ENERGY MARKETS
Incentives, Demand Pull and Innovation

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NAS Energy Panel

Determinants of Market Adoption of Advanced Energy Efficiency and Clean Energy Technologies

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ENERGY MARKETS Energy Uncertianty

Recognition of the importance of uncertainty can change the fundamental character of optimal policies.

> "…the range of uncertainty is impressive; it is so large that the *uncertainty may be the most important feature of the analysis*. The particular values for any one scenario-whether most likely case, expected value, or even the low and high scenarios, are suggestive of neither the limits of our knowledge nor the reach of the possible changes. The risk analysis with the probability distribution conveys qualitatively different information." (emphasis added)

Source: W. Hogan (1985), "Energy and Economy: Global Interdependences," *The Energy Journal*, Vol. 6. No. 4, p. 17.

The policy implications include hedging strategies, efficient incentives, and better institutional design to promote innovation and adaptation.

An emphasis on demand pull as a primary driver for innovation has a long history.

"Schmookler's (1966) main contention, contrary to the prevailing emphasis on changes in scientific and technological knowledge, was that demand played a leading role in determining both the direction and magnitude of inventive activity. His basic underlying premises were two: (1) That the ability to make inventions is widespread, flexible, and responsive to profit-making opportunities; and (2) That the larger an actual or potential market is, the more inventive activity will be directed toward it, partly because the profitability of invention rises with market size, all else equal, and partly because ***chance encounters*** between inventive talent and a problem needing solution are more frequent, the more productive activity there is devoted to meeting some demand." (emphasis added)

"Markets work, both internally and externally, in transmitting demand-pull stimuli. Both the pull of demand and differences in technological opportunity, which determine the specific industries in which inventive activity is concentrated, must be taken into account for an adequate conception of how technological change occurs."

Source: F.M. Scherer, "Demand-Pull and Technological Invention: Schmookler Revisted," *The Journal of Industrial Economics*, Vol. 30, No. 3 (Mar., 1982), pp. 225-237.

"…addressing climate change requires such a massive transformation of energy production and use that some have argued that incremental changes to existing technologies will be ineffective or prohibitively expensive; and yet, current and proposed policies are overwhelmingly dominated by demand-pull measures. Are the incentives provided by demand pull policies sufficient to induce non-incremental technological change?"

"Examples of government actions that raise the payoffs for successful innovations include: intellectual property protection, tax credits and rebates for consumers of new technologies, government procurement, technology mandates, regulatory standards, and taxes on competing technologies."

Source: Gregory F. Nemet, "Demand-pull, Technology-Push, and Government-Led Incentives for Non-Incremental Technical Change," *Research Policy*, 38 (2009) 700–709

"… subsidizing demand is generally more expensive and second best to pricing environmental, security, and other externalities directly."

Source: Gregory F. Nemet, "Subsidies for New Technologies and Knowledge Spillovers from Learning by Doing," *Journal of Policy Analysis and Management*, Vol. 31, No. 3, (2012), 601-622.

ELECTRICITY MARKET Going Green

The focus on the electricity sector's role in addressing climate change through improved efficiency, development of renewable energy, and use of low carbon fuels creates expanded demands for and of electricity restructuring.

The transformation envisioned is massive, long term, and affects every aspect of electricity production and use.

- Uncertain conditions require a broad range of activities to integrate new technology and practices.
- Innovation requires promoting technologies and practices not yet identified or imagined. "Silver buckshot rather than silver bullets." (RE<C)
- Smart grids can facilitate smart decisions, but only if the electricity structure provides the right information and incentives.
  - Open access to expand entry and innovation.
  - Smart pricing to support the smart grid technologies and information.
  - Internalizing externalities, while exploiting "chance encounters between inventive talent and a problem needing solution."
    - ***Good market design with efficient prices.***
    - ***Price on carbon and other emissions.***
    - Compatible infrastructure expansion rules.

Policies for smart grids emphasize better deployment of information and incentives. A major challenge is to improve the information and rationalize the incentives deployed. According to the White House plan:

> "A smarter, modernized, and expanded grid will be pivotal to the United States' world leadership in a clean energy future. This policy framework focuses on the deployment of information and communications technologies in the electricity sector. As they are developed and deployed, these smart grid technologies and applications will bring new capabilities to utilities and their customers. In tandem with the development and deployment of high-capacity transmission lines, which is a topic beyond the scope of this report, smart grid technologies will play an important role in supporting the increased use of clean energy.
>
> …
>
> This framework is premised on four pillars:

1. Enabling cost-effective smart grid investments
2. Unlocking the potential for innovation in the electric sector
3. Empowering consumers and enabling them to make informed decisions, and
4. Securing the grid." [1]

At least three of the four pillars imply a need for better pricing structures and signals.

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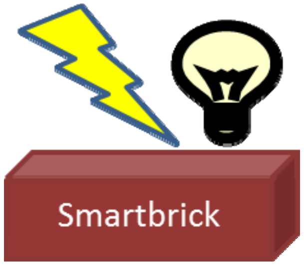
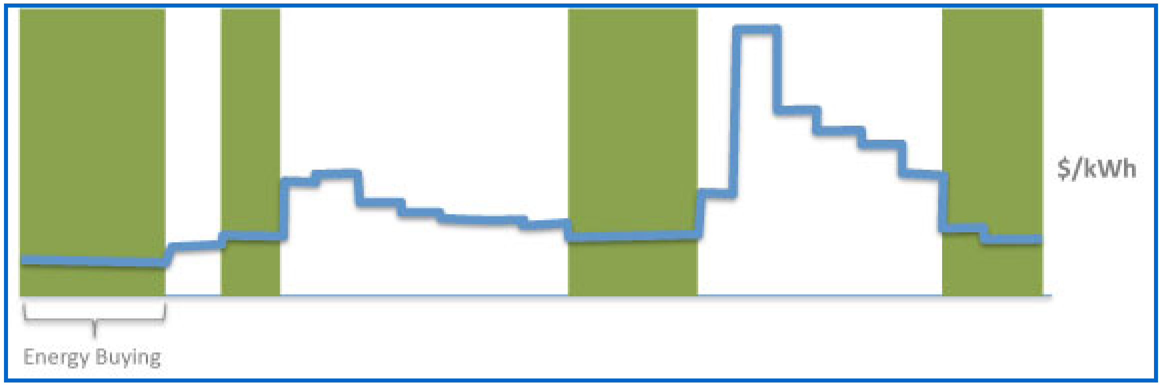
[1] Subcommittee on Smart Grid of the National Science and Technology Council, Committee on Technology, *A POLICY FRAMEWORK FOR THE 21st CENTURY GRID: Enabling Our Secure Energy Future*, White House, June 13, 2011, p. v.

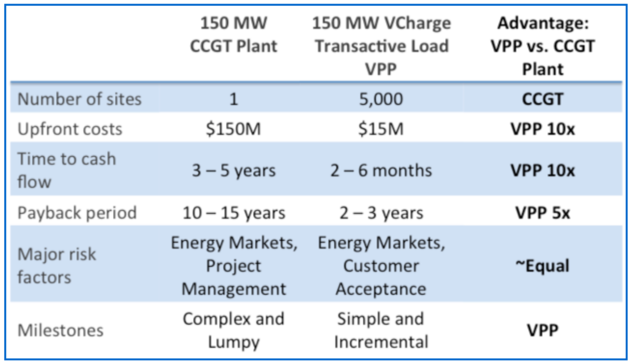
ELECTRICITY MARKET Pricing and Smartbricks

Vinalhaven, Fox Islands, Maine, is the site of one of the first large wind power projects on the east coast of the United States, approved by a vote of 383–5 on July 29, 2008. The “chance encounter” produced Vcharge and virtual power plants (VPP) using Smartbricks.

Smartbricks: Ceramic brick thermal storage heating systems and controllers in existing storage heaters.







	150 MW CCGT Plant	150 MW VCharge Transactive Load VPP	**Advantage: VPP vs. CCGT Plant**
Number of sites	1	5,000	**CCGT**
Upfront costs	$150M	$15M	**VPP 10x**
Time to cash flow	3 – 5 years	2 – 6 months	**VPP 10x**
Payback period	10 – 15 years	2 – 3 years	**VPP 5x**
Major risk factors	Energy Markets, Project Management	Energy Markets, Customer Acceptance	**~Equal**
Milestones	Complex and Lumpy	Simple and Incremental	**VPP**

http://vcharge-energy.com/solutions/

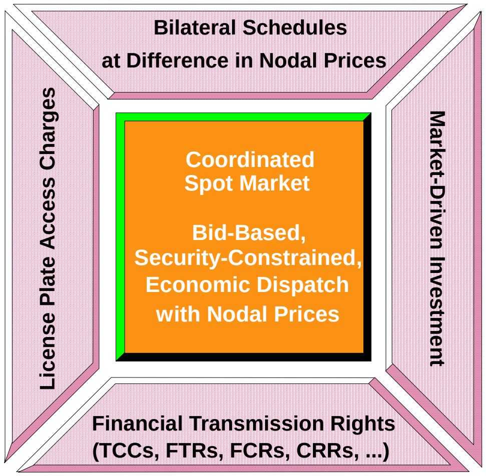
An “unknown unknown” that resulted from electricity market design?

ELECTRICITY MARKET A Consistent Framework

The example of successful central coordination, ~~CRT, Regional Transmission Organization (RTO) Millennium Order (Order 2000) Standard Market Design (SMD) Notice of Proposed Rulemaking (NOPR),~~ "Successful Market Design" provides a workable market framework that is working in places like New York, PJM in the Mid-Atlantic Region, New England, the Midwest, California, SPP, and Texas. This efficient market design is under (constant) attack.

> "Locational marginal pricing (LMP) is the electricity spot pricing model that serves as the benchmark for market design – the textbook ideal that should be the target for policy makers. A trading arrangement based on LMP takes all relevant generation and transmission costs appropriately into account and hence supports optimal investments."(International Energy Agency, Tackling Investment Challenges in Power Generation in IEA Countries: Energy Market Experience, Paris, 2007, p. 16.)

The ~~RTO NOPR~~ ~~Order~~ ~~SMD NOPR~~ "Successful Market Design"
Contains a Consistent Framework



Bilateral Schedules at Difference in Nodal Prices

License Plate Access Charges

Coordinated Spot Market

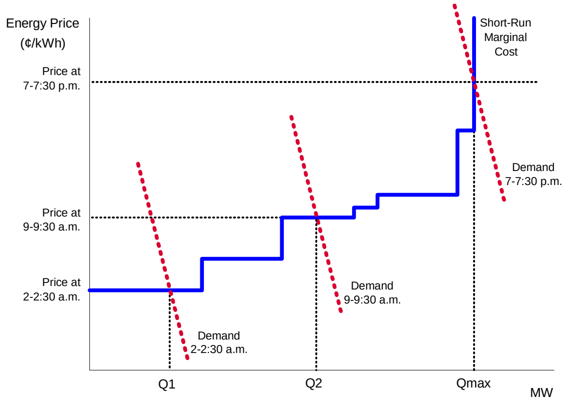
Bid-Based, Security-Constrained, Economic Dispatch with Nodal Prices

Market-Driven Investment

Financial Transmission Rights (TCCs, FTRs, FCRs, CRRs, ...)

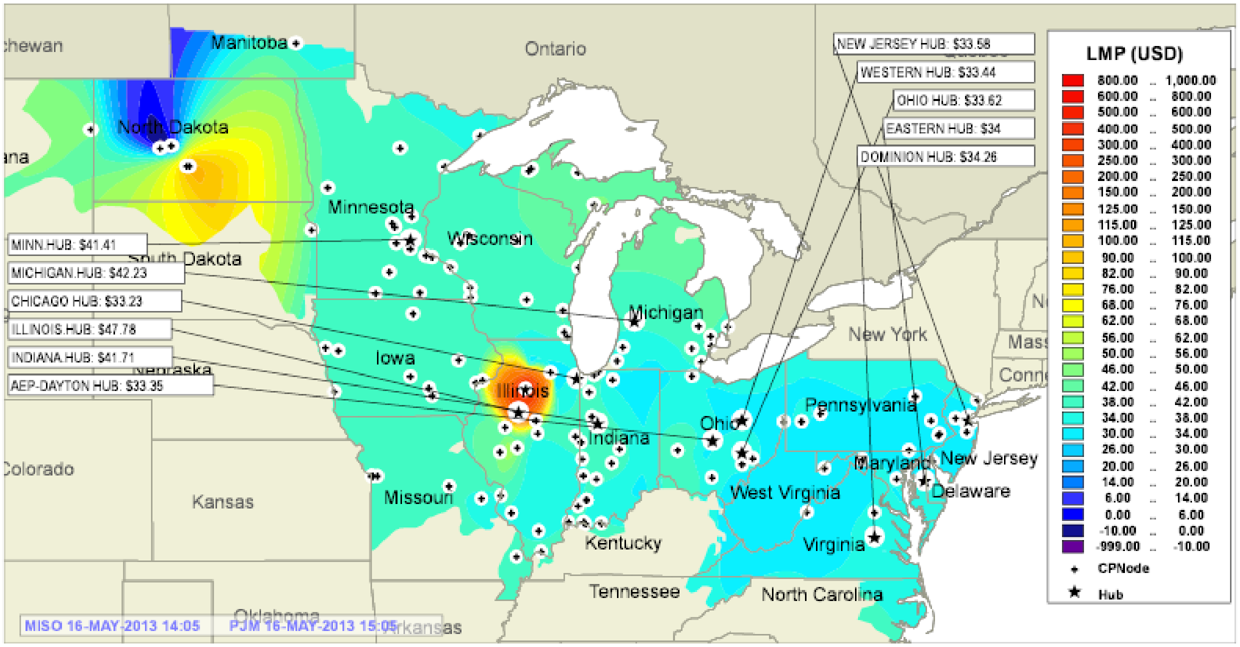
07/05
~~07/02~~
~~12/99~~
~~5/99~~

SHORT-RUN ELECTRICITY MARKET



NETWORK INTERACTIONS Locational Spot Prices

RTOs operate spot markets with locational prices. For example, PJM updates prices and dispatch every five minutes for over 10,000 locations. Locational spot prices for electricity exhibit substantial dynamic variability and persistent long-term average differences.



Illinois $529.71, North Dakota -$18.83

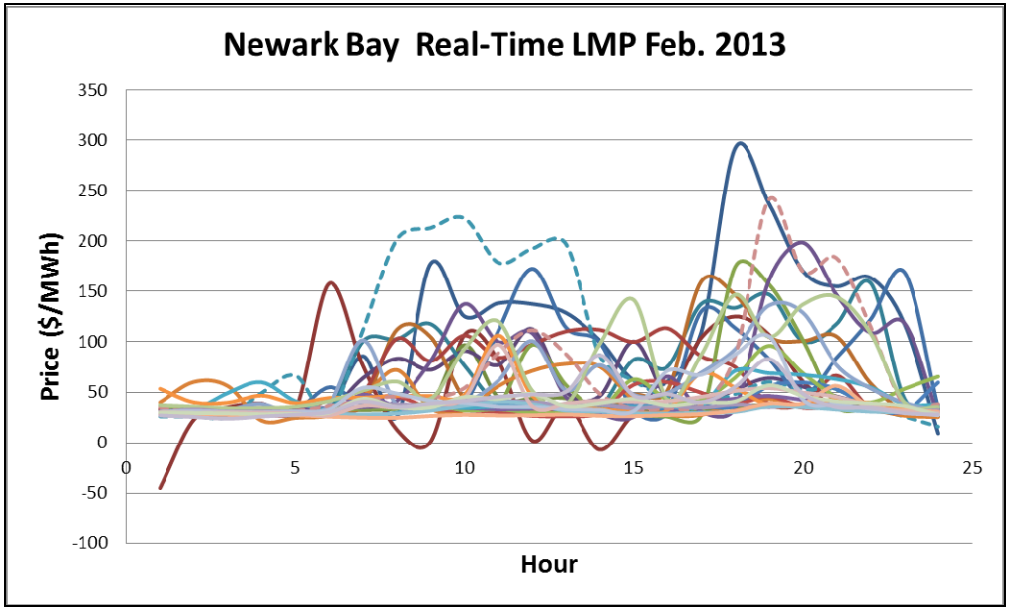
From MISO-PJM Joint and Common Market, http://www.jointandcommon.com/ for March 16, 2013, 3:05pm.

ELECTRICITY MARKET Pricing Challenges

Smarter pricing provides an opportunity for enhancing efficiency and the range of alternative technologies.

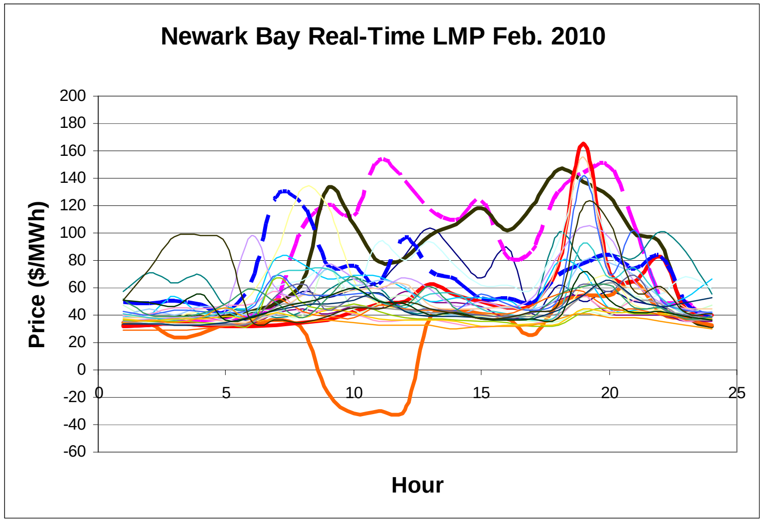
- **Smarter Pricing Challenges**
    - Average energy prices: $50/MWh.
    - Canonical bid baps: $1,000/MWh. $4,500/MWh in ERCOT. $12,500/MWh in Australia.
    - MISO average value of lost load: $3,500/MWh.
    - Reliability standard VOLL: $500,000/MWh.

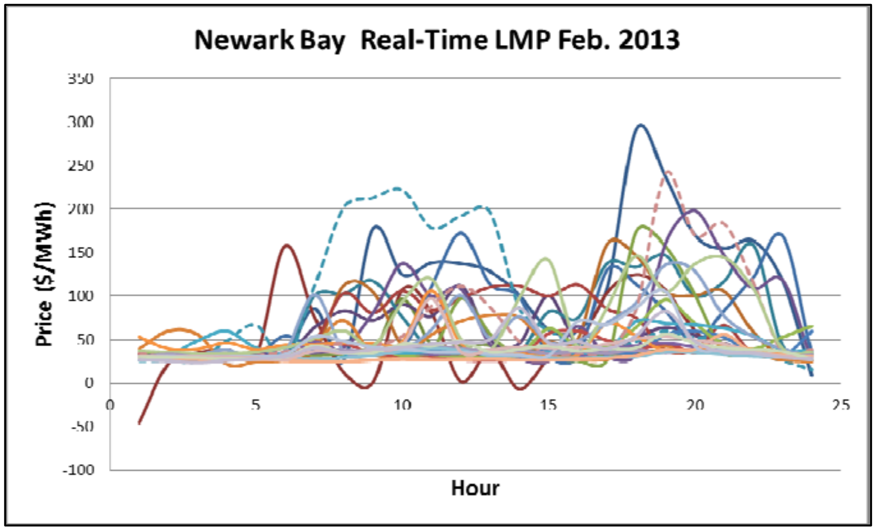
- **Real Time Pricing**
    - Time of Use (TOU) approximations do not track real-time prices: RTP >> CPP > CPR >> PP >> FR.
    - There is substantial geographic and temporal variability of real-time prices.



ELECTRICITY MARKET Pricing Challenges

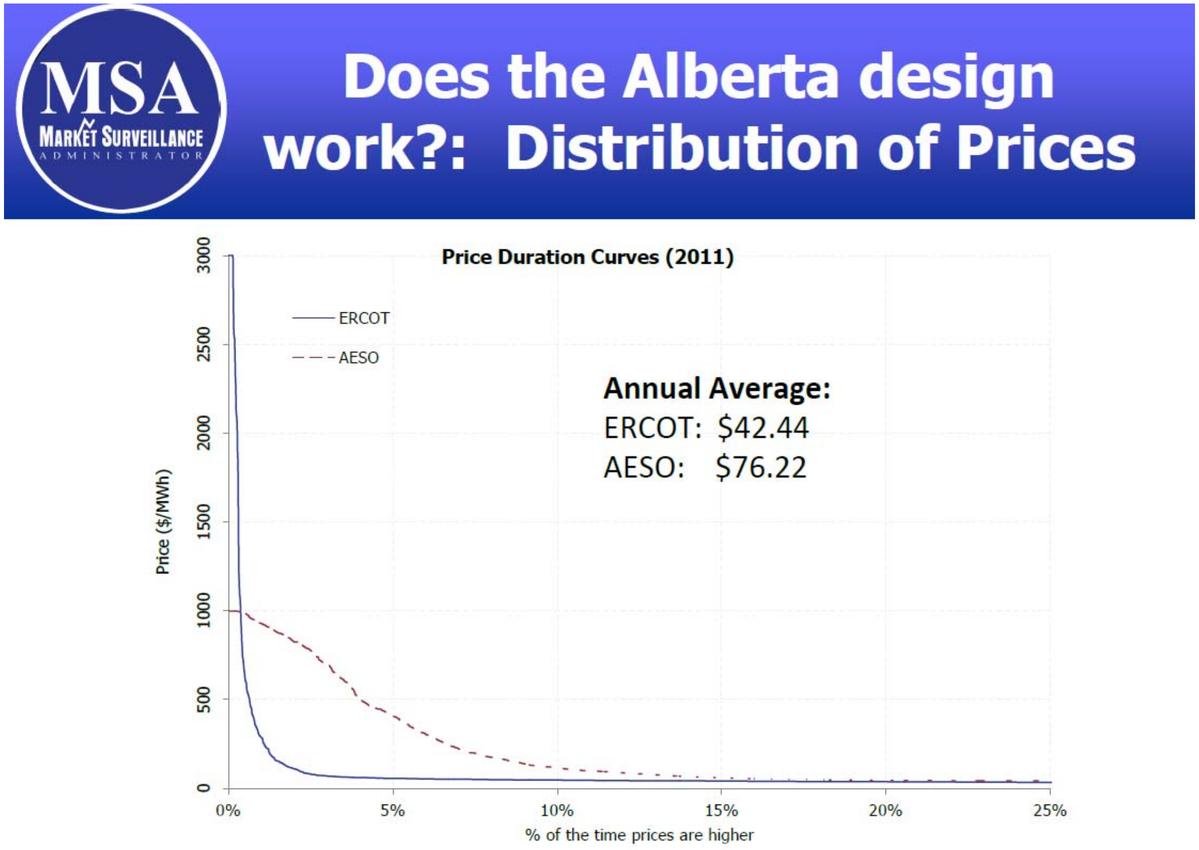
Smarter pricing provides an opportunity for enhancing efficiency and the range of alternative technologies. The Newark Bay example is persistent.





ELECTRICITY MARKET Pricing Challenges

Electricity markets have enjoyed major innovations in market design, but pricing challenges leave a great deal of room for improvement. The comparison of Alberta, with robust investment, and ERCOT, with resource adequacy concerns, illustrates the problems.



MSA MARKET SURVEILLANCE ADMINISTRATOR

Does the Alberta design work?: Distribution of Prices

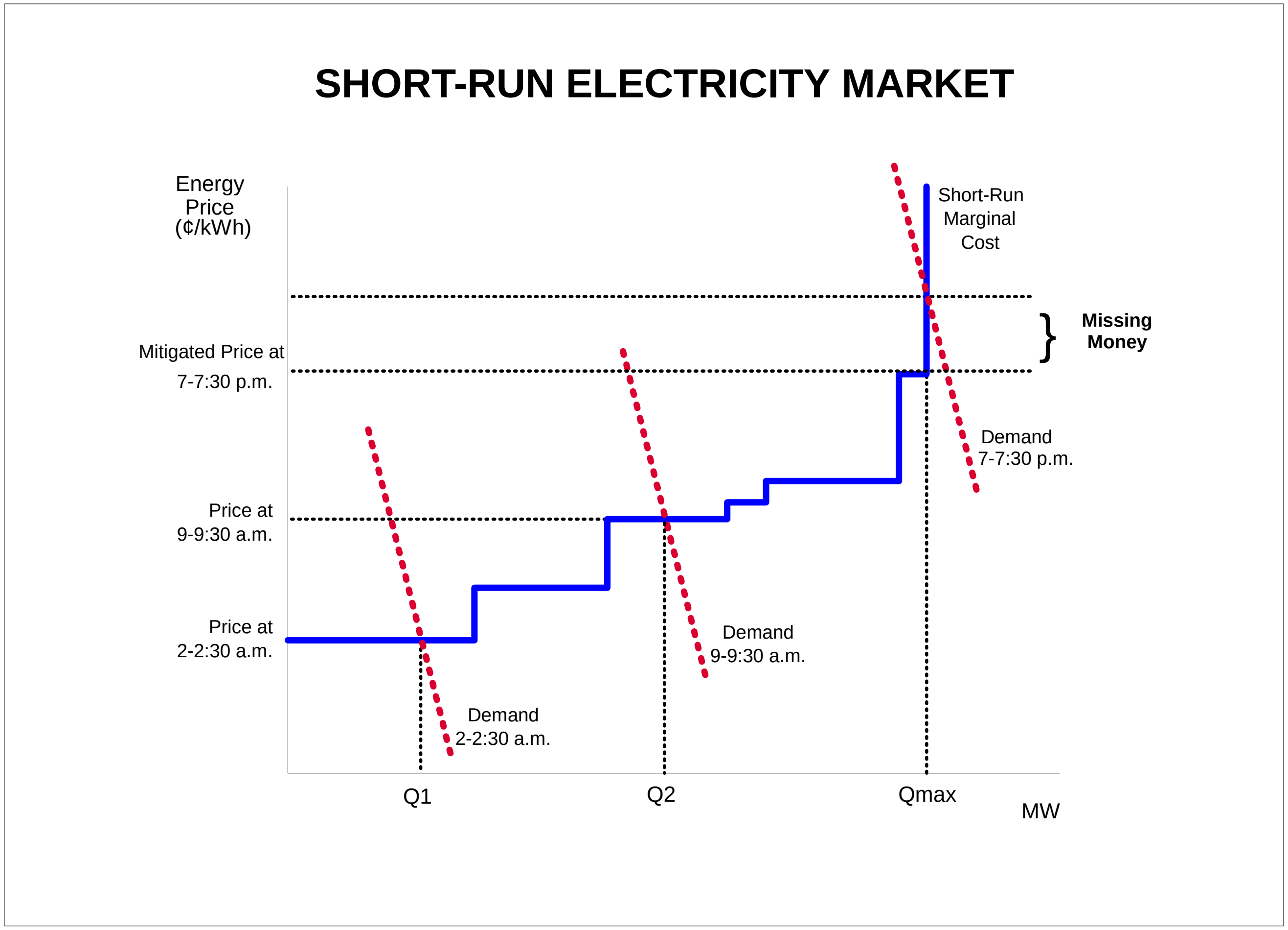
Price Duration Curves (2011)

Annual Average:
ERCOT: $42.44
AESO: $76.22

Source: Matt Ayres, Alberta Market Surveillance Administrator, Making ‘Energy Only’ Markets Work,” June 2013. http://www.hks.harvard.edu/hepg/Papers/2013/Ayres.pdf

ELECTRICITY MARKET Pricing and Demand Response

Early market designs presumed a significant demand response. Absent this demand participation most markets implemented inadequate pricing rules equating prices to variable costs even when capacity is constrained. This produces a "missing money" problem.



SHORT-RUN ELECTRICITY MARKET

The "missing money" problem is material and has a significant impact on investment incentives. Major efforts have been focused on defining new products and better pricing methods to address the incentives, ensure resource adequacy, and improve efficiency.

- **PJM, Missing Money, Combustion Turbine (1999-2010, per MW-Year).**

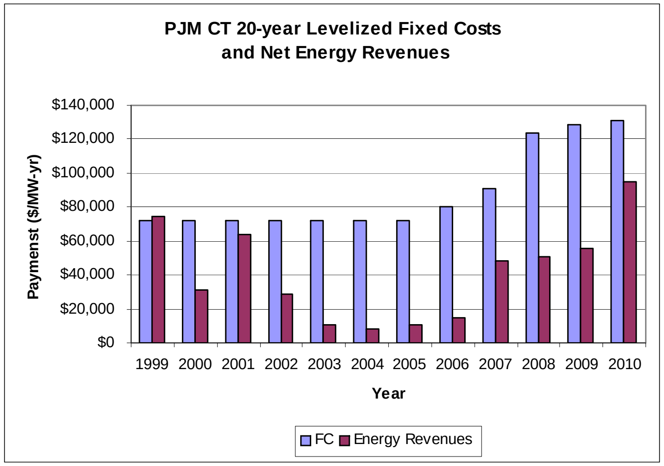
Average Net Energy Revenue = $40,943

Average Levelized Fixed Cost = $88,317

(PJM, State of Market Report, 2010, Vol. 2, p. 176)

- **Capacity Markets.** ISONE, NYISO, PJM, SWIS.
- **Scarcity Pricing.** Operating Reserve Demand Curve in MISO, NYISO, ISONE, PJM. (MISO FERC Electric Tariff, Volume No. 1, Schedule 28, January 22, 2009.)[2]

Payments for CT Peaker
PJM Economic Dispatch



Source: Monitoring Analytics, State of the Market Report, 2010, Table 3-21, Vol. 2, p. 171.

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[2] "For each cleared Operating Reserve level less than the Market-Wide Operating Reserve Requirement, the Market-Wide Operating Reserve Demand Curve price shall be equal to the product of (i) the Value of Lost Load ("VOLL") and (ii) the estimated conditional probability of a loss of load given that a single forced Resource outage of 100 MW or greater will occur at the cleared Market-Wide Operating Reserve level for which the price is being determined. … The VOLL shall be equal to $3,500 per MWh." MISO, FERC Electric Tariff, Volume No. 1, Schedule 28, January 22, 2009, Sheet 2226.

ELECTRICITY MARKET Scarcity Pricing and Volatility

Inadequate scarcity pricing dampens real-time price volatility, and has a material impact on incentives for innovation. Fixed rates, including pre-determined time-of-use rates, dampen volatility. Levelized rates and socialized costs eliminate volatility. Accurate scarcity prices would capture the marginal welfare effects of consumption and generation. Assuming cost recovery on average, incomplete scarcity pricing implies various forms of inefficiency.

- **Energy Efficiency and Distributed Generation.** With levelized rates, passive energy efficiency changes such as insulation are efficient only for customers with the average load profile. Customer load profiles are heterogeneous, so there is too little or too much incentive for most. For distributed generation and active load management, such as turning down air conditioning when away from home, sees too little incentive when it is needed most during high periods of (implicit) scarcity prices.
- **Load Management.** Changing the load profile to arbitrage price differences over time depends on exploiting price volatility. Suppressing and socializing scarcity prices dampens incentives for load management.
  - **Load Shifting.** Cycling equipment of moving consumption to “off-peak” hours receives too little incentive.
  - **PHEV/EV.** Managing the charging cycle for electric vehicles will affect the economics of both cars and the electricity system. Inadequate scarcity pricing and rate smoothing dampen incentives and raise costs.
  - **Batteries.** The principal benefit of batteries, from high tech flow batteries to low tech ceramic bricks, is profit from price arbitrage. Smooth prices undo the incentives for battery deployment.

Scarcity pricing presents an important challenge for Regional Transmission Organizations (RTOs) and electricity market design. Simple in principle, but more complicated in practice, inadequate scarcity pricing is implicated in several problems associated with electricity markets.

- **Investment Incentives.** Inadequate scarcity pricing contributes to the "missing money" needed to support new generation investment. The policy response has been to create capacity markets. Better scarcity pricing would reduce the challenges of operating good capacity markets.
- **Demand Response.** Higher prices during critical periods would facilitate demand response and distributed generation when it is most needed. The practice of socializing payments for capacity investments compromises the incentives for demand response and distributed generation.
- **Renewable Energy.** Intermittent energy sources such as solar and wind present complications in providing a level playing field in pricing. Better scarcity pricing would reduce the size and importance of capacity payments and improve incentives for renewable energy.
- **Transmission Pricing.** Scarcity pricing interacts with transmission congestion. Better scarcity pricing would provide better signals for transmission investment.

Smarter scarcity pricing would mitigate or substantially remove the problems in all these areas. While long-recognized, the need for smarter prices for a smarter grid promotes interest in better theory and practice of scarcity pricing.[3]

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[3] FERC, Order 719, October 17, 2008.

A critical connection is the treatment of operating reserves and construction of operating reserve demand curves. The basic idea of applying operating reserve demand curves is well tested and found in operation in important RTOs.

- **NYISO.** See NYISO Ancillary Service Manual, Volume 3.11, Draft, April 14, 2008, pp. 6-19-6-22.
- **ISONE.** FERC Electric Tariff No. 3, Market Rule I, Section III.2.7, February 6, 2006.
- **MISO.** FERC Electric Tariff, Volume No. 1, Schedule 28, January 22, 2009.[4]
- **PJM.** PJM Manual 11, Energy & Ancillary Services Market Operations, Revision: 59, April 1, 2013.

The underlying models of operating reserve demand curves differ across RTOs. One need is for a framework that develops operating reserve demand curves from first principles to provide a benchmark for the comparison of different implementations.

- **Operating Reserve Demand Curve Components.** The inputs to the operating reserve demand curve construction can differ and a more general model would help specify the result.
- **Locational Differences and Interactions.** The design of locational operating reserve demand curves presents added complications in accounting for transmission constraints.
- **Economic Dispatch.** The derivation of the locational operating demand curves has implications for the integration with economic dispatch models for simultaneous optimization of energy and reserves.

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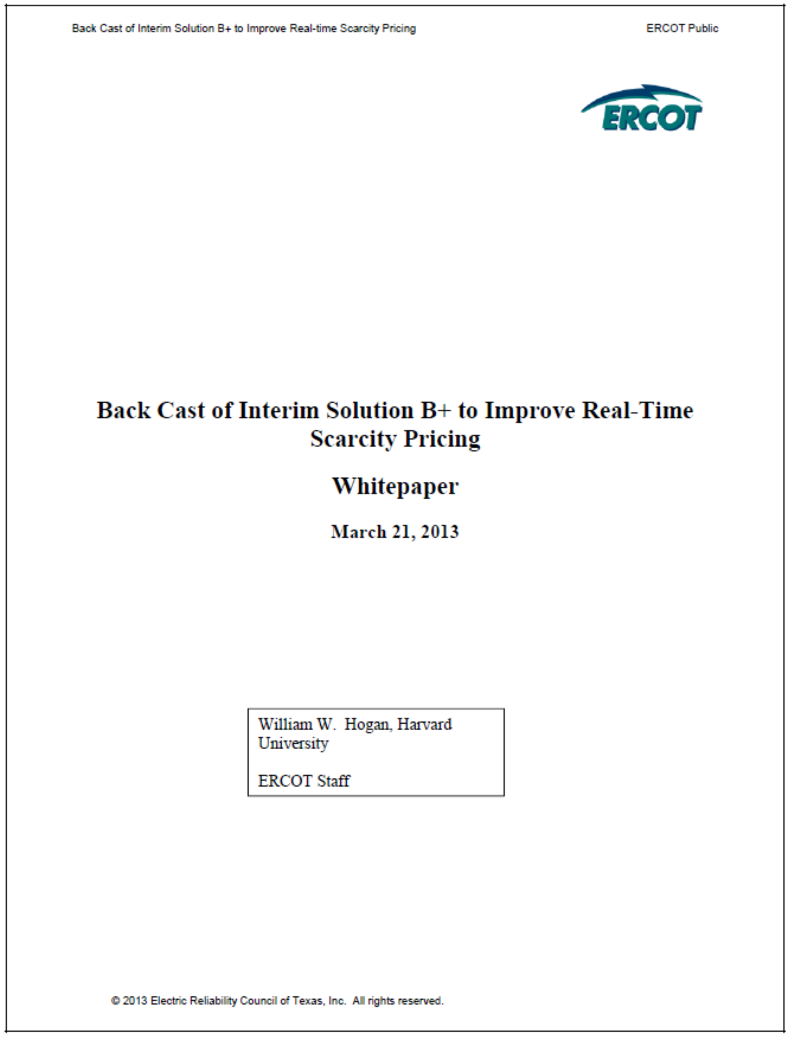
[4] "For each cleared Operating Reserve level less than the Market-Wide Operating Reserve Requirement, the Market-Wide Operating Reserve Demand Curve price shall be equal to the product of (i) the Value of Lost Load ("VOLL") and (ii) the estimated conditional probability of a loss of load given that a single forced Resource outage of 100 MW or greater will occur at the cleared Market-Wide Operating Reserve level for which the price is being determined. … The VOLL shall be equal to $3,500 per MWh." MISO, FERC Electric Tariff, Volume No. 1, Schedule 28, January 22, 2009, Sheet 2226.

ELECTRICITY MARKET ERCOT Operating Reserves

An application of the model for the case of ERCOT illustrates the possible scale of the impacts.



Back Cast of Interim Solution B+ to Improve Real-time Scarcity Pricing ERCOT Public

ERCOT

Back Cast of Interim Solution B+ to Improve Real-Time Scarcity Pricing

Whitepaper

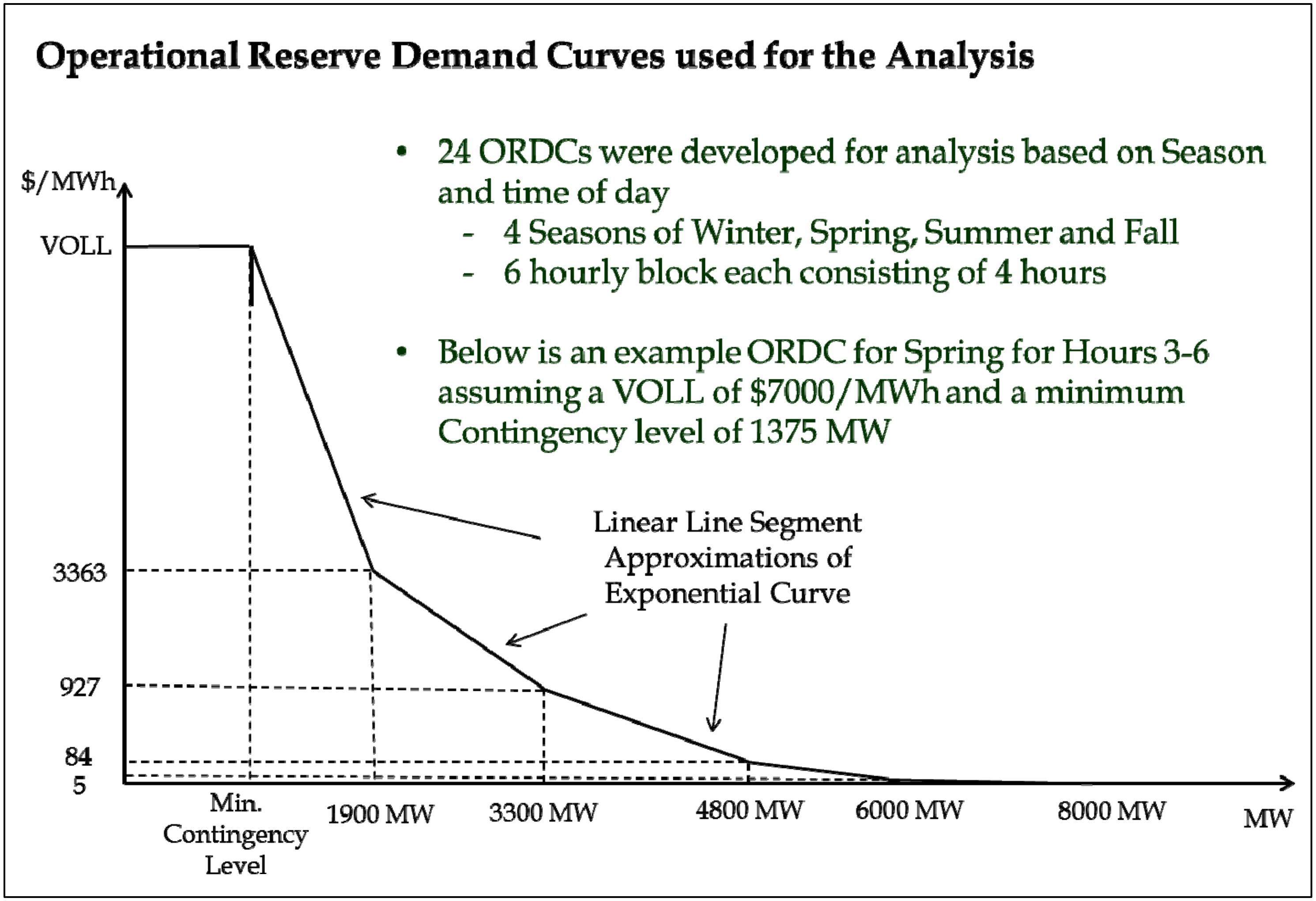
March 21, 2013

William W. Hogan, Harvard University

ERCOT Staff

ELECTRICITY MARKET ERCOT Operating Reserves

The ERCOT back cast applied various parameters to simulate the effect of a range of operating reserve demand curves.



Operational Reserve Demand Curves used for the Analysis

- 24 ORDCs were developed for analysis based on Season and time of day
  - 4 Seasons of Winter, Spring, Summer and Fall
  - 6 hourly block each consisting of 4 hours
- Below is an example ORDC for Spring for Hours 3-6 assuming a VOLL of $7000/MWh and a minimum Contingency level of 1375 MW

An application of the model for the case of ERCOT illustrates the possible scale of the impacts. The purpose of the back cast was to suggest the scale of the scarcity prices that would have been relevant under the tight conditions that existed in 2011 and the greater abundance of capacity in 2012. The charge was not to simulate the full system to include changes in behavior and dispatch, which could be expected to occur. Rather the mandate was to assume the same offers, bids and dispatch that actually occurred, and then recalculate the energy and reserve prices. This provides a first order approximation of the effects of scarcity pricing.

By way of comparison, the “ERCOT-wide load-weighted average real-time energy price was $53.23 per MWh in 2011, a 35 percent increase from $39.40 per MWh in 2010.” (Potomac Economics, 2012)

Table 1 : Energy-weighted average energy price adder (and Online reserve price) ($/MWh) for 2011 & 2012 for different VOLLs and minimum contingency levels (X)

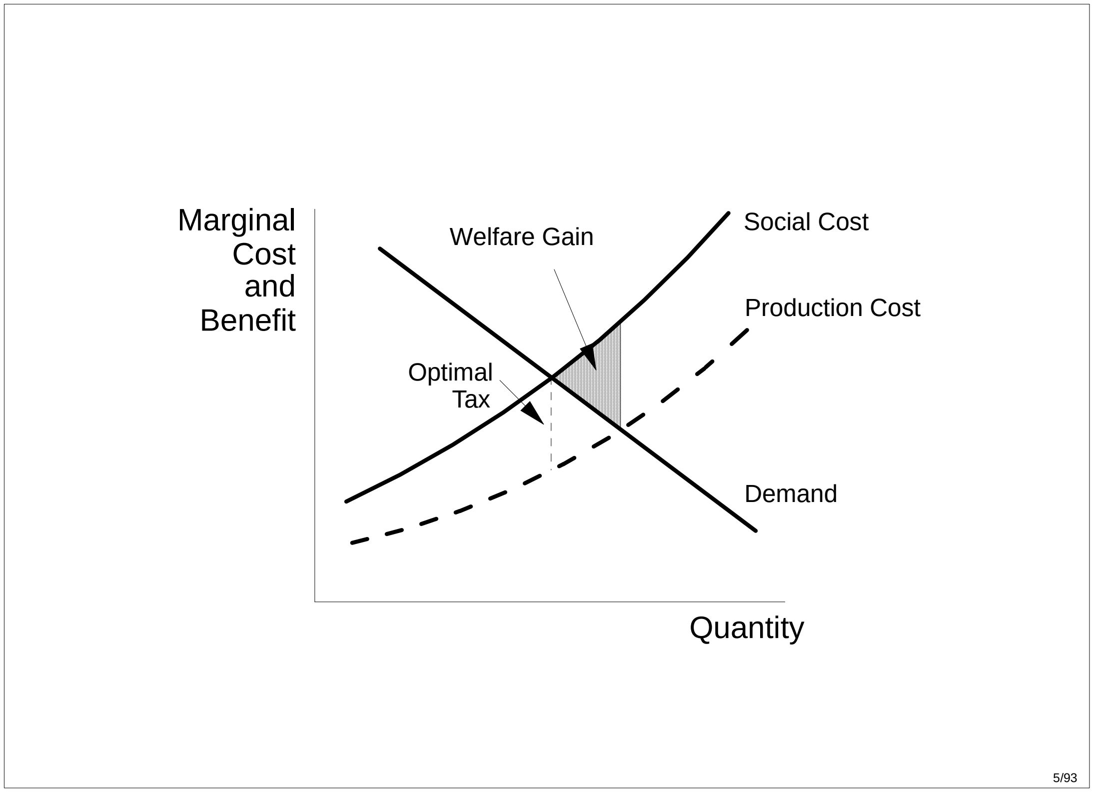
VOLL	Energy-weighted average price increase with X at 1375 MW ($/MWh)			Energy-weighted average price increase with X at 1750 MW ($/MWh)		
	2011	2012	2011 & 2012 combined	2011	2012	2011 & 2012 combined
$5000/MWh	7.00	1.08	4.08	12.03	2.40	7.28
$7000/MWh	11.27	1.56	6.48	19.06	3.45	11.35
$9000/MWh	15.54	2.05	8.87	26.08	4.50	15.42

Source:(ERCOT Staff & Hogan, 2013)

ERCOT Staff, & Hogan, W. W. (2013). “Back Cast of Interim Solution B + to Improve Real-Time Scarcity Pricing White Paper.” Potomac Economics. (2012). “2011 State of the Market Report for the ERCOT Wholesale Electricity Markets.”

The optimal Pigouvian tax internalizes the externalities. Getting the prices right improves efficiency. The revenue produced could be part of the tax reform solution rather than a problem for expanded subsidies.

- **Old News.** The principle is clear, but the politics are impossible.
- **Long Game.** The Green Agenda requires sustained incentives. Government mandates are inefficient, and subsidies are fickle,
- **Revenue Addiction.** The tax system provides a powerful constituency that will become dependent on the revenue.
- **Reform Opportunity.** The debate surrounding tax reform and deficit reduction provides a window of opportunity.



- **Big Bucks.** A carbon tax is only part of the story. Energy related emission involve much more.

ELECTRICITY MARKET Energy Externalities

The scope of energy externalities for the power generation sector is illustrated by the Muller-Mendelsohn-Nordhaus comparison of marginal damages and sector value added.

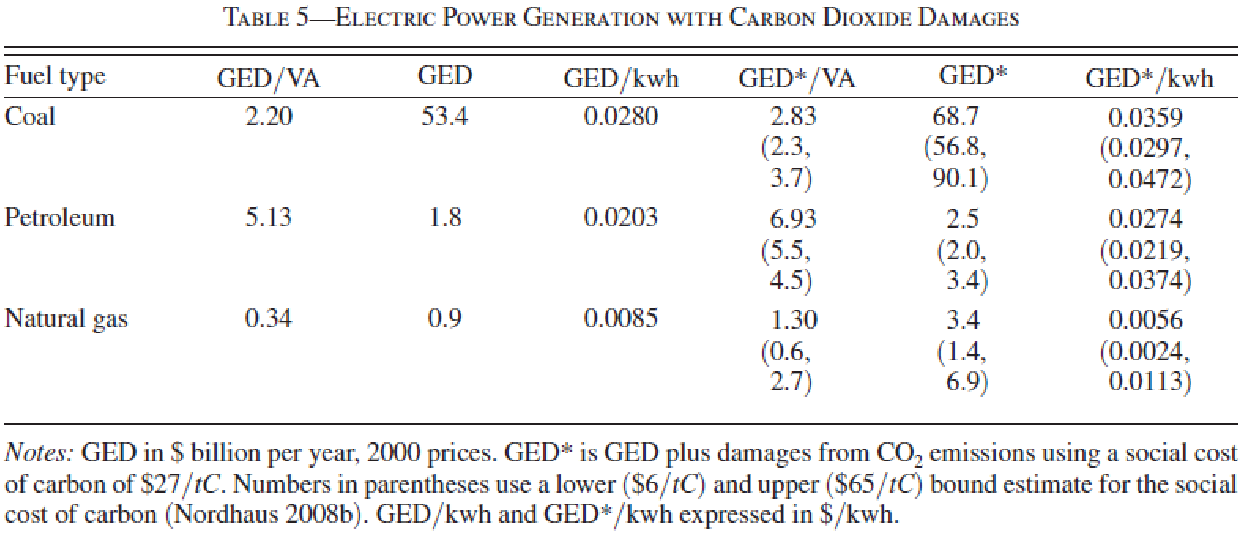


TABLE 5—ELECTRIC POWER GENERATION WITH CARBON DIOXIDE DAMAGES

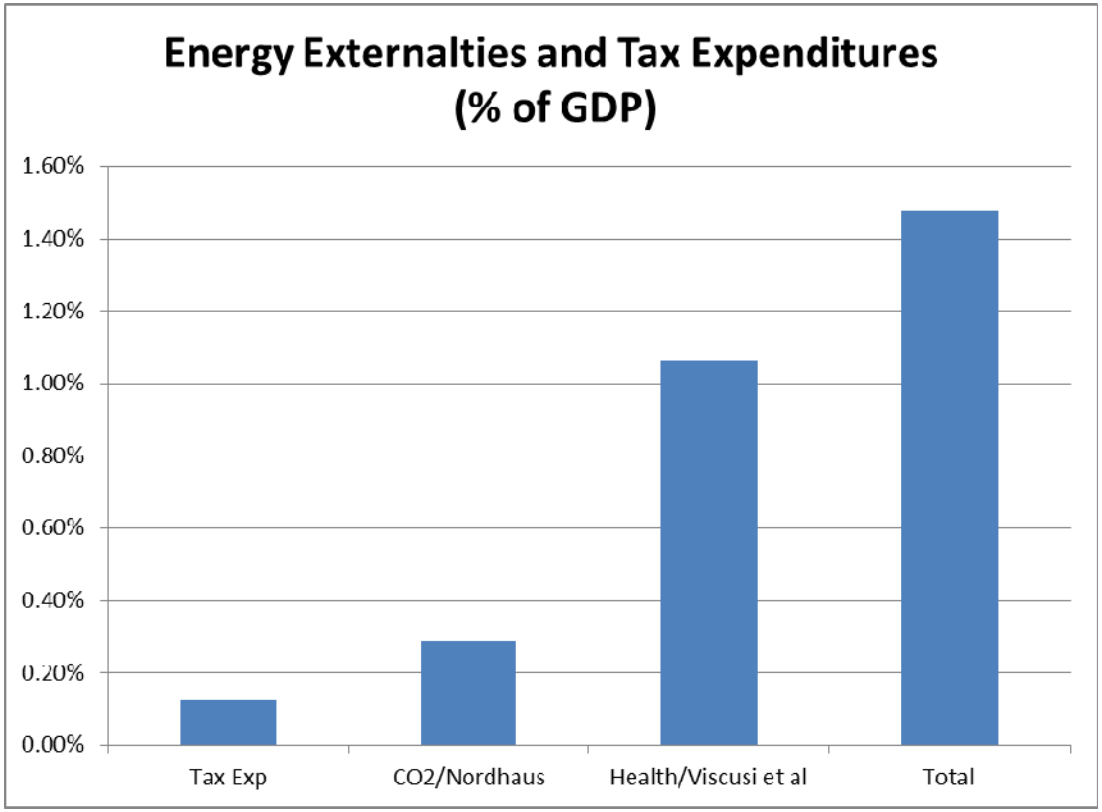
Fuel type	GED/VA	GED	GED/kwh	GED*/VA	GED*	GED*/kwh
Coal	2.20	53.4	0.0280	2.83 (2.3, 3.7)	68.7 (56.8, 90.1)	0.0359 (0.0297, 0.0472)
Petroleum	5.13	1.8	0.0203	6.93 (5.5, 4.5)	2.5 (2.0, 3.4)	0.0274 (0.0219, 0.0374)
Natural gas	0.34	0.9	0.0085	1.30 (0.6, 2.7)	3.4 (1.4, 6.9)	0.0056 (0.0024, 0.0113)

Notes: GED in $ billion per year, 2000 prices. GED* is GED plus damages from CO_2 emissions using a social cost of carbon of $27/*tC*. Numbers in parentheses use a lower ($6/*tC*) and upper ($65/*tC*) bound estimate for the social cost of carbon (Nordhaus 2008b). GED/kwh and GED*/kwh expressed in $/kwh.

Source: Nicholas Z. Muller, Robert Mendelsohn, and William Nordhaus, “Environmental Accounting for Pollution in the United States Economy,” *American Economic Review*, August 2011, pp. 1649–1675.

The calculation of damages valued at the marginal impact exceeding value added does not iimply that the industry should be shut down, But the numbers do get your attention. The impact of carbon is significant but other emissions are more important.

The National Research Council. (2010) *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use,* contains an extensive discussion of energy externalities. The study did not collect the implied revenue impacts, but other sources provide some insight.

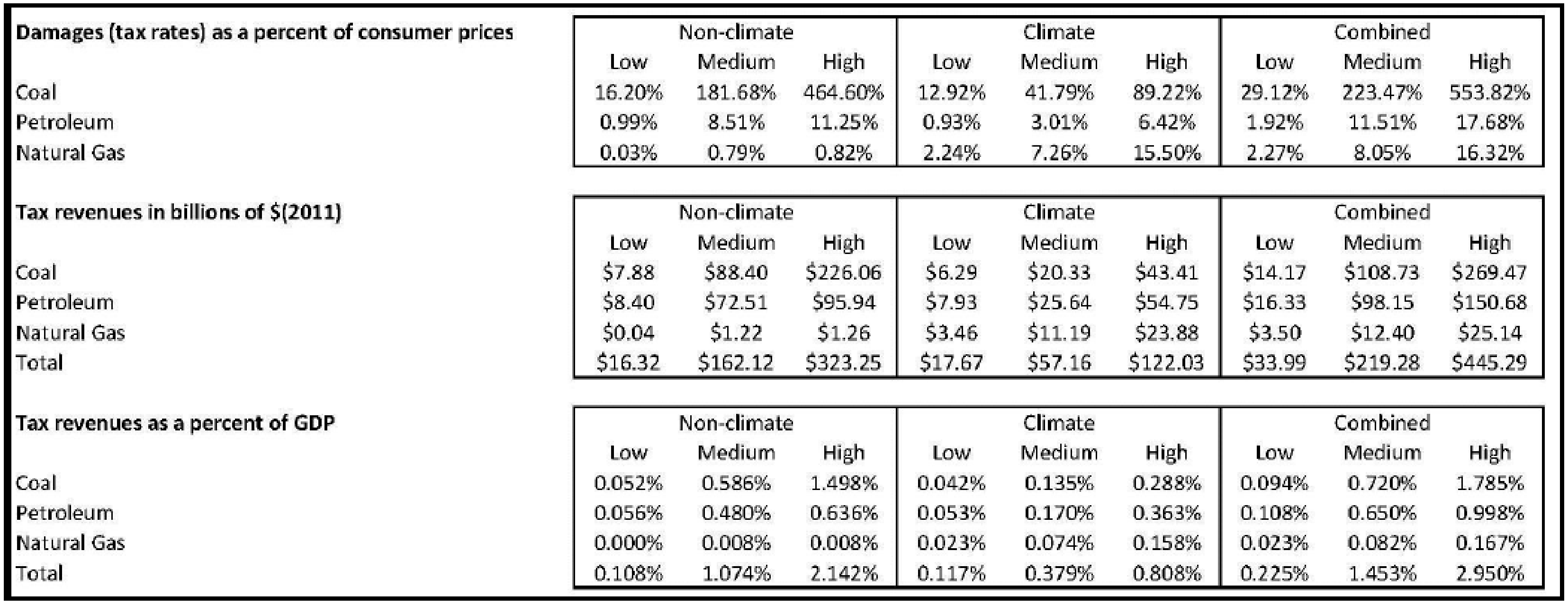


Sources: Tax Expenditures, Jorgenson, 2012. Nordhaus, William. 2008. *A Question of Balance: Weighing the Options on Global Warming Policies*. New Haven, CT: Yale University Press. W. Kip Viscusi, Wesley A. Magat, Alan Carlin, and Mark K. Dreyjus, “Environmentally Responsible Energy Pricing,” *The Energy Journal*, Vol. 15, No. 2, 1994, pp. 23-42.

ENERGY MARKETS Energy Externalities

The work of Jorgenson carries the analysis further to illustrate the importance of energy externalities, the role and revenue impacts of energy taxes in the context of comprehensive tax reform.

The Role of Energy Taxes



Damages (tax rates) as a percent of consumer prices	Non-climate			Climate			Combined		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Coal	16.20%	181.68%	464.60%	12.92%	41.79%	89.22%	29.12%	223.47%	553.82%
Petroleum	0.99%	8.51%	11.25%	0.93%	3.01%	6.42%	1.92%	11.51%	17.68%
Natural Gas	0.03%	0.79%	0.82%	2.24%	7.26%	15.50%	2.27%	8.05%	16.32%

Tax revenues in billions of $(2011)	Non-climate			Climate			Combined		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Coal	$7.88	$88.40	$226.06	$6.29	$20.33	$43.41	$14.17	$108.73	$269.47
Petroleum	$8.40	$72.51	$95.94	$7.93	$25.64	$54.75	$16.33	$98.15	$150.68
Natural Gas	$0.04	$1.22	$1.26	$3.46	$11.19	$23.88	$3.50	$12.40	$25.14
Total	$16.32	$162.12	$323.25	$17.67	$57.16	$122.03	$33.99	$219.28	$445.29

Tax revenues as a percent of GDP	Non-climate			Climate			Combined		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Coal	0.052%	0.586%	1.498%	0.042%	0.135%	0.288%	0.094%	0.720%	1.785%
Petroleum	0.056%	0.480%	0.636%	0.053%	0.170%	0.363%	0.108%	0.650%	0.998%
Natural Gas	0.000%	0.008%	0.008%	0.023%	0.074%	0.158%	0.023%	0.082%	0.167%
Total	0.108%	1.074%	2.142%	0.117%	0.379%	0.808%	0.225%	1.453%	2.950%

Source: Dale Jorgenson, "Comprehensive Tax Reform and US Energy Policy," Harvard University, October 15, 2012, http://www.hks.harvard.edu/m-rcbg/cepr/Papers/2012/Jorgenson_SenateFinanceCommittee%2012_1015_HKS_EnergyPolicy.pdf

Better scarcity pricing is an example of smarter pricing to reflect dynamic conditions in electricity systems and better match prices and costs. The alternative includes regulatory mandates and standards that create perverse incentives.

- **Mandates and Standards.** Regulatory mandates often raise average costs but dampen apparent price volatility. For example, capacity payments for the "missing money" induced by inadequate scarcity pricing are typically recovered through socialized and levelized rates.
- **Supply Creates Demand for Mandates.** Socialized costs produce inadequate signals and incentives for distributed generation, variable energy resources, and demand response. The pressure is for more mandates to overcome the poor incentives created by other mandates.
- **Efficient Market Design Competes with Regulatory Rent Seeking.** The principles of workable market design suffer from (constant) collateral attack in the give-and-take of regulatory rent seeking.

A challenge for regulators is to internalize and adhere to the principles of good market design. This often requires making distinctions that are not natural.

- **Between Costs and Prices.** Minimizing welfare costs is not the same as minimizing consumer prices.
- **Between Short-Run and Long-Run.** A familiar human challenge: "Penny wise and pound foolish."
- **Between Local and Global Optimization.** Seemingly attractive market design features can be collectively inconsistent. Better design seeks consistency to minimize unintended consequences.

As part of comprehensive tax reform, increased revenues from pricing energy externalities should become part of the solution rather than part of the problem.

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