Solar Photovoltaics and Fuel Cells: Valuing the Contributioin of Distributed Energy Resources to the State of California, U.S.A.

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Traditional Economic Analysis Limits Value Proposition

- Only benefits and costs with monetary values based on market exchange are included
- Externalities (+/-), which may be significant, are largely ignored
  - Quantification difficult and contentious
- Intuitively valuable attributes of distributed energy resources ("DER") implicitly value at zero
  - Health benefits associated with reduced emissions
  - Ability to add capacity in small chunks to meet incremental load

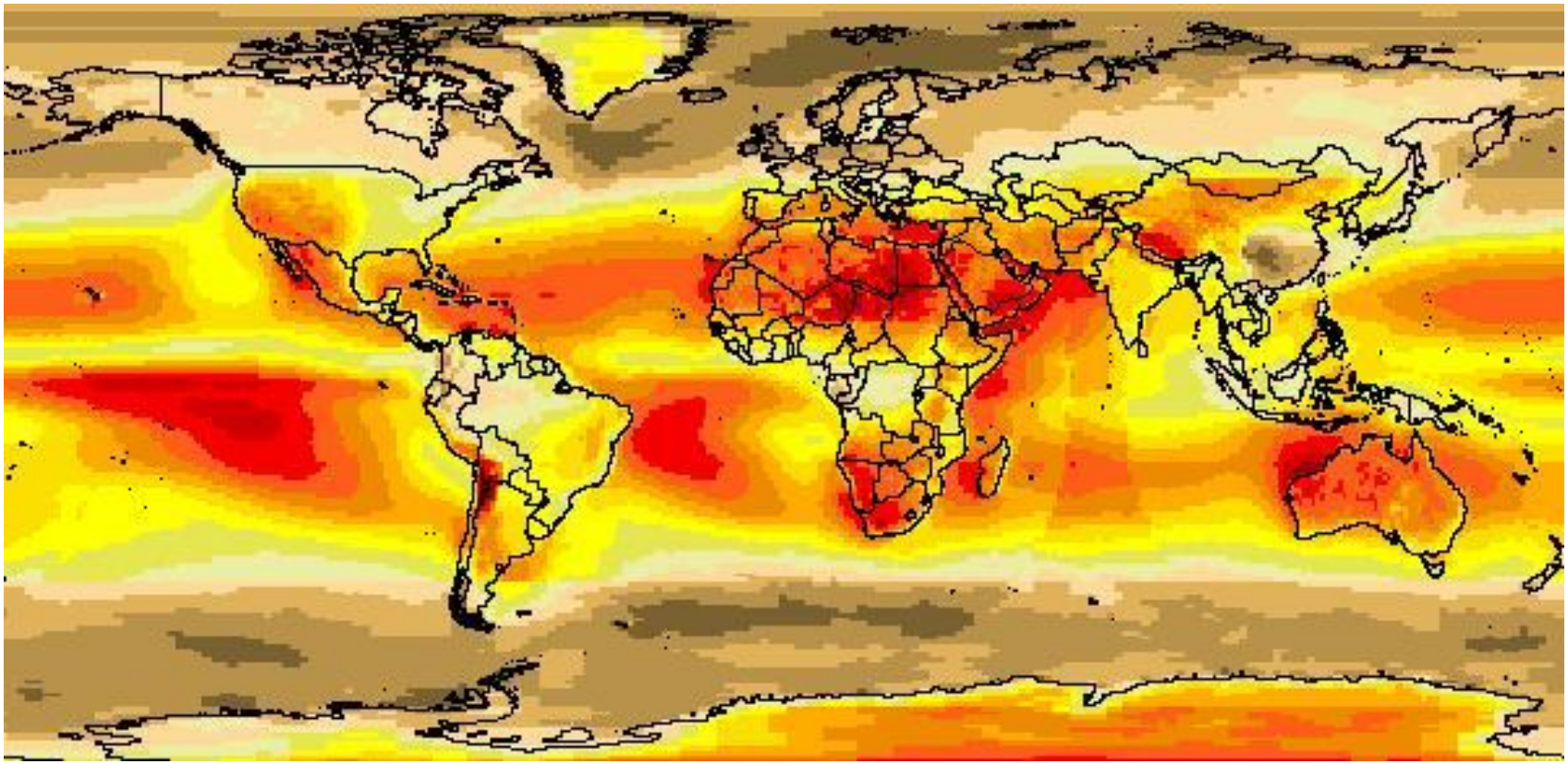
PLEASE Matrix: Valuable DER Attributes Often Not Quantified

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			

Unique Attributes = Technology-Specific Value Proposition

- Solar Photovoltaics ("PV") – Distributed on-peak power, no fossil fuel, no emissions, no noise, modular; weather-dependent, visual impact
- Fuel Cells – High electrical efficiency, 24/7 distributed power, cogeneration potential, low noise, modular; fossil or renewable fuel
- Wind Farms – Significant remote intermittent power, no fossil fuel, no emissions; visual and avian impact
- Hydro – Pumped storage enables price arbitrage, no fossil fuel; precipitation dependent, fish impact

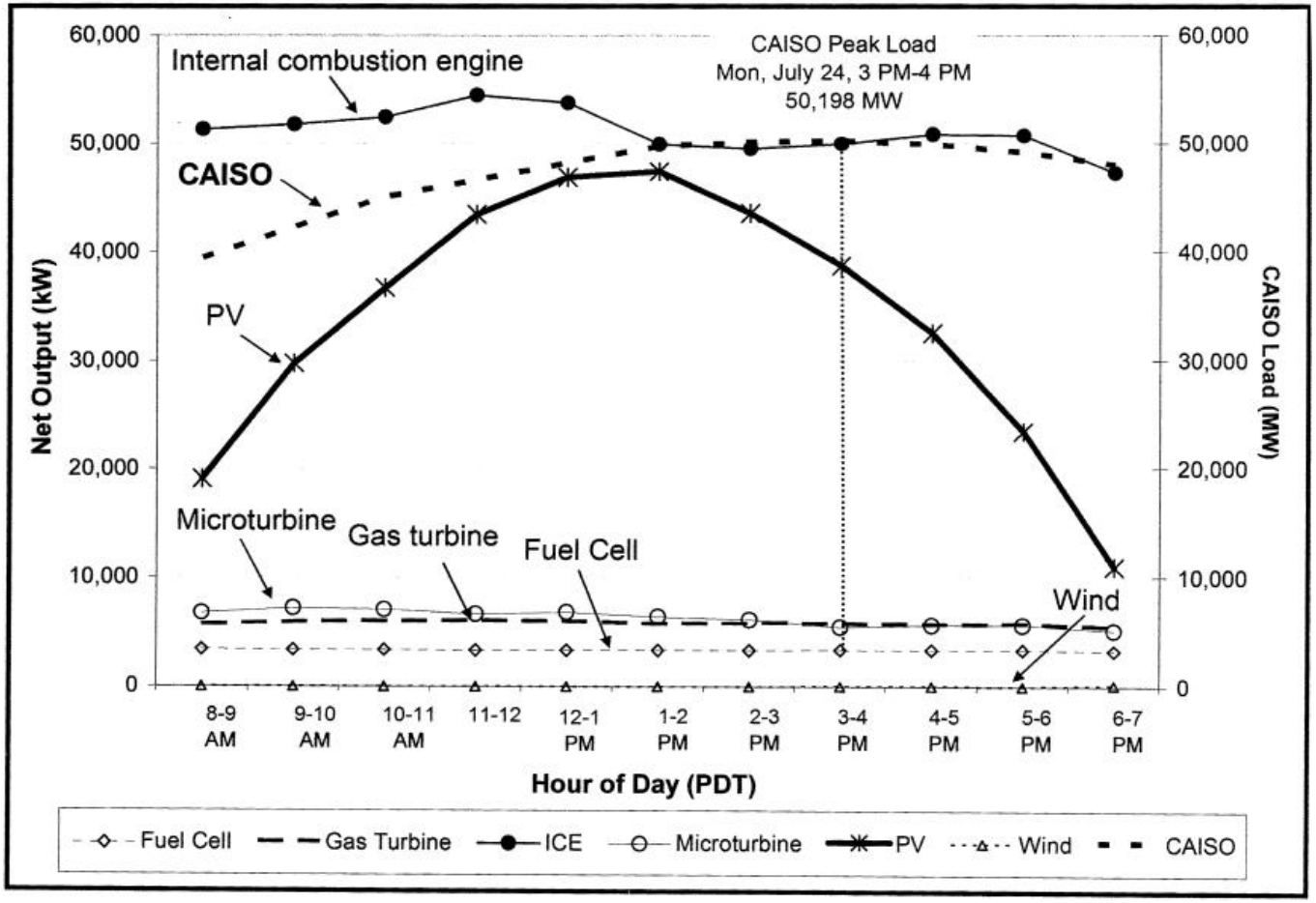
Solar PV: Value Proposition Varies Across the Globe



Source: United Nations Environment Programme, Solar and Wind Resource Assessment, http://na.unep.net/swera_ims/map/.

Technology-Specific Contribution to CAISO On-Peak Capacity: 2006

Figure 1-5: SGIP Project Impacts on 2006 System Peak Technology



Source: Itron, *CPUC Self-Generation Incentive Program Sixth Year Impact Evaluation Draft Report*, July 31, 2007.

Comparison of Solar PV and Fuel Cell Characteristics

	Solar PV	**Fuel Cells**
Capacity	3 kW+	300 kW+
Availability	20%; Peaking	91%; Baseload
Fuel	Sunlight	Natural Gas; Renewable Fuel
Cogeneration?	No	Yes
Avoided Generator	NGCC; NG Peaking Plant	NGCC; Coal-Fired Plant

Solar PV and Fuel Cells in California: Avoided Costs

- Solar PV and Fuel Cell Power Generation Avoid:
  - On-Peak Central Plant Generation
    - Capacity Costs
    - Operating & Maintenance Costs
    - Fuel Costs
    - Related Emissions
  - On-Peak Transmission and Distribution
    - Related Losses
- Avoided Emissions
  - Value Depends on Location of Avoided Generator
  - Allowances not (widely) traded Lack Market Transparency
- Value of Health Benefits
  - Limited to Avoided In-State Emissions

Fuel Cells in California: Additional Value Components

- Additional Fuel Cell Attributes:
  - Natural Gas Savings (& Related Emissions) due to:
    - Higher Fuel Cell Electrical Efficiency vs. Avoided Generator
    - Avoided Boiler Input due to Cogeneration
    - Avoided Flared Gas Emissions due to Use of Digester Gas
  - Increased Power Quality
- Fuel Cells and Solar PV Share:
  - Increased Reliability & Blackout Avoidance
    - Value Increases as Market Penetration of DER Increases
  - Job Creation Potential
    - Initially Installation Labor Only
    - Potential for Additional In-State Manufacturing Capacity

Fuel Cell & Solar PV Value Proposition In California (1 of 4)

	Fuel Cells	Solar PV
Value of Avoided Water Use	0,00 – 0,18	0,00 – 0,06
Value of Avoided Fossil Fuel as a Price Hedge*^	0,24 – 0,64	0,06 – 0,80
Value of Avoided Generation Fuel Cost*^ (PV = Natural Gas; Fuel Cells = Natural Gas or Coal)	0,85 – 4,68	2,26–11,10
Value of Avoided Generation Variable O&M Cost	0,00 – 0,16	0,16 – 0,18
Value of Avoided Generation Capacity Fixed Operation & Maintenance Cost	0,15 – 0,19	0,10 – 0,20
Value of Avoided Generation Capacity Capital Cost (Effective Load Carrying Capacity: PV = 65%; Fuel Cells = 93%)	1,14 – 1,54	1,07 – 1,08
GENERATION-RELATED VALUE (Euro ¢/kWh) :	2,4 – 7,4	3,6 – 13,4

* Includes Cogen Credit (60%)
^ Includes Digester Gas Credit (30%)

1 July 2008 Currency Conversion Rate = 1,50 US $ per 1,0 €

Fuel Cell & Solar PV Value Proposition In California (2 of 4)

	Fuel Cells	Solar PV
Added Reliability/Power Quality/Blackout Avoidance	<0,01 – 0,15	<0,01 – 0,12
Value of Grid Support	0,02 – 0,27	0,06 – 0,32
Value of Avoided Losses (Generation, T&D, Related Emissions)	0,17 – 0,43	0,29 – 0,85
Value of Avoided Distribution Cost (All Costs Allocated to Peak)	0,04 – 0,65	0,13 – 2,06
Value of Avoided Transmission Cost (All Costs Allocated to Peak)	0,01 – 0,16	0,03 – 0,50
GRID-RELATED VALUE (Euro ¢/kWh) :	**0,2 – 1,7**	**0,5 – 3,8**

* Includes Cogen Credit (60%)
^ Includes Digester Gas Credit (30%)

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Fuel Cell & Solar PV Value Proposition In California (3 of 4)

	Fuel Cells	Solar PV
Value of Health Benefits*^	1,56 – 1,69	1,29 – 1,41
Value of Avoided CO_2 Emissions*	0,07 – 1,47	0,27 – 1,22
Value of Other Avoided Emissions (NOx*^, SO2*, VOC*, PM10^, CO*^, Hg)	0,06 – 1,27	0,04 – 0,87
EMISSIONS-RELATED VALUE (Euro ¢/kWh) :	**1,7 – 4,4**	**1,6 – 3,5**

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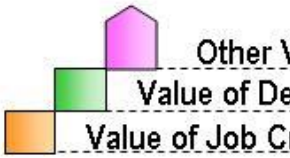
Fuel Cell & Solar PV Value Proposition In California (4 of 4)



	Fuel Cells	Solar PV
Other Values	TBD	
Value of Deployment Ease	Site Specific	
Value of Job Creation Potential	0,07 – 0,17	0,06 – 0,25

* Includes Cogen Credit (60%)
^ Includes Digester Gas Credit (30%)

JOB CREATION VALUE (Euro ¢/kWh) :	0,1 – 0,2	0,1 – 0,3

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Fuel Cell & Solar PV Value Proposition In California

Americans for Solar Power

	Fuel Cells	Solar PV
Other Values	TBD	
Value of Deployment Ease	Site Specific	
Value of Job Creation Potential	0,07 – 0,17	0,06 – 0,25
Value of Health Benefits*^	1,56 – 1,69	1,29 – 1,41
Value of Avoided CO_2 Emissions*	0,07 – 1,47	0,27 – 1,22
Value of Other Avoided Emissions (NOx*^, SO2*, VOC*, PM10^, CO*^, Hg)	0,06 – 1,27	0,04 – 0,87
Added Reliability/Power Quality/Blackout Avoidance	<0,01 – 0,15	<0,01 – 0,12
Value of Grid Support	0,02 – 0,27	0,06 – 0,32
Value of Avoided Losses (Generation, T&D, Related Emissions)	0,17 – 0,43	0,29 – 0,85
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Value of Avoided Generation Capacity Capital Cost (Effective Load Carrying Capacity: PV = 65%; Fuel Cells = 93%)	1,14 – 1,54	1,08 – 1,08
RANGE OF TOTAL VALUE (Euro ¢/kWh) :	**4,4 – 13,7**	**5,8 – 21,0**

* Includes Cogen Credit (60%)
^ Includes Digester Gas Credit (30%)

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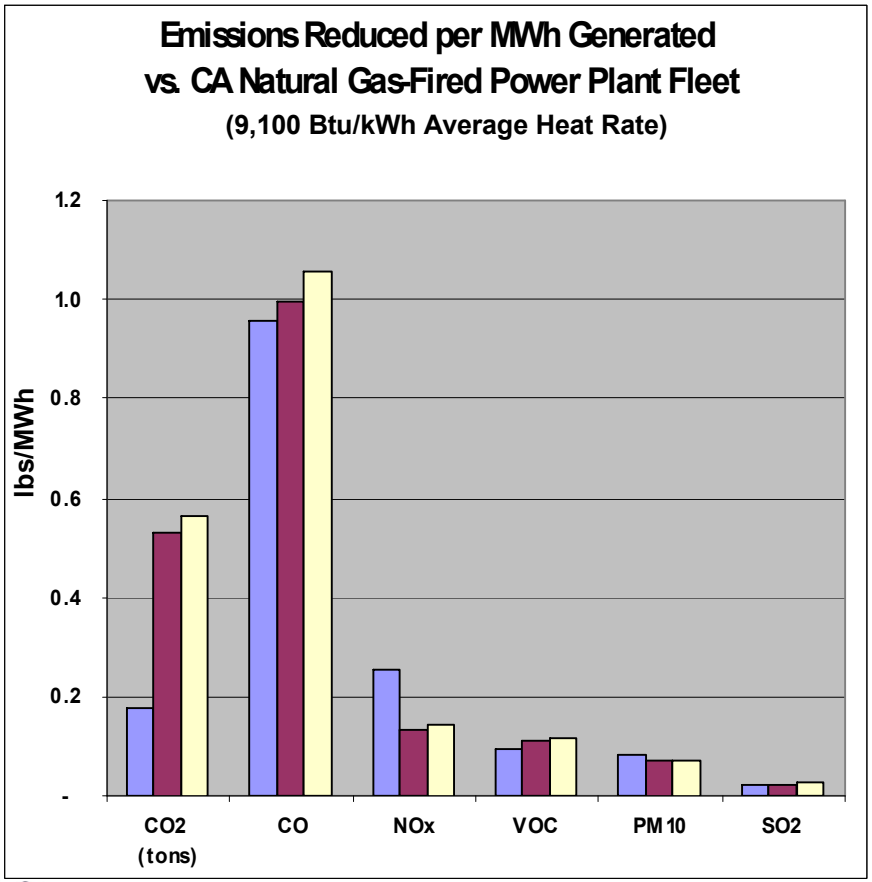
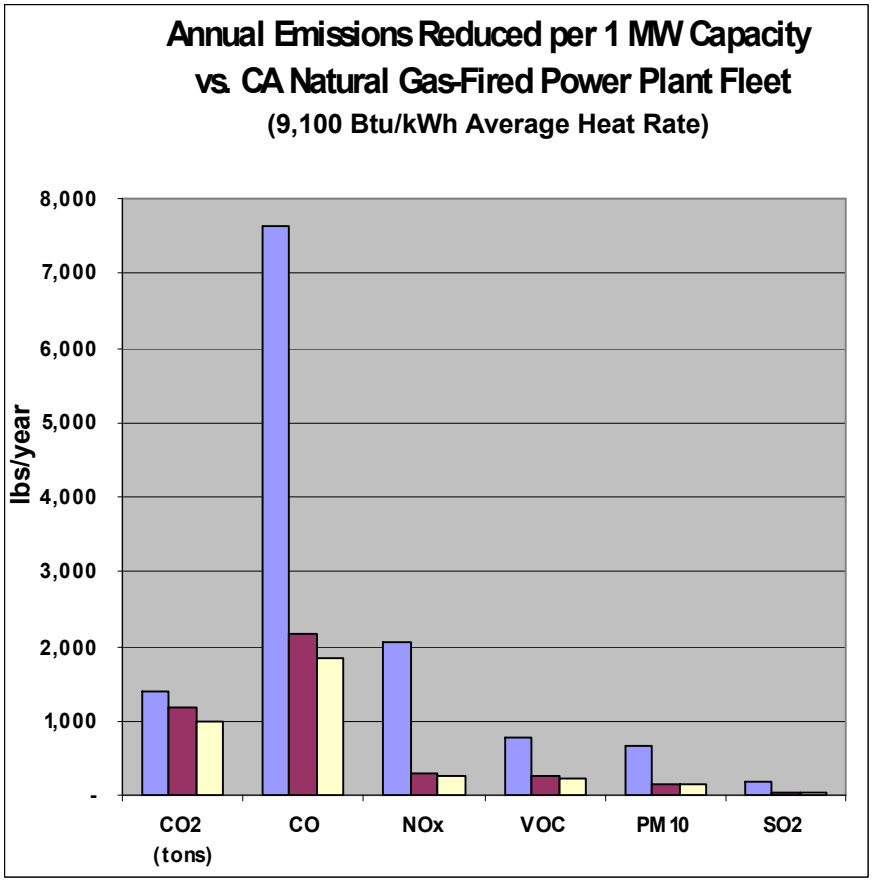
24/7 Fuel Cell Operations = Greater Avoided Emissions than PV & Wind





Fuel Cell @ 91% Capacity Factor; 30% Renewable Fuel; 60% Cogen.

Wind @ 25% Capacity Factor.

Solar PV @ 20% Capacity Factor.

Complementary Technologies: The Best of Both Worlds

- Fuel Cells + PV = Baseload + Peak-Shaving
  - Maximizes the most valuable attributes of each DER technology

- Fuel Cells + Wind = Intermittent wind power could be used to produce “green” hydrogen
  - To fuel the California Hydrogen Highway
  - To fuel distributed hydrogen-based fuel cells
  - To avoid need for transmission lines to bring remotely located wind power to lead centers.