The Potential Impact of Solar PV on Electricity Markets in Texas

SEIA and the Energy Foundation

June 19, 2012

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Agenda

- Introduction
  - Carrie Cullen Hitt, SEIA
- Opening Comments
  - Kip Averitt, Texas Clean Energy Coalition
- Report Review
  - Jurgen Weiss, The Brattle Group
  - Onur Aydin, The Brattle Group
- Questions

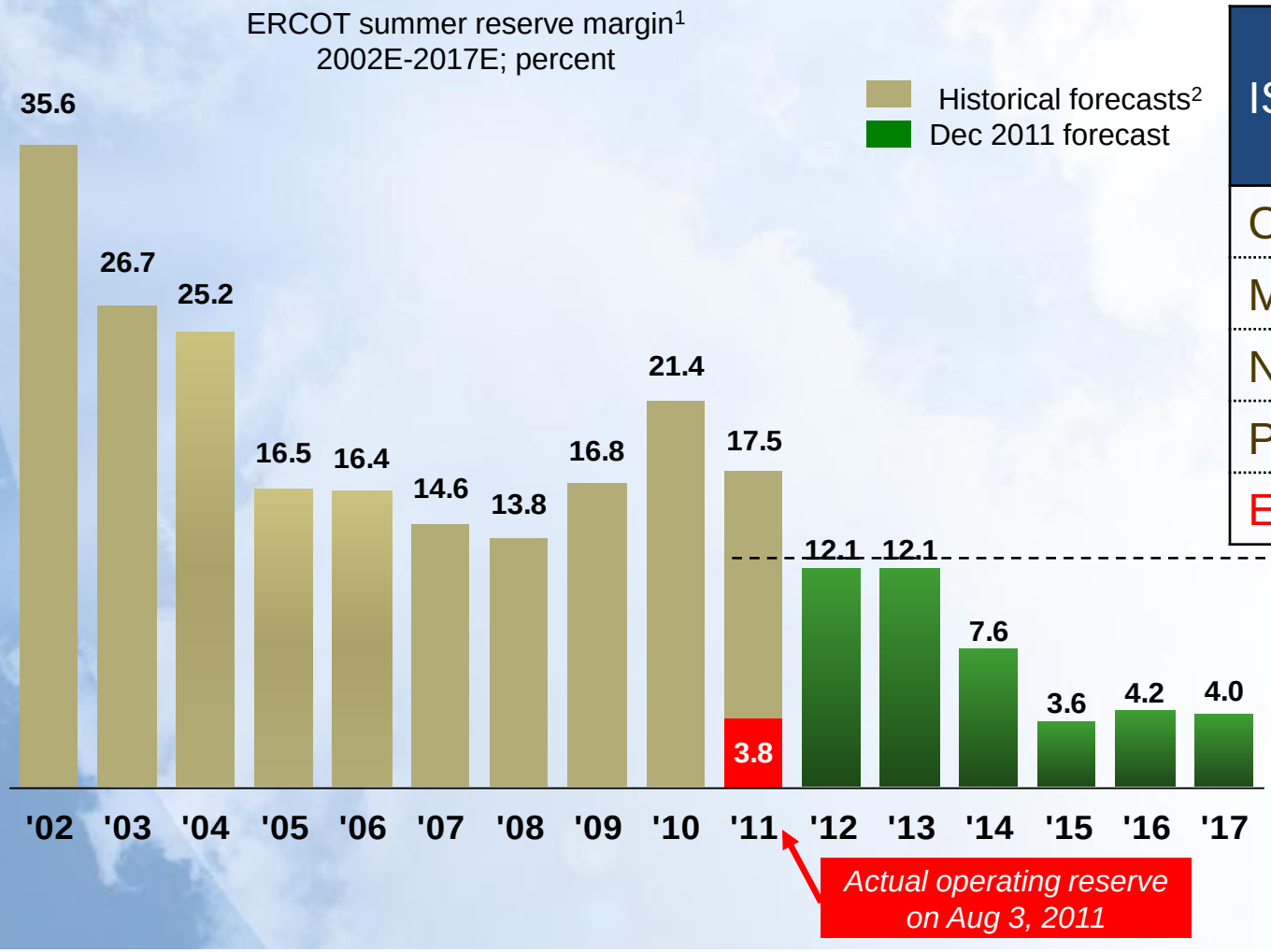
About SEIA

- Founded in 1974
- U.S. National Trade Association for Solar Energy.
  - 1,000 member companies from around the world.
  - Members in all 50 states.
  - Represent all solar technologies, all markets.
  - Federal and state solar policy advocacy.
- Mission:
  Build a strong solar industry to power America.
- Goal:
  10 gigawatts (GW) of annual installed solar capacity in the U.S. by 2015.

About the U.S. Solar Industry

- 100,000 solar energy workers
- 5,600 solar energy companies
- U.S. PV market projected to grow 75% in 2012
- U.S. ranked 4th globally for installed solar
- Texas ranked 13th for installed solar

The Issue: ERCOT's reserve margin is declining…



ISO[3]	Target reserve margin
CAISO	15.0%
MISO	17.4%
NYISO	15.5%
PJM	15.5%
ERCOT	13.75%

13.75% target reserve margin provides a buffer against de-rates, forced outages, wind variability, forecast error, and weather related spikes

[1] ERCOT Capacity, Demand and Reserves (CDR) Summary, Dec 1201, summer peak demand
[2] Historical reserve margins based on projections for each year prior to summer peak season, based on the formula in effect at the time.
[3] CAISO is the California Independent System Operator; MISO is Mid-West ISO; NYISO is New York ISO; PJM is ISO for13 state region including Pennsylvania, New Jersey and Maryland.

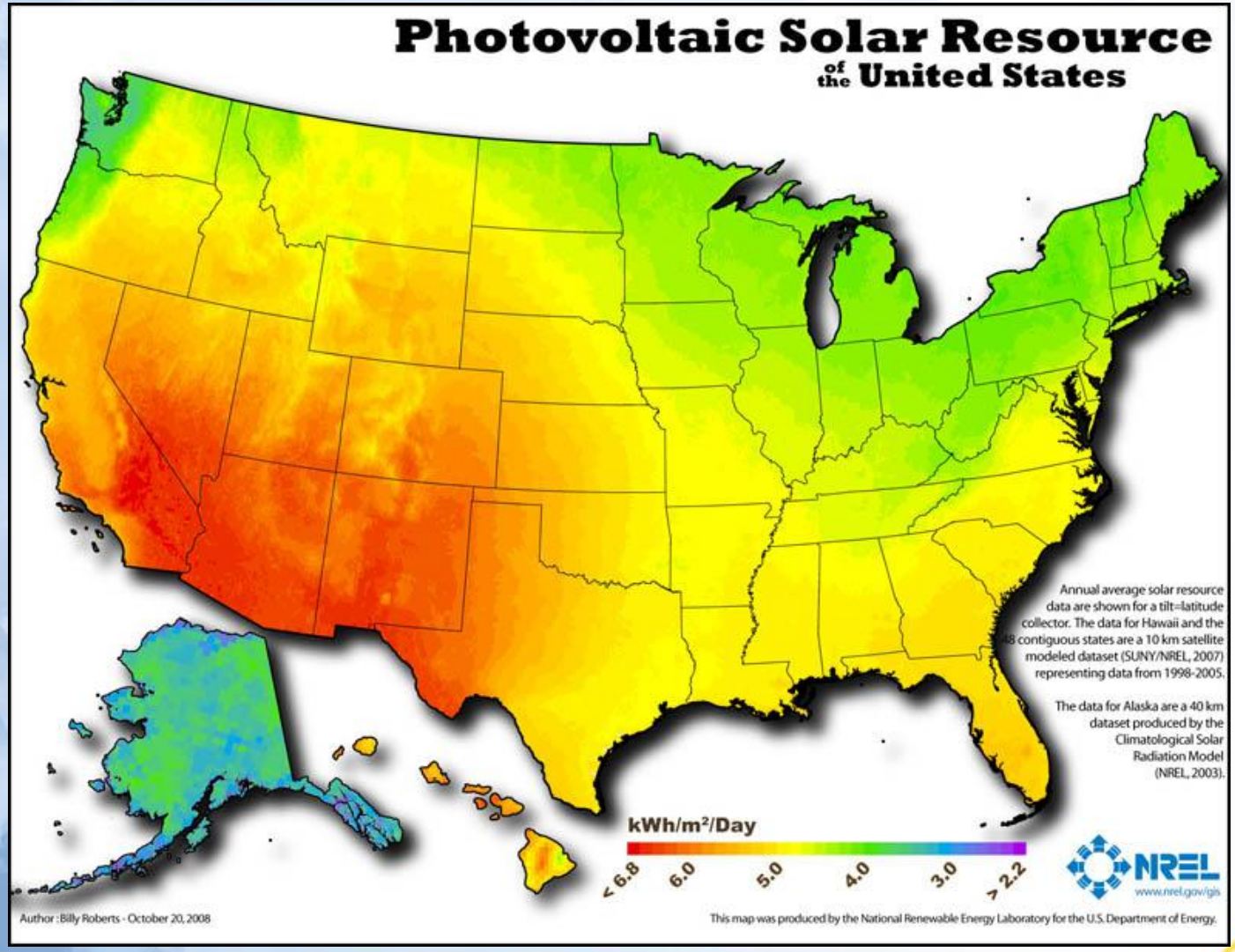
Recent Developments

Development	Implication
ERCOT issued its updated Capacity Demand and Reserves (CDR) report and its Seasonal Assessment of Resource Adequacy on December 1, 2011.	• The CDR indicates a decrease in available resources with **reserve margins falling to 12.1% beginning in the summer of 2012** (well below the targeted 13.75% level).
NERC's 2011 Long-Term Reliability Assessment was released Monday, November 28th.	• The report noted that **resource adequacy in ERCOT is a concern.** NERC very pointedly raised the ERCOT concern early in the report's summary, highlighting the ERCOT region as the primary region of concern.
FERC held a technical conference to discuss policy issues related to reliability of the Bulk-Power System on November 29th and 30th.	• Discussed how FERC should be interacting with the EPA regarding the reliability concerns associated with the new EPA rules. • Concerns with resource adequacy in the ERCOT region were highlighted.

Texas Policy Discussions

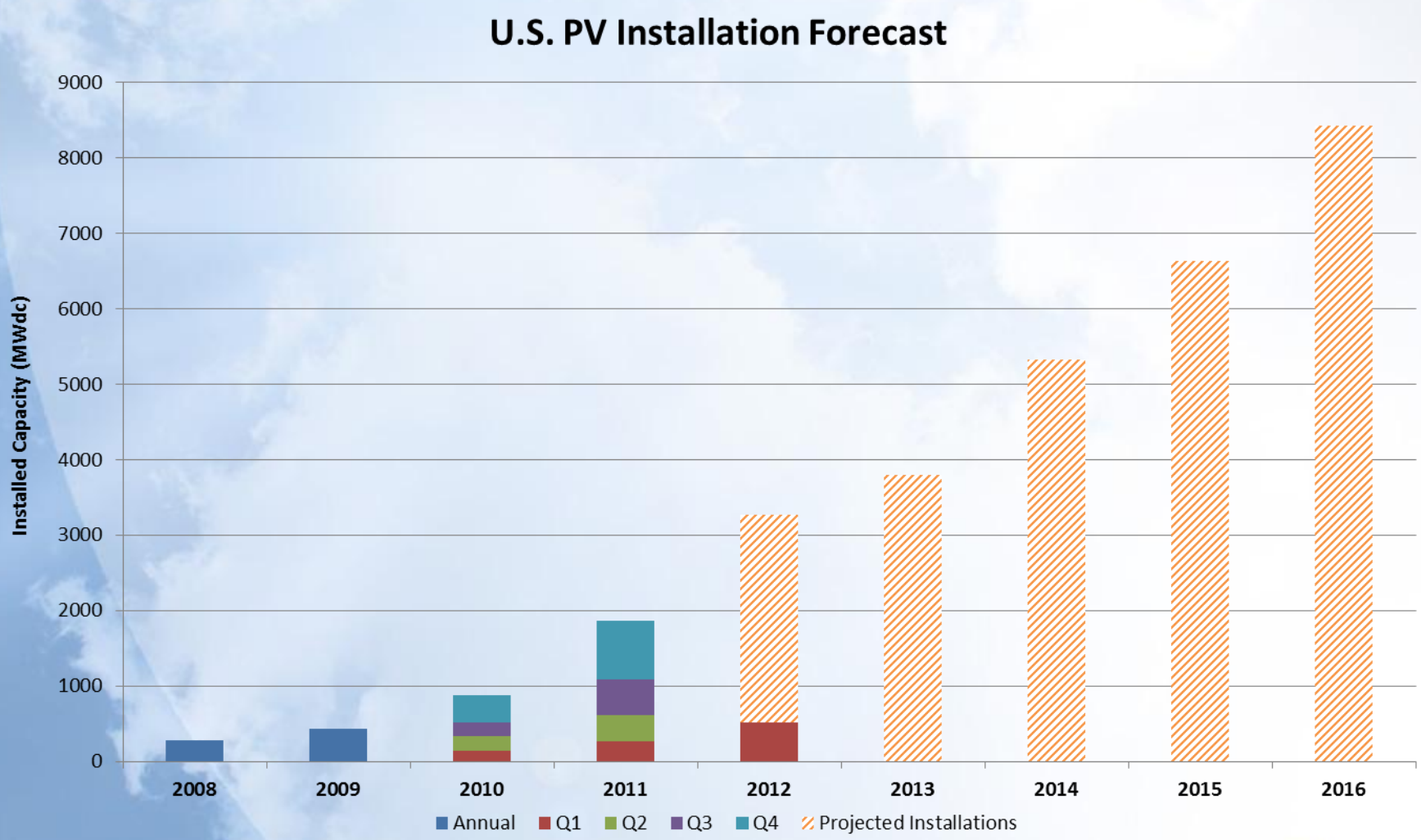
- PUCT PROJECT NO. 40268-Rulemaking on ERCOT and resource adequacy.
- PUCT Project No. 37897 – Rulemaking related to Resource and Reserve Adequacy and shortage pricing.
- PUCT Project 40480 - ERCOT Sponsored study (Brattle Group) released on June 1 stresses the need for change.
- Interim Legislative Committee charges in House State Affairs (generation adequacy), House Natural Resources (electric generation and water supply), and Senate Business & Commerce (generation adequacy and water supply).

Solar is An Abundant Natural Resource in Texas



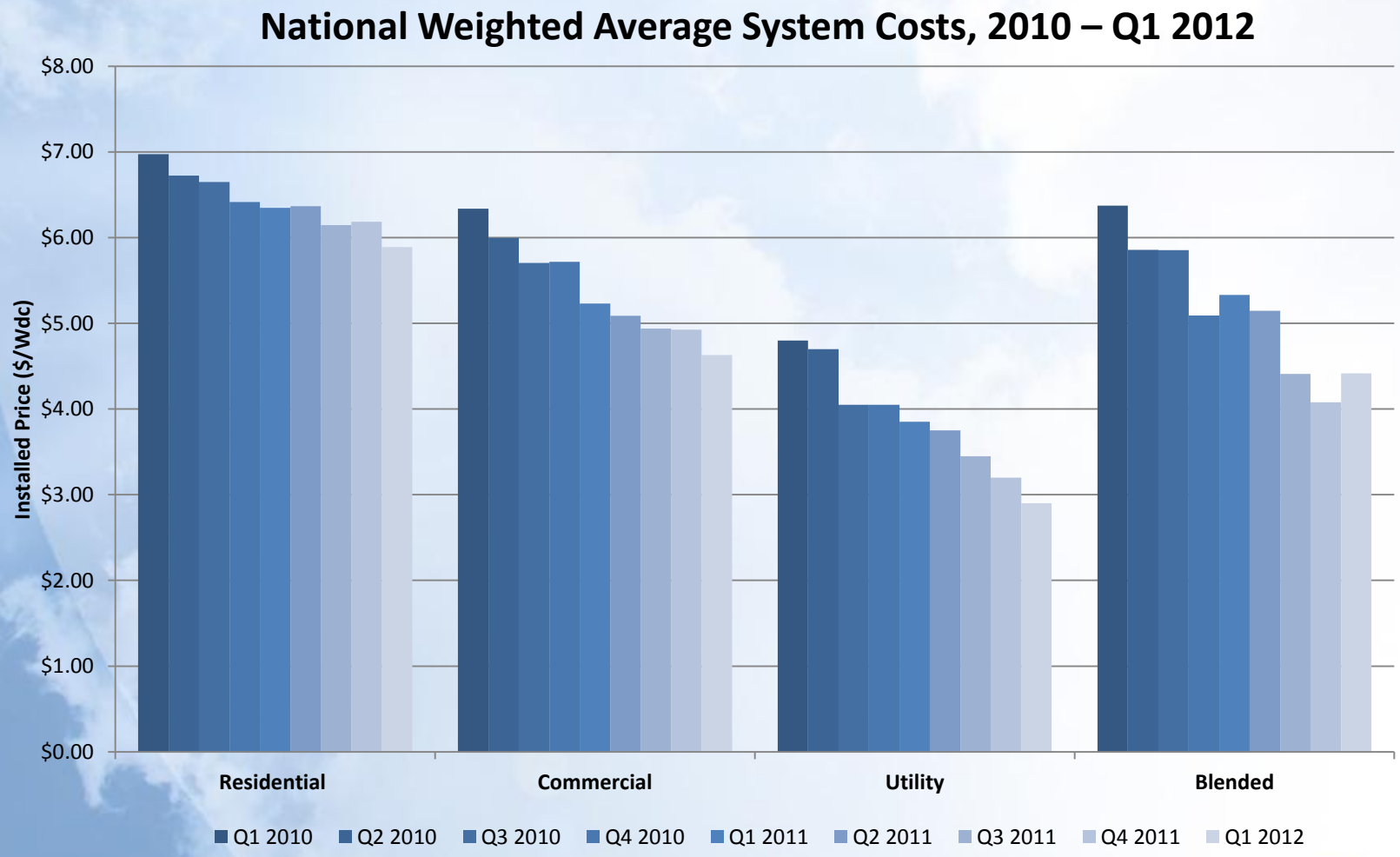
APPENDIX

U.S. PV Demand To Grow 75% to Over 3.2 GW in 2012

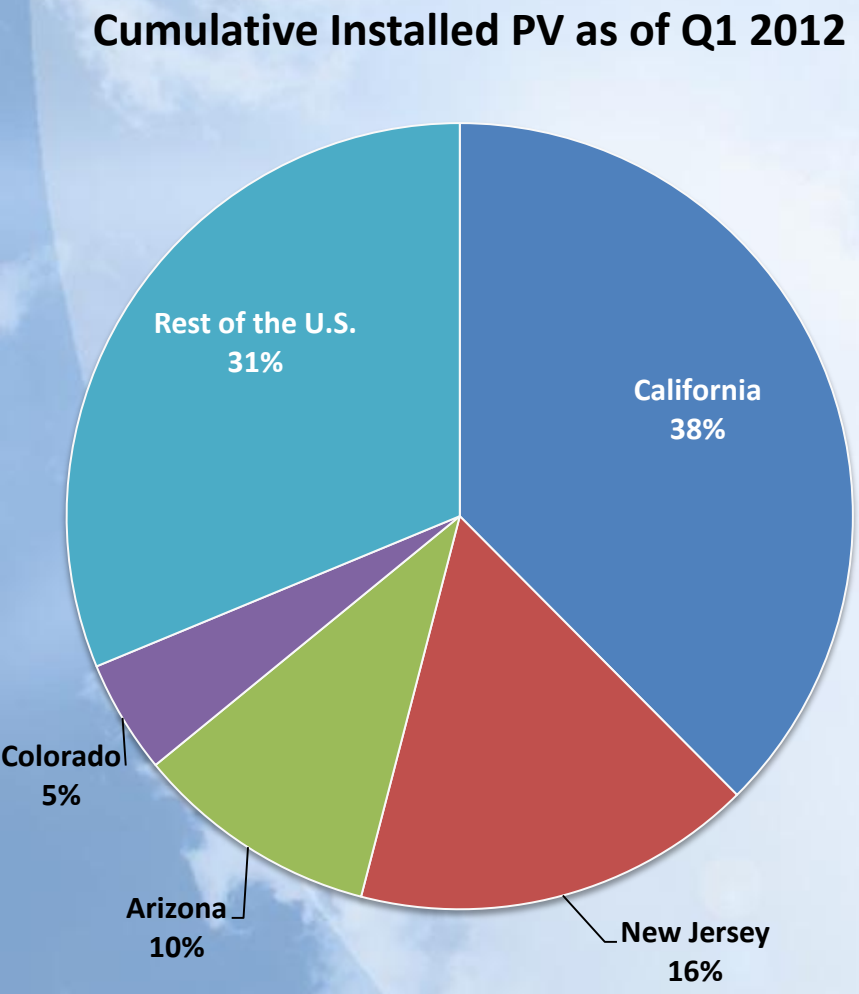


Source: SEIA/GTM Research "U.S. Solar Market Insight: Q1 2012"

Solar Continues To Become More Affordable



Status of Market Diversity



State	Cumulative Installed PV Capacity (MW)
1- California	1,662
2- New Jersey	730
3- Arizona	445
4- Colorado	207
5- New Mexico	163
6- Pennsylvania	149
7- Nevada	143
8- New York	121
9- North Carolina	108
10- Hawaii	96
13- Texas	77

The Brattle Group

The Potential Impact of Solar PV on Electricity Markets in Texas

Presented to:
Solar Energy Industries Association and the Energy Foundation

Presented by:
Jurgen Weiss
Onur Aydin

June 19, 2012

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Disclaimer

The analyses that our team provides are necessarily based on certain simplifying assumptions with respect to hypothetical conditions that may have existed over the study period considered. Actual outcomes are significantly dependent upon specific events that are outside our control, and therefore may differ, perhaps materially, from any predictions in our analyses.

While we believe that the assumptions we use are reasonable for the purposes of preparing our analysis, SEIA and the Energy Foundation should appreciate that they may differ from those used by other economic or industry experts.

Our analyses are intended solely to facilitate SEIA and the Energy Foundation's own consideration of the issues and are not to be considered in any way as investment advice. No member of this team will accept liability under any theory for losses suffered, whether direct or consequential, arising from SEIA and the Energy Foundation's reliance on the analyses or from the failure of the asset to have at any point or points in time any specific economic value.

Agenda

About *The Brattle Group*

Study Objective

Methodology

Key Findings

Caveats

Conclusions

Topics for Further Consideration

About *The Brattle Group* – Study Authors

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Jürgen Weiss is a Principal with *The Brattle Group*, where he heads the firm's climate change practice. He specializes in climate change and carbon market analysis, renewable energy, energy efficiency, energy storage and electric utility economics. He advises public and private clients on issues related to moving energy systems away from fossil fuel use, including the economics of renewable energy, integration of renewable energy into the existing grid, the design of incentive structures for low carbon technologies and the design of market structures to accommodate an increasing share of renewable generation.

Prior to joining The Brattle Group, Dr. Weiss was the managing director of Point Carbon's global advisory practice, a director at LECG and a consultant with Booz. He holds a Ph.D. in business economics from Harvard University and an MBA from Columbia University.

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Mr. Onur Aydin is an associate of *The Brattle Group*'s Cambridge office, who has in-depth experience in analysis and modeling of electricity markets, and the transmission system. He has assisted electric utilities, RTOs, regulators, and power producers in a wide range of issues, including regulatory filings, generation asset valuation and development, benefit-cost analysis of transmission enhancements, integrated resource planning, and renewable energy resources. His other works involve market monitoring, ratemaking and cost allocation, market manipulation, demand response, and plug-in electric vehicles.

Mr. Aydin received his M.S. in Civil and Environmental Engineering from Massachusetts Institute of Technology in Cambridge, Massachusetts, and his B.S. in Civil Engineering (with high honors) from Bogazici University in Istanbul, Turkey.

* The views expressed in this presentation are strictly those of the presenter(s) and do not necessarily state or reflect the views of *The Brattle Group, Inc*.

About *The Brattle Group* – Services

The Brattle Group provides consulting and expert testimony in economics, finance, and regulation to corporations, law firms, and governmental agencies around the world.

We combine in-depth industry experience, rigorous analyses, and principled techniques to help clients answer complex economic and financial questions in litigation and regulation, develop strategies for changing markets, and make critical business decisions.

Our services to the electric power industry include:

- Climate Change Policy and Planning
- Cost of Capital
- Demand Forecasting and Weather Normalization
- Demand Response and Energy Efficiency
- Electricity Market Modeling
- Energy Asset Valuation
- Energy Contract Litigation
- Environmental Compliance
- Fuel and Power Procurement
- Incentive Regulation
- Rate Design, Cost Allocation, and Rate Structure
- Regulatory Strategy and Litigation Support
- Renewables
- Resource Planning
- Retail Access and Restructuring
- Risk Management
- Market-Based Rates
- Market Design and Competitive Analysis
- Mergers and Acquisitions
- Transmission

About *The Brattle Group* – Renewables Experience

- Industry leader in analyzing renewable energy issues
  - Renewable energy investment evaluation and market assessment
  - Renewable resource effects on electricity market operations
  - Renewable long-term contract procurement
  - Renewable energy policy and strategic analysis
  - State resource planning in RPS environment
  - Benefit-cost analysis of new transmission projects needed to integrate renewable generation
  - Valuation of energy storage needed to enable large amounts of renewable resources
  - Job and economic impact of renewable energy development
  - Wind curtailment arbitration
  - Risk analysis of renewable generation portfolio

What would the effect of 1-5 GW additional solar PV have been on ERCOT energy prices in summer 2011?

- The Solar Energy Industries Association ("SEIA") and the Energy Foundation asked *The Brattle Group* to evaluate the potential effects of adding solar photovoltaic (PV) generation in the Texas wholesale energy market
- Analysis focused on what would have happened to energy prices in summer 2011 if there had been an additional 1-5 GW of solar PV capacity in ERCOT
- Also quantified the benefits associated with solar PV-related avoided generation from fossil-fuel plants, and reductions in CO_2 emissions
  - Impacts from "average" customer perspective (did not distinguish between benefits to system owners and other customers)
  - Provides basis for comparison against "all-in" costs of incremental solar PV generation (with some caveats)

We chose two alternative approaches: a statistical analysis, and a model-based simulation

- To evaluate the hypothetical impacts of incremental PV generation in Texas, we followed two approaches:

1. **Statistical Analysis:**

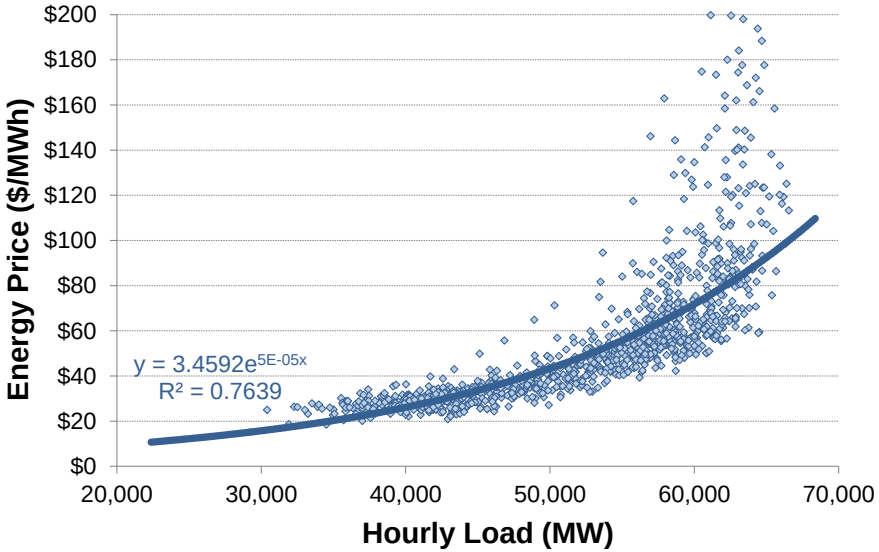
   Relies on historical data to construct a relationship between demand levels and energy prices, and uses this relationship to determine prices when "net" demand that needs to be served by other system resources is reduced by the amount of solar PV generation.

2. **Model-Based Simulation:**

   Uses publicly-available data to construct electricity supply curves, and estimates the prices by finding the most expensive generator that needs to run to meet demand in a given hour. Then, compares the results for a system with current levels of solar PV, to the results for a system with incremental amounts of solar PV added.

Statistical analysis focuses on the relationship between market prices and system demand

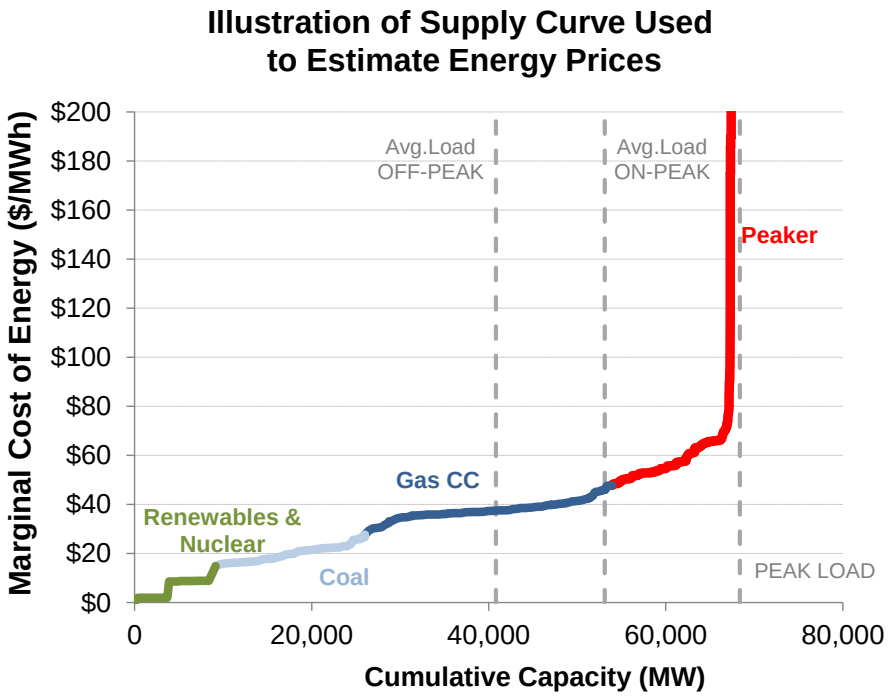
Relationship between Hourly Day-Ahead Energy Prices and Regional Demand in ERCOT
(for the period of June 2011 through August 2011)



Sources and Notes:
[1] Calculated based on the hourly data compiled by Ventyx, the Velocity Suite.
[2] Excludes hours in which the prices higher than $200/MWh.

- We studied the price impact of solar PV generation from a system demand perspective
  - Market prices increase or decrease with demand (more in peak hours than in off-peak hours)
  - Energy produced by solar PV reduces the "net" demand to be met by other generators – resulting in relatively lower prices (compared to a system without solar PV)
- We did not analyze the impact of other factors such as fuel price volatility, plant outages, transmission congestion
- Also, we did not include certain "scarcity" hours during which the prices are allowed to rise up to $3,000/MWh (needed to provide price signals to attract new builds; hence price reductions in such hours may not be long-lasting)

Model-based simulation uses supply curves to predict energy prices in any given hour

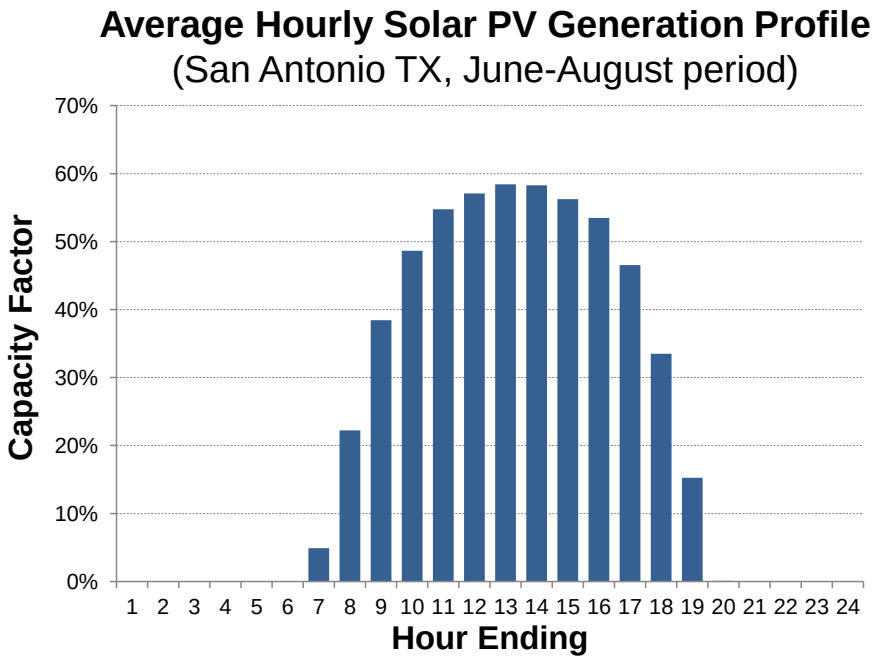


Sources and Notes:
[1] Calculated based on the unit-level data compiled by Ventyx, the Velocity Suite.
[2] Capacity numbers de-rated by forced outage rates.
[3] Wind generation at 35% capacity factor to reflect average output during on-peak.

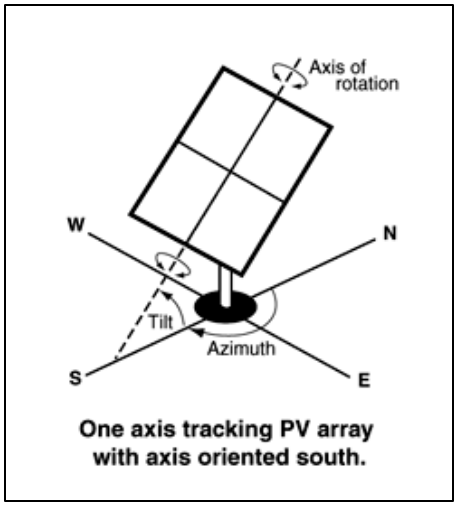
- Energy prices assumed to be set by the most expensive generator needed to run to meet hourly system demand
- To determine the impact of solar PV, we compared the results for a system without solar PV ("Base Case"), to the results with solar PV ("Alternative Case")
- Key model outputs include energy prices, power-sector CO_2 emissions, system production costs, and total payments by electricity consumers.
- Simplifying assumptions: forced outages spread evenly, no congestion costs, constant import/export schedule, constant fuel prices in any given month

Solar PV generation profiles are developed based on hourly data from NREL's Solar Advisor Model

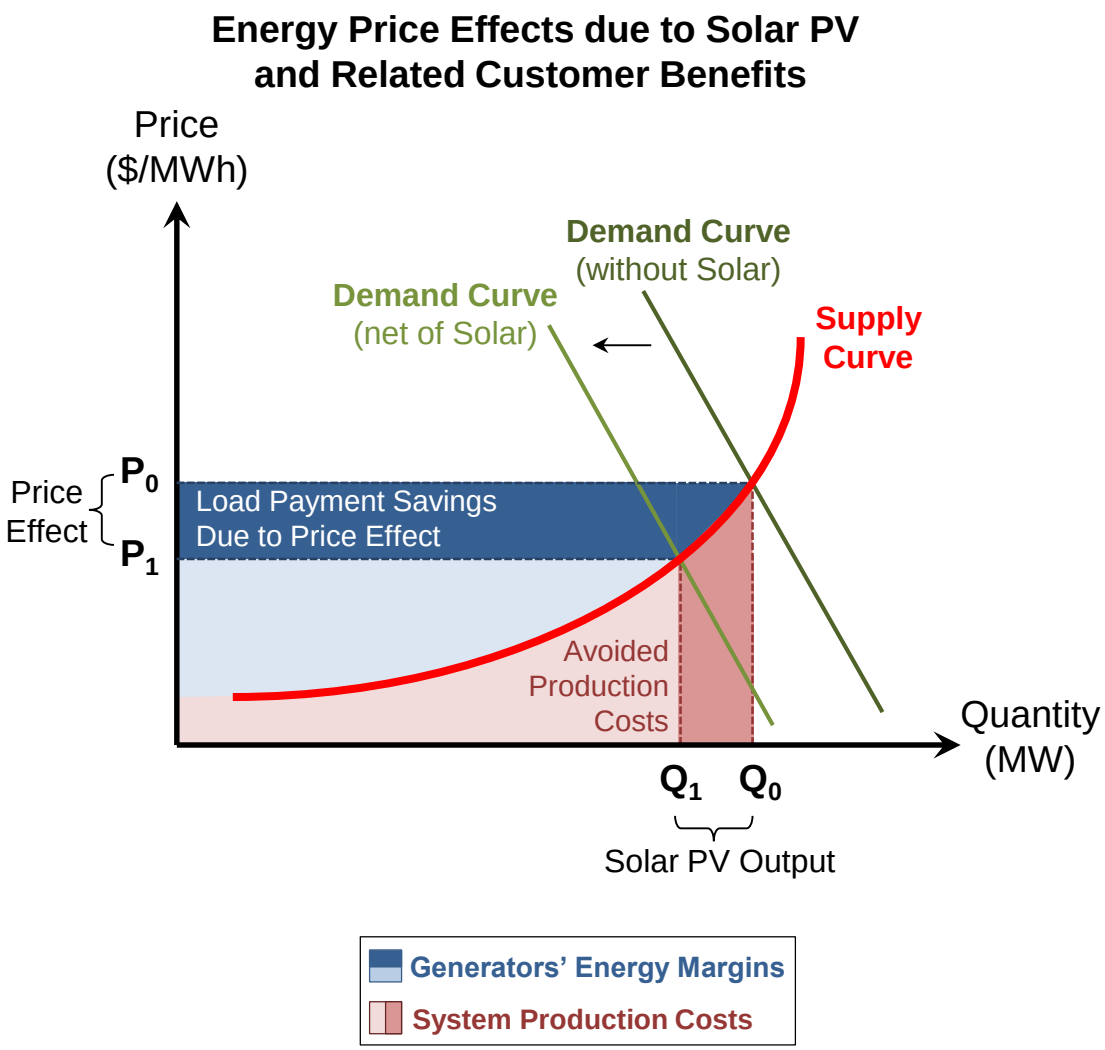
- Capacity factors average at 23% for June-August period, and approximately 45% for hours between 7am and 7pm.
- Assumed 1-axis, flat-plate residential PV system with a sun-tracking capability (axis oriented south, tilted at 30°) and located in San Antonio



Source: Calculated based on hourly generation data from NREL's Solar Advisor Model (SAM) version 2011.6.30.



Customer benefits are composed of avoided production costs and load payment savings



Customer benefits include:

- Avoided production costs as solar PV displaces conventional, fossil-fuel plants at the margin
- Load payment savings associated with solar PV-related energy price reductions (equal to decrease in generators energy margins)

Adding solar PV could have reduced the average energy prices in Texas by $0.6-$2.9/MWh

- We estimate that 1,000 MW of solar PV could have reduced the average energy prices by approximately $1.2-$1.9/MWh for the hours between 7am and 7pm, resulting in an average price decrease of $0.6-$1.0/MWh across all hours, including the nighttime hours (the ranges are driven by statistical versus model approach)

- The price effect increases roughly proportionally with higher MWs of solar PV additions (i.e., 2,500 MW of solar PV reduces the average prices by $1.5-$2.0/MWh, and 5,000 MW of solar PV by ~$2.9/MWh)

Estimated Energy Price Effects of Additional Solar PV Generation
(for the period of June 2011 through August 2011)

	Statistical Approach			Model-Based Approach		
	Daytime ($/MWh)	Nighttime ($/MWh)	**ALL HOURS ($/MWh)**	Daytime ($/MWh)	Nighttime ($/MWh)	**ALL HOURS ($/MWh)**
ERCOT Region						
1000 MW	$1.2	$0.0	**$0.6**	$1.9	$0.0	**$1.0**
2500 MW	$3.0	$0.0	**$1.5**	$3.9	$0.0	**$2.0**
5000 MW	$5.8	$0.0	**$2.9**	$5.6	$0.0	**$2.8**

* Does not include hours in which the prices exceed $200/MWh (107 hours for the period of June 2011 through August 2011).

Customers' savings in load payments could have been $206-$333 per MWh of solar PV generation

- In the summer of 2011, solar PV-related energy price reduction could have saved Texas customers an average of $155-$281 per MWh (of solar PV generation)
- Avoiding the fuel and variable O&M costs associated with operating fossil-fuel plants could have saved the customers an additional $52 per MWh
- Per MWh savings decrease at higher levels of solar PV penetration (due to diminishing price effects)

Estimated Energy Market Benefits Related to Additional Solar PV Generation
(for the period of June 2011 through August 2011)

	Load Payment Savings Due to Energy Price Reduction		+	Production Cost Savings Due to Avoided Fuel and O&M Costs		=	**Total Customer Benefits from Add'l Solar PV**	
	(million dollars)	*($/MWh of solar)*		*(million dollars)*	*($/MWh of solar)*		***(million dollars)***	***($/MWh of solar)***
ERCOT Region								
1000 MW	**$141.9**	*$281*		**$26.0**	*$52*		**$167.9**	*$333*
2500 MW	**$283.0**	*$225*		**$65.4**	*$52*		**$348.4**	*$276*
5000 MW	**$390.5**	*$155*		**$129.8**	*$51*		**$520.3**	*$206*

* Does not include hours in which the prices exceed $200/MWh (107 hours for the period of June 2011 through August 2011).

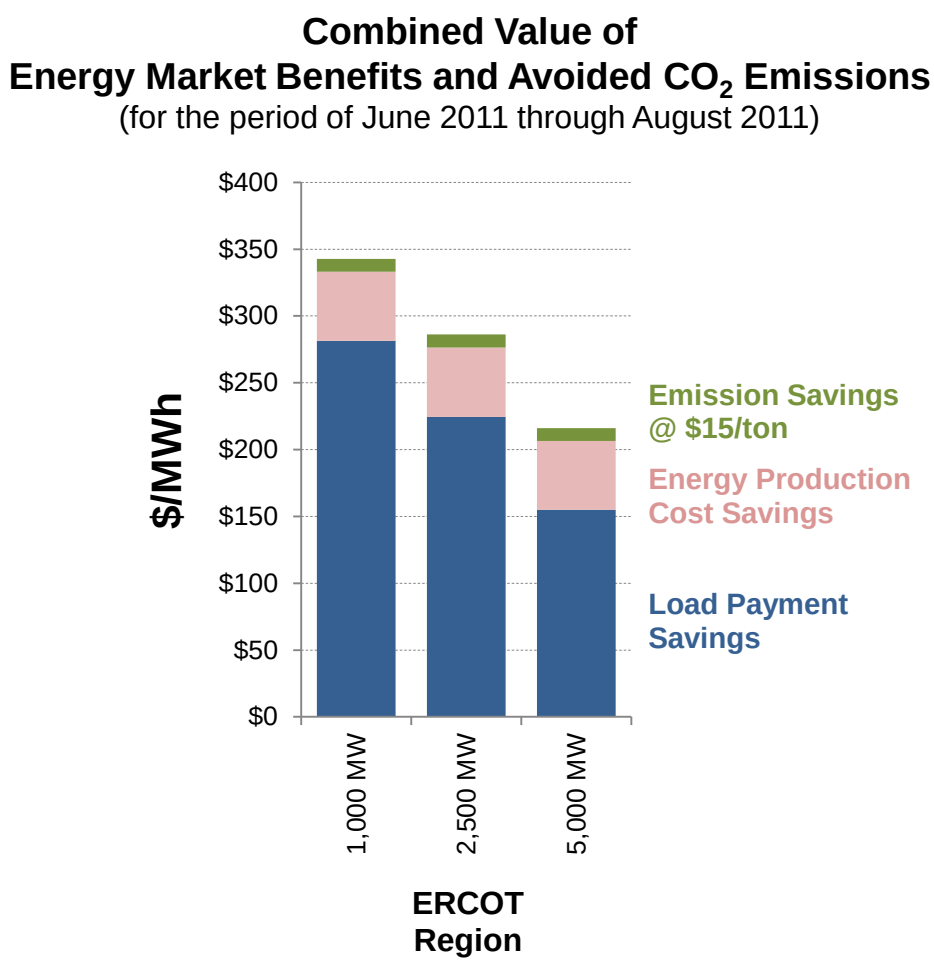
By replacing generation from fossil-fuel plants, solar PV could have reduced CO_2 emissions

- We estimated that CO_2 emissions could have been reduced by approximately 0.64 tons for each MWh of solar PV generation (roughly equal to the emission rate of a gas-fired combustion turbine).
- These emissions savings would have a corresponding economic value of an incremental $10/MWh of solar PV generation relative to a modest CO_2 price of $15/ton, and $19/MWh at a CO_2 price of $30/ton.

Estimated CO_2 Emissions Savings Related to Solar PV Generation
(for the period of June 2011 through August 2011)

	Avoided Power-Sector CO_2 Emissions		Economic Value @ $15/ton of CO_2 Price		Economic Value @ $30/ton of CO_2 Price	
	(thousand tons)	*(tons/MWh of solar)*	*(million dollars)*	*($/MWh of solar)*	*(million dollars)*	*($/MWh of solar)*
ERCOT Region						
1000 MW	**323**	*0.64*	**$4.9**	*$10*	**$9.7**	*$19*
2500 MW	**811**	*0.64*	**$12.2**	*$10*	**$24.3**	*$19*
5000 MW	**1,612**	*0.64*	**$24.2**	*$10*	**$48.4**	*$19*

Combined savings could have been as high as $216-$343 per MWh of solar PV generation



- Including a relatively modest assumption about the value of avoided CO_2 emissions of $15/ton, the combined value of avoided emissions, production cost savings and reduced wholesale power costs due to price effects could have been $216-$343/MWh (of solar PV generation).
- This suggests that, at least during the summer months when solar PV production and energy prices are highest, the short-term benefits of increased solar PV production approach or exceed the likely cost of incremental solar PV

The results of our analysis require some caveats

- Assumed reductions in wholesale prices are for summer 2011 only
  - Effect would likely be smaller during other periods of the year.
  - Future market conditions that are different than in 2011 would result in different levels of benefits (e.g., higher gas prices or tighter markets would likely see higher production cost savings, and vice versa).
  - Means that the benefit on a $/MWh of PV generation cannot be directly compared to levelized cost of PV.
- Estimated reductions in wholesale prices are potentially temporary
  - In an energy-only market like ERCOT, prices may need to rise to attract entry by conventional generators
  - Whether or not this will erode the effect of lower wholesale prices due to additional PV capacity will depend on a number of factors, including:
    - Load growth
    - Pattern of retirements from conventional generators
    - Natural gas prices
- Lower wholesale prices are good for consumers in the long-run only if they represent a social market equilibrium
  - Lower wholesale prices are at least partial transfers from producers to consumers
  - Resulting lower producer margins may reflect value of remaining externalities

Conclusions

- Additional solar PV generation in ERCOT would likely have had a significant impact on electricity prices in the summer of 2011
  - Total impact on customer's load payments would have been between $206 and $333 per MWh of solar PV output
  - While we did not examine the cost of PV in ERCOT, it is likely that <u>if</u> these benefits were annualizable and permanent, this would make PV cost effective (or close to it).
- Especially where alternative generating sources face difficulties, this likely makes solar PV an attractive option to address local capacity constraints and shortages
- Concerns on CO_2 and other GHG emissions would further improve the economics of solar PV in ERCOT

Topics for further consideration

- Sensitivities to understand how customer savings may have changed under different market conditions
- A multi-year study that considers plausible futures and analyzes life-cycle benefits of solar PV generation
- A full cost-benefit analysis that includes not only solar PV, but also other clean energy alternatives such as:
  - Energy efficiency and demand response
  - Other types of renewables (e.g., wind, biomass, etc.)

Contact

Thank-you!

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