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# Designing Power Markets to Support Optimal Decisions: How Can Our Models Contribute?

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# Outline

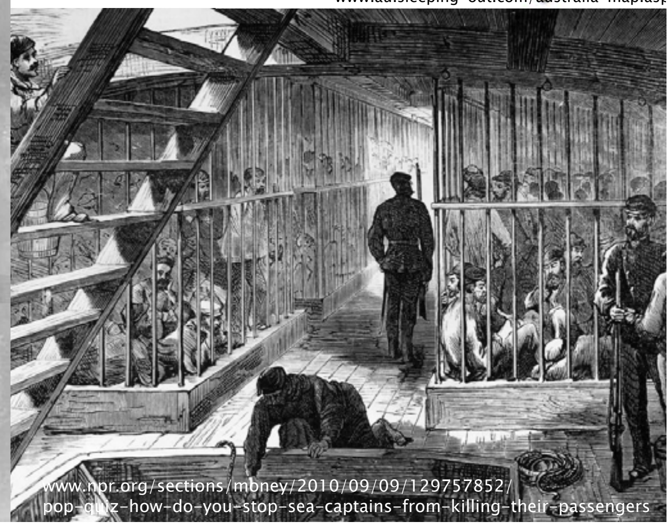
1. Why do incentives matter?
2. Market design: Goals & Model roles
3. Two key results: competitive market simulation & supporting prices
4. Two simple analyses of supporting prices in power:
   - Can spot energy prices support optimal (i) *capital* & (ii) *ramping* decisions?
5. Four market designs to overcome market failures
   - *i.* ***Ramsey pricing*** to efficiently recover fixed network costs
   - *ii.* ***Make-whole payments*** to recover nonconvex costs by generators in spot markets
   - *iii.* ***Clean Power Plan*** to fix environmental externalities ($CO_2$ control)
   - *iv.* ***Capacity markets*** to fix "missing money" in spot markets
6. Conclusion: we need your O.R. and econ skills!

http://www.caltech.edu/news/why-do-people-choke-when-stakes-are-high-4199

# 1. Incentives matter!

www.au.sleeping-out.com/australia-map.asp

en.wikipedia.org/wiki/File:Success_prison_hulk.jpg



www.npr.org/sections/money/2010/09/09/129757852/pop-quiz-how-do-you-stop-sea-captains-from-killing-their-passengers

# Getting incentives right is tricky!

(*thanks to Cindy Bothwell for this example*)

PNM offers two incentives that reduce your electric bill:

- **PNM REC Purchase Program:** Because you're adding renewable-fueled power to the PNM system, and that helps us meet our environmental goals, we credit your account 15 cents per kilowatt-hour for energy that your facility generates and consumes on site within a given billing period.

7/6/2010

**Alamogordo Daily News**

Kloepper said he set up a system to waste power in a small building at the site in order to recoup the value of his RECs from PNM, and showed the system to Teague. He explained a water heater heats 30 gallons of water to about 120 degrees, then the water is circulated through 450 feet of garden hose inside a refrigerator to cool back down and is then piped back into the water heater. The process repeats 12 times per day.

# Why focus on the Power Sector?

http://cdn.themetapicture.com/media/ cat-static-electricity.jpg

# Why is getting incentives in *power* so crucial?

- ***It's important***
  - Economy
  - Environmental problems & potential
- ***Market failures need attention***
  - Externalities → ☠, Kirchhoff's laws
  - Nonconvexities → $\nexists$ supporting prices, natural monopoly
  - Market power → California 2001
  - Incomplete markets → Lack of investment, reliability problems, half a market
- ***Opportunity presented by restructuring…***
  - Vertical unbundling & the missing consumer
  - New technologies & environmental mandates

***… Which is a process, not a destination***

# 2. Market Design: Goals & Model Roles

# The Necessity & Goals of Market Design

- ***Can't escape***
  - Local regulation: Samuel Insull
  - Federal Power Act: "Fair & Reasonable Prices"
  - Political demands for environmental benefits, control of market power
- ***Goals … and the debate over them***
  - Reliability/adequacy
  - Market efficiency: MAX social surplus
  - Supports optimal solution (no incentives to lie)
    - Incentives linked to ultimate objectives
  - Surplus for individual parties:
    - Fair distribution of benefits
    - Consumer surplus, consumer prices
    - Producer surplus
  - Sustainability
    - $CO_2$ , Conventional pollutants (e.g., High Electric Demand Days)
    - Human health
  - Technology promotion
    - Renewables & storage

# Roles for Models

- *What's the __optimal solution__ look like?*
  - For social surplus maximization?
  - Under multiple objectives?
- *What prices/policies __support__ the optimal solution?*
  - And how can they be calculated?
  - Market failures & the theory of the "second best"
- *How __distorted__ are present prices/policies?*
  - Are optimal choices supported or not?
  - What market outcomes are likely?
- *What are the __net benefits__ of better market designs?*
  - Metrics:
    - social surplus
    - consumer surplus, producer surplus, interregional distribution
    - revenue adequacy for grid owner, system operator
    - sustainability

*Focus of politics: Income redistribution is ~10X as large as efficiency gain*

# 3. A "Couple" of Key Modeling Results

## Key result #1: Equivalence of competitive market equilibrium to optimization

- ***Competitive Market equilibrium problem:***
  - Let each market party solve a (convex) profit maximization problem:

    $\text{MAX}_{\{\underline{s}_i, \underline{x}_i\}}\ \underline{p}^T \underline{s}_i - C_i(\underline{x}_i)$ =Revenue – Cost (1)

    s.t. $\underline{G}_i(\underline{s}_i, \underline{x}_i) \leq 0$ =Production function (2)
  - With the equilibrium satisfying market clearing:

    $\Sigma_i\ \underline{s}_i = \underline{0}\quad (\underline{p})$ Supply = Demand (3)
- ***Solution methods:***
  - i. Derive equilibrium problem: KKT conditions for each party $i$'s problem (1)-(2), concatenated with market clearing (3)
    - → Complementarity problem
    - Directly solve with PATH
  - ii. Equivalent single optimization problem (Samuelson, 1954)

    $\text{MAX}_{\{\underline{s}_i, \underline{x}_i, \forall i\}}\ -\Sigma_i C_i(\underline{x}_i)$ = Social surplus = Market efficiency

    s.t. (2) $\forall i$, (3)
    - Its KKTs = equilibrium problem (i)
    - This "market model" is solved by the ISOs

## Key result #2: Supporting prices

- ***Corollary of Samuelson's theorem:***
  - Duals of (3) (=prices) in market model "support" the profit-maximizing problem for each party
- Implications:
  1. ***Definition of "supporting":*** Given optimal commodity prices, no competitive firm wants to deviate from the optimal "schedule" (primal solution $\underline{s}_i$) that the ISO gives them
     - Avoid incentives to misrepresent physical characteristics or costs in order to obtain a higher profit schedule
       → *incentive compatibility*
  2. Market parties make socially optimal decisions for other primals $\underline{x}_i$
  3. Revenues cover each party's costs

# 4. Two simple applications

## Simple applications to two common market design questions (thanks to Saint Fred Schweppe for inspiration)

1. *Won't revenues in short-run energy markets fail to cover capital costs of new generators, endangering reliability?*
2. *Renewables increase the need for "ramping" capability…But since generators are only paid for energy, won't there be inadequate incentive for flexible generation?*

## *(1) Won't revenues in short-run energy markets fail to cover capital costs of new generators, endangering reliability?*

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- *Caramanis (IEEE TPWRS, 1982); Schweppe et al. (1988)*
  - Market equilibrium model:
    - Consumers: $\text{MAX}_{\{d_{jt}\geq 0\}} \; \Sigma_t \, B_{jt}(d_{jt}) - p_t \, d_{jt}$ (1) — Benefit – Expenditure
    - Generators: $\text{MAX}_{\{g_{it}, cap_i \geq 0\}} \; \Sigma_t \, (p_t - CG_i) g_{it} - CC_i \, cap_i$ (2) — Gross Margin – Cap Cost
      $s.t. \quad g_{it} - cap_i \leq 0 \;\; \forall t$ (3) — Output ≤ Cap
    - Market clearing: $\Sigma_j \, d_{jt} - \Sigma_i \, g_{it} = 0 \;\; (p_t) \;\; \forall t$ (4) — Demand – Supply = 0
  - By Result 1: Samuelson competitive market model: — Net Market Surplus
    $\text{MAX}_{\{d_{it}, g_{it}, cap_i \geq 0\}} \; \Sigma_j \Sigma_t \, B_{jt}(d_{jt}) - \Sigma_i \, [\Sigma_t \, CG_i \, g_{it} + CC_i \, cap_i]$
    $s.t. \quad (3) \; \forall i,t; \;\; (4), \; \forall t$
  - By Result 2, energy prices $p_t$ not only support optimal generation $g_{it}$, but also the optimal investment $cap_i$

## How does a power system with low operating costs pay for its capital?

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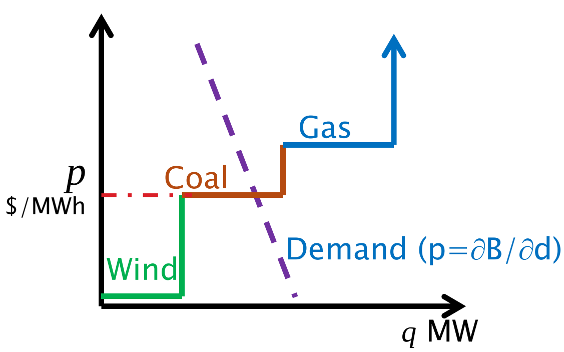
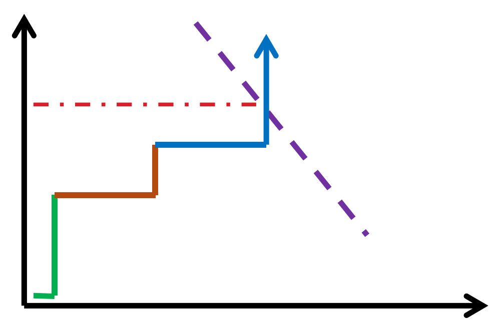
*Short run supply and demand:*




Low demand/high wind period:
→ marginal fuel cost likely to set price



High demand/low wind hour:
→ demand (marginal benefits ∂B/∂d) sets price
(*"scarcity pricing"*)

***Today***: active demand absent from the short-term market,
→*scarcity prices must come from elsewhere*

# (2) Ramp problems

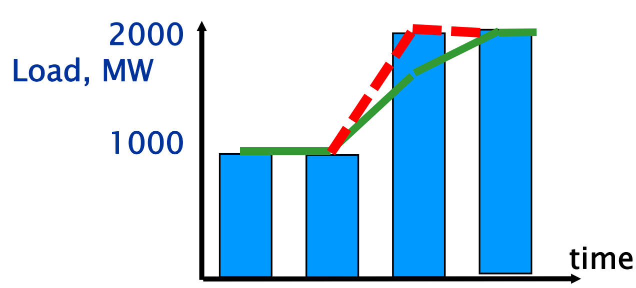
## (2) Renewables increase the need for "ramping" capability; yet generators are only paid for energy, so won't there be inadequate incentive for flexible generation?

- ***It turns out that energy prices support optimal ramping decisions. Example:***

A system with two types of generation:

- 1000 MW of quick start peakers @ $70/MWh
- 2100 MW of slow thermal @ $30/MWh, with max ramping = 600 MW/hr

Morning ramp up and resulting generation:




| | | | | | |
|---|---|---|---|---|---|
| Fast | 0 | 0 | 400 | 0 | MW |
| Slow | 1000 | 1000 | 1600 | 2000 | MW |
| Price: | 30 | -10 | 70 | 30 | $/MWh |

# Crucial research:

How to set real-time prices that reflect value of scarcity?
How often to update 'em?
How to communicate them, and get all parties to act on them?

## 5. Four Applications of Models to Correct Market Failures

www.pinterest.com

## Case 1: Optimizing regulated prices to recover fixed network costs (thanks to F. Alvarado for inspiration)

## Example Case 1: Must recover fixed costs of natural monopoly network (AC>MC)


- Approach: Use analysis to define "2nd-best" (surplus maximizing) prices, subject to cost recovery: *Ramsey(1927)-Boiteux(1956) Pricing*
  - *"2nd best": in an economy with market failures, the surplus maximizing P doesn't necessarily = MC.*
  - *I.e., one distortion might be best countered by another*
- Model:
  - *3 Features: Fixed costs to be recovered; Multiple consumers with demand functions; You can price discriminate*
  - $$\text{MAX}_{\{s, d_j, p_j \geq 0\}} \; \Sigma_j B_j(d_j) - C(s) \quad \textbf{(Market surplus)}$$

$$\textit{s.t.} \quad \Sigma_j p_j d_j = C(s) + \textit{Fixed Cost} \quad \textbf{(Revenue recovery)}$$

$$p_j = \partial B_j(d_j) / \partial d_j \quad \forall j \quad \textbf{(Demand function)}$$

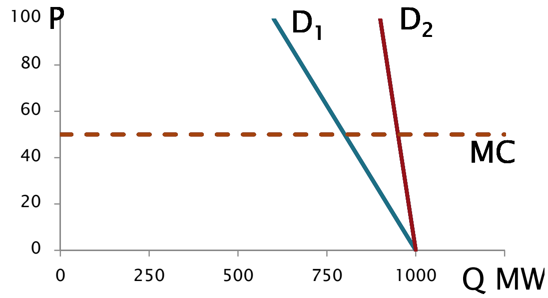
$$\Sigma_j d_j - s = 0 \;\; (p_t) \quad \textbf{(Energy balance)}$$

- *Lagrangian → Inverse elasticity rule for "2nd best" price:*

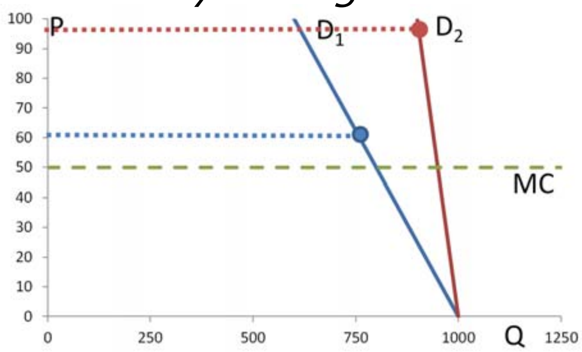
$$(p_j - \text{MC})/p_j \propto 1/\textit{Elasticity}_j$$

# Example: Recover $50K in distribution costs from two customer classes (elastic, inelastic)

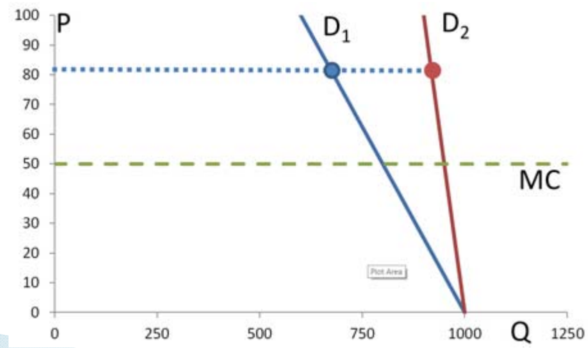
*Assumptions*




*Price Results:*
*Ramsey Pricing*

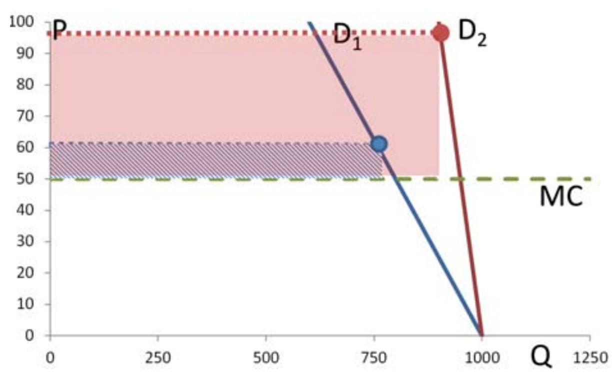



*Identical Prices*

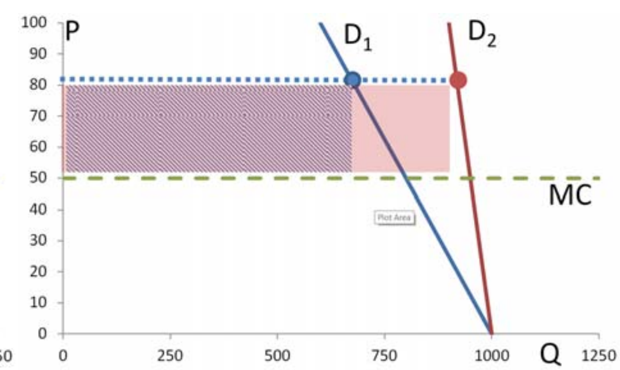



# Contributions to $50K fixed costs

*Ramsey Pricing*



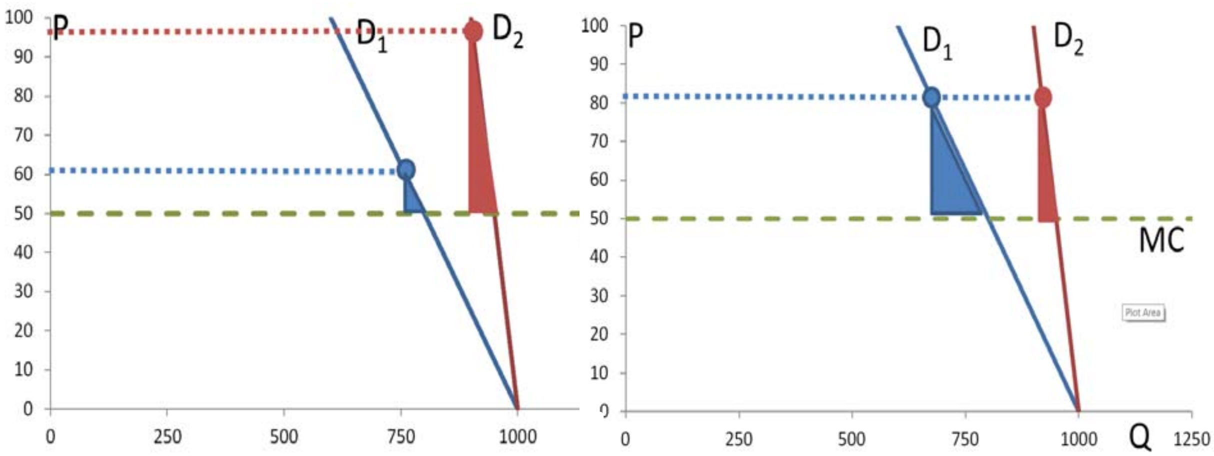

*Identical Prices*




The differences in *who* pays is >>
the efficiency gain on the next slide

# Market efficiency impacts: "Dead Weight" loss of efficiency

*Ramsey Pricing* *Identical Prices*




Ramsey Pricing imposes 47% less efficiency loss

- Ramsey: $0.74/MWh loss (1.5% of cost)
- Uniform: $1.41/MWh loss (3% of cost)

# Crucial research:

How to appropriately incent behind-the-meter generation & demand-response, s.t. financial sustainability for network?

## Case 2: Optimizing "make whole payments" to recover nonconvex costs (thanks to R. O'Neill, B. Hogan, A. Conejo, S. Siddiqui for inspiration)

http://robertlovespi.net/2014/06/22/tessellation-using-only-non-convex-polygons/

## *Example Case 2: Nonconvex operating costs → P might not support optimal unit commitment schedules*

- Can we define optimal "side payments" to scheduled generators who lose money to keep them in the market?
  - *... And optimal "penalties" to unscheduled generators to keep them out?*
- Approach: Use analysis to define side payments that support the equilibrium
- Present practice:
  1. "Make Whole Payments": If a generator loses money in a schedule (due to fixed costs of start-up or minimum-run), then operator writes a check
     - *Ad hoc, revenue inadequate for operator*
  2. "Dispatchable Model": Separate scheduling & pricing runs: in pricing run, relax 0-1 binary constraints for small inflexible units (CAISO, NYISO, MISO Extended LMP)
     - *Higher energy prices, but prices not supporting*

## An optimal "side payment" model ("Restricted model" O'Neill, Sotkiewicz, Hobbs, Rothkopf, Stewart, EJOR, 2005)

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- *Step 1: Solve MILP for optimal primal unit commitment schedule (simple example):*

$$\text{MIN}_{\{z_{it} \in \{0,1\},\, g_{it}\}} \Sigma_i \Sigma_t [CG_i\, g_{it} + CZ_i\, z_{it}] \quad (1)$$
$$\textit{s.t.} \quad g_{it} \geq z_{it} MR_i \quad (2)$$
$$-g_{it} \geq -z_{it} CAP_i, \quad \forall i,t \quad (3)$$
$$\Sigma_i g_{it} = D_t \quad (p_t), \ \forall t \quad (4)$$

Energy + Commitment Cost (1)
Minimum output (2)
Maximum output (3)
Supply = Demand (4)

  - Let $z_{it}$* be the optimal commitment
- *Step 2: Solve LP for supporting prices, given* $z_{it}$*

$$\text{MIN}_{\{z_{it},\, g_{it} \text{ both continuous}\}} \Sigma_i \Sigma_t [CG_i\, g_{it} + CZ_i\, z_{it}]$$
$$\textit{s.t.} \quad \text{(2)-(4), and } z_{it} = z_{it}^* \quad (\mu_{it}), \quad \forall i,t$$

- ***Step 3: Settlement:***
  - If $z_{it}$* =1, then pay: $p_t\, g_{it}$ + MAX(0, $\mu_{it}\, z_{it}$)
  - If $z_{it}$* =0, then pay nothing, but assess penalty of $-\mu_{it}\, z_{it}$ if unit starts up

# Results:

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- ***The payments support equilibrium***
  - A scheduled generator gets a "make whole" payment if otherwise would lose money
  - Unscheduled generator will not earn profit if it self-schedules
  - System operator not necessarily revenue adequate
    - Worst case: revenue shortfall = make whole payments
- ***Annoyingly:***
  - Massively degenerate→ many possible sets of payments
  - Unsuccessful in search for transparent, practical method to MIN "side payments" & resulting uplift
- ***Present debate:***
  1. "Extended LP"/Convex Hull pricing (see Bill Hogan's talk)
     - Originally proposed by MISO
     - Too complex for stakeholders, settled for a CAISO/NY system
  2. Choose uplifts as optimal tradeoff between objectives of MAX short run efficiency & MIN payments (Conejo; Siddiqui)
     - MPEC structure, would require FERC policy change

# Simple example:

- *One period, D = 250 MW*

| Generator | MR [MW] | CAP [MW] | CG [$/MWh] | CZ [$] |
|---|---|---|---|---|
| Flex Baseload | 0 | 100 | 40 | 0 |
| Flex Cycling | 0 | 100 | 60 | 0 |
| Inflex Peaker | 100 | 100 | 100 | 0 |

- *Results of "restricted model" (O'Neill et al.)* → $p$ = $60/MWh:

| Generator | $z_i^*$ | $g_i$ MW | Cost | $p^*g_i$ | $M_i$ | Make Whole Payment | Profit |
|---|---|---|---|---|---|---|---|
| Flex Baseload | 1 | 100 | $4,000 | $6,000 | -$2,000 | $0 | $2,000 |
| Flex Cycling | 1 | 50 | $3,000 | $3,000 | $0 | $0 | $0 |
| Inflex Peaker | 1 | 100 | $10,000 | $6,000 | $4,000 | $4,000 | $0 |

← *All nonnegative*

- *Results of "dispatchable model" (NYISO/CAISO method):*
  - Solve pricing model (relax peaker's $z$ from {0,1} to [0,1]) → $p$=$100

| Generator | $z_i^*$ | $g_i$ MW | Cost | $p^*g_i$ | Make Whole Payment | Profit |
|---|---|---|---|---|---|---|
| Flex Baseload | 1 | 100 | $4,000 | $10,000 | $0 | $6,000 |
| Flex Cycling | 1 | 50 | $3,000 | $5,000 | $0 | $2,000 |
| Inflex Peaker | 1 | 100 | $10,000 | $10,000 | $0 | $0 |

← *Schedule not supported*

# Crucial research:

How to incent honest disclosure of nonconvex costs?
How to avoid distorting investment decisions?

# Case 3: Optimal pricing for $CO_2$ reductions (inspired by Anthony Paul, JHU & RfF)

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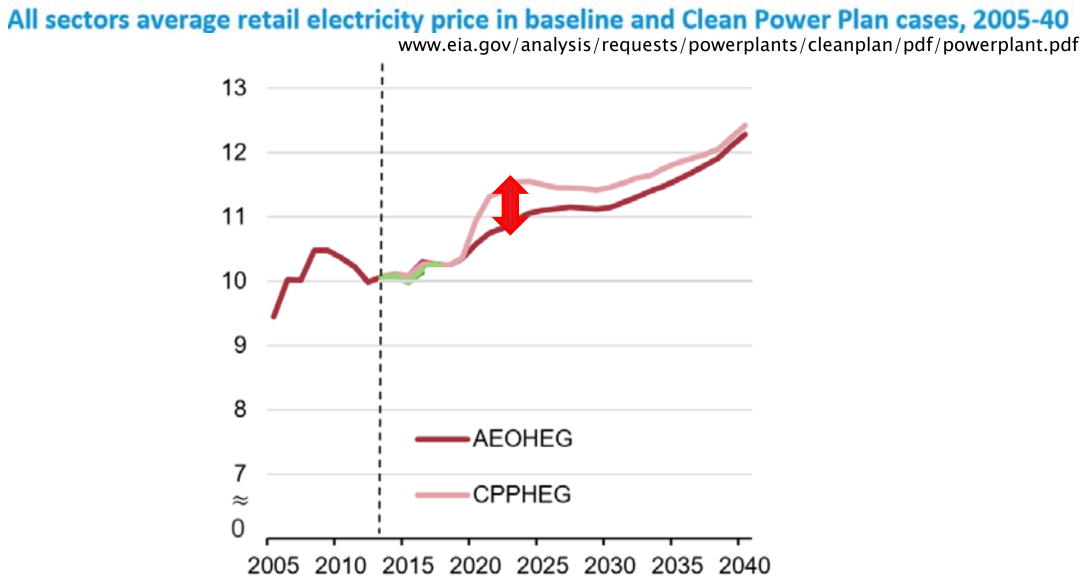
www.whitehouse.gov/climate-change

## The huge economic stakes




- A 29-36% reduction in power sector $CO_2$ by 2030 (EIA, 2015)
  → *loss of 0.17-0.25% of GNP by 2040*

## Example 3: $CO_2$ regulation under Clean Power Plan

- ***Two types of carbon caps by state . Max allowed either:***
  - Tons/MWh (rate-based)
  - Total tons (mass-based)

- ***Different cap types will be adopted by states. What does this imply for electricity & $CO_2$ market efficiency?***
  - Rate-based cap states may have lower wholesale power P's than mass-based states
    → Output expands in former, shrinks in latter
  - Rate-based cap
    → Total $CO_2$ might increase

- ***How important is correct pricing of $CO_2$ for economic & environmental efficiency?***

## Model: (1) *Neighboring states trade power; (2) Mass-based states trade $CO_2$; (3) Rate-based states trade ERCs*

- ***Each mass-based state i has problem:***

$$\text{MIN}_{\{0 \le g_{ik} \le CAP_{ik};\ t_{ji}, co2cr_i\}} \ \Sigma_k C_{ik}(g_{ik}) + \Sigma_{j \in j(i)} p_{ji} t_{ji} + p_{CO2}\, co2cr_i \quad \text{Gen+Import+C Credit Cost}$$

$$\text{s.t.} \quad \Sigma_k g_{ik} + \Sigma_{j \in j(i)} p_{ji} (t_{ji} - t_{ij}) = D_i \quad \text{Energy Balance}$$

$$\Sigma_k CO2_{ik}(g_{ik}) - co2cr_i \le MBCAP_i \quad \text{Carbon mass cap}$$

- ***Each rate-based state i has problem:***

$$\text{MIN}_{\{0 \le g_{ik} \le CAP_{ik};\ t_{ji}, erc_i\}} \ \Sigma_k C_{ik}(g_{ik}) + \Sigma_{j \in j(i)} p_{ji} t_{ji} + p_{erc}\, erc_i \quad \text{Gen+Import+ERC Cost}$$

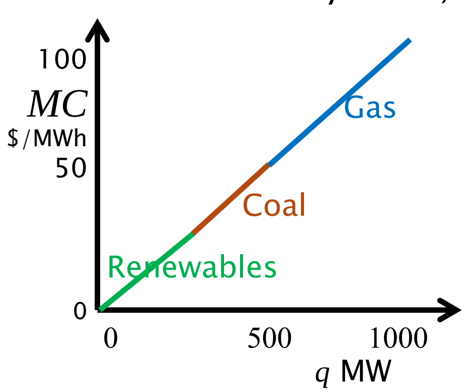
$$\text{s.t.} \quad \Sigma_k g_{ik} + \Sigma_{j \in j(i)} p_{ji} (t_{ji} - t_{ij}) = D_i \quad \text{Energy Balance}$$

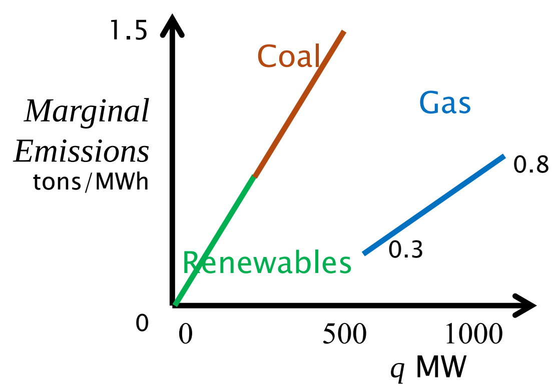
$$[\Sigma_k CO2_{ik}(g_{ik})]/[\Sigma_k g_{ik} + erc_i] \le RBCAP_i \quad CO_2\text{/MWh rate cap}$$

- ***Market clearing:***
  - Power trade: $t_{ji} - t_{ij} = 0 \ (p_{ij}, p_{ji}); \ -T_{ij} \le t_{ij} \le T_{ij}, \ \forall i; j \in j(i), j > I$
  - Mass-based $CO_2$: $\Sigma_{i \in MB}\, co2cr_i = 0 \ (p_{co2cr})$
  - Rate-based $CO_2$: $\Sigma_{i \in RB}\, erc_i = 0 \ (p_{erc})$
- ***Solve by concatenating KKTs of problems with market clearing, or a single equivalent optimization***

## Case study: Plant redispatch for $CO_2$ reduction

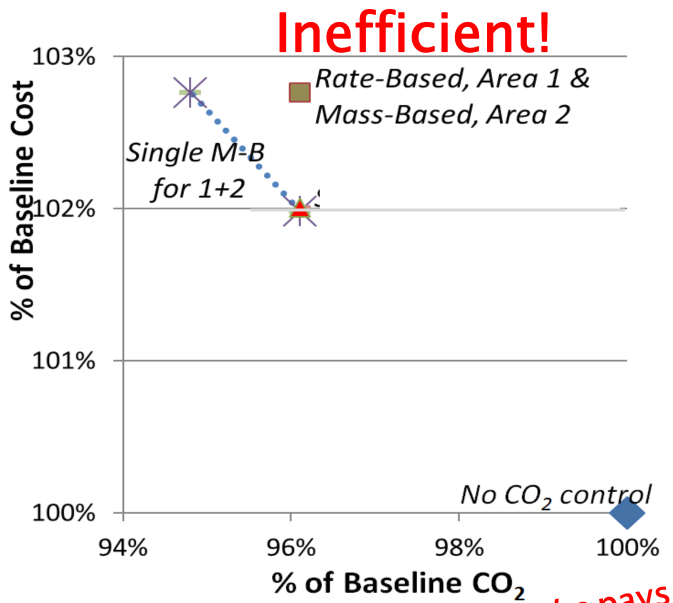
- Two systems, each with the following generation mix:




- Load in each area=750 MW; ∞ transmission capacity
- $CO_2$ Rules
  1. No control
  2. Goal of 6.9% decrease: Different rules among states:
     - *System 1: Rate based (0.6 tons/MWh)*
     - *System 2: Mass-based (450 tons)*
  3. Both systems with mass-based

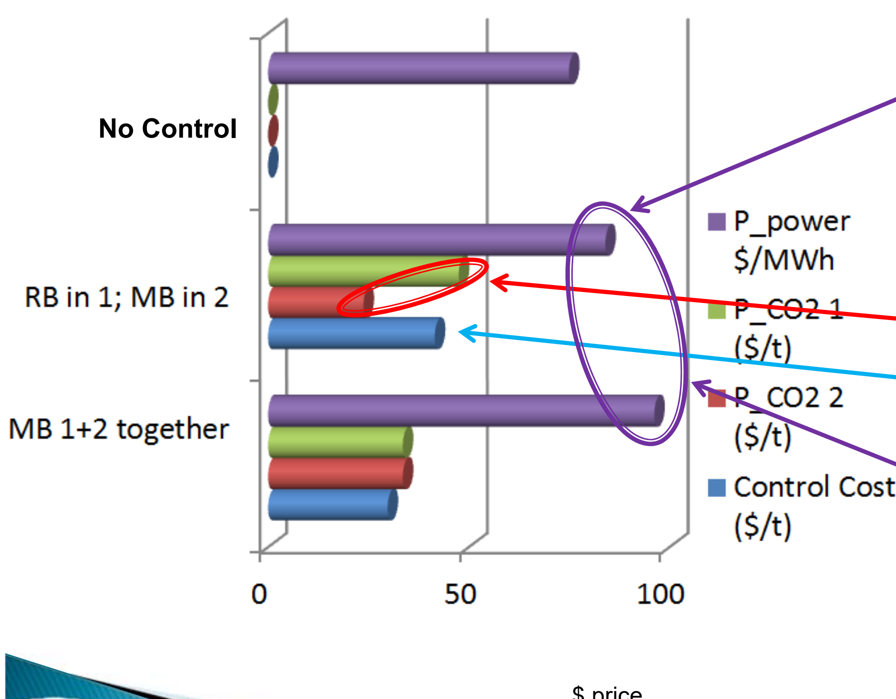
# Cost + $CO_2$ Results




The differences in *who* pays is >> the efficiency gain

- Mix of Cap types fails to achieve 6.9% reduction goal, and is inefficient
- *Major reason:* Rate-based policy subsidizes power sales → System 1 produces 11% more (at higher cost) and exports to System 2

# Price Results




1. Inefficiently low power price → discourages energy efficiency as $CO_2$ control
2. Inefficient $CO_2$ prices → 40% higher cost of control
3. Consumers pay more under all MB (10-20X efficiency gain)

# Crucial research:

How to design C markets so that they yield efficient C reductions, and don't mess up power markets?

# Case 4: Supporting prices in capacity markets

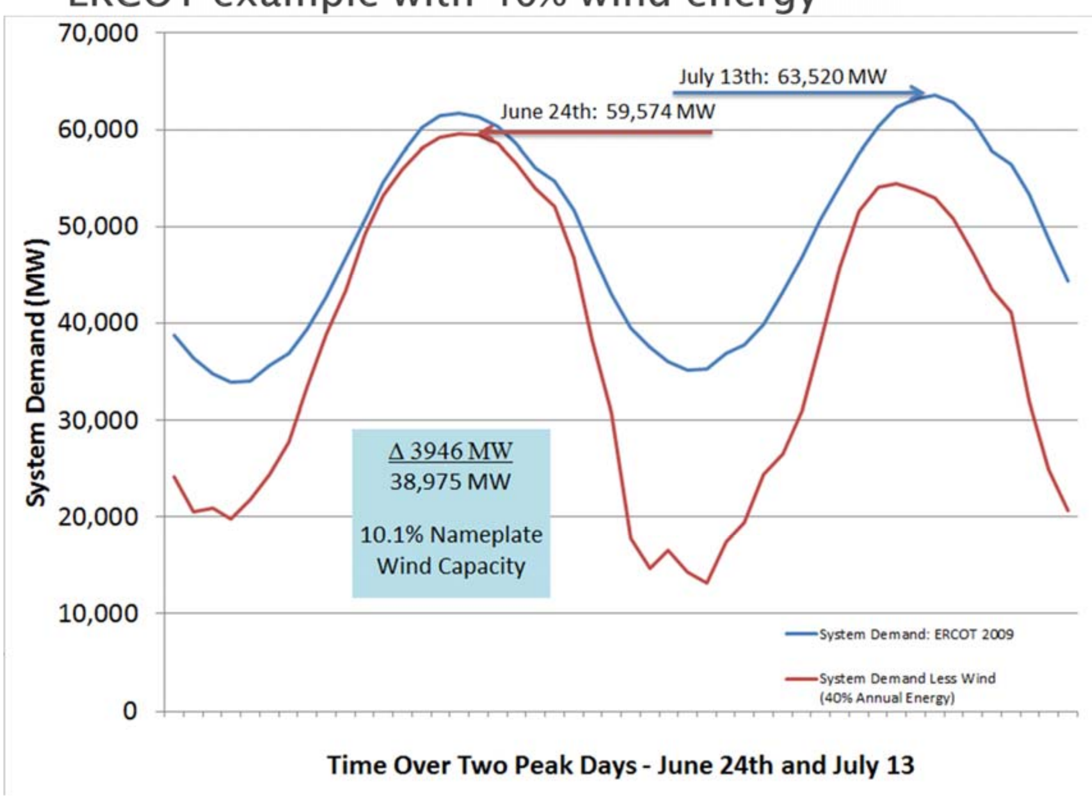
(Lead author: Ph.D. student Cindy Bothwell)

# Supporting Prices in Generation Capacity Markets

- ***Market failure: Caps on energy P's mean that generators do not earn the full value of their production during periods of scarcity → underinvestment***
  - Also: missing markets (for long-term contracts), regulatory uncertainty
- ***Policy response: Markets for capacity in several ISOs***
  - PJM Reliability Pricing Model (administrative demand curve for centralized 3 yr-ahead capacity market)
  - CAISO: requirement 1 yr ahead for "capacity showing" by load serving entities, met through bilateral contracts
- ***Issue: what "credit"/capacity payment to give to renewables …. and what (if any) distortions result from the wrong credit?***

# What do renewables contribute?

## ERCOT example with 40% wind energy



# Capacity market model

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- Market model (no energy P cap):
  - Consumers:

    $MAX_{\{0 \le d_t \le D_t\}}$ $VOLL\, d_t - p_t\, d_t$ Value of Lost Load – Payment
  - Generators:

    $MAX_{\{g_{it},\, cap_i \ge 0\}}$ $\Sigma_t\, (p_t - CG_i)\, g_{it} + (p_{capacity} - CC_i)\, cap_i$ Energy&Capacity Revenue–Cost

    $s.t.$ $g_{it} - cap_i \le 0 \quad \forall t$ Capacity constraint
  - Market clearing (energy):

    $\Sigma_j\, d_{jt} - \Sigma_i\, g_{it} = 0 \quad (p_t)\ \forall t$ Demand – Supply = 0
  - Market clearing (capacity):

    $\Sigma_i\, \beta_i\, cap_i \ge (1+RM)\, D_{Peak} \quad (p_{capacity})$ Weighted capacity ≥ Reserve Req.
- Policy experiments:
  - Base case: no market failure (energy-based market, no price cap)
  - Market failures: price cap < VOLL; wrong capacity credits $\beta_i$

# Data

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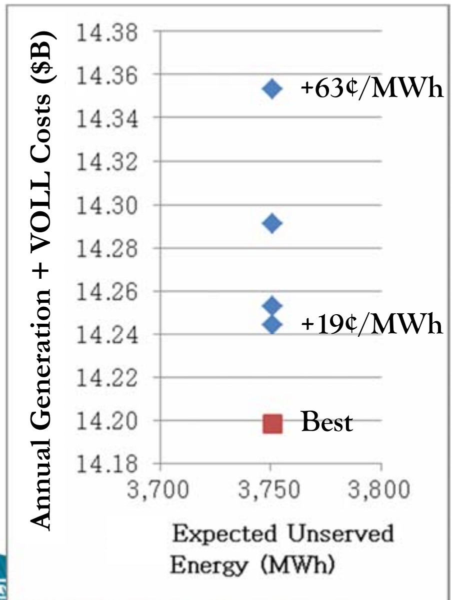
- ERCOT 2013 existing system using normalized hourly actual load, wind, and solar data
- Load scaled to 50,000 MW Peak
- New generation costs (EIA), except 22.5 GW existing coal (lower "going forward" costs)

| | 2013 |
|---|---|
| Load Factor | 56.3% |
| Wind cf | 38.9% |
| Solar cf | 24.0% |

| Technology | Fixed Cost $/MW/yr | Variable & Fuel | Variable Subsidy | Availability Factor | EFORd |
|---|---|---|---|---|---|
| ACT | $ 80,154 | $ 79.6 | | 90% | 11.0% |
| ACC | $ 136,419 | $ 53.6 | | 86% | 5.4% |
| Conv Coal | $ 120,253 | $ 29.4 | | 85% | 7.0% |
| Wind | $ 222,329 | $ - | $ (23.0) | | |
| Solar PV - 45% | $ 159,257 | $ - | | | |

# Results: Compare reserve margin solutions with optimal VOLL solution

*…reserve margin adjusted to achieve same unserved energy*




Energy P Cap \$1,000/MWh; $\beta_{Wind}$ = 40%, $\beta_{Solar}$ = 75%*

$\beta_{Wind}$ = 25%, $\beta_{Solar}$ = 50%

$\beta_{Wind}$ = 14.6%, $\beta_{Solar}$ = 50%

$\beta_{Wind}$ = 0%, $\beta_{Solar}$ = 0%

Optimal Energy: VOLL \$10,000, No Price Cap

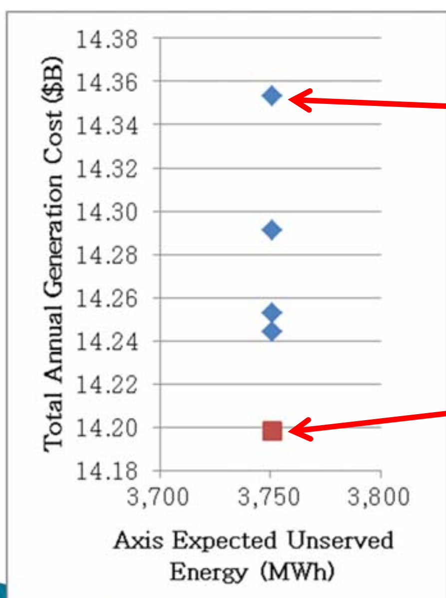
~*Also: $\beta_{Wind}$ = 54.5%, $\beta_{Solar}$ = 10%*

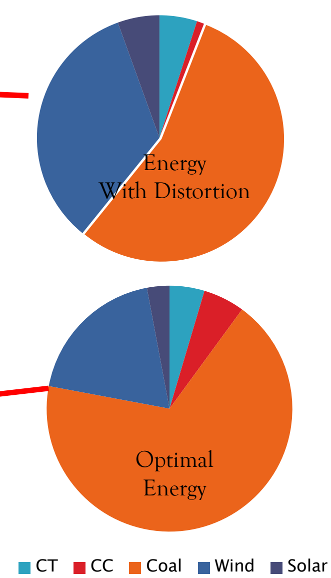
*Assumed W/S capacity contribution: 40%/75%

*Actual marginal W/S contribution: 8%/40.5%*

*Actual average W+S contribution: 23%*

# Results: Investment Mix




| Installed Capacity (MW) | | |
|---|---|---|
| Type | Optimal | β= 40%S/ 75%W |
| CT | 21,071 | 22,754 |
| CC | 4,932 | 1,029 |
| Coal | 22,500 | 22,500 |
| Wind | 13,816 | 24,465 |
| Solar | 3,476 | 6,480 |

# Crucial research:



What's the capacity value of new technologies, and how can we correctly reward it?

# Conclusions

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# Market design: a journey, not a destination

- *We need optimal solutions, supporting prices, & market designs for many issues!*
- *You need economic insights & modeling skills*


Current initiatives and stakeholder processes

- 2015-2016 Transmission planning process
- 2014-2015 Transmission planning process
- 2013-2014 Transmission planning process
- Bid cost recovery and variable energy resource settlements
- Bidding rules enhancements
- Budget and grid management charge
- Capacity procurement mechanism replacement
- Commitment costs
  - Commitment cost enhancements phase 3
  - Commitment cost enhancements phase 2
  - Commitment cost enhancements
- Commodity Futures Trading Commission (CFTC) related initiatives
  - Inter-SC trades oversight exemption
- Competitive solicitation process enhancements
- Contingency modeling enhancements
- Contingency reserve cost allocation
- Demand response
  - Supply resource demand response integration
  - Demand response net benefits test
- Energy Imbalance Market year 1 enhancements
- Energy Imbalance Market governance development
- Energy Imbalance Market participants
- Energy storage and distributed energy resources
- Energy storage interconnection
- Expanding metering and telemetry options
- FERC order 1000 compliance
  - FERC order 1000 compliance phase 2
- FERC order no 764 market changes
- Flexible capacity needs technical study process
- Flexible capacity procurement
- Flexible ramping product
- Flexible resource adequacy criteria and must offer obligations
- Frequency response
- Full network model expansion
- Generator interconnection procedures
  - Deliverability allocation procedures reassessment
  - Interconnection process enhancements
  - Interconnection process enhancements 2015
- **Interregional transmission planning**
- Load granularity refinements
- Local capacity requirements process
- Merced Irrigation District transition
- Natural gas pipeline penalty recovery
- PacifiCorp participation study
- Participating transmission owner per unit costs
- Pay for performance regulation
- Payment default allocation
- Peak reliability coordinator funding
- Pricing enhancements
- Reactive power requirements and financial compensation
- Reliability must-run pump load
- Reliability services
- Renewable resources integration
  - Market and product review phase 2
- Stakeholder initiatives catalog process
- Tariff clarifications filing process
- Transmission access charge options

# When ought you kludge, and when start from scratch?

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J. Ely, *American Economic Review 2013* (thanks to Steve Stoft)

In July of 2004, Microsoft announced that the release of Vista, the next generation of the Windows operating system, would be delayed until late 2006. Jim Allchin famously walked into the office of Bill Gates and proclaimed, "It's not going to work." Development of Windows had become unmanageable and Allchin decided that Vista would have to be rewritten essentially from scratch.

> *Mr. Allchin's reforms address a problem dating to Microsoft's beginnings. PC users wanted cool and useful features quickly. They tolerated—or didn't notice—the bugs riddling the software. Problems could always be patched over. With each patch and enhancement, it became harder to strap new features onto the software since new code could affect everything else in unpredictable ways.*[1]