Economic Analysis of Large Stationary Fuel Cell Value in California

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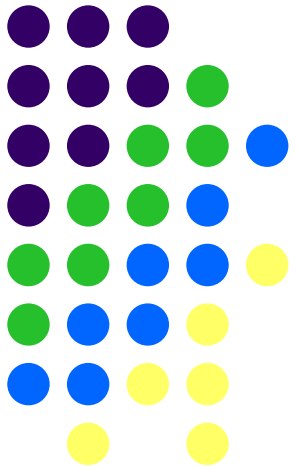
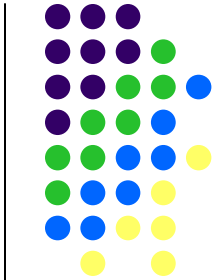
Empowered Energy

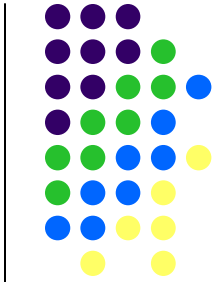


Economic Analysis Can Inform Policy Debate & Implementation



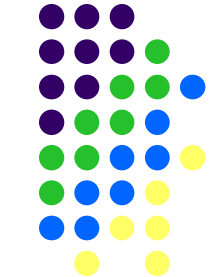
- Energy and environmental policies often target the electricity sector for (i) reduced emissions or (ii) minimum generation/sales from renewable energy.
- Implementation of political and policy mandates should be accomplished as efficiently and cost-effectively as possible.
- Economic analysis can inform the policy debate and provide relative rankings of available generation technology options available to meet mandates.
  - Distributed generation ("DG")
  - Central plant generation
- And is, more often than not, required.

PLEASE Matrix: Valuable DG Attributes Often Not Quantified



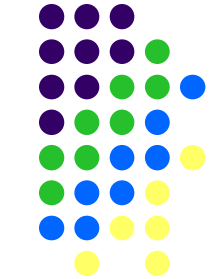
POLITICAL	LOCATIONAL	ENVIRONMENTAL	ANTIDOTAL Hedge against:	SECURITY	EFFICIENCY (Market, Technical)
Impact on local control of resources	Impact on local tax base	"Renewable energy credits" and "green certificates" impact	Fossil fuel price volatility	Impact on likelihood of system outages	Impact of combined chilling, heating & power ("CCHP")
Impact on "political capital"	Land use impact (*e.g.*, T&D rights of way)	Impact on NOx and SOx emissions levels	Future electricity price volatility	Impact on supply diversity	Impact on competition & market power mitigation
Impact on achieving RPS goals	Impact on local property values	Impact on PM10 emissions level	Utility power outages	Impact on power quality	Impact on project carrying costs
	Noise level impact	Impact on CO2 emissions level	Utility load forecast uncertainty	Impact on utility grid VAR support	Impact on decision making time required
	Impact on NIMBY and BANANA attitudes	Impact on other emissions levels (*e.g.*, VOCs, mercury)	Uncertain reserve % requirements	Impact on likelihood & severity of terrorist attacks	Impact on project installation time (due to modularity)
	Impact on local economic activity (*e.g.*, job creation)	Impact on material input (*e.g.*, solar panels replace some roofing)	Wheeling costs	Impact on domestic fossil fuel use	Impact on supply options (as DG markets & technologies mature)
	Ability to impact urban load pockets	Healthcare cost impact related to emissions level changes	Future changes in environmental regulations	Impact on fossil fuel import reliance	Impact on load growth responsiveness (due to modularity)
	Ability to impact suburban load pockets	Visibility impact due to emissions impact	Site remediation costs (current and future)		Impact on permitting time and cost
	Ability to impact rural or remote loads	Impact on consumptive water use			Impact on operating life of grid components
	Impact of DG fuel delivery system	Impact on urban "heat islands" (*e.g.*, shading ability)			Impact on resale or salvage value of equipment
	Visual impact	Impact on water & soil pollution levels			

Quantification of Fuel Cell Value Proposition Engaged the Debate



- Analyses performed on behalf of California Fuel Cell Manufacturer Initiative ("CAFCMI").
- Initial quantification of PLEASE matrix benefits was expanded to a full benefit-cost analysis.
- Cost-benefit analysis, in turn, led to extension of California Air Resources Board ("ARB") cost-effectiveness test for emissions reduction measures.
  - ARB proposed emissions reduction measures always ***cost***
  - Head-to-head technology comparison may result in either costs ***or*** savings for emissions reductions.

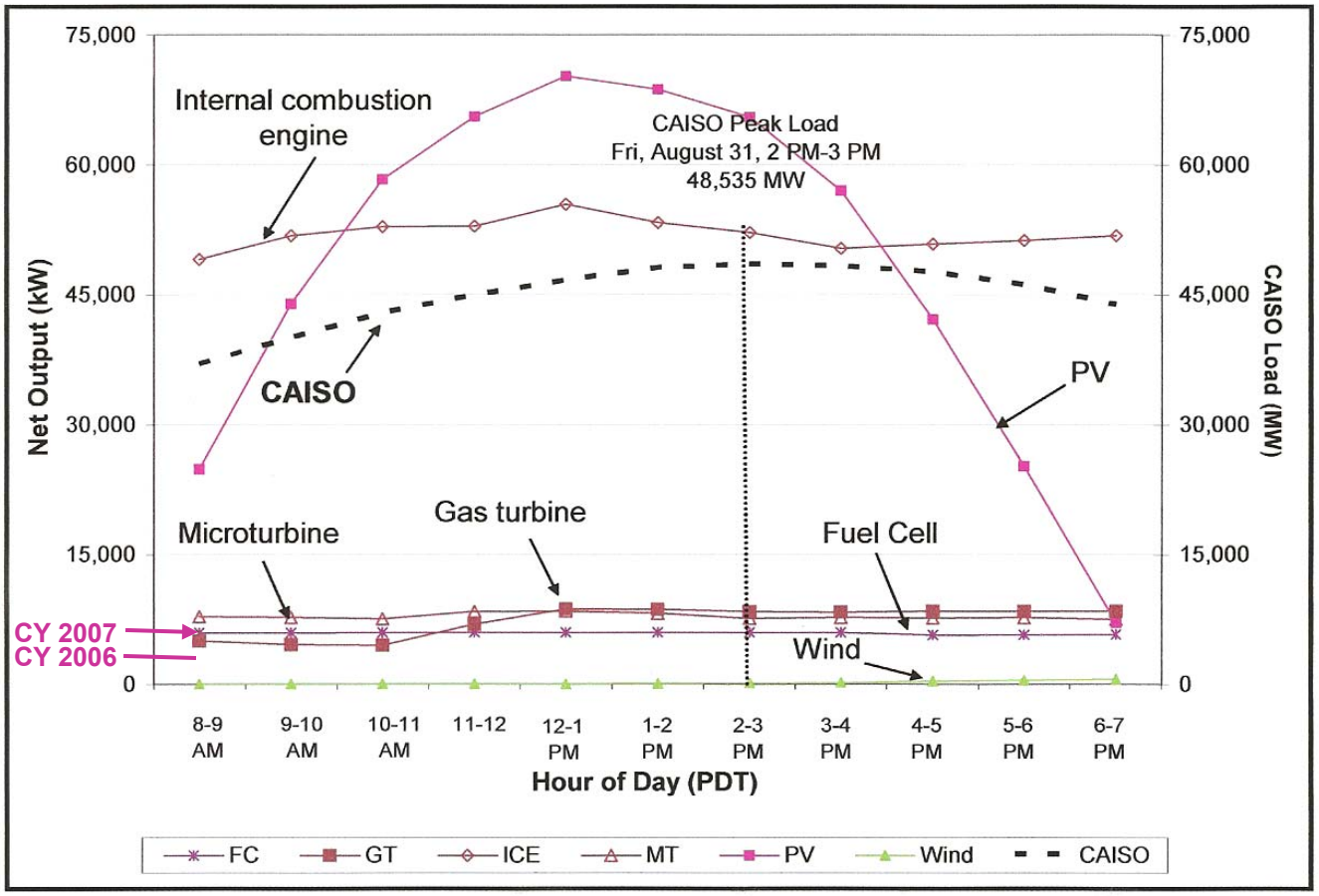
Importance of Market Identification: Application Determines Value



- Baseload DG Fuel Cell Markets:
  - Cogeneration from Capture of High-Quality Waste Heat
  - Renewable Power – Digester & Landfill Gas (as available)
  - Flexible Fuel Applications Follow Natural Gas Lead
  - High-Efficiency Hybrid Applications
  - Co-Generation of Renewable Hydrogen
- Baseload Central Plant Generation Markets:
  - Hybrid Applications
  - Natural Gas- and Coal-Fired Configurations
  - Enhanced Grid Support
  - Large Volume Co-Generation of Hydrogen

Peak Output of Fuel Cells: 100% Higher in 2007 than 2006

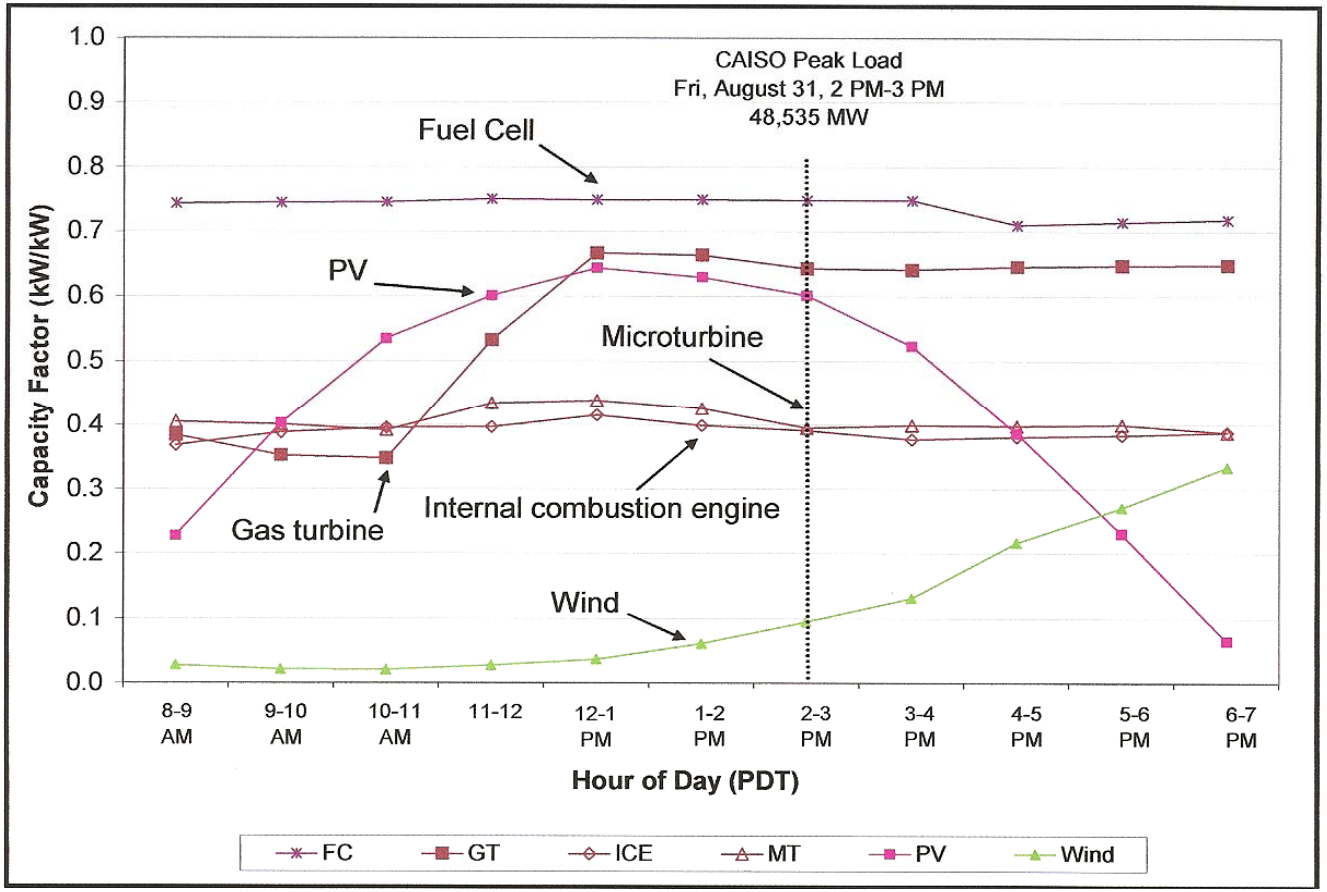
Figure 5-5: SGIP Impact on CAISO 2007 Peak Day



***Source*: Itron, Inc., September 2008, "CPUC Self-Generation Incentive Program Seventh-Year Impact Evaluation, Final Report," p. 5-13.**

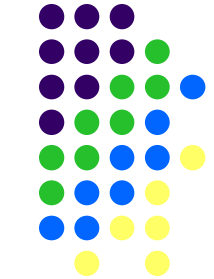
Baseload Fuel Cells Provide Reliable On-Peak Capacity

Figure 5-4: CAISO Peak Day Capacity Factors by Technology (2007)



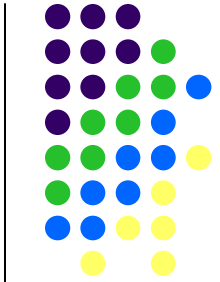
***Source*: Itron, Inc., September 2008, "CPUC Self-Generation Incentive Program Seventh-Year Impact Evaluation, Final Report," p. 5-12.**

Large-Unit Stationary Fuel Cell Value Proposition in California



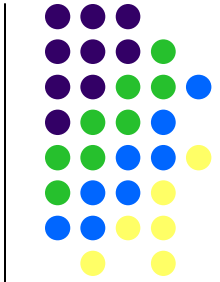
- Large-Scale Distributed Baseload Power Generation
  - Capacity: 100's of kW – 10's of MW
  - Availability: > 90%
  - Fuel Cell Technologies: Molten Carbonate ("MCFC"); Solid Oxide ("SOFC"); Phosphoric Acid ("PAFC")
  - Combined Heat & Power: 60% of Total Installed Capacity
- Fuel
  - Natural Gas
  - Renewable – Digester Gas from Waste Water Treatment Plants, Landfill Gas, Other Biogas Sources: 30% of Total Installed Capacity

Four Broad Categories of Benefits Quantified (1 of 2)



- Generation-Related
  - Avoided Generator
    - In-State Natural Gas Combined Cycle ("NGCC") or
    - Out-of-State Pulverized Coal Central Plant
  - Natural Gas Savings (and Related Avoided Emissions)
    - Higher Fuel Cell Electrical Efficiency
    - Avoided Boiler Fuel Input due to Cogeneration
    - Avoided Flared Gas Emissions from Digester Gas Use
- Grid-Related
  - Increased Reliability and Blackout Avoidance – Value Increases as Market Penetration of Fuel Cells Increases
  - Increased Power Quality

Four Broad Categories of Benefits Quantified (2 of 2)



- Emissions- and Health-Related
  - Avoided Emissions – Value Depends on Location of Avoided Generator
  - Value of Health Benefits – Limited to Avoided In-State Emissions
- Job Creation Potential
  - Initially Only Fuel Cell Installation
  - Potential for Future In-State Fuel Cell Manufacturing Capacity Adds Significant Value

Build-Up of Large Stationary Fuel Cell Value In California

	¢/kWh
Value of Avoided Water Use	0.00 - 0.26
Value of Avoided Fossil Fuel as a Price Hedge*^	0.36 - 0.96
Value of Avoided Generation Fuel Cost*^ (Efficiency Gain + Cogen Credit + 30% Renewable Fuel Use)	1.28 - 7.03
Value of Avoided Generation Variable O&M Cost	0.00 - 0.25
Value of Avoided Generation Capacity Fixed Operation & Maintenance Cost	0.22 - 0.29
Value of Avoided Generation Capacity Capital Cost (93% Effective Load Carrying Capacity)	1.71 - 2.31

* Indicates inclusion of Cogen Credit
^ Indicates inclusion of Digester Gas Credit

GENERATION-RELATED VALUE: **6.6 – 20.5¢/kWh**

Build-Up of Large Stationary Fuel Cell Value In California

	¢/kWh
Increased Reliability/Power Quality/Blackout Avoidance	<0.01 - 0.22
Value of Grid Support	0.03 - 0.40
Value of Avoided Losses (Generation, T&D, Related Emissions)	0.26 - 0.64
Value of Avoided Distribution Cost (All Costs Allocated to Peak)	0.06 - 0.97
Value of Avoided Transmission Cost (All Costs Allocated to Peak)	0.01 - 0.24

* Indicates inclusion of Cogen Credit
^ Indicates inclusion of Digester Gas Credit

GRID-RELATED VALUE: **6.6 – 20.5¢/kWh**

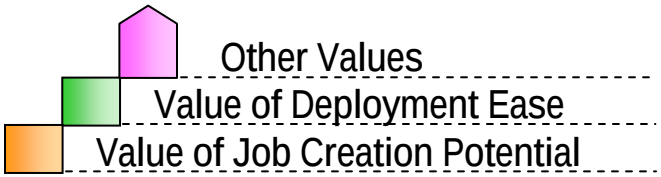
Build-Up of Large Stationary Fuel Cell Value In California

	¢/kWh
Value of Health Benefits*^	2.34 - 2.54
Value of Avoided CO_2 Emissions*	0.11 - 2.21
Value of Other Avoided Emissions (NOx*^, SO2*, VOC*, PM10^, CO*^, Hg)	0.11 - 1.90

* Indicates inclusion of Cogen Credit
^ Indicates inclusion of Digester Gas Credit

EMISSIONS- & HEALTH-RELATED VALUE: **6.6 – 20.5¢/kWh**

Build-Up of Large Stationary Fuel Cell Value In California



¢/kWh
TBD
Site Specific
0.11 - 0.26

* Indicates inclusion of Cogen Credit
^ Indicates inclusion of Digester Gas Credit

RANGE OF JOB-CREATION VALUE: 0.1 – 0.3¢/kWh

Build-Up of Large Stationary Fuel Cell Value In California

	¢/kWh
Other Values	TBD
Value of Deployment Ease	Site Specific
Value of Job Creation Potential	0.11 - 0.26
Value of Health Benefits*^	2.34 - 2.54
Value of Avoided CO_2 Emissions*	0.11 - 2.21
Value of Other Avoided Emissions (NOx*^, SO2*, VOC*, PM10^, CO*^, Hg)	0.11 - 1.90
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7/29/2007 R7

* Indicates inclusion of Cogen Credit
^ Indicates inclusion of Digester Gas Credit

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RANGE OF TOTAL FUEL CELL VALUE: 6.6 – 20.5¢/kWh

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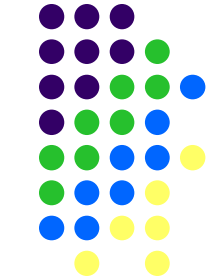
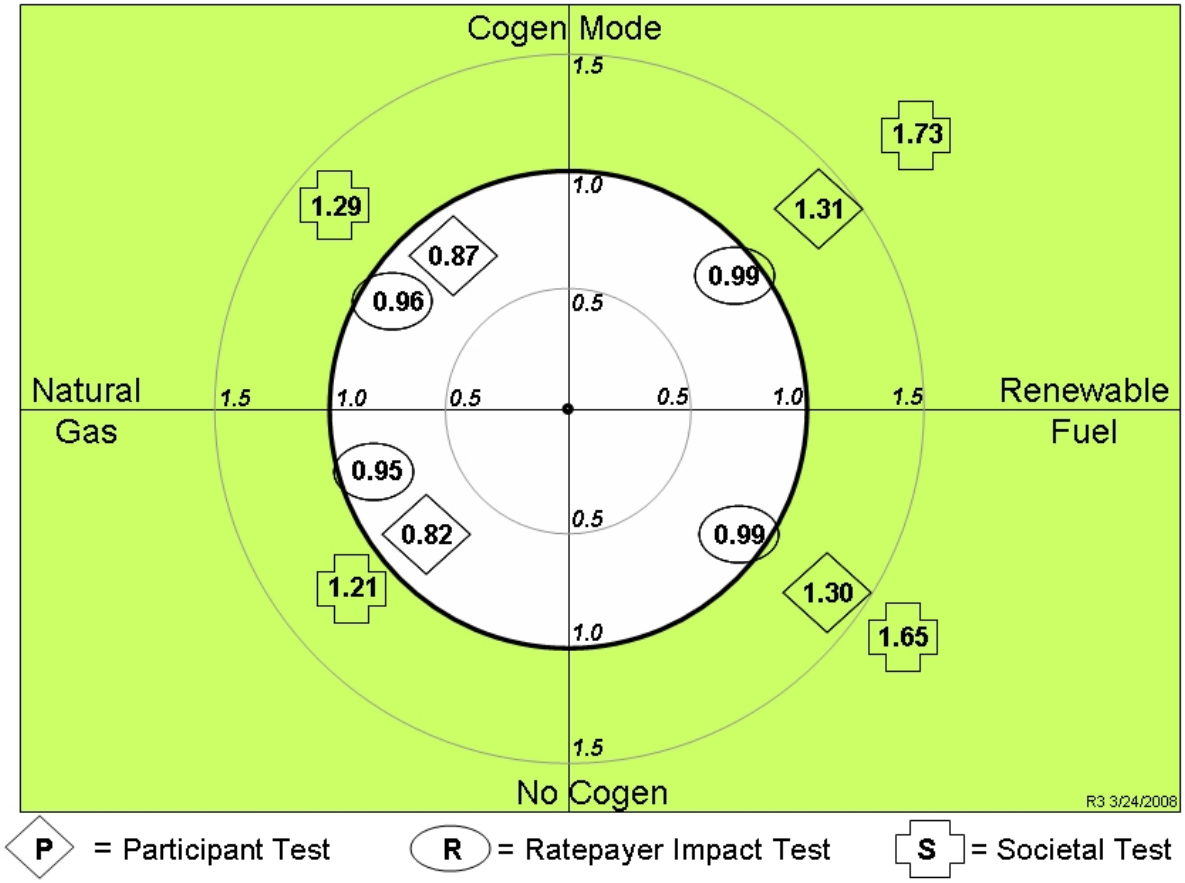
Waterfall Benefits Incorporated into Full Benefit-Cost Analysis



- Traditional California Public Utilities Commission ("CPUC") benefit-cost analysis tests include only transparent, market-traded monetary values
  - Participant Test
  - Ratepayer Impact Measure ("RIM") Test
  - Societal Test
- Externalities (+/-), which may be significant, are largely ignored due to quantification difficulties
  - Many waterfall benefits implicitly valued at zero
- Extended traditional benefit-cost analysis by including waterfall benefits in Societal Test

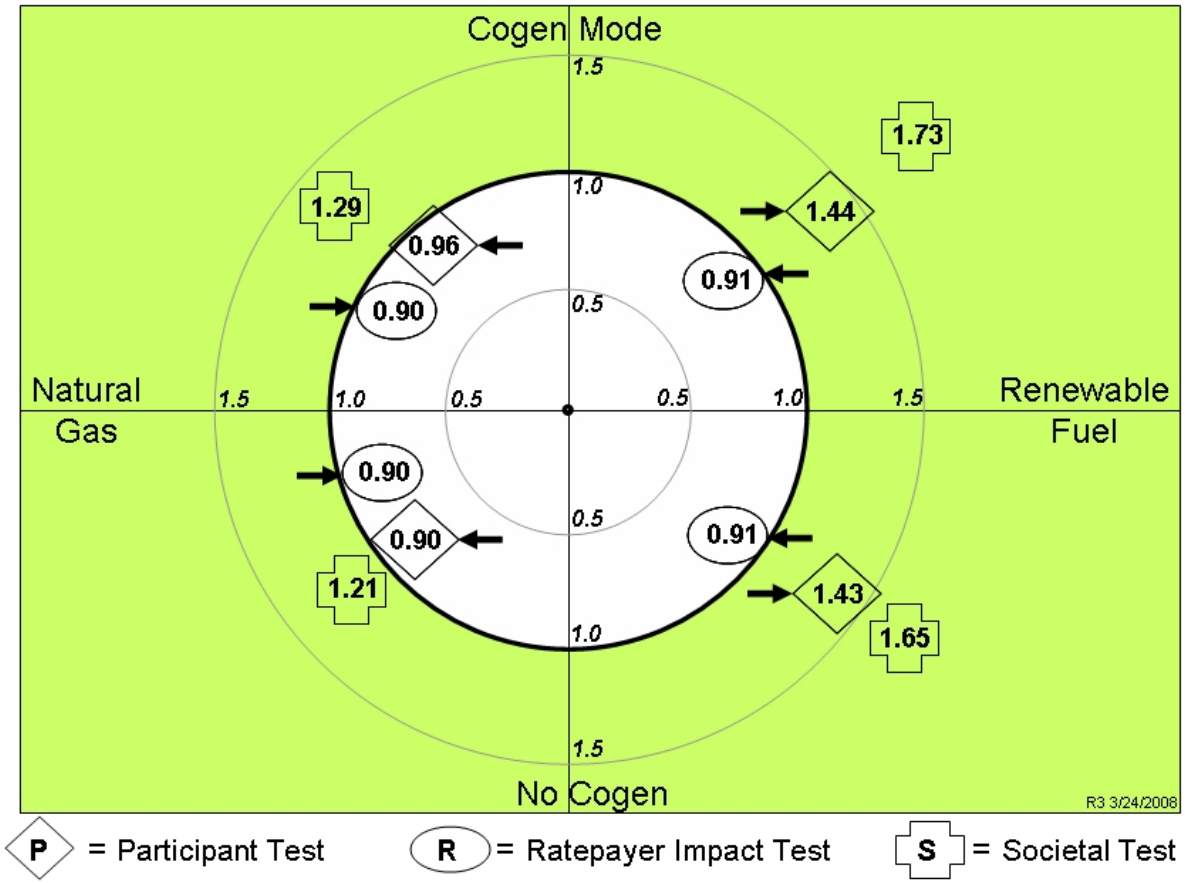
Benefit:Cost Analysis Supports Self-Generation Incentive Program

Benefit:Cost Ratios for Fuel Cell Baseload Electricity Generation in California, without SGIP Funding

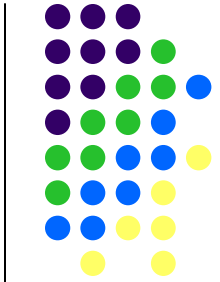


SGIP Incentives Move Fuel Cells Toward Cost-Effectiveness

Benefit:Cost Ratios for Fuel Cell Baseload Electricity Generation in California, with SGIP Funding **($2,500/kW, up to 1 MW)**

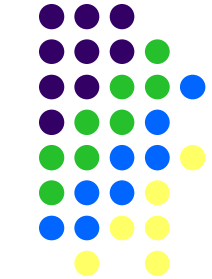


CPUC Cost-Effectiveness ≠ ARB Cost-Effectiveness



- Lesson learned: *Clarify definitions at the outset!*
- CPUC cost-effectiveness depends on perspective of the selected test
- ARB cost-effectiveness focus is specifically on cost per unit of avoided emissions
  - Traditional cost-effectiveness = Cost of emissions reduction measure / quantity of avoided emissions
  - Head-to-head technology comparison expanded application of the cost-effectiveness concept

Fuel Cells Can Avoid Emissions at a Per Unit Cost Savings



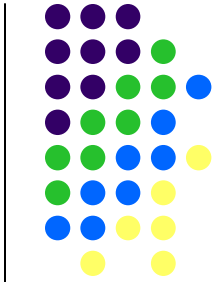
Step 1: Value Incremental CO_2 Emissions; Apply to Technology Cost Difference

Incremental CO2 Market Cost/(Value) ($/MWh)	vs. Simple Turbine	vs. NGCC	vs. Microturbine	vs. Diesel Engine
PAFC	(8.41)	(5.44)	2.20	(17.34)
MCFC	(8.53)	(5.55)	2.08	(17.45)
MCFC/T	(9.89)	(6.92)	0.72	(18.82)
PEMFC	(1.55)	1.43	9.06	(10.47)

Step 2: Calculate Cost-Effectiveness of Fuel Cell Emissions Reduction

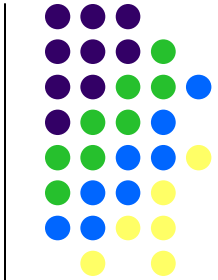
CO/NOx/VOC Cost-Effectiveness (NPV$/ton)	vs. Simple Turbine	vs. NGCC	vs. Microturbine	vs. Diesel Engine
PAFC	(129,769)	(11,030)	No Emissions Reduction	(29,386)
MCFC	(146,249)	10,056	No Emissions Reduction	(28,560)
MCFC/T	(204,509)	6,101	No Emissions Reduction	(29,569)
PEMFC	(72,011)	44,413	No Emissions Reduction	(24,115)

Pushing the Analytical Envelope to Inform the Policy Debate



- Quantification of waterfall benefits
- Inclusion of waterfall benefits in traditional benefit-cost analysis
- Applying ARB cost-effectiveness in head-to-head technology comparison
- Transparency of analysis is a must to ensure credibility and reproducibility of results
  - You may not agree with the underlying assumptions, but you know what they are

Conclusion: Steps to Inform Policy Debate & Implementation



Identify Technology-Specific Attributes

↓

Quantify Technology-Specific Value Proposition

↓

Rank Power Generation Technologies by Value Proposition and Suitability for Achieving Policy Mandates

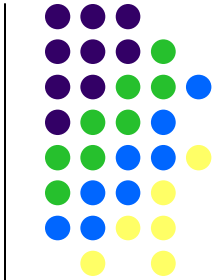
↓

Contribute to the Efficient Achievement of Policy Mandates at Minimum Cost

↓

Enable Evolution of Next Generation Products:
(i) Flexible Fuel Hybrid DG;
(ii) Natural Gas- & Coal-Fired Hybrid Central Plant Generation.

Acknowledgments



- For Providing Data and Financial Support:
  - Altergy Systems
  - FuelCell Energy, Inc.
  - HydroGen LLC
  - Hydrogenics Corporation
  - Idatech, LLC
  - Plug Power Inc.
  - Rolls-Royce Fuel Cell Systems (US) Inc.
  - Siemens Power Generation, Inc.
  - UTC Power Corporation

- For Collaboration and Project Coordination:
  - National Fuel Cell Research Center