RAP Energy solutions for a changing world

Module 1
Overview: How Does Our Electric System Work?

Electric Energy Training
for Air Regulatory & Planning Staff
US EPA OAQPS – August 15-16, 2011

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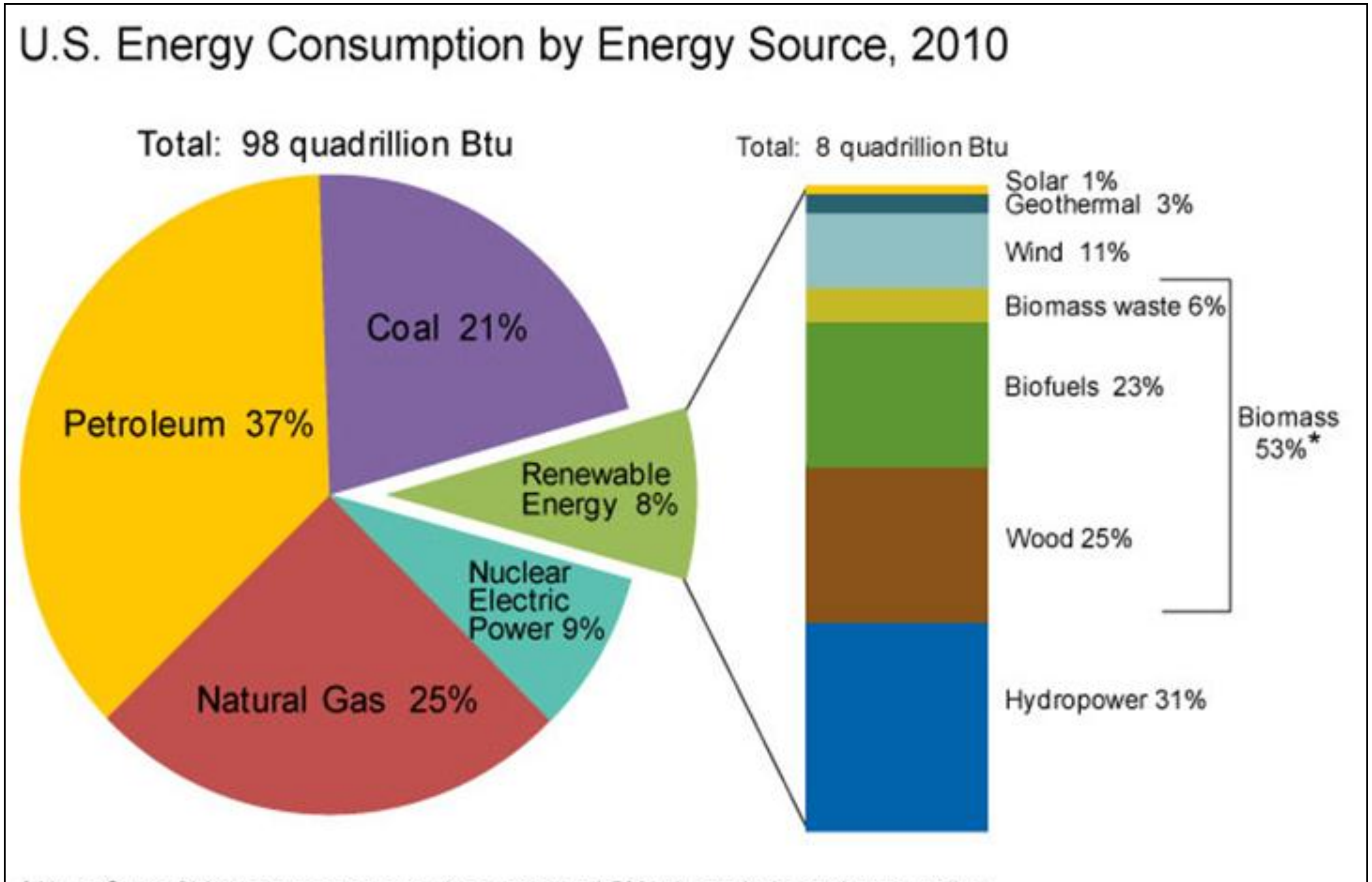
U.S. Energy Sources Overall

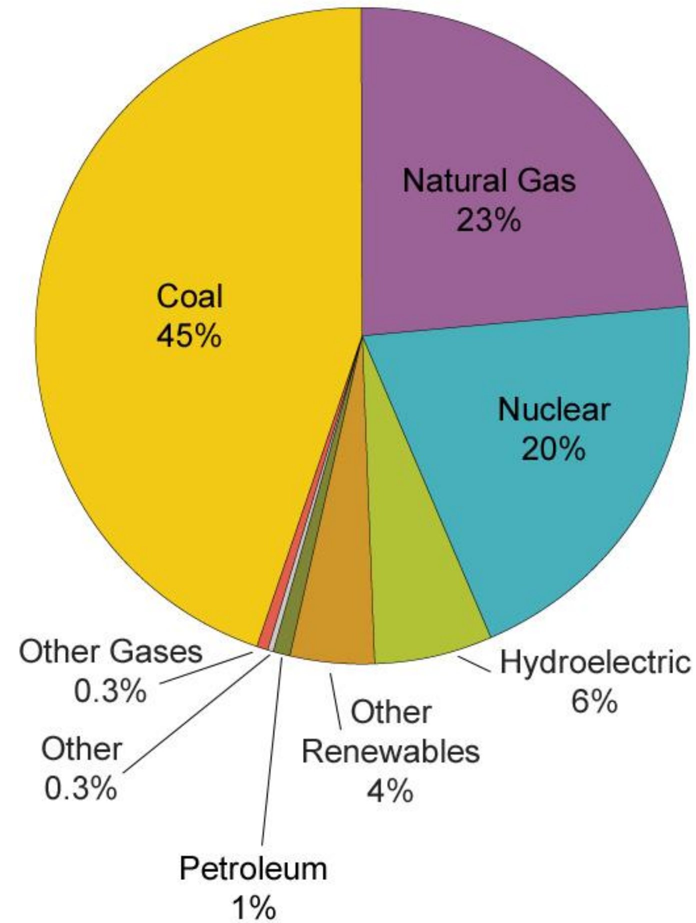


* Note: Sum of biomass components does not equal 53% due to independent rounding.
Source: U.S. Energy Information Administration, Monthly Energy Review, Table 10.1 (June 2011), preliminary 2010 data.

U.S. Electricity-Only

- Coal and nuclear share ~double
- “Supply-Side” Resources
  - i.e., supply power to the grid to meet demand
  - Fossil (coal, natural gas, oil)
  - Nuclear
  - Renewable (hydro, wind, solar, etc.)

U.S. Net Electricity Generation by Fuel, 2010

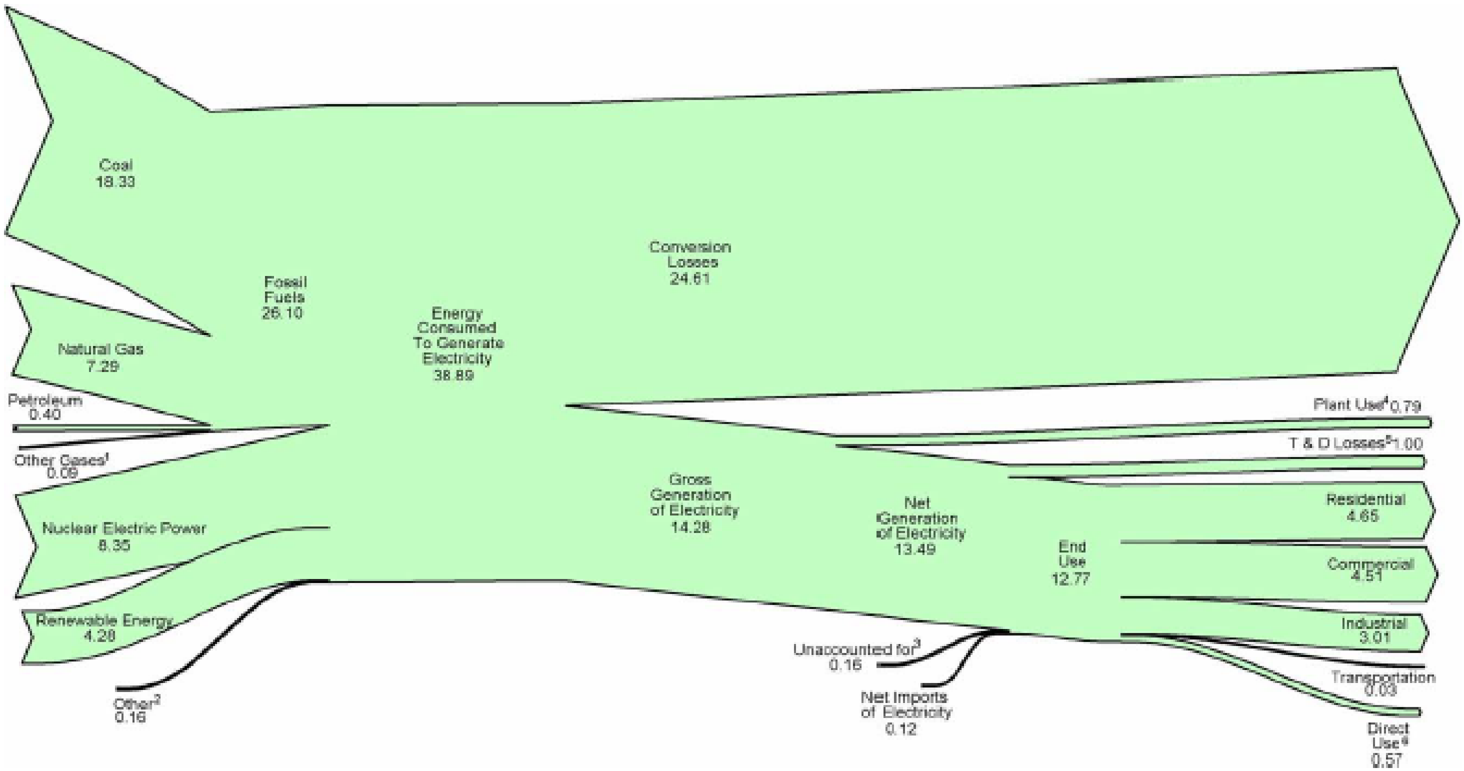


Source: U.S. Energy Information Administration, *Electric Power Monthly,* Table 1.1 (March 2011), preliminary data.

Electric System Fundamentals (1)

- Today, most electricity is generated by combustion of fuels to produce steam or exhaust which in turn drives a turbine.
- This combustion process emits criteria and toxic air pollutants and greenhouse gases (GHG).

Figure 8.0 Electricity Flow, 2009
(Quadrillion Btu)



[1] Blast furnace gas, propane gas, and other manufactured and waste gases derived from fossil fuels.

[2] Batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, miscellaneous technologies, and non-renewable waste (municipal solid waste from non-biogenic sources, and tire-derived fuels).

[3] Data collection frame differences and nonsampling error. Derived for the diagram by subtracting the "T & D Losses" estimate from "T & D Losses and Unaccounted for" derived from Table 8.1.

[4] Electric energy used in the operation of power plants.

[5] Transmission and distribution losses (electricity losses that occur between the point of generation and delivery to the customer) are estimated as 7 percent of gross generation.

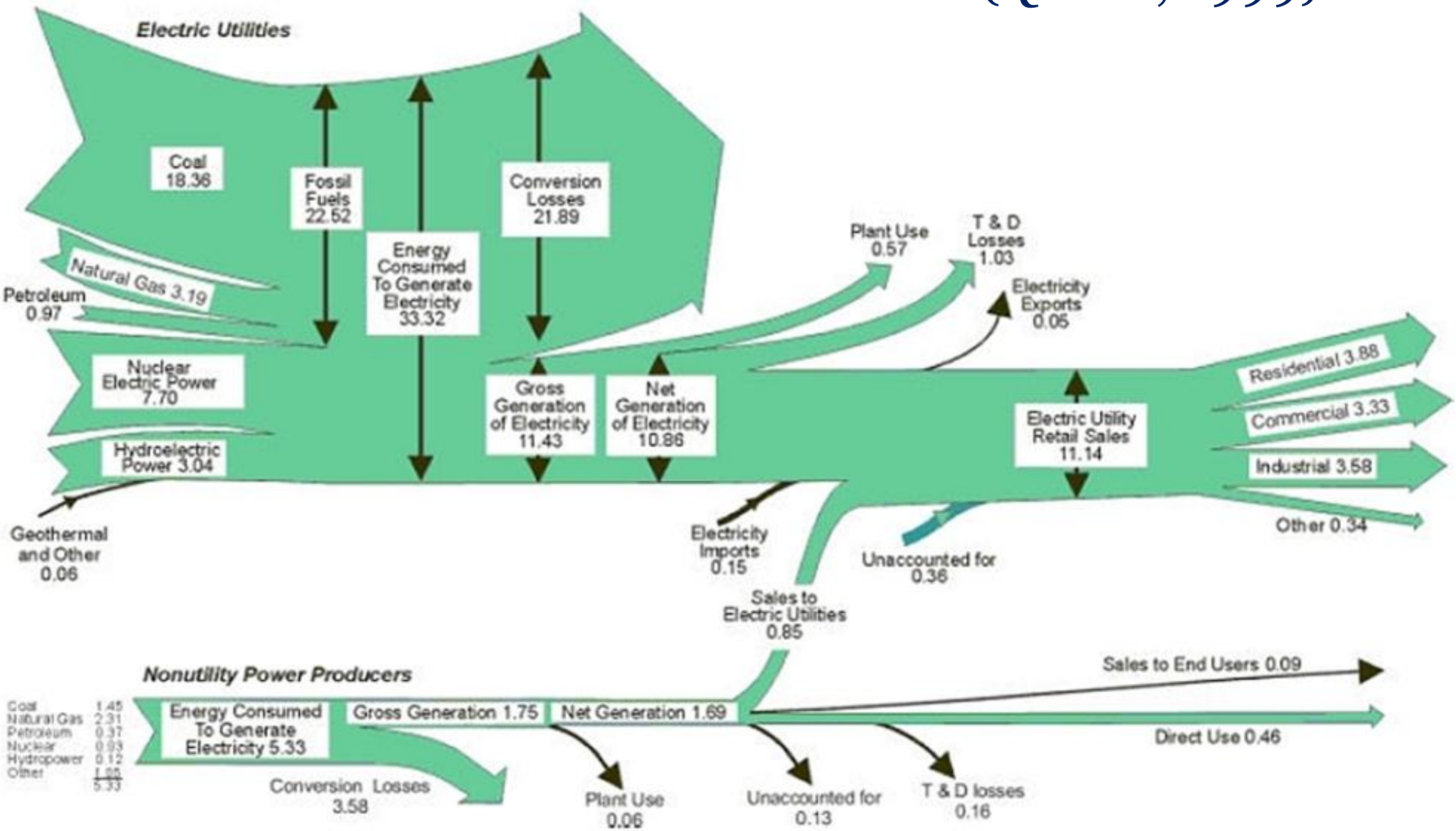
[6] Use of electricity that is 1) self-generated, 2) produced by either the same entity that consumes the power or an affiliate, and 3) used in direct support of a service or industrial process located within the same facility or group of facilities that house the generating equipment. Direct use is exclusive of station use.

Notes: • Data are preliminary. • See Note, "Electrical System Energy Losses," at the end of Section 2. • Net generation of electricity includes pumped storage facility production minus energy used for pumping. • Values are derived from source data prior to rounding for publication. • Totals may not equal sum of components due to independent rounding.

Sources: Tables 8.1, 8.4a, 8.9, A6 (column 4), and U.S. Energy Information Administration, Form EIA-923, "Power Plant Operations Report."

EIA Electricity Flow Diagram

(Quads, 1999)

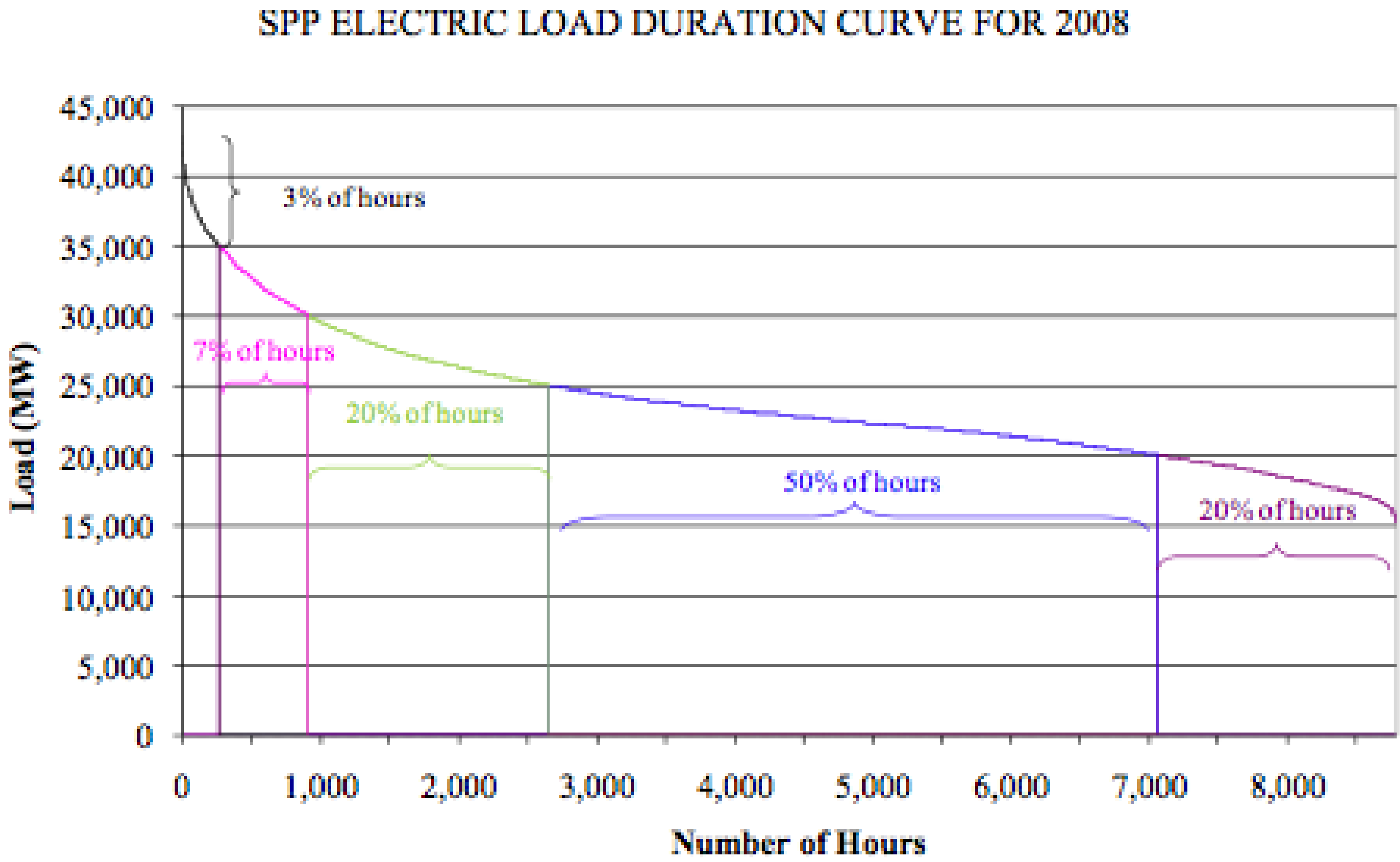


Electric System Fundamentals (2)

- Electricity demand ("load") must be dynamically balanced with supply
  - Electricity can't be stored in volume
    - Minor exceptions (e.g., pumped storage)
  - Every time a light, motor, or machine is turned on, its load must be satisfied by a power plant
  - Creates "peak load" capacity problems
    - Accompanying cost peaks, pollution peaks
  - Worse, peak load in U.S. growing faster than baseload, driven by air conditioning, especially homes

Electric System Fundamentals (2)

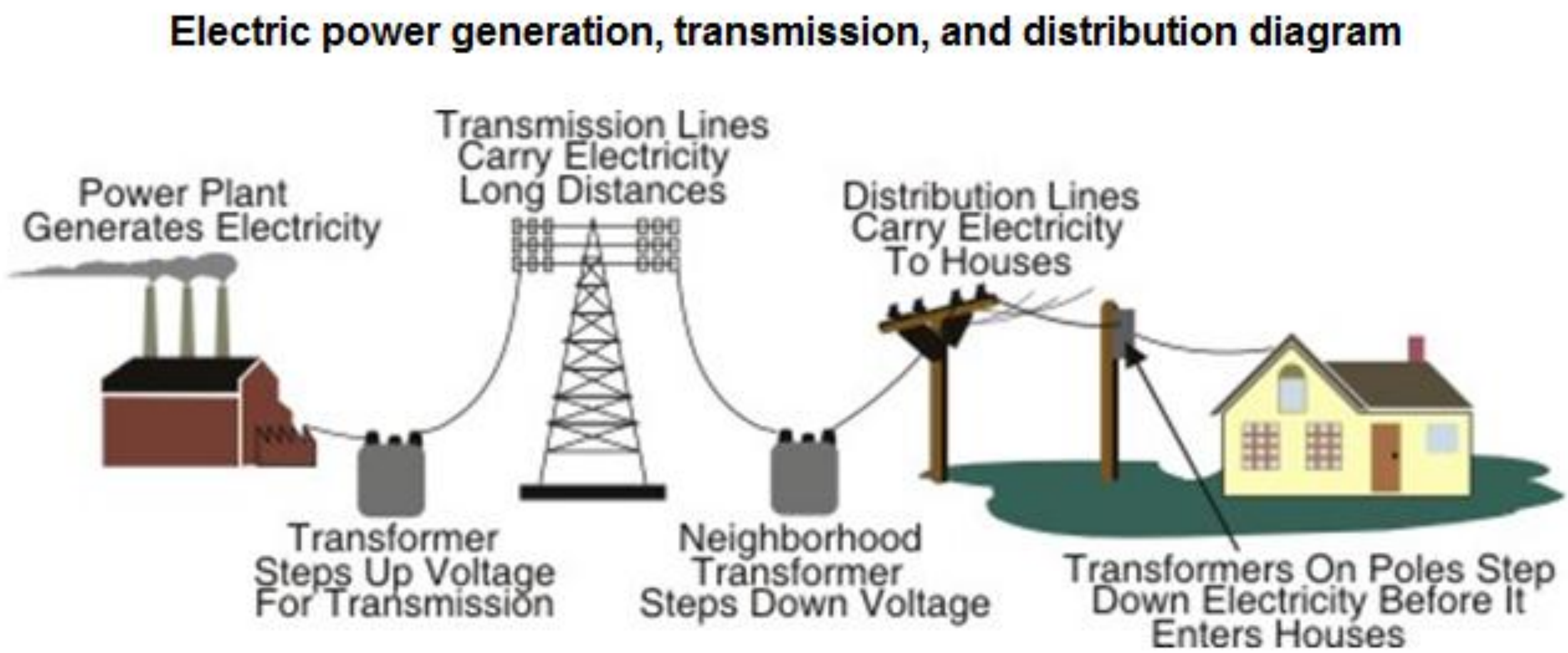
- Dynamic balancing historically achieved by intensive management of supply-side resources
  - Reserve capacity, spinning reserves, etc.
  - Instantaneous balancing through frequency regulation
- Increasingly addressed by "Demand-Side" measures:
  - Energy Efficiency - Usually reduces load permanently
  - "Demand Response" (DR) – Usually temporary load curtailment



SOURCE: SPP: Self-reported data by the members and eDNA

Electric System Fundamentals (3)

- Power plants can be close to the electrical loads they serve, but are often tens or hundreds of miles away.

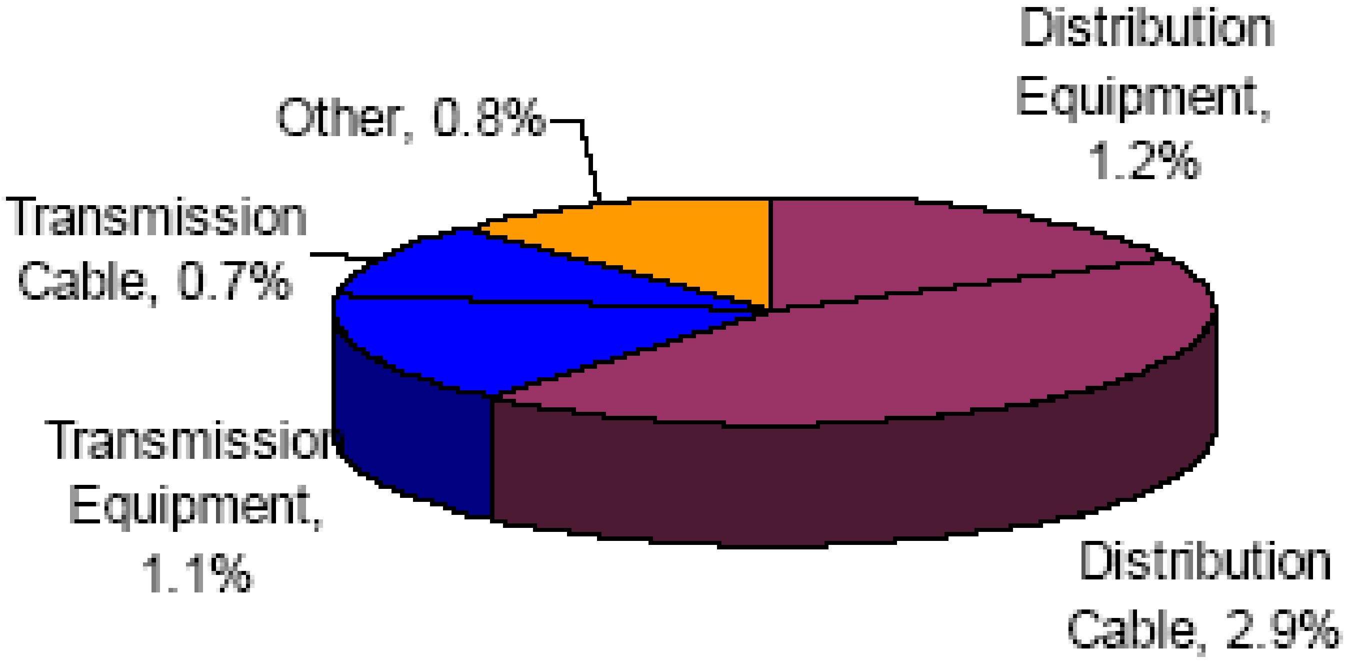


Source: EIA, National Energy Education Development Project
http://www.eia.gov/energyexplained/index.cfm?page=electricity_delivery

Electric System Fundamentals

- Transmission & Distribution (T&D) electric grid systems:
  - Impose T&D costs ($20-$30/MWH)
  - Impact reliability (i.e., imposes storm and other risks, requires maintenance, etc.)
  - Require additional generation due to "line losses" averaging at least 6-7%

Average Line Loss Components

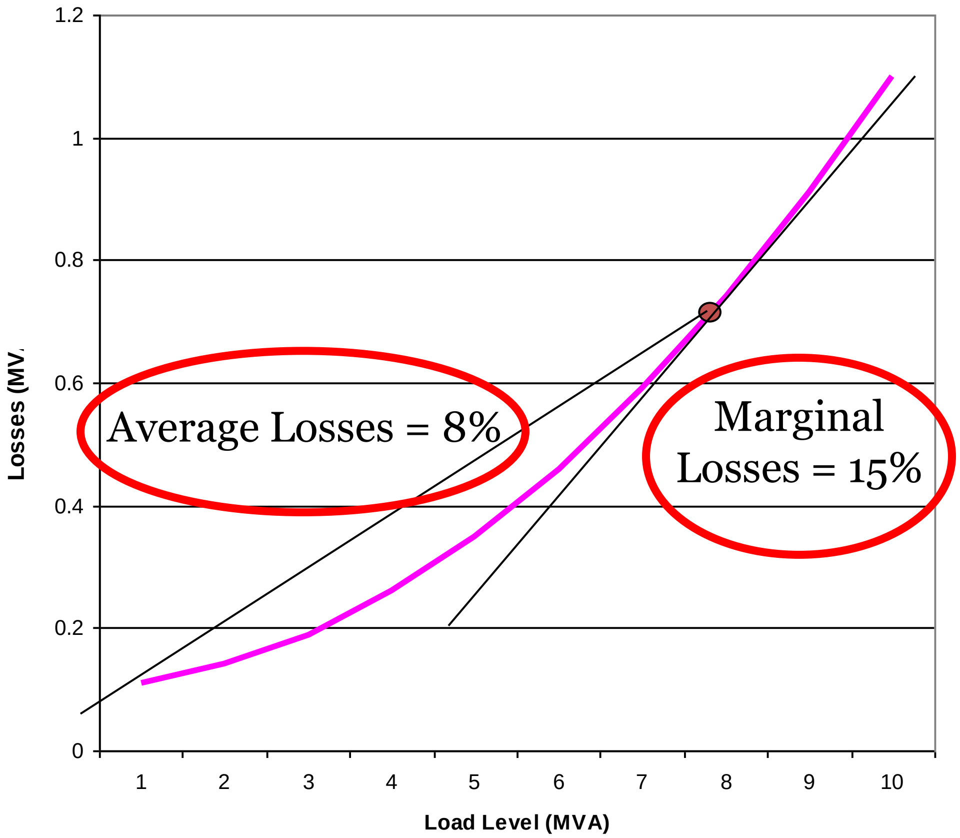


Source: ConEd

Marginal Energy Losses are Greater

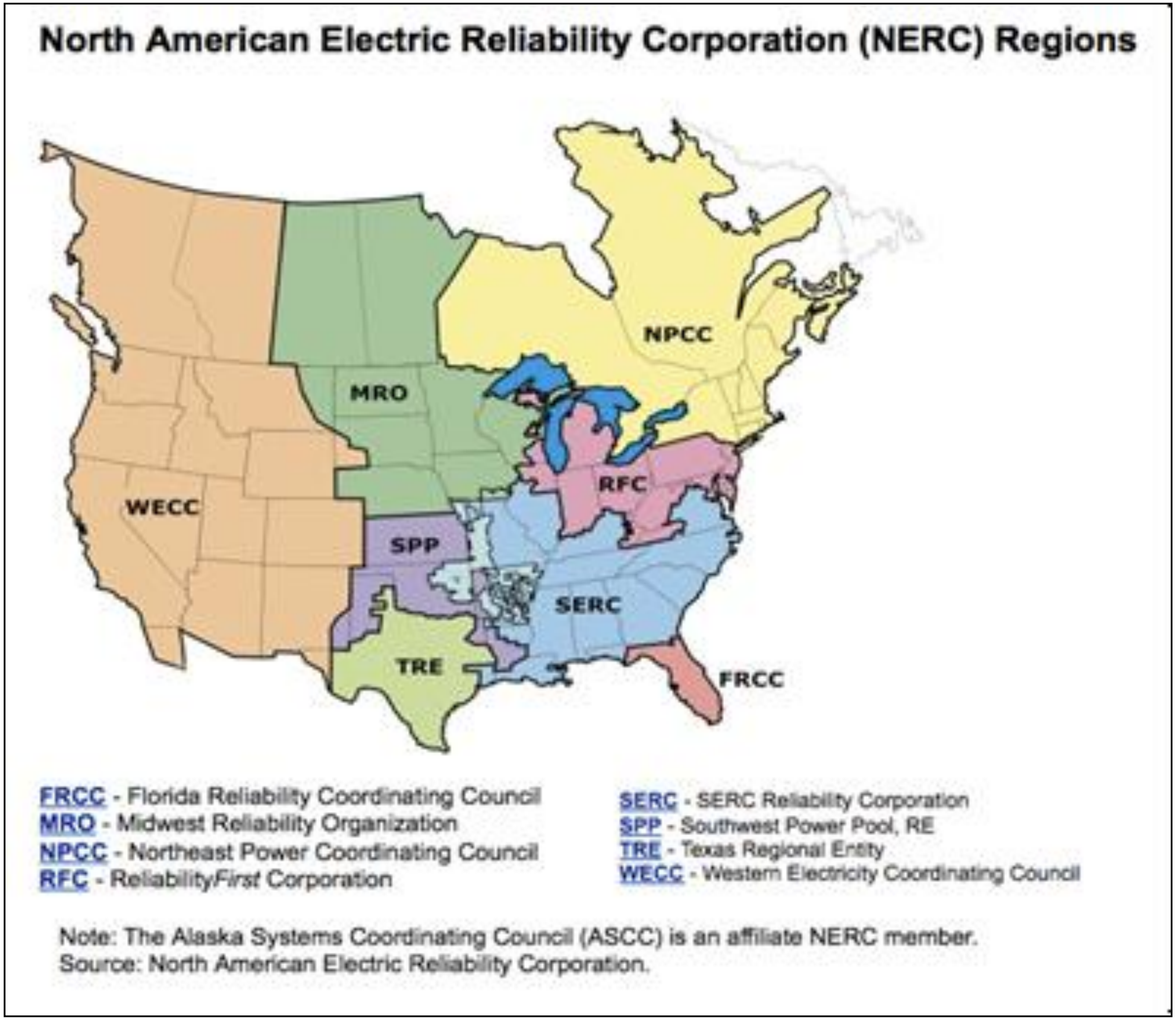
- Losses should be applied for both energy and capacity savings
- Average losses are typically used in ratemaking for recovery of losses
- Marginal losses measure the change in losses due to change in load
  - Approximately 2x average losses
- 'Average Marginal' losses are typical – the average of the marginal loss savings over a period of time

Example of Losses as Function of Load



Electric System Fundamentals (4)

- Electricity's Holy Grail: "Reliability"
- Analogous to "attainment of NAAQS" for air regulators
- Reliability means:
  1. Adequate generation capacity to meet peak load plus a margin of safety; and
  2. Reliable means to deliver it (T&D)



NERC:

- Develops & enforces reliability standards;
- Monitors the bulk power system;
- Assesses adequacy via forecasts;
- Audits owners, operators, and users for preparedness;
- Trains industry personnel;
- Helps ensure open access.

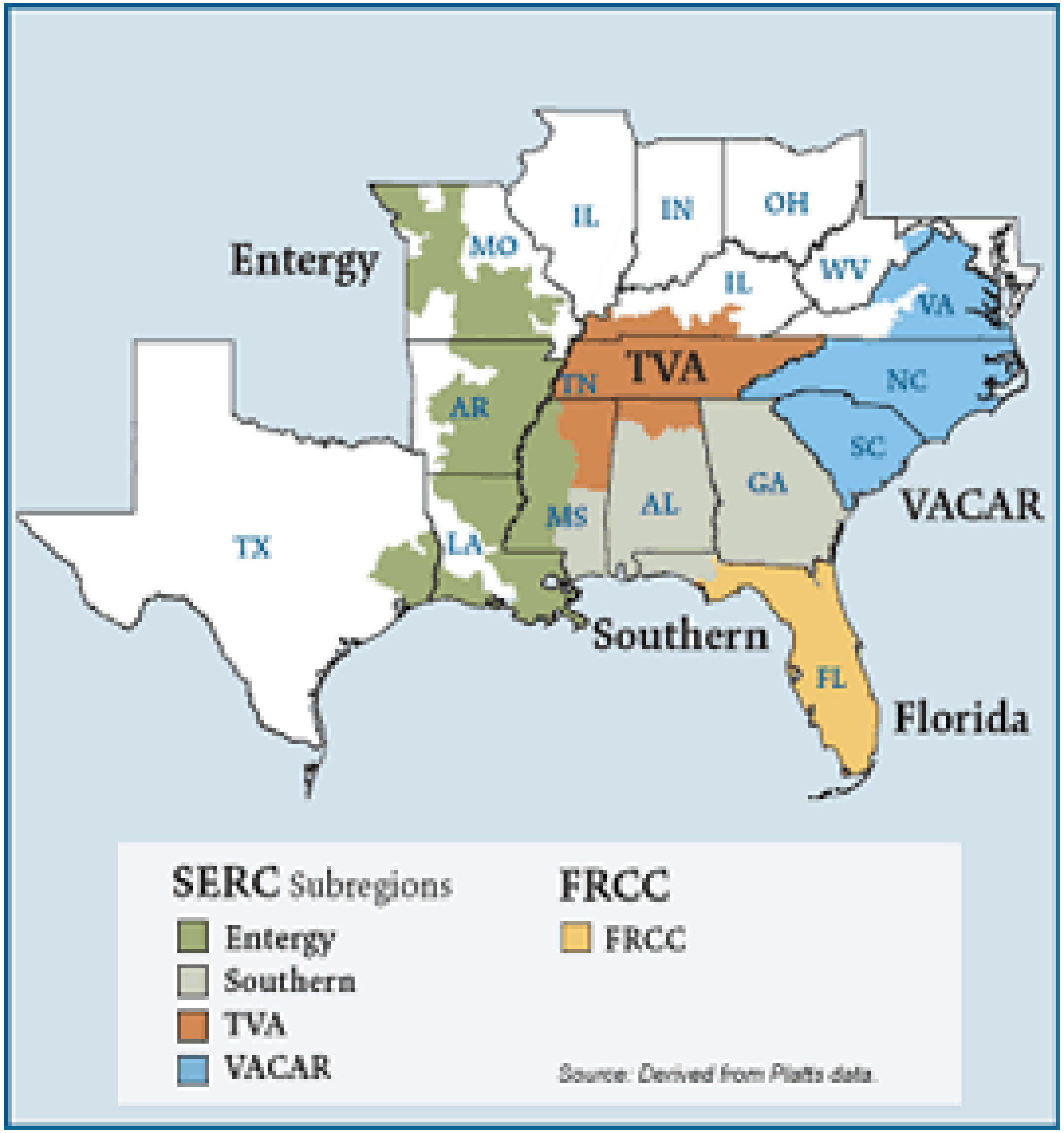
Planning Standard:

<1 day in 10 years

Regional Transmission Organizations (RTO) and Independent System Operators (ISO) responsible for meeting NERC reliability standards through transmission planning, ensuring generation capacity, and day-to-day grid operation (i.e., scheduling & dispatching power plants).

Non-RTO/ISO Areas

- Largely traditional utility-based reliability management

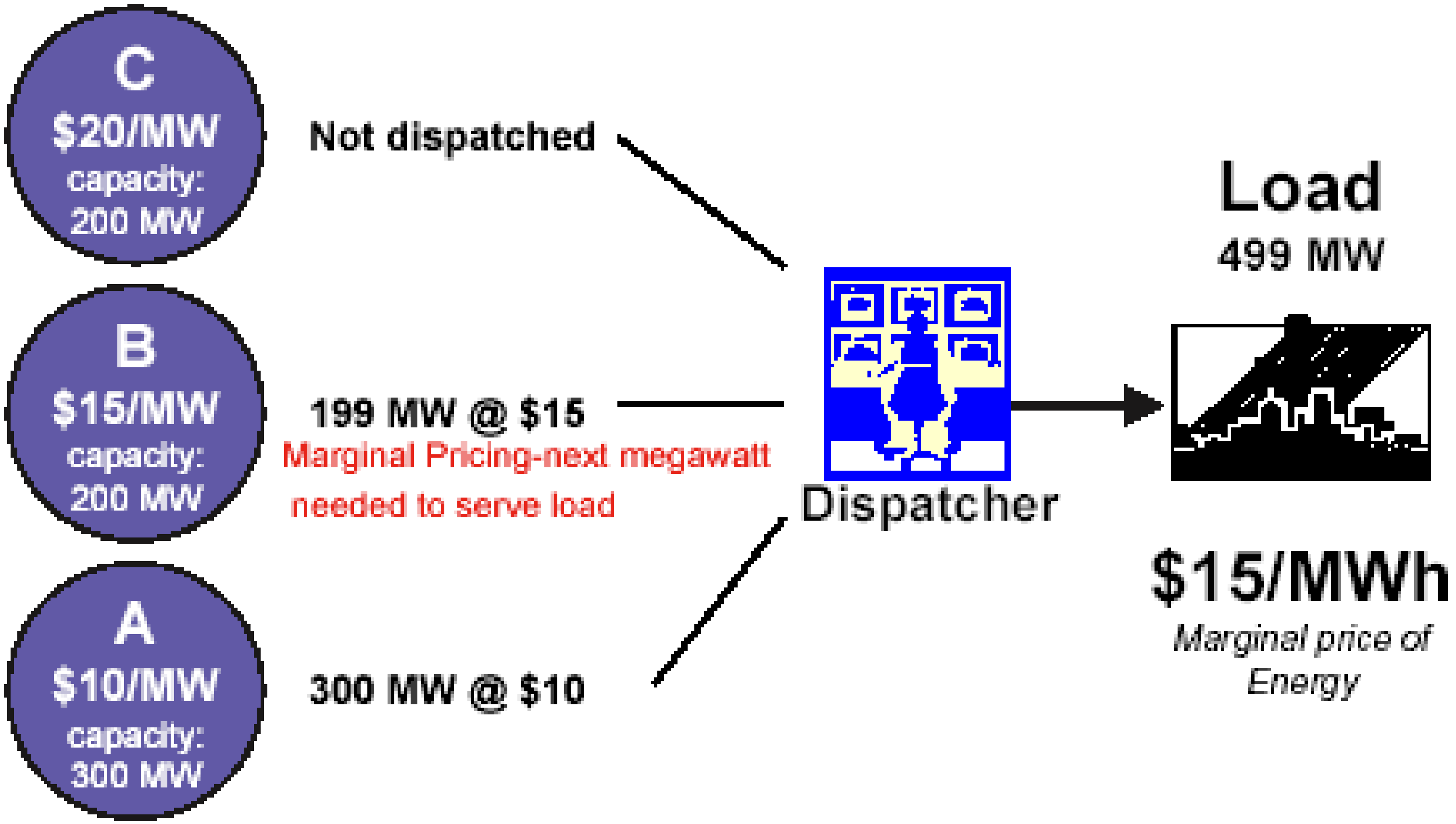


Market Clearing Prices & Economic Dispatch

- The bid price of the marginal unit necessary to satisfy the last bit of load is paid to <u>all</u> generators
- Avoids turmoil due to gaming, but…
- Small load changes at the margin, especially near peak loads, create very large cost differences
- System arguably benefits old, low-cost, high-emitting units
- Opportunity: "Demand Reduction Induced Price Effect" (DRIPE)

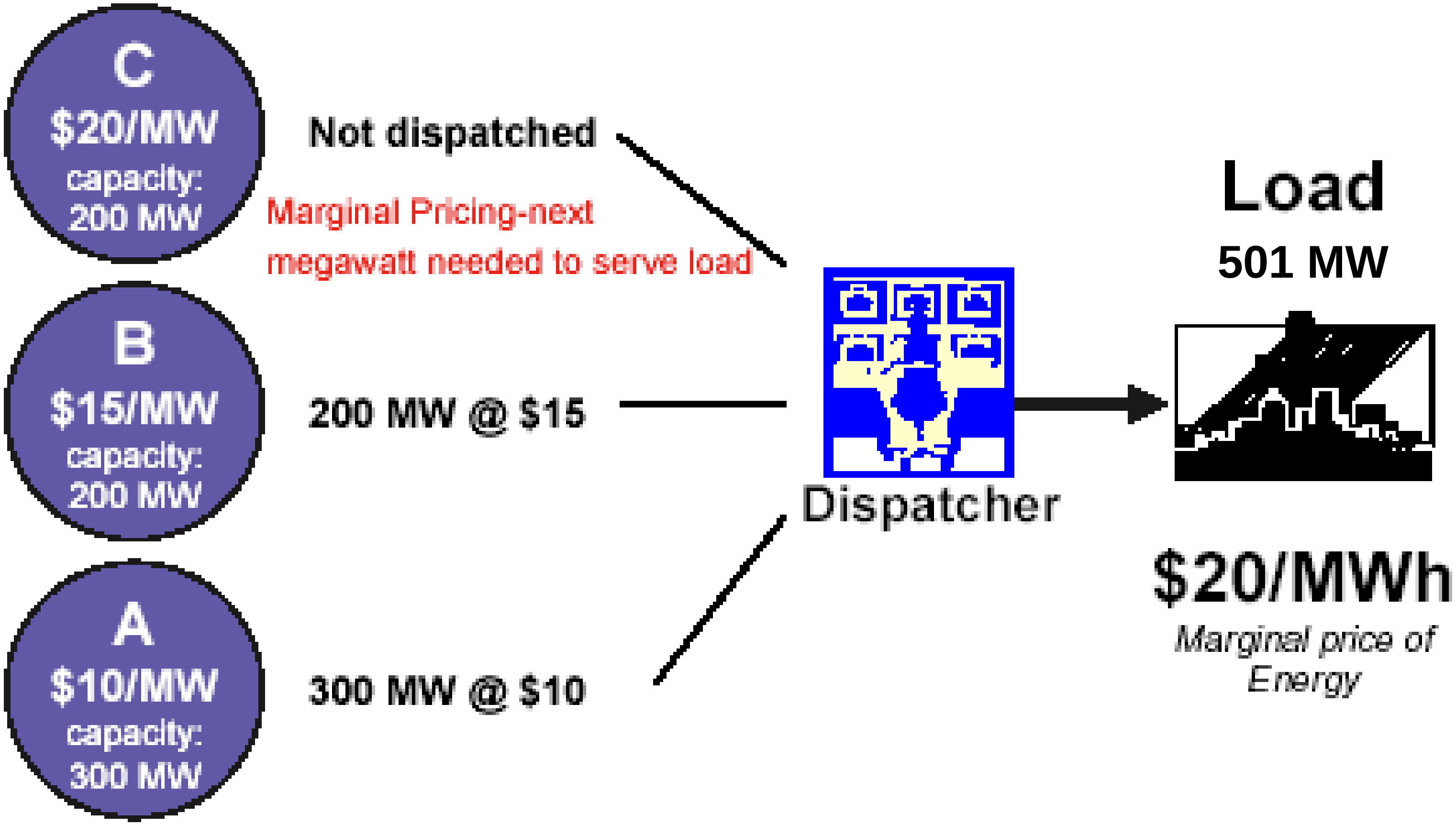
Economic Dispatch – Marginal Pricing

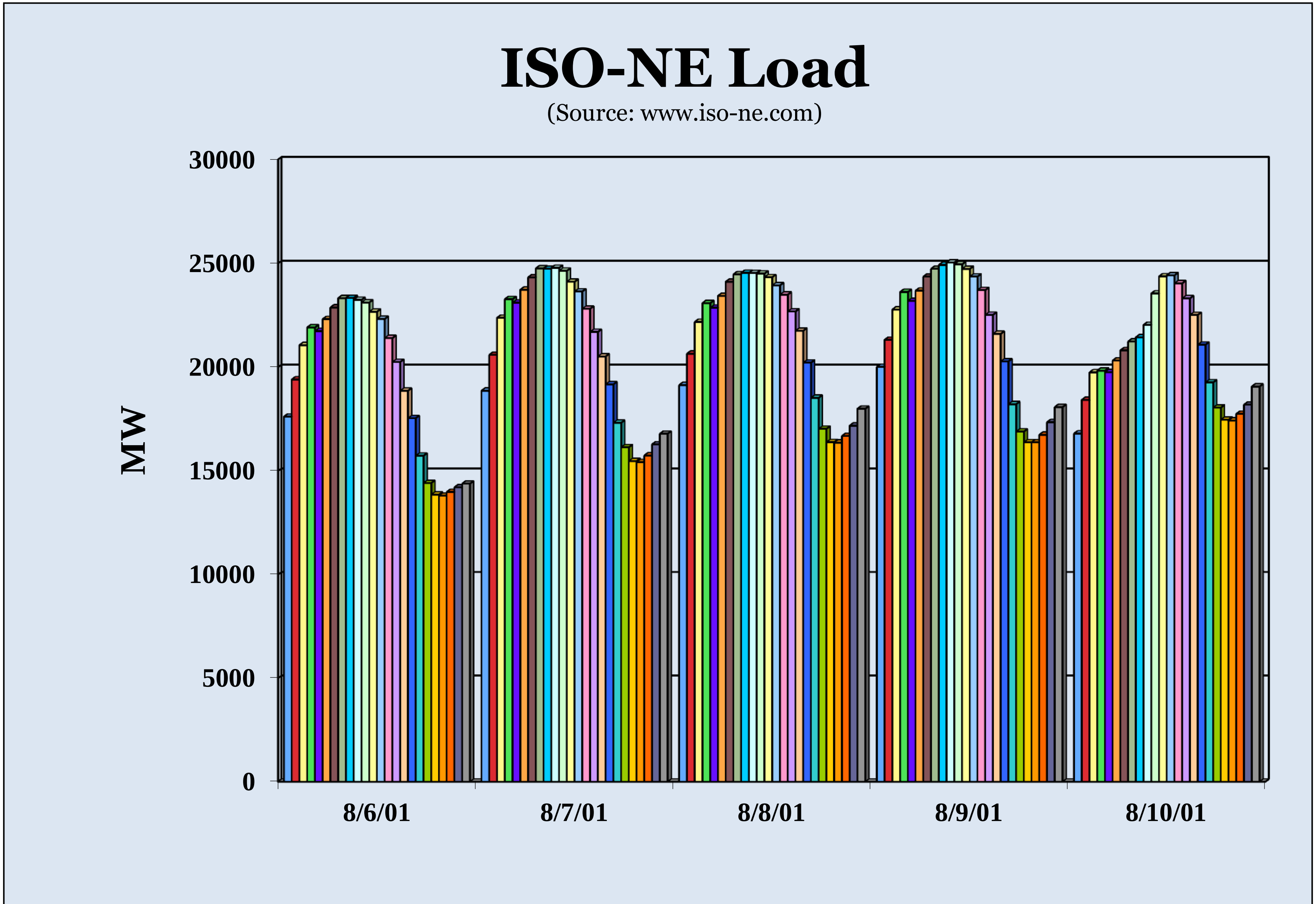
Highest-priced Generator is not dispatched.



Economic Dispatch – Marginal Pricing (cont.)

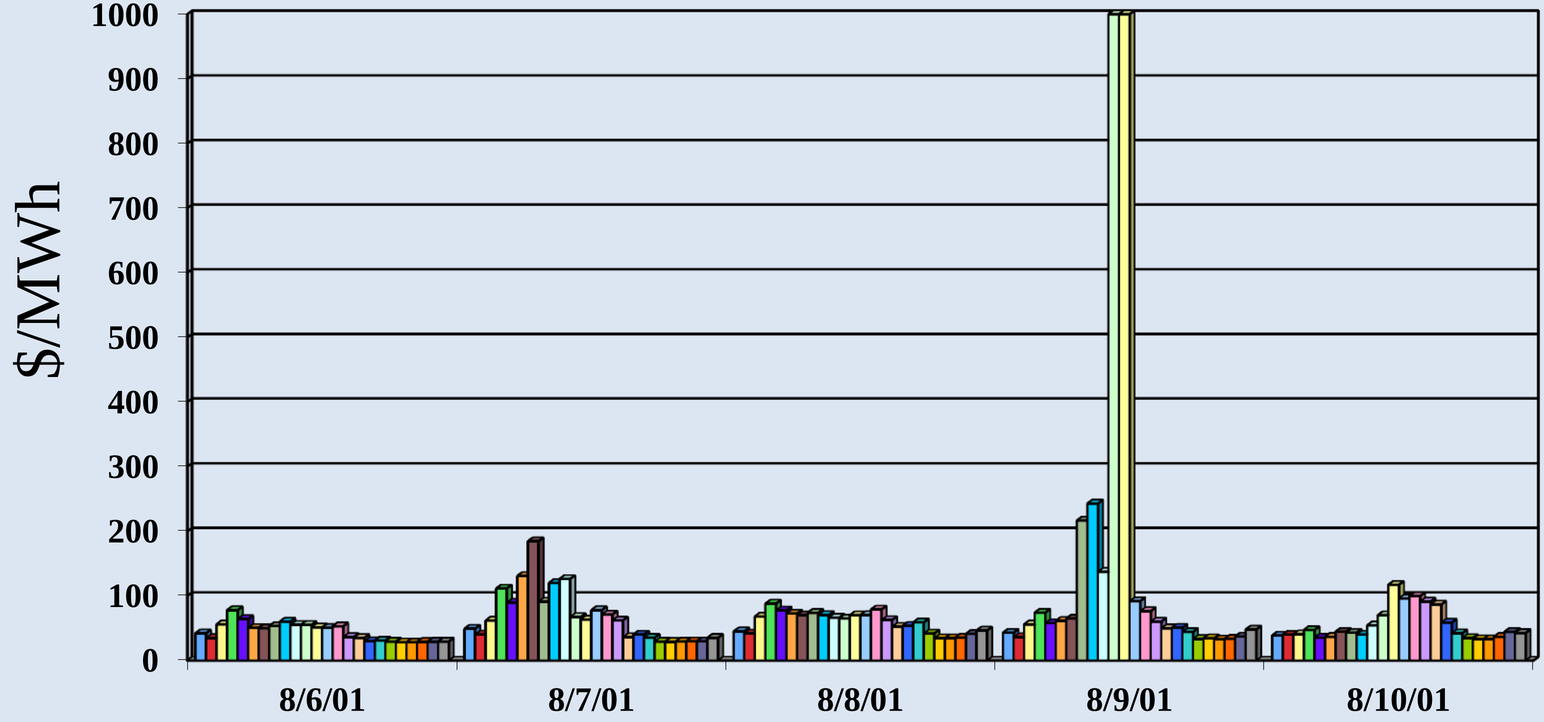
Highest-priced Generator sets price.




ISO-NE Load
(Source: www.iso-ne.com)
MW
30000
25000
20000
15000
10000
5000
0
8/6/01
8/7/01
8/8/01
8/9/01
8/10/01

Hourly Bids ISO-NE

(Source: www.iso-ne.com)



Economic Dispatch Problems

- Generators' bid prices don't include <u>all</u> costs, particularly environmental costs
  - Emissions are considered "externalities" and not valued
  - Additional benefits are also not valued, e.g., CHP's thermal energy
- Newer (often cleaner) plants bear greater depreciation costs, so dispatched less
- Special exceptions exist, e.g., "Reliability Must Run (RMR)"

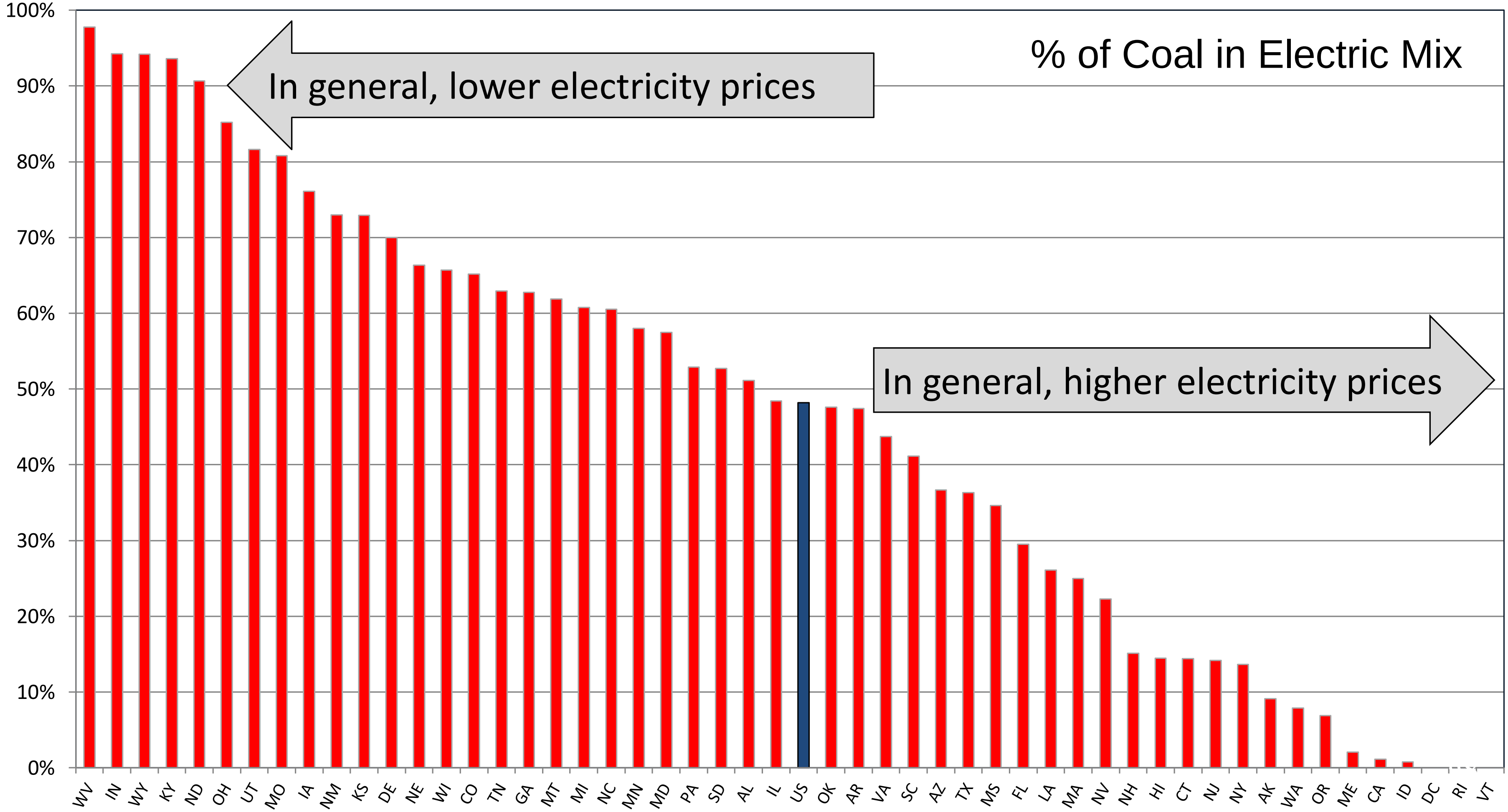
Economic Dispatch Opportunities

- Some states have adopted preferential "loading order" requirements
  - e.g., efficiency 1st , renewables 2nd , etc.
  - China is using "Efficiency Power Plants" in at least 5 provinces
- "Environmental dispatch"
  - In RAP terms, "*Clean First*"
  - China has implemented environmental dispatch using grid-telemetered CEMS-based SO_2 data

Electricity Rates (Prices) vs. Bills

- Public/political attention had been trained to focus on electric “rates” or “electricity prices,” but…
- Customers pay “bills,” not rates!

Electricity Prices Generally Lower in Coal Country



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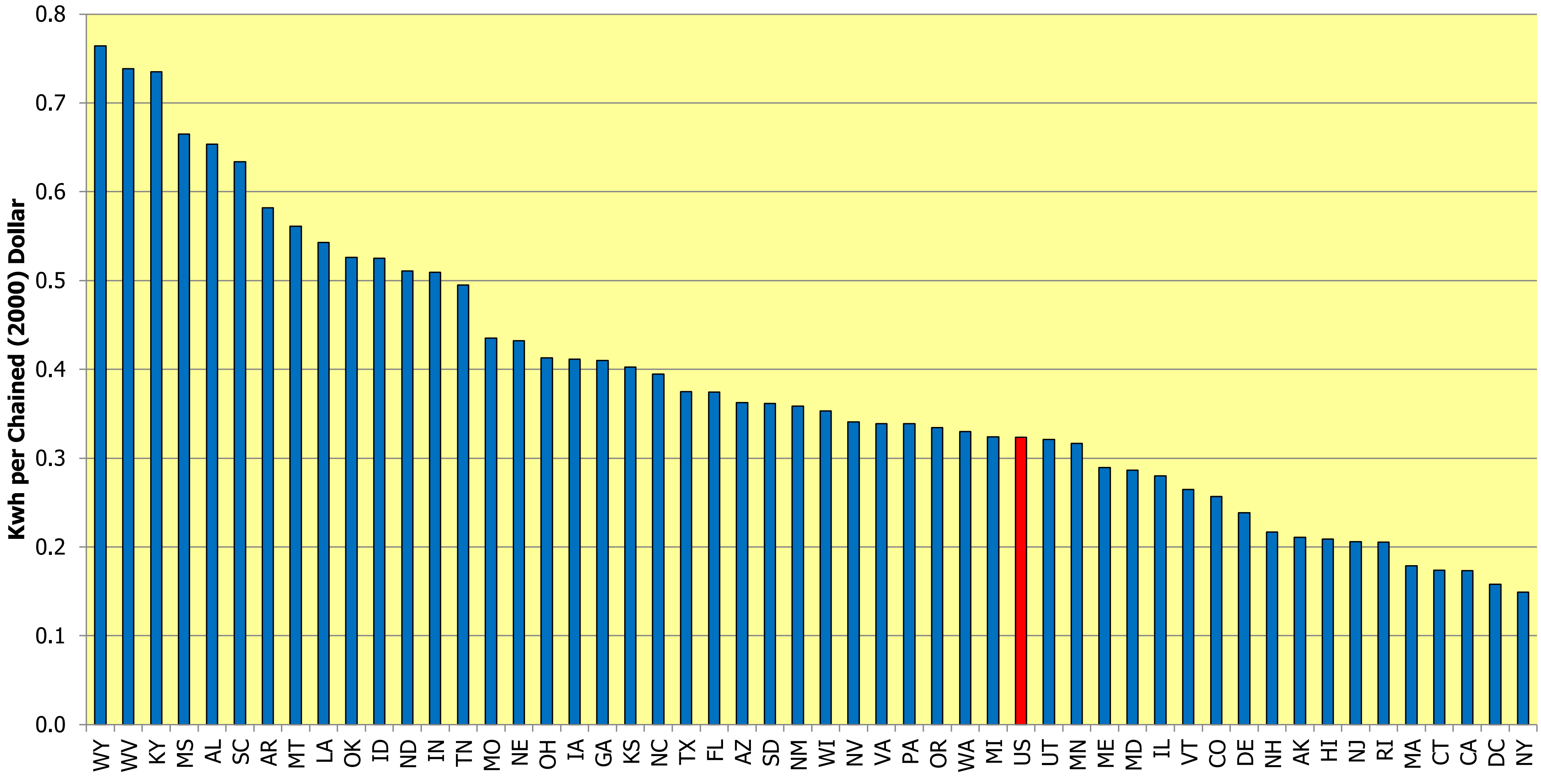
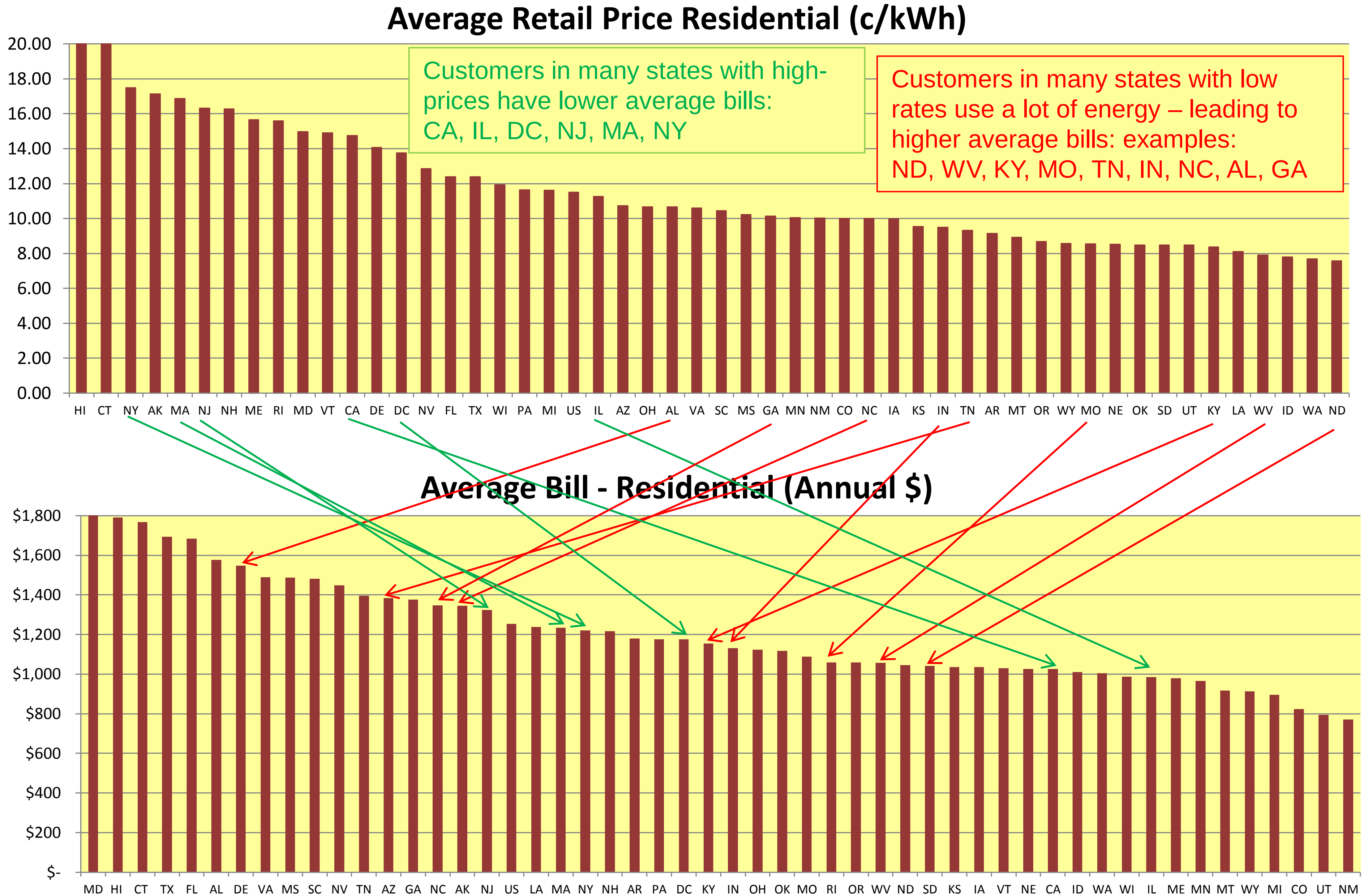
Retail Sales of Electricity per Dollar of GSP





Source: Sue Tierney, Analysis Group, 2011

Revenue Decoupling

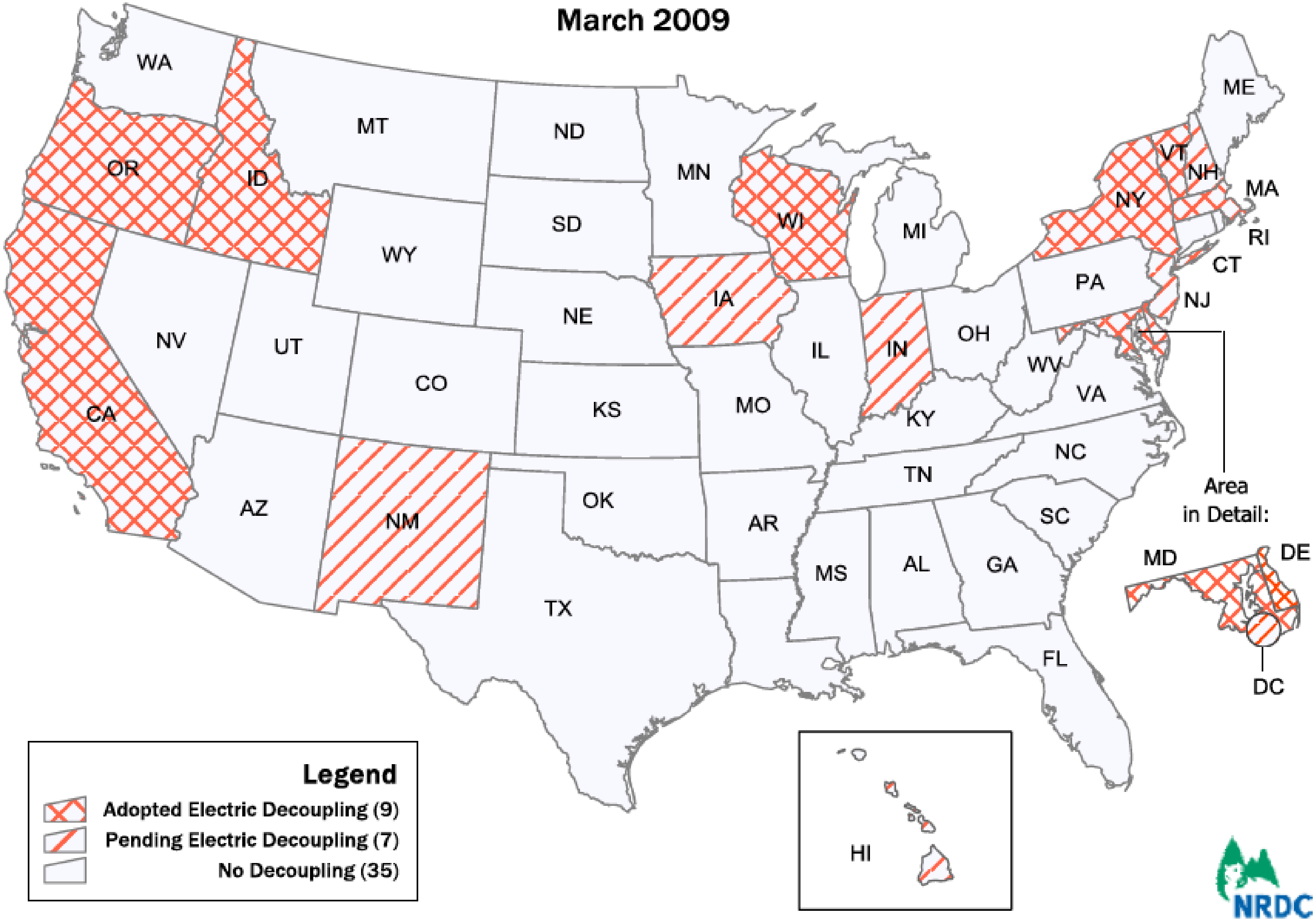
- Rates are normally set based on sales volumes and provide the revenue needed to cover costs plus a reasonable rate of return. If actual sales are higher or lower, rates are not adjusted in most cases.
  - Creates a "throughput incentive"
- Decoupling separates a utility's fixed cost recovery from the amount of electricity it sells.
  - Utilities are protected from sales declines due to efficiency, so are more likely to invest it (or less likely to resist)

How Changes in Sales Affect Earnings

	Revenue Change		Impact on Earnings		
% Change in Sales	Pre-tax	After-tax	Net Earnings	% Change	Actual ROE
5.00%	$9,047,538	$5,880,900	$15,780,900	**59.40%**	17.53%
4.00%	$7,238,031	$4,704,720	$14,604,720	**47.52%**	16.23%
3.00%	$5,428,523	$3,528,540	$13,428,540	**35.64%**	14.92%
2.00%	$3,619,015	$2,352,360	$12,252,360	**23.76%**	13.61%
1.00%	$1,809,508	$1,176,180	$11,076,180	**11.88%**	12.31%
0.00%	$0	$0	$9,900,000	**0.00%**	11.00%
-1.00%	-$1,809,508	-$1,176,180	$8,723,820	**-11.88%**	9.69%
-2.00%	-$3,619,015	-$2,352,360	$7,547,640	**-23.76%**	8.39%
-3.00%	-$5,428,523	-$3,528,540	$6,371,460	**-35.64%**	7.08%
-4.00%	-$7,238,031	-$4,704,720	$5,195,280	**-47.52%**	5.77%
-5.00%	-$9,047,538	-$5,880,900	$4,019,100	**-59.40%**	4.47%

Electric Decoupling in the US

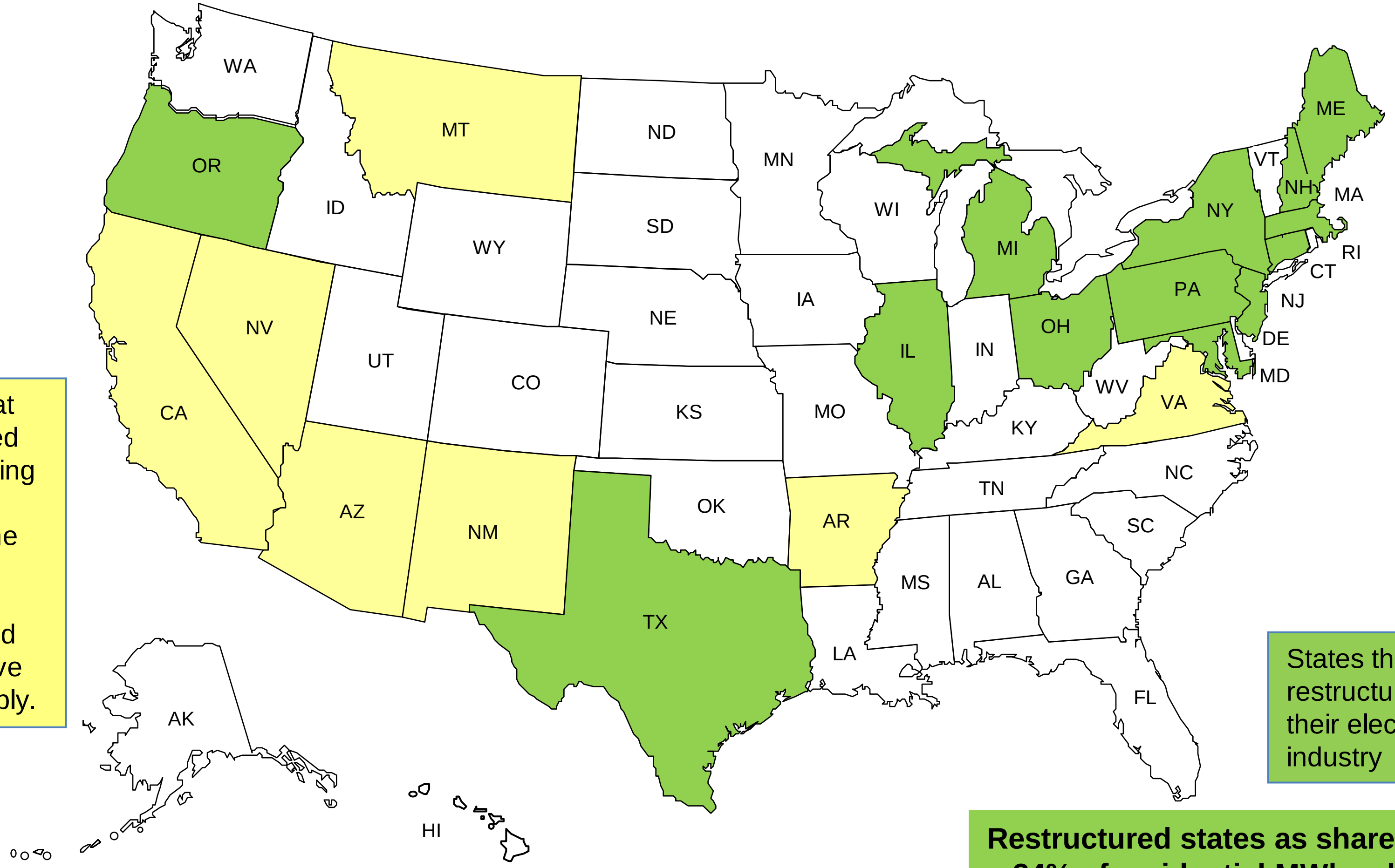
March 2009



Utility Restructuring or Deregulation

- THEN: Central generating stations and T&D systems (poles & wires) were "natural monopolies," thus regulated
- NOW: New options for electric generation (financial, technological, operational) enable "merchant generation" – generation is no longer a "natural monopoly" and should be a competitive market
  - And retail choice enables customers to "shop" for generation
- T&D is still a natural monopoly, so "wire companies" remain regulated
- DG threatens more, faster change

States with Restructured Retail Electric Markets



States that suspended restructuring – and still have some residual customer choice and competitive retail supply.

States that restructured their electric industry

Restructured states as share of U.S.:
= 34% of residential MWh sales
= 38% of commercial sales

Source: EIA, as of September 2010.

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Some Impacts of Deregulation

- Utility "Integrated Resource Planning" (IRP) often abolished or weakened
- System benefits charge (SBC) for EE, low-income aid, etc. weakened or restructured
- No automatic recovery of pollution control costs
- New approaches were needed to ensure "resource adequacy" or "capacity"

Future of Deregulation?

- Progress came to a halt with California's 2000-2001 experience
  - Poor policy design, plus Enron's "market manipulation"
- Technological, financial pressure building for further progress

Federal & State Roles (1)

"Electricity is a political issue the world over, but especially so in _[nation]_. The debate over reform pits the central government against regional governors. Although _[nation]_ controls wholesale electricity tariffs, the governors control retail prices. They are adamant about keeping this power so they can protect industries to which they have ties. Moreover, they are determined to maintain low electricity prices for households, …

… which pay about $2 a month to keep their lights on, roughly the price of a cheap bottle of vodka."

Source: RFF, Brennan, April 2003, citing *The Economist*, Aug. 31, 2002.

Federal & State Roles (2)

- Federal Energy Regulatory Commission
  - Wholesale electricity markets, i.e., interstate transmission, market design, pricing, etc.
  - Some authority (as yet largely unexercised) over transmission siting
  - Groundbreakers:
    - 1996 Order 888 (open access)
    - 1999 Order 2000 (RTOs)
    - 2011 Order 1000 (include "policy considerations" in planning)

Federal & State Roles (3)

- States (via Legislatures and Public Service Commissions):
  - Construction approval and siting
  - Retail rates
  - Whether, when, and how choice of energy provider is offered
  - *Note: State PUCs generally have strong authority over IOUs but weak or no authority over municipal electric utilities and electric cooperatives.*

Federal & State Roles (4)

- Note key differences in fed vs. state; energy vs. environment
  - Environment (AQ) – Strong federal oversight
    - Federal (EPA) delegation; within federal law & regs; subject to review & approval (SIPs)
  - Energy – Complete freedom at retail
    - History of state initiative/leadership
    - EE, RE (RPS), siting, etc.

Agency Roles & Operation

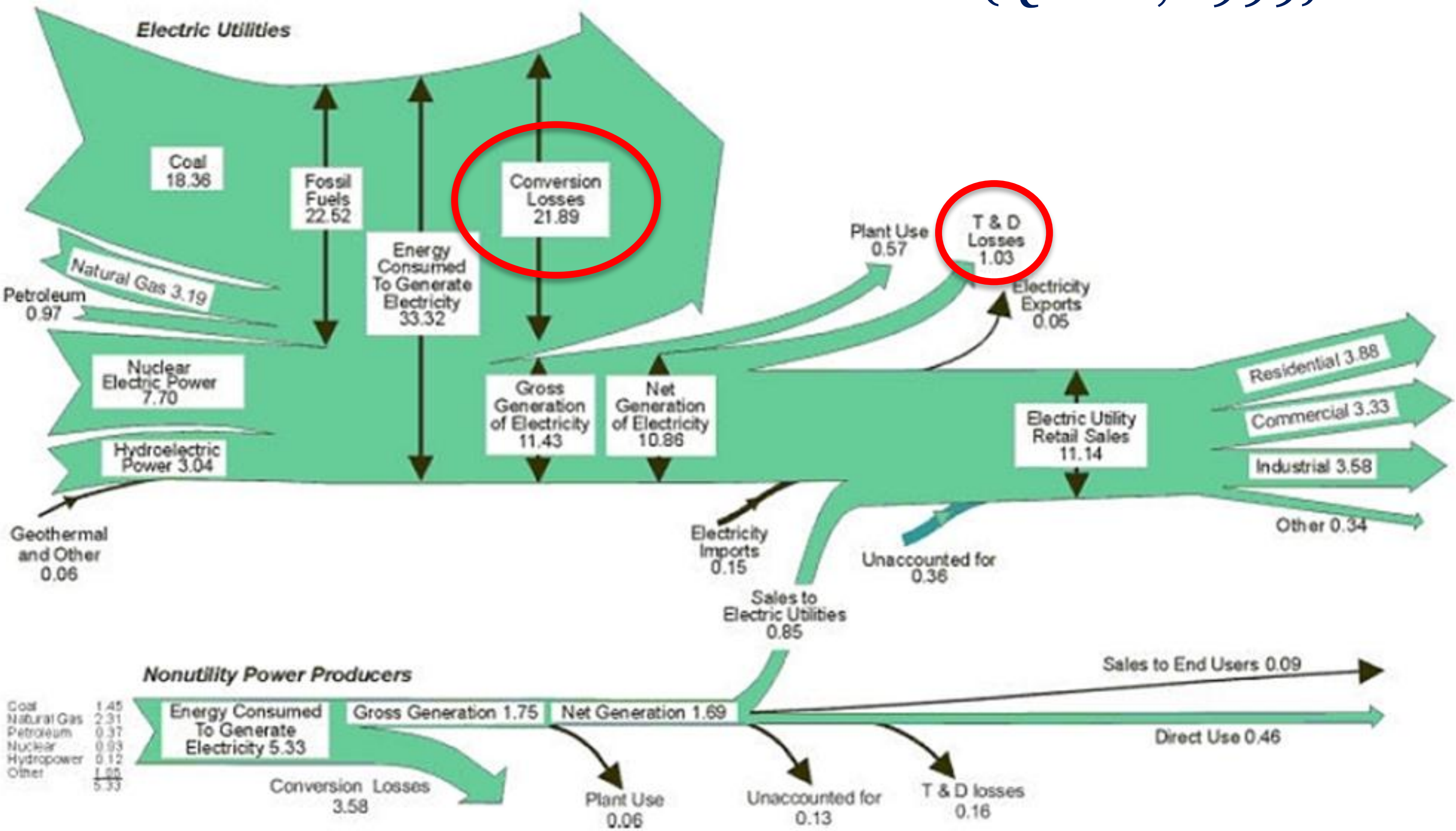
- PSCs:
  - Formal, quasi-judicial docket processes
- DEPs:
  - Delegated authority (primarily)
  - Notice-and-comment rulemaking
- SEOs:
  - Typically non-regulatory; "everything else"
  - Key implementing arms (e.g., ARRA); lead-by-example; research, review, and report issues & opportunities; assist economic development

What's the "Take Home" Message for AQ? (1)

- Peak AQ concerns (O_3) coincide with peak power days
- On the margin at peak:
  - – Generation to meet load: 1.00
  - – Line losses (@ ~1.5x): up to 0.20
  - – Generation efficiency loss: 0.03
  - – Capacity: 0.20
- ~1.5 EGUs operating to deliver 1.0 of power

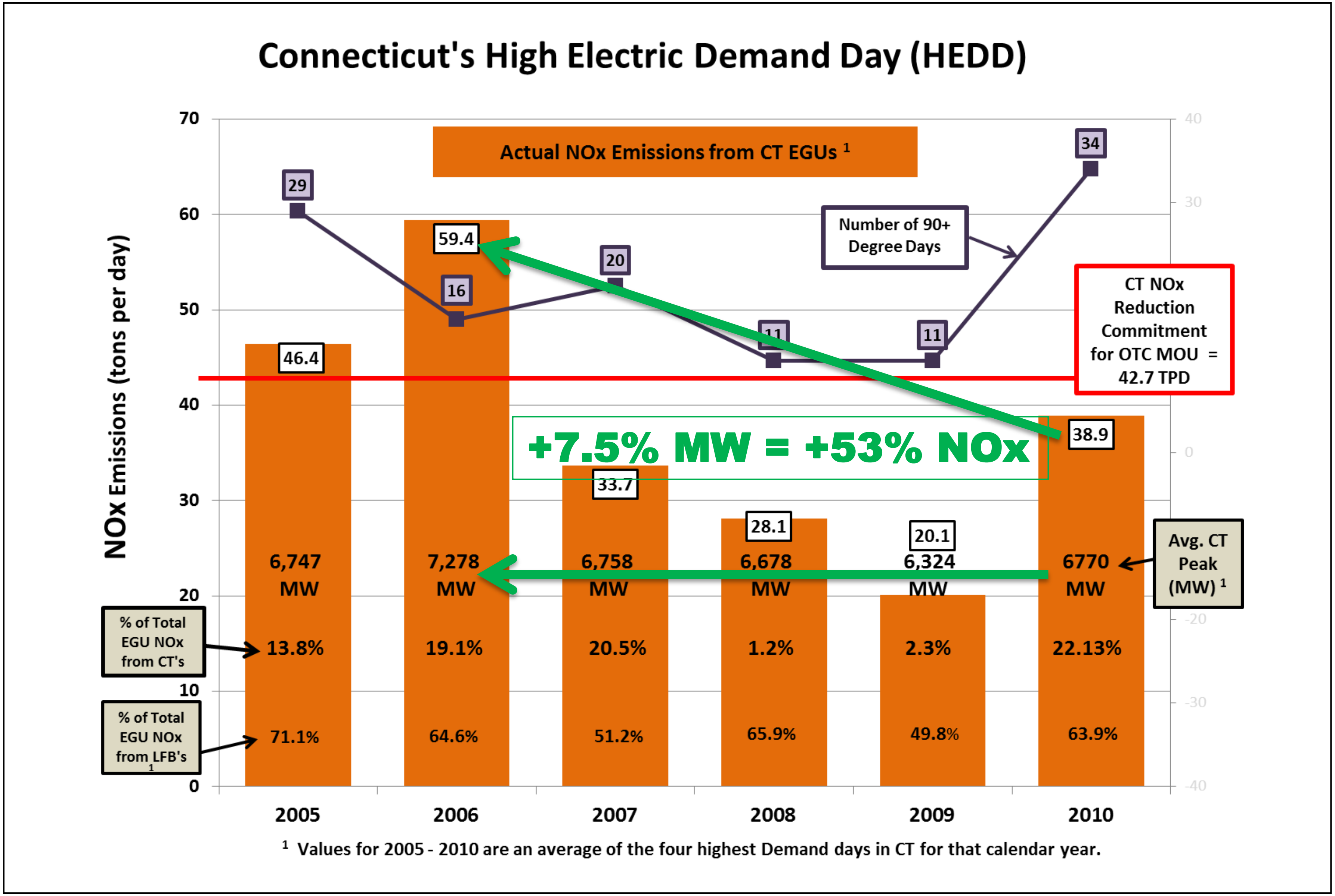
EIA Electricity Flow Diagram

(Quads, 1999)



What's the "Take Home" Message for AQ? (2)

- ~1.5 EGUs => 4.5 (3x) emissions due to conversion losses
- Plus, meeting peak load requires that higher-emitting EGUs run…


Connecticut's High Electric Demand Day (HEDD)
Actual NOx Emissions from CT EGUs [1]
NOx Emissions (tons per day)
70
60
50
40
30
20
10
0
40
30
0
-20
-30
-40
29
16
20
11
11
34
Number of 90+ Degree Days
59.4
46.4
33.7
28.1
20.1
38.9
CT NOx Reduction Commitment for OTC MOU = 42.7 TPD
+7.5% MW = +53% NOx
6,747 MW
7,278 MW
6,758 MW
6,678 MW
6,324 MW
6770 MW
Avg. CT Peak (MW) [1]
% of Total EGU NOx from CT's
13.8%
19.1%
20.5%
1.2%
2.3%
22.13%
% of Total EGU NOx from LFB's [1]
71.1%
64.6%
51.2%
65.9%
49.8%
63.9%
2005
2006
2007
2008
2009
2010
[1] Values for 2005 - 2010 are an average of the four highest Demand days in CT for that calendar year.

Is there any question why it’s important for EPA and the states to encourage EE/RE/DR in environmental & energy regulation?

(and we haven’t even touched on savings, jobs, competitiveness or security benefits yet…)

Question & Answer Period

- Thank You!

About RAP

The Regulatory Assistance Project (RAP) is a global, non-profit team of experts that focuses on the long-term economic and environmental sustainability of the power and natural gas sectors. RAP has deep expertise in regulatory and market policies that:

- Promote economic efficiency
- Protect the environment
- Ensure system reliability
- Allocate system benefits fairly among all consumers

Learn more about RAP at www.raponline.org

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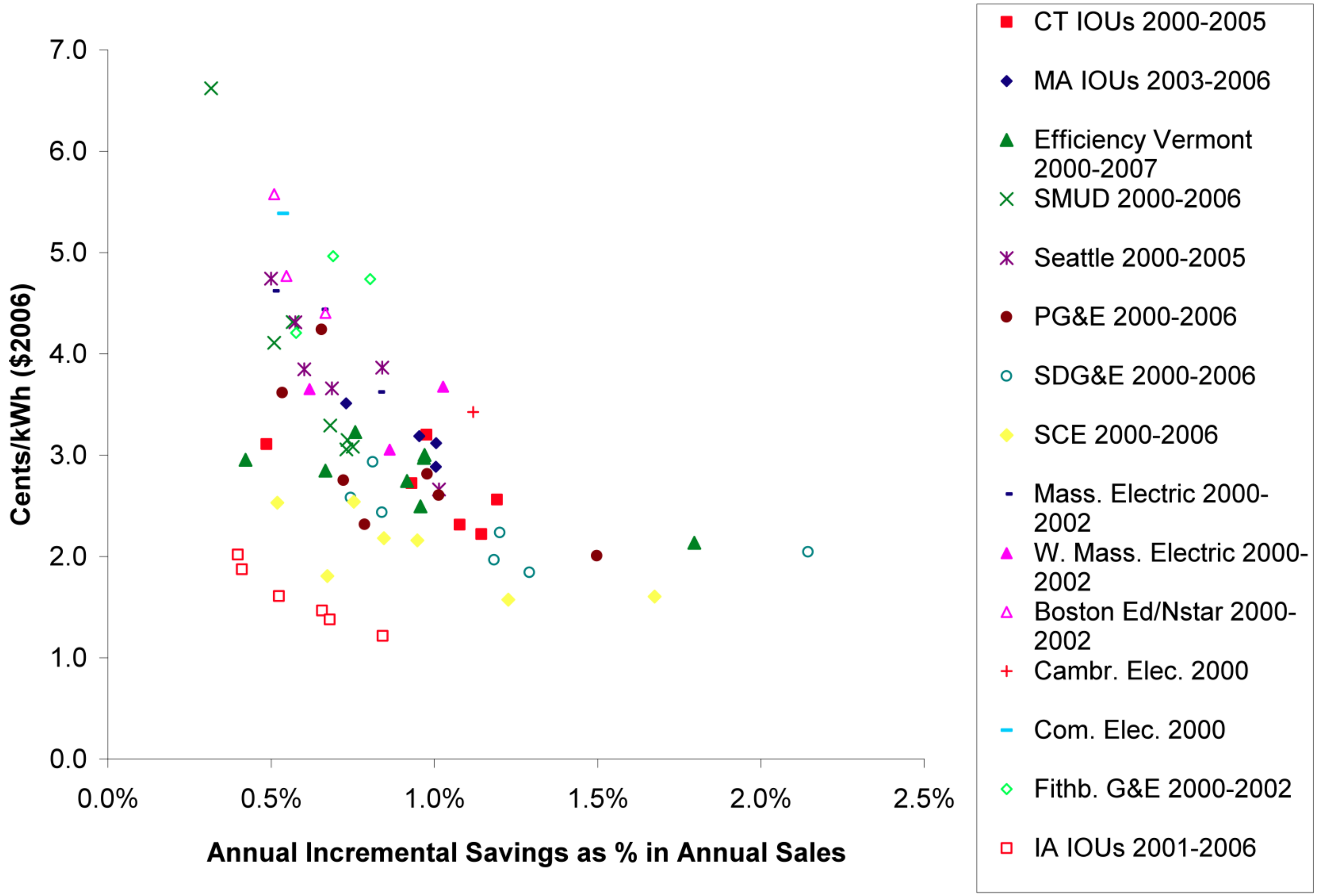
Additional Slides

“BHAG” vs. the Cost of Saved Energy



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