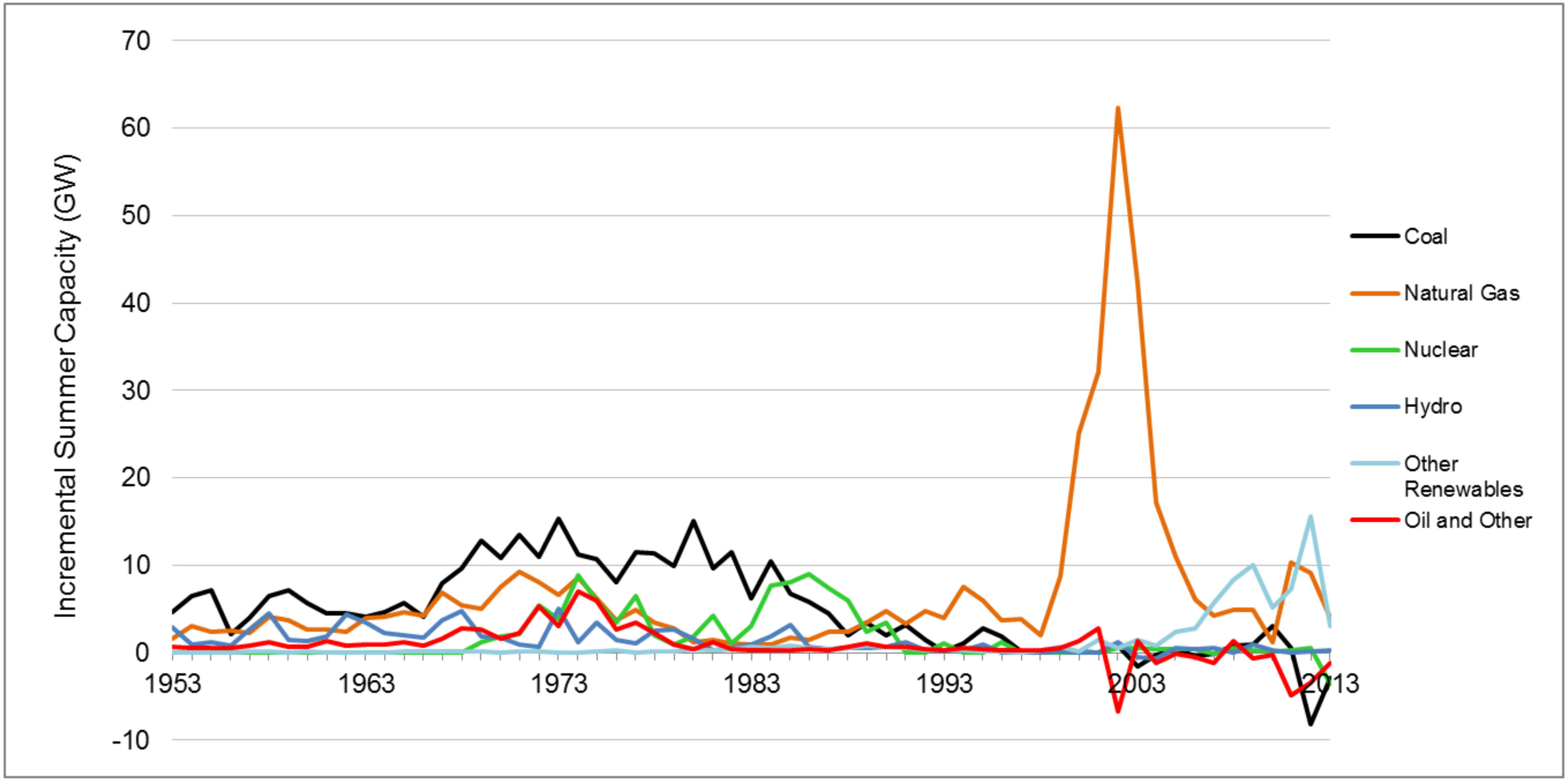
U.S. quarterly generation by fuel type



Source: EIA Form 923, 2001 - 2013

3. PLANNING

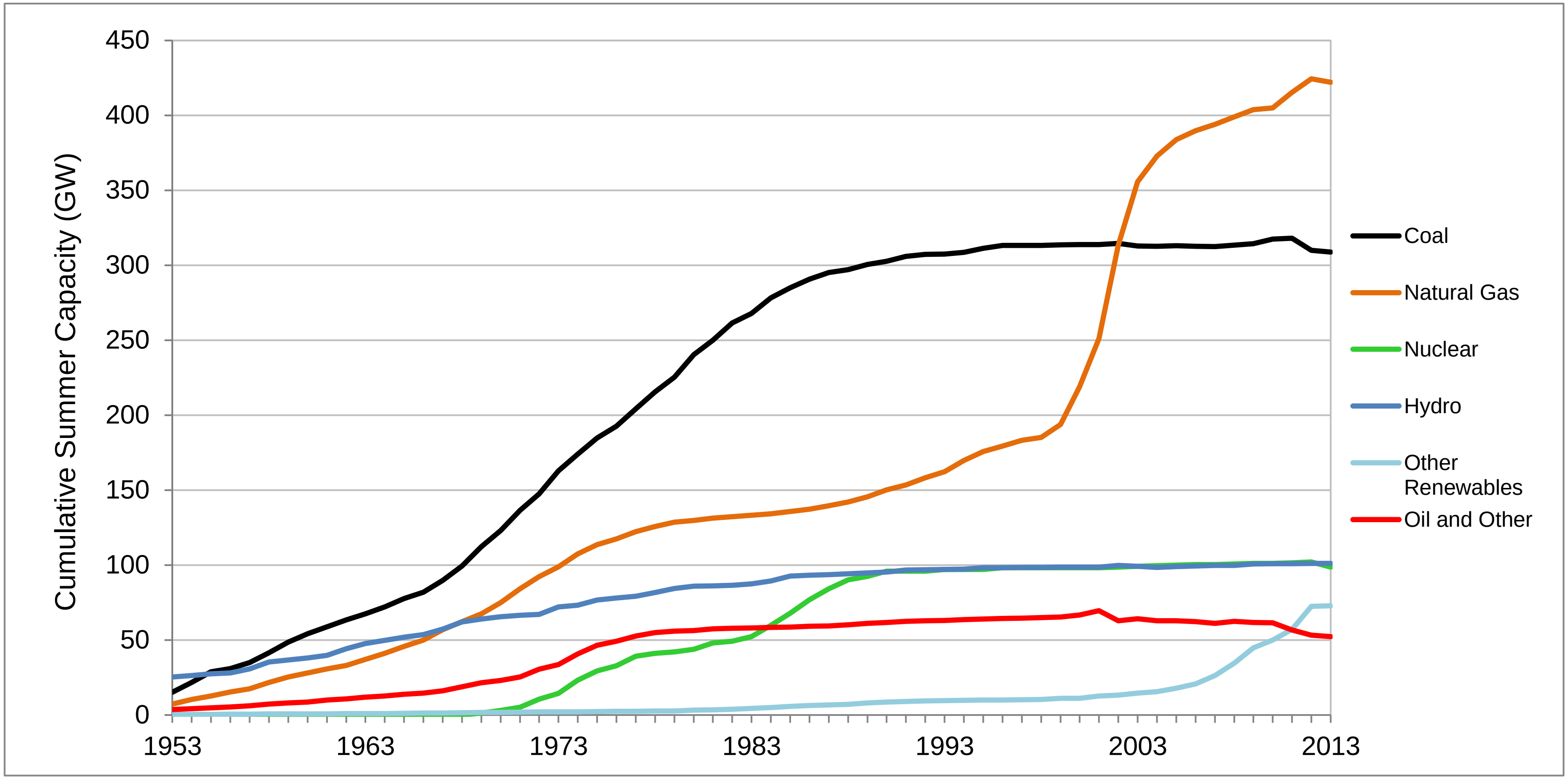
Incremental summer capacity



"Other Renewables" includes wind, solar, and geothermal.
"Oil and Other" includes fuel oil, petroleum coke, tires, waste heat, and other miscellaneous resources.

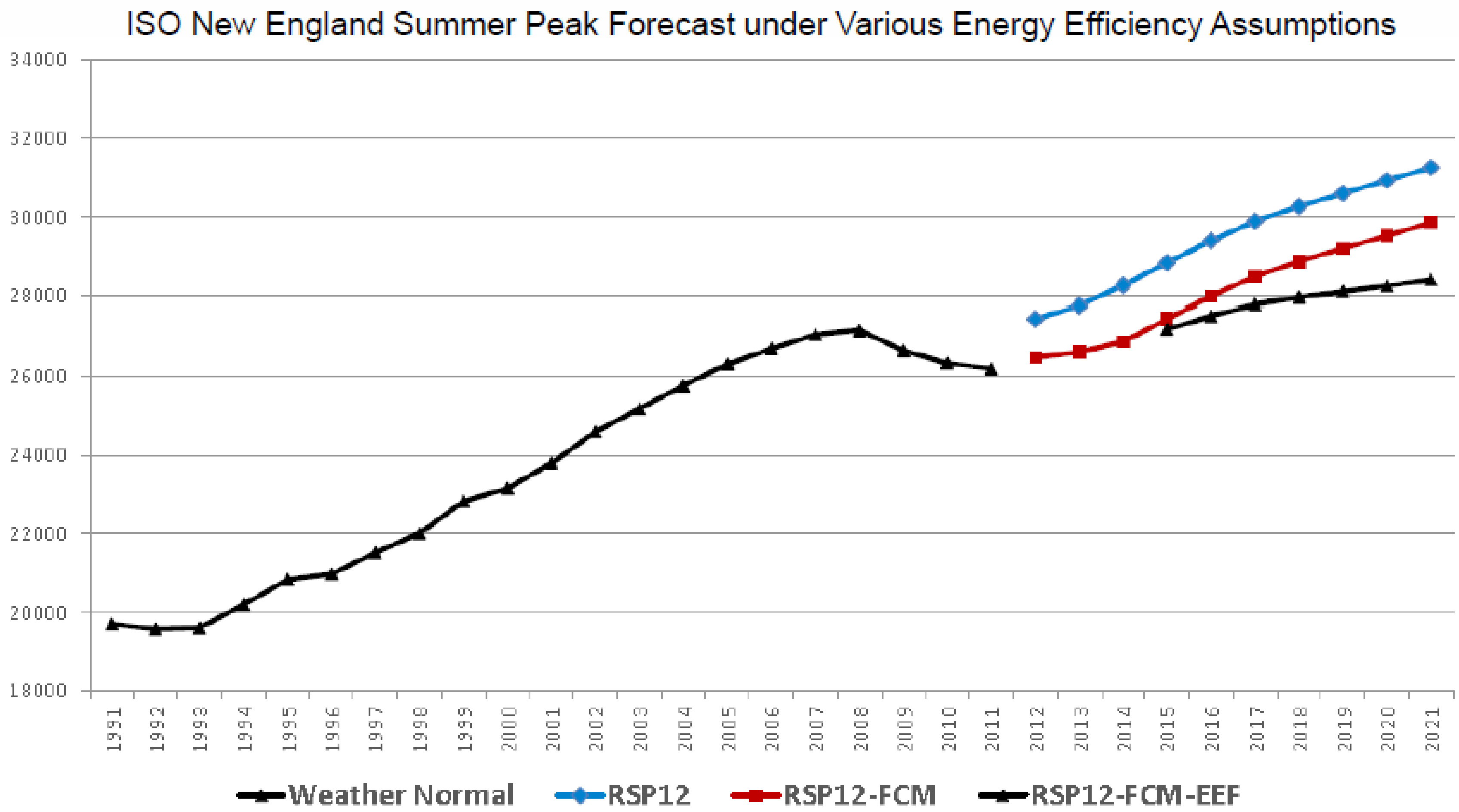
Source: EIA 860 2001-2013. Note that 2013 data is preliminary and only available through November 2013.

U.S. generating capacity by type



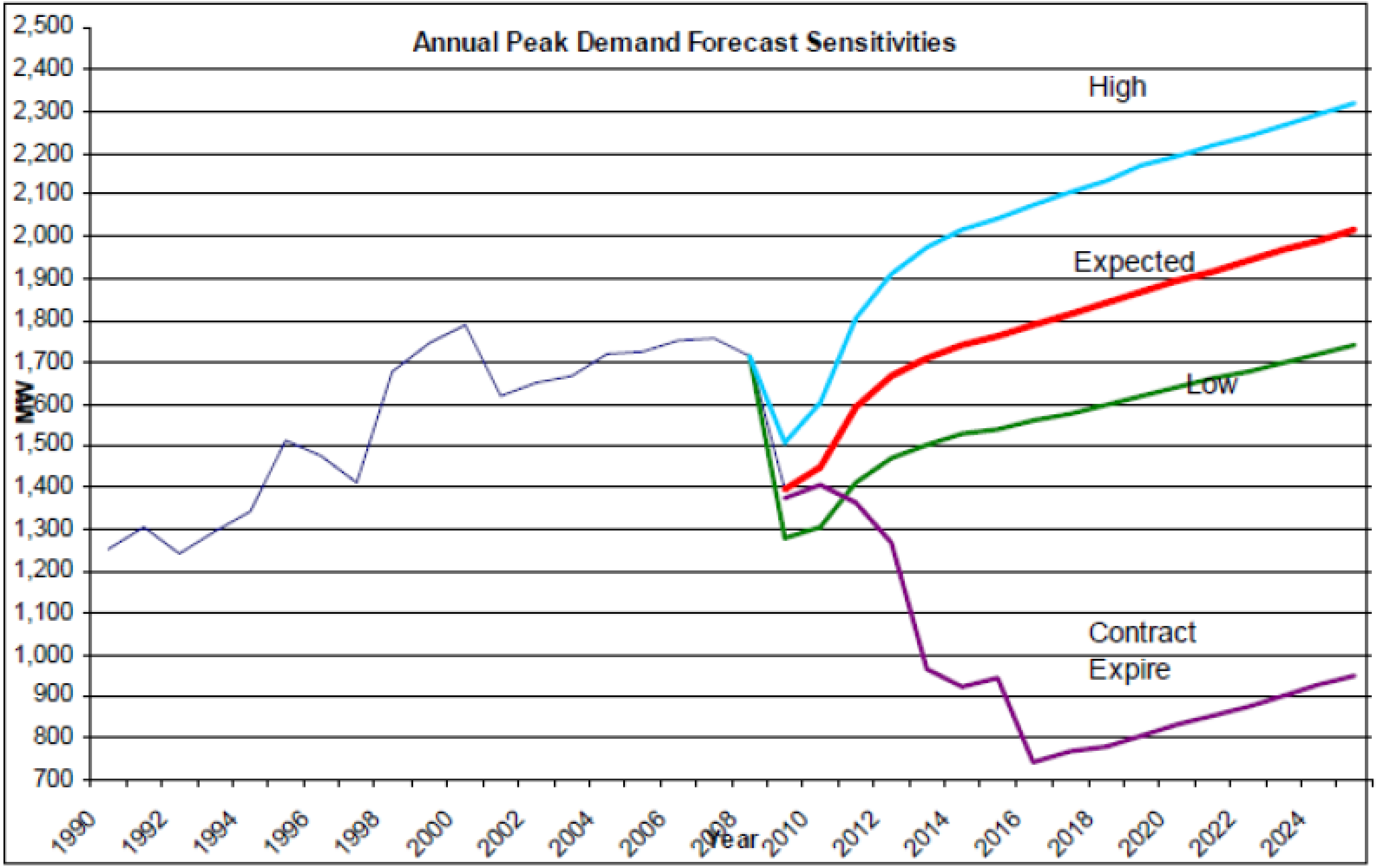
Source: EIA Form 860, 2001 – 2012, Electric Power Monthly

Energy efficiency forecasts



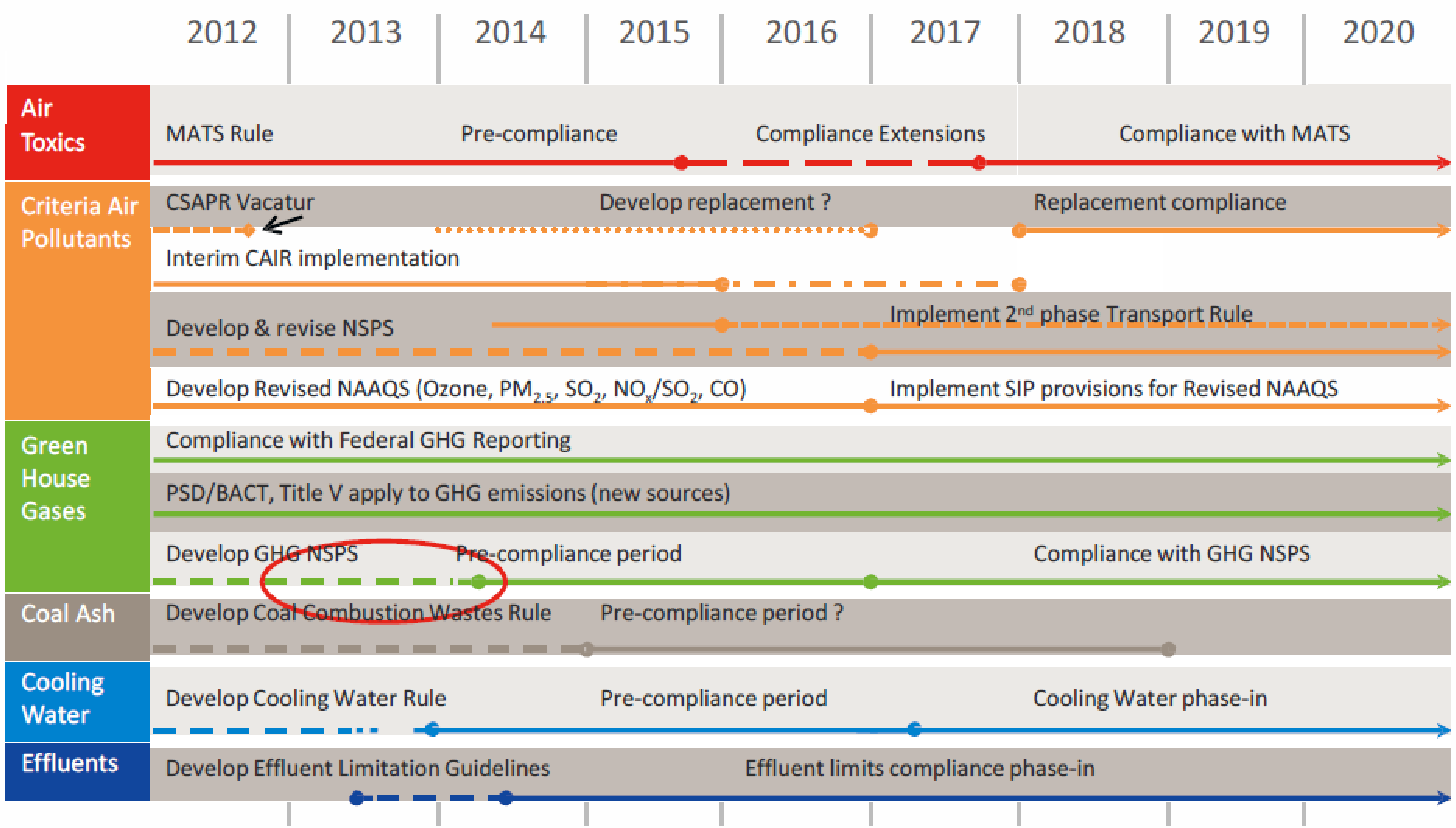
Source: Peterson, et al. 2012

Minnesota Power's 2009 electric utility forecast



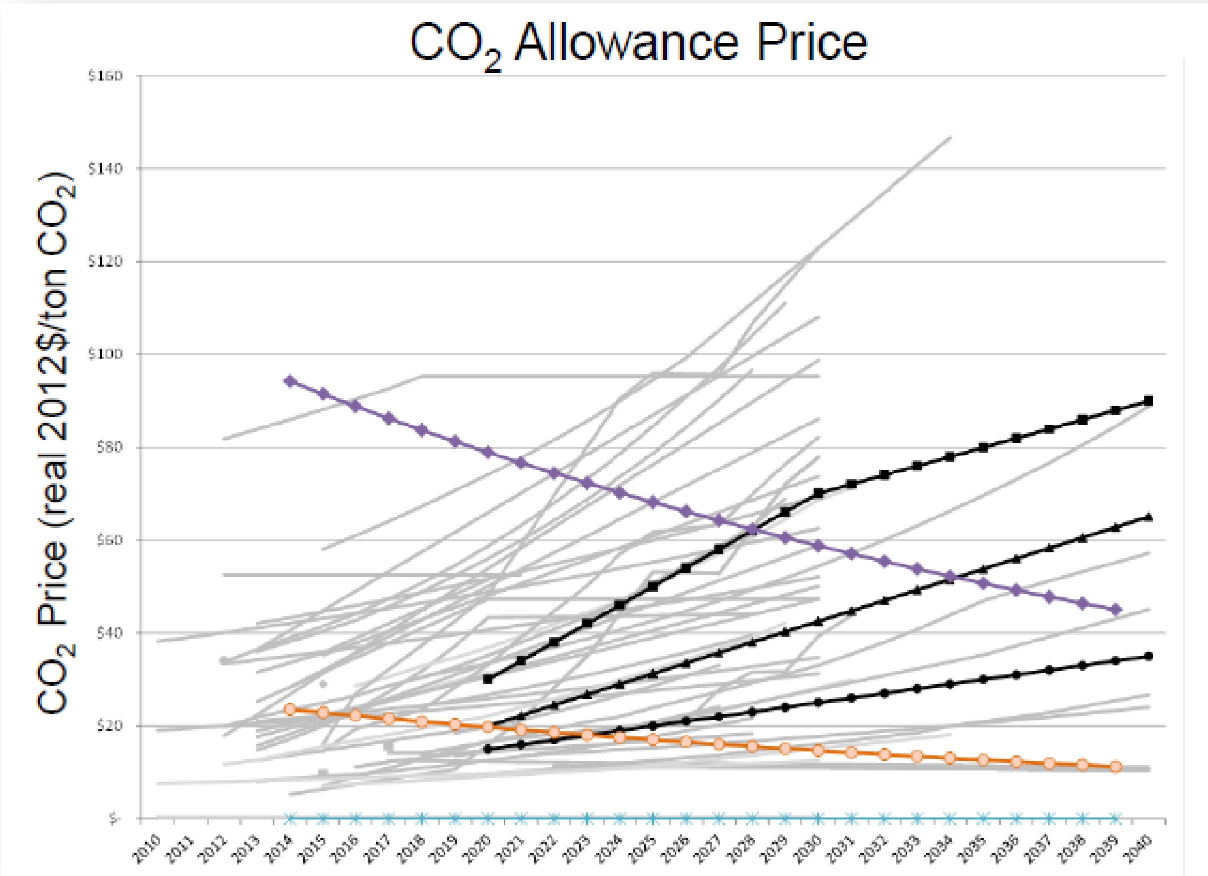
Source: Minnesota Power 2009

Environmental Compliance Obligations



Commodity Prices

Hawaii Electric Company (HECO) 2013 IRP



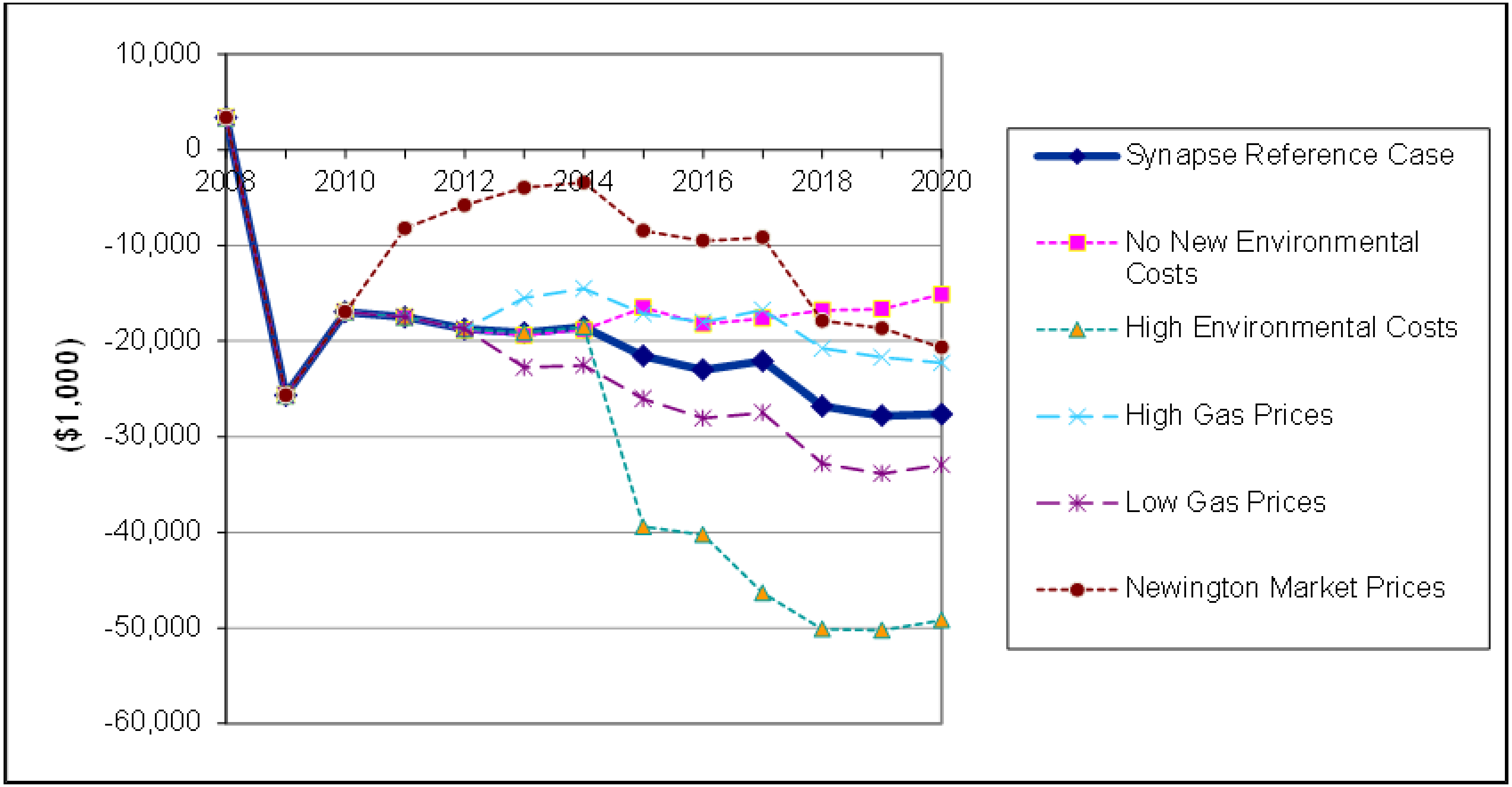
Source: Hawaii Electric Company, 2013

Review of CO_2 price assumptions are critical.

Does price include "allowances." If so, what assumptions underlie those allowances? Does it rise faster than inflation? Or much, much slower?

Zero is a strong forecast.

Schiller 4 and 6 net revenue



Source: Synapse. *Economic Analysis of Schiller Station Coal Units*. 2011.

Poor electric system planning practice

- Passive attitude toward information
- Rely on out-of-date construction cost estimates
- Consider only “existing” environmental regulations
- Ignore CO_2 price, or treat it “at the end” as a sensitivity case
- Assume existing plants continue to operate
- Overly constrain alternatives such as renewables and energy efficiency

IMPRUDENT!

Good electric system planning practice

- Actively seek out relevant information
- Rely on up-to-date and realistic construction cost estimates
- Anticipate reasonably likely future environmental regulations
- Include reasonable CO_2 price forecast in the reference case, and analyze high and low sensitivities
- Evaluate continued operation vs. retirement options for existing plants
- Include full consideration of alternatives

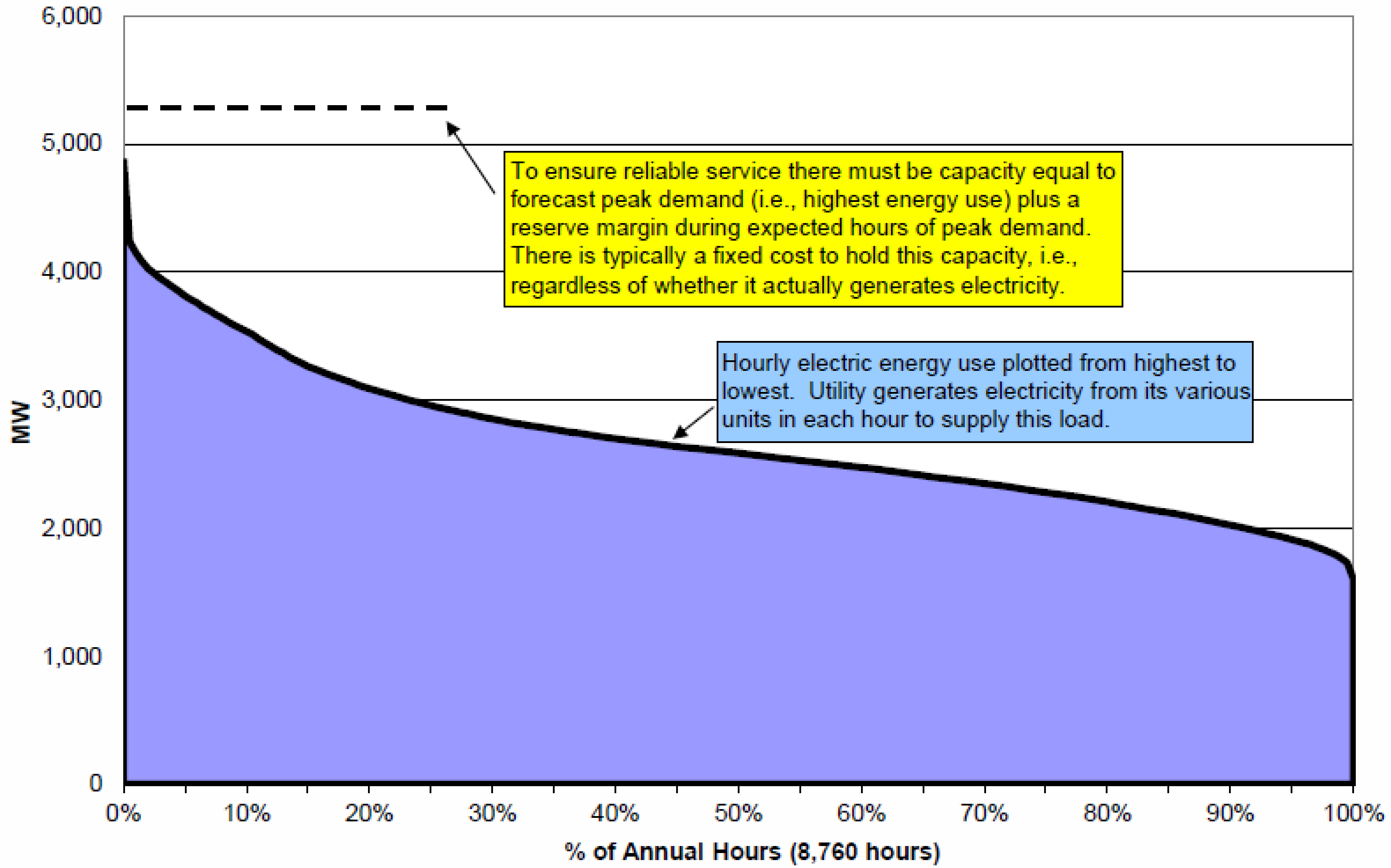
PRUDENT

4. RELIABILITY

Requirement: reserves and reliability

- **Planning Reserve:** Reserve requirements to provide capacity adequacy based on rigorous analysis of system characteristics and proper treatment of intermittent resources
  - Planning reserve margin of approx. 12 – 18%
- **Operating Reserve:** Short term (day ahead, week ahead) requirements
  - Spin, non-spin, and regulation (and load-following)
  - Covers contingency requirements and forecast uncertainties

Illustrative Lead Duration Curve (8,760 hours)

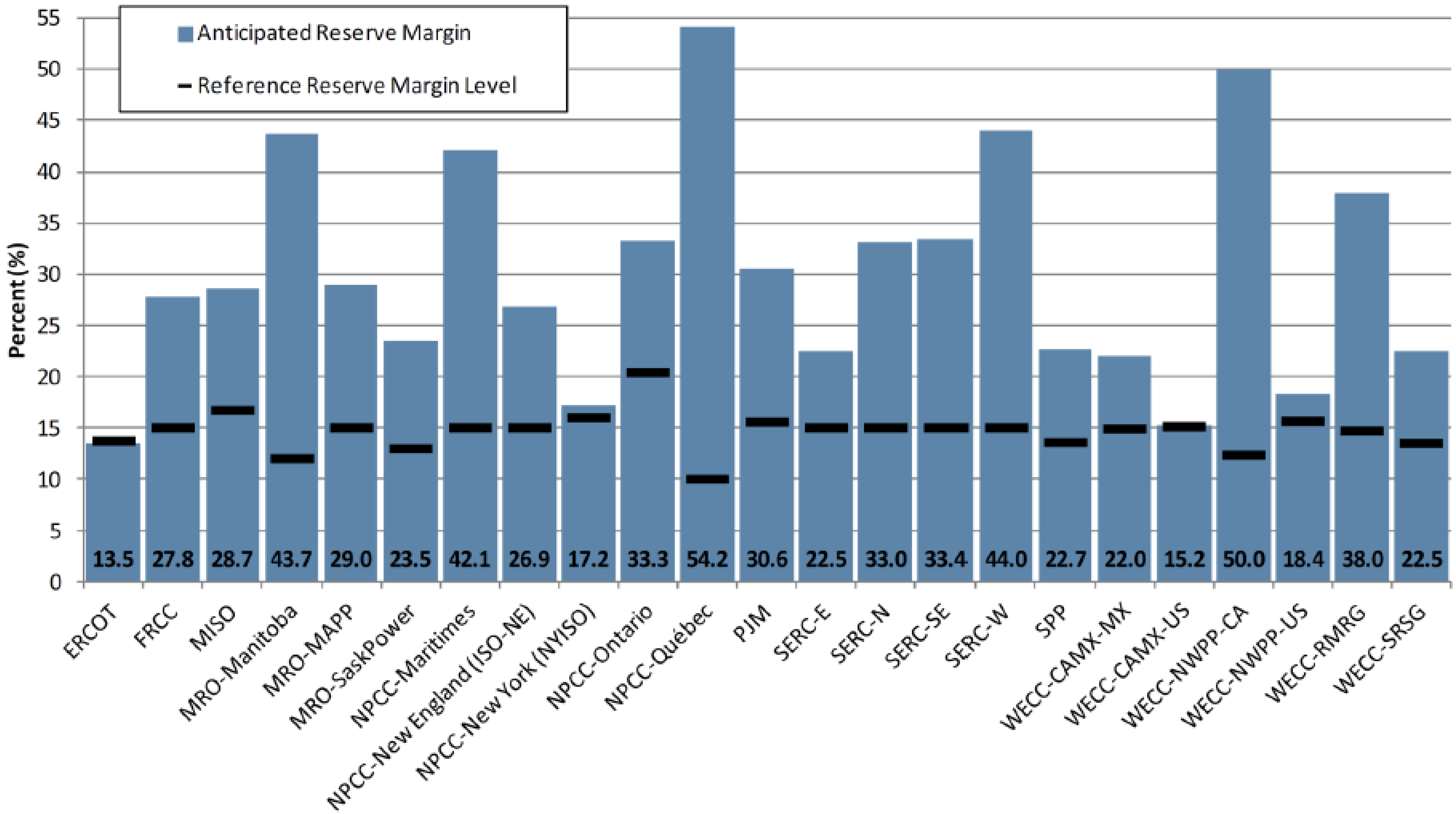


Source: Hornby, Hurley, & Knight 2011

General characteristics of utility systems that affect reliability and reserves requirements

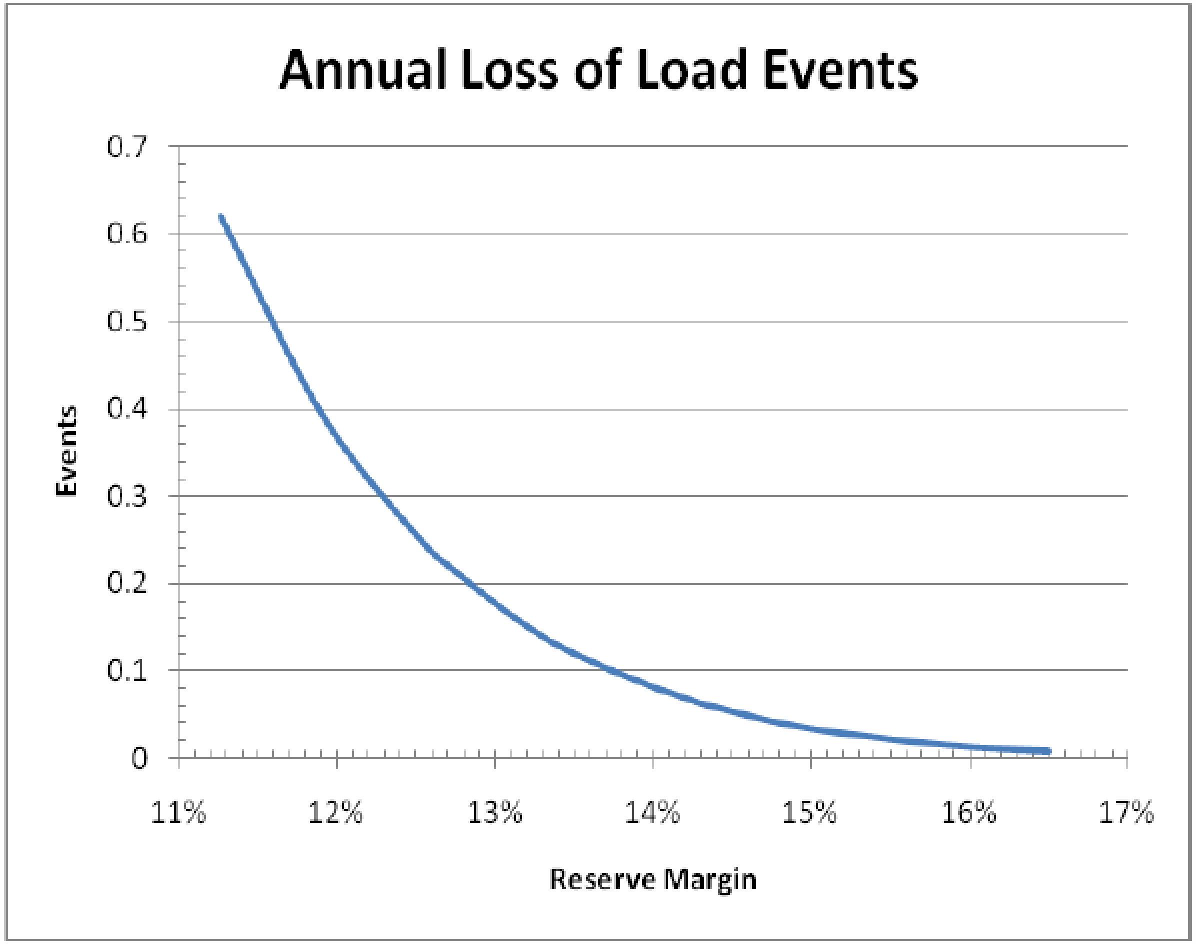
1. Load shape
2. Forced outage rates
3. Maintenance outage requirements
4. Number and size of generating units
5. Transmission interties with neighboring utilities
6. Availability and effectiveness of intervention procedures

NERC anticipated reserve margins for summer 2012



Source: NERC 2012

LOLE and reserve margin



Source: ERCOT 2010

Reliability: where did "1 in 10" standard come from?

"The fraction of time… will be called the *loss of load duration*… expressed in terms of "so many days upon which loss of load may be expected to occur during a given number of years," say 10 or 100.

This number of days provides a first index for measuring and comparing service reliabilities."

- Giuseppe Calabrese, 1947

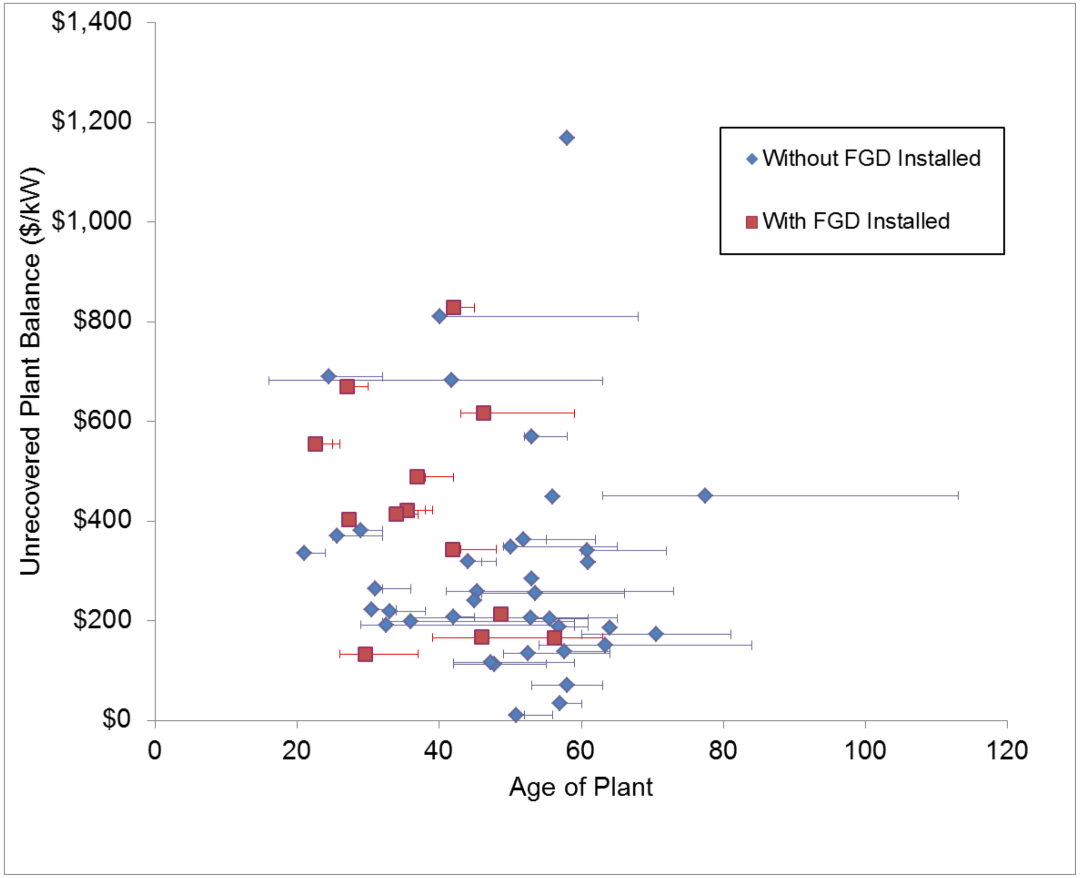
Source: NERC 1991

5. RATEMAKING

Utility ratemaking

- Regulated Monopoly Economics
- Electric utility prices are not set by “the market.” They are set by state public utility commissions in “rate cases”
- Fuel, O&M, purchased power, and administrative costs are passed through as expenses
- Power plant investments are put into “ratebase” and recovered over time with an allowed administratively determined return on equity
- Plant investment that is not prudently incurred should be removed from rates
- Plan investment that is not “used and useful” should be removed from rates

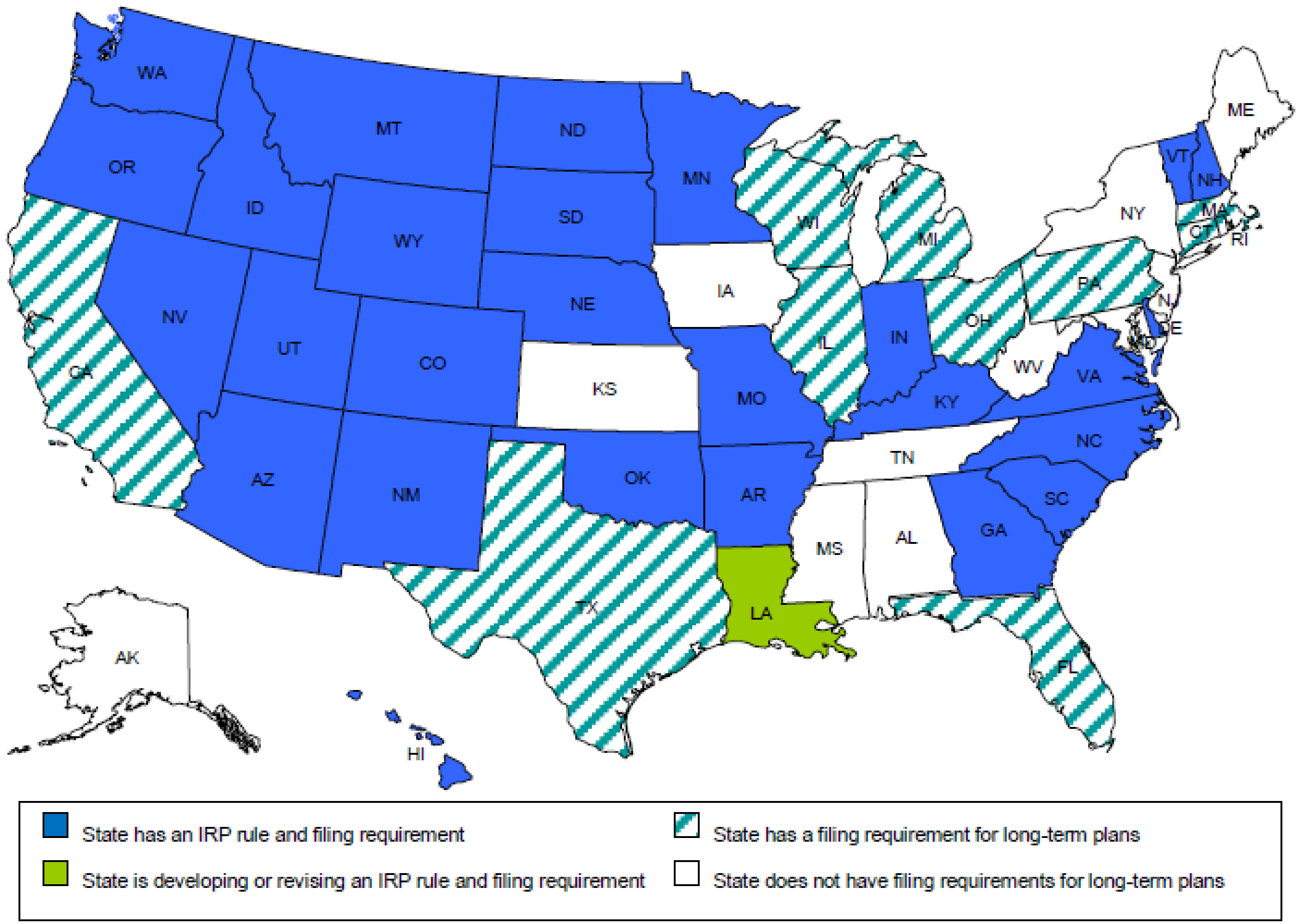
Utility incentives:
Old coal plants have significant investment in rate base



- Data from data collected from 52 coal plants owned by 11 utilities
- Average plant age weighted by capacity: ~47 years
- Average plant capacity: ~675 MW
- Average unrecovered plant balance: ~$336/kW
- Average unrecovered balance as a percentage of Total Plant Balance: 50%

Source: Presentation by Bruce Biewald, August 8, 2013, "Synapse 2013 Technical Training. Session 3: Components of Good Planning IRP and CPCN," slide 19.

Presence or absence of State IRP rules and procurement plan filing requirements



Source: Peterson & Wilson 2011