Quantifying the Value of Distributed Fuel Cells in California: A Case Study

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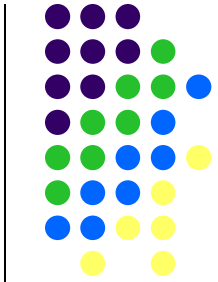
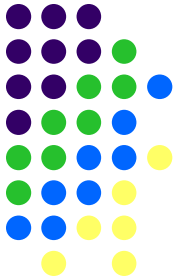
Economic Analysis Can Inform Policy Debate & Implementation



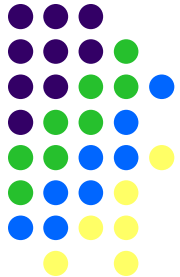
- Energy and environmental policies often target the electricity sector for (i) reduced emissions or (ii) minimum generation/sales from renewable energy.
- Implementation of political and policy mandates should be accomplished as efficiently and cost-effectively as possible.
- Economic analysis can inform 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



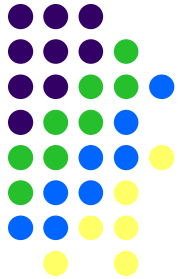
POLITICAL	**L**OCATIONAL	**E**NVIRONMENTAL	**A**NTIDOTAL **Hedge against:**	**S**ECURITY	**E**FFICIENCY **(Market, Technical)**
Impact on local control of resources	Impact on local tax base	"Renewable energy credits" and "green certificates" impact	Fossil fuel price volatility	Impact on likelihood of 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 achieving environmental justice	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 NO_x, SO_x & PM10 emissions levels	Utility power outages	Impact on power quality	Impact on project carrying costs
	Noise level impact	Impact on reducing CO_2 emissions	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 Manufacturers Initiative ("CAFCMI").
  - Original 2008 study updated in 2011
- Initial quantification of PLEASE matrix benefits was expanded to a traditional full benefit-cost analysis.
- Results prompted expanded application 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.

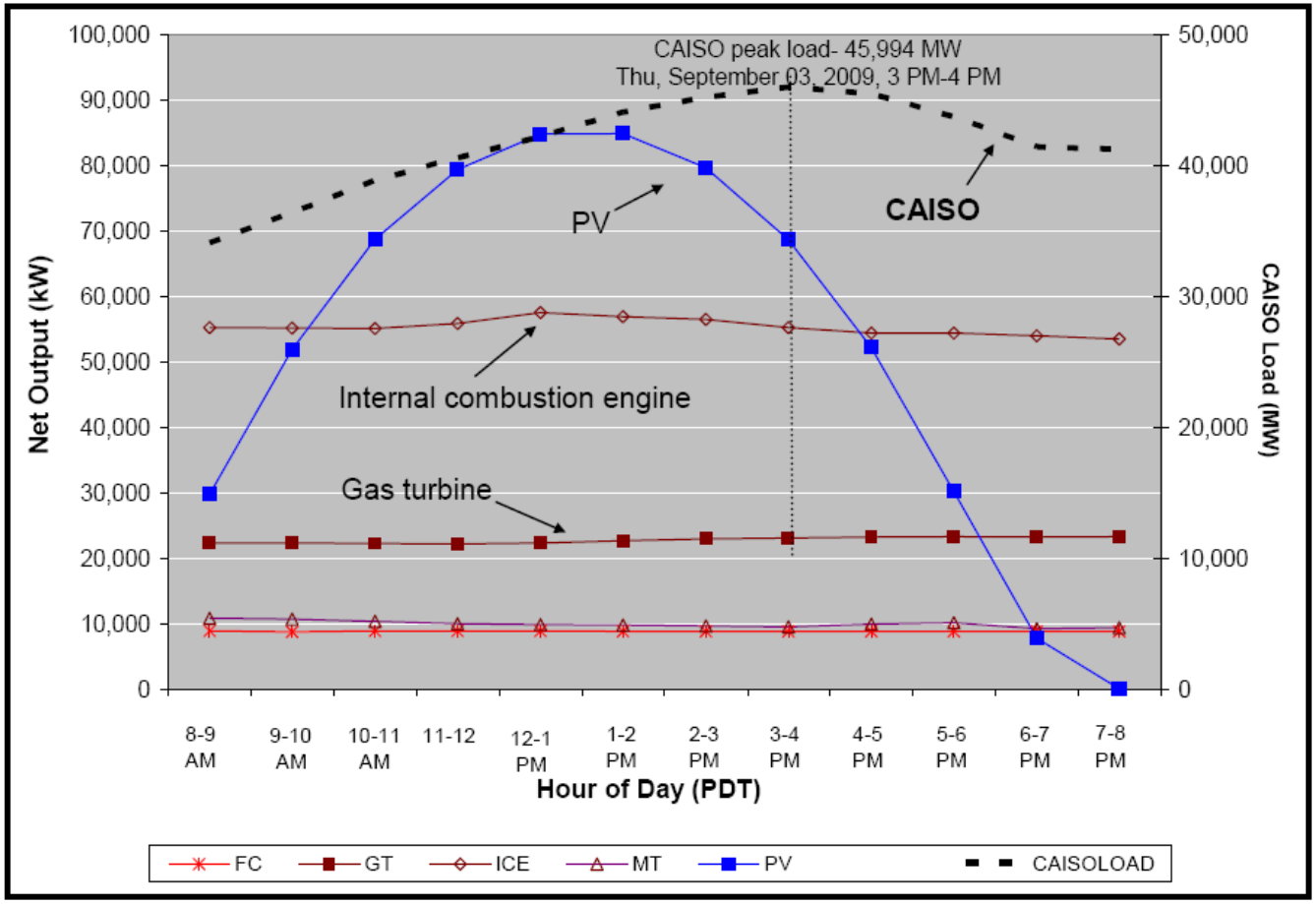
Importance of Market Identification: Application Determines Value



- 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

Fuel Cells Provided Consistent Output on CAISO 2009 Peak Day

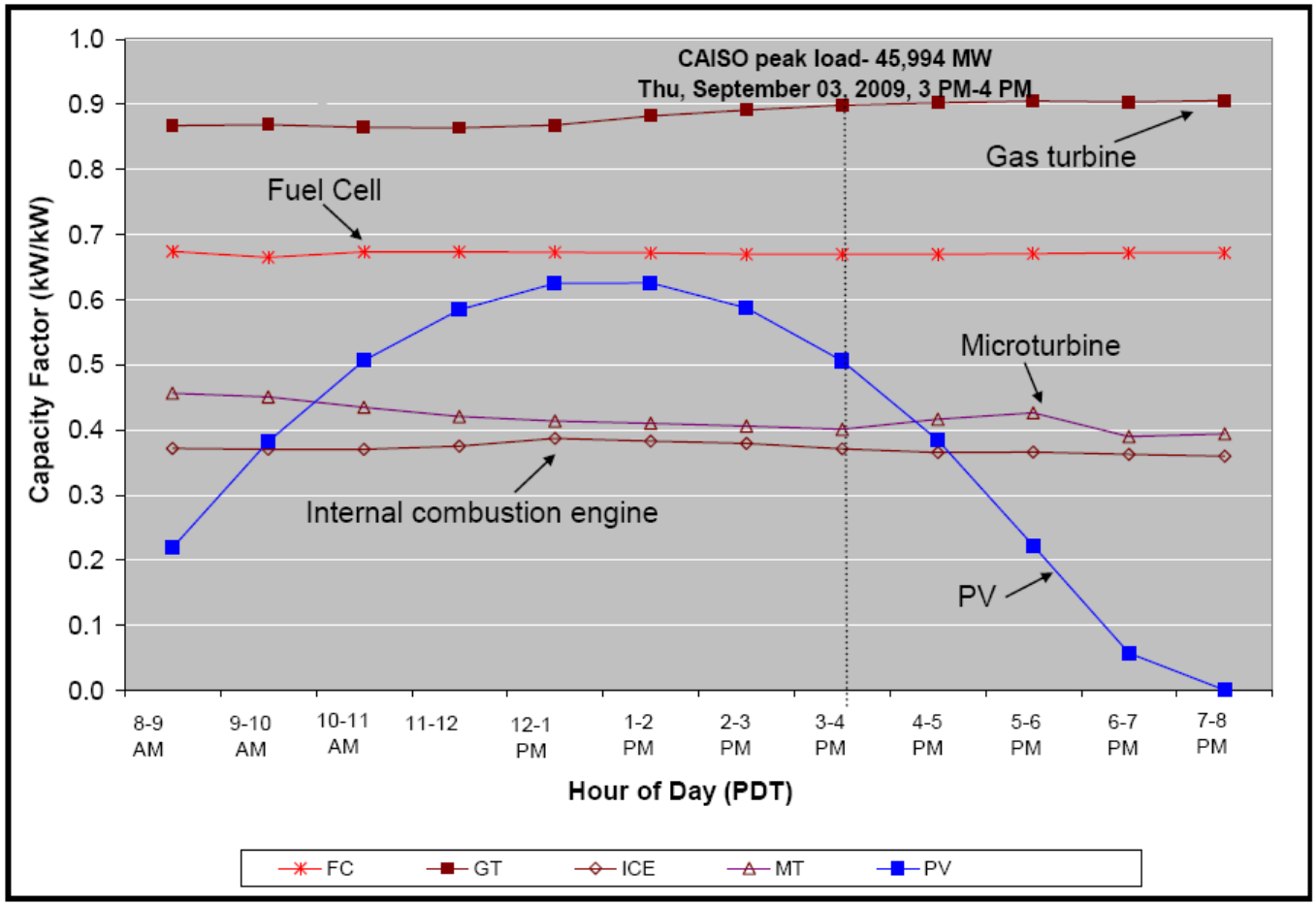
Figure 5-12: SGIP Impact on CAISO 2009 Peak Day



***Source*: Itron, Inc., June 2010, "CPUC Self-Generation Incentive Program Ninth-Year Impact Evaluation, Final Report," p. 5-22.**

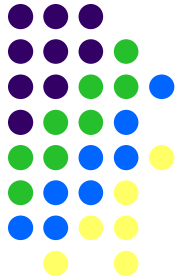
Baseload Fuel Cells Provide Reliable On-Peak Capacity

Figure 5-13: CAISO Peak Day Capacity Factors by Technology (2009)



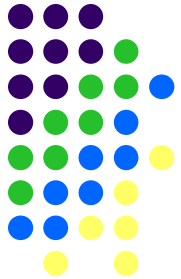
***Source*: Itron, Inc., June 2010, "CPUC Self-Generation Incentive Program Ninth-Year Impact Evaluation, Final Report," p. 5-24.**

Large-Unit Stationary Fuel Cell Value Proposition in California



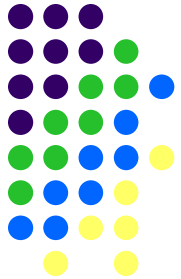
- Large-Scale Distributed Baseload Power Generation
  - Capacity: 350 – 1800 kW “Representative” Fuel Cell
  - Availability: > 90%
  - Fuel Cell Technologies: Molten Carbonate (“MCFC”); Solid Oxide (“SOFC”); Phosphoric Acid (“PAFC”)
  - Combined Heat & Power Mode: 100% of Operations
- Fuel
  - Case 1: 100% Natural Gas
  - Case 2: 75% Renewable, 25% Natural Gas Backup
    - Digester Gas from Waste Water Treatment Plants, Landfill Gas, Other Biogas Sources

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)

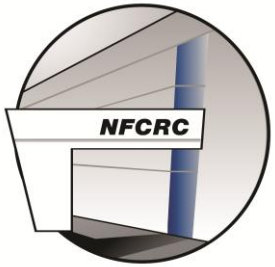


- Emissions- and Health-Related
  - Avoided Emissions – Value Depends on Location of Avoided Generator
  - Value of Health Benefits – Limited to Avoided In-State Emissions
- Job Creation Potential
  - Initially Only Fuel Cell Installation
  - Potential for Future In-State Fuel Cell Manufacturing Capacity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

California Fuel Cell Value

75% Renewable Fuel, 100% CCHP

¢/kWh



	¢/kWh
Value of Avoided Water Use	<0.01 - 0.10
Value of Avoided Fossil Fuel as a Price Hedge*^	0.39 - 1.28
Value of Avoided Central Station Generation Fuel Cost*^ (Efficiency Gain + CHP Credit + 75% Renewable Fuel Use)	2.02 - 12.06
Value of Avoided Generation Variable O&M Cost	<0.01 - 0.44
Value of Avoided Generation Capacity Fixed Operation & Maintenance Cost	0.13 - 0.27
Value of Avoided Generation Capacity Capital Cost (93% Effective Load Carrying Capacity)	0.72 - 2.06

7/15/2011 R1

* Indicates inclusion of Cogen Credit

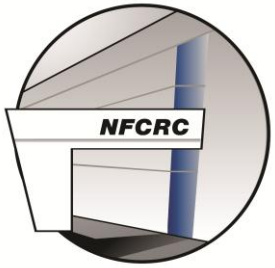
^ Indicates inclusion of Digester Gas Credit

GENERATION-RELATED VALUE: 3.3 – 16.2¢/kWh

¢/kWh

California Fuel Cell Value

75% Renewable Fuel, 100% CCHP



Increased Reliability/Blackout Avoidance/Power Quality	<0.01 - 0.37
Value of Avoided Losses (Generation, T&D, Related Emissions)	0.30 - 0.79
Value of Grid Support	0.04 - 0.26
Value of Avoided Distribution Cost (All Costs Allocated to Peak)	0.06 - 0.95
Value of Avoided Transmission Cost (All Costs Allocated to Peak)	0.01 - 0.23

7/15/2011 R1

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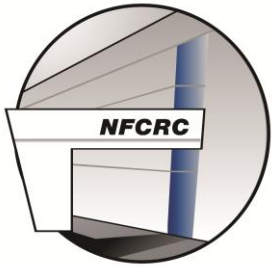
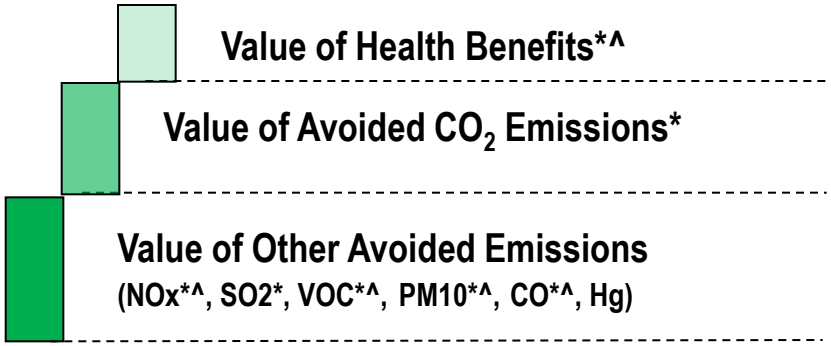
GRID-RELATED VALUE: 0.4 – 2.6¢/kWh

California Fuel Cell Value

75% Renewable Fuel, 100% CCHP

¢/kWh





7/15/2011 R1

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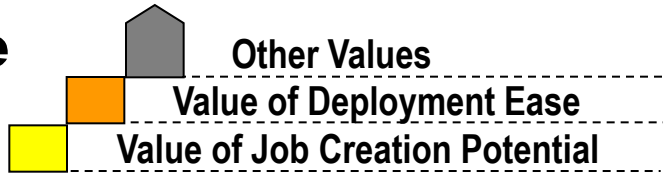
^ Indicates inclusion of Digester Gas Credit

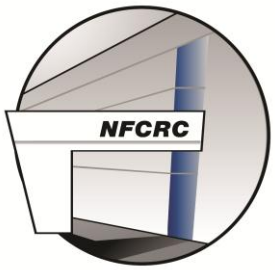
EMISSIONS- AND HEALTH-RELATED VALUE: 3.1 – 11.5¢/kWh

California Fuel Cell Value

75% Renewable Fuel, 100% CCHP



¢/kWh
TBD
Site Specific
0.12 - 0.16



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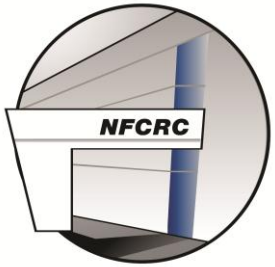
^ Indicates inclusion of Digester Gas Credit

RANGE OF JOB CREATION VALUE: 0.1 – 0.2¢/kWh

California Fuel Cell Value

75% Renewable Fuel, 100% CCHP



	¢/kWh
Other Values	TBD
Value of Deployment Ease	Site Specific
Value of Job Creation Potential	0.12 - 0.16
Value of Health Benefits*^	2.18 - 2.24
Value of Avoided CO_2 Emissions*	0.48 - 3.55
Value of Other Avoided Emissions (NOx*^, SO2*, VOC*^, PM10*^, CO*^, Hg)	0.43 - 5.77
Increased Reliability/Blackout Avoidance/Power Quality	<0.01 - 0.37
Value of Avoided Losses (Generation, T&D, Related Emissions)	0.30 - 0.79
Value of Grid Support	0.04 - 0.26
Value of Avoided Distribution Cost (All Costs Allocated to Peak)	0.06 - 0.95
Value of Avoided Transmission Cost (All Costs Allocated to Peak)	0.01 - 0.23
Value of Avoided Water Use	<0.01 - 0.10
Value of Avoided Fossil Fuel as a Price Hedge*^	0.39 - 1.28
Value of Avoided Central Station Generation Fuel Cost*^ (Efficiency Gain + CHP Credit + 75% Renewable Fuel Use)	2.02 - 12.06
Value of Avoided Generation Variable O&M Cost	<0.01 - 0.44
Value of Avoided Generation Capacity Fixed Operation & Maintenance Cost	0.13 - 0.27
Value of Avoided Generation Capacity Capital Cost (93% Effective Load Carrying Capacity)	0.72 - 2.06

7/15/2011 R1

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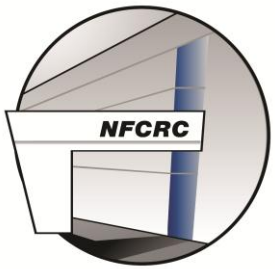
^ Indicates inclusion of Digester Gas Credit

RANGE OF TOTAL FUEL CELL VALUE: 6.9 – 30.5¢/kWh

California Fuel Cell Value

100% Natural Gas, 100% CCHP



	¢/kWh
Other Values	TBD
Value of Deployment Ease	Site Specific
Value of Job Creation Potential	0.13 - 0.17
Value of Health Benefits*	2.18 - 2.22
Value of Avoided CO_2 Emissions*	0.21 - 2.65
Value of Other Avoided Emissions (NOx*, SO2*, VOC*, PM10*, CO*^, Hg)	0.34 - 4.75
Increased Reliability/Blackout Avoidance/Power Quality	<0.01 - 0.40
Value of Avoided Losses (Generation, T&D, Related Emissions)	0.22 - 0.39
Value of Grid Support	0.04 - 0.28
Value of Avoided Distribution Cost (All Costs Allocated to Peak)	0.07 - 1.02
Value of Avoided Transmission Cost (All Costs Allocated to Peak)	0.02 - 0.25
Value of Avoided Water Use	<0.01 - 0.11
Value of Avoided Fossil Fuel as a Price Hedge*	0.37 - 0.90
Value of Avoided Central Station Generation Fuel Cost* (Efficiency Gain + CHP Credit)	1.27 – 7.13
Value of Avoided Generation Variable O&M Cost	<0.01 - 0.47
Value of Avoided Generation Capacity Fixed Operation & Maintenance Cost	0.14 - 0.29
Value of Avoided Generation Capacity Capital Cost (93% Effective Load Carrying Capacity)	0.78 - 2.23

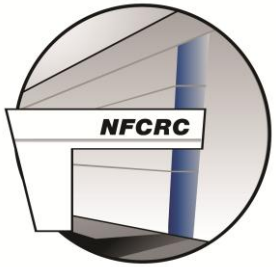
7/15/2011 R1

* Indicates inclusion of Cogen Credit

RANGE OF TOTAL FUEL CELL VALUE: 5.8 – 23.3¢/kWh

California Fuel Cell Value

100% Natural Gas, 75% CCHP



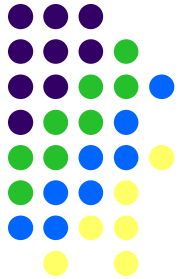
	¢/kWh
Other Values	TBD
Value of Deployment Ease	Site Specific
Value of Job Creation Potential	0.13 - 0.17
Value of Health Benefits*	2.14 - 2.18
Value of Avoided CO_2 Emissions*	0.16 - 2.43
Value of Other Avoided Emissions (NOx*, SO2*, VOC*, PM10*, CO*^, Hg)	0.27 - 3.88
Increased Reliability/Blackout Avoidance/Power Quality	<0.01 - 0.40
Value of Avoided Losses (Generation, T&D, Related Emissions)	0.22 - 0.39
Value of Grid Support	0.04 - 0.28
Value of Avoided Distribution Cost (All Costs Allocated to Peak)	0.07 - 1.02
Value of Avoided Transmission Cost (All Costs Allocated to Peak)	0.02 - 0.25
Value of Avoided Water Use	<0.01 - 0.11
Value of Avoided Fossil Fuel as a Price Hedge*	0.28 - 0.67
Value of Avoided Central Station Generation Fuel Cost* (Efficiency Gain + CHP Credit)	0.95 - 5.35
Value of Avoided Generation Variable O&M Cost	<0.01 - 0.47
Value of Avoided Generation Capacity Fixed Operation & Maintenance Cost	0.14 - 0.29
Value of Avoided Generation Capacity Capital Cost (93% Effective Load Carrying Capacity)	0.78 - 2.23

7/15/2011 R1

* Indicates inclusion of Cogen Credit

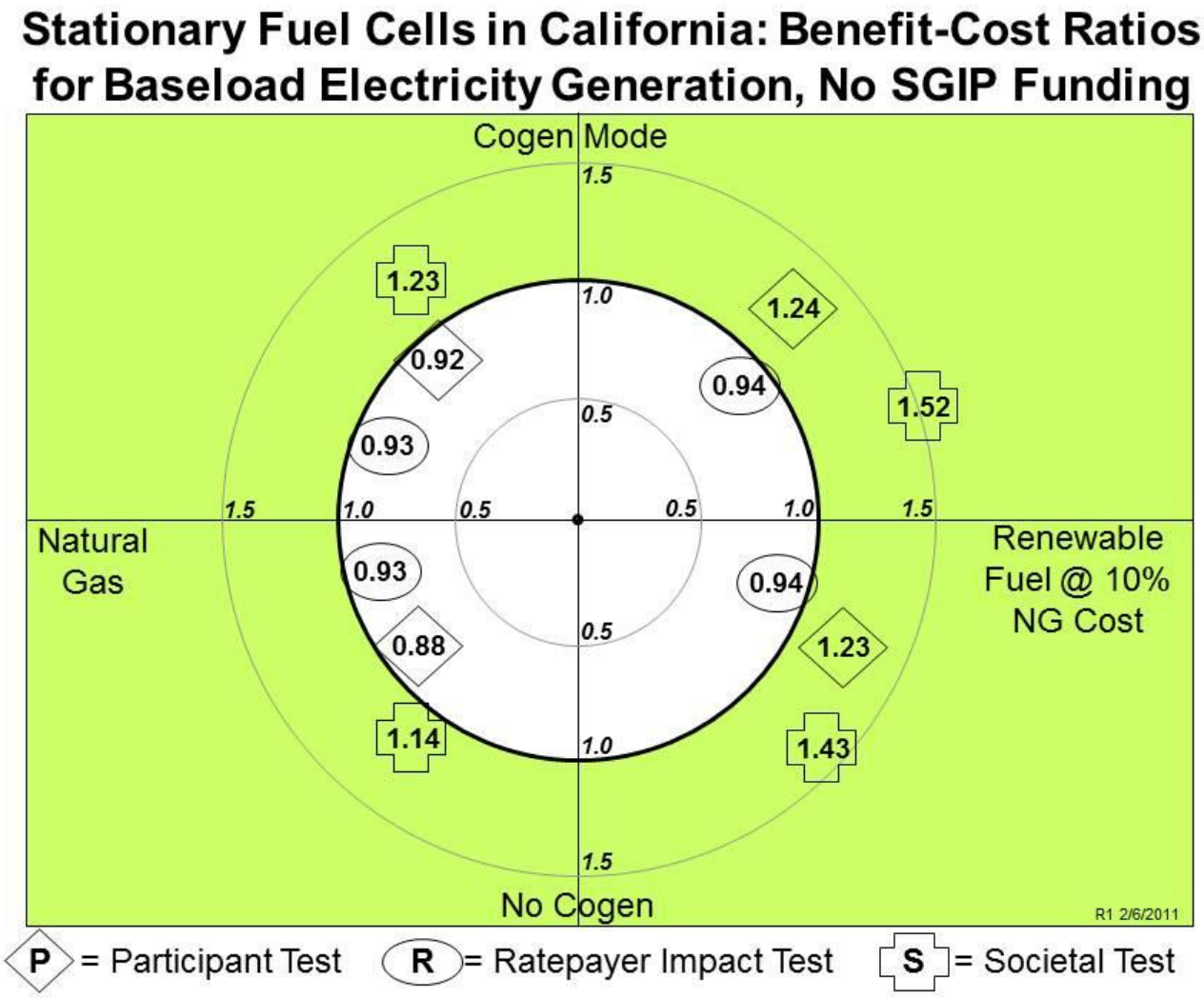
RANGE OF TOTAL FUEL CELL VALUE: 5.2 – 20.1¢/kWh

Pushing the Analytical Envelope to Inform the Policy Debate

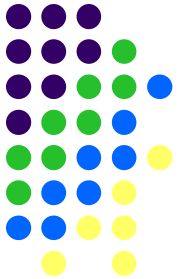


- Traditional California Public Utilities Commission ("CPUC") benefit-cost analysis tests include only transparent, market-traded monetary values
  - Participant Test
  - Ratepayer Impact Measure ("RIM") Test
  - Societal Test
- Externalities (+/-), which may be significant, are largely ignored due to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

Benefit:Cost Analysis Supports Self-Generation Incentive Program

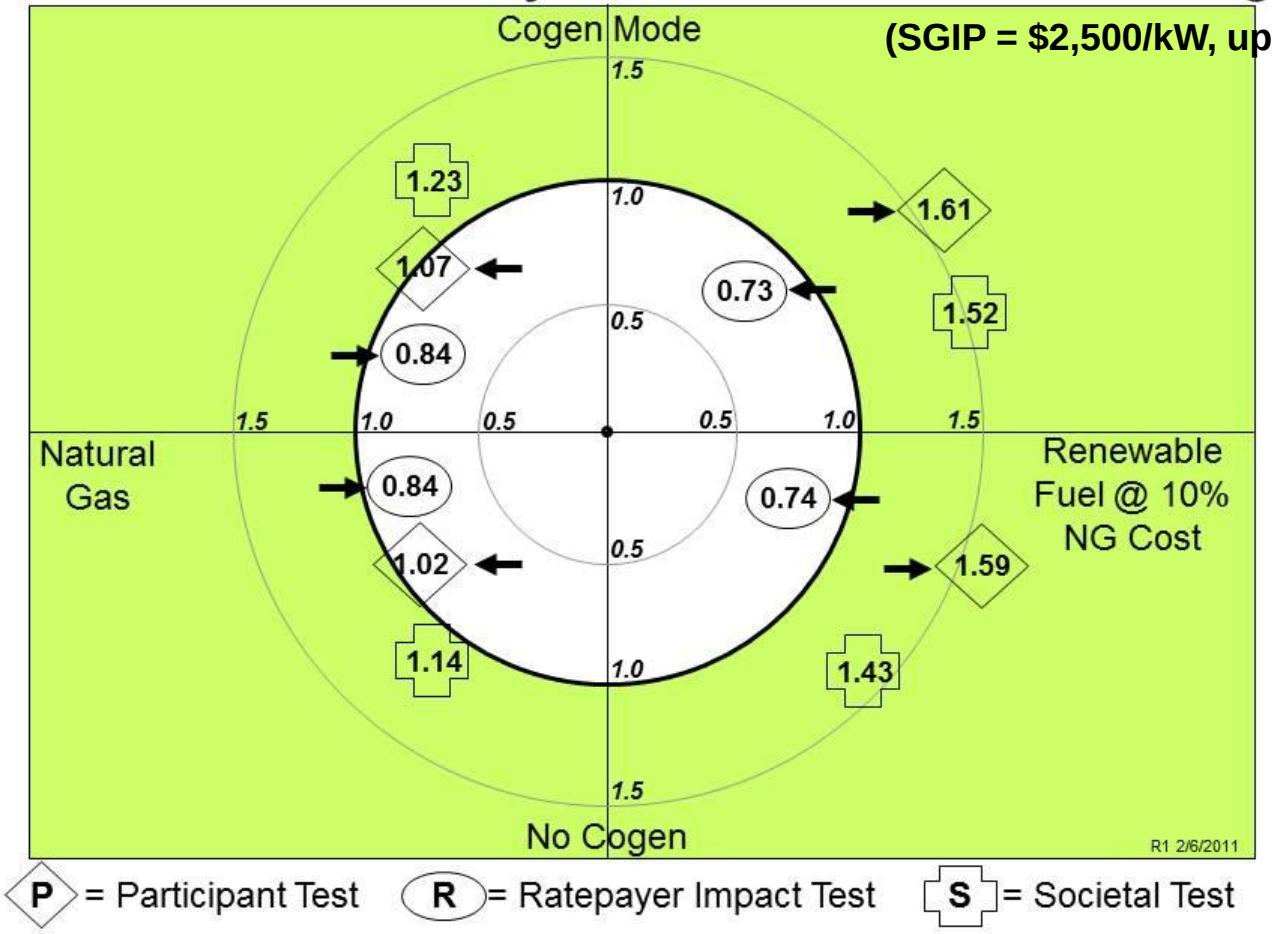


SGIP Incentives Move Fuel Cells Toward Cost-Effectiveness

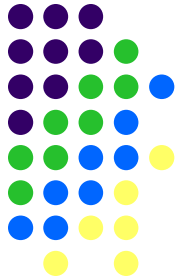


Stationary Fuel Cells in California: Benefit-Cost Ratios for Baseload Electricity Generation, With SGIP Funding

(SGIP = $2,500/kW, up to 1 MW)



Conclusion: Steps to Inform Policy Debate & Implementation



Identify Technology-Specific Attributes

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Quantify Technology-Specific Value Proposition

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

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Contribute to the Efficient Achievement of Policy Mandates at Minimum Cost

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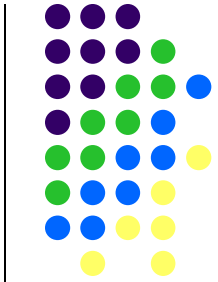
Enable Evolution of Next Generation Products

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