Achieving California's 2030 Renewable Portfolio Standard and Electricity Sector Greenhouse Gas Emission Reduction Target

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Introduction

California has set a target to reduce greenhouse gas emissions to 40 percent below 1990 levels by the year 2030. To achieve this goal, the California Air Resources Board recommends emissions reductions of 43 to 61 percent below 1990 levels from the electricity sector in particular. The primary vehicle for achieving greenhouse gas reductions from electricity generation is the state's Renewable Portfolio Standard, which requires retail sales to consist of 50 percent renewables by the year 2030. This paper examines the challenges to creating a low-carbon grid, and discusses the regulatory, infrastructural, and operational changes that will be necessary to achieve California's greenhouse gas reduction and renewables portfolio standard targets.¹

I. California's Climate and Energy Goals

a. Policies

For the past decade, California has been aggressively pursuing a variety of climate change mitigation policies.² The Global Warming Solutions Act of 2006, Assembly Bill (AB) 32, established a comprehensive program to reduce statewide greenhouse gas (GHG) emissions. AB 32 required the state to reduce total GHG emissions to 1990 levels by 2010. In 2015, Governor Brown signed Executive Order No. B-30-15, setting a new statewide GHG emissions reduction target of 40 percent below 1990 levels by 2030.³ Senate Bill (SB) 32 codified Brown's GHG emissions reduction goal in 2016.

The Brown Administration announced six "pillars" that make up California's climate change strategy:

- 1. Increase production of electricity from renewables to 50%.
- 2. Reduce petroleum use in vehicles by 50%.
- 3. Double energy efficiency in existing buildings.
- 4. Reduce GHG emissions from natural and working lands.
- 5. Reduce short-lived climate pollutants.
- 6. Update the state's climate adaptation strategy, "Safeguard California."⁴

The first pillar, increasing electricity production from renewable sources, is the focus of this paper. The California Renewables Portfolio Standard (RPS) was created in 2002 under SB 1078, setting mandates for the procurement of electricity from renewable sources by investor-owned utilities (IOUs), electric service providers, and community choice aggregators.⁵ The program has been repeatedly updated; in 2011, the RPS target was increased to 33 percent of total procurement by 2020.⁶ In 2015, Governor Brown signed SB 350, increasing the state's RPS target to 50 percent by 2030.⁷

California has also been promoting the adoption of renewable distributed energy resources (DER) through the development of interconnection standards, net energy metering (NEM) programs, and rebates. By the end of 2016, California had 5,096 megawatts (MW) of installed distributed generation capacity.⁸

b. Plans

On January 20, 2017, the California Air Resources Board (CARB) published a Scoping Plan update, laying out a proposed strategy for achieving California's 2030 GHG emissions reduction goal.⁹ The Scoping Plan includes estimates for the amount of GHG reductions required

from each sector in order to meet the statewide target. Emissions reductions required from the electric power sector, achieved primarily through the RPS program, are estimated to be 43 to 61 percent below 1990 levels.¹⁰ To achieve this target range, emissions from electricity generation must fall between 61 and 42 million metric tons of CO_2 equivalent (MMTCO₂e).

c. Progress

Thus far, California has been on track to meet its 2020 GHG and RPS goals. The statewide 2020 GHG emissions limit (reduction to 1990 levels) is approximately 431 MMTCO₂e.¹¹ California's emissions inventory for 2014 (its most recent) calculates statewide emissions to be 441.5 MMTCO₂e – about 2.4 percent above the 2020 target.¹² This represents a 9.4 percent decrease since peak emissions levels in 2004.

In 1990, GHG emissions from the electric power sector were approximately 108 $MMTCO_2e^{13}$ Total emissions from electric generation in 2014 were 88.39 $MMTCO_2e^{14}$ This represents an 18 percent decrease from 1990, despite a nearly 80 percent growth in the state economy and a 30 percent growth in state population.¹⁵



State- and sector-wide emissions inventories for the past two years have not been published. However, the California Independent System Operator (CAISO) recently began tracking CO₂ emissions (but not total GHG emissions) from resources serving the CAISO grid.¹⁷ CAISO manages the flow of electricity across transmission lines that make up 80 percent of California's and a small part of Nevada's grid.¹⁸ In 2014, total CO₂ emissions to serve CAISO load were 68.78 MMTCO₂, about 78 percent of total GHG emissions from the electricity sector. Between 2014 and 2016, CAISO CO₂ emissions dropped to 57.40 MMTCO₂.¹⁹ If CAISO CO₂ emissions reductions are proportional to GHG emissions reductions from statewide electricity generation, then 2016 electricity emissions are approximately 74 MMTCO₂, or 31 percent below 1990 levels. However, this figure is speculative. Because more recent statewide electricity

generation emissions data is not available, it is difficult to estimate how much more progress is necessary to reach the Scoping Plan's range.

California is ahead of schedule for meeting its 2020 RPS target. The California Energy Commission (CEC) estimates that about 27 percent of California's electricity retail sales were served be renewable sources in 2016.²⁰ From 2010 through 2016, renewable energy generation grew from around 40,000 gigawatt hours (GWh) to nearly 70,000 GWh.²¹ To reach its 2030 RPS target, California must nearly double its renewable energy percentage within 14 years.



Self-generation from distributed solar is not included in the renewable portfolio standard. California's distributed solar capacity grew by seven-fold from 2010 through 2016, totaling 5,096 MW of installed capacity.²³

II. Challenges to Achieving a Low-GHG Grid

Management of the grid becomes increasingly complex as intermittent renewables contribute a greater share of electricity generation. Furthermore, more renewables in the energy portfolio does not directly correlate with reductions in GHG emissions. This section examines the challenges to achieving California's RPS and GHG emissions targets.

a. Frequency Regulation and the Duck Curve

Electricity is transmitted as alternating current (AC), because the transmission of AC across long distances is easier and more efficient than transmission of direct current.²⁴ AC on the grid oscillates at a specific frequency. A gap between power supply and demand causes the grid frequency to change. Under-generation causes frequency to fall, creating brownouts and blackouts, whereas over-generation causes frequency to go up, potentially damaging the grid or electrical devices plugged into it.²⁵ Grid operators must continually balance the grid to maintain power frequency within tight frequency tolerance limits.²⁶

Generation from renewable sources like solar and wind is intermittent. If a cloud passes over the sun, generation from solar resources falls. If the wind picks up, generation from wind resources increases. As penetration of intermittent resources into California's generation mix grows, management of grid load becomes more challenging. Wind (39 percent of renewable generation) and solar (23 percent of renewable generation) now represent over a majority of renewables in retail sales.²⁷

Solar is California's fasted growing renewable source. In addition to being intermittent, solar can only generate electricity during daylight hours. Absent energy storage, this limits the share of electricity demand that can be met by solar generation. When the sun sets, solar energy must be replaced by capacity from other sources. Currently, natural gas "peaker" plants are California's main source of fast-ramping capacity.

The timing imbalance between solar power production and peak electricity demand creates what is called a "duck curve." Solar generation makes up a significant portion of total load during the day (creating the "belly" of the duck), but tapers out just before peak demand, when people come home from work and use the most electricity. The "neck" of the duck represents the rapid ramp in electricity required from other sources in order replace solar generation and meet peak demand in the evenings.



As solar continues to grow in California, the duck curve has rapidly become more pronounced. (See Figure 3). Analysis by consultancy ScottMadden demonstrates that the California duck curve is growing even quiker than anticipated by CAISO projections in 2013.²⁹ As the duck curve becomes more pronounced, so does the need for flexible, quick-reacting, fast-ramping capacity that can start from zero or low-electricity operating levels.³⁰ Reliance on a fleet of fossil fueled "peaker" plants to offset an increasingly pronounced duck curve is detrimental to California's low-carbon goals.

b. Over-Generation and Curtailment

Increased penetration of intermittent resources also leads to greater risk of overgeneration. As mentioned above, over-generation (greater supply than demand) causes the grid frequency to go up, which can damage the grid. To mitigate imbalance, grid operators must "curtail" generation by sending a signal to generators to operate at a lower capacity. ³¹ However, a large portion of California's fleet is inflexible and unable to respond quickly to load changes.³² Nuclear and hydro must continue to operate for safety reasons. Contractual obligations and technical limitations impose high "must-run" requirements on many conventional sources.³³ Furthermore, certain Southern California Edison (SCE) and San Diego Gas & Electric (SDG&E) regions require that conventional power plants supply 25 percent of electricity demand in each hour, in order to comply with NERC reliability standards. These "regional generation requirements" are due to transmission line limitations, necessitating reliable local capacity in the event of transmission losses.³⁴ Together, these facilities "crowd out" renewable generation, forcing renewable sources to operate below their maximum output to prevent oversupply on the grid.

A February 2017 memorandum from CAISO states that, "[w]ith the bountiful hydro conditions expected this year and significant additional solar installations both in the form of central station and on rooftops" CAISO forecasts "the need to curtail from 6,000 MW to 8,000 MW" this coming spring.³⁵ As California's renewable capacity grows, CAISO predicts that curtailment events could surpass 13,000 MW by 2024.³⁶ Without additional changes to the grid, a 50 percent RPS would result in significant curtailment of renewable generation, impacting electricity costs and GHG emissions.³⁷

c. Decreased Hydropower and Nuclear Generation

Large hydroelectric and nuclear plants have historically been significant sources of zeroemission generation. However, hydropower can vary greatly from year to year. For example, from 2011 to 2014, drought caused generation from large hydropower to drop from 35,682 GWh (17.7 percent of total generation) to 11,569GWh (5.8 percent of total generation).³⁸ The same time frame witnessed a similar plunge in nuclear generation, due to closure of the San Onofre nuclear facility. (See Figure 4). These losses in conventional zero-emission generation have been



offset by natural gas-fired power plants, leading to increases in GHG emissions from in-state generation.³⁹

Figure 4: (*Left*) *In-state zero-GHG generation*. (*Right*) *In-state electricity generation by fuel type*.⁴⁰ *Credit: CARB*

Hydroelectricity will become increasingly unreliable as climate change progresses, and California's last remaining nuclear power plant is scheduled to shut down in 2025.⁴¹ California must therefore turn to other zero-emission capacity to ensure reductions in GHG emissions from electricity generation.

III. Tools for Renewables Integration and GHG Reduction

a. Value-Driven Renewable Energy Procurement

Thus far, California has been successful at achieving its renewables portfolio targets. However, California's prevailing methodology for valuating renewables projects only considers how cheap the power source is, without considering "true integration costs" and the impacts to grid stability.⁴² Renewable sources have very different generation patterns depending on source type and location. Taking generation patterns into account while developing the renewable portfolio can go a long way towards regulating grid load.⁴³ A National Renewable Energy Laboratory (NREL) study that compared different 50 percent renewable portfolio scenarios found that portfolios with greater diversity (i.e. greater investment in geothermal, biomass, and concentrated solar thermal) would also achieve greater emissions reductions than portfolios with a high percentage of solar generation.⁴⁴ (See Section IV(b) below).





Geothermal has a stable generation output, making it an excellent zero-emission baseload resource. With its high capacity factor, a modest sized geothermal facility can produce as much electricity as a much larger wind or solar facility.⁴⁶ A U.S. Geological Survey has estimated that "conventional and unconventional geothermal resources in the western U.S. are equivalent to half of the current installed generation capacity of the U.S.; however, commercial development of these resources would require significant technological advances to lower the cost of geothermal deployment."⁴⁷ As of March 2016, California had 2,700 MW of geothermal capacity, which generated around 4.4 percent of California's total production.⁴⁸ Planned projects are estimated to increase total capacity to about 4,000 MW.⁴⁹ The CEC recently awarded the Lawrence Berkeley National Laboratory (Berkeley Lab) \$2.7 million dollars for two projects aimed at making geothermal energy more cost-effective to deploy and flexible to operate.⁵⁰

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In contrast to PV systems, solar thermal power plants can guarantee capacity. At night or when cloudy, a parallel burner can produce steam. This burner can be fired by fossil fuels, or renewable sources like biomass.⁵¹ Furthermore, solar thermal facilities provide the opportunity to store solar energy in the form of superheated fluids or salts, allowing generation to occur hours after the solar energy has been gathered.⁵²

Although intermittent, the time period during which wind and solar PV generate electricity can be adjusted depending on location and orientation.⁵³ This offers an opportunity to diversify on the basis of project siting and design. Locations that generate more wind electricity in the evenings and at night can help mitigate the solar duck curve. Solar panels that are oriented to the west can produce power up to two hours later in the afternoon than south-facing panels (allowing more solar energy to meet peak demand), but produce fewer total kilowatt hours. Time-differentiated compensation could induce producers to install west-facing panels or tracking systems to increase generation during ramping hours when generation is most valuable.⁵⁴



Figure 6: Average daily generation profile (kW) from rooftop PV systems for south and west oriented systems.⁵⁵ Credit: RAP

b. Demand Response Capacity

Demand Response (DR) mechanisms can be used to influence end-use consumption patterns, shifting demand and modifying load shape. This can reduce ramping requirements and reduce over-generation that leads to renewables curtailment. DR tools can also provide flexible capacity to the grid, capable of responding to short ramp-ups and disturbances. The CPUC and CEC are actively working to enhance the role of DR in California's resource planning and grid operations.⁵⁶

A recent report by the Berkeley Lab, commissioned by the CPUC, defines four types of DR services:

- 1) *Shape* includes DR tools that reshape "the underlying load profile through relatively long-run price response or on behavioral campaigns," such as time-of-use and critical peak pricing rates.
- 2) *Shift* is "DR that encourages the movement of energy consumption from times of high demand to times of day when there is surplus of renewable generation," through the use of behind-the-meter storage, EV charging, and pre-cooling with HVAC units.

- 3) *Shed* refers to "loads that can occasionally be curtailed to provide peak capacity and support the system in emergency or contingency events," such as interruptible processes, advanced lighting controls, AC cycling, and behind-the-meter storage.
- 4) Shimmy describes the use of "loads to dynamically adjust demand on the system to alleviate short-run ramps and disturbances at timescales ranging from seconds up to an hour," with tools such as advanced lighting, fast-response motor control, and EV charging.⁵⁷



"Shift" DR resources were identified as having the highest potential value to the grid.⁵⁸

Figure 7: Demand Response service types presented over timescale for grid service dispatch frequency and/or response.⁵⁹ Credit: Lawrence Berkeley National Laboratory

The Berkeley Lab Report found that time-of-use (TOU) pricing "could be a low-cost opportunity to advanced adoption of DR technologies."⁶⁰ TOU rates are higher during peak demand periods and lower during off-peak periods. This encourages customers to reduce electricity consumption during peak hours (e.g. reducing AC use) and shift use to off-peak hours (e.g. running laundry machine mid-day), thereby reducing peak load. TOU pricing should encourage customers to adopt management technologies like price-responsive thermostats, and to "configure their [distributed energy resource] systems to generate energy at times that better align with the later-shifted peak periods,"⁶¹ such as by installing west-facing PV panels, and investing in behind-the-meter energy storage.⁶² In January 2017, the CPUC adopted a decision setting guidelines for establishing default TOU rates for all customers by 2019.⁶³

The CPUC is also in the process of developing a Demand Response Auction Mechanism (DRAM), in which third parties bid to provide demand response capacity in CAISO's day-ahead electricity market.⁶⁴ The first DRAM pilot was implemented in 2016. California's IOUs selected 40 MW of demand response from four categories of providers: (1) energy management service companies that strategically dial down energy use for commercial-industrial customers during peak pricing, (2) a smart EV charging technology company that recruits EV battery storage to assist the grid in load shifting, (3) energy management service companies that reward residential and small business companies for use of smart thermostats, and (4) companies that aggregate behind-the-meter battery storage at the commercial-industrial and residential levels.⁶⁵ The CPUC

is working toward expansion of the auction, opening up the DR market to third-party competition.

c. Energy Storage

Energy storage is a form of flexible capacity that offers multiple benefits. Storage can replace curtailment as a tool for managing over-generation. Storage can smooth out the duck curve by storing renewable energy generated mid-day and making it available during peak demand. Storage can also serve as a voltage and frequency regulator for intermittent renewable energy sources.⁶⁶ There are a host of energy storage technologies, including pumped hydro, thermal heating or cooling, compressed-air, flywheels, solid state batteries, and flow batteries.⁶⁷

In 2016, the CPUC ordered IOUs to fast-track energy storage projects after a rupture at Aliso Canyon Natural Gas Storage Facility released 1.6 million pounds of methane into the atmosphere.⁶⁸ In January 2017, Southern California Edison (SCE) unveiled the world's largest lithium-ion battery storage systems,⁶⁹ a 20MW, 80MWh installation that was completed by Tesla in just 3 months.⁷⁰ A month later, San Diego Gas and Electric (SDG&E) unveiled a 30MW, 120MWh battery installation built by AES Energy Storage in San Diego, as well as a 7,5 MW installation in El Cajon.⁷¹

California passed new legislation in 2016 that enhanced the state's mandate for energy storage acquisition. The legislation includes four bills:

- <u>AB 33</u> directs the CPUC and CEC to evaluate and analyze large-scale storage options, specifically pumped hydro.
- <u>AB 2868</u> would allow IOUs to develop an additional 500 MW of storage capacity, in addition to the 1,325 MW already mandated by 2024.
- <u>AB 1637</u> doubles funding for the Self-Generation Incentive Program. The CPUC recently earmarked 75% of the program budget for energy storage.⁷²
- <u>AB 2861</u> authorizes the CPUC to create an expedited dispute-resolution process for behind-the-meter energy resources attempting to establish an interconnection to an IOU's distribution network.

While this legislation is a step in the right direction, more flexible storage capacity will be needed for California to reach its 2030 RPS and GHG tartgets.

IV. What Would Achieving 2030 Targets Look Like? A Look at Recent Studies

a. Report by the Union of Concerned Scientists

A 2015 study by the Union of Concerned Scientists (UCS), "Achieving 50 Percent Renewable Electricity in California," modeled the impact of non-generation flexibility on renewable curtailment, CO_2 emissions, and production cost in a 50 percent RPS scenario.⁷³ The study's authors note that achieving state-wide GHG targets by 2030 may require California to deploy renewables more quickly than required by a 50 percent RPS in 2030. The authors therefore model various scenarios for the year 2024.⁷⁴

The study's authors used industry-standard software to simulate hour-by-hour operation of the power system run by the California Independent System Operator (CAISO).⁷⁵ CAISO manages the flow of electricity across transmission lines that make up 80 percent of California's grid.⁷⁶ In 2014, CO₂ emissions that served CAISO load represented nearly 80 percent of California's total GHG emissions from electricity generation.⁷⁷

All of the UCS report's scenarios included 1,325 MW of new electricity storage already mandated for deployment by 2024 by state law, and 2.4 GW of conventional demand response.⁷⁸

The models included a diverse portfolio of renewables, but did not seek to optimize the portfolio or focus on specific technology.⁷⁹ The model found that, without making additional changes to the grid, the move from 33 percent RPS to 50 percent RPS results in a 22 percent reduction in CO_2 emissions (down from 52.4 MMTCO₂ at 33 percent RPS to 41.1 MMTCO₂ at 55 percent RPS), but would require curtailment of 4.8 percent of total generation.⁸⁰

The authors then ran the model under three new scenarios, each time increasing three sources of non-fossil flexibility by 1 GW each: demand response, energy storage, and net energy exports.⁸¹ Compared with a 33 percent RPS scenario, raising the RPS to 50 percent and adding 1 GW of each resource – 3GW total – reduces CO_2 emissions by 27 percent.⁸² The scenario also results in a 77 percent drop in renewables curtailment, compared to the 50 percent RPS base scenario without added flexibility.

The study concluded that, "[t]o dramatically reduce GHG emissions from the power grid, non-fossil resources will need to gradually replace contributions to the flexibility and reliability of the power system now provided by natural gas plants [...] Allowing both renewable and non-generation resources to provide flexibility and reliability services to the grid will be an important step in creating a low-GHG energy system."⁸³

b. Report by the National Renewable Energy Laboratory

In 2016, the National Renewable Energy Laboratory (NREL) published a study titled "Low Carbon Grid Study: Analysis of a 50% Emission Reduction in California." The study analyzed the grid impacts of a variety of scenarios that achieve 50 percent carbon emissions reductions from California's electric power sector, below 2012 levels.⁸⁴ A 50 percent reduction below 2012 levels is approximately 47 MMTCO₂e. Note that this falls on the low-end of the emissions range (61 to 42 MMTCO₂e) proposed in CARB's 2017 Scoping Plan.⁸⁵



The study's *baseline* scenario assumed 36 percent renewable penetration (including seven percent from distributed PV), CEC projections for energy efficiency, and 1.5GW of battery storage buildout to meet the existing legislative mandate. The *target* scenario increased renewable penetration to 56 percent, with a diverse renewable portfolio mix and a higher level of energy efficiency. The *high solar* scenario assumes the same conditions as the target scenario,

but with a less diverse renewable portfolio (more PV and less solar thermal, biomass, and geothermal).⁸⁷ The *dry hydro* scenario applies the same conditions as the target scenario, but assumes the hydro availability of a "dry year" (substituting hydropower estimates from 2001).⁸⁸ Each of these scenarios was run twice, applying *conventional flexibility* assumptions and *enhanced flexibility* assumptions. Enhanced flexibility assumed greater import and export flexibility, removed minimum regional generation requirements for conventional sources, added 2.2 GW of additional storage buildout, and assumed greater ancillary service capacity.⁸⁹

The study found that California can achieve 50 percent reductions in CO_2 from the electricity sector under a wide variety of scenarios and assumptions. The scenario with the greatest emissions reductions was the target portfolio with enhanced flexibility. The only scenario that did not achieve 50 percent GHG reductions below 2012 levels was the dry hydro scenario without enhanced flexibility.

Note that the dry hydro scenario in this study did not contemplate a multi-year drought event, such as experienced by California from 2011-2017, which would significantly reduce available hydropower availability. If severe drought events become more frequent as a result of climate change, California would need even greater renewables penetration and grid flexibility to maintain GHG reductions.



Figure 9: Carbon emissions in eight NREL study scenarios.⁹⁰ Credit: NREL

V. Recommendations

a. Take the Full Value of Distributed Energy Resource Services into Account

Not all renewable energy is created equal. The value of electricity varies depending on when and where it is available. California's prevailing methodology for valuating renewable energy projects only considers how cheap the power source is without giving consideration to "true integration costs," such impacts to grid stability.⁹¹ Regulators must take grid impacts into account during the procurement process, and incentivize generation when and where it is most valuable.⁹² This will mean greater investment in reliable renewable sources such as geothermal, solar thermal, and biomass, as well as emphasis on "peak oriented" solar PV and wind.

For storage to reach its economic potential, California's regulatory structure must be reformed to recognize the value of storage's multiple functions. One reason that energy storage costs remain high is because the many services that storage can provide have not been monetized.⁹³ Storage can provide 13 different fundamental services to the grid, depending on

where it is located and how it is used.⁹⁴ These services are often "stackable," meaning that the same system can provide more than one service.

To achieve their full potential, distributed energy resources – including renewable generation, storage, and demand response technologies – must be much more integrated in the grid system.

SB 350 requires the CPUC to implement an integrated resource plan (IRP) process to identify optimal portfolios of resources to achieve the state's GHG goals and meet the challenge of renewable integration. The CPUC's 2016 Distributed Energy Resource (DER) Action Plan includes three groups of current proceedings and initiatives currently underway: (1) rates and tariffs, (2) distribution grid infrastructure, planning, interconnection and procurement, and (3) wholesale DER market integration and interconnection.⁹⁵ For these proceedings to be successful, California's agencies must coordinate to remove barriers and develop market opportunities for these DER technologies.

b. Develop Robust Demand Response Capacity

Demand response has significant potential to provide flexible, non-generation capacity to address a variety of long- and short-term grid management challenges. Technologies that further California's energy efficiency and transportation goals – such as smart thermostats and plug-in electric vehicles – should be harnessed to provide DR services to the electricity grid as well.

In 2014, California IOUs offered a variety of DR programs, totaling approximately 2 GW of capacity.⁹⁶ However, the benefit of these programs to the grid was limited. A study by CPUC staff found that IOUs underutilized their demand response programs.⁹⁷ Furthermore, due to lack of coordination with CAISO, IOU DR programs were not being used to help balance the grid.⁹⁸ In the subsequent two years, regulators have made an effort to study DR's potential, pilot a market for third-party DR providers, and develop TOU pricing. Much work still needs to be done. The Berkeley Lab study commissioned by the CPUC developed a new DR taxonomy and an analytic framework to facilitate comparisons between the cost and value created by different DR services.⁹⁹ A transition to a system with advanced DR capabilities will likely require the following:

- Coordinated policies at the CPUC and CAISO to ensure that market designs are matched with the most cost-effective pathways for DR services.
- Integrated demand-side management of energy efficiency, behind-the-meter storage, and DR programs.
- Distributed resource planning that integrates value streams at the system scale, on the distribution system, and at the site-level, so that DR technology can provide multi-scale service.¹⁰⁰

c. Increase Energy Storage Mandates

Existing law imposes a target of 1.325 GW of new, "cost effective" energy storage, to be installed by the end of 2024. In addition to this target, AB 2868 authorized the procurement of an additional 500MW of energy storage.¹⁰¹ However, studies indicate that more storage capacity will be necessary. The NREL report found that, even with greater renewable portfolio diversity, enhanced efficiency, import and export capabilities, and greater ancillary services, the grid will require an additional 2.2 GW to achieve the study's target GHG emissions reductions.¹⁰² California legislature and regulatory agencies must therefore implement more aggressive storage targets. Luckily, battery storage prices are dropping even faster than anticipated, and utility-scale

battery storage can be installed very quickly, making rapid buildout feasible in the coming years.¹⁰³

d. Limit Renewable Generator Curtailment; Use Flexible, Zero-Emission Capacity to Meet Regional Generation Requirements

Renewable generation should be prioritized during over-generation events. CAISO has already suggested that over-generation could be addressed by down-ramping flexible natural gas plants.¹⁰⁴ However, energy storage could be substituted for peaker plants to serve this load balancing function at lower cost, greater efficiency, and lower emissions than gas-fired peaker plants.¹⁰⁵

Minimum local generation requirements from conventional sources entrench GHG emissions and cause the curtailment of renewable sources. In testimony before the CPUC, CAISO representative Dr. Shucheng Liu has asserted that renewables, demand response, and battery storage could meet regional generation requirements if they meet NERC reliability and CAISO operational requirements.¹⁰⁶ To reduce curtailment of renewable resources, CAISO should allow conventional sources to be replaced by non-fossil fuel capacity that is "(1) controllable in order to balance the system and control frequency, (2) dispatchable to respond to contingency, and (3) able to support voltage in the local area."¹⁰⁷

e. Create Inter-Regional Import and Export Capabilities

Over-generation and curtailment issues could also be mitigated by increasing CAISO's export capabilities.¹⁰⁸ Importing renewable power from other regions with different peaking periods could also reduce the duck curve.¹⁰⁹ In NREL's report, grid flexibility from import and export capabilities were necessary to achieve GHG emission reduction goals in "dry hydro" years.¹¹⁰

CAISO has agreed that increased export capabilities should be pursued, and has taken steps in this direction by developing the Energy Imbalance Market with PacifiCorp and NV Energy.¹¹¹ However, achieving these improvements will require dialogue with, and commitment from, external balancing authorities.

Conclusion

Achieving a 50 percent RPS and a 43 to 61 percent GHG reduction below 1990 levels from the electricity sector is not possible under current regulatory, infrastructural, and operational conditions. The changes necessary are significant, but they are nevertheless feasible. The technological capabilities exist. California must integrate DER services, develop advanced DR service capacity, increase energy storage mandates, limit renewable energy curtailment, and expand inter-regional energy import and export capabilities. Ongoing regulatory proceedings are grappling with these barriers. California is leading the way into new territory, but the path forward is visible.

References

¹ Other California greenhouse gas reduction strategies – such as energy efficiency programs and an executive order

 7 Id.

https://www.arb.ca.gov/cc/scopingplan/2030sp_pp_final.pdf.

 10 Id. at 43.

¹¹ Id. Note that 1990 baseline figures in this paper are taken from The 2017 Scoping Plan Update, but differ somewhat from the figures in the 1990-2004 Emissions Inventory. See CAL. AIR RES. BD., 1990-2004 GHG EMISSION INVENTORY (MILLIONS OF METRIC TONNES OF CO2 EQUIVALENT) – BY PCC CATEGORY (last updated Nov. 19, 2007) https://www.arb.ca.gov/cc/inventory/archive/tables/ghg_inventory_ipcc_90-04_all_2007-11-19.pdf.

¹² CAL. AIR RES. BD., CALIFORNIA GREENHOUSE GAS INVENTORY FOR 2000-2014 – BY SECTOR AND ACTIVITY (last updated March 30, 2016) [hereinafter 2000-2014 GHG INVENTORY]

https://www.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_sector_sum_2000-14.pdf.

- ¹⁴ 2000-2014 GHG INVENTORY, *supra* note 12.
- ¹⁵CAL. ENERGY COMM'N, TRACKING PROGRESS GREENHOUSE GAS EMISSIONS REDUCTIONS (Dec. 20, 2016) at 5, http://www.energy.ca.gov/renewables/tracking_progress/documents/Greenhouse_Gas_Emissions_Reductions.pdf.
- ¹⁶ 1990 baseline and 2030 target figures come from the CARB 2017 Scoping Plan, supra note 9. 2000-2014 electricity generation emissions come from the CARB California GHG Inventory for 2000-2014, supra note 12.
- ¹⁷ CAL. INDEPENDENT SYSTEM OPERATOR. GREENHOUSE GAS EMISSION TRACKING: FAQS. (Dec. 28, 2016) at 1 [hereinafter GHG TRACKING: FAQS]

http://www.caiso.com/Documents/GreenhouseGasEmissionsTrackingReport-FrequentlyAskedQuestions.pdf. (accessed on 23 March 2017).

¹⁸ Understanding the ISO, CAL. INDEPENDENT SYSTEM OPERATOR,

https://www.caiso.com/about/Pages/OurBusiness/Default.aspx (last visited March 23, 2017).

¹⁹ CAL. INDEPENDENT SYSTEM OPERATOR, GREENHOUSE GAS EMISSION TRACKING REPORT JANUARY 30, 2017 [herein after GHG EMISSION TRACKING REPORT] http://www.caiso.com/Documents/GreenhouseGasEmissions-TrackingReport-January2017.pdf (last visited March 23, 2017).

²⁰ CAL. ENERGY COMM'N, TRACKING PROGRESS – RENEWABLE ENERGY, (Dec. 22, 2016) at 1 [hereinafter TRACKING PROGRESS – RENEWABLE ENERGY]

http://www.energy.ca.gov/renewables/tracking_progress/documents/renewable.pdf.

²¹ *Id*. at 9.

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