More Distributed Solar Means Fewer New Combustion Turbines

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A strategic renewable energy strategy that prioritizes distributed solar would eliminate the justification of a new generation of fast-start gas turbines presumed to be necessary to address rapid swings in output from utility-scale solar and wind projects.

PLAN SUBSTANTIAL RENEWABLES

California strategic energy policy is focused on local, distributed clean energy solutions. The California *Energy Efficiency Strategic Plan* sets ambitious energy-efficiency, rooftop photovoltaic (PV), and air conditioning peak load reduction targets for California.[1] A primary focus of this plan is zero net energy (ZNE) residential and commercial buildings. Major goals for this plan are 25 percent of residential near ZNE by 2020, 50 percent of commercial ZNE by 2030, residential efficiency to reduce energy by 30 to 40 percent by 2020, and 50 percent reduction in air conditioning loads by 2020.

The California *Energy Action Plan* loading order is a core element of strategic energy planning in the state. The *Energy Action Plan* prioritizes energy efficiency, rooftop PV, demand response, and combined heat and power (CHP) over conventional gas-fired generation to meet California's electricity needs. The *Energy Action Plan* priority list, or loading order, was established as an investor-owned utility regulatory requirement by the California Public Utilities Commission in January 2012.[2]

In addition, Gov. Jerry Brown has established a target of 12,000 megawatts of new local renewable energy resources by 2020. Achieving the *Energy Efficiency Strategic Plan* ZNE goals would result in substantially more than 12,000 megawatts of new distributed solar by 2020.[3] California currently has more than 4,000 megawatts of wind and more than 2,000 megawatts of solar online. Most of the solar, over 1,200 megawatts, is distributed solar installed under the state's net-metering program.[4]

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To meet the state's local renewable energy targets, utility-scale renewable-portfolio-standard (RPS) project output is assumed to reach 20 percent of statewide electricity consumption and not grow beyond this level. California utilities are mandated to achieve a 20 percent RPS by December 31, 2013.[5] Expansion of the renewable energy supply beyond 20 percent would be provided by distributed PV. The amount of large hydro electricity production available during the 2008 base-case year is assumed to remain relatively static over time. Nuclear production is also assumed to be constant over time through 2020.[6] **Exhibit 1** summarizes how California's electricity needs will be met in 2020.

IN 2020, WORLD TURNS UPSIDE DOWN: LOWEST DEMAND ON GRID AT MIDDAY

Exhibit 2 shows the effect of achieving the statewide goals in 2020 on the load profile of a typical hot summer day. This profile includes a steep ramp in the morning hours and again in the evening. This ramp rate can be as much as 4,000 megawatts an hour in the California Independent System Operator control (CAISO) area.[7] California's current gas-fired generation mix, which includes more than 16,000 megawatts of combined-cycle units, 7,400 megawatts of combustion turbines and internal combustion engines, and over 16,000 megawatts of steam boiler units, can readily accommodate this ramp rate.[8] For example, the 50-megawatt LM6000 combustion turbine, when hot and online, can move through its entire 50-megawatt load range in one minute.[9]

However, CAISO asserts that the need for fast-start combustion capacity may triple by 2020 to address the intermittency of expanding solar and wind resources.[10] The example used by CAISO to support this position is a fast-mov-

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Exhibit 1. 2020 California Electricity Profile if Energy Efficiency Strategic Plan Targets Met

Element	2020 (GWh)
2008 statewide total retail delivered electricity, basecase year[a]	277,000
Energy-efficiency reductions:	
residential, single-family	18,000
residential, multifamily	9,000
commercial	32,000
industrial	11,000
agriculture	3,000
Distributed PV additions:	
residential, single-family	11,000
residential, multifamily	3,000
commercial	19,000
Utility-scale RPS[b] (none beyond 2013 20% RPS)	55,000
Large hydroelectric[c] (2008 California + imports total)	34,000
Nuclear[d] (2008 California + imports total)	44,000
Natural gas/coal (new CHP to displace imported and in-state coal power)	38,000

[a] CEC, *California Electricity Demand 2010–2020 Commission-Adopted Forecast*, Forms 1.1 and 1.1c, December 2009. See http://www.energy.ca.gov/2009publications/CEC-200-2009-012/index.html. The approximate 277,000 GWh (276,509 GWh) statewide total is from Form 1.1c.
[b] CPUC, *33% Renewables Portfolio Standard Implementation Analysis Preliminary Results*, June 2009, Appendix C, p. 86, 20% RPS Reference Case (table).
[c] CEC, *2008 Net System Power Report*, July 2009, Table 2, p. 5. Large hydro 2008 total = 33,733 GWh.
[d] In addition to the 2,200 MW San Onofre Nuclear Generating Station and the 2,200 MW Diablo Canyon Generating Station, California utilities own a combined 27.4 percent share, about 1,000 MW, of the 3,700 MW (net) Palo Verde Nuclear Generating Station (PVNGS) in Arizona. See this link for a breakdown of California utility ownership of the PVNGS: http://www.srpnet.com/about/stations/paloverde.aspx.

ing cloud covering a 500-megawatt utility-scale solar facility in a matter of minutes.[11]

As shown in Exhibit 2, air-conditioner efficiency improvement combined with air-conditioner demand response (on/off cycling control by utility), energy-efficiency reductions, and the addition of 4,000 megawatts of new CHP reduce afternoon peak load by about 40 percent in 2020, to around 30,000 megawatts. The addition of approximately 17,000 megawatts of distributed solar statewide by 2020 reduces the grid demand at midafternoon to around 13,000 megawatts.[12] The peak shifts to early evening when the rooftop PV systems are no longer producing electricity, and reaches about 25,000 megawatts in the 6:00 p.m.-to-9:00 p.m. window.

Midday grid demand in 2020 will be met entirely with existing nonfossil resources, as shown in Exhibit 2. These resources include utility-scale RPS generation with about 7,000-megawatt peak availability, existing large hydro with about 4,000-megawatt average output and 12,000-megawatt peak output, and about 5,000 megawatts of existing California nuclear generation and Arizona nuclear generation dedicated to California utilities. Nighttime and cloudy weather demand will be met, in part, by these same nonfossil resources: nonsolar renewable, large hydro, and nuclear.

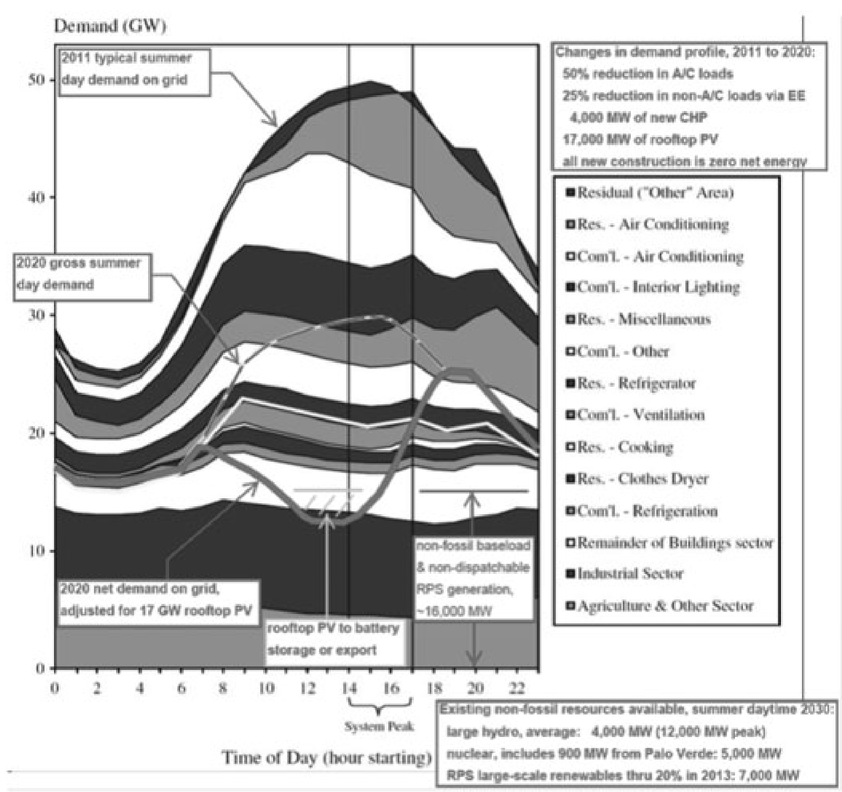
Battery storage will steadily supplement these nonfossil resources. The stationary battery storage capacity statewide would reach 2,500 megawatts in 2020, consistent with the 2020 target in the initial version of AB 2514, the California energy storage bill passed in 2010.[13]

The function of the battery storage would be to (1) store PV electricity generated in excess of need at midday, (2) supplement other nonfossil resources to assist in meeting the 2020 evening peak load and nighttime low load demand, (3) provide an additional nighttime nonfossil electricity source of supply for electric vehicles, and (4) load leveling to address short-term variations in nighttime wind energy production.

IN GERMANY AND TEXAS, HIGH LEVELS OF SOLAR SEEN TO DRIVE DOWN SUMMER PRICES

High levels of PV production in Germany on clear days have resulted in the lowest 24-hour wholesale market prices occurring at midday.[14] Germany has approximately 28,000 megawatts of distributed solar resources online as of mid-2012. The German power market has an average peak load of 60,000–70,000 megawatts.[15] A clear-day German solar output profile is shown in **Exhibit 3**.

Exhibit 2. California 2020 Summer Day Demand Curve Following Achievement of 2020 Statewide Goals



Summer midday electricity prices would be the lowest prices of the 24-hour clock cycle due to the large amount of nondispatchable PV electricity being generated during the 9:00 a.m.-to-5:00 p.m. window. This phenomenon of low midday prices has already been observed in the German power market and is projected for the Texas power market if substantial solar resources are added in the ERCOT control area.[16] The lower summer wholesale market prices caused by solar power inflows at midday may more than offset the incrementally higher cost of solar compared to new conventional resources.[17]

One of the strengths of distributed solar is how rapidly the rate of deployment can be increased. For example, Germany installed more than 3,000 megawatts of PV in the *month* of December 2011.[18] The rate of PV installation can be accelerated to meet greenhouse gas reduction targets for traditional stationary electric loads and to supply electric vehicles.

FOCUS ON DISTRIBUTED SOLAR ELIMINATES NEED FOR NEW FAST-START COMBUSTION TURBINES

Clear-day and partly cloudy distributed solar profiles are shown in **Exhibit 4**. The clear-day

Exhibit 3. Clear-Day German Solar Output Profile, May 25, 2012

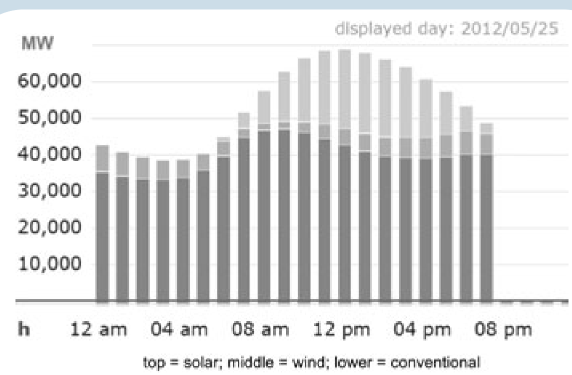


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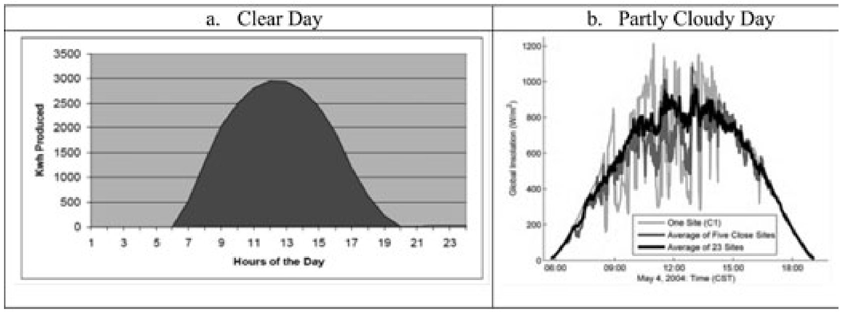
Exhibit 4. Output Profile of Distributed Solar on Clear and Partly Cloudy Days



profile, shown in Exhibit 4a, is a smooth bell curve that would require no fast-response combustion turbine resources as the ramp rate is substantially less steep than a typical hot summer day ramp rate in California. The collective output profile of tens of thousands or hundreds of thousands of individual solar PV arrays distributed over hundreds of square miles in a major urban demand center is also a smooth bell curve, flattened to the extent of cloud cover. This phenomenon is shown in Exhibit 4b.

Thus, a renewable energy strategy primarily focused on distributed solar would eliminate the need for new fast-start combustion turbine capacity.

NOTES

1. CPUC, California Energy Efficiency Strategic Plan, January 2011 Update. See http://www.cpuc.ca.gov/NR/rdonlyres/A54B59C2-D571-440D-9477-3363726F573A/0/CAEnergyEfficiencyStrategicPlan_Jan2011.pdf.
2. CPUC Decision D.12-01-033, Decision Approving Modified Bundled Procurement Plans, January 12, 2012, pp. 20–21, 51. See http://docs.cpuc.ca.gov/word_pdf/FINAL_DECISION/157640.pdf.
3. This statement is based on the slightly modified Energy Efficiency Strategic Plan goals developed for the Bay Area Smart Energy 2020 report (March 2012). See http://pacificenvironment.org/downloads/BASE2020_Full_Report.pdf. The modified goals assume 25 percent of residential achieves ZNE in 2020, and that 25 percent of commercial buildings also achieve ZNE in 2020. All new residential and commercial construction is assumed to be ZNE beginning in 2015.
4. KCET, July 11, 2012, http://www.kcet.org/news/rewire/solar/california-keeps-breaking-solar-records.html.
5. Text of SB 2 (1X), http://www.leginfo.ca.gov/pub/11-12/bill/sen/sb_0001-0050/sbx1_2_bill_20110412_chaptered.pdf.
6. This assumption may be non-conservative. The San Onofre Nuclear Generating Station is currently offline indefinitely due to excessive tube wear issues related to the design of its recently installed steam generators.
7. CAISO article, ramping and intermittent renewables, January 2012.
8. CEC, Thermal Efficiency of Gas-Fired Generation in California—Staff Paper, August 2011, Table 2, p. 3. Combined-cycle plants = 16,196 MW; combustion turbines = 4,331 MW; internal combustion engines and plants low load plants built in 1980s and 1990s = 3,029 MW; aging steam plants = 16,748 MW; and gas-fired cogeneration = 5,992 MW.
9. See GE FlexAero LM6000-PH Fact Sheet, http://www.ge-flexibility.com/static/global-multimedia/flexibility/documents/GE_FlexAero_Fact_Sheet2.pdf.
10. *Combined Cycle Journal* Online, Integrating Renewables: Grid Impacts—CALISO, January 2012, p. 3.
11. Ibid, p. 3.
12. Assume 1 kW_{ac} of solar capacity produces 1,900 kWh-yr of output. Therefore 33,000 GWh-yr of distributed solar production (33,000,000 MWh-yr) would require approximately 17,000 MW_{ac} of solar capacity.
13. AB 2514 Chaptered, September 29, 2010, ftp://leginfo.public.ca.gov/pub/09-10/bill/asm/ab_2501-2550/ab_2514_bill_20100929_chaptered.html.
14. German power exports to France increasing. (2012, February 6). *Renewables International Magazine*: "Prices on the power exchange peaked at 11.3 cents a kilowatt-hour in the evening, but only reached 7.7 cents a kilowatt-hour around noon. One reason might be that clear skies are ensuring a fairly strong performance for solar arrays."
15. The 28,000 MW solar capacity figure is "direct current." Assuming a direct current to alternating current conversion factor of 0.85, this direct current capacity is equivalent to about 24,000 MW of alternating current capacity.
16. Euro utilities declare war on solar PV. (2012, February 12). Energymatters.com.au, http://www.energymatters.com.au/index.php?main_page=news_article&article_id=3072. See also Brattle Group. (2012, June 19). The potential impact of solar PV on electricity markets in Texas, http://www.slideshare.net/SEIA/impacts-of-solar-pv-on-texas-electricity-markets.
17. Merit order: How solar FITs could cut energy bills for all. (2012, February 2). Energymatters.com.au, http://reneweconomy.com.au/2012/merit-order-how-solar-fits-could-cut-energy-bills-for-all.
18. Solar Observer, German PV installations in 2011 even higher than in record year 2010, January 10, 2012. The 3,000 MW figure is direct current capacity.