# Value Proposition of Solar Photovoltaics and Fuel Cells in California

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Lori Smith Schell, Ph.D.

Empowered Energy

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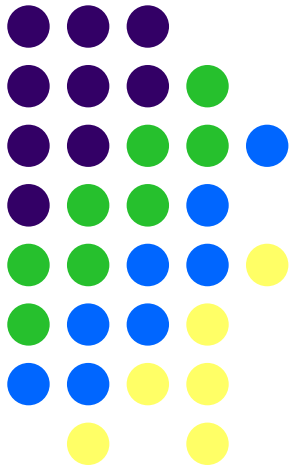
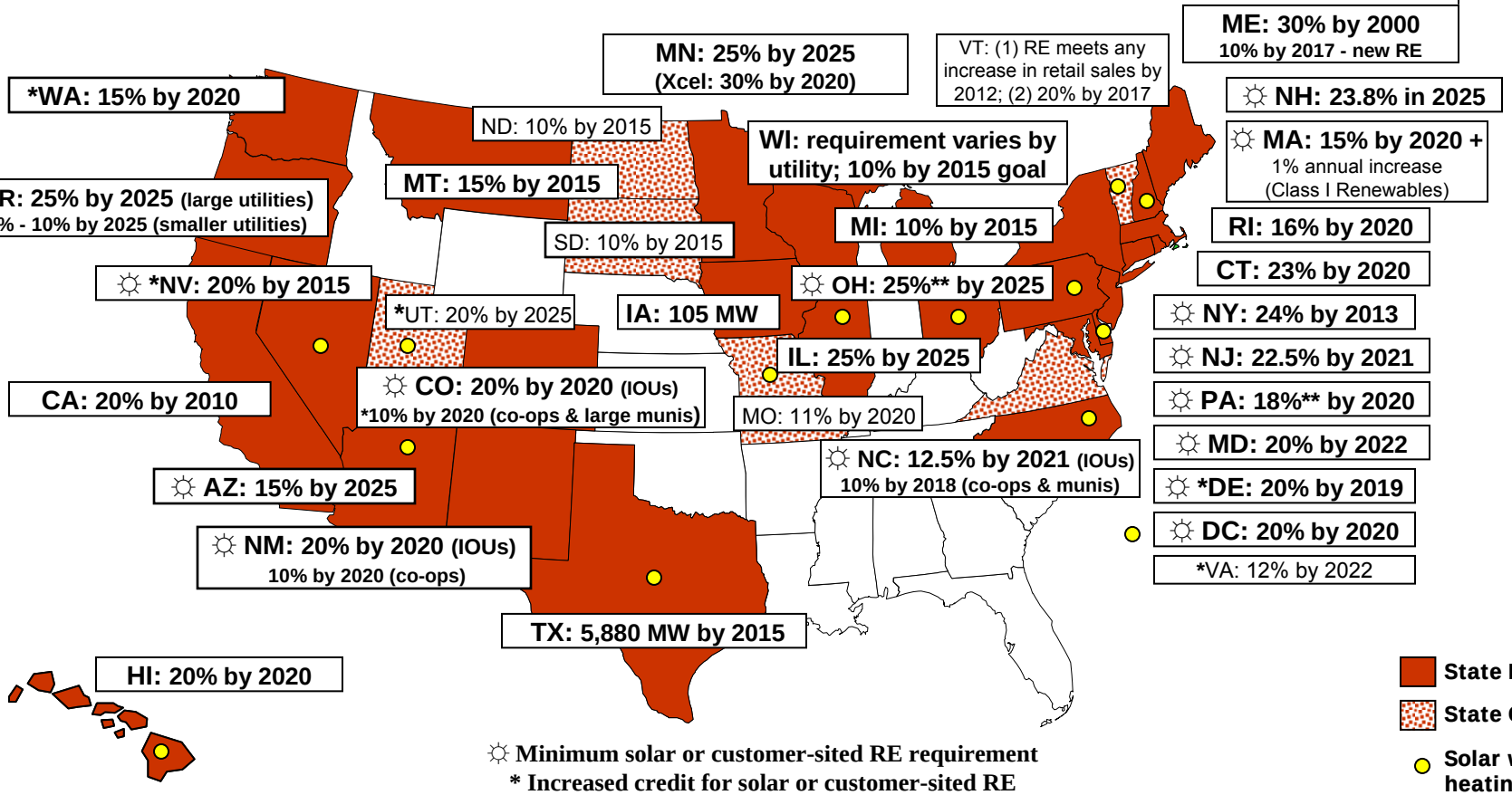


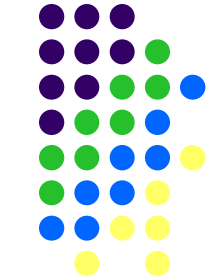
# Renewable Portfolio Standards and State Renewable Goals




☼ Minimum solar or customer-sited RE requirement
* Increased credit for solar or customer-sited RE
**Includes separate tier of non-renewable "alternative" energy resources

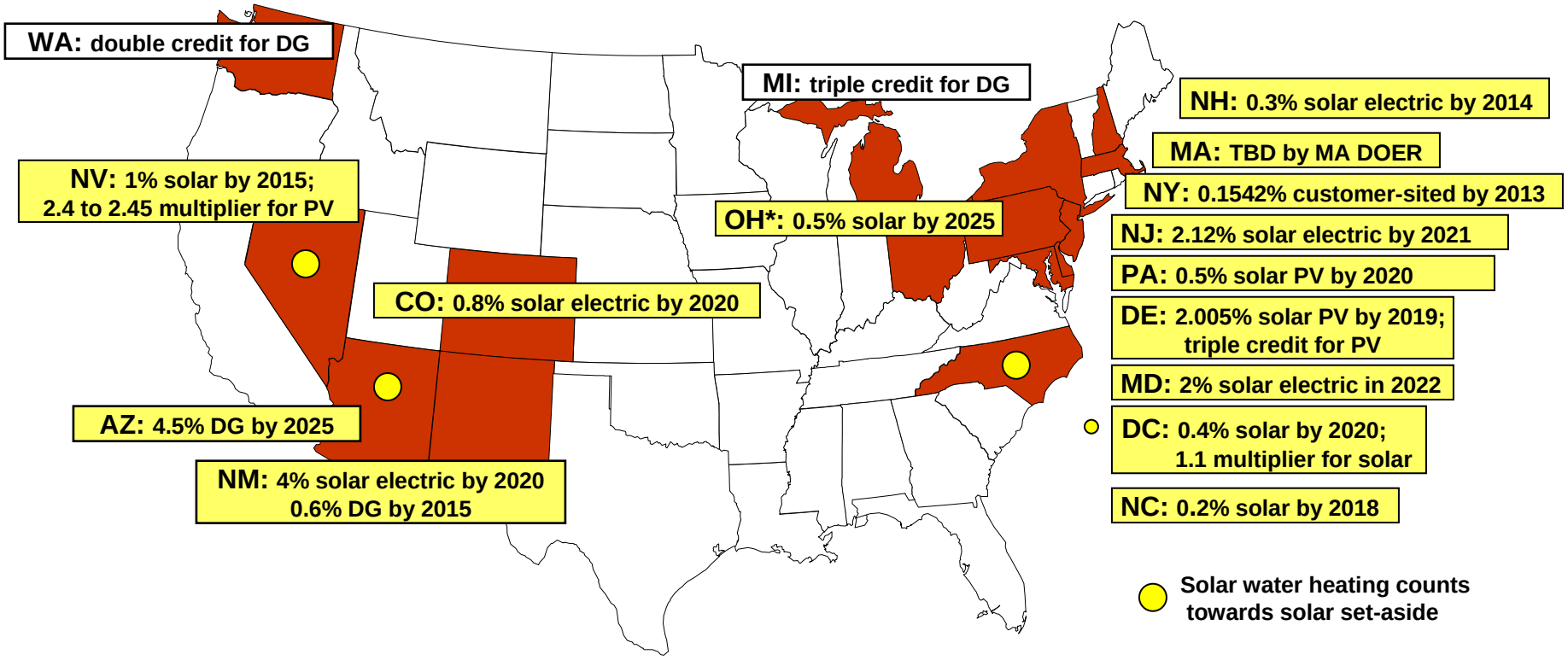
**Source: www.dsireusa.org**

# Samson and Goliath Proved that Bigger is *Not* Always Better



- Central Station Generation
  - Big, bigger, biggest
  - Located far from electricity consumers
  - Requires long-distance transmission lines and local distribution networks
- Distributed Generation ("DG")
  - Small, smaller, smallest
  - Typically located on the electricity consumer's property "behind the meter"
    - Grid-connected (electric company still plays a role)
    - Off-grid or islanded (all electricity self-generated)
  - Avoids transmission and distribution & related losses

# RPS: Solar and DG Set-Asides Ensure Participation

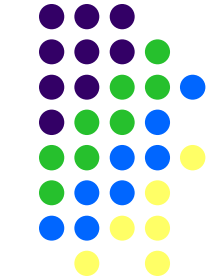



**DG: Distributed Generation**

** It is unclear at this point if solar water heating is eligible for OH's solar carve-out.*

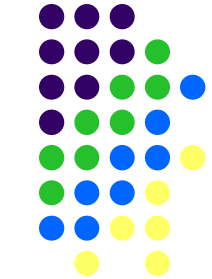
**Source: www.dsireusa.org**

# Traditional Economic Analysis Limits Value Proposition



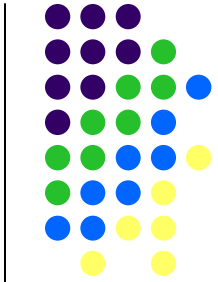
- Only benefits and costs with transparent "$" and "¢" market prices are included
- Externalities (+/-), by definition ***not*** reflected in market prices, may be significant, but are essentially ignored
  - Quantification difficult and contentious
- Intuitively valuable attributes of DG implicitly valued at zero
  - Health benefits associated with reduced emissions
  - Ability to add capacity in small chunks to meet incremental load

# PLEASE Matrix: Valuable DG Attributes Often Not Quantified



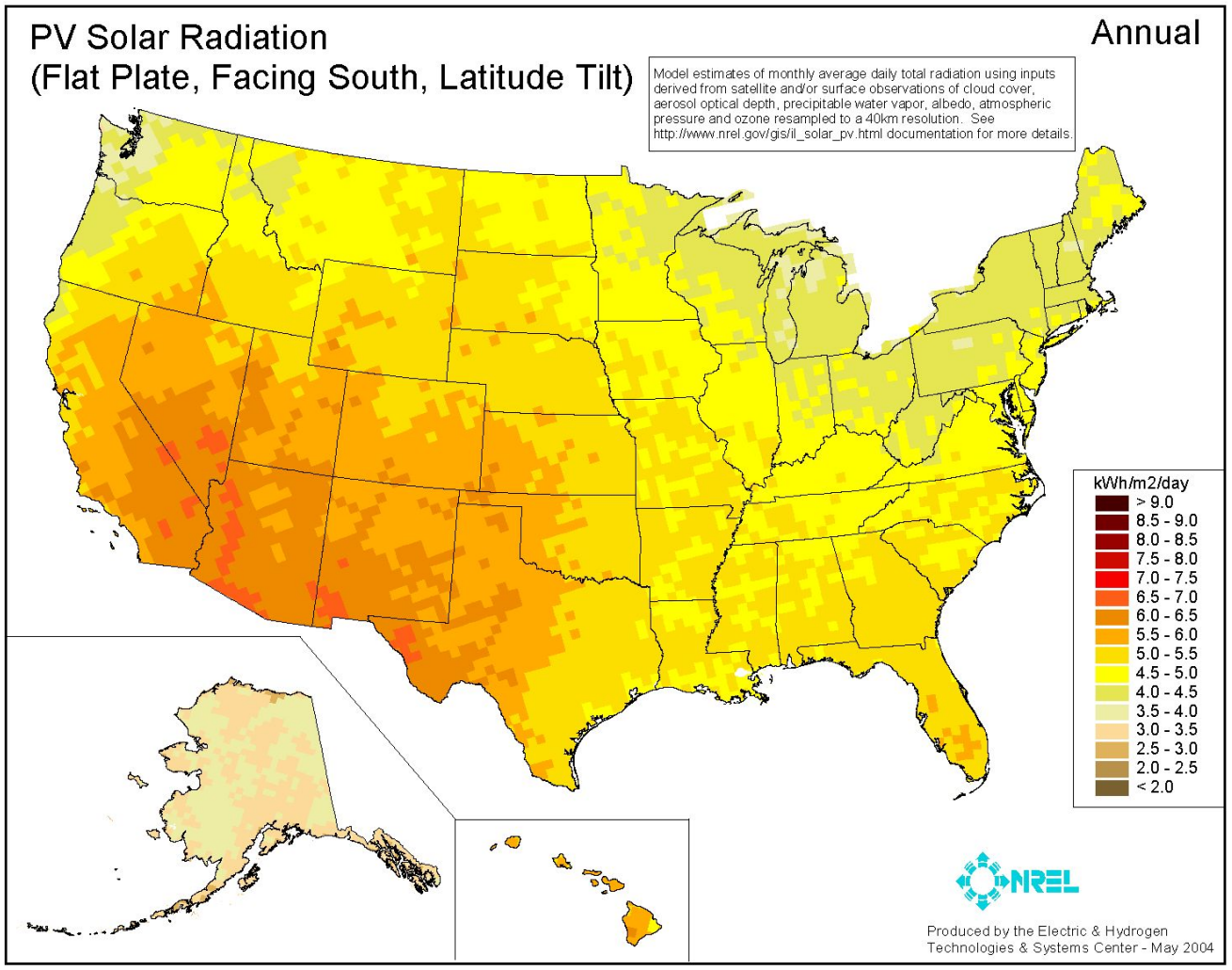
| POLITICAL | LOCATIONAL | ENVIRONMENTAL | ANTIDOTAL<br>Hedge against: | SECURITY | EFFICIENCY<br>(Market, Technical) |
|---|---|---|---|---|---|
| Impact on local control of resources | Impact on local tax base | "Renewable energy credits" and "green certificates" impact | Fossil fuel price volatility | 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



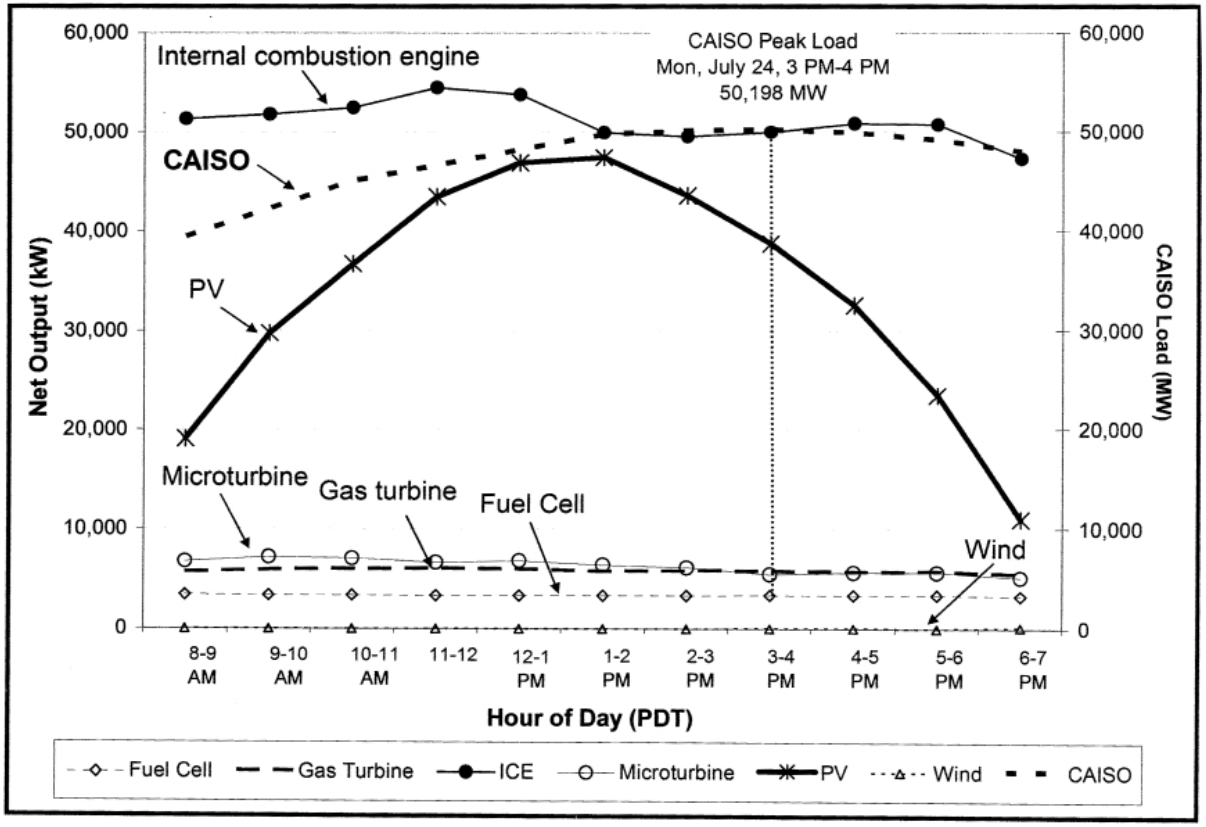
- Solar Photovoltaics (“PV”) – Distributed on-peak power, no fossil fuel, no emissions, no noise, modular; weather-dependent, visual impact
- Fuel Cells – High electrical efficiency, 24/7 distributed power, cogeneration potential, low noise, modular; fossil or renewable fuel
- Wind Farms – Significant but remote intermittent power, requires transmission capacity, 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 Country



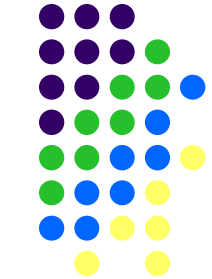
# Technology-Specific Contribution to CAISO On-Peak Capacity: 2006

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



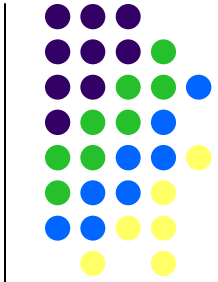

**Source: Itron, *CPUC Self-Generation Incentive Program Sixth Year Impact Evaluation Draft Report*, July 31, 2007.**

# Comparison of Solar PV and Fuel Cell Characteristics



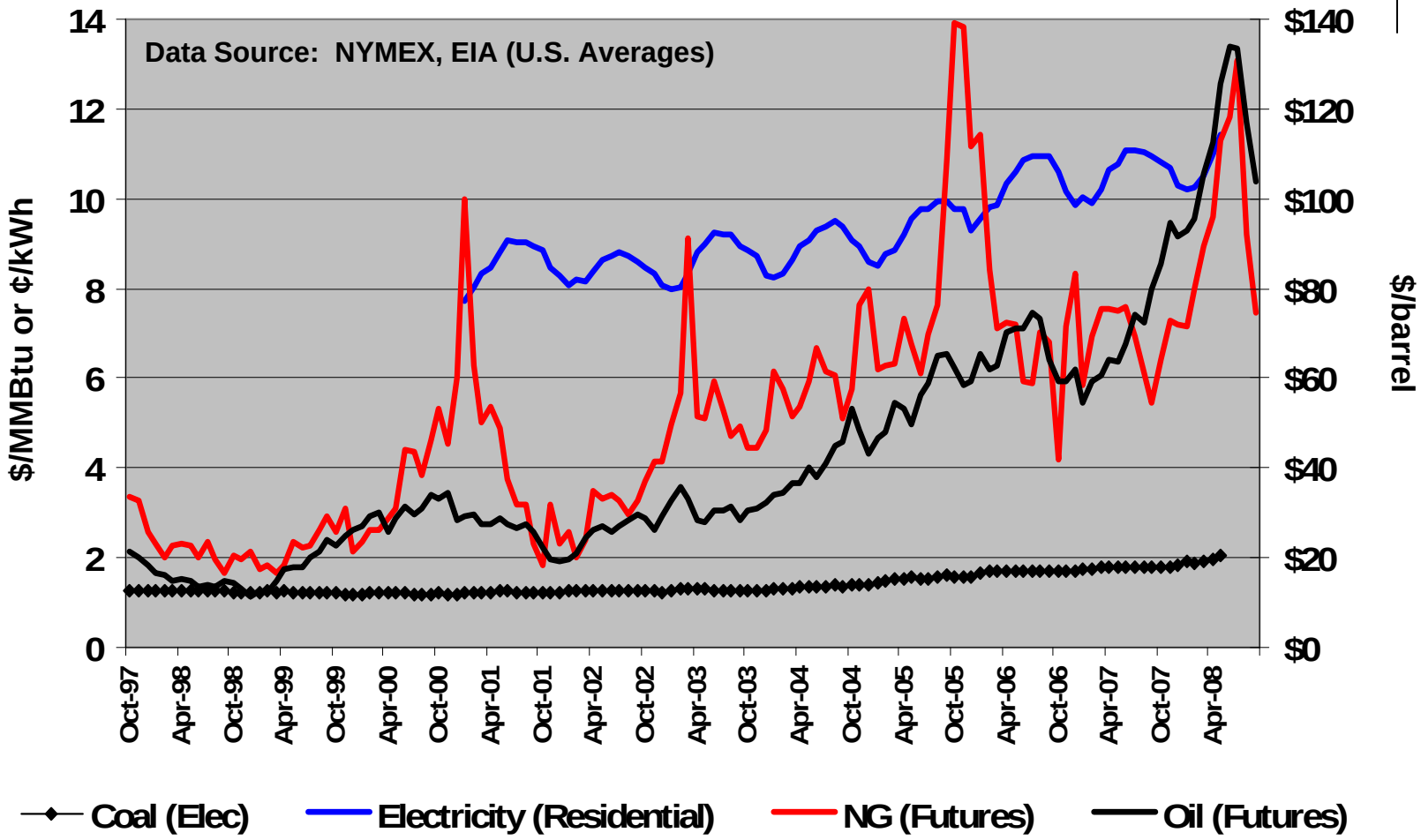
| | Solar PV | Fuel Cells |
|---|---|---|
| **Capacity** | 3 kW+ | 300 kW+ |
| **Availability** | 20%; Peaking | 91%; Baseload |
| **Fuel** | Sunlight | Natural Gas; Renewable Fuel |
| **Cogeneration?** | No | Yes |
| **Avoided Generator** | NGCC; NG Peaking Plant | NGCC; Coal-Fired Plant |

# Solar PV and Fuel Cells in California: Avoided Costs

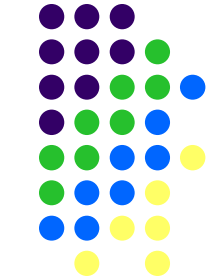


- Solar PV and Fuel Cell Power Generation Avoid:
  - On-Peak Central Plant Generation
    - Capacity Costs
    - Operating & Maintenance Costs
    - Fuel Costs
    - Related Emissions
  - On-Peak Transmission and Distribution
    - Related Losses
- Avoided Emissions
  - Value Depends on Location of Avoided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

# Renewable Energy – Protection From Volatile Fossil Fuel Prices



# 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 DG 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 | ≤0.01 – 0.26 | ≤0.01 – 0.09 |
| Value of Avoided Fossil Fuel as a Price Hedge*^ | 0.36 – 0.96 | 0.09 – 1.21 |
| Value of Avoided Generation Fuel Cost*^ (PV = Natural Gas; Fuel Cells = Natural Gas or Coal) | 1.28 – 7.03 | 3.40–16.64 |
| Value of Avoided Generation Variable O&M Cost | 0.00 – 0.25 | 0.25 – 0.26 |
| Value of Avoided Generation Capacity Fixed Operation & Maintenance Cost | 0.22 – 0.29 | 0.15 – 0.29 |
| Value of Avoided Generation Capacity Capital Cost (Effective Load Carrying Capacity: PV = 65%; Fuel Cells = 93%) | 1.71 – 2.31 | 1.62 – 1.63 |
| **GENERATION-RELATED VALUE (¢/kWh) :** | **3.6 – 11.1** | **5.5 – 20.0** |

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

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



| | Fuel Cells | Solar PV |
|---|---|---|
| Added Reliability/Power Quality/Blackout Avoidance | <0.01 – 0.22 | <0.01 – 0.18 |
| Value of Grid Support | 0.03 – 0.40 | 0.10 – 0.47 |
| Value of Avoided Losses (Generation, T&D, Related Emissions) | 0.26 – 0.64 | 0.43 – 1.27 |
| Value of Avoided Distribution Cost (All Costs Allocated to Peak) | 0.06 – 0.97 | 0.20 – 3.09 |
| Value of Avoided Transmission Cost (All Costs Allocated to Peak) | 0.01 – 0.24 | 0.05 – 0.76 |
| **GRID-RELATED VALUE (¢/kWh) :** | **0.4 – 2.5** | **0.8 – 5.8** |

* 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*^ | 2.34 – 2.54 | 1.94 – 2.12 |
| Value of Avoided $CO_2$ Emissions* | 0.11 – 2.21 | 0.40 – 1.83 |
| Value of Other Avoided Emissions (NOx*^, SO2*, VOC*, PM10^, CO*^, Hg) | 0.09 – 1.90 | 0.06 – 1.31 |
| **EMISSIONS-RELATED VALUE (¢/kWh) :** | **2.5 – 6.6** | **2.4 – 5.3** |

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

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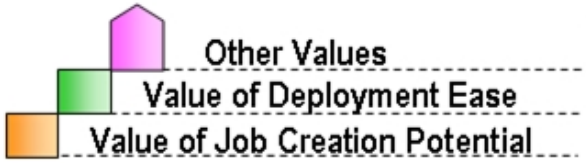
# Fuel Cell & Solar PV Value Proposition In California (4 of 4)






| | Fuel Cells | Solar PV |
|---|---|---|
| Other Values | TBD | |
| Value of Deployment Ease | Site Specific | |
| Value of Job Creation Potential | 0.11 – 0.26 | 0.09 – 0.38 |

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

| JOB CREATION VALUE (¢/kWh) : | 0.1 – 0.3 | 0.1 – 0.4 |
|---|---|---|

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# Fuel Cell & Solar PV Value Proposition In California



| | Fuel Cells | Solar PV |
|---|---|---|
| Other Values | TBD | |
| Value of Deployment Ease | Site Specific | |
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| Value of Avoided Water Use | <0.01 – 0.26 | <0.01 – 0.09 |
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| Value of Avoided Generation Fuel Cost*^ (PV = Natural Gas; Fuel Cells = Natural Gas or Coal) | 1.28 – 7.03 | 3.40–16.64 |
| Value of Avoided Generation Variable O&M Cost | 0.00 – 0.25 | 0.25 – 0.26 |
| Value of Avoided Generation Capacity Fixed Operation & Maintenance Cost | 0.22 – 0.29 | 0.15 – 0.29 |
| Value of Avoided Generation Capacity Capital Cost (Effective Load Carrying Capacity: PV = 65%; Fuel Cells = 93%) | 1.71 – 2.31 | 1.62 – 1.63 |
| **RANGE OF TOTAL VALUE (¢/kWh) :** | **6.6 – 20.5** | **8.8 – 31.5** |

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

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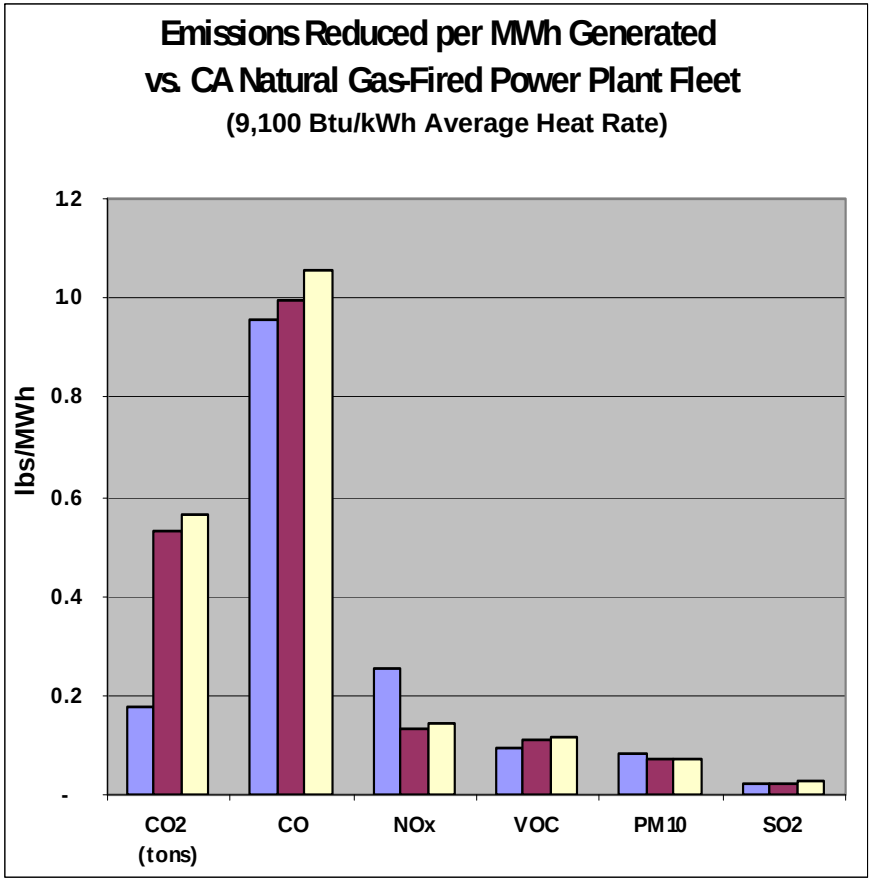
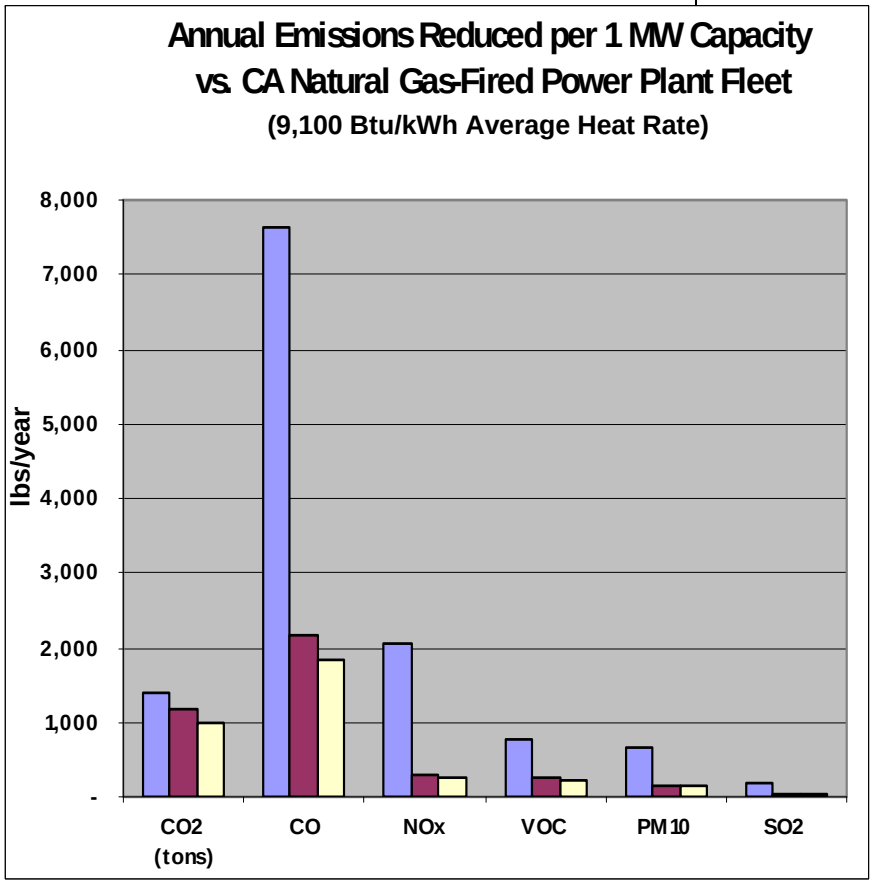
# 24/7 Fuel Cell Operations = Greater Avoided Emissions than PV & Wind



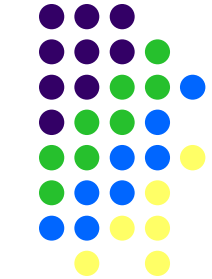




**Fuel Cell @ 91% Capacity Factor; 30% Renewable Fuel; 60% Cogen.**

**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 DG 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.