McCullough Research

Robert F. McCullough, Jr.
Principal

Date: October 5, 2016

To: Mr. Ken Boon

From: Robert McCullough

Subject: Renewables Cost Report

Dear Mr. Boon:

I am pleased to enclose our report detailing the continued decline in cost of solar and on-shore wind energy.

This assessment only reinforces the conclusion I reached in my report last year – renewables such as solar and wind are less than half the cost of hydro.

Average Levelized Cost of Energy for Selected Renewable and Site C Generation

Type of Energy	Average Levelized Cost of Energy (2016 Can$/MWh)[1,2,3,4,5]
Utility-Scale Solar PV (crystalline and thin film)	$59.29
Onshore Wind	$72.57
Site C	$83.91

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[1] Solar and wind estimates from Lazard. "Levelized Cost of Energy Analysis – Version 9.0." November 2015. Accessed October 5, 2016. <https://www.lazard.com/perspective/levelized-cost-of-energy-analysis-90/>. See page 2.

[2] Site C estimate from British Columbia Legislature. "Site C Final Investment Decision Technical Briefing" December 2014. Accessed October 5, 2016. < http://docs.openinfo.gov.bc.ca/d7689015a_response_package_gcp-2014-00162.pdf>.
See page 111.

[3] Solar and wind estimates converted to 2016 $USD using the Bureau of Labor Statistics Consumer Price Index Inflation Calculator. Accessed August 28, 2016. See: <http://data.bls.gov/cgi-bin/cpicalc.pl>.

[4] Solar and wind estimates stated in $CAD using Oanda Currency Converter. Accessed October 5, 2016. See: <https://www.oanda.com/currency/converter/>.

[5] Site C estimate stated in 2016 $CAD using the Bank of Canada Inflation Calculator. Accessed October 5, 2016. See: < http://www.bankofcanada.ca/rates/related/inflation-calculator/>.

While there would be costs associated with suspending or halting construction of Site C, I remain of the view that BC Hydro could save Can$112.74 million on an annual basis by instead building wind and solar.[6] This amount could be higher if tax credits for renewable energy were considered.

To put it another way, BC Hydro could free up an estimated Can$112.74 million annually to spend on other pressing infrastructure projects. Alternatively, BC Hydro could write a cheque for Can$57.84 to every BC household every year.

Some critics say that wind and solar are not viable options because they are intermittent, not firm sources of power. However, hydroelectric projects also provide energy subject to monthly and annual variability. As penetration of renewables increases, the portfolio effect of many different projects has reduced the overall variability of output very significantly in recent years.

Sincerely,

Robert McCullough

[6] This calculation compares Lazard's estimates for the levelized cost of renewable energy to the levelized cost of energy for Site C, and assumes that Site C would generate with a 65% capacity factor. For levelized cost estimates of Site C, see: McCullough Research. "Site C Business Case Assumptions Review." May 25, 2015. Accessed October 4, 2016. <http://www.mresearch.com/pdfs/20150525-SiteC_Economic_evaluation.pdf>. See page 10.

ROBERT F. MCCULLOUGH, JR.
MANAGING PARTNER

Date: October 3, 2016

To: McCullough Research Clients

From: Robert McCullough
Jacob Gellman
Charles Noble
Xian Ng
Ted Sand

Subject: The falling price of renewable energy relative to conventional generation

On June 21 it was reported that the 2,200 MW Diablo Canyon nuclear plant, located in Southern California, will close both its units by 2025. A major factor for Pacific Gas & Electric's (PG&E) agreement to this decision is the economics of the aging plant: the operating costs associated with nuclear power are simply too high compared with the low market cost of electricity.

On a cost basis, nuclear no longer competes favorably with natural gas and renewable energy. The same is true for new coal and hydropower generation. While natural gas prices plummeted over the past decade, the cost of renewables also fell – sharply – as economies of scale in wind and solar dominated the market. Once thought to be too expensive, renewables are becoming a viable option for utilities, as demonstrated by the recent decision in California to replace Diablo Canyon's output with renewables. The cost effectiveness of renewable resources has traditionally been controversial. However, numerous recent studies indicate that renewables are now competitive with thermal resources. As John Maynard Keynes once quipped, "When my information changes, I alter my conclusions. What do you do, sir?"

Prices for renewables are still higher than wholesale market prices, but they have fallen sharply enough that they are now below the operating costs of existing nuclear and new coal and hydropower. Figure 1, taken from a 2016 report by the Under Secretary of the U.S. Department of Energy (DOE), illustrates the dramatic decline in renewable prices.[1]

[1] Orr, Franklin M. "Addressing Climate Change with Clean Energy Technology." American Chemical Society Energy Letters 1, 113-114. June 13, 2016. Accessed August 28, 2016. <http://pubs.acs.org/doi/pdfplus/10.1021/acsenergylett.6b00136>.

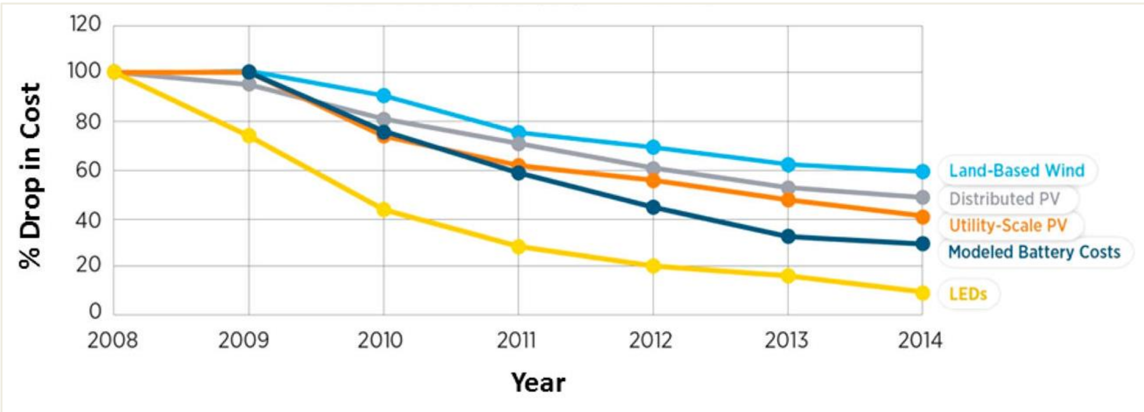

Figure 1: Indexed Cost Reductions Since 2008

The Diablo Canyon decision has relied upon cost reductions in renewables as one argument for closure. The operator, PG&E, details these plans in its joint report, "Joint Proposal for the Orderly Replacement of Diablo Canyon Power Plant with Energy Efficiency and Renewables."[2] The same dynamics apply to other large-scale projects in the Pacific Northwest, such as existing nuclear and large hydropower projects.

In light of the changing landscape for energy, this report explores the cost effectiveness of adding renewable energy to the Pacific Northwest grid.

Contents

[2] M.J. Bradley & Associates, LLC. "Joint Proposal for the Orderly Replacement of Diablo Canyon Power Plant with Energy Efficiency and Renewables." Attachment A, "Application of Pacific Gas and Electric Company (U 39 E) For Approval of the Retirement of Diablo Canyon Power Plant, Implementation of the Joint Proposal, and Recovery of Associated Costs Through Proposed Ratemaking Mechanisms." Filed August 11, 2016 for California Public Utilities Commission (CPUC). Accessed August 11, 2016. <http://www.pge.com/includes/docs/pdfs/safety/dcpp/diablo-canyon-retirement-joint-proposal-application.pdf>.

Figures

Tables

I. The Falling Cost of Renewables

Significant expansion of renewable generation, especially for solar photovoltaics (PV) and on-shore wind, is both plausible and economically sound. Economies of scale, technological innovation, "learning by doing" effects, and fuel price movements for conventional generation have brought significant reductions in the relative cost of solar PV and wind installations, and have made them economically competitive with conventional fossil fuel generations, even without subsidies.

Table 1 presents the levelized cost of energy (LCOE), in 2016 dollars, for various forms of newly built generation. A LCOE compares the cost of new generating resources over the financial and technological lifetime of the project, averaged on a per MWh basis.

Table 1: National Levelized Cost of Energy for Selected Renewable and Conventional Generation

Levelized Cost of Energy (2016 $/MWh)[3]	Joint Institute for Strategic Energy Analysis (2014, excluding subsidies)[4]	Lazard's LCOE Analysis v9.0 (2015, with federal subsidies)[5]	Lazard's LCOE Analysis v9.0 (2017 estimate including subsidies)[6]	EIA American Energy Outlook 2016 (2022 estimate with scheduled tax credits)[7]	NREL Renewable Electricity Futures Study (2050 estimate)[8]
Utility-Scale Solar PV (crystalline)	$86.40-286.66	$47.72-57.87	$38.58	$59.09	$84.13-112.17
Utility-Scale Solar PV (thin film)	$85.10-282.33	$41.63-49.75	$35.54	$59.09	$84.13-112.17
Onshore Wind	$52.86-96.57	$14.21-63.96		$51.68	$56.09-67.30
Nuclear		$98.49-138.08		$101.23	
Gas Combined Cycle	$50.83-108.77	$52.80-79.19		$57.26	
Coal	$64.04-131.13	$66-152.30		$141.76	
Hydroelectric				$64.73	$84.20-168.40

The estimates are suggestive for renewable energy in the Pacific Northwest. For renewables, the key LCOE input that varies by region is the capacity factor, since operation and maintenance (O&M) is negligible and capital costs are constant across regions. Lazard's LCOE for solar assumes between 21% and 32% capacity factor, while the onshore wind estimates assume 30% to 55% capacity factor. In its Seventh Power Plan, the Northwest Power and Conservation Council assumes 32% and 40% capacity factor for wind in the Columbia Basin and in Montana, respectively. Solar capacity factor is assumed at 26% in Southern Idaho and 19% in Western Washington. The LCOE estimates in Table 1 are thus reasonable approximations for costs in the Pacific Northwest.

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[3] All estimates adjusted to 2016 dollars using the Bureau of Labor Statistics Consumer Price Index Inflation Calculator. Accessed August 28, 2016. See: <http://data.bls.gov/cgi-bin/cpicalc.pl>.
[4] Stark, Camila et al. "Renewable Electricity: Insights for the Coming Decade." Joint Institute for Strategic Energy Analysis. February 2015. Accessed August 28, 2016. <http://www.nrel.gov/docs/fy15osti/63604.pdf>.
[5] Lazard. "Levelized Cost of Energy Analysis – Version 9.0." November 2015. Accessed August 28, 2016. <https://www.lazard.com/perspective/levelized-cost-of-energy-analysis-90/>. See page 2 for unsubsidized estimates and page 4 for values including federal tax subsidies.
[6] Ibid., page 4.
[7] EIA. "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2016." August 2016. Accessed August 28, 2016. <https://www.eia.gov/forecasts/aeo/electricity_generation.cfm>. See page 6.
[8] Mai, Trieu et al. "Renewable Electricity Futures Study." National Renewable Energy Laboratory (NREL). 2012. Accessed August 28, 2016. <http://www.nrel.gov/analysis/re_futures/>. See pages A-16 to A-17.

The drop in renewables costs has largely been due to the falling capital costs for installation. The Joint Institute for Strategic Energy Analysis, a partnership between the U.S. DOE and several academic institutions, comments that renewable generation technologies "have zero fuel costs and relatively small variable operation and maintenance costs, so their LCOEs are roughly proportionate to estimated capital costs and the cost of financing."[9]

The capital costs for solar PV and wind installation are already lower than those for new coal or nuclear generation, and are approaching or have already matched those of natural gas. Table 2 presents estimates of the overnight capital cost of installing a number of renewable and conventional generation types from various sources.

[9] Stark, Camila et al. "Renewable Electricity: Insights for the Coming Decade." Joint Institute for Strategic Energy Analysis. February 2015. Accessed August 28, 2016. <http://www.nrel.gov/docs/fy15osti/63604.pdf>.

Table 2: National Overnight Capital Cost for Installation of Conventional and Renewable Energy Sources

Capital Costs (2016 $/kW)[10]	Lazard LCOE Analysis (2015)[11]	Lazard LCOE Analysis (2017 estimate)[12]	V. John White and Associates and James Caldwell[13]	EIA American Energy Outlook 2016[14]	NREL RE Futures (2030 Estimate)[15]	NREL RE Futures (2050 Estimate)[16]
Utility-Scale Solar PV (crystalline)	$1,522.97-$1,776.80	$1,370.68	$1,541.05	$2,517.98	$2,591.14	$2,277.06
Utility-Scale Solar PV (thin film)	$1,421.44-$1,624.50	$1,370.68	$1,541.05	$2,517.98	$2,591.14	$2,277.06
Wind	$1,269.14-$1,726.04			$1,669.18	$2,108.80	$2,108.80
Nuclear	$5,482.70-$8,325.59			$6,206.85		
Gas Combined Cycle	$1,015.32-$1,319.91			$971.47		
Coal	$3,045.95-$8,528.65			$5,180.51		
Hydroelectric				$2,450.02	$3,929.32-6,174.65	$3,929.32-6,174.65

For the NWPP specifically, EIA estimates capital costs of $2,012.05/kW for wind and $2,482.54/kW for solar photovoltaic, compared to $2,450.02/kW for new hydropower, stated in 2016 dollars.[17]

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[10] All estimates adjusted to 2016 dollars using the Bureau of Labor Statistics Consumer Price Index Inflation Calculator. Accessed August 30, 2016. See: <http://data.bls.gov/cgi-bin/cpicalc.pl>.
[11] Lazard. "Levelized Cost of Energy Analysis – Version 9.0." November 2015. Accessed August 28, 2016. <https://www.lazard.com/perspective/levelized-cost-of-energy-analysis-90/>.
[12] Lazard. "Levelized Cost of Energy Analysis – Version 9.0." November 2015. Accessed August 28, 2016. <https://www.lazard.com/perspective/levelized-cost-of-energy-analysis-90/>.
[13] V. John White and Associates and Caldwell, James. "A Cost Effective and Reliable Zero Carbon Replacement Strategy for Diablo Canyon Power Plant." Study commissioned by Friends of the Earth. 2016. Accessed August 28, 2016. <http://lowcarbongrid2030.org/wp-content/uploads/2016/PDFs/160627_Diablo-Final-Report.pdf>. See page 40.
[14] EIA. "Cost and Performance Characteristics of New Generating Technologies, Annual Energy Outlook 2016." June 2016. Accessed August 28, 2016. <http://www.eia.gov/forecasts/aeo/assumptions/pdf/table_8.2.pdf>. See page 2.
[15] Ibid., page A-11.
[16] Ibid., page A-11.
[17] EIA. "Cost and Performance Characteristics of New Generating Technologies, Annual Energy Outlook 2016." June 2016. Accessed August 28, 2016. <http://www.eia.gov/forecasts/aeo/assumptions/pdf/table_8.2.pdf>. See page 3.

A. Developments in Utility-Scale Solar

The majority of growth in solar PV generation in recent years has been at a utility-scale. Nationally, utility-scale generation grew from only 157 GWh in 2009 to 23,232 GWh in 2015, representing two-thirds of all solar PV generation in 2015.[18]

In Oregon, Washington, Idaho, and Montana, solar PV had a total installed capacity of 18.4 MW in 2009, but grew to 109.2 MW in 2015.[19] The BPA Interconnection Queue is a strong indicator of the market's readiness to transition to renewable electricity. Of the transmission service requests processed since 2011, there are 2,940 MW of solar resources in queue.[20] See Figure 17.

The cost of solar generation fell dramatically in the 2009-2015 period. The reduction in LCOE for solar PV over this period is estimated to be 82%, according to the annual analysis conducted by the financial advisory firm Lazard.[21] Lazard estimates the LCOE for solar PV in 2016 to be between $41 and $57/MWh based on current tax policy, and forecasts further cost declines to bring the LCOE to below $40/MWh in 2017.[22]

Lazard's estimates are based on existing regulation and standard assumptions on financing, and focus primarily on the upfront costs of installation. As such, they do not take into account the potential costs related to transmission, storage, or back-up generation, nor do they account for the relative savings due to future regulation such as the Environmental Protection Agency (EPA) Clean Power Plan, or regulated carbon pricing.

Other estimates of the cost of solar generation broadly reflect the same result: utility-scale solar PV has become dramatically cheaper. It is close to or already competitive with conventional generation, such as combined-cycle natural gas, even when unsubsidized. Research from the Lawrence Berkeley National Laboratory finds that recently signed Power Purchase Agreements (PPAs) for solar PV at $50/MWh are economically sound, even when unsubsidized.[23]

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[18] EIA. "Electric Power Monthly with Data for June 2016." August 24, 2016. Accessed August 28, 2016. <http://www.eia.gov/electricity/monthly/>.
[19] Renewable Northwest Project. "Renewable Energy Projects." Accessed September 26, 2016. <http://www.rnp.org/project_map>.
[20] BPA. "Interconnection Request Queue." Accessed August 28, 2016. <https://www.bpa.gov/transmission/doing%20business/interconnection/pages/default.aspx>.
[21] Lazard. "Levelized Cost of Energy Analysis – Version 9.0." November 2015. Accessed August 28, 2016. <https://www.lazard.com/perspective/levelized-cost-of-energy-analysis-90/>.
[22] Ibid., page 4. Figures stated in 2015 dollars.
[23] Bolinger, Mark et al. "Is $50/MWh Solar for Real? Falling Project Prices and Rising Capacity Factors Drive Utility-Scale PV Toward Economic Competitiveness." Ernest Orlando Lawrence Berkeley National Laboratory. May 2015. Accessed August 28, 2016. <https://emp.lbl.gov/sites/all/files/lbnl-183129_0.pdf>.

Various estimates of the LCOE for new solar PV installations are displayed in Table 1. Given current tax policy, solar PV represents an economically viable substitute for fossil fuel generation on a LCOE basis.

The Lawrence Berkeley National Laboratory recently published its annual review of solar technology.[24] The report cites a substantial reduction in utility-scale solar installations for power purchase agreements (PPA):

> "PPA Prices: Driven by lower installed project prices and improving capacity factors, levelized PPA prices for utility-scale PV have fallen dramatically over time, by $20-$30/MWh per year on average from 2006 through 2013, with a smaller price decline of ~$10/MWh per year evident in the 2014 and 2015 samples. Most PPAs in the 2015 sample—including many outside of California and the Southwest—are priced at or below $50/MWh levelized (in real 2015 dollars), with a few priced as aggressively as ~$30/MWh. Even at these low price levels, PV may still find it difficult to compete with existing gas-fired generation, given how low natural gas prices (and gas price expectations) have fallen over the past year. When stacked up against new gas-fired generation (i.e., including the recovery of up-front capital costs), PV looks more attractive—and in either case can also provide a hedge against possible future increases in fossil fuel costs."[25]

The technology for utility-scale solar is based on two major approaches: crystalline silicon ("c-SI") and thin film ("CdTE"). There are numerous reasons why the efficiency and cost effectiveness of solar has improved in recent years. Bolinger and Seel, the report writers, cite technological improvement, especially the rapid increase in tracking – 70% of capacity added in 2015 used tracking technology.[26] Solar equipment costs have also declined in price due to improvements in manufacturing costs.[27]

There is a continuing efficiency competition between the two major solar technologies. Again, Bolinger and Seel report that the efficiencies of the two approaches are currently comparable.[28]

Figure 3 shows changes in Lazard's cost estimates since 2010.

[24] Bolinger, Mark and Seel, Joachim. "Utility-Scale Solar 2015: An Empirical Analysis of Project Cost, Performance, and Pricing Trends in the United States." Lawrence Berkeley National Laboratory, U.S. Department of Energy. August 2016. Accessed August 28, 2016. <https://emp.lbl.gov/sites/all/files/lbnl-1006037_report.pdf>.

[25] Ibid., page ii.

[26] Ibid., page 5, page ii.

[27] Chung, Donald et al. "U.S. Photovoltaic Prices and Cost Breakdowns: Q1 2015 Benchmarks for Residential, Commercial, and Utility-Scale Systems." NREL. 2015. Accessed September 1, 2016. <http://www.nrel.gov/docs/fy15osti/64746.pdf>. See pages iv and 2.

[28] Ibid., page 5.

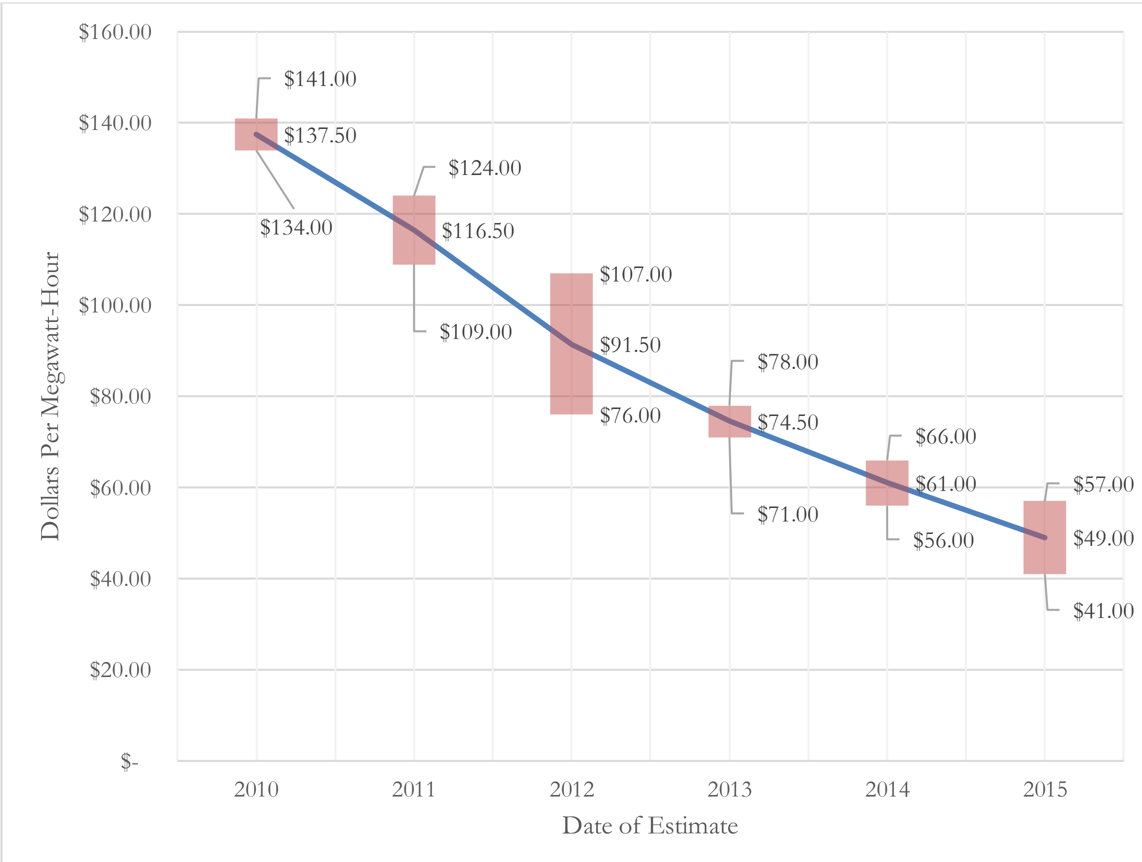

Figure 2: Levelized Cost of Energy for Solar (Lazard Historical Estimates)

i) Solar Peaking

Recent developments in storage also suggest renewables may be a viable alternative to conventional gas peaker plants. Solar PV generation already has a lower LCOE than that of gas peakers, estimated at $165-218/MWh; as Lazard notes, "utility-scale solar is becoming a more economically viable peaking energy product in many areas of the U.S."[29] Pumped hydro and battery storage present a means to add the requisite dispatchability to use renewable generation as a peaker option. Already, Southern California Edison Co. has picked a battery storage option to replace a 100 MW gas peaker in 2021.[30]

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[29] Lazard. "Levelized Cost of Energy Analysis – Version 9.0." November 2015. Accessed August 28, 2016. <https://www.lazard.com/perspective/levelized-cost-of-energy-analysis-90/>.
[30] Fialka, John. "World's Largest Storage Battery Will Power Los Angeles." Scientific American. July 7 2016. Accessed August 28, 2016. <http://www.scientificamerican.com/article/world-s-largest-storage-battery-will-power-los-angeles/>.

B. Developments in Onshore Wind

Wind generation is a more mature technology compared to solar PV. In 2015, wind generation in the U.S. totaled 190,927 GWh, representing 4.7% of all electricity generation.[31] In recent years the cost of onshore wind generation has also declined steeply, if less dramatically, than that of solar PV generation. Lazard reports that the LCOE for onshore wind has fallen by 61% over the 2009-2015 period.[32]

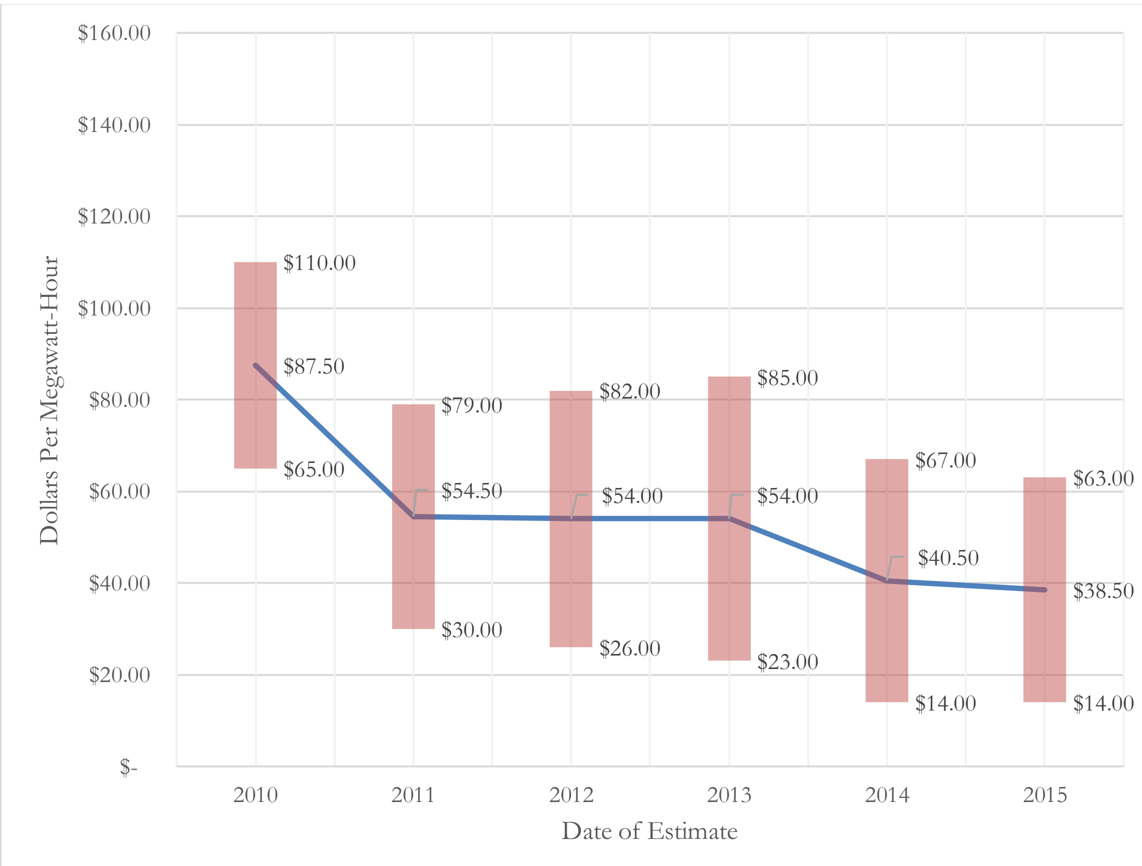

Figure 3: Levelized Cost of Energy for Wind (Lazard Historical Estimates)

In Oregon, Washington, Idaho, and Montana, onshore wind had a total installed capacity of 4,253.55 MW in 2009, and grew to 7,866.95 MW in 2015.[33] Since 2011, of the transmission

[31] EIA. "Electric Power Monthly with Data for June 2016." August 24, 2016. Accessed August 28, 2016. <http://www.eia.gov/electricity/monthly/>.
[32] Lazard. "Levelized Cost of Energy Analysis – Version 9.0." November 2015. Accessed August 28, 2016. <https://www.lazard.com/perspective/levelized-cost-of-energy-analysis-90/>.
[33] Renewable Northwest Project. "Renewable Energy Projects." Accessed September 26, 2016. <http://www.rnp.org/project_map>.

service requests in BPA's Interconnection Queue, there are 2,361 MW of wind resources in queue.[34] See Figure 17.

Table 1 compares LCOE estimates for renewable and conventional generation technologies. Adjusted to 2016 dollars, wind generation had a LCOE $14.21 to $63.96/MWh when accounting for subsidies. This competes favorably with nuclear, which was estimated at $98.49 to $138.08/MWh in 2016 dollars. Table 2 presents the overnight capital costs to install various forms of generating technology. Onshore wind is competitive with conventional fossil fuel generation technologies, with an LCOE comparable to or even lower than that of combined cycle natural gas generation. Capital costs for wind installation have fallen significantly in recent years and are also comparable to, or lower than, conventional generation technologies.

Wind generation has many of the same advantages and drawbacks of solar PV. Wind generation enjoys no fuel price risk, but is not dispatchable. Both technologies are resource-dependent. Expansion of storage technology, namely from battery and pumped hydroelectric storage, are potential future solutions to the problem of dispatchability. In the future, transmission infrastructure may connect uncorrelated or negatively correlated loads across large geographic distances.[35] Going forward, we expect investments in storage and transmission to reduce the salience of dispatchability issues, even as the total share of renewable generation continues to grow.

II. Contribution to Resource Adequacy

A. Capacity Requirements

One concern with replacing conventional generation with renewables is the intermittent nature of solar and wind power. The Western Electricity Coordinating Council (WECC) uses a "Rule of Thumb" to evaluate the effects of wind and solar power on resource adequacy and loss of load expectation (LOLE).

Michael Milligan of the NREL summarized capacity valuations across the WECC in a recent presentation for the agency.[36]

[34] BPA. "Interconnection Request Queue." Accessed August 28, 2016. <https://www.bpa.gov/transmission/doing%20business/interconnection/pages/default.aspx>.
[35] Mai, Trieu et al. "Renewable Electricity Futures Study." NREL. 2012. Accessed August 28, 2016. <http://www.nrel.gov/analysis/re_futures/>. See pages A-16 to A-17.
[36] Milligan, Michael. "Capacity Value: Evaluation of WECC Rule of Thumb." WECC. May 2015. Accessed August 28, 2016. <https://www.wecc.biz/Administrative/wecc%20elcc%20milligan%20May%202015.pdf>. See page 9.

Contribution to Resource Adequacy

Capacity credit by technology and pool that
TEPPC uses to meet the reserve margin criteria

Generation Type	AZ-NM-NV	Basin	Alberta	BC	CA-North	CA-South	NWPP	RMPA
Biomass RPS	100%	100%	100%	100%	66%	65%	100%	100%
Geothermal	100%	100%	100%	100%	72%	70%	100%	100%
Small Hydro RPS	35%	35%	35%	35%	35%	35%	35%	35%
Solar PV	**60%**	**60%**	**60%**	**60%**	**60%**	**60%**	**60%**	**60%**
Solar CSP0	90%	95%	95%	95%	72%	72%	95%	95%
Solar CSP6	95%	95%	95%	95%	100%	100%	95%	95%
Wind	**10%**	**10%**	**10%**	**10%**	**16%**	**16%**	**5%**	**10%**
Hydro	70%	70%	90%	90%	70%	95%	70%	70%
Pumped Storage	100%	100%	100%	100%	100%	100%	100%	100%
Coal	100%	100%	100%	100%	100%	100%	100%	100%
Nuclear	100%	100%	100%	100%	100%	100%	100%	100%
Combined Cycle	95%	95%	100%	95%	95%	95%	95%	95%
Combustion Turbine	95%	95%	100%	95%	95%	95%	95%	95%
Other Steam	100%	100%	100%	100%	100%	100%	100%	100%
Other	100%	100%	100%	100%	100%	100%	100%	100%
Negative Bus Load	100%	100%	100%	100%	100%	100%	100%	100%
Dispatchable DSM	100%	100%	100%	100%	100%	100%	100%	100%

Figure 4: Milligan presentation on WECC rule of thumb for renewable capacity value

In the NWPP only 5% of wind capacity and 60% of solar PV capacity are used to meet the reserve margin criteria. For nuclear, 100% is counted; for hydropower, 70% is counted.

However, the existing and projected capacity for the NWPP indicate no problems relative to resource adequacy. The NERC 2015 Long-Term Reliability Assessment reports that the NWPP will exceed its reference margin level through 2025.[37]

[37] North American Electric Reliability Corporation (NERC). "2015 Long-Term Reliability Assessment." December 2015. Accessed August 17, 2016. <http://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/2015LTRA%20-%20Final%20Report.pdf>.

WECC

WECC-NWPP-US: Peak Season Demand, Resources and Reserve Margins

Demand (MW)	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Total Internal Demand	50,001	50,417	50,941	51,387	51,803	52,172	52,579	52,956	53,367	53,796
Demand Response	1,285	1,294	1,292	1,289	1,286	1,283	1,285	1,293	1,290	1,287
Net Internal Demand	48,716	49,123	49,649	50,098	50,517	50,889	51,294	51,663	52,077	52,509
Resources (MW)	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Anticipated	65,322	65,928	65,680	65,651	66,174	64,814	64,701	64,311	64,211	63,103
Prospective	65,201	66,043	64,965	64,820	65,342	63,811	63,586	63,196	63,095	61,988
Reserve Margins (%)	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Anticipated	34.09%	34.21%	32.29%	31.04%	30.99%	27.36%	26.14%	24.48%	23.30%	20.18%
Prospective	33.84%	34.44%	30.85%	29.39%	29.35%	25.39%	23.96%	22.32%	21.16%	18.05%
Reference Margin Level	15.40%	15.40%	15.40%	15.40%	15.40%	15.40%	15.40%	15.40%	15.40%	15.40%
Excess/Shortfall (MW)	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Anticipated	9,104	9,240	8,385	7,838	7,877	6,088	5,508	4,692	4,114	2,508
Prospective	8,983	9,355	7,670	7,007	7,046	5,085	4,392	3,577	2,999	1,392

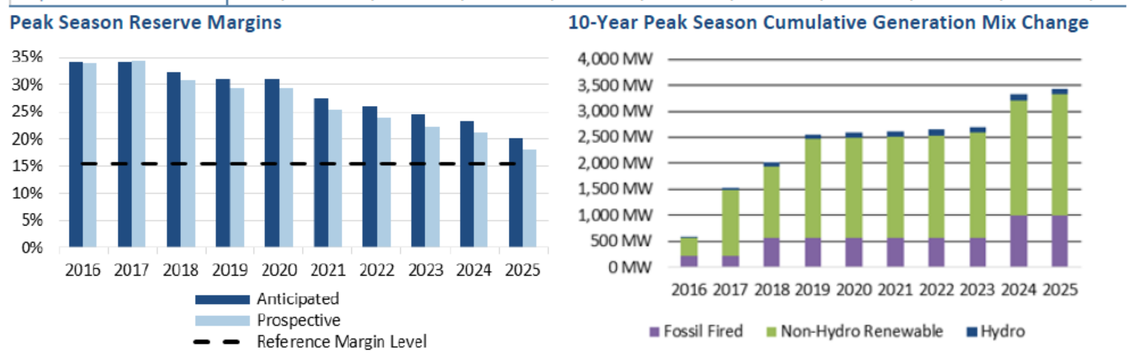

Figure 5: NERC forecast on NWPP peak season demand, resources, and reserve margins

B. Increasing Renewable Resource Diversity

Traditionally, the intermittent nature of thermal resources caused by planned and forced outages is mitigated by assembling a portfolio of diverse thermal resources. It is broadly recognized that assembling a similar portfolio of renewable resources will gradually increase the potential capacity contribution.

An indication of the impact of additional geographic and technological diversity can be seen in EIA monthly generation data. See Figure 16.

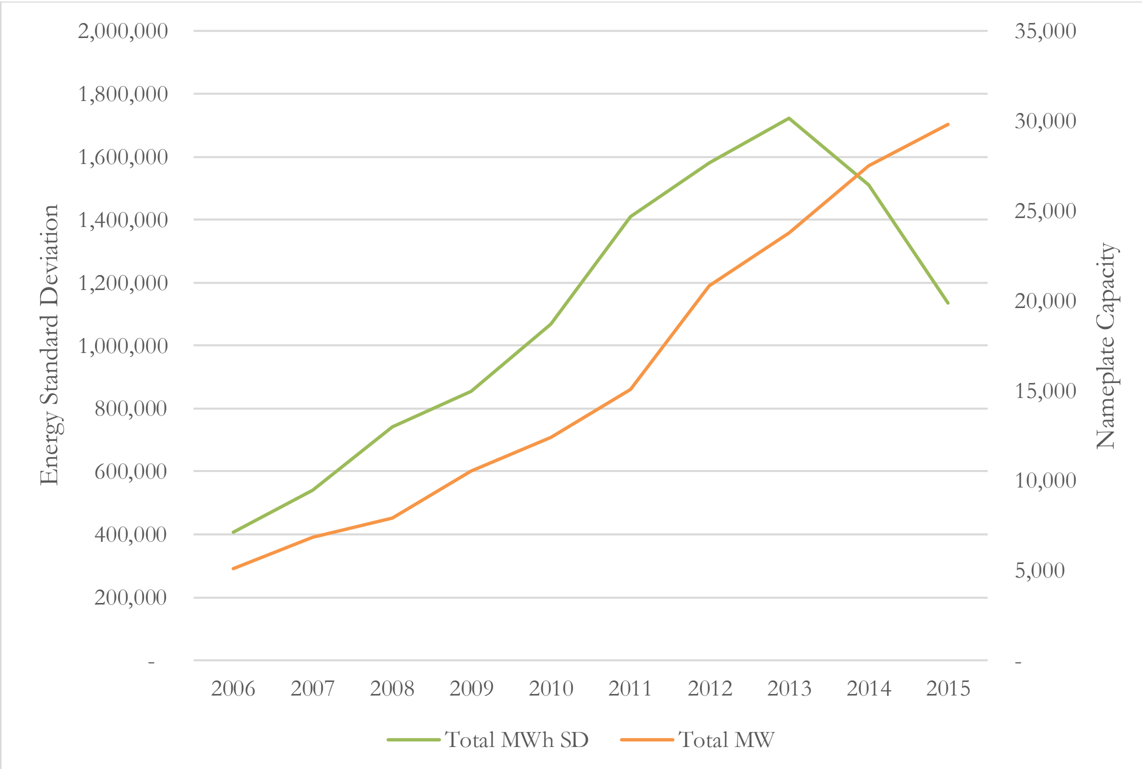

Figure 6: WECC Renewable Generation: Nameplate Capacity and Standard Deviation of Energy Generation

On a monthly basis, Figure 16 indicates that the variability of renewables has been decreasing as additional diversity – both geographical and technological – has been added.

C. BPA Interconnection Queue

The BPA Interconnection Queue is a strong indicator of the market's readiness to transition to renewable electricity.[38] Of the transmission service requests processed since 2011, there are 2,940 MW of solar resources in queue and 2,361 MW of wind resources in queue. Both of those resources surpass the natural gas requests, which total 2,902 MW of capacity.

[38] BPA. "Interconnection Request Queue." Accessed August 28, 2016. <https://www.bpa.gov/transmission/doing%20business/interconnection/pages/default.aspx>.

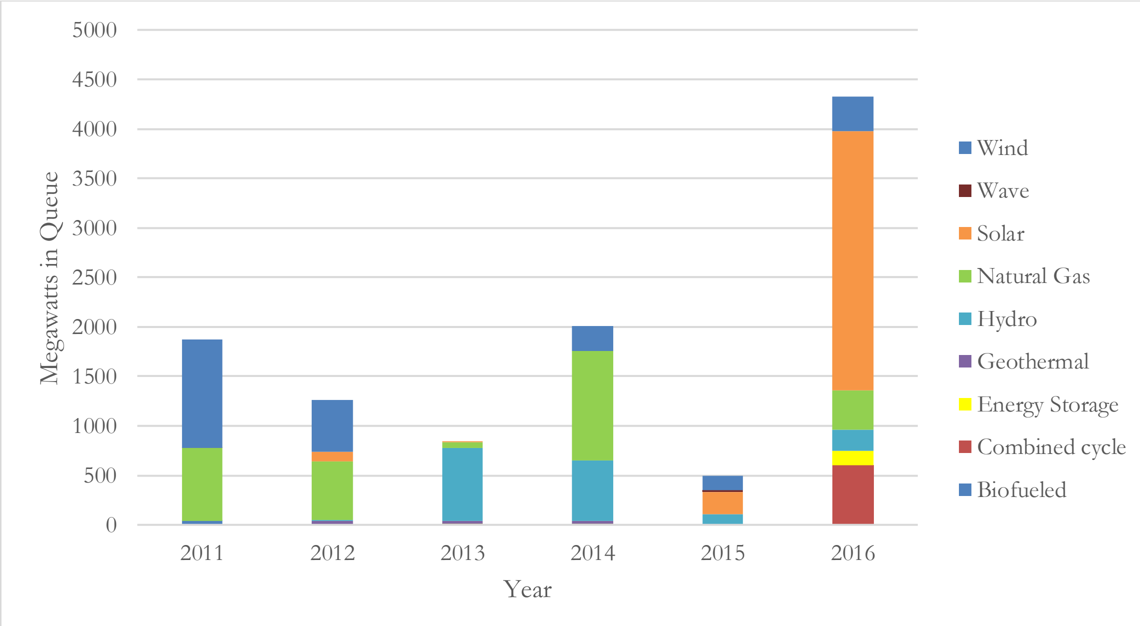

Figure 7: BPA Transmission Service Requests by Technology

While not all of these resources will be built, it is a strong sign of the shift in the market and the availability of cost effective alternatives.

III. Conclusion

When PG&E surveyed its options, it found that an old, expensive nuclear plant was no longer competitive. Cheaper renewable technologies were available, and the inflexible generation of Diablo Canyon did not meet its customers' needs.

Similarly, large-scale generation projects in the Pacific Northwest should be viewed with caution, as renewable resources provide cheaper and more diverse resource options. Due to falling costs, solar and wind provide a lower-cost and more flexible alternative.