Energy, Capacity, Renewables, CO_2, & Transmission Rights:
What's Happening in US Markets

Benjamin F. Hobbs

Theodore K. and Kay W. Schad Professor of Environmental Management
Director, Environment, Energy, Sustainability & Health Institute
Whiting School of Engineering , The Johns Hopkins University

Chairman, Market Surveillance Committee
California Independent System Operator

Research Associate
Electricity Policy Research Group, University of Cambridge

KU Leuven, 15 December 2011

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C. De Jonghe, R. O'Neill , S. Oren, W. Hogan for their collaboration

Mark Twain:

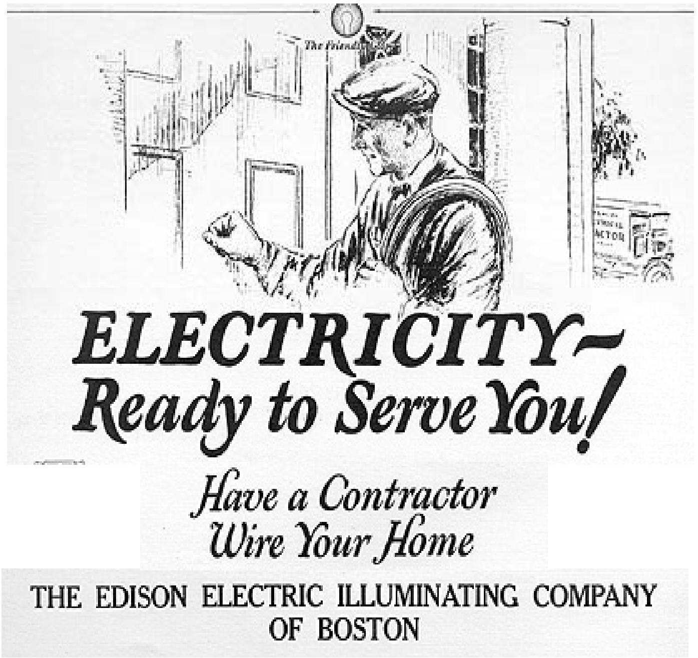
“The researches of many commentators have already thrown much darkness on the subject

….. and it is probable that, if they continue, we shall soon know nothing at all about it”

(thanks to Dick O’Neill for the quote)

Outline

1. History
2. LMP
3. Renewable Integration
   – Dispatch flexibility
   – Transmission construction
4. Capacity Markets
5. Greenhouse Gas Regulation
6. Financial Transmission Rights



1. A Brief History of US Regulation & Restructuring

- **400 BC: Athens city regulates flute & lyre girls**
- **1978: Public Utilities Regulatory Policy Act**
- **1978: Schweppe's "Power Systems 2000" article**
- **Federal:**
  - **1992 US Energy Policy Act**
  - **FERC Orders 888, 2000**
  - **FERC "Standard Market Design"**

- **States:**
  - **California leads 1995**
  - **Most states were following**
  - **Response to California 2000-01: "*Whoa!!*"**
  - **Response to FERC SMD, Fuel price increases**

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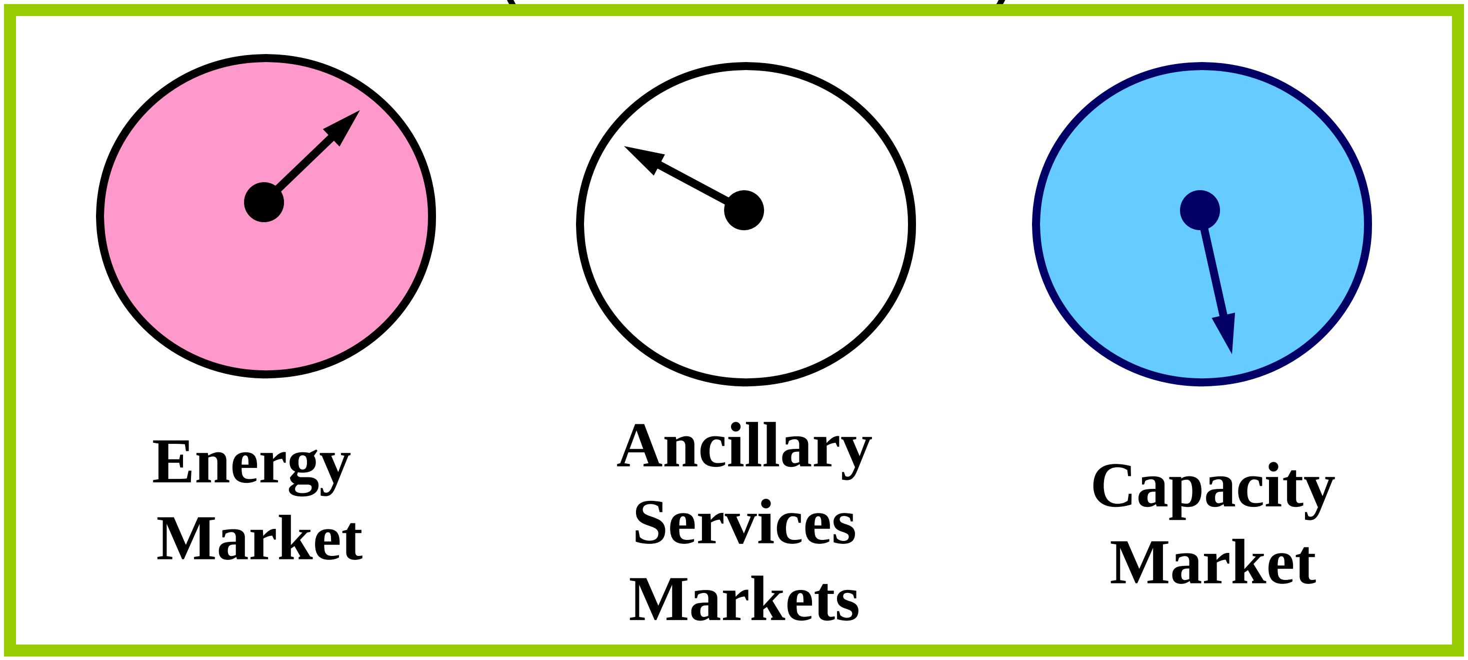
Lessons Learned from California?

- **Restructuring: “Unsafe at any speed”?**
  (Pryce C. Watts, Elect. J. 2002)
  - *Can we competently deregulate?*
  - *Analogy:*

    “Communism didn’t fail in Poland, they just didn’t do it right”
- **More constructive (yet naïve?) approach:**
  - *Incremental; cautious experiments*
  - *Avoid over-simplicity--and over-complexity*
  - *Capacity markets as confidence builder*
  - *Market power: it’s real, be proactive*
  - *Anticipate problems (models, lab experiments, learn from others’ mistakes)*

Design Choices

Key to Power Market Design: *Balance the Three Dials*
(thanks to Steve Stoft)



- Dials: scarcity pricing, market power mitigation rules, …
- Settings should:
  - ***Prevent market power abuse***
  - ***Provide appropriate investment incentives***
    - **<u>Ample</u> when generation shortage**
    - **<u>Absent</u> under surplus**

April 2003: "S~~tandard Market Desi~~gn"
"Wholesale Power Market Platform"

FERC's mea culpa:

"The proposed rule was too prescriptive in substance and in implementation timetable, and did not sufficiently accommodate regional differences"

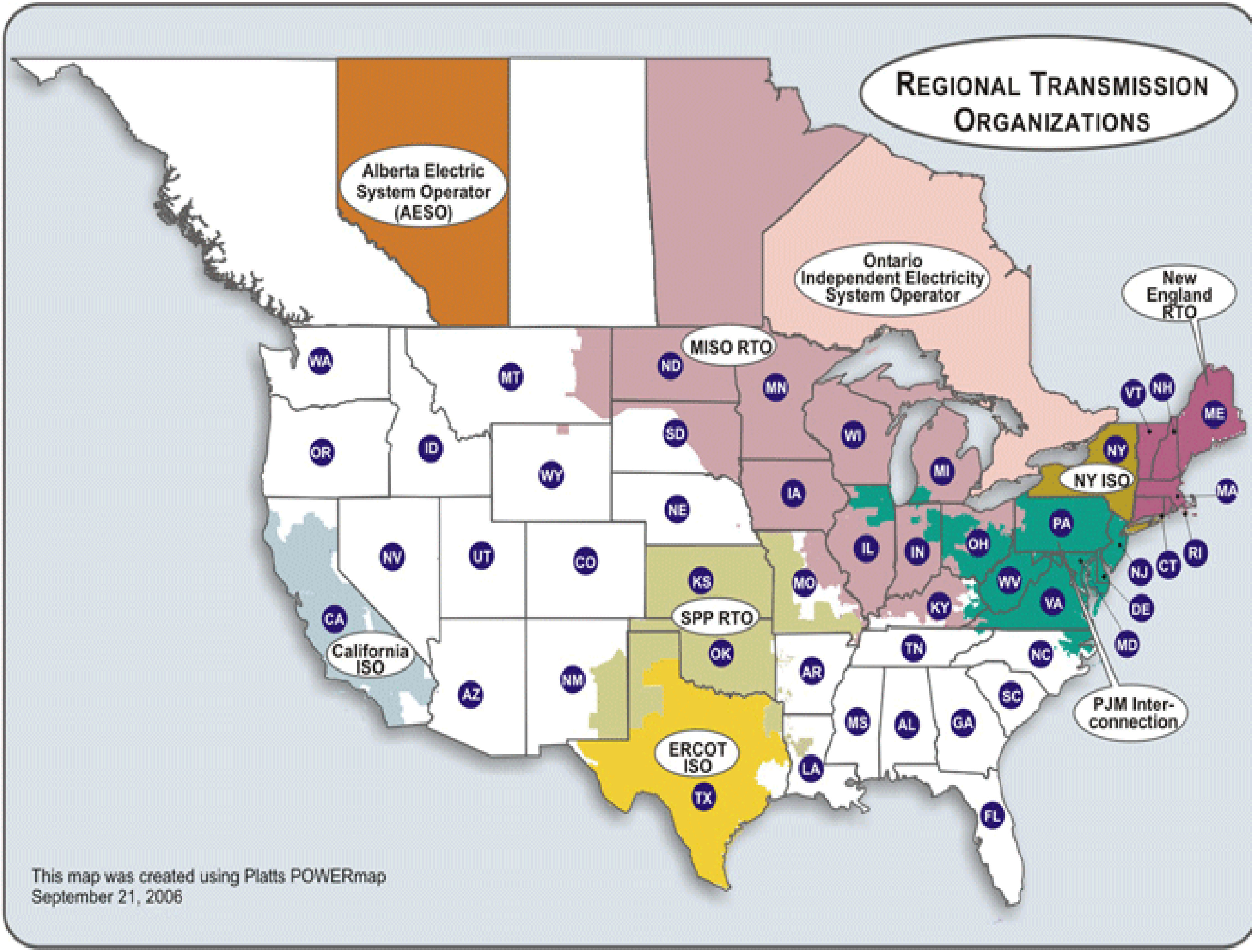
"Specific features … infringe on state jurisdiction"

Market Design Principles of “Platform”

1. Grid operation:
   - Regional
   - Independent
2. Spot markets:
   - Day ahead & balancing
   - Integrate energy, ancillary services, transmission
   - Congestion Pricing
3. Market power:
   - Local mitigation
   - Monitoring

More Principles of “Platform”

4. Firm transmission rights:
   – Financial, not physical
   – Don’t need to auction
5. Generation capacity adequacy:
   – State led
6. Grid planning:
   – Regional
   – State and stakeholder led


REGIONAL TRANSMISSION ORGANIZATIONS
Alberta Electric System Operator (AESO)
Ontario Independent Electricity System Operator
MISO RTO
New England RTO
NY ISO
PJM Inter-connection
SPP RTO
California ISO
ERCOT ISO
WA
MT
ND
MN
OR
ID
SD
WI
WY
MI
VT
NH
ME
NY
MA
IA
NE
PA
NV
UT
CO
IL
IN
OH
NJ
CT
RI
KS
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FL
This map was created using Platts POWERmap
September 21, 2006

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2. Locational Marginal Pricing

Why?
"Zonal" pricing failed:
Learning the Hard Way

- **PJM 1997**
- **New England 1998**
- **California 2004**
- **Texas 2000's**

The “DEC” Game in Zonal Markets

- Clear zonal market day ahead (DA):
  - All generator bids used to create supply curve in zone
  - Clear supply against zonal load
  - All paid same DA price
- In real-time, “intrazonal congestion” arises—constraint violations must be eliminated
  - “INC” needed generation (e.g., in load pockets) that wasn’t taken DA
    - Pay them > DA price
  - “DEC” unneeded generation (e.g., in gen pockets) that can’t be used
    - Allow generator to pay back < DA price

Problems arising from "DEC" games

1. Congestion worsens

2. Encourages DA bilateral contracts with "cheap" DEC'ed generation
   – Destroyed PJM zonal market in 1997

3. DEC game is a money machine
   – Gen pocket generators bid cheaply, knowing they'll be taken and can buy back at low price
     - E.g., P_{DA} = \$70/MWh, P_{DEC} = \$30
     - You make \$40 for doing nothing
   – Market power not needed for game (but can make it worse)

Problems arising from "DEC" games

4. Short Run Inefficiencies

- If DEC'ed generators are started up & then shut down
- If INC'ed generation is needed at short notice

5. Encourages siting in wrong places

- Complex rules required to correct disincentive to site where power is needed
- E.g., New England 1998,
  UK late 1990s

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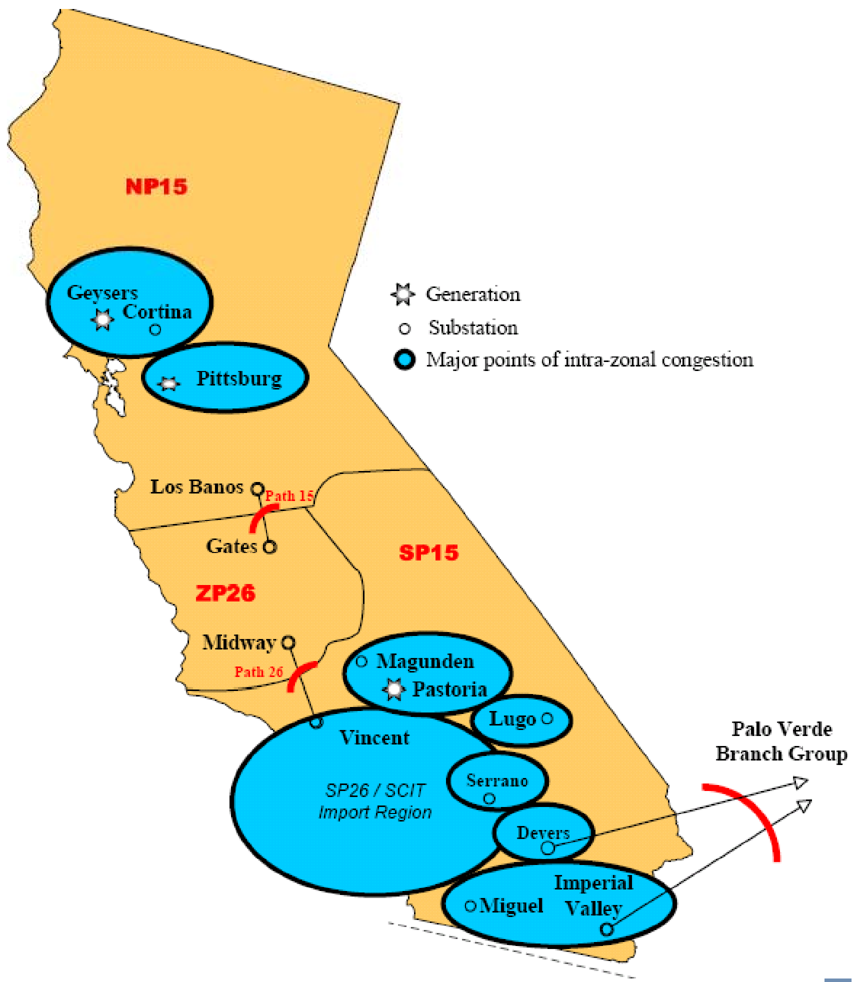
E.g., Intrazonal Congestion in California

- **$426M ('04), $151M ('05), $207M ('06),**
  - **>> Interzonal congestion**
- **Mostly transmission within load pockets**
- **Managed by (2004):**
  1. **"Reliability Must Run" unit dispatch ($49M)**
  2. **"Minimum load" units that lost money ($274M)**
  3. **INC's/DEC's ($103M):**
     - **Mean INC price = $67.33/MWh**
     - **Mean DEC price = $39.20/MWh**



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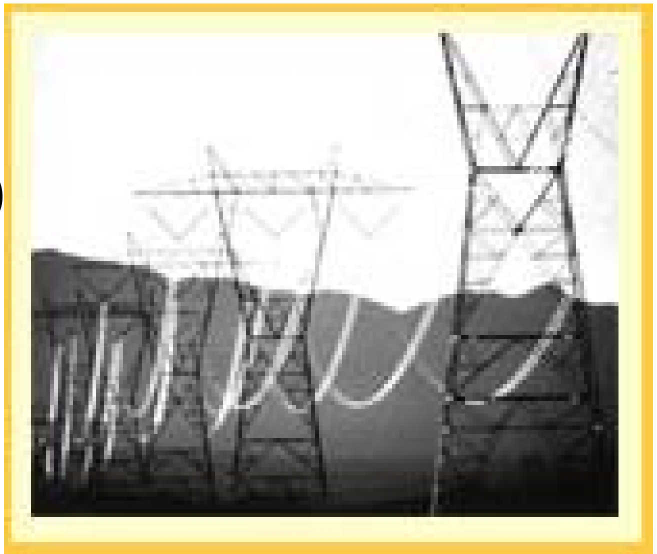
Locational Marginal Pricing Review

- **Price of energy (LMP) at bus i**

  = Marginal cost of energy at bus

  = Dual of bus energy balance (KCL) in Optimal Power Flow (OPF)
- **General Statement of OPF**
  - **Objective f(X):**
    - **Elastic demand: MAX Net Benefits**

      = Σ (Consumer Value - Gen Cost)
  - **Decision variables X:**
    - **Generation**
    - **Accepted demand bids**
    - **Operating reserves**
    - **Real, reactive power flows**
  - **Constraints G(X) $\leq$ 0:**
    - **Generator limits (including dynamics, e.g., ramp rates)**
    - **Demand (net supply = load L at each bus for P,Q)**
    - **Load flow constraints (e.g., KCL, KVL)**
    - **Transmission limits**
    - **Reserve requirements**



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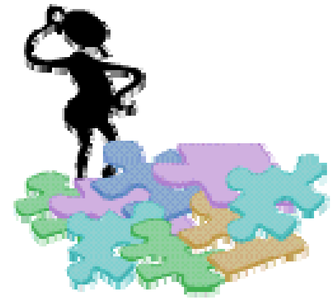
Remaining LMP Problems: Left-behind λ's



Ideally, LMPs reflect all constraints. But:

1. **Spatial λ's left behind:**
   - **"The seams issue" – interconnected systems with different congestion management systems**
     - **Can lead to "Death Star"-type games ("money machines")**
2. **Temporal λ's left behind:**
   - **Ramp rates often not considered in real-time LMPs**
     - **Distorts incentives for investment in flexible generation**
3. **Interacting commodity (ancillary services) λ's left behind:**
   - **Operator constraints not priced**
     - **Can systematically depress energy prices**
4. **The problem of nonconvex costs**
   - **Unit commitment (min run, start up costs)**
     - **Marginal costs ambiguous**

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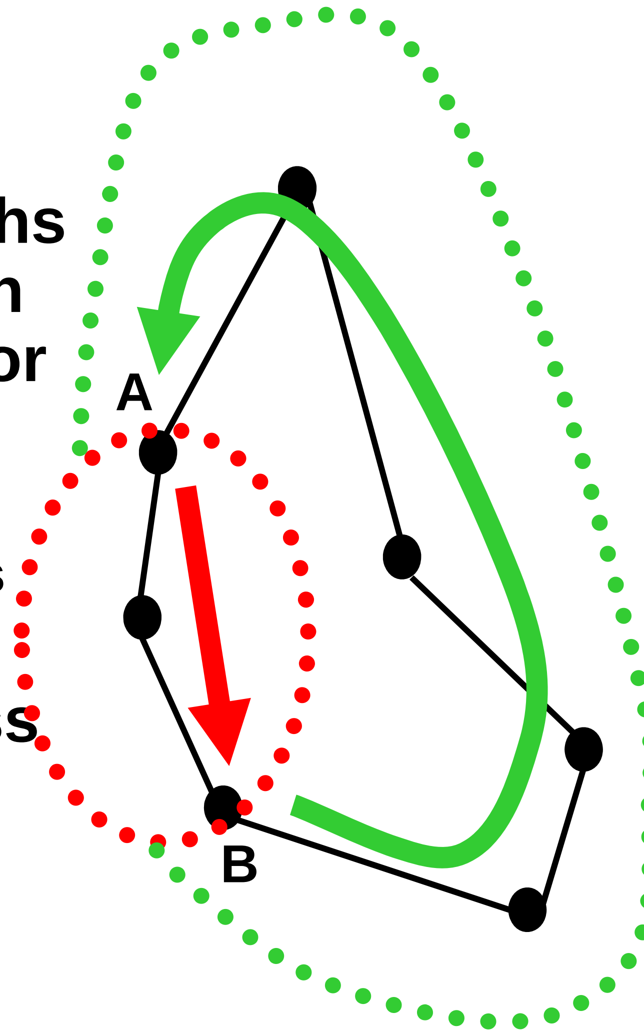
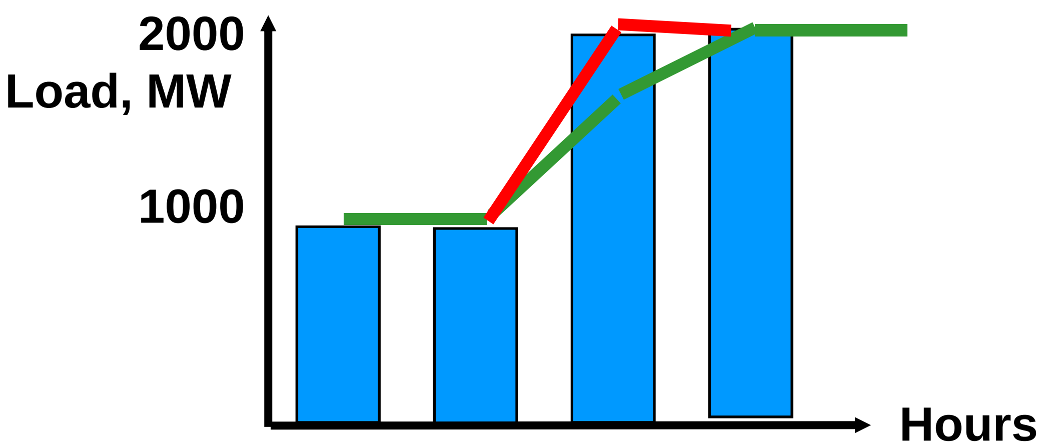
Spatial λ's left behind

- Green and Red systems interconnect at A and B. They manage congestion differently:
  - Green: LMP-based
  - Red: Path-based
- Power from A to B follows all paths and can cause congestion in both systems: there is one correct P for each & one correct transmission charge
  - But Green ignores Red's constraints and miscalculates LMPs
- If Red's charge from A to B is less than P_A-P_B for Green…
  - Money machine! Have a 1000 MW transaction from A to B in Red, and 1000 MW back from B to A in Green



Temporal λ's left behind

- **Some ISOs set real-time LMPs considering just constraints active at that time ("static optimization")**
  - This skews LMPs by ignoring binding dynamic constraints in other intervals
- **E.g., a system with two types of generation:**
  - 2100 MW of slow thermal @ $30/MWh, with max ramping = 600 MW/hr
  - 1000 MW of quick start peakers @ $70/MWh
- **Morning ramp up and resulting generation:**



True LMP:	30	-10	70	30
"Static LMP"	30	30	30	30

Kudos to Shmuel Oren for pointing this out

Depresses LMP volatility – undervalues flexible generation

- ***Crucial with more wind!***
- ***Answers:***
  - ➢ ***Ramp product? (CAISO, MISO)***
  - ➢ ***Ramp capacity payment? (PJM)***

Other Commodities' λ's left behind

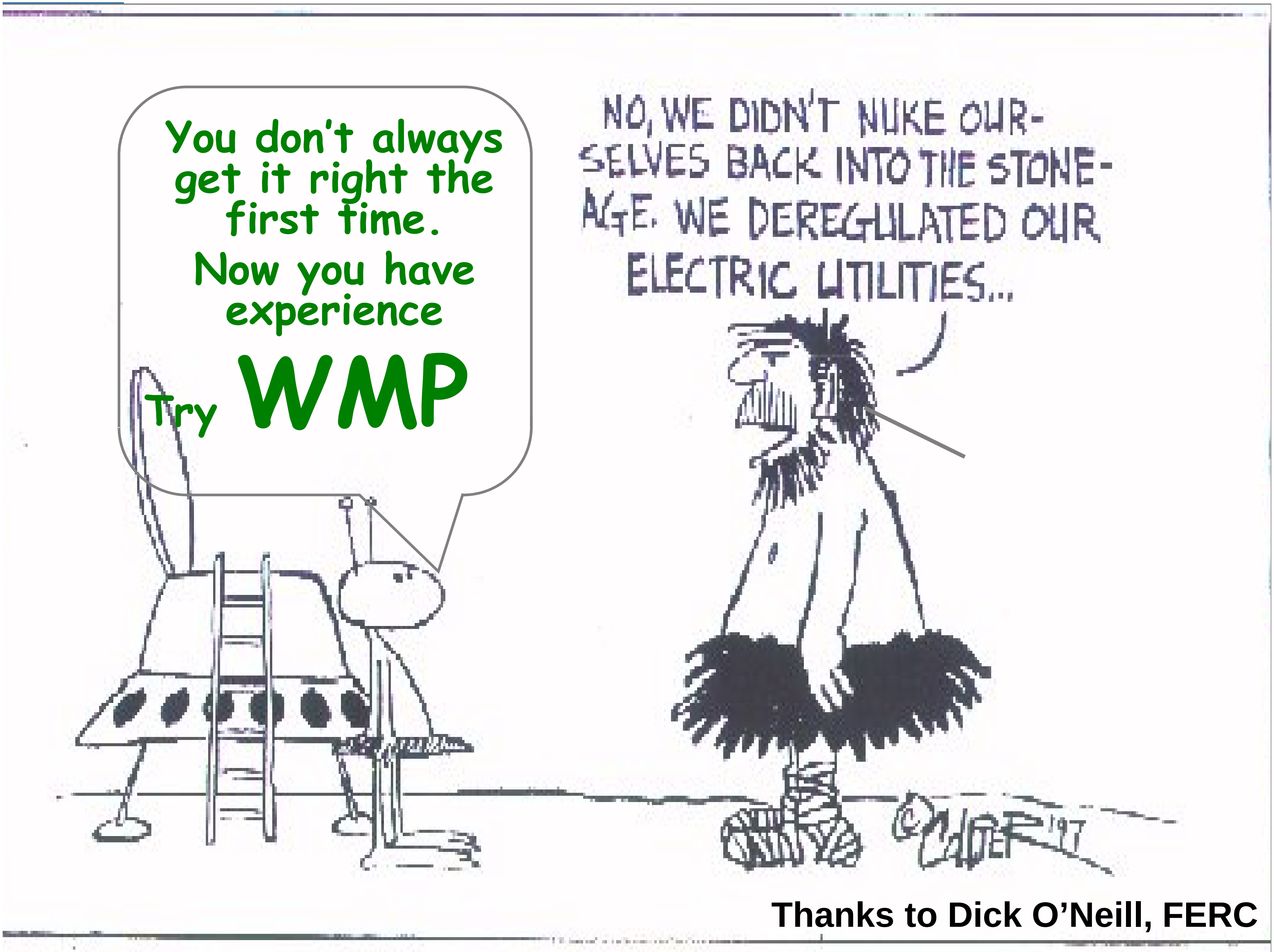
- Operators often call generators "OOM" ("out of merit order") to ensure that important contingency & other constraints met
  - to some extent inevitable
- But if frequent & predictable, these constraints should be priced in the market. Else:
  - P depressed for other generators who help meet that constraint
  - P inflated for generators who worsen that constraint
  - Could skew investment
- Identified as a chronic problem in some U.S. markets by market monitors

JHU Nonconvex Costs: What are the Right λ's?

- **Common situation:**
  - Cheap thermal units can continuously vary output
  - Costly peakers are either "on" or "off"
  - $\Rightarrow$ Even during high loads, LMP set by cheap generators
  - $\Rightarrow$ Too little incentive to reduce load
  - $\Rightarrow$ Peakers don't cover costs ("uplift" required)
  - $\Rightarrow$ Cheap units get inadequate incentive to invest

- **California, New York solutions:**
  - If peaking units are small relative to variation in load,
  - … then set LMP = <u>average</u> fuel cost of peaker, if peakers running
  - Note: LMP doesn't "support" thermal unit dispatch, so must constrain output
- **Alternative:Supporting prices in mixed integer programs**
  - Calculated from LP that constrains {0,1} variable to optimal level
  - Results in separate prices for supply (thermal plant MC) and demand (higher LMP), and uplifts to peakers

Source: R. O'Neill, P. Sotkiewicz, B. Hobbs, M. Rothkopf, and W. Stewart, "Efficient Market-Clearing Prices in Markets with Nonconvexities," <u>Euro. J. Operational Research</u>, 164(1), July 1, 2005, 269-285



Thanks to Dick O'Neill, FERC

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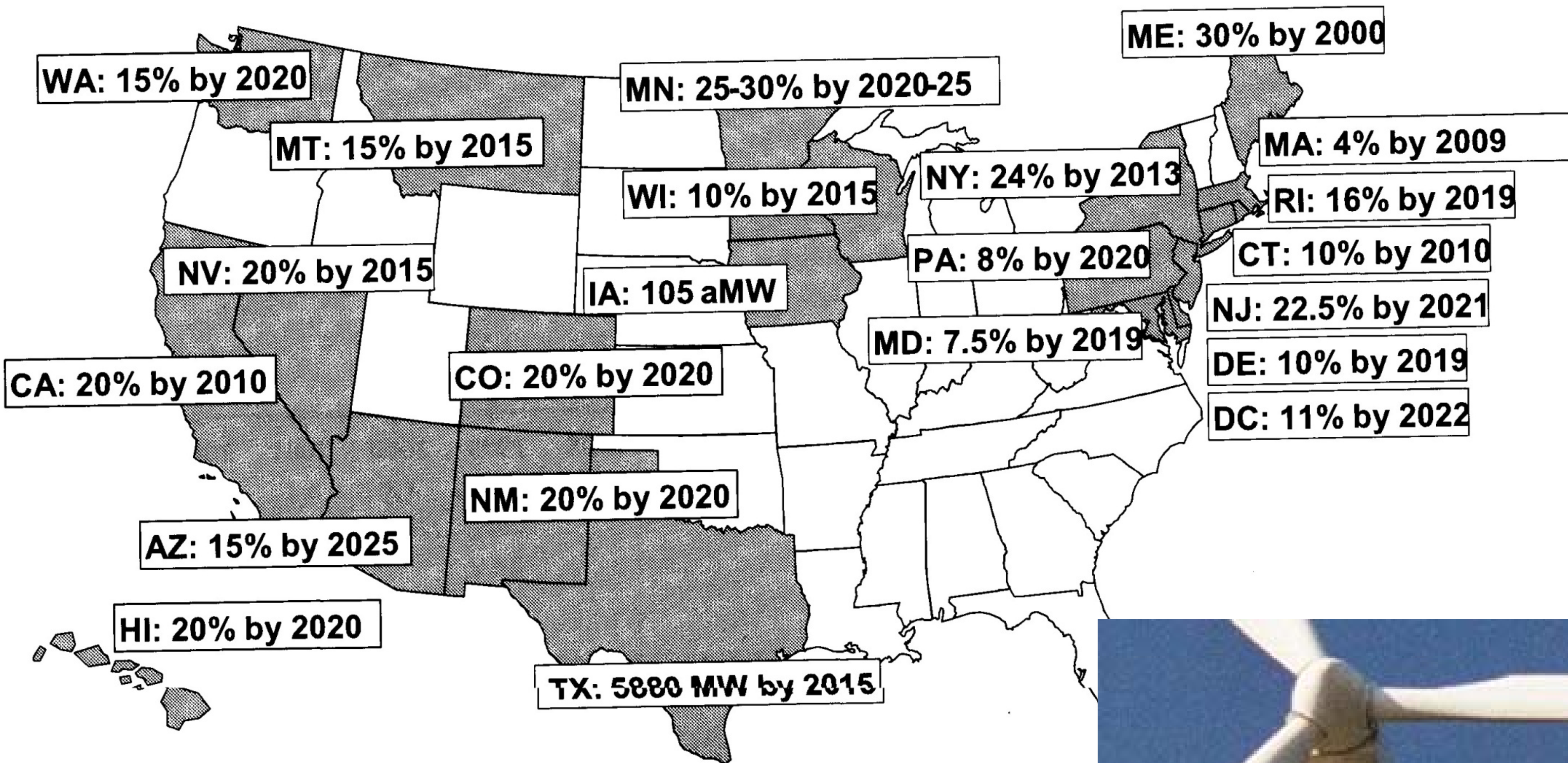
3. Renewable Portfolio Standards
Status of State Programs



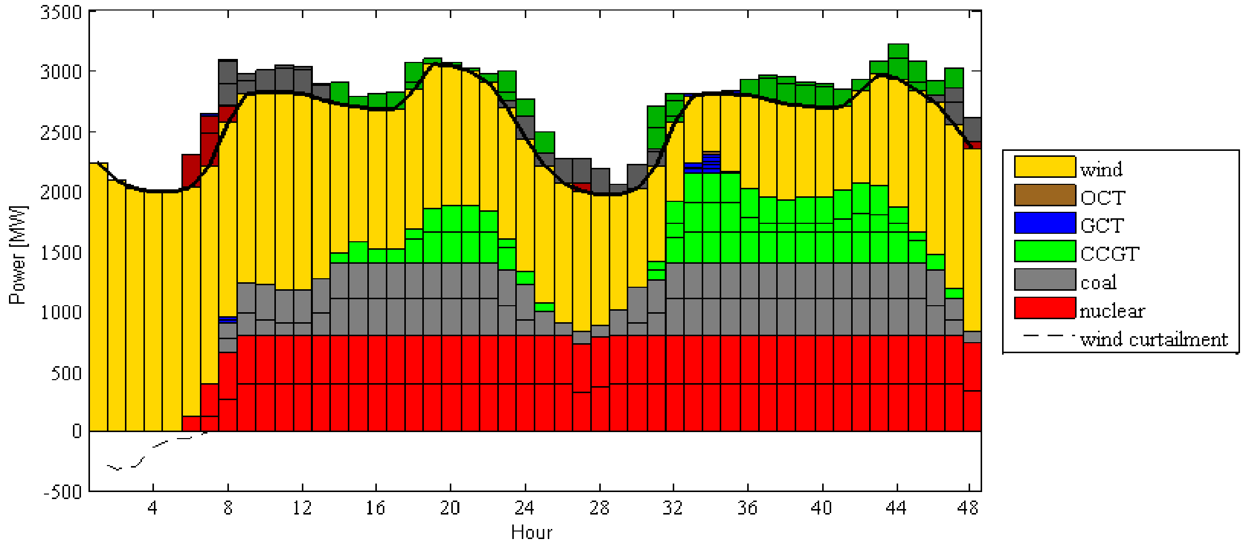
Source: R. Wiser et al., "The Experience with Renewable Portfolio Standards in the U.S., *Electricity J.*, May 2007

- **33% in California by 2020**
- **No national RPS**

3a. Operational Problems Increasing:

Giving Wind Absolute Priority Makes no Economic or Environmental Sense

- **-150$/MWh bids or lower for wind in CAISO likely**
- **Can increase *<u>both</u>* costs and emissions**
  - KU-Leuven stochastic unit commitment (De Jonghe, Hobbs, Belmans 2011):



- **Minimizing wind spill <u>increases</u> fuel costs & CO_2 (relative to dispatch under 0€/MWh wind bid)**
  - **17% reduction in spill possible**
  - **Per MWh of spill reduction:**
    - **0.71 t CO_2 <u>increase</u> (+1.5% total CO_2)**
    - **49 € cost <u>increase</u> (+1.3% total cost)**
  - **Assumes no demand elasticity**

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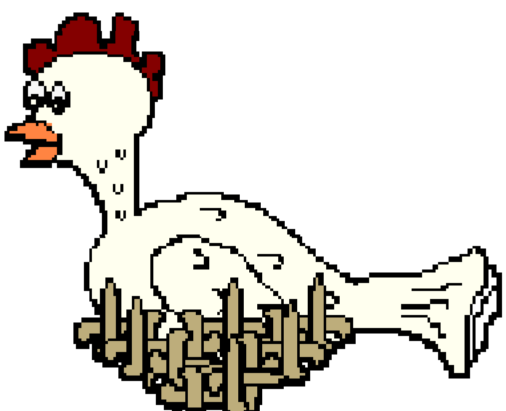
3b. Quandary: Which comes first? The transmission or the wind generation?

- **FERC policy until 2007: The ISO has two types of transmission**
  - ***Generation interties*—paid for upfront by the generator**
  - ***Network facilities*—paid for by the ratepayer**

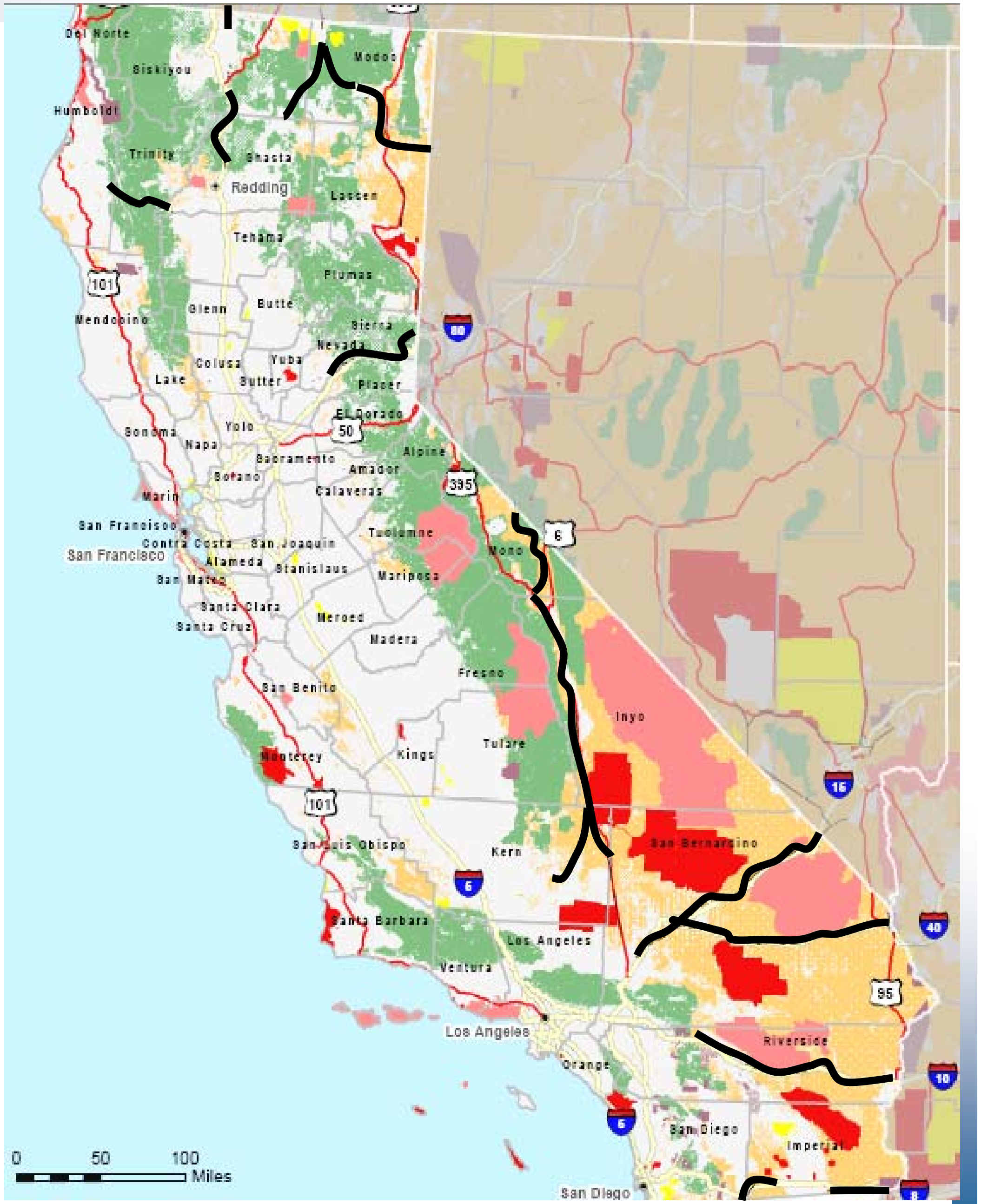
- **Problem with previous FERC policy**
  - **Gen-ties too costly for small renewables:**
    - **Most efficient scale of transmission >> size of individual wind developments**
    - **Classic infrastructure market failure**
  - **Not a network facility**



www.cartooncottage.com/html/food2.html

Addressing the Market Failure

- **Merchant Transmission?**
  - **Earn $ from:**
    - **contracts with wind generators**
    - **granted FTRs**
  - **No proposals due to risks of $billion investment**
- **State transmission development agencies?**
  - **Texas "Competitive Renewable Energy Zones" (CREZ)**
  - **NM "Renewable Energy Transmission Authority"**
- **Federal Western "Energy Corridors" (EPAct 2005)?**
  - **Might facilitate proposals that cross federal land**



Addressing the Market Failure

- CAISO: "3rd Category" of Transmission for dispersed generation
  - PTO (Participating Transmission Organization) puts $ up front
    - As development proceeds, generators pay *pro rata* share
    - Ratepayers bear "stranded asset" risk
  - Safeguards:
    - Proposal subject to ISO review ("TEAM methodology")
    - Showing needed (25-30% of capacity subscribed; another 25-35% reasonably expected)
  - FERC Declaratory Order 4/19/07
    - "Proposal is not unduly preferential or discriminatory and would be just and reasonable"

- Issues with 3rd category
  - Favors large concentrated development: Eggs in 1 basket
  - Subsidy that discriminates against local renewables?

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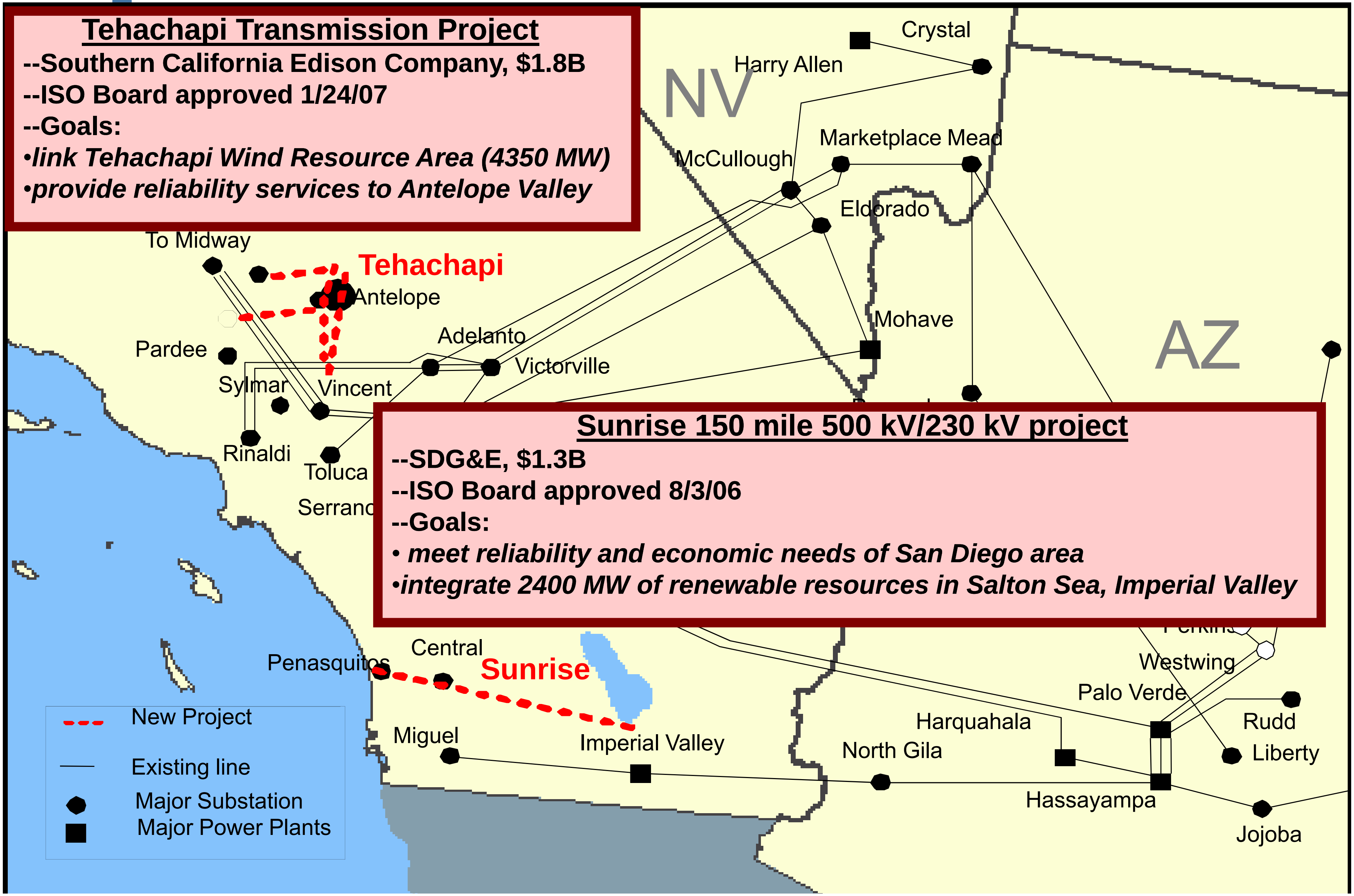
California “3rd Category” Proposals: 230kV/500kV Additions



Tehachapi Transmission Project

--Southern California Edison Company, $1.8B

--ISO Board approved 1/24/07

--Goals:

•link Tehachapi Wind Resource Area (4350 MW)

•provide reliability services to Antelope Valley

Sunrise 150 mile 500 kV/230 kV project

--SDG&E, $1.3B

--ISO Board approved 8/3/06

--Goals:

• meet reliability and economic needs of San Diego area

•integrate 2400 MW of renewable resources in Salton Sea, Imperial Valley

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4. Why Markets for Capacity?

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- **Adequacy ≡ Sufficient installed generation & transmission capacity to:**
  - **Meet electric load with acceptable LOLP**
    ….engineering definition
  - **Clear market; P's/Q's at efficient levels**
    .... ***economics definition***

- **Who's responsible?**
  - **In a market, individual generators *not* responsible for (engineering) adequacy**
  - **Governments are! EU Directive 2005/89/EC:**
    - **'The guarantee of a high level of security of electricity supply is a key objective for the successful operation of the internal market …**
    - **'Measures which may be used to ensure that appropriate levels of generation reserve capacity are maintained'**

Why Not Just Use Energy Markets?

Saint Fred's (Schweppe) 1978 vision of a demand-responsive market unfulfilled

- Demand-side market failures lead to wrong P's, capacity shortages

- **Reasons:**
  - No market information on value of reliability
    - Height of price spikes reflect:
      - regulatory decisions
      - willingness of ISOs and suppliers to stomach political fallout
    - Least valued uses not curtailed during shortages
    - Long-term contracts with consumers infeasible

    ⇒Optimal amount of capacity unlikely under a pure energy market
  - Bid & price caps in response to market power

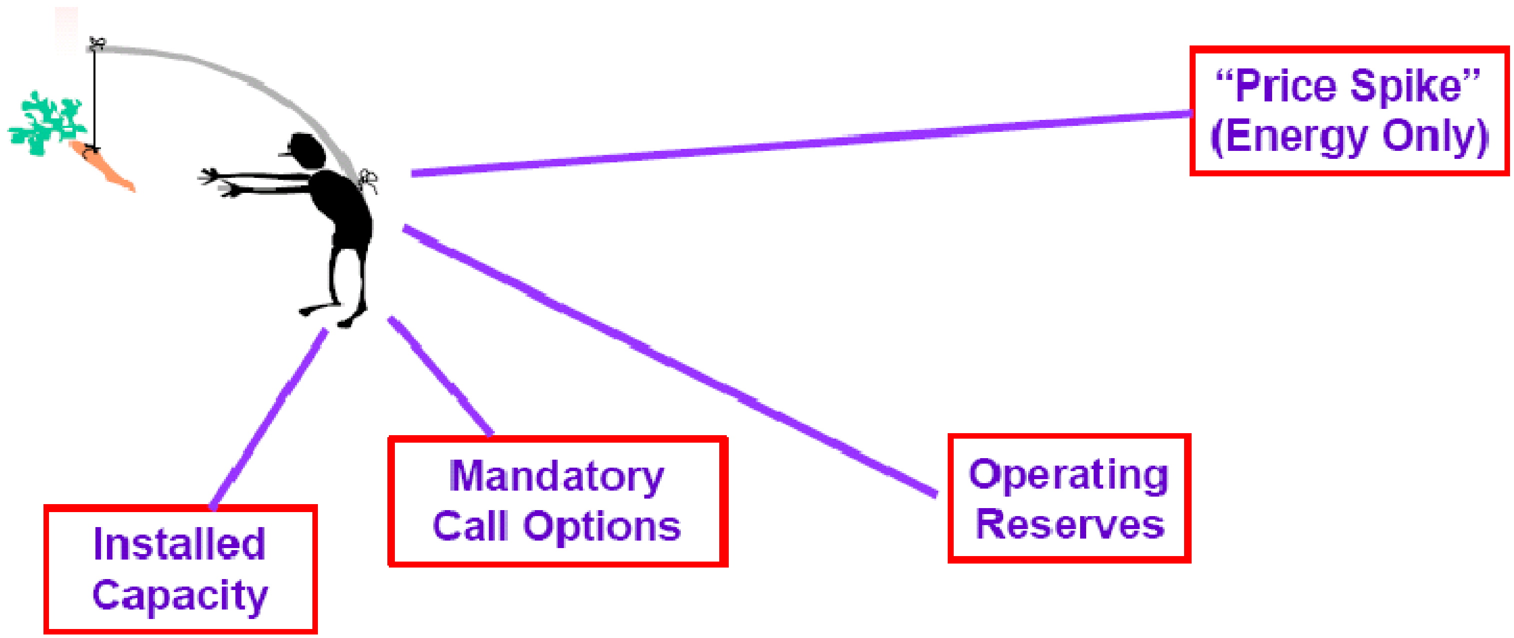
    ⇒'Missing money' – energy revenues don't cover peaker fixed costs

- **Cost of overcapacity << Cost of undercapacity**

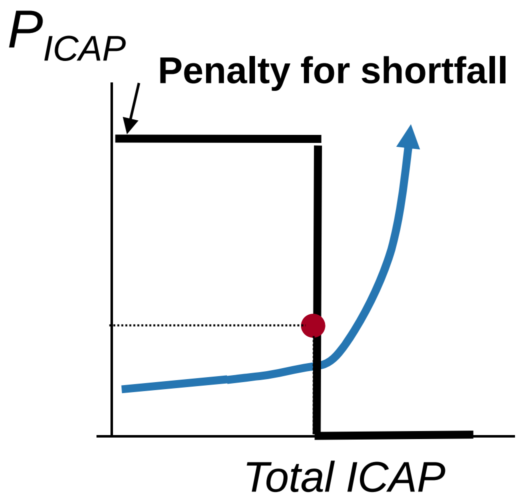
  ⇒ Capacity markets = insurance

How Can Market Designers Respond?

1. **Demand-side / pricing reforms**
   - **Correct the market failure**
2. **Mandatory contracts (“bottom up”)**
3. **Capacity markets (“top down”)**

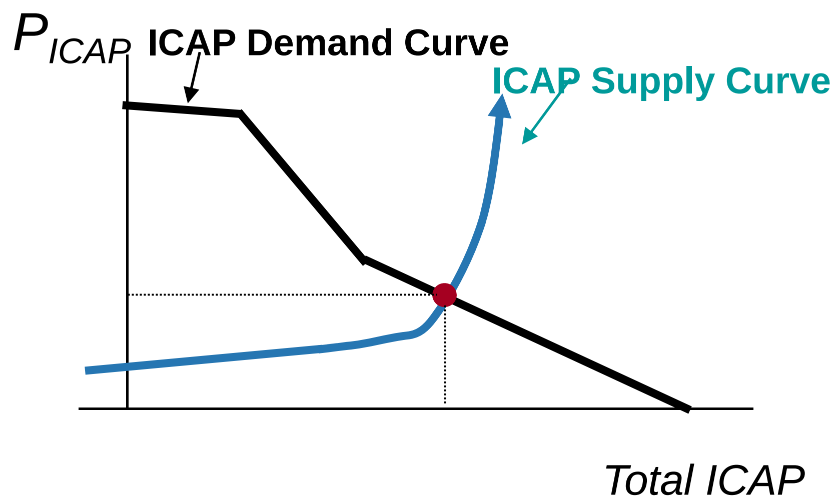


ICAP Variant: Demand Curves for Capacity



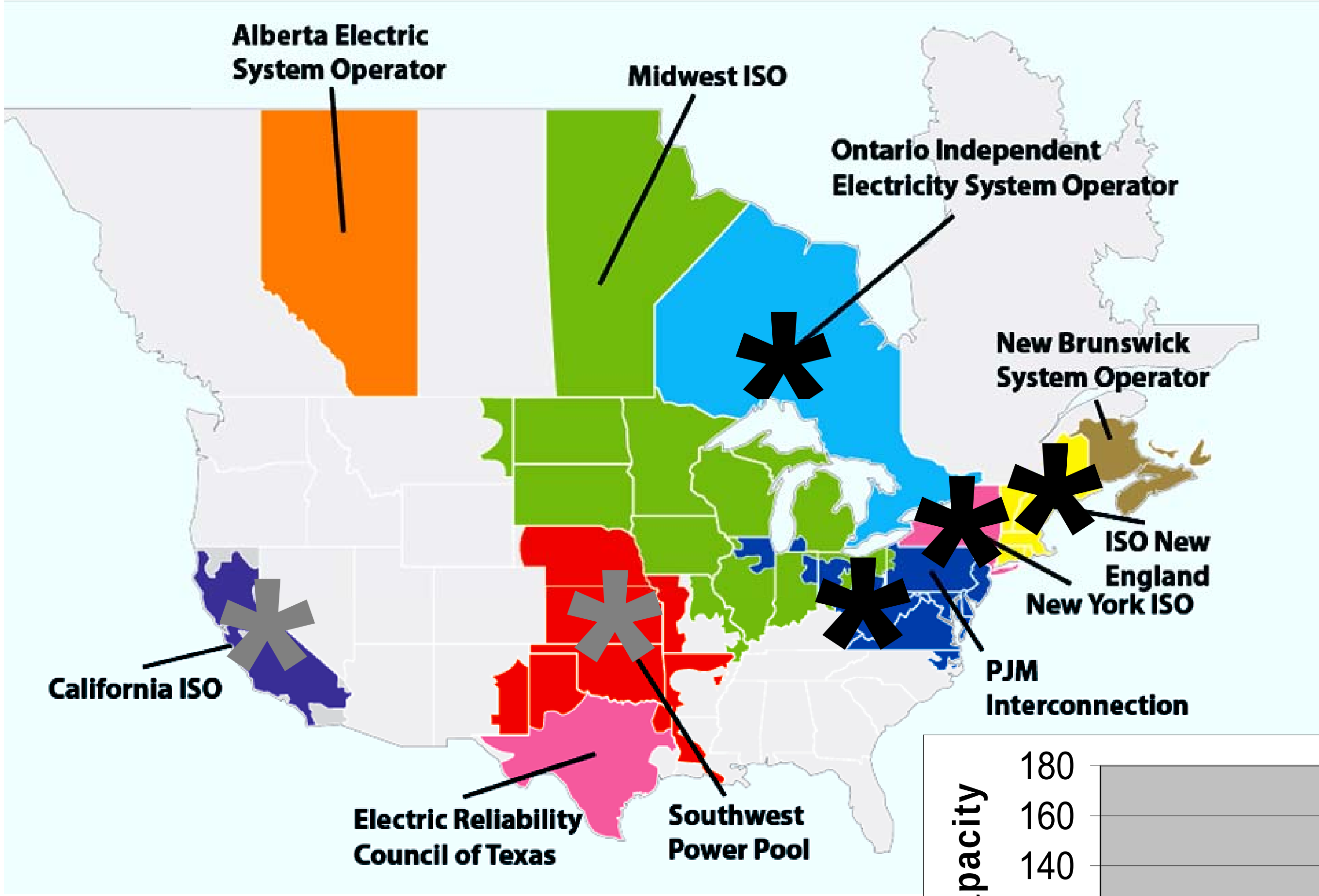
Old ICAP systems: fixed requirements, with penalty for falling short ("vertical demand")

New systems: Administrative payment from ISO depends on reserve margin



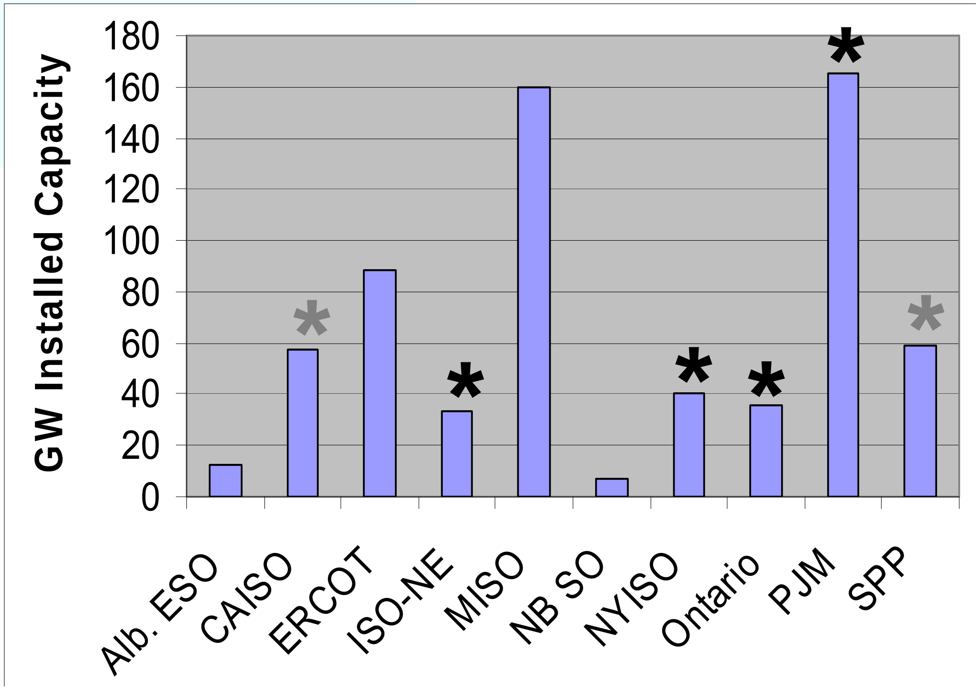
B.F. Hobbs, M.C. Hu, J. Inon, M. Bhavaraju, and S. Stoft, "A Dynamic Analysis of a Demand Curve-Based Capacity Market Proposal: The PJM Reliability Pricing Model," IEEE TPWRS, 22(1), Jan. 2007.

Status of Capacity Markets in North America



* Mandatory capacity markets

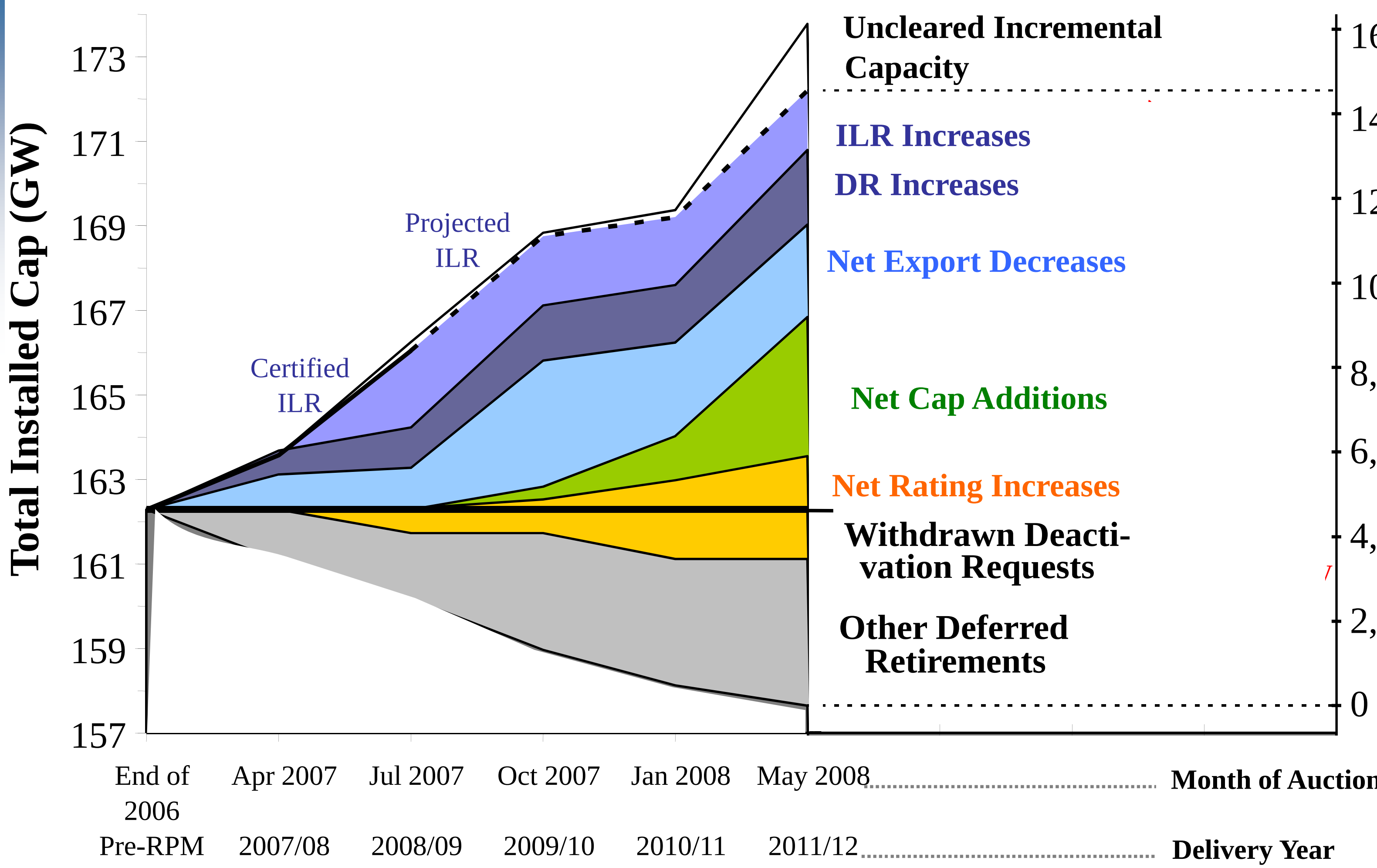
* Capacity requirement



Desirable Features for Capacity Markets

- Reward availability when valuable
  - Scarcity pricing in energy market
  - Penalize plant unavailability during shortages
- Pay all capacity
  - Reward renovation as well as new-build
  - Don’t discriminate among capacity types
  - Pay transmission & demand-response
    - *Beware double-payments*
- Pay locationally
- Contract 2-3 years ahead
- Adapt

PJM: Breakdown of New & Retained Resources



Source: J. Pfeifenberger & S. Newell, "Review of PJM's Reliability Pricing Model," Brattle Group, Presentation to PJM Stakeholders, July 11 2008

Net additional resources in 2012/13: +7210 MW
2013/14: +2908 MW

Brattle Report Conclusions

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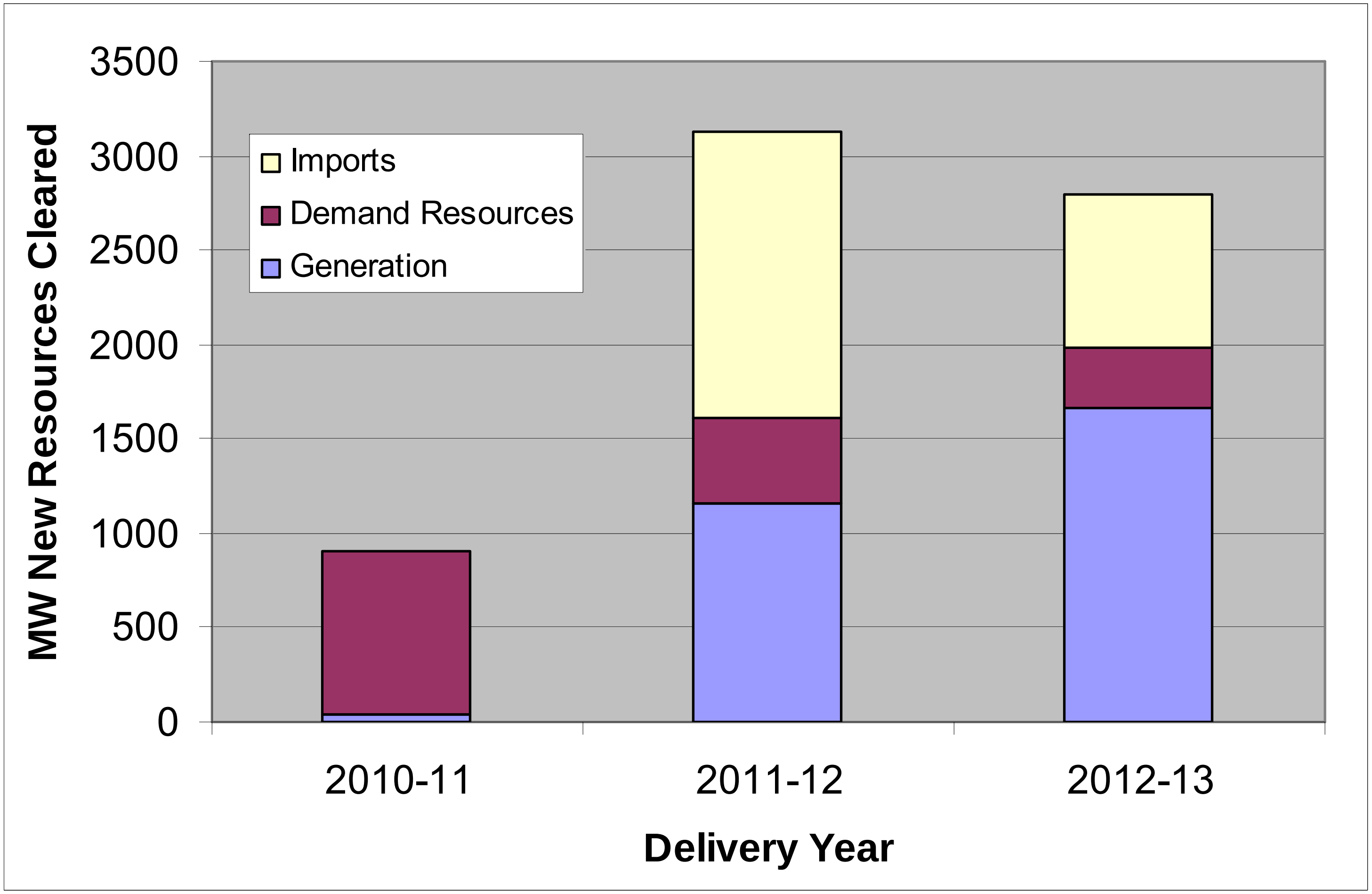
- **RPM successfully achieved reliability & economic objectives**
  - **Attracted resources**
    - ~10,000 MW of additional new capacity
    - ~4,500 MW of capacity that would otherwise have retired

- **Recommended maintaining basic design elements**
  - **sloped demand curve**
  - **3-year forward time frame**

From J. Pfeifenberger & S. Newell, "Review of PJM's Reliability Pricing Model,“ Brattle Group, Presentation to PJM Stakeholders, July 11 2008

ISO-New England

- **The "Forward Capacity Market" has cleared large amounts of new capacity**



Source: Internal Market Monitoring Unit, 2009 Annual Markets Report, ISO-New England, May 18, 2010

Challenges to Capacity Markets

- Political consequences of explicit capacity costs
- Contentious administrative decisions:
  - *Right amount of capacity?*
  - *CONE?*
  - *Load forecast?*
- Monitoring/verifying demand response
- Tension between short- (demand) & long-term (gen) resources
- How transition to "promised land" of energy-only markets?
- Buyer market power

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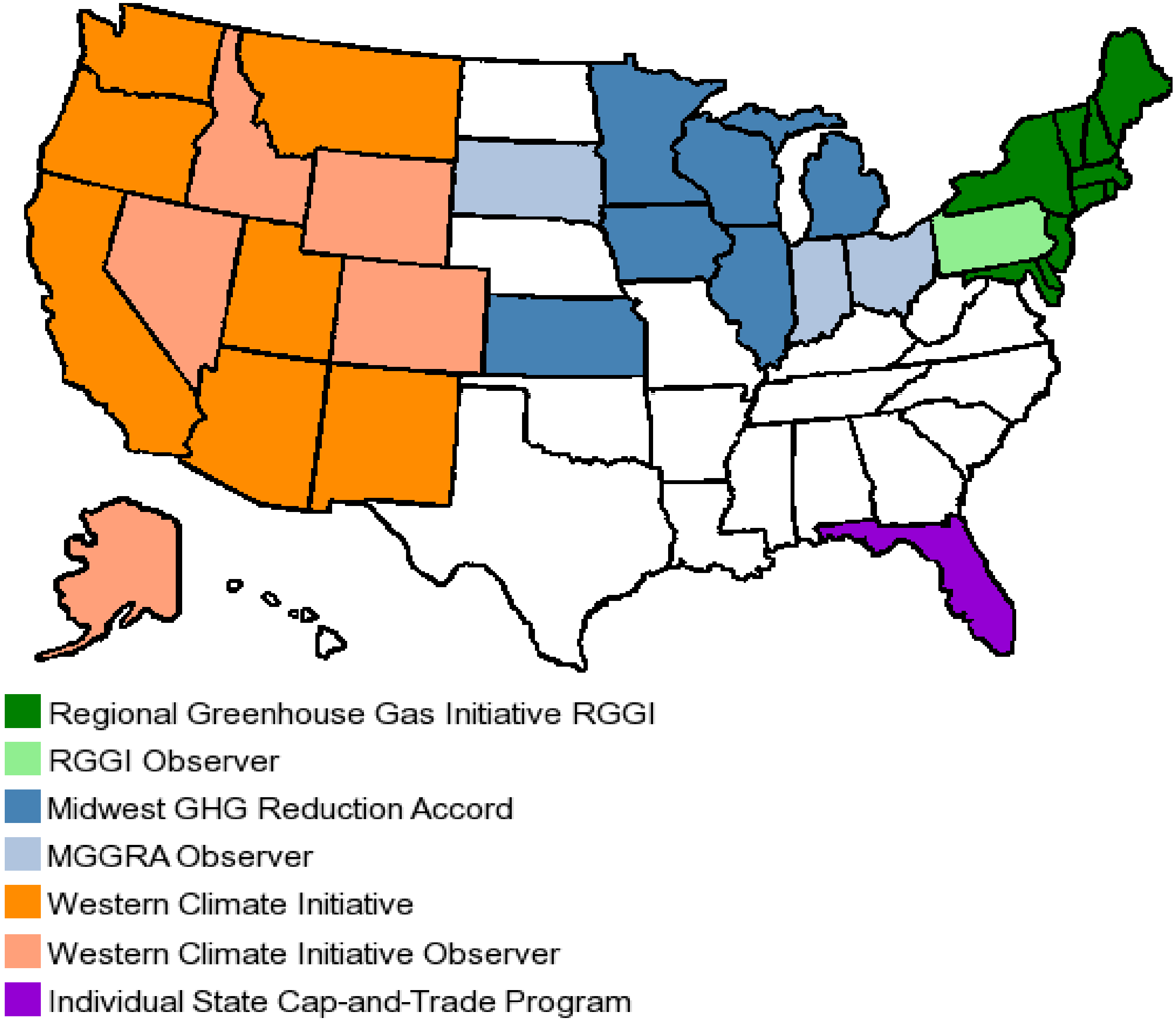
5. Regional CO_2 Cap-and-Trade Systems



Source: Pew Center, www.pewclimate.org/what_s_being_done/in_the_states/regional_initiatives.cfm

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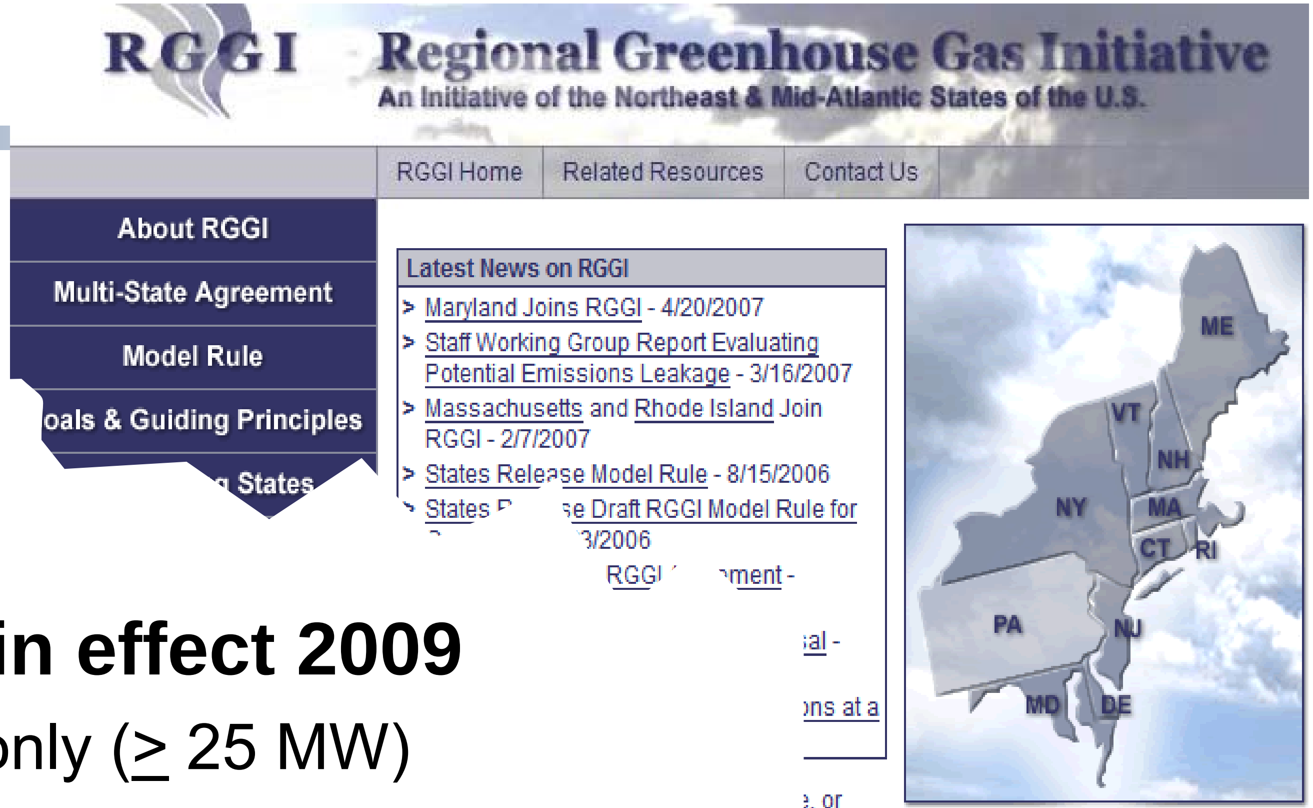

~~10~~ 9 Northeastern States: RGGI

- **Regional cap in effect 2009**
  - Power plants only ($\geq$ 25 MW)
    - 24% of region's CO_2
    - 188 MT/yr
  - Target:
    - Projected 2009 levels through 2014
    - Then decrease 2.5%/yr through 2018
  - Allowance prices: $2-3/ton
    - Some secondary trading
    - Active futures market

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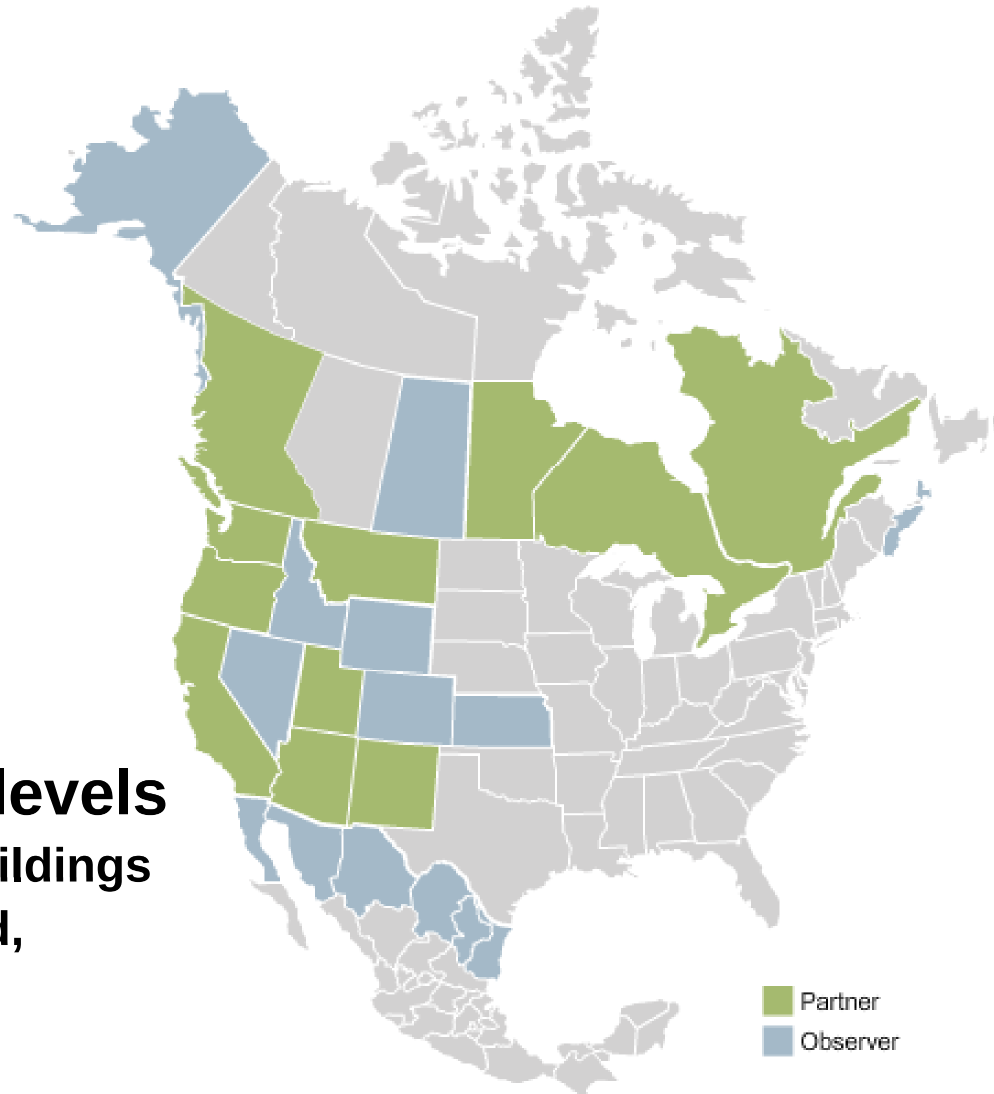
State Initiatives in Progress: California (AB32, 2006)→Western Climate Initiative (2007)

Gov. Schwarzenegger is joined by international leaders with a consistent record of addressing the global threat of climate change, New York Governor George Pataki and other environmental and industry leaders at a bill signing for AB 32 on Treasure Island in San Francisco on Tuesday, September 27, 2006.

- **By 2020: 15% below 2005 levels**
  - **Power, transport, industrial, buildings**
  - **90% of GHG emissions covered, including non-CO_2**
- **Timetable**
  - **California (AB32): cap-and-trade by 2012 for large stationary sources**
  - **WCI fully implemented by 2015**



Source: www.westernclimateinitiative.org

Midwest Greenhouse Gas Reduction Accord (MGGRA)

- **2007 Agreement**
- **Advisory Group Recommendations (6/09):**
  - **Broad coverage**
  - **2020: 20% below 2005**
  - **80% drop by 2050**
  - **Cap-and-trade. Responsibility:**
    - ***Source:* Producers, importers of transport/building fuels**
    - ***End-user:* Power, industrial combustion/process**
- **Next: State review and (?) approval**

Other State Actions

- Florida Climate Protection Act 2008
  - Authorizes cap-and-trade for power generation
  - Reduce to:
    - 2017: 2000 levels
    - 2025: 1995 levels
    - 2050: 20% of 1990 levels
- Maryland GHG Emissions Reduction Act 2009
  - 2020: 25% below 2006 levels
  - Massive expansion of state environmental agency
- 15 states impose fleet-wide CO_2 standards for autos (de facto mileage standards)
  - California: 30% reduction by 2016
  - Noncarbon fuel standards
- Strong Renewable Portfolio Standards

Federal Actions

- **Congress: Stymied**
  - **Obama proposes “Clean Energy Standard”**
- **USEPA acting, given Congressional inaction**
  - **“Endangerment” finding: mobile sources, maybe stationary**
  - **Could accomplish most of 2020 electricity goals of Waxman bill**
  - **… If Congress doesn’t tie EPA’s hands**

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Outline

1. History
2. LMP
3. Renewable Integration
   – Dispatch flexibility
   – Transmission construction
4. Capacity Markets
5. Greenhouse Gas Regulation
6. Financial Transmission Rights

6. FTR Questions:

- **Structure?**
  - **What's covered?**
  - **Allocation & trade?**

- **Performance?**
  - **Activity?**
  - **Congestion hedging?**
  - **Convergence of FTR prices & payoffs?**
  - **Revenue adequacy, other credit risks?**

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In a Nutshell:

	PJM Interconnection (FTRs)	CAISO (CRRs)
LMP Since:	1998	2009
LMP Includes:	*Congestion & Losses*	
Rights:	Point-to-Point Obligation & Options	PTP Obligation (+Options if construct new line) ~~(+Multiple PtP Obligation)~~
Rights Cover:	*Congestion Only*	
Hours:	All Hours; On & Off Peak	On & Off Peak
Duration:	1 & 3 months; 3 yrs	1 & 3 months; 10 yrs
What's Allocated:	Auction Revenue Rights	CRRs
Auction:	Buy & Sell monthly, annual	Buy (& Sell de facto) monthly, annual
Revenue Adequacy Test:	*Linearized DC Network Model*	
If Revenue Inadequate:	Pro-rate payment (monthly)	Fully funded (draw from auction revenues)
Bilateral Trading	Yes, active	Yes, inactive

CAISO Market Overview

Transmission-Right Markets

Day Ahead Market

Real-Time Market

Monthly, seasonal and TOU intervals

Hourly intervals

15- or 5-minute intervals

“Congestion Revenue Rights“ CRRs Obligations)

Energy
Ancillary Services
Residual Capacity

Energy
Ancillary Services

Source: G. Bautista, IEEE PES

Types of CRRs

- 2 time of use
  - ON- and OFF-Peak
- Seasonal CRRs
  - Calendar quarterly basis
- Monthly CRRs
  - Calendar months
- Long Term CRRs extend 9 years after annual term (10 yrs total)
- Merchant Transmission CRRs: terms of up to 30 yrs

Source: A. Isemonger, CAISO

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Allocation → Auction → Trade

CRRs can be obtained through

- ***Allocations;*** **participants can nominate if they are either:**
  - **Load Serving Entity (LSE)**
  - **"Out of Balancing Authority Area Load Serving Entity"**
  - **Project sponsors of Merchant Transmission**

- ***Monthly Auctions;*** **participants can bid if**
  - **They qualify as (candidate) CRR holders**
  - **Collateral posted 7 business days prior to the auction**

- **Also, existing CRRs may be obtained through**
  - **Bilateral trades – at will**
  - **Load migration –not at will**

- ***Merchant transmission***

Source: A. Isemonger, CAISO

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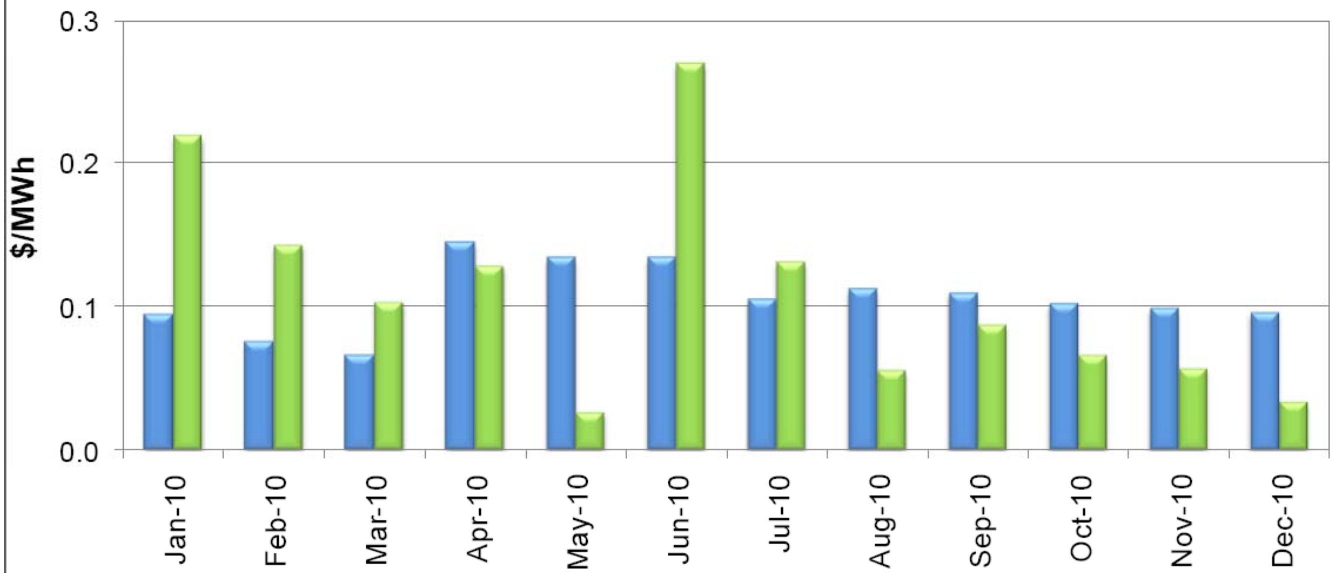
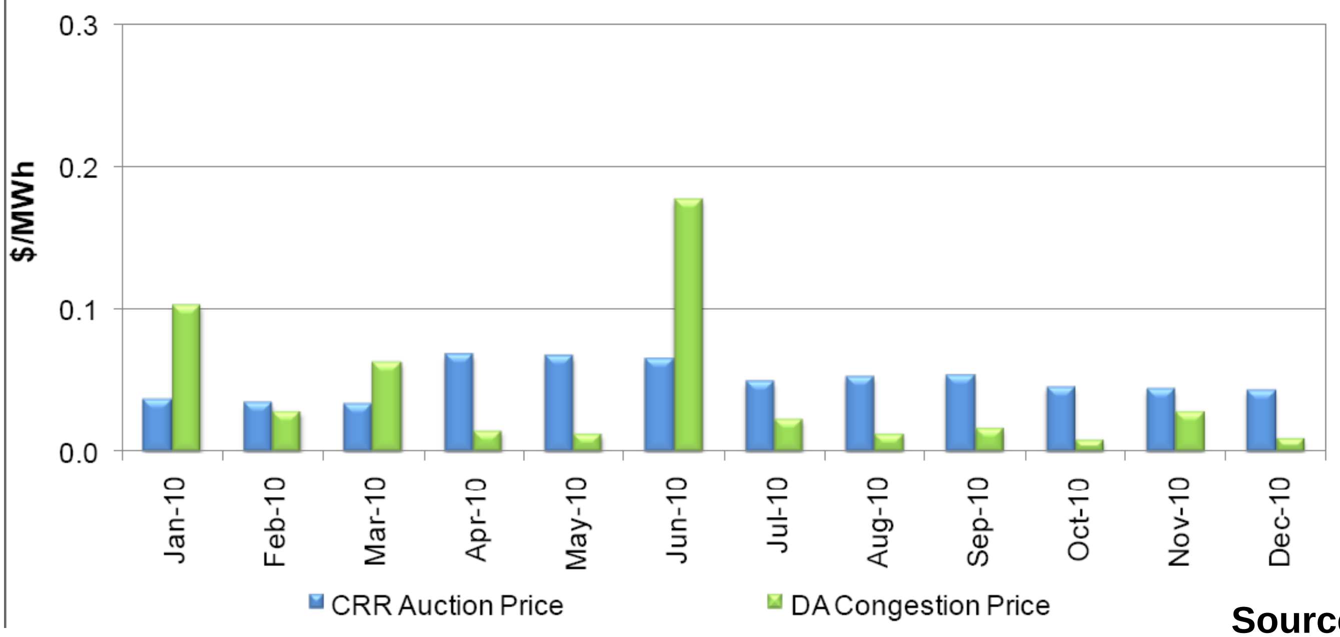
Convergence of CRR Prices & Payoffs: Average



On Peak



Off Peak

Source: CAISO, Annual Market Performance CRR Report, 3/2011

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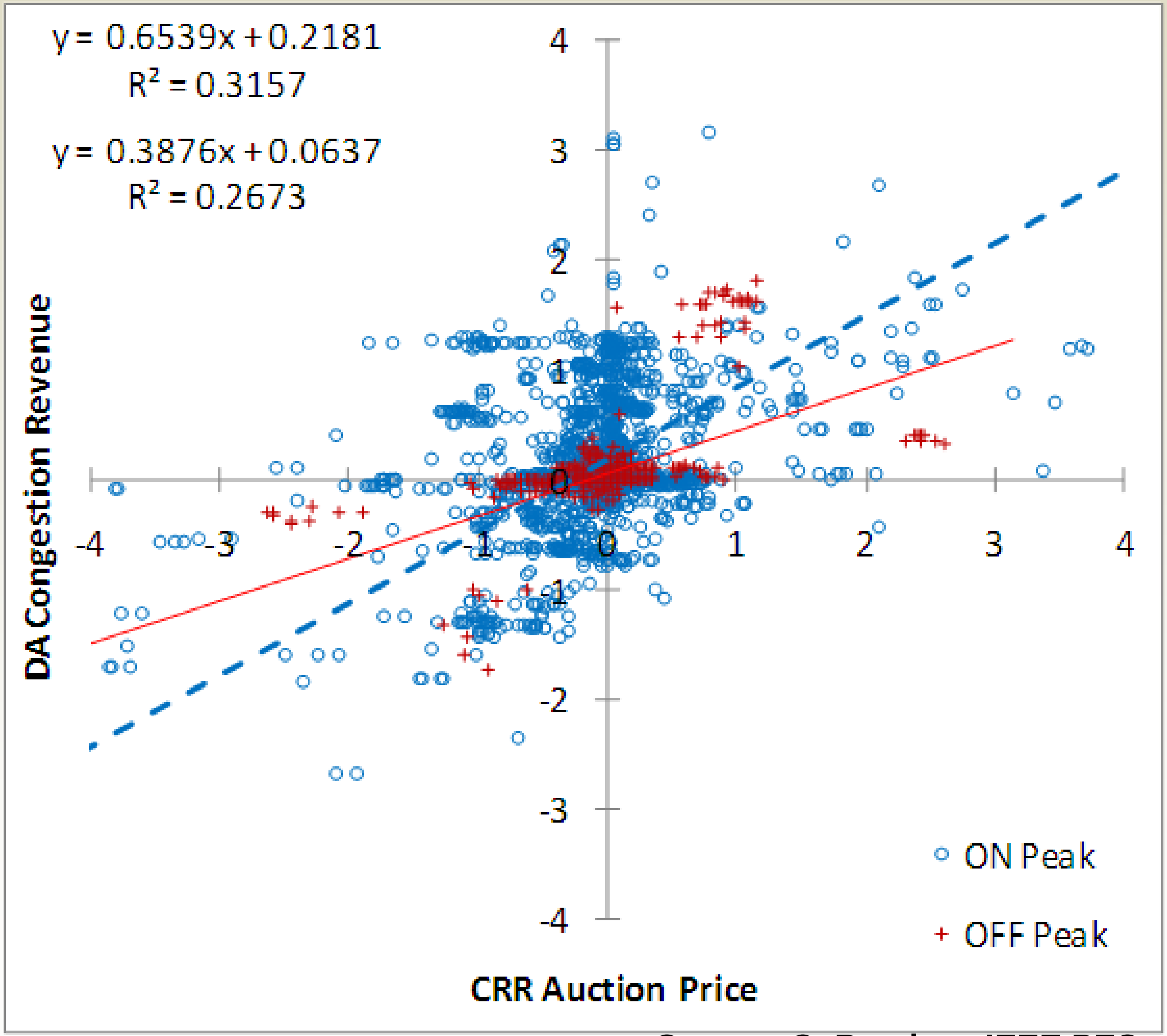
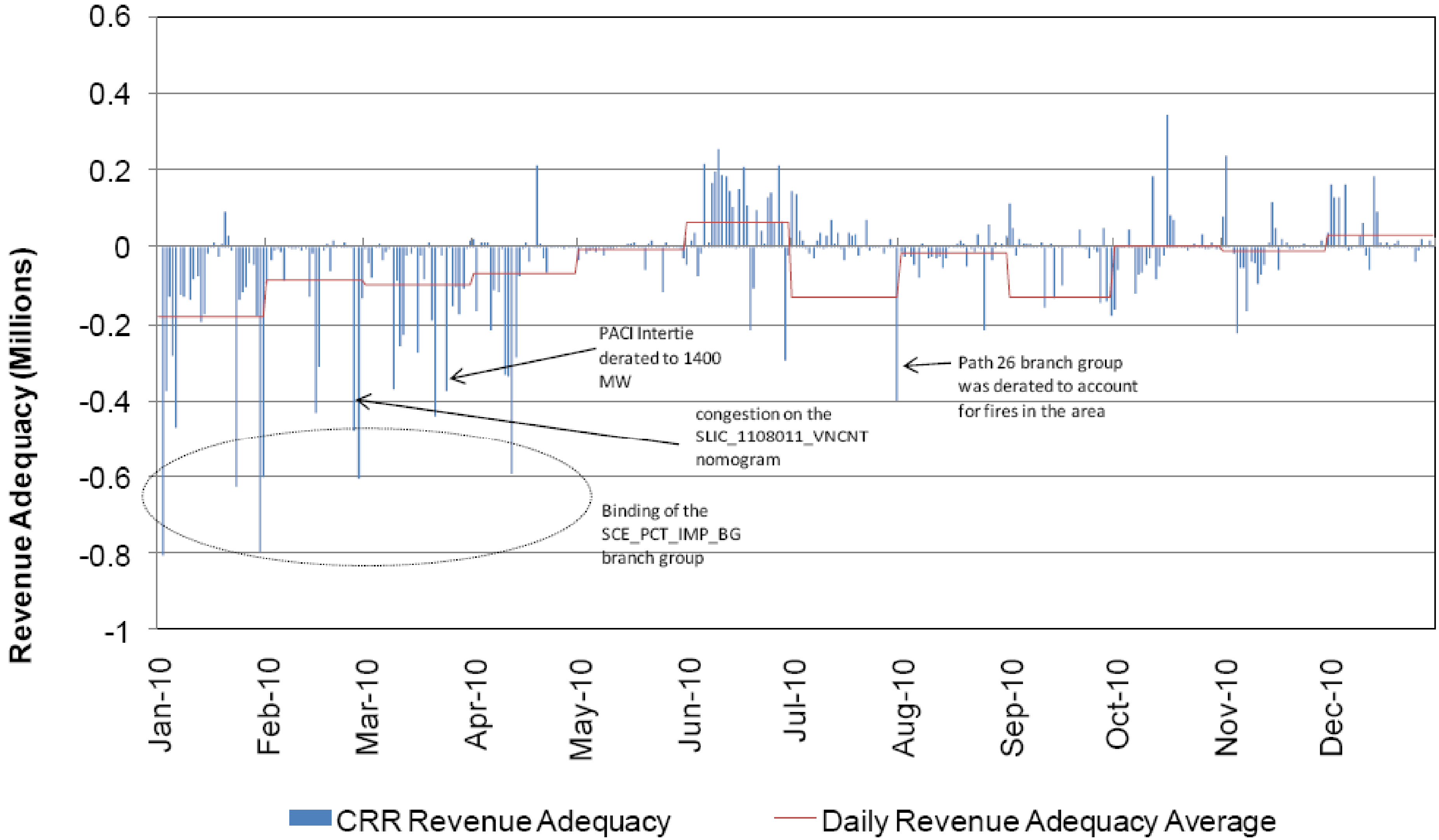
Convergence of CRR Prices & Payoffs: Individual CRRs



Source: G. Bautista, IEEE PES

CRR Revenue (In)Adequacy 2010



Source: CAISO, Annual Market Performance CRR Report, 3/2011

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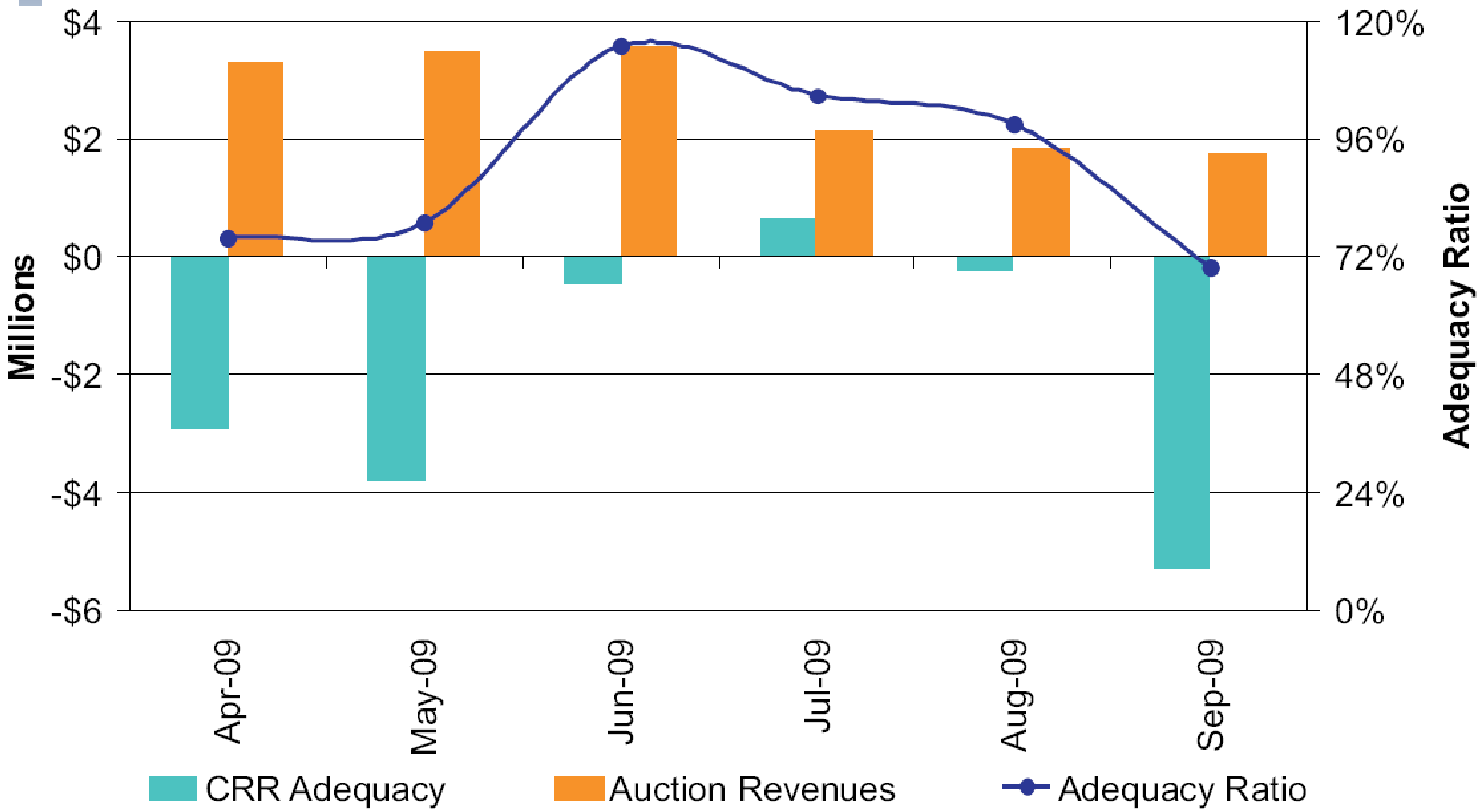
How to Cope with Revenue Inadequacy: *Method 1:* Draw on Auction Revenues



Source: G. Bautista

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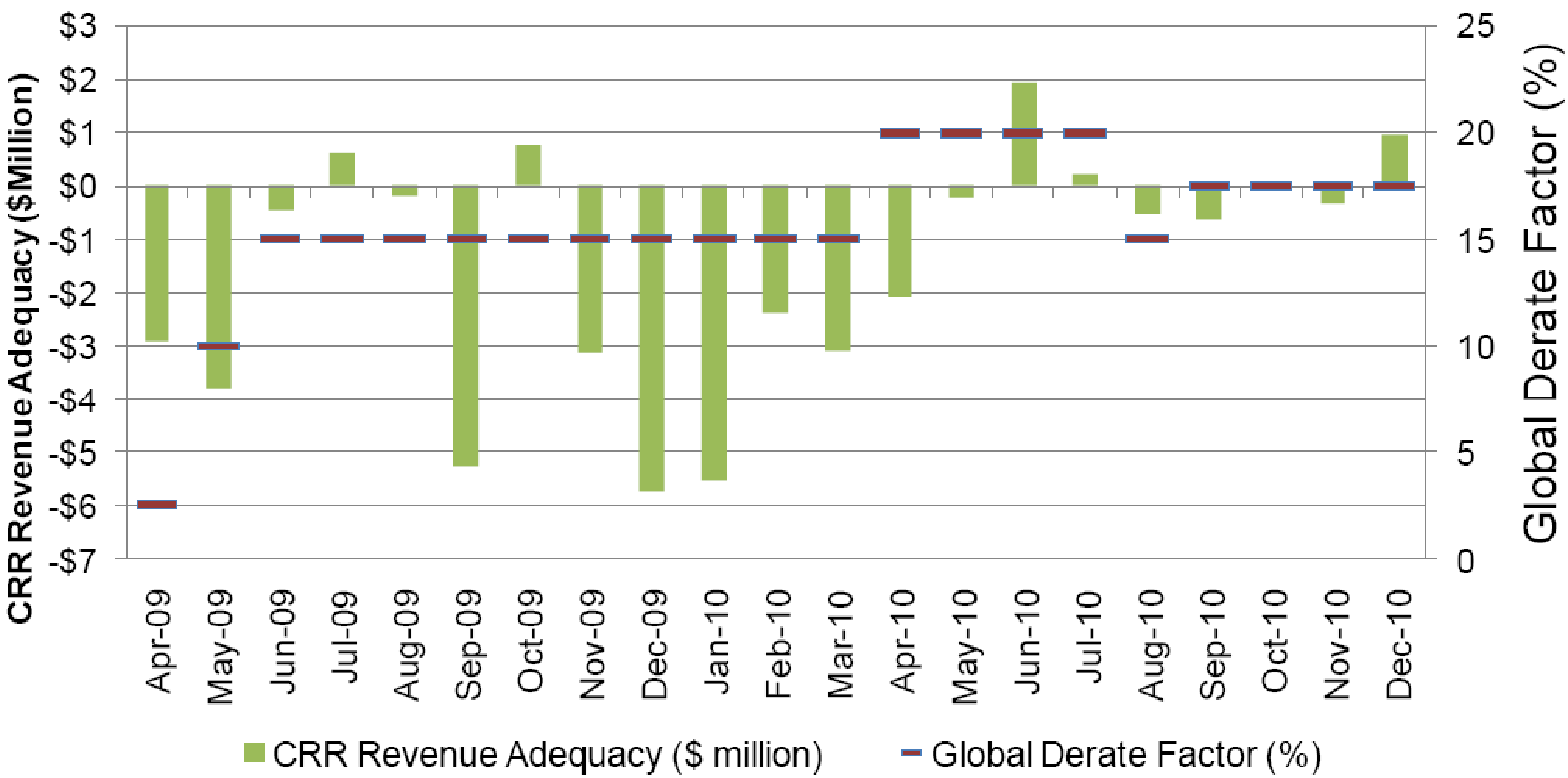
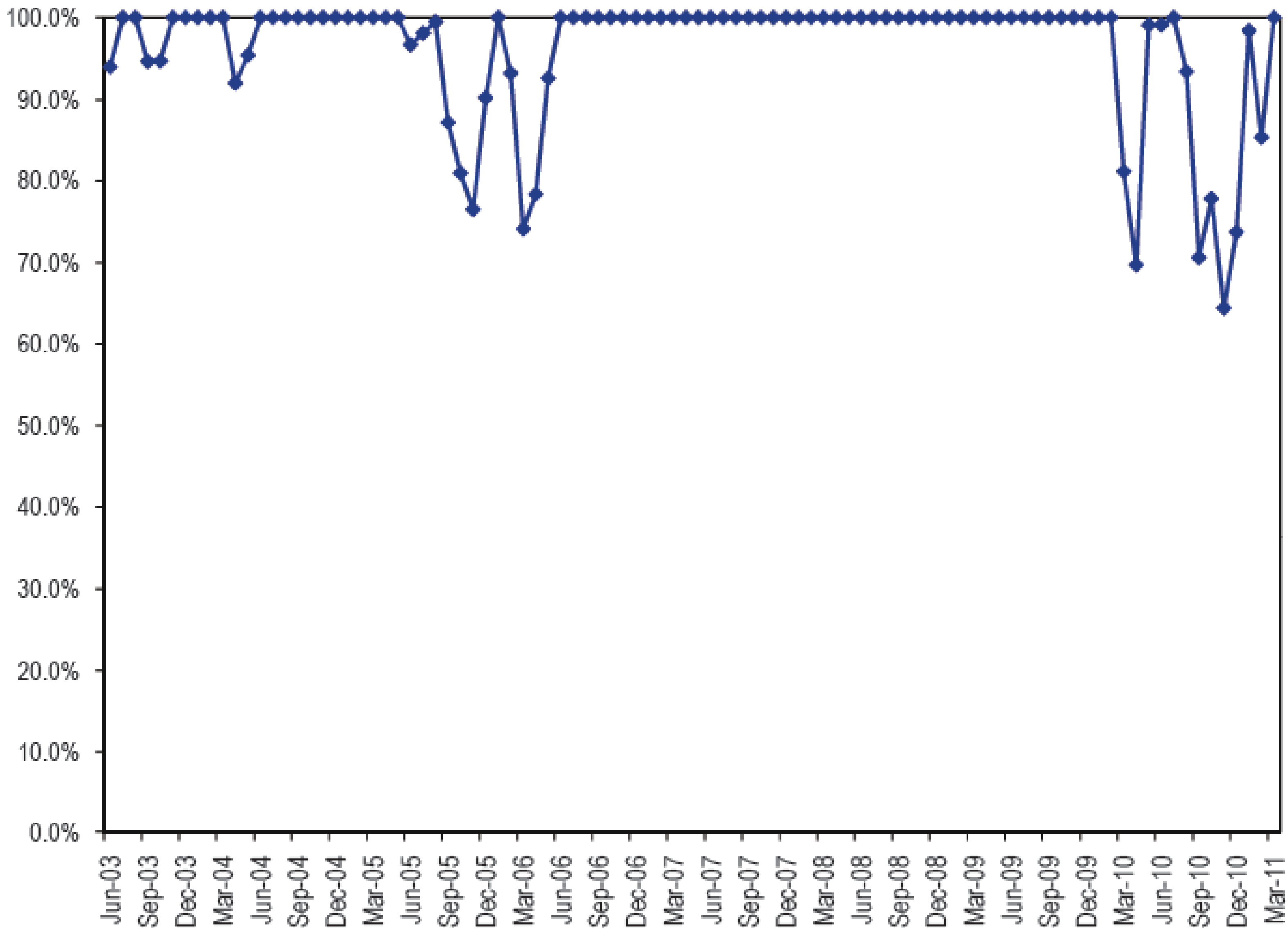
How to Cope with Revenue Inadequacy: *Method 2:* Derate Monthly Auction Qs



Source: CAISO, Annual Market Performance CRR Report, 3/2011

How to Cope with Revenue (In)Adequacy 3: Derate FTR Payout Ratio by Month (PJM)



Source: PJM State of Market Report, 2011


Market Design: a journey,
not a destination
Questions?