Nomenclature: kWh = kilowatt hour
MWh = megawatt hour
J = Joule
MJ = Megajoule = 1 x 10^6 Joule
GJ = Gigajoule = 1 x 10^9 Joule
HHV = higher heating value
g = gram
kg = kilogram = 1000 g
kW-year = kilowatt-year
m^3 = cubic meters
tonne = metric ton = 1000 kg

Main Text:

I. INTRODUCTION

This paper provides the results of a step-by-step avoided cost analysis undertaken to determine the value that is provided today by distributed solar photovoltaics ("PV") and stationary fuel cells in the U.S. state of California.[1] Some of the avoided costs are quantified based on observable market prices, and some are quantified based on values derived from a broad-based literature search.

The categories of avoided costs quantified in this paper relate to a number of so-called "distributed value elements." Distributed value elements are attributes of distributed energy resources vis-à-vis a central station electricity generating plant. Distributed value elements are categorized as being Political, Locational, Environmental, Antidotal, Security-related, or Efficiency-related. Taking the first letter of each category, the "PLEASE" matrix is developed to summarize the potential distributed value elements in each category, as shown in Attachment A.[2]

Solar PV is an on-peak distributed energy resource, whose electricity generation is determined by the level of solar insolence. Solar PV produces no generation-related emissions, resulting in significantly reduced emissions when compared to conventional natural gas-fired generating technologies. As a peaking technology, valuing the avoided costs associated with distributed solar PV is based on a comparison of the electricity generating attributes of solar PV with those of a natural gas combined cycle generator and a natural gas-fired peaking generator, these being the avoided central station electricity generating technologies serving peak electricity demand in California.

The stationary fuel cells considered in this analysis operate as a baseload distributed generation technology, generating electricity through an electrochemical process rather than through combustion. It is estimated that 30% of California's stationary fuel cells operate using renewable digester gas from landfills and wastewater treatment plants, thereby avoiding the emissions associated with flaring that digester gas. Sixty percent of California's stationary fuel cells are

1 Funding for the solar PV portion of this analysis was provided by the U.S. Department of Energy for work done on behalf of the Americans for Solar Power ("ASPv"). Funding for the fuel cell portion of the analysis was provided by the California Fuel Cell Manufacturers Initiative ("CAFCMI") and coordinated through the National Fuel Cell Research Center at the University of California-Irvine.

2 The PLEASE Matrix was first presented on April 13, 2005, in testimony before the California Public Utilities Commission on behalf of the Americans for Solar Power by Lori Smith Schell, Ph.D., in proceeding R.04-03-107.

estimated to operate in combined cooling, heating, and power ("CCHP") mode, thereby avoiding boiler fuel (and related emissions) equivalent to the amount of useful waste heat captured. These aspects of California's stationary fuel cell market result in significantly reduced emissions when compared to conventional natural gas- or coal-fired generation, enhancing the potential contribution that such fuel cells can make to achieving California's reduced greenhouse gases emissions goals.

As a baseload technology, valuing the avoided costs associated with the deployment of distributed fuel cells must be based on a comparison with the avoided baseload central station electricity generating technology serving California customers. The avoided baseload technologies considered in this analysis are in-state natural gas combined cycle generators and out-of-state (subcritical) pulverized coal-fired generators that export electricity to California.

Attachment B illustrates the results of quantifying a number of the distributed value elements identified in the "PLEASE" matrix for solar PV and stationary fuel cells in California. In each case, a range of values is provided, with the underlying assumptions discussed in some detail in this paper. Based on this analysis, the "Fuel Cell & Solar PV Value Proposition in California" waterfall chart in Attachment B illustrates that distributed stationary fuel cells in California currently provide 5,1-15,8 Euro cents/kWh of value to ratepayers, while distributed solar PV in California currently provides 6,8-24,2 Euro cents/kWh of value. In both cases, the value proposition depends on the location of the distributed energy resource and on the avoided central station generation technology.[3]

II. DESCRIPTION OF METHODOLOGY

A. Avoided Generation Costs

The avoided generation costs include separate estimates for avoided capacity costs and for avoided energy/generation costs.

Capacity: Fuel cells achieve their highest efficiency when operated as a baseload electricity generating technology. Fuel cells in California have an estimated annual capacity factor of 91% and also have high availability during periods of peak electric demand ([42] at p. 8-15).[4] Solar PV is a peaking technology whose capacity factor depends on orientation, shading, and time of year. An estimated summer capacity factor of approximately 20% has been used in this analysis ([42] at p. 8-14).

Value of Avoided Generation Capacity Capital Cost – The range of the Value of Avoided Generation Capacity Capital Cost is calculated here based on the annualized capacity value of the avoided central station electricity generating technology. Thus, for the stationary fuel cells, the range is determined by a repowered subcritical pulverized coal-fired generator (low end of range) and a natural gas combined cycle generator (high end of range). Repowering costs are used for the coal generator based on the assumption that California's resource planning and reduced greenhouse gas requirements will preclude any new coal-fired generators from being built to serve California's electricity demand. For solar PV, the low end of the range is determined by a natural gas-fired

3 Original values were calculated in US $ per kWh. A conversion rate of 1,3 US $ per 1,0 € has been used throughout this paper to convert monetary values to Euro cents per kWh.

4 Separate monthly capacity factors were reported for the first time for fuel cells operating on natural gas and for fuel cells operating on renewable digester gas in [41] at p. 1-5. The "significantly lower capacity factors of Level 1 (renewable fuel based) fuel cells…attributed to increased operational issues associated with the cleaning of renewable fuels" are expected to be first-year start-up issues that will show significantly improved results in subsequent reports.

peaking plant and the high end of the range is determined by a natural gas combined cycle generator.

The unadjusted avoided capacity cost is the annual capacity charge rate (15% from [29] at p. 9) times the capital cost for the avoided technology. The capital costs used in the analysis are as follows: €592 per kW-yr for repowering a baseload coal plant;[5] €754 per kW-yr for a new combined cycle gas generator;[6] and, €336 per kW-yr for a new natural gas-fired peaking plant.[7] The Avoided Generation Capacity Fixed Operation & Maintenance ("O&M") Cost is an additional avoided capacity cost, with unadjusted values of €15,07/kW-yr for a repowered baseload coal generator, €10,72/kW-yr for a natural gas combined cycle generator and €9,12/kW-yr for a natural gas-fired peaking plant, derived from the same sources as above.

System peak loads are predominantly driven by air conditioning demand on sunny days. The capacity credit (avoided cost) for any distributed generation technology should be set based on the effective load carrying capacity ("ELCC") of that technology at a certain area within the system. The ELCC is the capacity of any electricity generator, whether distributed or conventional, to contribute effectively to a utility's capacity to meet its peak load ([36] at p. 2). Based on the performance of fuel cells participating in the California Public Utilities Commission ("CPUC") Self-Generation Incentive Program ("SGIP"), the average ELCC in California for fuel cells is 93% ([42] at p. 8-15). The average ELCC for solar PV is California varies year-to-year, depending largely on the weather at the time of the system peak; an average ELCC of 65% has been assumed for this analysis. Therefore, a 93% ELCC and a 65% ELCC are used to adjust both the Avoided Generation Capacity Capital Cost and the Avoided Generation Capacity Fixed O&M Cost for fuel cells and solar PV, respectively. ***Note that for any given solar PV or fuel cell project, the capacity-related avoided costs should reflect the localized system average ELCC.***

To recognize the dispersion value of distributed energy resources (*e.g.*, solar PV, fuel cells), the generation-related avoided capacity costs are multiplied by the California electric generation reserve margin of 1,14 that is not applied to distributed generation projects.

To convert €/kW-yr capacity values to Euro cents/kWh, it is necessary to divide the €/kW-yr capacity value by the number of hours per year during which a distributed energy resource is expected to generate electricity; this number is derived using the annual capacity factor for solar PV and fuel cells. Using 20% and 91% for the average annual capacity factor for distributed solar PV and fuel cells, respectively, yields 1.742 hours of expected solar PV generation per year (*i.e.*, 8.760 hours/year x 0,20) and 7.972 hours of expected fuel cell generation per year (*i.e.*, 8.760 hours/year x 0,91).

Energy/Generation*:* The energy should be valued at the avoided real-time cost on at least an hourly basis. Avoided energy/generation costs include the central station electricity generating plant avoided variable O&M costs and the avoided cost of that central station generating plant's fuel.

---

[5] The repowering-related capital and O&M costs used in this analysis are derived from repowering costs used by the U.S. Environmental Protection Agency ("EPA") in its Base Case 2004 Integrated Planning Model ([59] at Exhibit 4-21). EPA's repowering costs were inflated to 2007$ and escalated by the ratio of applicable costs from: (i) Assumptions to the AEO 2007 ([54] at p. 77), and (ii) EPA ([59] at Exhibit 4-9) for a new conventional pulverized coal plant. Application of such a ratio is necessary because no cost estimates for repowering are included in Assumptions to the AEO 2007 [54].

[6] As determined by the California Public Utilities Commission in its 2006 MPR Resolution [19].

[7] *See* [54] at p. 77.

Value of Avoided Generation Variable O&M Cost – The Value of Avoided Generation Variable O&M Cost range of 0-0,19 Euro cents/kWh for fuel cells is determined by a new natural gas combined cycle plant on the low side and by the adjusted EPA repowering costs on the high side; the range of 0,19-0,20 Euro cents/kWh for solar PV is determined by the new natural gas combined cycle plant on the low side and by a new natural gas-fired peaking plant on the high side. The Value of Avoided Water Use is subtracted out as a separate variable that sets an upper limit on the Value of Avoided Generation Variable O&M Cost, as discussed below.

Value of Avoided Generation Fuel Cost – Solar PV requires only sunlight for fuel. Therefore, the Value of Avoided Generation Fuel Cost for solar PV is equal to the cost of natural gas associated with its avoided central station electricity generating technologies. Conversely, most fuel cells today use natural gas as their fuel, albeit operating at a higher electrical efficiency than the average California natural gas-fired generator. Thus, for fuel cells operating on natural gas, the Value of Avoided Generation Fuel Cost in this analysis reflects this electrical efficiency gain. Fuel cells may also be fueled with waste hydrogen from industrial processes or with digester gas from landfills, waste water treatment plants, or other "renewable" sources. Electricity generated using these renewable fuels contributes to the Value of Avoided Generation Fuel Cost in proportion to the renewable share of total installed fuel cell capacity in California, as described below. Similarly, the proportion of fuel cells that capture waste heat that is used to displace steam or hot water production from a natural gas-fired boiler also contributes to the Value of Avoided Generation Fuel Cost, as described below.

The (unadjusted) range of avoided natural gas prices is based on the range of daily settlement prices for prompt-month natural gas futures contract prices on the New York Mercantile Exchange ("NYMEX"). Since the beginning of calendar year 2005, this range has been €3,06-11,21/GJ, for natural gas located at the Henry Hub, onshore Louisiana.[8] The value of the avoided natural gas is converted to Euro cents per kWh by multiplying the NYMEX natural gas price times the following:

- The range of heat rates assumed for the average California avoided natural gas-fired plant (*i.e.*, 8,531-9,599 GJ/MWh) for the fuel cell value proposition.[9]

- The range of heat rates bracketed by: (i) the average California avoided natural gas-fired plant (*i.e.*, 8,531-9,599 GJ/MWh); and, (ii) a new natural gas-fired peaking plant (*i.e.*, 11,023-11,400 GJ/MWh) for the solar PV value proposition.

The range of avoided coal prices is based on the monthly national average cost of coal delivered to electric utilities, as reported on the Federal Energy Regulatory Commission's Form 423. Since the beginning of 2004, this monthly average coal price has ranged from 0,93-1,25 €/GJ [56]. The coal price is converted to Euro cents per kWh by multiplying it times the range of heat rates assumed for the baseload coal generation plant (*i.e.*, 9,329-11,472 GJ/MWh). Note that the coal price is used only in the fuel cell analysis, since out-of-state baseload coal-fired electricity generation is one of the central station generating technologies potentially avoided by fuel cells.

---

8 No cost adjustment has been made to reflect the value of transportation from the Henry Hub to California, since this transportation value (known as the "basis") is highly volatile, varies seasonally, and may be either positive or negative.

9 The average California avoided natural gas-fired plant had a five-year weighted-average heat rate for 2001-2005 that was approximately 21% less efficient than that of a new natural gas combined cycle plant, based on state-specific electricity generation and fuel consumption values reported by EIA [52] [55].

The (unadjusted) Value of Avoided Generation Fuel Cost values calculated using the above methodology yields a range of 0,86-1,43 Euro cents/kWh for a baseload coal plant; 2,61-10,78 Euro cents/kWh for a natural gas combined cycle plant; and, 3,38-12,80 Euro cents/kWh for a natural gas-fired peaking plant.

For solar PV in California, the range of Value of Avoided Generation Fuel Cost is 2,61-12,80 Euro cents/kWh. The low end of the range of Value of Avoided Generation Fuel Cost is set by the low end of the range for the avoided natural gas combined cycle plant; the high end of the range is set by the high end of the range for the avoided natural gas-fired peaking plant.

Assuming that 30% of all installed fuel cell capacity in California uses renewable digester gas instead of natural gas, the Value of Avoided Generation Fuel Cost (attributed only to renewable fuel cells in this analysis) is 30% of the maximum range of 0,86-10,78 Euro cents/kWh, *i.e.*, 0,26-3,23 Euro cents/kWh.[10] The avoided coal price sets the lower end of the range, and the avoided natural gas price for the natural gas combined cycle plant sets the upper end of the range. The Value of Avoided Generation Fuel Cost component for avoided boiler fuel due to fuel cell captured waste heat and CCHP operations adds another 0,72-1,54 Euro cents/kWh (as explained below in Section E). The increased electrical efficiency of fuel cells compared to the avoided natural gas combined cycle plant adds an additional <0.01-0,63 Euro cents/kWh to the Value of Avoided Generation Fuel Cost. The total Value of Avoided Generation Fuel Cost range for distributed fuel cells in California is therefore 0,98-5,40 Euro cents/kWh.

Value of Avoided Fossil Fuel as a Price Hedge – Fossil fuel price volatility can wreck havoc with personal and corporate budgets. To the extent that fossil fuel input is avoided by distributed energy resources, electricity consumers are protected from unpredictable fossil fuel price volatility. Solar PV, therefore, provides a perfect hedge against fossil fuel price volatility for the electricity it generates. Fuel cells using renewable fuel and/or using captured waste heat also provide a hedging mechanism against the fossil fuel price of the avoided central station electricity generating plant ([4] at p. 8).

The Value of Avoided Fossil Fuel as a Price Hedge for distributed solar PV in California is 0,07-0,93 Euro cents/kWh. As was the case for the Value of Avoided Generation Fuel Cost, the Value of Avoided Fossil Fuel as a Price Hedge for distributed fuel cells consists of two components:

- A hedge value of 0,02-0,28 Euro cents/kWh is attributed to the 30% of California fuel cells using renewable fuel.

- An additional Value of Avoided Fossil Fuel as a Price Hedge of 0,26-0,46 Euro cents/kWh, attributed to the 60% of total California fuel cell capacity that captures waste heat for CCHP, thereby avoiding natural gas input to the avoided boiler.

Combined, these two components have a total hedge value range of 0,28-0,74 Euro cents/kWh for distributed fuel cells in California.

B. Avoided Water Use

[10] It is assumed that all power generated fuel cells using such renewable fuel will continue to be used on-site, as is currently the case.

Value of Avoided Water Use – Solar PV consumes no water as it generates electricity. Some fuel cells consume water for the electrochemical reaction that generates electricity and for the water purification required to meet fuel cell input requirements.[11] Other fuel cells either produce a net output of water or use no water during normal operations, and only a nominal amount during startup and shutdown.

The Value of Avoided Water Use attributed to electricity generated by solar PV and by fuel cells is calculated based on avoided water consumption relative to the avoided central station electricity generating technologies for each of these distributed energy resources. The 2006 natural gas combined cycle proxy plant standard defined by the CPUC assumes the use of dry cooling; California Energy Commission ("CEC") data for a similar plant indicates that only 0,08 liters of raw water are required per kWh of generation ([11] at p. 36).[12] A natural gas-fired combustion turbine (peaking) plant uses 0,67 liters of raw water per kWh of generation ([46] at p. 58). Thus, the avoided water use for solar PV ranges from 0,08-0,67 liters per kWh.

Recall that the avoided central station electricity generating technologies for fuel cells in California are a baseload natural gas combined cycle plant and a pulverized coal-fired plant. The existing fleet of baseload coal generators serving California is assumed to use closed recirculating cooling, which requires 4,24 liters of raw water per kWh of generation ([46] at p. 68). These values compare to an estimated range of raw water use per kWh for fuel cells of 0-0,66 liters. The low end of this range indicates that even the minimal 0,08 liters per kWh of water used by the dry-cooled natural gas combined cycle proxy plant may be avoided by fuel cells. At the other extreme, the avoided water use for fuel cells as compared to the baseload coal plant is significant at 3,58 liters per kWh.

Commercial water prices in California are used to calculate the (unadjusted) range of Value of Avoided Water Use at 0-0,07 Euro cents/kWh for solar PV and 0-0,35 Euro cents/kWh for fuel cells.[13] The Value of Avoided Water Use varies significantly depending on location. In addition, commercial prices for water will underestimate the Value of Avoided Water Use to the extent that those prices do not fully reflect the societal cost of the water used. Since the cost of water usage is typically included in the Value of Avoided Generation Variable O&M Cost,[14] the (adjusted) Value of Avoided Water Use cannot exceed the Value of the Avoided Generation Variable O&M Cost. The resultant (adjusted) Value of Avoided Water Use of 0-0,07 Euro cents/kWh for solar PV and 0-0,20 Euro cents/kWh for fuel cells has been subtracted from the respective Value of Avoided Generation Variable O&M Cost category to avoid double counting.

C. Avoided Transmission & Distribution Costs

---

[11] This water, as well as other water generated by some fuel cells, may be recovered and used for non-potable purposes such as irrigation.

[12] The CEC dry-cooled water usage for a natural gas combined cycle plant [11] represents a 95% reduction from the National Energy Technology Laboratory ("NETL") recirculating cooling water usage for a similar plant [46]. This is in line with the 90% reduction discussed in [51].

[13] The Value of Avoided Water Use for solar PV is (counter-intuitively) lower than the Value of Avoided Water Use for fuel cells because the natural gas-fired avoided central station electricity generating technologies for solar PV both use significantly less water than the (high end) coal-fired avoided central station electricity generating technology for fuel cells.

[14] *See* California Energy Commission, "California Distributed Energy Resource Guide," online at http://www.energy.ca.gov/distgen/economics/operation.html.

Because solar PV and fuel cells are distributed energy resources that are typically located close to the point of use, solar PV and fuel cells require much less transmission and distribution ("T&D") infrastructure than does a conventional central station electricity generating plant.

Value of Avoided T&D Cost (All T&D costs allocated to Summer Peak) – The value of avoided T&D is very much dependent on location and on the adequacy of T&D infrastructure relative to load growth in that location. Distributed energy resources such as solar PV and fuel cells installed in "load pockets" where transmission capacity is constrained will provide maximum value to the electrical grid. The same applies to areas located within a constrained distribution grid, or in a new housing development where marginal investment can be directly avoided.

The range of avoided T&D costs is from the E3 Avoided Cost Study [33], in which avoided transmission costs are separate and distinct from avoided distribution costs. For valuation purposes, both transmission and distribution costs must be adjusted to reflect the average ELCC and the annual capacity factor of the distributed energy resource.

Thus, T&D costs are adjusted to reflect the assumed 65% California average ELCC of solar PV installations and converted to Euro cents/kWh using the assumed 20% annual solar PV capacity factor. The (adjusted) Value of Avoided Transmission Cost for solar PV ranges from a low of 0,04 Euro cents/kWh to a high of 0,58 Euro cents/kWh, depending on location and utility. Similarly, the (adjusted) Value of Avoided Distribution Cost for solar PV ranges from a low of 0,16 Euro cents/kWh to a high of 2,38 Euro cents/kWh.

T&D costs are similarly adjusted to reflect the assumed 93% average ELCC and 91% annual capacity factor for distributed fuel cells in California. The (adjusted) Value of Avoided Transmission Cost for fuel cells ranges from a low of 0,01 Euro cents/kWh to a high of 0,18 Euro cents/kWh, depending on location and utility. Similarly, the (adjusted) Value of Avoided Distribution Cost for fuel cells ranges from a low of 0,05 Euro cents/kWh to a high of 0,75 Euro cents/kWh.

Value of Avoided Losses – This category of avoided cost accounts for the fact that electricity generated by distributed energy resources such as solar PV and fuel cells does not have to pass through the electrical grid and thus does not incur the associated T&D line losses. This means that 6% less electricity has to be generated by central station electricity generating plants, with an equivalent percentage reduction in generation-related emissions.[15] The 6% in avoided losses proportionately increases the value of each of the other distributed value elements illustrated in Attachment B, except for:

- The Value of Avoided Transmission Cost and the Value of Avoided Distribution Cost, each of which has losses built into the underlying E3 Avoided Cost Study values [33].
- The Value of Cogeneration Credit (applicable to fuel cells only), which relates to avoided boiler fuel rather than to total kWh generated.
- The Value of Fossil Fuel as a Price Hedge, which depends on relative heat rates rather than on the total kWh generated.
- The Value of Job Creation, which is indirectly affected by the need to install relatively less fuel cell capacity than central station electricity generating capacity.
- The Value of Increased Reliability and Blackout Avoidance.
- The Value of Power Quality Improvement (applicable to fuel cells only).

[15] This value approximates the 5,52% volume-weighted average for California's three investor-owned utilities as agreed to by Working Group for use in 2007 Market Price Benchmark ([18] at p.7).

Value of Grid Support – The estimated Value of Grid Support reflects the avoided ancillary services costs associated with the electricity load displaced by generation from distributed energy resources such as solar PV and fuel cells. The value is based on 2,84% of the applicable range of (unadjusted) Avoided Generation Fuel Cost, since fuel cost is assumed to be a major driver of wholesale electricity prices in California ([33] at pp. 146-147).

Value of Improved Reliability and Blackout Avoidance – Electricity generated by distributed energy resources reduces the amount of electricity generated by central station electricity generating plants that must pass through the electric grid, thereby relieving potential overloading of many grid components (*e.g.*, transformers). To the extent that reduced overloading reduces the likelihood of load loss, distributed solar PV and fuel cells have additional value in enhancing grid reliability and blackout avoidance.

The calculated Value of Improved Reliability and Blackout Avoidance for any given distributed energy resource in California is based on the following five factors:

- The percentage of the state's population affected by a blackout.
- The duration of a blackout.
- The penetration level of the distributed energy resource.[16]
- California's daily per capita Gross State Product, as a surrogate measure of the direct costs of a blackout.
- An assumption that indirect costs related to a blackout are 60% as large as the direct costs.

The current calculated range of the Value of Improved Reliability and Blackout Avoidance is 0,001-0,135 Euro cents/kWh for solar PV and 0,001-0,148 Euro cents/kWh for fuel cells, using 2005 values for Gross State Product and 2006 penetration levels. The lower end of the range is based on a 1-hour blackout that affects 10% of the state's population; the upper end is based on a 24-hour blackout affecting 50% of the state's population. The calculated range of the Value of Improved Reliability and Blackout Avoidance is anticipated to increase significantly as the penetration level of solar PV and fuel cells throughout the state increases.

Results calculated using the methodology described above were compared to estimated losses derived by others for both California (in whole or in part) and for the Northeastern U.S. August 2003 blackout (as it affected New York City).[17] Although not identical, the results were such that the methodology used here was deemed to be a reasonable means of valuing the improved reliability and blackout avoidance attributable to distributed energy resources in California.

Value of Improved Power Quality Improvement – The Value of Improved Power Quality is calculated only for fuel cells, due to: (i) the 24/7 baseload operation of fuel cells; and, (ii) the high quality of the power generated. (Because solar PV is a peaking resource and dependent on the weather, there is no Value of Improved Power Quality attributed to this distributed energy resource.) The Value of Improved Power Quality for fuel cells is calculated as being 15% of the

[16] The penetration level of any given distributed energy resource is calculated as the ratio of MWH generated by the distributed energy resource to total California retail electricity sales in MWh. For 2006, this ratio was estimated to be 0,03% for solar PV and 0,04% for fuel cells.

[17] *See*, for instance, [2]; [14]; [24]; [27]; [28]; [30]; [39]; and, [40].

Value of Reliability and Blackout Avoidance.[18] The calculated range for the current Value of Improved Power Quality is <0,001-0,022 Euro cents/kWh. As was the case for the Value of Increased Reliability and Blackout Avoidance, this value is expected to increase as the penetration level of fuel cells in California increases.

Combined, the total calculated value of Increased Reliability/Power Quality/Blackout Avoidance for fuel cells is <0,01-0,17 Euro cents/kWh.

D. Digester Gas Credit (Applicable to Fuel Cells Only)

Bio-methane is considered a renewable fuel source, with technically feasible for use digester gas levels (conservatively) estimated to reach over 79 million GJ in California by 2020 ([10] at p. 12, Figure 1.6). This level of bio-methane availability could support nearly 40% of the state's potential 2020 installed fuel cell capacity of 3200 MW. The analysis underlying the results presented in this paper assumes that 30% of the state's installed fuel cell capacity operates using digester gas.

Digester gas is assumed to be approximately half biogenic carbon dioxide (CO_2)[19] and half methane (CH_4)[20], with small amounts of N_2, O_2, hydrogen sulfide (H_2S), and particulate matter (PM10); average heat content is about 22.26 MJ/m^3 (HHV). Use of digester gas by fuel cells has several benefits. First, such use means that the digester gas will not be flared, thereby avoiding flare-related emissions of NO_x, CO, and PM10. Second, use of digester gas by fuel cells directly displaces natural gas use, resulting in avoided natural gas use whose value contributes to the Value of Avoided Generation Fuel Cost.

The direct benefits of avoided central station electricity generating plant fuel use and of the avoided emissions from digester gas use by fuel cells, as well as the indirect health-related benefits of those avoided emissions, contribute a total value ranging from 0,58-3,83 Euro cents/kWh. This range of values is included in the fuel cell values illustrated in Attachment B and can be broken down as follows:

- Value of Avoided Generation Fuel Cost = 0,26-3,23 Euro cents/kWh.
- Value of Avoided Fossil Fuel as a Price Hedge = 0,02-0,28 Euro cents/kWh.
- Value of Health Benefits of Avoided In-State Emissions = 0,30-0,31 Euro cents/kWh.
- Value of Avoided Emissions = 0,002-0,012 Euro cents/kWh.

E. Cogeneration Credit (Applicable to Fuel Cells Only)

---

[18] This percentage is based on an analysis done for the New York State Energy Research and Development Authority ("NYSERDA") that provided separate estimates of the total U.S. cost of outages and of power quality problems. As defined in the NYSERDA report ([32] at pp. ES1 and ES3):

- "The ability of the electric system to deliver electric power without interruption is termed 100% *reliability*.
- The ability to deliver a clean signal without variations in the nominal voltage or current characteristics is termed high *power quality*." (Emphasis in original.)

[19] Biogenic carbon dioxide is considered to be part of the natural carbon cycle, and is not generally included in CO_2 emissions inventories.

[20] Both carbon dioxide and methane are greenhouse gases, though methane is about 21 times more damaging as a greenhouse gas than is carbon dioxide.

Fuel cells typically capture the waste heat from the electrochemical reaction process that produces electricity. The waste heat is then used to cogenerate another useful product such as hot water, steam, or process heating. As a result, whatever process would otherwise have been used to provide the cogenerated product(s) is avoided, reducing the amount of input fuel required for that process and the amount of output emissions.

The Value of Cogen Credit for fuel cells in California is calculated using a format similar to that used by the CPUC in calculating avoided greenhouse gas emissions ([20] at Attachment 5). It is assumed that approximately 46% of the fuel cell's captured waste heat is available as useful energy, and that this useful energy replaces the output from an in-state natural gas-fired boiler operating at 80% efficiency. The avoided natural gas is priced using the same range of NYMEX futures prices that was used for the Value of Avoided Generation Fuel Cost, averaged over a six-month period to reflect a more conservative (seasonal) fuel procurement practice. The avoided emissions are valued at in-state emissions prices (as summarized in Attachment C). All values are adjusted to reflect the 60% of fuel cell capacity that is assumed to operate in a cogeneration or CCHP mode.

Values related to cogeneration and CCHP are calculated over the range of fuel cell heat rates for the avoided natural gas boiler fuel, for the corresponding fossil fuel price hedge, and for avoided emissions of NO_x, SO_2, and CO_2. The following Value of Cogeneration Credit ranges for fuel cells are included in the total range of values for the appropriate category in the "Fuel Cell & Solar PV Value Proposition in California" waterfall chart illustrated in Attachment B:

- Value of Avoided Generation Fuel Cost = 0,72-1,54 Euro cents/kWh.
- Value of Avoided Fossil Fuel as a Price Hedge = 0,26-0,46 Euro cents/kWh.
- Value of Health Benefits of Avoided In-State Emissions = 0,015-0,016 Euro cents/kWh.[21]
- Value of Avoided Emissions = 0,09-0,76 Euro cents/kWh.[22]

The cumulative Value of Cogen Credit for fuel cells in California is 1,09-2,78 Euro cents/kWh.

F. Avoided Emissions and Related Health Benefits

The E3 Avoided Cost Study [33] assumes that the cost of regulated emissions is captured in the market price of electricity. The category of regulated emissions includes only generation-related emissions for which emissions allowances are currently mandated, including NO_x, SO_2, and particulate matter (PM10). However, due to the decision made in this analysis to separate generation capacity value from a derived energy-only value, it is necessary to consider separately those values captured in the market value of electricity in California that are neither capacity- nor fuel-related.

Natural gas is typically the marginal fuel source that sets the market price of electricity in California. In this analysis, natural gas prices determine the entire range of the Avoided Generation Fuel Cost for solar PV. For fuel cells, natural gas prices set the upper bound on the Avoided Generation Fuel Cost, and coal prices (as a component of the electricity import price) set the lower

---

[21] Details regarding the Value of Health Benefits of Avoided In-State Emissions related to fuel cell cogeneration are provided below in the Value of Health Benefits section.

[22] Avoided NO_x, SO_2, and CO_2 emissions from the natural gas-fired boiler are calculated using the "CHP Emissions Calculator" [58] developed by the U.S. EPA's Combined Heat and Power Partnership. Avoided CO and VOC emissions are calculated using results derived by the Scottish Executive [50].

bound. Natural gas as the avoided generation fuel cost thus acts (in part) as a surrogate for the market price of electricity. However, since NYMEX natural gas futures contract prices do not include the cost of emissions allowances, the value of avoided emissions must be calculated as a separate distributed value element for each of the avoided emissions identified.

Value of Avoided Emissions - To calculate the value of avoided emissions related to any distributed energy resource, it is first necessary to identify *for each pollutant* the emissions rate applicable to the avoided central station electricity generating technology (or technologies) over the relevant range of heat rates. The resultant emissions rate range for each avoided central station electricity generating technology is then compared to the emissions rate for the given distributed energy resource to identify the quantity (if any) of avoided emissions in kg/MWh (tonne/MWh for carbon dioxide). The minimum and maximum avoided emissions are then valued at the end points of a range of emissions allowance prices either observed in the marketplace or derived from the literature.

Solar PV has no generation-related emissions. Therefore, the Value of Avoided Emissions is determined by the emissions rate range of the average California avoided natural gas-fired baseload plant and a natural gas-fired peaking plant. For fuel cells, the Value of Avoided Emissions is determined by comparing the fuel cell emissions to the emissions rate range determined by the average California avoided natural gas-fired plant and the existing fleet of baseload coal generating plants serving California.

The assumptions underlying the calculations and the results for the Value of Avoided Emissions (and related health benefits) are summarized in Attachment C. All reported values for avoided emissions include: (i) The value of generation-related avoided emissions; (ii) the value of avoided emissions (where applicable) for avoided digester gas flaring for that 30% of fuel cells assumed to use digester gas (as reported above in Section D); and, (iii) the value of avoided emissions for fuel cell cogeneration and CCHP (as reported above in Section E).

Value of Health Benefits of Avoided In-State Emissions – By far the largest contributor to the Value of Health Benefits of Avoided In-State Emissions is reductions in particulate matter, particularly reductions in particulate matter less than 2,5 microns in diameter ("PM2,5"). PM2,5 emissions are a subset of particulate matter less that 10 microns in diameter ("PM10"), but PM2,5 emissions are more damaging to health because they lodge deeper in the lungs, and cannot readily be coughed out.

California's PM2,5 emissions are estimated at 90% of PM10 emissions in the electricity generation sector, based on the statewide estimated annual average emissions published by the California Air Resources Board ("CA ARB") for calendar year 2000 for electric generation and cogeneration [8]. Calendar year 2000 emissions levels were used to correspond to California-specific calculations of the health-related economic value of reducing PM2,5 and PM10 emissions ([13]; [15]; [16]; and, [35]).

Attachment C shows that the combined results from the above sources lead to a Value of Health Benefits of Avoided In-State Emissions for PM2,5 ranges from 1,47-1,61 Euro cents/kWh for both solar PV and fuel cells. The additional value for avoided >PM2,5-PM10 emissions is 0,013-0,016 Euro cents/kWh for solar PV; for fuel cells the additional value for avoided >PM2,5-PM10 emissions is 0,023-0,027 Euro cents/kWh, significantly larger than for solar PV because of the added health benefits of avoided digester gas flare emissions.

The health benefits of reduced NO_x and SO_2 power plant emissions on a Euro cents/kWh basis are derived using the results of an extensive study by Abt Associates [1].[23] The Abt Associates study [1] provides both nationwide and state-specific estimates of health benefits in terms of avoided incidences of mortality, hospitalizations, and various categories of illness. These estimates were used to calculate the value of California-specific benefits based on the proportion of California-specific avoided health-related incidences to nationwide totals ([1] at Exhibits 6-2 and 6-7).

The Value of Health Benefits of Avoided In-State Emissions for avoided NO_x and SO_2 emissions for solar PV ranges from 0,013-0,016 Euro cents/kWh; for fuel cells, the value range is 0,023-0,027 Euro cents/kWh, including the health benefits of avoided digester gas flare emissions and avoided boiler emissions in the appropriate proportions.

No attempt is made in this analysis to estimate a California-specific health benefit from mercury emissions reductions attributed to electricity generated by distributed fuel cells for two reasons. First, the estimate made by Lutter, *et al.*, [44] is a national average estimate, with no state-specific breakdown of data provided. Second, the avoided baseload coal generator for fuel cells is assumed to be located outside of California, so any health benefits related to mercury removal would benefit Californians only indirectly.

The total calculated range of Value of Health Benefits of Avoided In-State Emissions is 1,49-1,63 Euro cents/kWh for solar PV and 1,80-1,96 Euro cents/kWh for fuel cells. The larger Value of Health Benefits of Avoided In-State Emissions for fuel cells is due to the inclusion of health benefits related to avoided digester gas flare emissions and avoided boiler emissions from fuel cell cogeneration and CCHP operations.

G. Job Creation Potential

Value of Job Creation Potential – Every kilowatt of installed capacity of a given distributed energy resource generates immediate local employment opportunities for the initial installation and for the ongoing maintenance and service requirements. In addition, because fuel cells are extremely heavy and costly to ship, as the market for fuel cells in California grows, at some point it will likely become economic for fuel cell manufacturing, assembly, and re-manufacturing facilities to be built in California; the same is true for solar PV manufacturing, as market penetration levels increase.

The Value of Job Creation Potential related to installation and ongoing maintenance of solar PV in California is estimated to range from 0,07-0,29 Euro cents per kWh. This range is based on the following set of assumptions:

- Installation of a solar PV project requires three full-time workers to work for one week, for a total of 120 hours.
- Ongoing maintenance of a solar PV installation requires $1/10^{th}$ as much labor as the initial installation (12 hours per year, primarily for cleaning PV modules for optimum performance).
- The average labor cost is €69,25/hour.

[23] A summary of the Abt Associates study [1] can be found in the Clean Air Task Force report [26].

The Value of Job Creation Potential related to installation and ongoing maintenance of fuel cells in California is estimated to range from 0,08-0,20 Euro cents per kWh. This range is based on the following set of assumptions:

- California represents 1/3rd of the total U.S. market for fuel cells.
- Labor represents 25% of the total installed cost of fuel cells.
- Installation of a fuel cell requires three full-time workers to work for three weeks, for a total of 360 hours.
- Ongoing maintenance of a fuel cell requires 1/4th as much labor as the initial installation (90 hours per year).
- The average labor cost is €69,25/hour.

Although more speculative, the additional Value of Job Creation Potential due to fuel cell companies building actual manufacturing capacity in California could in the longer term add another 1,48 Euro cents/kWh (in 2007€). No estimate has been made of the longer-term Value of Job Creation Potential due to increased solar PV manufacturing capacity in California.

Both current and longer-term estimates of the Value of Job Creation Potential are purposefully conservative; these estimates could be significantly higher, given their dependence on the specific types of jobs created, local wage rates, and the actual growth of the market for distributed energy resources in California.

H. Additional Values

Value of Deployment Ease – Solar PV and fuel cell systems can both be sited and installed in a relatively short period of time, given available rooftop space, land, and equipment. The carrying costs associated with the lead times necessary for siting, permitting and constructing a central station electricity generating plant are largely avoided. Zero or low emissions and quiet operation mean that solar PV and fuel cell systems can be rapidly deployed with minimal to no "greenfield" or unmanageable "NIMBY" impact.[24] The value created through solar PV and fuel cell modularity is especially dependent on the localized circumstances and difficult to quantify in average terms. In much of California, as is true in much of the United States, opposition to new infrastructure usually results in opponents availing themselves of the full suite of administrative remedies to thwart or delay investment. No specific estimate of this value is provided since the Value of Deployment Ease may vary significantly for each distributed energy resource project site.

Other Values - The estimated values in the "Fuel Cell & Solar PV Value Proposition in California" illustrated in Attachment B are not all-inclusive, and do not reflect many of the distributed value elements identified in the PLEASE matrix in Attachment A. Among those distributed value elements not included because they are difficult to quantify are the visibility impact due to reduced emissions, the impact on local control of resources, and the impact on responsiveness to load growth due to modularity.

III. CONCLUSIONS

Solar PV and fuel cells provide significant value to California's ratepayers today as distributed energy resources. As solar PV and fuel cell installed capacity and market penetration

---

[24] NIMBY is the acronym for the expression "Not In My Back Yard," which reflects the socio-political difficulties of siting large infrastructure project.

levels increase throughout the state, the value provided to California's ratepayers through avoided central station generation, cogeneration, digester gas use, and the associated avoided emissions can be expected to grow significantly. Distributed solar PV and fuel cells have the potential to make a significant contribution to meeting the state's greenhouse gas reduction goals while adding ratepayer value in many different respects.

*   *   *   *   *

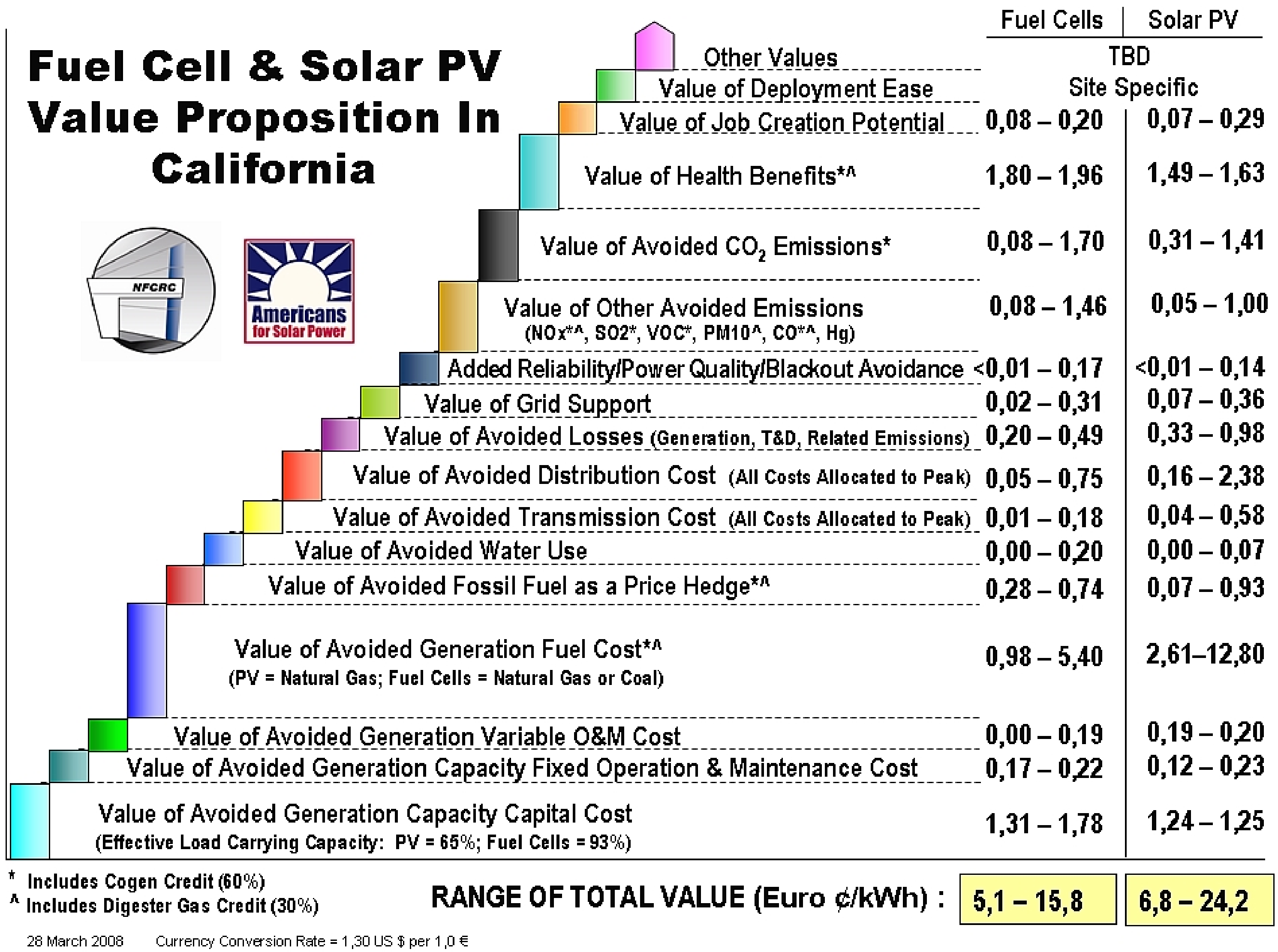
Attachment A

"PLEASE" Matrix of Distributed Value Elements

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 due to combined cooling, heating & power (CCHP) configuration
Impact on "political capital"	Land use impact (*e.g.*, T&D line rights of way)	Impact on NO_x and SO_x emissions levels	Future electricity price volatility	Impact on supply diversity	Impacts 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 cost
	Noise level impact	Impact on CO_2 emissions level	Utility load forecast uncertainty	Impact on utility grid VAR support	Impact on decision making time required
	Impact on NIMBY-BANANA-NOPE- 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 # of available 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 responsiveness to load growth (due to modularity)
	Ability to impact suburban load pockets	Visibility impact due to emissions impact	Site remedia-tion costs (current and future)		Impact on permitting time and cost
	Ability to impact rural or remote loads	Impact on urban "heat islands" (*e.g.*, shading ability)			Impact on operating life of grid components
	Impact of DG fuel delivery system	Impact on consumptive water use			Impact on resale or salvage value of equipment
	Visual impact	Impact on water & soil pollution levels			

Attachment B

Fuel Cell & Solar PV Value Proposition in California



Attachment C

Summary Table of Assumptions and Results: Value of Avoided Emissions and Related Health Benefits

GENERATING PLANTS:	Heat Rate Range (GJ/MWh)	Emissions Rate (CO_2 in tonne/MWh; all others in kg/MWh)						
		NO_x	SO_2	PM10	CO	VOC	Mercury	CO_2
Fuel Cells	8,801	0,03	0,002	-	0,05	0,009	-	0,44
	8,502	<0,01	<0,001	-	0,05	0,009	-	0,42
Average CA Natural Gas-Fired Generator	9,599	0,07	0,011	0,033	0,48	0,053	-	0,51
	8,531	0,05	0,010	0,031	0,43	0,047	-	0,45
Natural Gas-Fired Peaking Plant	11,023	0,09	0,014	0,038	0,57	0,062	-	0,61
	11,400	0,08	0,013	0,037	0,55	0,060	-	0,59
Pulverized Coal-Fired Generator	11,472	0,39	0,784	0,157	0,10	0,012	1,54E-05	1,09
	9,329	0,31	0,638	0,128	0,08	0,010	1,25E-05	0,88
EMISSIONS PRICES:		NO_x	SO_2	PM10	CO	VOC	Mercury	CO_2
	In-State:	(€/g/day)	(€/g/day)	(€/g/day)	(€/g/day)	(€/g/day)	(€/g)	(€/tonne)
	Maximum	604,01	276,45	442,94	14,14	501,79	59,36	23,12
	Minimum	42,40	67,83	135,67	7,15	8,48	8,48	6,78
	Out-of-State:	(€/kg)	(€/kg)	(€/kg)	(€/kg)	(€/kg)	(€/g)	(€/kg)
	Maximum	6,36	1,40	1,70	n/a	1,70	59,36	23,12
	Minimum	0,42	0,08	1,70	n/a	1,70	8,48	6,78
AVOIDED EMISSIONS:	(Euro ¢/kWh)	NO_x	SO_2	PM10	CO	VOC	Mercury	CO_2
Solar PV	Maximum	0,43	0,03	0,16	0,09	0,289	-	1,41
	Minimum	<0,01	<0,01	0,01	0,03	0,004	-	0,31
Fuel Cells (60% Cogen; 30% Digester Gas)	Maximum	0,76	0,10	0,17	0,08	0,266	0,09	1,70
	Minimum	0,05	0,01	0,02	0,01	0,001	-	0,08
HEALTH BENEFITS:	(Euro ¢/kWh)	NO_x & SO_2		PM10	PM2,5*			
Solar PV	Maximum	0,016		0,007	1,61			
	Minimum	0,013		0,006	1,47			
Fuel Cells (60% Cogen; 30% Digester Gas)	Maximum	0,027		0,316	1,61			
	Minimum	0,023		0,308	1,47			

** PM2,5 emissions make up 98% of the PM10 emissions category by weight, per California Air Resources Board 2000 Emissions Inventory.*

Data Sources: [1]; [12]; [22]; [23]; [25]; [29]; [31]; [33]; [34]; [43]; and, [45].

Select Bibliography

[1] Abt Associates, Inc., October 2000, "The Particulate-Related Health Benefits of Reducing Power Plant Emissions." http://www.abtassociates.com/reports/particulate-related.pdf

[2] Anderson Economic Group, August 19, 2003, "Northeast Blackout Likely to Reduce US Earnings by $6,4 Billion," AEG Working Paper 2003-2. http://www.andersoneconomicgroup.com/modules/Content/dl.php?format=application/pdf&filename=Doc544.pdf

[3] Bolinger, Mark and Ryan Wiser, December 13, 2004, "Comparison of AEO 2005 Natural Gas Forecast to NYMEX Futures Prices." http://repositories.cdlib.org/cgi/viewcontent.cgi?article=2922&context=lbnl

[4] Bolinger, Mark, Ryan Wiser and William Golove, January 2004, "Accounting for Fuel Price Risk When Comparing Renewable to Gas-Fired Generation: The Role of Forward Natural Gas Prices," LBL-54751. http://eetd.lbl.gov/EA/EMP/reports/54751.pdf

[5] Bolinger, Mark, Ryan Wiser and William Golove, June 2002, "Quantifying the Value that Wind Power Provides as a Hedge against Volatile Natural Gas Prices," Proceedings of WINDPOWER 2002, June 2-5, 2002, Portland, Oregon. http://eetd.lbl.gov/EA/EMP/reports/50484.pdf

[6] Breakthrough Technologies Institute, Inc., 2003, "Fuel Cells at the Crossroads: Attitudes Regarding the Investment Climate for the U.S. Fuel Cell Industry and a Projection of Industry Job Creation Potential," Report ANL/OF-00405/300. http://www.fuelcells.org/info/charts/economicstudy.pdf

[7] California Air Resources Board, 2006, "The California Almanac of Emissions and Air Quality, 2006 Edition." http://www.arb.ca.gov/aqd/almanac/almanac06/almanac2006all.pdf

[8] California Air Resources Board, 2001, "2000 Estimated Annual Average Emissions, Statewide," available online at: http://www.arb.ca.gov/app/emsinv/emssumcat_query.php?F_YR=2000&F_DIV=-4&F_SEASON=A&SP=2006&F_AREA=CA

[9] California Air Resources Board and South Coast Air Quality Management District, April 20, 2001, "Refinement of Selected Fuel-Cycle Emissions Analyses," Final Report FR-00-101 (Volume 1 of 2). http://www.arb.ca.gov/research/apr/past/98-338_1.pdf

[10] California Energy Commission, December 2006, "A Preliminary Roadmap for the Development of Biomass in California," PIER Collaborative Report, CEC-500-2006-095-D. http://www.energy.ca.gov/2006publications/CEC-500-2006-095/CEC-500-2006-095-D.PDF

[11] California Energy Commission, April 2006, "Cost and Value of Water Use at Combined-Cycle Power Plants," CEC-500-2006-034. http://www.energy.ca.gov/2006publications/CEC-500-2006-034/CEC-500-2006-034.PDF

[12] California Environmental Protection Agency, May 2005, "California Hydrogen Blueprint Plan, Volume 2." http://www.hydrogenhighway.ca.gov/plan/reports/volume2_050505.pdf

[13] California Environmental Protection Agency and California Air Resources Board, March 21, 2006, "Proposed Emission Reduction Plan for Ports and Goods Movement in California." http://www.arb.ca.gov/planning/gmerp/march21plan/march22_plan.pdf

[14] California Environmental Protection Agency and California Air Resources Board, June 2005, "Characterization of Ambient PM10 and PM2.5 in California – Technical Report." http://www.arb.ca.gov/pm/pmmeasures/pmch05/pmch05.htm

[15] California Environmental Protection Agency and California Air Resources Board, May 31, 2003, "The Economic Value of Respiratory and Cardiovascular Hospitalizations," Final Research Report, Contract Number 99-329. http://www.arb.ca.gov/research/apr/past/99-329.pdf

[16] California Environmental Protection Agency and California Air Resources Board, May 3, 2002, "Staff Report: Public Hearing to Consider Amendments to the Ambient Air Quality Standards for Particulate Matter and Sulfates." http://www.arb.ca.gov/research/aaqs/std-rs/pm-final/pm-final.htm

[17] California Independent System Operator, Department of Market Monitoring, April 2007, "Annual Report, Market Issues and Performance." http://www.caiso.com/1bb7/1bb776216f9b0.pdf

[18] California Public Utilities Commission, January 25, 2007, Decision 07-01-030, "Opinion Granting Joint Petition for Modification of Decision 06-07-0303," Order Instituting Rulemaking Regarding the Implementation of the Suspension of Direct Access Pursuant to Assembly Bill 1x and Decision 01-09-060, R.02-01-011. http://www.cpuc.ca.gov/WORD_PDF/FINAL_DECISION/64048.PDF

[19] California Public Utilities Commission, December 14, 2006, Resolution E-4049. ("2006 MPR Resolution") http://www.cpuc.ca.gov/word_pdf/FINAL_RESOLUTION/63132.pdf

[20] California Public Utilities Commission, December 13, 2006, "Proposed Decision of President Peevey and ALJ Gottstein – Interim Opinion on Phase 1 Issues: Greenhouse Gas Emissions Performance Standard," Order Instituting Rulemaking to Implement the Commission's Procurement Incentive Framework and to Examine the Integration of Greenhouse Gas Emissions Standards into Procurement Policies, R.06-04-009. http://www.cpuc.ca.gov/EFILE/PD/62840.htm

[21] California Public Utilities Commission, September 4, 2003, D.03-09-021, "Opinion Authorizing Rate Increases (Attachment G)." http://www.cpuc.ca.gov/Published/Final_Decision/29515.htm

[22] Cantor Environmental Brokerage, Historic Electronic Pricing Files and Various Dates, "Monthly Market Price Indices." http://www.emissionstrading.com

[23] Center for Energy Efficiency and Renewable Technologies, Environmental Defense, and Western Resource Advocates, 2005, "Clearing California's Coal Shadow from the American West." ("CEERT Study") http://www.ceert.org/reports/Coalreport.pdf

[24] Center for Risk and Economic Analysis of Terrorism Events ("CREATE"), May 31, 2005, "DRAFT Electricity Case: Main Report – Risk, Consequences, and Economic Accounting," CREATE Report #05-014 under FEMA Grant EMW-2004-GR-0112, University of Southern California, Los Angeles, California. http://www.usc.edu/dept/create/assets/001/50773.pdf

[25] Chicago Climate Exchange, Historic Electronic Pricing Files and Various Dates, "CCX Market Report." http://www.chicagoclimateexchange.com

[26] Clean Air Task Force, October 2000, "Death, Disease & Dirty Power: Mortality and Health Damage Due to Air Pollution from Power Plants." http://www.catf.us/publications/reports/Death_Disease_Dirty_Power.pdf

[27] Clean Power Research, LLC, March 17, 2006, "The Value of Distributed Photovoltaics to Austin Energy and the City of Austin," Prepared for Austin Energy under Solicitation Number: SL04300013. http://www.clean-power.com/research/distributedgeneration/AE_PV_ValueReport.pdf

[28] Consortium for Electric Infrastructure to Support a Digital Society ("CEIDS"), June 2001, "The Cost of Power Disturbances to Industrial & Digital Economy Companies," EPRI Report #1006274. http://www.epri-intelligrid.com/intelligrid/docs/Cost_of_Power_Disturbances_to_Industrial_and_Digital_Technology_Companies.pdf

[29] Duke, Richard, Robert Williams and Adam Payne, 2004, "Accelerating Residential PV Expansion: Demand Analysis for Competitive Electricity Markets," *Energy Policy*. http://www.nrel.gov/ncpv/thin_film/pdfs/energy_policy_pv_expansion_residential_demand_issues.pdf

[30] Electricity Consumers Resource Council ("ELCON"), February 9, 2004, "The Economic Impacts of the August 2003 Blackout." http://www.elcon.org/Documents/EconomicImpactsOfAugust2003Blackout.pdf

[31] Energy and Environmental Economics, Inc., March 20, 2006, "Avoided Cost Calculation Spreadsheets, Updated Electric and Gas Avoided Costs – 2006 Update (5/23/06 Draft Decision): Electric Avoided Costs." http://www.ethree.com/cpuc_avoidedcosts.html

[32] Energy and Environmental Analysis, Inc., and Pace Energy Project, December 2005, "The Role of Distributed Generation in Power Quality and Reliability – Final Report," Prepared for New York State Energy Research and Development Authority ("NYSERDA"). http://www.eea-inc.com/natgas_reports/DGPowerQualityReport-NYSERDA.pdf

[33] Energy and Environmental Economics, Inc., and Rocky Mountain Institute, October 25, 2004, "Methodology and Forecast of Long Term Avoided Costs for the Evaluation of California Energy Efficiency Programs," report prepared for the California Public Utilities Commission. ("E3 Avoided Cost Study") http://www.ethree.com/cpuc_avoidedcosts.html

[34] Evolution Markets, Inc., Various Dates, "Weekly Market Update." http://www.evomarkets.com

[35] Hall, Jane V., Victor Brajer, and Frederick W. Lurmann, March 2006, "The Health and Related Economic Benefits of Attaining Healthful Air in the San Joaquin Valley," Institute for Economic and Environmental Studies, California State University-Fullerton. http://business.fullerton.edu/Centers/iees/reports/SJVFinalReport.pdf

[36] Herig, Christy, "Using Photovoltaics to Preserve California's Electricity Capacity Reserves," National Renewable Energy Laboratory. NREL/BR-520-31179 September 2001. http://www.nrel.gov/docs/fy01osti/31179.pdf

[37] Hewlett Foundation Energy Series, April 2003, "The Last Straw: Water Use by Power Plants in the Arid West." ("Hewlett Foundation Report") http://www.catf.us/publications/reports/The_Last_Straw.pdf

[38] Hoff, Thomas E., and Robert Margolis, 2003, "Distributed Photovoltaics in New Jersey," under contract to the Department of Energy through the National Renewable Energy Laboratory. http://www.clean-power.com/research/distributedgeneration/DistributedPVInNewJersey.pdf

[39] ICF Consulting, August 21, 2003, "The Economic Cost of the Blackout – An issue paper on the Northeastern Blackout, August 14, 2003." http://www.icfi.com/Markets/Energy/doc_files/blackout-economic-costs.pdf

[40] ICF Consulting, Summer 2003, "Measuring the Economic Costs of Terrorist Attacks," in *ICF Perspectives*. http://www.icfi.com/Markets/Homeland-Security/doc_files/costs_terrorist.pdf

[41] Itron, Inc., March 1, 2007, "CPUC Self-Generation Incentive Program Fifth Year Impact Evaluation: Final Report," Submitted to PG&E and The Self-Generation Incentive Program Working Group. ("SGIP Fifth Year Impact Report") http://www.cpuc.ca.gov/NR/rdonlyres/888A94D9-14C4-48B2-8146-05B98C2EA852/0/SelfGen_Fifth_Year_Impact_Report.pdf

[42] Itron, Inc., April 15, 2005, "CPUC Self-Generation Incentive Program Fourth-Year Impact Report: Final Report," Submitted to Southern California Edison and The Self-Generation Incentive Program Working Group. ("SGIP Fourth Year Impact Report") http://www.cpuc.ca.gov/static/energy/electric/050415_sceitron+sgip2004+impacts+final+report.pdf

[43] Krotz, Dan, October 26, 2006, "Clamping Down on Mercury Emissions," Science@Berkeley Lab online article. http://www.lbl.gov/Science-Articles/Archive/sabl/2006/Oct/2.html

[44] Lutter, Randall, Elizabeth Mader, and Nathan Knuffman, March 2001, "Regulating Mercury Emissions: What Do We Know About Costs and Benefits?" Report for AEI-Brookings Joint Center for Regulatory Studies. http://www.aei-brookings.org/admin/authorpdfs/page.php?id=143&PHPSESSID=d42102724eb433734d11631791ada144

[45] National Energy Technology Laboratory, February 5, 2007, "2006 Cost and Performance Baseline for Fossil Energy Plants: Updated Technical Performance," U.S. Department of Energy. http://www.netl.doe.gov/energy-analyses/pubs/Sept-06%20Pitt%20Coal%20Conf_Update_Jan07.pdf

[46] National Energy Technology Laboratory, August 2005, "Power Plant Water Usage and Loss Study," U.S. Department of Energy. http://www.netl.doe.gov/technologies/coalpower/gasification/pubs/pdf/WaterReport_IGCC_Final_August2005.pdf

[47] Pew Center on Global Climate Change, 2005, "The European Union Emissions Trading Scheme (EU-ETS) Insights and Opportunities." http://www.pewclimate.org/docUploads/EU-ETS%20White%20Paper.pdf

[48] PriceWaterhouseCoopers, June 2002, "Fuel Cells: The Opportunity for Canada," Report for Fuel Cells Canada.
http://www.pwc.com/extweb/pwcpublications.nsf/docid/1CD4C1A4CD21E707852570CA001790BC

[49] Rose, Adam, Gbadebo Oladosu, and Shu-Yi Liao, October 14, 2005, "Business Interruption Impacts of a Terrorist Attack on the Electric Power System of Los Angeles: Customer Resilience to a Total Blackout," Working Draft; Not for Quotation, Presented at Carnegie Mellon Electricity Industry Center, November 8, 2005.
http://wpweb2.tepper.cmu.edu/ceic/SeminarPDFs/R_O_L_Bus_Int10_14.pdf

[50] Scottish Executive, 2006, "Review of Greenhouse Gas Life Cycle Emissions, Air Pollution Impacts and Economics of Biomass Production and Consumption in Scotland," Table 5.4: Indicative Comparison of Emissions from Biomass and Fossil Fuels in Small Boilers.
http://www.scotland.gov.uk/Publications/2006/09/22094104/6

[51] University of Arizona, "'Dry' Power Plants Produce Energy Using Less Water," in *Arizona Water Resource*, Volume 10, Number 4, March-April 2002.

[52] U.S. Department of Energy, Energy Information Administration, June 2007, "Natural Gas Consumption by End Use: California, Monthly, Series History."
http://tonto.eia.doe.gov/dnav/ng/xls/ng_cons_sum_dcu_SCA_m.xls

[53] U.S. Department of Energy, Energy Information Administration, March 2007, "Annual Energy Outlook 2007, With Projections to 2030," U.S Department of Energy, DOE/EIA-0363(2007). http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2007).pdf

[54] U.S. Department of Energy, Energy Information Administration, March 2007, "Assumptions to the Annual Energy Outlook 2007, With Projections to 2030," U.S Department of Energy, DOE/EIA-0554(2007). http://www.eia.doe.gov/oiaf/aeo/assumption/pdf/0554(2007).pdf

[55] U.S. Department of Energy, Energy Information Administration, March 2007, "California Electricity Profile, 2005 Edition, Table 5: Electric Power Industry Generation by Primary Energy Source, 1990-2005," DOE/EIA-0348.
http://www.eia.doe.gov/cneaf/electricity/st_profiles/california.html

[56] U.S. Department of Energy, Energy Information Administration, November 19, 2006, "Electric Power Annual with Data for 2005 (Revised)," Table 4.2. Receipts, Average Cost, and Quality of Fossil Fuels: Electric Utilities, 1992 through November 2006. Microsoft Excel file epmxlfile4_2.xls at: http://www.eia.doe.gov/cneaf/electricity/epa/epat4p5.html.

[57] U.S. Department of Energy, Energy Information Administration, October 7, 2006, "Electric Power Annual with Data for 2005," Table 5.1. Emissions from Energy Consumption at Conventional Power Plants and Combined-Heat-and-Power Plants, 1994 through 2005. Microsoft Excel file emission_state.xls at: http://www.eia.doe.gov/cneaf/electricity/epa/epat5p1.html.

[58] U.S. Environmental Protection Agency, Combined Heat and Power Partnership, "CHP Emissions Calculator," at http://www.epa.gov/chp/project_resources/calculator.htm.

[59] U.S. Environmental Protection Agency, October 2004, "Documentation Summary for EPA Base Case 2004 (V.2.1.9) Using the Integrated Planning Model," EPA430/R-04-008.
http://www.epa.gov/airmarkets/progsregs/epa-ipm/docs/basecase2004.pdf

[60] Western Resource Advocates, 2004, "A Balanced Energy Plan for the Interior West." In Collaboration with Synapse Energy Economics, Inc. and the Tellus Institute. http://www.westernresourceadvocates.org/energy/BEP/WEB_pdfs/BEP_West_lwres.pdf