Externalities and Incentives

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Linking Regulatory Means and Environmental Ends:
Intended and Unintended Consequences

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Energy Externalities

"'Externalities' refers to situations when the effect of production or consumption of goods and services imposes costs or benefits on others which are not reflected in the prices charged for the goods and services being provided." (OECD Glossary of Statistical Terms)

- Air, Water, Land Pollution.
- Occupational Risks in Energy Production.
- Oil Imports and Energy Security.
- Greenhouse Gases and Global Warming.
- Network Congestion.
- Learning by Doing.

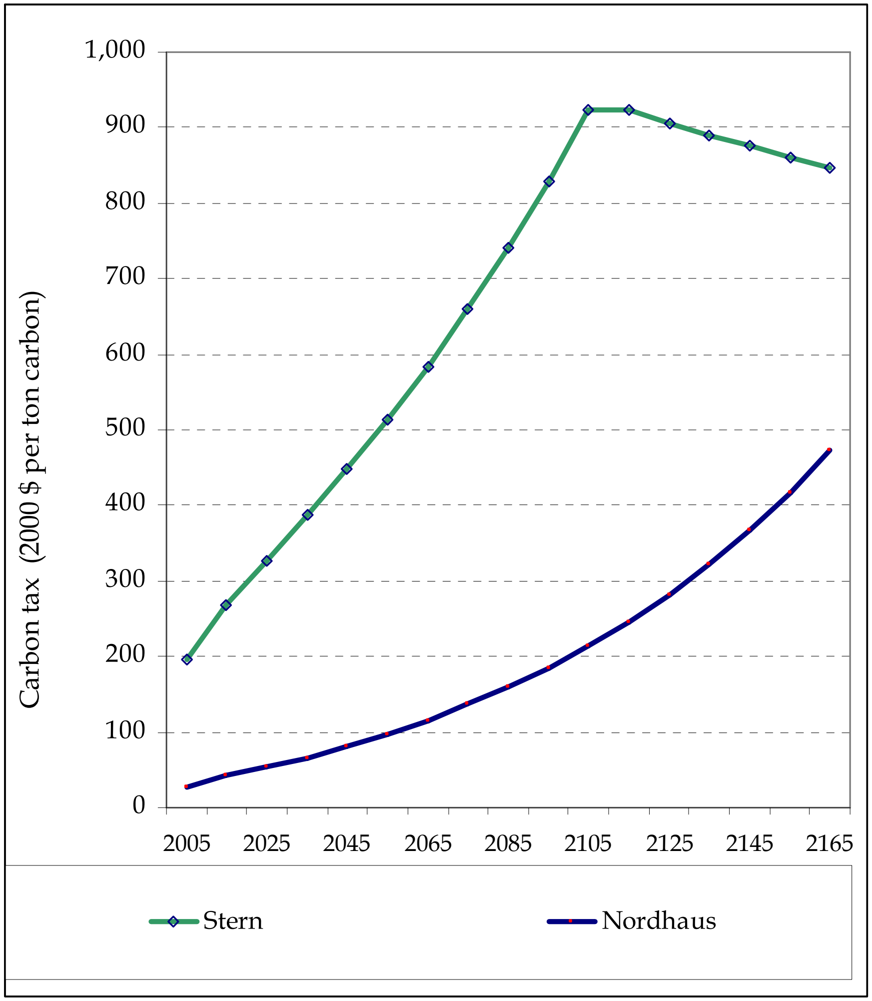
Externalities and Market Failures

- R & D and Information Spillovers
  - Government Funding
  - ARPA-E Innovation
- Infant Industries and Learning by Doing
  - Getting Started
  - Targeted Subsidies
- Environmental Pollution
  - Large and Sustained
  - Efficiency Standards
  - Cap and Trade or Taxes

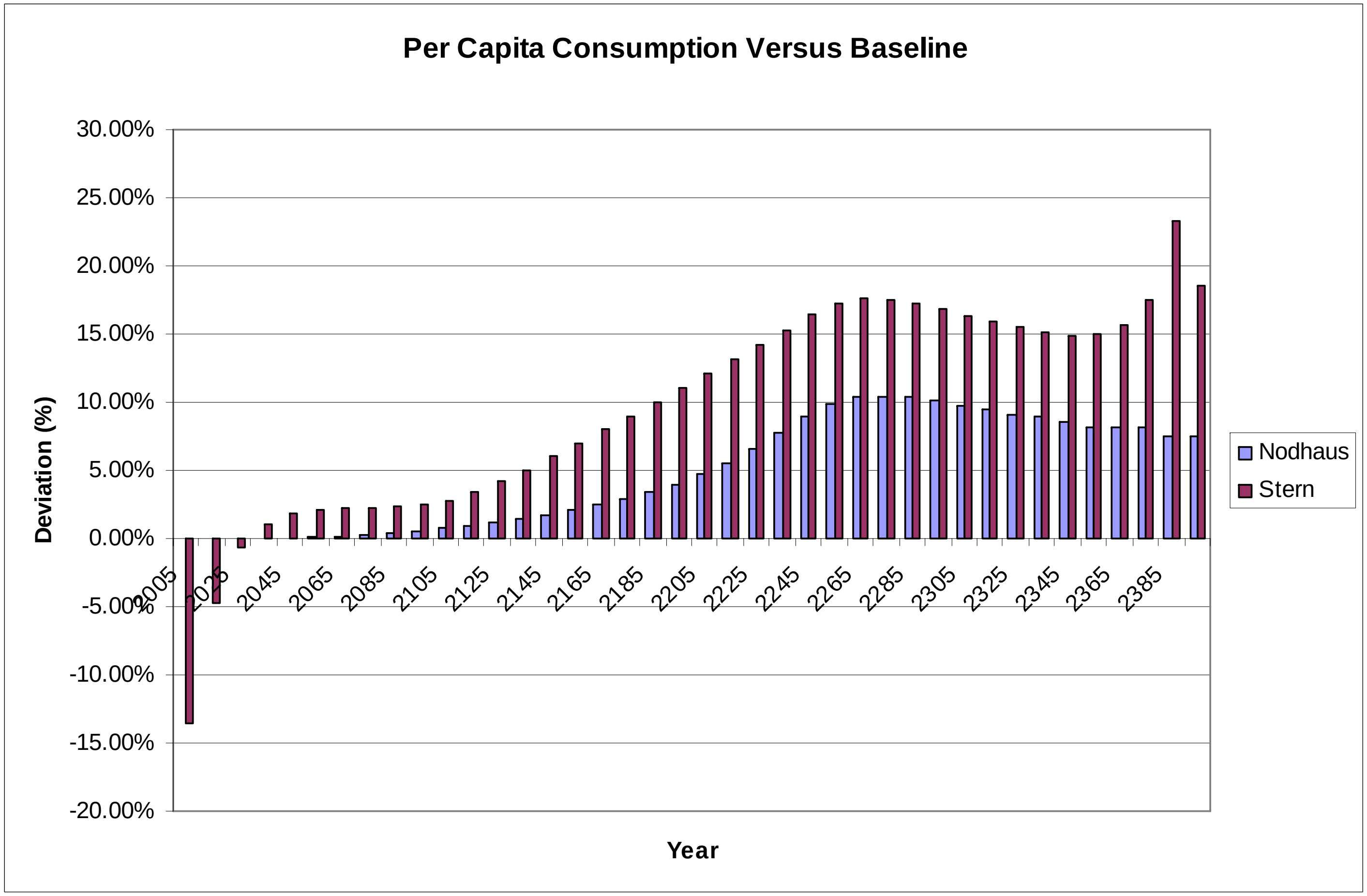
Example Policy Instruments

- Quantity Targets
- Renewable Portfolio Standards
- Feed-in Tariffs
- Production Tax Credits
- Investment Tax Credits

DICE Tax Under Stern Discount Rates



Comparing Consumption Profiles



Learning-By-Doing

Linking Regulatory Means and Environmental Ends

Example of the
California Solar Initiative

Schwarzenegger Plan

- January 2004. “Million Solar Roofs Initiative.”
- Target Date of 2015.
- California Public Utilities Commission (CPUC) Rulemaking, January 12, 2006.
- “California Solar Initiative” (CSI).
- Solar Installation Incentives Over 11 Years.

Externalities and Solar Policy

- Consumer Choice
  - Net Present Value
  - Diffusion Process
- Environmental Externalities, CO_2
- Learning By Doing
  - Cumulative Production (global)
  - Cumulative Installations (local)

Modeling Consumer Choice

Demand Curve	$q_t = \dfrac{a_t q_{\max}}{a_t + \left(q_{\max} - a_t\right) e^{-bNPV_t}} + diff_t$
Diffusion (indirect LBD)	$diff_t = \gamma q_{t-1} \left(1 - \dfrac{q_{t-1}}{q_{\max}}\right)$
Base Demand Updating	$a_t = a_{t-1} \left(\dfrac{q_{t-1} + diff_{t-1}}{q_{t-1}}\right)$
Consumer Net Present Value	$NPV_t \left(Cost, Subsidy\right)$

Learning-By-Doing

Production Cost $P_t = \alpha_M Q_{G,t-1}^{-\beta_M} + \alpha_{BOS} Q_{t-1}^{-\beta_{BOS}}$

Learning Rate (LR) is the percentage decrease in cost from a doubling of experience.

Learning Rates

Global Production, $LR = 1 - 2^{-\beta_M} = 10\%$

Local Installation, $LR = 1 - 2^{-\beta_{BOS}} = 10\%$

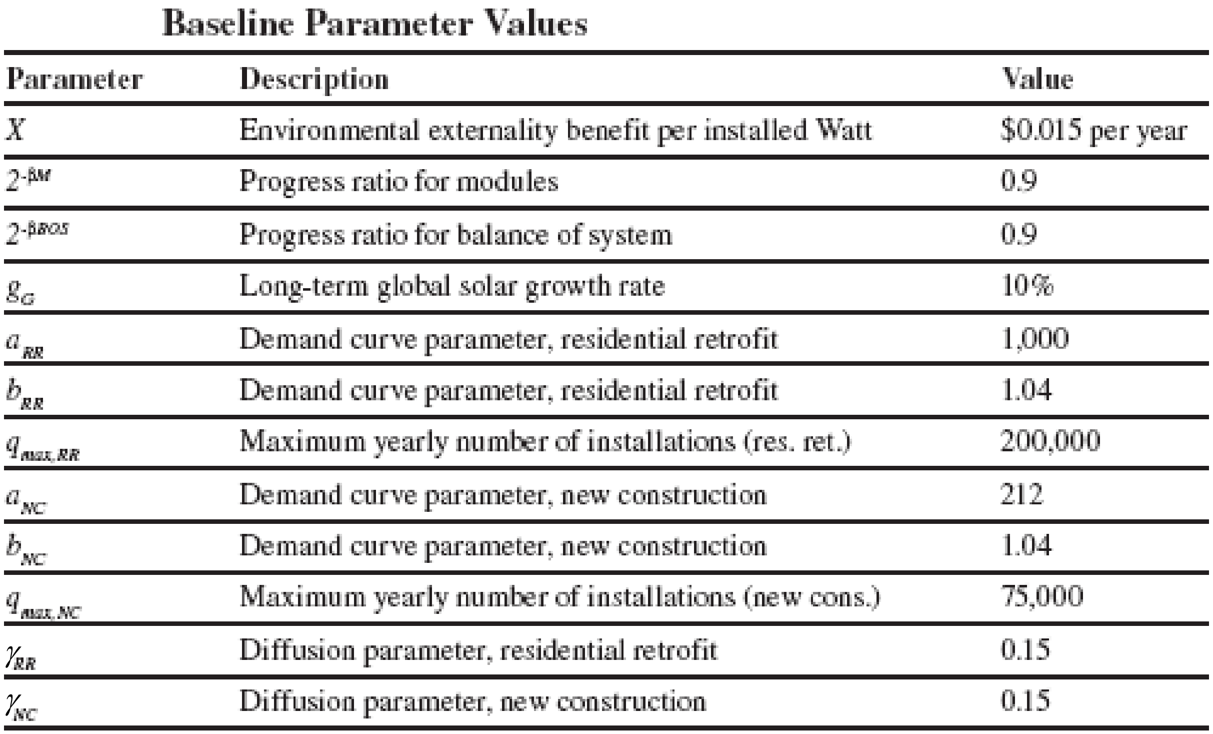
Economic Efficiency

Choose the trajectory of incentives to maximize the present value of the CSI.

$$\underset{I_t}{Max}\, PVSB\left(I_t\right) = \sum_{t=1}^{T} \frac{\left\{ Xq_t\left(I_t\right) + q_t\left(I_t\right) NPV_t\left(I_t, Q_t, e\right) - q_t\left(I_t\right) I_t \right\}}{\left(1+r\right)^t}$$

Carbon Externality	X
Electricity Price Growth Rate	e
Consumer Incentives	I_t

Model Parameters



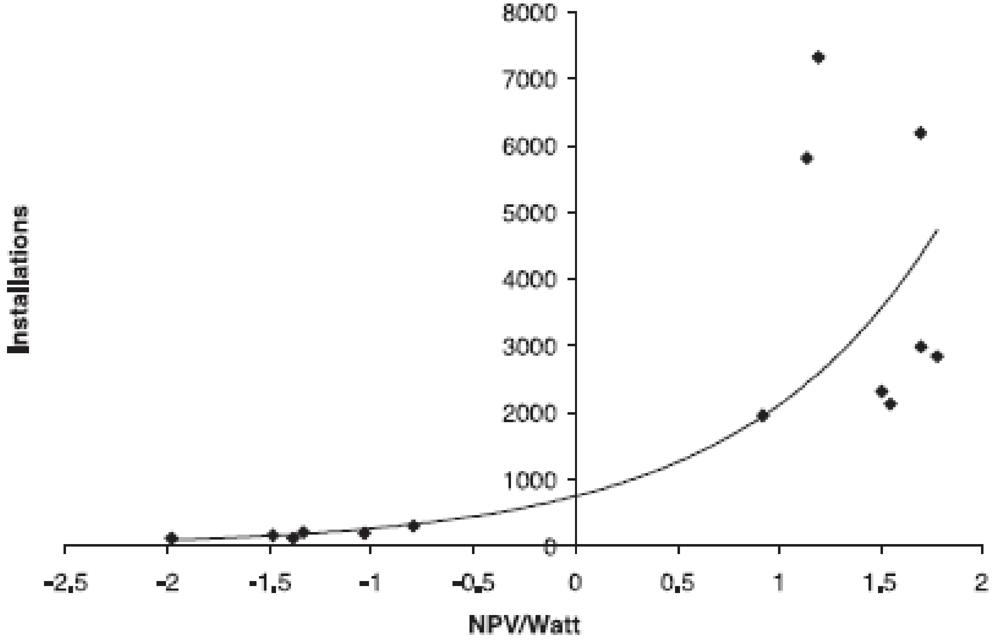
Baseline Parameter Values

Parameter	Description	Value
X	Environmental externality benefit per installed Watt	$0.015 per year
$2^{-\beta_M}$	Progress ratio for modules	0.9
$2^{-\beta_{BOS}}$	Progress ratio for balance of system	0.9
g_G	Long-term global solar growth rate	10%
a_{RR}	Demand curve parameter, residential retrofit	1,000
b_{RR}	Demand curve parameter, residential retrofit	1.04
$q_{max,RR}$	Maximum yearly number of installations (res. ret.)	200,000
a_{NC}	Demand curve parameter, new construction	212
b_{NC}	Demand curve parameter, new construction	1.04
$q_{max,NC}$	Maximum yearly number of installations (new cons.)	75,000
γ_{RR}	Diffusion parameter, residential retrofit	0.15
γ_{NC}	Diffusion parameter, new construction	0.15

Source: Benthem, Gillingham and Sweeney, “Learning-by-Doing and the Optimal Solar Policy in California,” *The Energy Journal*, Vol. 29, No. 3., 2008, pp. 131-152.

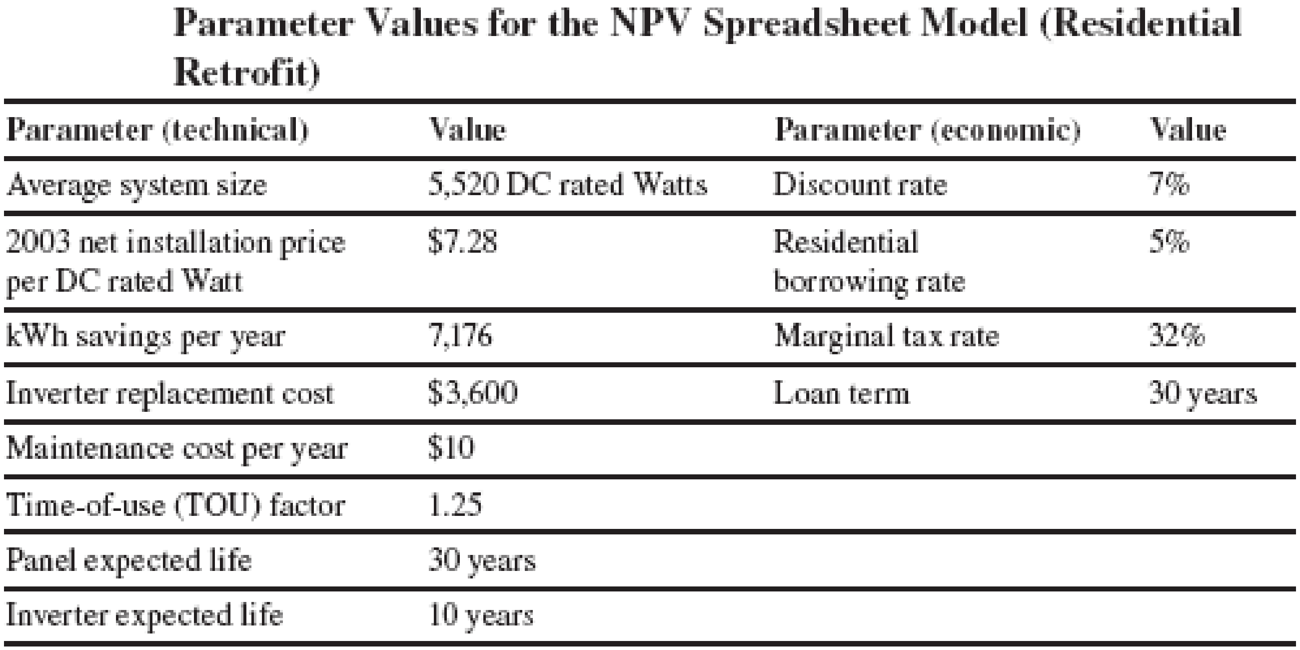
Demand Model

Yearly Installations of Residential PV Systems Versus NPV per Watt, and the Fitted Demand Curve



Source: Benthem, Gillingham and Sweeney, “Learning-by-Doing and the Optimal Solar Policy in California,” *The Energy Journal*, Vol. 29, No. 3., 2008, pp. 131-152.

NPV Parameters

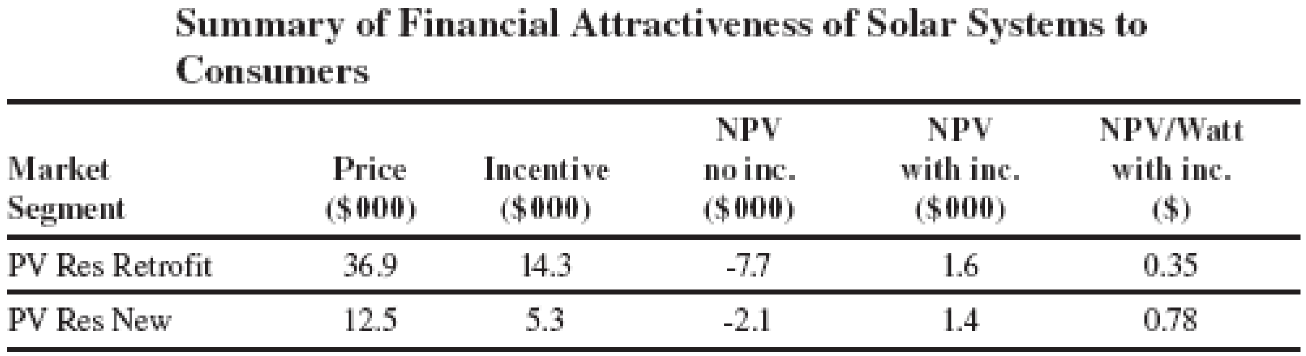


Parameter Values for the NPV Spreadsheet Model (Residential Retrofit)

Parameter (technical)	Value	Parameter (economic)	Value
Average system size	5,520 DC rated Watts	Discount rate	7%
2003 net installation price per DC rated Watt	$7.28	Residential borrowing rate	5%
kWh savings per year	7,176	Marginal tax rate	32%
Inverter replacement cost	$3,600	Loan term	30 years
Maintenance cost per year	$10		
Time-of-use (TOU) factor	1.25		
Panel expected life	30 years		
Inverter expected life	10 years		

Source: Benthem, Gillingham and Sweeney, “Learning-by-Doing and the Optimal Solar Policy in California,” *The Energy Journal*, Vol. 29, No. 3., 2008, pp. 131-152.

Solar Requires Subsidies

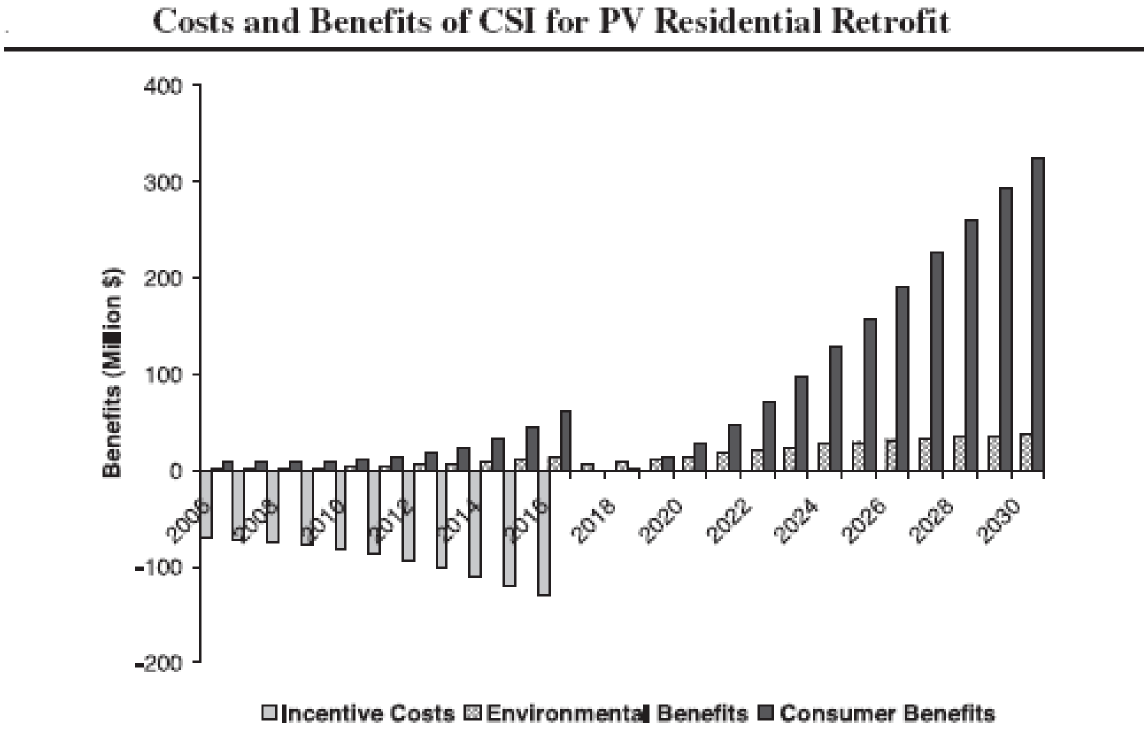


Summary of Financial Attractiveness of Solar Systems to Consumers

Market Segment	Price ($000)	Incentive ($000)	NPV no inc. ($000)	NPV with inc. ($000)	NPV/Watt with inc. ($)
PV Res Retrofit	36.9	14.3	-7.7	1.6	0.35
PV Res New	12.5	5.3	-2.1	1.4	0.78

Source: Benthem, Gillingham and Sweeney, “Learning-by-Doing and the Optimal Solar Policy in California,” *The Energy Journal*, Vol. 29, No. 3., 2008, pp. 131-152.

Retrofit Costs and Benefits

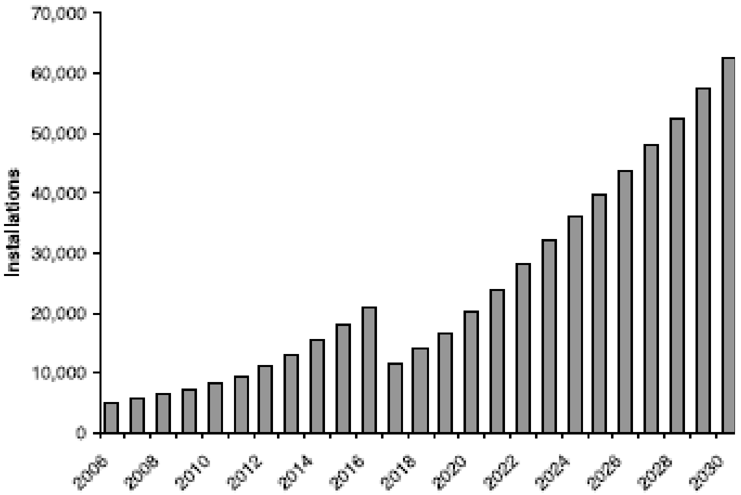


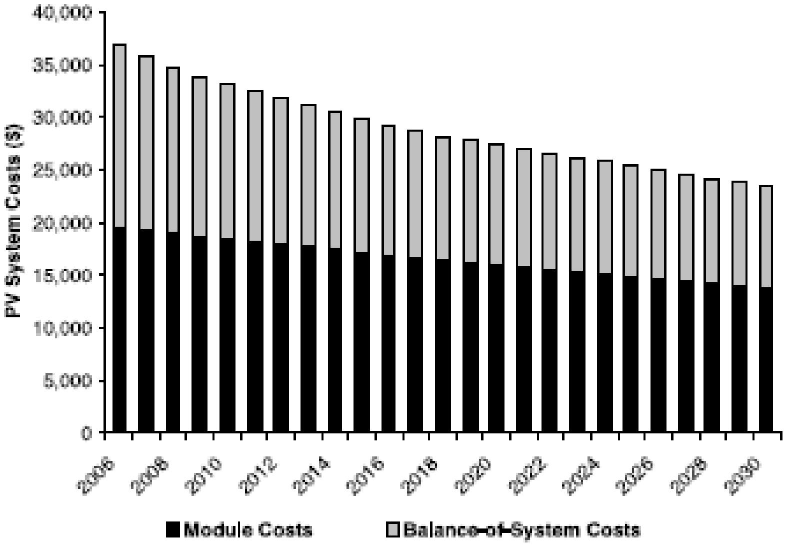
Costs and Benefits of CSI for PV Residential Retrofit

Source: Benthem, Gillingham and Sweeney, “Learning-by-Doing and the Optimal Solar Policy in California,” *The Energy Journal*, Vol. 29, No. 3., 2008, pp. 131-152.

Installation Profile

Incentives End in 2016. Solar Photovoltaic is Self Sustaining.





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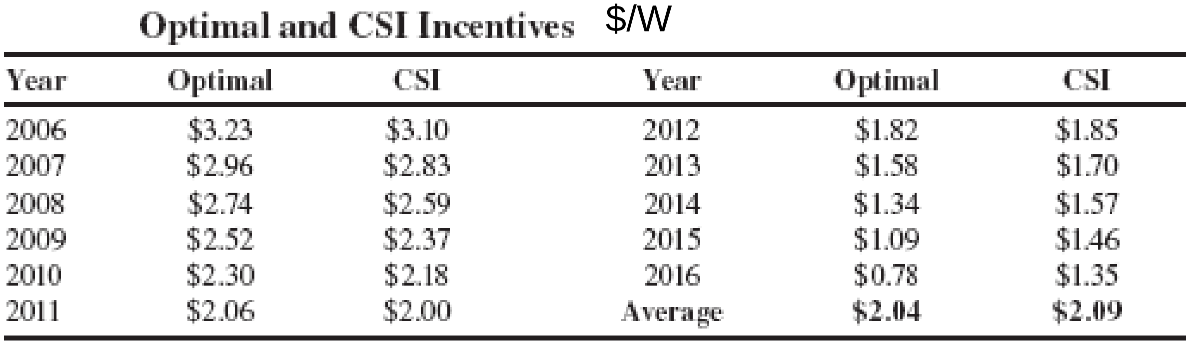
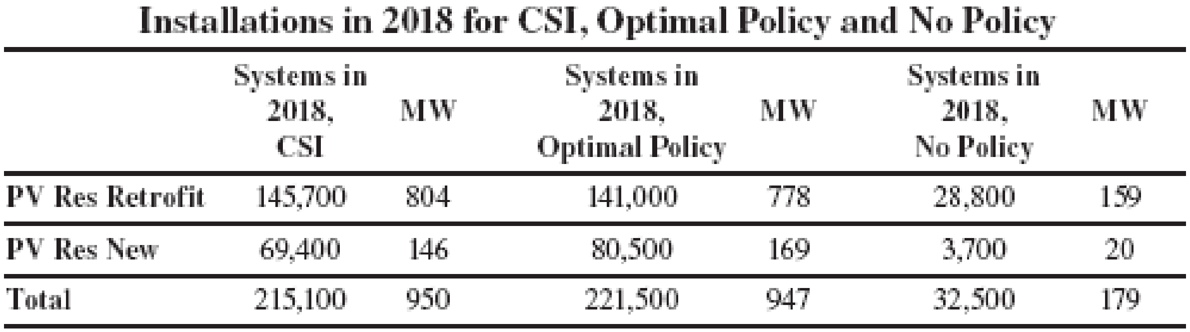
Comparing Policy Profiles



Optimal and CSI Incentives $/W

Year	Optimal	CSI	Year	Optimal	CSI
2006	$3.23	$3.10	2012	$1.82	$1.85
2007	$2.96	$2.83	2013	$1.58	$1.70
2008	$2.74	$2.59	2014	$1.34	$1.57
2009	$2.52	$2.37	2015	$1.09	$1.46
2010	$2.30	$2.18	2016	$0.78	$1.35
2011	$2.06	$2.00	**Average**	**$2.04**	**$2.09**



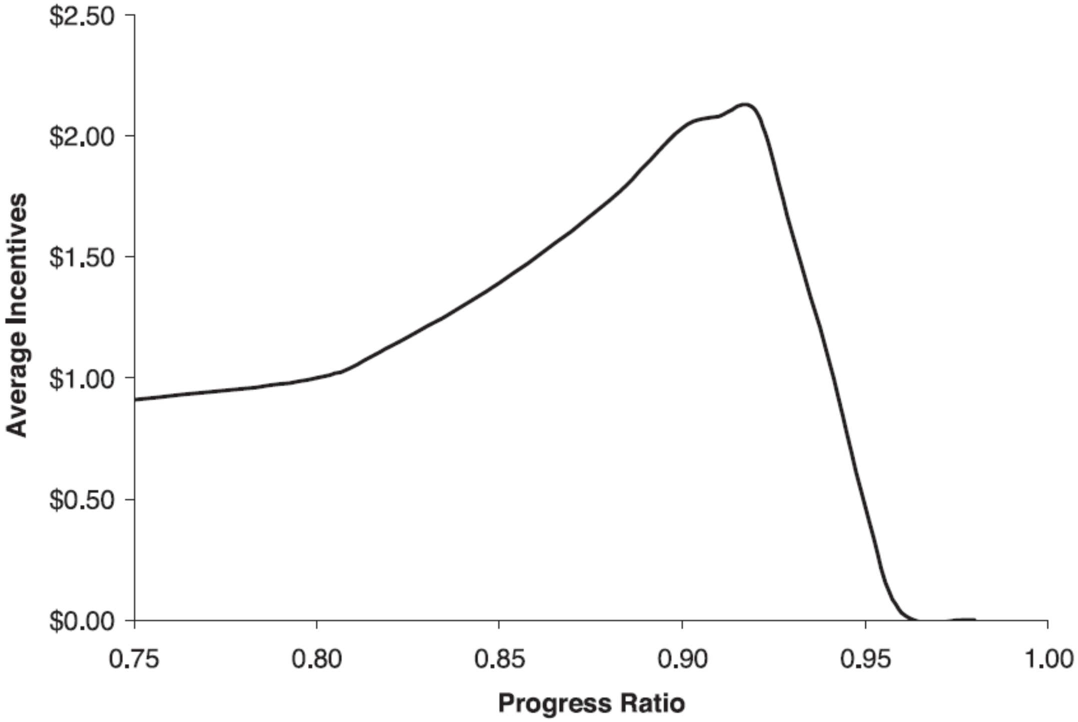
Installations in 2018 for CSI, Optimal Policy and No Policy

	Systems in 2018, CSI	MW	Systems in 2018, Optimal Policy	MW	Systems in 2018, No Policy	MW
PV Res Retrofit	145,700	804	141,000	778	28,800	159
PV Res New	69,400	146	80,500	169	3,700	20
Total	215,100	950	221,500	947	32,500	179

Source: Benthem, Gillingham and Sweeney, “Learning-by-Doing and the Optimal Solar Policy in California,” *The Energy Journal*, Vol. 29, No. 3., 2008, pp. 131-152.

Optimal Policy Depends on LBD Rate

Average Incentives as a Function of the Progress Ratio, Holding All Other Parameters Constant



Source: Benthem, Gillingham and Sweeney, “Learning-by-Doing and the Optimal Solar Policy in California,” *The Energy Journal*, Vol. 29, No. 3., 2008, pp. 131-152.

California Solar Initiative

- Dominant Market Failure
  - LBD Incentive Provides Most of the Benefits.
  - Carbon Impact is a Byproduct.
- At Nominal 90% Progress Rate
  - Substantial Expected Net Benefits.
  - 250,000 Home by 2017 vs. 1,000,000 Target.
  - Actual Installations Higher or Lower Depending on LBD Rate.

Externalities and Incentives

- Structure of Externality Problem Materially Affects Structure of Optimal Policy.
- With Many Competing Policies, There is a High Risk of Unintended Consequences.
- Bad Outcomes Include High Costs and Little Sustainable Environmental Benefit.
- Strong Interactions with Market Design, Smart Grids, and Smart Pricing Incentives.

William W. Hogan is the Raymond Plank Professor of Global Energy Policy, John F. Kennedy School of Government, Harvard University and a Director of LECG, LLC. This paper draws on work for the Harvard Electricity Policy Group and the Harvard-Japan Project on Energy and the Environment. The author is or has been a consultant on electric market reform and transmission issues for Allegheny Electric Global Market, American Electric Power, American National Power, Australian Gas Light Company, Avista Energy, Barclays, Brazil Power Exchange Administrator (ASMAE), British National Grid Company, California Independent Energy Producers Association, California Independent System Operator, Calpine Corporation, Canadian Imperial Bank of Commerce, Centerpoint Energy, Central Maine Power Company, Chubu Electric Power Company, Citigroup, Comision Reguladora De Energia (CRE, Mexico), Commonwealth Edison Company, COMPETE Coalition, Conectiv, Constellation Power Source, Coral Power, Credit First Suisse Boston, DC Energy, Detroit Edison Company, Deutsche Bank, Duquesne Light Company, Dynegy, Edison Electric Institute, Edison Mission Energy, Electricity Corporation of New Zealand, Electric Power Supply Association, El Paso Electric, GPU Inc. (and the Supporting Companies of PJM), Exelon, GPU PowerNet Pty Ltd., GWF Energy, Independent Energy Producers Assn, ISO New England, Luz del Sur, Maine Public Advocate, Maine Public Utilities Commission, Merrill Lynch, Midwest ISO, Mirant Corporation, JP Morgan, Morgan Stanley Capital Group, National Independent Energy Producers, New England Power Company, New York Independent System Operator, New York Power Pool, New York Utilities Collaborative, Niagara Mohawk Corporation, NRG Energy, Inc., Ontario IMO, Pepco, Pinpoint Power, PJM Office of Interconnection, PPL Corporation, Public Service Electric & Gas Company, PSEG Companies, Reliant Energy, Rhode Island Public Utilities Commission, San Diego Gas & Electric Corporation, Sempra Energy, SPP, Texas Genco, Texas Utilities Co, Tokyo Electric Power Company, Toronto Dominion Bank, TransÉnergie, Transpower of New Zealand, Westbrook Power, Western Power Trading Forum, Williams Energy Group, and Wisconsin Electric Power Company. The views presented here are not necessarily attributable to any of those mentioned, and any remaining errors are solely the responsibility of the author. (Related papers can be found on the web at www.whogan.com).