Appendix C - Focus Group Working Papers

Electricity and Natural Gas Working Paper

Section 1: Introduction

In California, the energy sector contributes about 85 percent of the greenhouse gases (GHG) emitted on a yearly basis and roughly 40 percent comes from the electricity and natural gas systems and the remainder from transportation services and fuel infrastructure.[1] Reducing GHG emissions 80 percent below 1990 levels by 2050 will require nothing less than a complete transformation of the energy system. Since transportation is covered separately, this paper focuses on the electricity and natural gas systems and only references transportation in terms of how it directly impacts the electricity or natural gas systems. To position California to achieve the 2050 vision, innovation and unprecedented advancements are needed in:

- Energy efficiency in existing buildings, new buildings, and appliances. Key state actors are: California Energy Commission (Energy Commission), California Public Utilities Commission (CPUC), and Governor's Office.
- Demand response so that it can be an effective tool to help reduce energy demand and provide a zero-GHG mechanism for matching variable supply and demand. Key state actors are: Energy Commission, CPUC, and California Independent System Operator (California ISO).
- Combined heat and power (CHP) as a tool to reduce energy demand and provide distributed generation (DG) for use on-site. Key state actors are: Energy Commission, CPUC, California ISO, and the California Air Resources Board (ARB).
- Renewable energy to displace electricity generated from fossil fuels. Key state actors include: CPUC, California ISO, Energy Commission, and Governor's Office.
- Renewable DG to develop localized energy sources that do not create GHGs. Key state agencies include: Energy Commission, CPUC, California ISO, local governments, and Governor's Office.
- Energy storage, smart grid, demand response, and forecasting to maintain grid reliability while integrating increasing amounts of variable renewable resources into the electricity system. Key state actors are: Energy Commission, CPUC, and California ISO.
- Bioenergy to displace electricity generated from fossil fuels. Key state agencies include: Natural Resources Agency, Energy Commission, Department of Forestry and Fire Protection, CPUC, California Department of Food and Agriculture, ARB, CalRecycle, and California Environmental Protection Agency.

[1] Energy Commission staff analysis. Data accessed on 06/07/2013 from http://www.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_scopingplan_00-10_2013-02-19.pdf (Scoping Plan Category) and http://www.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_ipcc_00-10_all_2013-02-19.pdf (IPCC Category).

- Carbon capture, utilization, and storage (CCUS) coupled with some natural gas fired electricity to help manage the variability in supply and demand and maintain the reliability of the electricity system. Key state agencies are: Energy Commission, CPUC, and California Department of Conservation, Division of Oil Gas and Geothermal.
- Solar for space and water heating to reduce natural gas consumption as an alternative to electrification of the residential and industrial sectors. Key state agencies are: Energy Commission and CPUC.
- Research, development and demonstration (RD&D) in each sector noted above to achieve advancements and breakthroughs in technology and systems planning. Also, RD&D is needed, to better understand how climate change will affect energy systems and what changes can make the energy sector more resilient to climate change. Key state agencies: Energy Commission, CPUC, and the California Natural Resources Agency.

Recognizing the uncertainty surrounding technological and economic changes over the next several decades, this working paper proposes pursuing a set of GHG emission reduction strategies, where each strategy will help ratchet down emissions. This provides a diversified portfolio of actions to help California manage uncertainty and reduce risk related to GHG emission reductions.

Also, the state's "loading order" policy provides guiding principles by prioritizing energy efficiency, and demand response as the state's preferred means of meeting growing energy needs, followed by renewable resources, and DG, and then clean and efficient fossil-fueled generation. The loading order also calls for improvements in the transmission and distribution systems.

The state cannot achieve the needed GHG emission reductions by simply building from current trends and no single party can transform the energy sector. The state will play an important role to help facilitate meeting the 2050 goal, including setting policies, establishing market rules, implementing programs, and, perhaps most importantly, advancing needed RD&D. Strong partnerships with the federal and local government, utilities, industry, environmental groups, environmental justice organizations, universities, national laboratories, and others are also needed to help spur and deploy innovation.

This working paper is organized as follows:

- **Section 2** provides an update on energy programs that have helped reduce GHG emissions in California since 2008 and describes the climate change impacts on California's electricity and natural gas sectors.
- **Section 3** puts forward a vision for California's electricity and natural gas systems both mid-term and long-term to meet the GHG reduction goal, identifies the major barriers to achieving the vision, and recommends solutions.
- **Section 4** summarizes the priority recommendations set forth in this working paper to achieve the vision outlined in Section 3.

- **Section 5** ties together critical points into a conclusion.

Section 2: GHG Reductions and Climate Change Impacts

The 2008 AB 32 *Scoping Plan* laid out a pathway to achieve almost 30 percent of the Plan's total GHG emission reductions by implementing the following measures: energy efficiency standards and programs (including goals for increasing CHP), the 33 percent Renewables Portfolio Standard (RPS), and Senate Bill 1 (SB 1, Murray, Chapter 132, Statutes of 2006). At the same time, the 2008 Scoping Plan included actions to reduce GHG emissions from the transportation sector, including electrification of ports and increased penetration of electric vehicles.

From 2004 to 2011, GHG emissions from California's electricity sector have declined annually. The electricity sector produced 120.14 million metric tons (MMT) of carbon dioxide equivalent emissions (CO_2E) in 2008 and 86.57 MMT CO_2E in 2011.[2] A portion of this drop can be attributed to temporary conditions such as fluctuations in zero-emissions hydroelectric production and reduced electricity demand because of the recession. Other emission reductions are the result of more permanent changes from the development and implementation of programs and regulations for increased energy efficiency and renewable energy.

Electricity emissions were higher in 2012 than in 2011. In both 2012 and 2013, demand levels recovered slightly. The retirement of the San Onofre Nuclear Generation Station (San Onofre) in 2013 cut in-state nuclear GHG-free generation in half. The expansion of energy efficiency, as well as solar and wind resources offset some of these effects, but the main source of incremental power has been natural gas. Such variations are to be expected on a year-to-year basis, but the long-term trend of carbon reductions will continue. Although renewable generation is increasing, emissions may increase due to several factors. These factors include: potential below average generation for hydropower in 2012 and 2013, the retirement of San Onofre by Southern California Edison (SCE) in 2013, and electricity demand growth of about 1.2 percent in 2012. Energy Commission staff is projecting an annual electricity demand growth rate of 1.15 percent over the next decade.[3] Also, the GHG benefits of increased renewable energy will vary depending on how well generation matches demand and the extent to which gas-fired electricity generation is needed.

In the natural gas sector, gas end-use has been flat and use per person has been slowly dropping since the late 1990s.[4] Individual year variations and the recession caused end-uses of natural gas to decrease between 2008 and 2009, followed by a slow recovery so that 2011 natural gas end-use consumption was essentially the same

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[2] California Air Resources Board-Revised, California Greenhouse Gas Inventory for 2000-2010 – by Category as Defined in the Scoping Plan, 8-1-2013, http://www.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_scopingplan_00-11_2013-08-01.pdf

[3] Projected consumption is projected to dip slightly in 2013 due to expected electricity rate increases and because 2012 had an unusually high number of warm days with increased cooling loads.

[4] California Energy Demand, 2012,CEC-200-2012-011cmf, p. 47.

as four years before. For the period 2000 to 2010, natural gas consumption shows a general modest declining trend. In addition to direct carbon dioxide emissions from the combustion of natural gas, the natural gas system also emits fugitive methane emissions (leaks) that increase the net emissions from this system. In 2008, the ARB Scoping Plan identified measures that "would regulate fugitive emissions from oil and gas recovery and gas transmission activities." Natural gas plays three roles in California's economy – an electricity generation source, a direct combustion fuel for end-uses including CHP, and a combustion source at oil and gas extraction and refineries.

For electricity generation, natural gas has traditionally substituted for hydropower, renewables, and nuclear resources when they were not available and in recent years it has helped integrate intermittent renewable generation such as wind and solar. The overall efficiency of the natural gas fleet continued to improve over the past decade as older units were replaced with more efficient ones.[5]

Natural gas prices have tended to be volatile around an average natural gas price that increased by almost 30 percent per year between 2000 and 2008. The most recent price spike was in 2008, but prices started to drop in 2009 and continued their descent with increased supplies from the large expansion of shale gas resources. Between 2009 and 2012, natural gas prices decreased by an average annual rate of almost 20 percent. This price reduction has led to a national shift away from coal and towards natural gas use in the electricity sector. From 2010 to 2012, GHG emissions from power generation have decreased 10 percent nationally. It has also led to lower consumer gas and electric bills than was previously estimated.

Activities that Reduce Electricity and Natural Gas Emissions Since 2008

California's energy agencies share the goal of creating an electricity sector that will provide safe, reliable, affordable, efficient, and environmentally-sustainable power while reducing GHG emissions. The energy agencies developed and implemented a suite of programs and regulations since 2008 that contributed to emission reductions, with additional reductions expected in future years.

Energy Efficiency

- The Energy Commission's building and appliance energy efficiency standards reduced electricity use by 11,828 gigawatt hours (GWh)[6] from 2008 to 2011. Building efficiency standards were updated in 2008 and 2013 for residential and non-residential buildings that are new, additions, or alterations. The 2013 standards are 25 percent more energy efficient than previous standards for

[5] California Energy Commission, *Thermal Efficiency of Gas-Fired Generation in California: 2012 Update*, http://www.energy.ca.gov/2013publications/CEC-200-2013-002/CEC-200-2013-002.pdf, p. 10.

[6] Computed from *California Energy Demand, 2012-2022 Final Forecast* , June 2012, Form 2.2 on Committed Energy Impacts.

residential construction and 30 percent better for non-residential construction.[7] Appliance standards for televisions adopted in 2009 are projected to save 6,515 GWh by 2013 after the existing television stock is replaced, and the first-in-the-nation efficiency standards for battery chargers adopted in 2012 will save nearly 2,200 GWh per year.[8, 9] In addition, the Energy Commission accelerated implementation of federal energy efficiency standards for light bulbs set by the Energy Independence & Security Act of 2007, resulting in energy and consumer savings sooner for Californians. Under the Energy Commission's American Recovery and Reinvestment Act of 2009 (ARRA) programs, three targeted commercial programs focused on the installation of heating, ventilation, and air conditioning (HVAC) and lighting controls created with technology that received Public Interest Energy Research (PIER) funding, as well as refrigeration case lighting in grocery stores statewide. A total of 3,728 targeted commercial upgrades were completed, saving 91 GWh annually.

- In September 2008, the CPUC developed its long-term Energy Efficiency Strategic Plan and implementation roadmap for the Big Bold Energy Efficiency Strategies. This Plan was later updated in January 2011 and puts forward the following goals:[10]
    - All new residential construction in California will be zero net energy (ZNE) by 2020.
    - All new commercial construction in California will be ZNE by 2030.
    - HVAC will be transformed to ensure that its energy performance is optimal for California's climate.
    - All eligible low-income customers will be given the opportunity to participate in the low income energy efficiency program by 2020.
- For the investor-owned utilities' (IOUs) 2010-2012 portfolio of energy efficiency programs, in 2009 the CPUC approved several billion dollars[11] of investments that were coupled with commercial and private business and home financing and $341 million ARRA funds. Reported (unverified) electricity savings as of December 2012 for the current program cycle were 10,406 gross annual GWhs.[12] By law, utilities are directed to achieve all cost-effective energy efficiency that is reliable and feasible.[13]

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[7] Computed from *California Energy Demand, 2012-2022 Final Forecast* , June 2012, Form 2.2 on Committed Energy Impacts.

[8] http://www.energy.ca.gov/appliances/tv_faqs.html.

[9] http://www.energy.ca.gov/releases/2013_releases/2012_Accomplishments.pdf.

[10] Detailed strategies and goals can be found at http://www.cpuc.ca.gov/NR/rdonlyres/A54B59C2-D571-440D-9477-3363726F573A/0/CAEnergyEfficiencyStrategicPlan_Jan2011.pdf

[11] In September 2009, the CPUC issued Decision 09-09-047 approving the IOUs' 2010–2012 $3.1 billion efficiency program portfolios, a 42 percent increase in expenditures from the previous 2006–2008 program cycle.

[12] California Public Utilities Commission, http://eega.cpuc.ca.gov/.

[13] SB 1037 (Kehoe, Chapter 366, Statutes of 2005) and AB 2021 (Levine, Chapter 734, Statutes of 2006) as cited in *Achieving Cost-effective Energy Efficiency in Californi*a 2011-2020, CEC-200-2011-007-SD, pages 5 and 6

- About 25 percent of the state's electricity consumption is served by the state's publicly-owned utilities which include municipal districts, city departments, irrigation districts, and rural cooperatives. In 2012, the publicly-owned utilities spent approximately $127 million on energy efficiency and reduced their peak demand by 82.5 megawatts (MW), up 2 percent from 2011 (unverified). Publicly-owned utilities achieved 440 GWh in energy savings in fiscal year 2011/2012, down 4 percent from 2011 (unverified).
- In 2010, the Energy Commission, CPUC, utilities, local governments, non-governmental organizations, and the private sector launched Energy Upgrade California, a "whole building" approach to advance upgrades to existing buildings. The Energy Commission deployed $131.7 million in ARRA funding for the program; local governments leveraged $60 million in United States Department of Energy (U.S. DOE) grants and other leveraged funds; and California's IOUs contributed $102 million of ratepayer funds. Funding was used to develop innovative programs to upgrade commercial, multifamily, and single family buildings; conduct outreach and education; and provide homeowners with rebates of up to $4,000 for energy efficiency upgrades. From program start through the end of ARRA funding on April 30, 2012, more than 9,200 projects were completed. From May 2012 to April 2013, an additional 3,550 energy upgrade projects were completed as part of the program's continuation.
- Executive Order B-18-12[14] sets aggressive goals for improving the efficiency of state buildings including: reducing grid-based energy purchases for state-owned buildings by at least 20 percent by 2018; requiring all new state buildings and major renovations designed after 2025 to be constructed as ZNE; and achieving ZNE for 50 percent of the square footage of existing state-owned buildings by 2025.
- A major effort is underway to improve the measurement and verification (M&V) of the impacts of efficiency initiatives; and application of M&V to design more effective efficiency programs.

Demand Response

- IOUs are responsible for implementing demand response programs under the oversight and evaluation of the CPUC. The current program cycle (2012-14) has a total budget of approximately $1 billion per year for a variety of energy efficiency programs. It is anticipated that some of these programs will provide over 2,000 MWs of demand response capacity during the peak hours. Demand response receives Resource Adequacy credits, thereby displacing supply-side generation capacity that the utilities would otherwise procure.
- In 2012, the CPUC adopted a decision[15] that sets policies for the participation of demand response in California ISO wholesale energy markets. These policies

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[14] Executive Order B-18-12, April 25, 2012, http://gov.ca.gov/news.php?id=17508

[15] D.12-11-025 http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M037/K494/37494080.PDF

are expected to be embodied in a set of utility tariff rules, known as "Rule 24". The purpose of Rule 24 is to provide the administrative, technical, and financial mechanisms to allow demand response providers to bid resources directly into the California ISO market while protecting customers and ratepayers. Finalization of Rule 24 is anticipated in 2014.

- Starting in 2006, the CPUC began authorizing the deployment of smart meters by IOUs across their respective territories. Smart meters can measure customer energy usage in hourly increments or less, and are necessary for customer participation in demand response programs or time-varying rates. Smart meter deployment has now been completed by Pacific Gas and Electric (PG&E), San Diego Gas and Electric (SDG&E), and SCE, although PG&E will still be working on a few remote locations until the end of 2013. This does not, of course, include those households that have opted out of receiving a smart meter.

Renewables

- In 2011, California codified and implemented an RPS program requiring 33 percent of retail sales to be served by renewable energy by 2020. The RPS requires retail sellers of electricity and publicly-owned utilities to procure: an average of 20 percent of retail sales from eligible renewable resources between January 1, 2011 and December 2013, quantities that reflect reasonable progress sufficient to achieve 25 percent by December 31, 2016, quantities that reflect reasonable progress sufficient to achieve 33 percent by December 31, 2020, and no less than 33 percent in all subsequent years.[16] In 2012, California served about 22 percent[17] of retail sales with renewable energy.
- During 2012, nearly 2,000 MW of new large-scale renewable generation came on line[18] and more than 3,000 MW is scheduled to come online before the end of 2013. In addition, in 2012, the IOUs filed 63 new contracts for 1,311 MW of renewable capacity and the CPUC approved 64 contracts representing 3,725 MW of renewable capacity.[19] In the last few months, the California ISO has witnessed a number of record breaking events for renewable generation of wind and solar. Wind broke the 4,000 MW instantaneous capacity mark in April 2013 and solar broke the 2,000 MW instantaneous capacity mark in early June 2013, which do not include the nearly 1,500 MW of solar photovoltaic behind the meter. The California ISO will likely continue to shatter the solar record as more capacity is installed.

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[16] Senate Bill X1-2 Simitian, Chapter 1, Statutes of 2011.

[17] Energy Commission staff estimate, based on data from the Renewable Net Short data, http://www.energy.ca.gov/2013publications/CEC-200-2013-001/CEC-200-2013-001.pdf for 2012 and the Preliminary California Energy Demand Forecast , June 2013 http://www.energy.ca.gov/2013_energypolicy/documents/2013-05-30_workshop/spreadsheets/

[18] California Public Utilities Commission, *Renewables Portfolio Standard Quarterly Report*, 3rd and 4th Quarter 2012, http://www.cpuc.ca.gov.

[19] California Public Utilities Commission, Renewables Portfolio Standard Quarterly Report, 3rd and 4th Quarter 2012, http://www.cpuc.ca.gov/NR/rdonlyres/4F902F57-78BA-4A5F-BDFA-C9CAF48A2500/0/2012_Q3_Q4RPSReportFINAL.pdf.

- Progress was made toward the SB 1 program goal of 3,000 MW of self-generation solar by the end of 2016, and towards the Governor's goal of 12,000 MW of renewable DG (20 MW or less) by 2020. As of January 2013, renewable DG facilities (20 MW or smaller) operating in California totaled more than 3,800 MW, with over 1,700 MW pending as of January 2013.[20] About half of these installations are behind the meter and in addition to the renewable capacity noted above.

Fossil-fuels

- Natural gas: In the end-use sector, several decades of building and appliance standards and utility efficiency programs have decreased per capita natural gas use, causing total natural gas consumption to remain flat in spite of California's increasing population. In total, an incremental 322 MM therms[21] were avoided by the incorporation of state and federal standards into building design and appliance operation from 2008 to 2013.[22]

  Because residential natural gas use is primarily addressed through standards, utilities have focused more of their energy efficiency assistance on the industrial and commercial sectors.[23] The California Solar Initiative established incentives for replacing residential gas or electric water heating with solar water heating. Because natural gas accounts for 90 percent of domestic water heating, this is primarily a natural gas measure.

  For industrial natural gas use, ARB has conducted audits to help facilities identify energy saving opportunities. Natural gas that fuels large industry and refineries that emit more than 25,000 metric tons of CO_2E per year was included in the first phase of cap-and-trade covering emissions from 2013 through 2014. Fuel distributors, such as natural gas utilities, that emit more than 25,000 tons of CO_2E per year will be added in the second phase from 2015 to 2020.

- Coal: Termination of out-of-state coal contracts and the conversion or closure of in-state coal burning facilities will largely be accomplished by 2020. Due to utilities' change-over investment, generation from coal and the associated GHG emissions will drop by three-fifths between 2010 and 2020. California's Emission Performance Standard (SB 1368, Perata, Chapter 598, Statutes of 2006) prohibits California utilities from renegotiating or signing new contracts for baseload generation that exceeds 1,100 lbs of CO_2E emission per MWh, absent a coal-fired plant's ability to sequester roughly half or more of its GHG emissions.

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[20] California Energy Commission, http://www.energy.ca.gov/renewables/tracking_progress/documents/renewable.pdf

[21] Computed from *California Energy Demand, 2012 Final Forecast*, June 2012, Form 2.X, Natural Gas Efficiency Impacts.

[22] California Energy Commission, *California Energy Demand, 2012-2022 Final Forecast, Volume 1: Statewide Electricity Demand and Methods, End-User Natural Gas Demand, and Energy Efficiency,* June 2012, http://www.energy.ca.gov/2012publications/CEC-200-2012-001/CEC-200-2012-001-CMF-V1.pdf.

[23] See CPUC data website for IOU details at: http://eega.cpuc.ca.gov/.

California utilities retain ownership shares in two out-of-state coal plants whose contracts expire after 2020. Several California utilities co-own San Juan Units 3 and 4 in Farmington, New Mexico with purchase obligations that expire in the 2020's, but are pursuing early divestiture of these facilities. Early divestiture makes sense for these utilities in light of significant investments that will be necessary to comply with federal pollution standards and the relative cost advantage of natural gas generation over coal. The Los Angeles Department of Water and Power recently stated its intent to convert the Intermountain Power Plant in Delta, Utah to natural gas by 2025, and is working with the other plant owners to accomplish this conversion. Los Angeles Department of Water and Power also announced in 2013 that it is divesting its interest in the coal-burning Navajo Generating Station by 2015, which it plans to replace with solar power from Copper Mountain 3 and K Road Moapa Solar projects as well as gas-fired generation from Apex Power Project. Divestitures of coal from California have resulted in utilities from other states following suit. For example, NV Energy from Nevada supported legislation requiring exit from Navajo and Reid Gardner and PNM of New Mexico supported a partial retirement of San Juan Generating Station.

Also, cap-and-trade has resulted in several coal or petroleum-coke plants closing or converting to biomass in California. For example, in 2012 Rio Bravo-Jasmin (38 MW), Rio Bravo-Poso (38 MW) and Hanford LP (24 MW) closed. Mount Poso Cogeneration (64 MW) in Kern County and DTE Stockton (50 MW) converted to biomass.

- Combined Heat and Power: CHP, both heat and electricity, emissions dropped from 11.86 MMT CO2E in 2008 and 9.62 MMT CO2E in 2011 as reported to the ARB.[24] The reduction was largely because some older, less efficient facilities shut down. However, CHP continues to be the most efficient technological approach to meet large on-site thermal and electrical loads, especially with today's advancements in combustion technology, stationary fuel cells, and waste-heat recovery devices.

Electricity Planning, Permitting, Siting, and Grid Management

- Reducing the GHG impacts of electricity cannot occur without a wide array of supporting infrastructure activities. Over the past several years, state and local governments have prepared planning guidelines for where and how new renewable energy projects may be sited.
- Between 2008 and 2011, the Energy Commission provided permits for nine large solar thermal power plants and two natural gas/solar thermal hybrid projects. The Bureau of Land Management and local governments also permitted many renewable energy projects. In all, over 170 renewable energy power plants have been permitted since 2010 that will have a maximum capacity of over 19,000 MW.

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[24] ARB, http://www.arb.ca.gov/cc/reporting/ghg-rep/reported_data/ghg-reports.htm#registering_specified.

- The Desert Renewable Energy Conservation Plan (DRECP) is a collaborative, comprehensive effort to plan for the development of renewable energy and environmental conservation in the Mojave and Colorado deserts.
- Utilities and the California ISO have worked diligently to analyze and start funding the transmission and distribution infrastructure necessary to incorporate new renewable projects into the electricity grid. The California ISO and utilities are developing new software and tariffs to provide economic signals for desirable generation attributes and effective monitoring of the system so that reliability and safety are maintained. In addition, the CPUC has been working with the California ISO to define the types and quantities of flexible generation that will be needed to support large quantities of variable wind and solar generation.
- In February 2013, the California ISO and PacifiCorp entered into a memorandum of understanding to create a regional real-time energy imbalance market by October 2014. This regional market will provide ease of entry for balancing authorities and optimize supply and demand with more precision through 5-minute energy dispatch which will help grid operators better integrate renewable resources into the electricity system. The California ISO board approved the design framework for the energy imbalance in November 2013.[25] Nevada's leading utility company (NV Energy) announced its plan to seek permission from Nevada regulators to allow it to participate in the energy imbalance market. The Nevada utility company, in cooperation with the California ISO, recently completed a regional imbalance market analysis. The results of the analysis demonstrate that participation in a regional imbalance market would benefit consumers in Nevada and California.

Research and Development

Research and development efforts have laid the groundwork for achieving many of the activities noted above. In the last decade, the Energy Commission's PIER and Natural Gas Research Programs have been the state's premier energy RD&D programs, advancing science and technology in the fields of energy efficiency, renewable resources, DG, smart grid[26], energy storage, pipeline safety, transportation, and climate vulnerability and readiness for the energy sector. Between 2008 and 2012, PIER provided $233 million in funding for RD&D in the electricity sector and $87 million for the natural gas sector as discussed below.

- Energy efficiency and demand response RD&D includes: advanced HVAC, lighting, consumer and office electronics (plug loads), building envelopes, hot water heating and distribution, food service operations, ZNE buildings, indoor

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[25] California ISO, *Decision on Energy Imbalance Market Design*, http://www.caiso.com/Documents/Board%204)%20Decision%20on%20energy%20imbalance%20market%20design

[26] As defined in the 2012 Integrated Energy Policy Report Update, an electric grid that uses computer intelligence and networking to allow all components of the grid to both "talk" and "listen," thereby improving operations, maintenance, and planning.

environmental quality, development of OpenADR (automated demand response),[27] and improvements to industrial, water/wastewater and data center processes. Energy Commission-funded innovations in these areas resulted in new industry standards and significant energy savings: demonstrations of smart data center cooling technologies already save 17.7 GWh, or $1.7 million, in California and the technologies are expected to be saving up to $45 million by 2020, avoiding up to 111,000 metric tons of CO_2 emissions by that year.[28] OpenADR is another product of research that continues to spread and provide energy and cost savings. It currently reduces peak load in the state by 260 MW annually and has projected savings in California of up to $118 million by 2020.[29] RD&D also contributed to 14 enhancements to the Building and Appliance Energy Efficiency Standards, which will save ratepayers an estimated $10.1 billion between 2005 and 2025.[30]

- Renewable energy and CHP RD&D includes: cost reductions, improved generation efficiency, improved durability and maintainability, renewable resource characterization and management, hybrid generation and fuel flexibility, energy storage, integration of intermittent resources, DG, CHP, clean fossil fuel (primarily natural gas), and microgrids coupled with clean technologies like renewable energy, energy efficiency, demand response, and electric vehicles while maintaining reliability for vital loads.
- CCUS reduces GHG emissions in two ways: (1) through gas separation processes at large point sources such as power plants and refineries to create CO2 streams for productive economic use with integral storage and/or long-term deep geologic storage, and (2) carbon storage through terrestrial projects such as tree planting and wetlands. Research efforts have included forest management pilots and associated carbon stock measurements, drilling a well to characterize the geologic storage potential of the Central Valley, bench-scale research and a roadmap to identify carbon utilization options to meet the state's 2020 and 2050 goals, and analyses of the technical, economic, political, and social aspects of commercial application of CCUS.

The CPUC has established funding and is considering investment plans for a new program to support pre-commercial clean energy technologies and strategies. This program, known as the Electric Program Investment Charge (EPIC), is designed to provide funding for research and development, technology demonstration and deployment, and market facilitation. The CPUC has identified the Energy Commission and the state's three largest IOUs to administer EPIC. The Energy Commission's

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[27] OpenADR is a communication standard protocol to increase demand response availability in California. ADR substantially increases participation compared to manual systems.

[28] *Public Interest Energy Research 2012 Annual Report*, Publication # CEC-500-2013-013-CMF, March 2013, pages 37-38.

[29] *Public Interest Energy Research 2012 Annual Report*, Publication # CEC-500-2013-013-CMF, March 2013, page 44.

[30] *Public Interest Energy Research 2012 Annual Report*, Publication # CEC-500-2013-013-CMF, March 2013, page 22.

portion of the EPIC program proposes to invest over three years: $158.7 million in applied research and development, $129.8 million for technology demonstration and deployment, and $43.3 million for market facilitation of pre-commercial clean energy technologies, plus $50 million for the New Solar Homes Partnership.[31] PG&E, SCE, and SDG&E will administer $86.6 million for technology demonstration and deployment projects. The benefits to electricity ratepayers include greater reliability, lower costs, and increased safety, and reduced GHG emissions.

In November 2012, the administrators filed investment plans addressing the first three years of the program with the CPUC. In June 2013, Governor Brown signed the state's 2013-14 fiscal year budget act, authorizing the Energy Commission to expend EPIC funds. In September 2013, Governor Brown signed SB 96 which provides additional program guidance for EPIC. The CPUC issued a proposed decision on the first investment plans submitted by the four program administrators in October 2013. The proposed decision, in accordance with SB 96, denies the Energy Commission's request for an additional $25 million in 2013 and 2014 for purposes of funding the New Solar Homes Partnership. On November 14, 2013, the CPUC adopted Decision 13-11-025, approving the first investment plans for EPIC.

Climate Change Impacts on the Electricity and Natural Gas Sectors

Although California is making advances in reducing GHG emissions, the state is already experiencing climate change and current and expected emissions will result in further climate change that will impact energy demand and supply over the next several decades. Below is a review of potential impacts that draws on various studies as noted and does not use a common set of climate projections.

Energy Demand

Climate change is expected to increase demand for cooling in the increasingly hot and longer summer season and decrease demand for heating in the cooler season. California's residential sector uses relatively little electricity for heating, but the overall demand for electricity will increase as households operate existing air conditioners more frequently and as more air conditioners are installed in regions where there are currently few. Higher temperatures in the next decade could increase demand by up to 1 gigawatt (GW) during hot summer months, although technological advances in energy efficiency could offset some or all of this impact. Further, a 10 percent increase in peak demand is projected by the middle of the century.[32] This peak demand will occur at the hottest time of day when thermal power plants may not be able to deliver at full capacity

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[31] California Energy Commission, *Application of the California Energy Commission for Approval of Electric Program Investment Charge Proposed 2012 Through 2014 Triennial Investment Plan*, November 1, 2012. http://www.energy.ca.gov/research/epic/documents/final_documents_submitted_to_CPUC/2012-11-01_EPIC_Application_to_CPUC.pdf

[32] Sathaye, J.A., et al. 2013. Estimating impacts of warming temperatures on California's electricity system. Global Environ. Change, in press, http://dx.doi.org/10.1016/j.gloenvcha.2012.12.005.

(discussed below), requiring a 13 percent nameplate capacity increase for thermal power plants to be able to satisfy increased load. These results are based solely on projected climate change and actual impacts will depend on how the energy system evolves during the 21st century, and superimposing future climate scenarios to the current system may overestimate impacts.

The Energy Commission began factoring climate change into its *2011 Integrated Energy Policy Report (IEPR)* demand forecast to include estimates of the impact on peak demand. Along with an updated peak demand analysis, the *2013 IEPR* preliminary demand forecast incorporates estimates of climate change impacts on electricity and natural gas consumption. Impacts for both peak demand and consumption were developed using temperature scenarios developed by the Scripps Institute of Oceanography based on various climate change models.

Energy Supply

Impacts on energy supply are expected to include reduced efficiency of thermal power plants to generate electricity, reduced capacity of the transmission and distribution infrastructure, increased damage from extreme weather events, and changes in the availability and timing of renewable resources, particularly hydropower. These impacts were assessed in a comprehensive study conducted by the Lawrence Berkeley National Laboratory (LBNL) for the 2012 California Climate Change Vulnerability and Adaptation Study. The study suggests that the current electricity infrastructure is more vulnerable to climate change than previously believed;[33] although a rapidly evolving electricity system offers the opportunity to reduce that vulnerability.

The LBNL study found that higher temperatures would decrease the capacity of thermal power plants (for example, natural gas, solar thermal, nuclear, and geothermal) to generate electricity during particularly hot periods. The estimated decrease varies by region, emission scenario, and climate model. California's gas-fired generating plants have a nameplate capacity of 44.1 GW, and by the end of the century this could be reduced by 10.3 GW on hot days. Assuming no change in technology advancements or population, the study suggests energy supplies need to increase by about 39 percent by the end of the century simply to meet increased demand resulting from climate change and to offset diminished capacity of thermal generating plants and substations.

The energy system will also become more vulnerable to extreme weather events such as wildfires and flooding.[34] Under some climate scenarios, the likelihood of wildfires occurring near large transmission lines is expected to increase dramatically in parts of California by the end of the century. The LBNL study found a 40 percent increased probability of wildfire exposure for certain transmission lines, including the line that

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[33] Sathaye, J.A., et al. 2013. Estimating impacts of warming temperatures on California's electricity system. Global Environ. Change, in press, http://dx.doi.org/10.1016/j.gloenvcha.2012.12.005.

[34] Sathaye, Jayant, Larry Dale, Peter Larsen, Gary Fitts, Kevin Koy, Sarah Lewis, and Andre Lucena. 2012. Estimating Risk to California Energy Infrastructure From Projected Climate Change. California Energy Commission. Publication Number: CEC-500-2012-057.

brings hydropower generation from the Pacific Northwest to California during peak demand periods. Also, as many as 25 coastal power plants and 86 substations are at risk of flooding or partial flooding due to sea level rise.

The amount and timing of energy generation from renewable resources could change over time due to climate change.[35] Solar photovoltaic and wind energy are likely less vulnerable than conventional power plants to climate change, but the effects of future climatic conditions on wind and solar energy generation in California need to be investigated further.[36]

Hydropower contributes on average about 15 percent of California's in-state generation and provides critical low-cost, low-carbon power in the hot months of the year when electricity demand is at its peak. Higher temperatures will mean that more precipitation falls as rain instead of snow, and the remaining snowpack will melt and run off earlier in the year. The system may not be able to store sufficient water for release in high-demand periods.[37] Many climate projections show a dryer climate by late-century, although some suggest increased precipitation especially in northern California.

Overall, the studies show that the state's efforts to further reduce GHG emissions will be complicated and challenged by the impacts of climate change, even before considering the challenge of fundamentally changing how we use and generate energy to sharply reduce GHG emissions.

Section 3: Vision for Electricity and Natural Gas Sectors: Mid and Long-Term

In 2012, the Energy Commission adopted the following vision as part of an investment plan for clean energy in California:[38]

> "California's future electricity system will consist of near ZNE buildings, highly efficient businesses, low carbon generation, sustainable bioenergy systems, more localized generation, and electrification of transportation, supported by a highly flexible and robust distribution and transmission infrastructure."

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[35] Vine, Edward. 2012. Adaptation of California's electricity sector to climate change. Climatic Change 111:75–99.

[36] Vine, Edward. 2012. Adaptation of California's electricity sector to climate change. Climatic Change 111:75–99.

[37] Guegan M., K. Madani, and C. B. Uvo. 2012. *Climate Change Effects on the High-Elevation Hydropower System with Consideration of Warming Impacts on Electricity Demand and Pricing.* California Energy Commission. Publication number: CEC-500-2012-020.

[38] California Energy Commission, *Application of the California Energy Commission for Approval of Electric Program Investment Charge Proposed 2012 Through 2014 Triennial Investment Plan*, November 1, 2012. http://www.energy.ca.gov/research/epic/documents/final_documents_submitted_to_CPUC/2012-11-01_EPIC_Application_to_CPUC.pdf.

This vision could be expanded to allow for a future that includes more significant use of hydrogen or possibly biofuels in addition to electrification of the transportation sector. Also, further emphasis is needed on increasing efficiency in existing buildings as ZNE for new construction will be a small fraction of total housing in the mid-term and even 2050.

In the electricity sector, energy efficiency gains are needed and energy production must be highly decarbonized by 2050. Some natural gas will likely be needed to meet reliability requirements and should be coupled with CCUS technologies. Electricity generation will likely rely heavily on renewable resources, but other low-GHG solutions could also be considered for the 2050 timeframe, including nuclear and even fusion. The state also encourages local governments to find creative ways to lower GHG emissions from the electricity sector by providing local communities with the choice to purchase electricity with a higher renewable content. In addition, the Energy Commission encourages local governments to adopt residential building efficiency "Reach Standards" which are more stringent than state minimum energy efficiency standards.

What breakthroughs will happen by 2050 is unknown, but 40 years ago no one imagined the monumental changes that have occurred in personal computers and software and in the energy sector, including the introduction of competition in generation and retail sales, the emergence of natural gas as the primary fossil fuel, improvements of 30 percent in the thermal efficiency of gas-fired generation, stunning increases in the cost competitiveness of solar generation, advancements in smart grid, and revolutionary advances in load management technologies. Further innovation and breakthroughs are critical for the state to make the deep cuts in GHG emissions needed by 2050.

Overview of State and National Studies, 2050 Vision

Studies at the national and international levels (ECF, 2010;[39] CCSP, 2007[40]) suggest that the best option for deep GHG emission reductions involves substantial improvements in energy efficiency, followed by deep decarbonization of electricity generation, and the electrification of most energy services (e.g. heating homes and buildings using electricity). As discussed below in the section on Solar Space and Water Heating, solar thermal applications can provide a better option, both environmentally and economically, for natural gas displacement in the residential and industrial sectors than electrification.

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[39] ECF. European Climate Foundation, "Roadmap 2050: A practical guide to a prosperous, low-carbon Europe, technical analysis" (Brussels, 2010; www.europeanclimate.org).

[40] CCSP, 2007: Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations (Part A) and Review of Integrated Scenario Development and Application (Part B). A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research [Clarke, L., J. Edmonds, J. Jacoby, H. Pitcher, J. Reilly, R. Richels, E. Parson, V. Burkett, K. Fisher-Vanden, D. Keith, L. Mearns, C. Rosenzweig, M. Webster (Authors)]. Department of Energy, Office of Biological & Environmental Research, Washington, DC., USA, 260 pp.

In 2004, Pacala and Socolow[41] analyzed how to globally reduce GHG emissions using existing technologies, which provides a useful framework for California. The Pacala and Socolow study represented the necessary emission reductions as a triangle, where stabilization of fossil fuel use is a “flat” trajectory, business as usual is an upward “ramp,” and the difference between the two trajectories forms the “stabilization triangle.” To bring global emissions down, the triangle is divided into equal “wedges” that include 15 measures such as reducing vehicle miles traveled, increasing building and appliance efficiency, increasing the use of renewable fuels, replacing coal with natural gas, introducing CCUS at baseload gas or coal facilities, and decreased deforestation.[42] Recent research suggests that additional wedges are necessary to meet GHG emissions reduction goals, including 10 new wedges to phase-out all CO2 emitting land-use practices.[43]

Looking at how California can reach its 2050 GHG reduction goal, three recent studies (Williams et al., 2011; Greenblatt et al., 2012; Wei et al., 2013) used different methodologies and assumptions about the availability of resources and technologies, but reached the same general conclusion: reducing GHG emissions by 80 percent by 2050 is *technically* feasible. However, these deep reductions would require similar efforts outside California in large areas such as the Western Electricity Coordinating Council (WECC)[44] region. Some of the overall findings from the California studies are discussed below, and the appendix summarizes the assumptions and findings of the three studies.

One step needed to achieve the 2050 GHG emission reduction goal is to enhance energy efficiency programs to dampen growth of electricity demand by about 1.3 percent per year relative to forecasted demand.[45] This rate is similar to the observed rate of efficiency and conservation[46] gains during the 2000-2001 electricity crisis but “is historically unprecedented over a sustained period.”[47] If there are no improvements in energy efficiency (frozen efficiency case), a study by Wei et al (2013) suggests that the 2050 GHG emission reduction goal will not be achieved. However,

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[41] Pacala, Stephen W., and Robert H. Socolow, 2004: Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies. Science, 305, doi:10.1126/science.1100103 968-972. http://www.princeton.edu/mae/people/faculty/socolow/Science-2004-SW-1100103-PAPER-AND-SOM.pdf.

[42] Pacala, Stephen W., and Robert H. Socolow, 2004: Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies. Science, 305, doi:10.1126/science.1100103 968-972. http://www.princeton.edu/mae/people/faculty/socolow/Science-2004-SW-1100103-PAPER-AND-SOM.pdf.

[43] Davis, Steven; Cao, Long; Caldeira, Ken; Hoffert, Martin. *Rethinking Wedges*. Environmental Research Letters. 2013 IOP Publishing LTD. http://iopscience.iop.org/1748-9326/8/1/011001.

[44] WECC's service territory extends from Canada to Mexico. It includes the provinces of Alberta and British Columbia, the northern portion of Baja California, Mexico, and all or portions of the 14 Western states.

[45] Williams et al., 2011.

[46] Efficiency refers here to the provision of similar levels of energy services but using less energy. Conservation reduces energy services (e.g., curtailed electricity demand during peak demand periods).

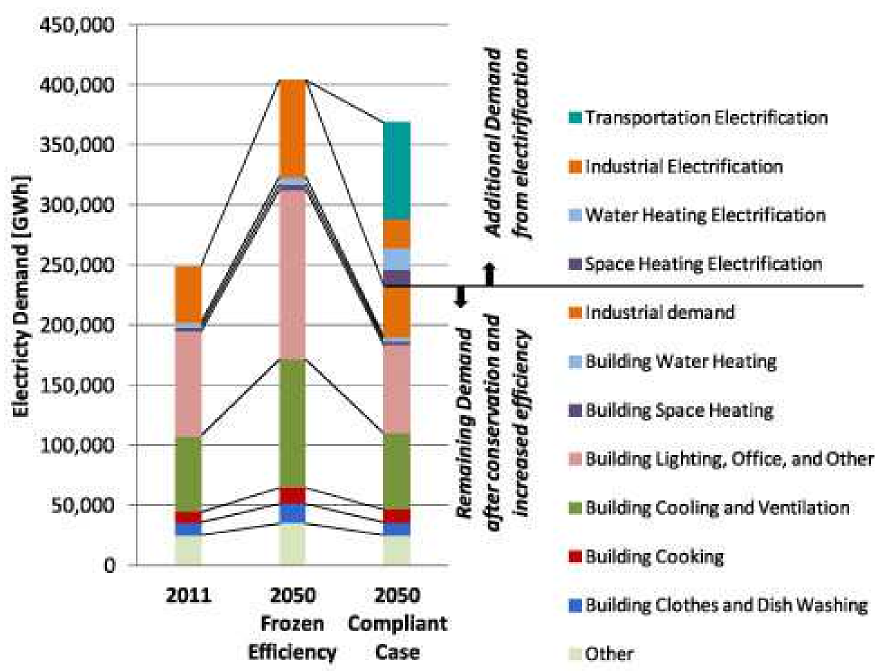
[47] Williams et al., 2011.

that study also finds that the 2050 GHG emission reduction goal *can* be achieved through a scenario with high energy efficiency and heating electrification, industrial electrification, and electrification of most of the transportation sector.[48]

Wei et al. (2013) find that total natural gas demand in 2050 would be greatly reduced if energy services that currently depend on natural gas were electrified (e.g. water and space heating). All three California studies (Williams et al., 2011; Greenblatt et al., 2012; Wei et al., 2013) suggest that while most of the transportation sector would also be electrified, biofuels would serve transportation services that cannot be electrified such as air and marine transport.

The Wei et al. (2013) 2050 compliance scenario shown in **Figure 1** assumes that the electrification of transportation becomes a major source of electricity demand with most electric vehicle charging occurring at night.[49] This, together with electrification of space heating, would change the electricity demand load profiles for California, with peak demand showing up at night and during the winter season. The traditional summer electricity peak driven by demand for air conditioning would continue. Nightly winter peaks would tend to make wind power more attractive because wind energy is usually produced at night.

Figure 1. Electricity Demand Scenarios to reduce California Greenhouse Gas Emissions to 80 percent below 1990 levels by 2050



Source: Wei et al, 2013

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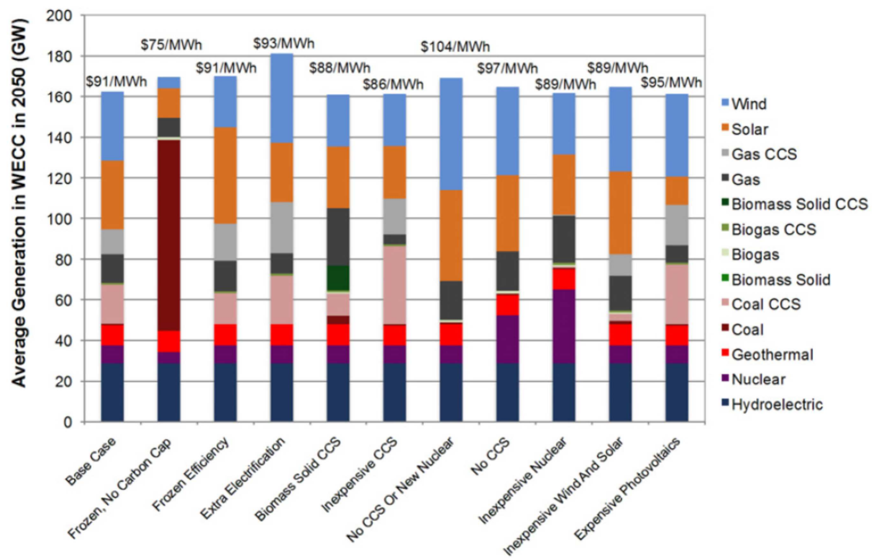
[48] Wei et al., 2013.

[49] Wei et al, 2013.

2050: Studies indicate need for Heavily Decarbonized Electricity Generation

The three studies find that there are multiple decarbonization options for the electricity system. Wei et al. (2013) used a relatively sophisticated model of the electricity network for the WECC with hourly simulation of electricity demand and resource availability. As shown in **Figure 2**, the contribution of natural gas-fired power plants to average generation in the WECC would be relatively minor by 2050. To put things in perspective, in recent year's power plants burning natural gas provided about half of the electricity generated for California. The study by Wei et al (2013) suggests that natural gas-fired power plants will provide some limited amount of energy because they will still be needed to address the intermittent nature of wind and solar.

Figure 2. Comparison of 2050 Low Greenhouse Gas Scenarios by Fuel Type in WECC



Source: Wei et al, 2013

The study by Williams et al. (2012) sets an upper limit of 74 percent on the amount of renewable electricity generation resources serving California by 2050; others have estimated an 80 percent upper limit for renewables at the national level by 2050[50] including large hydropower. In California, large hydropower does not count towards the 33 percent RPS by 2020 target, but provides about 10 to 20 percent of electricity for California (in-state and out-of-state generation).[51] Also, the studies did not attempt to capture operational constraints of such high amounts of intermittent renewable penetration and further analysis by the California ISO is needed.

[50] NREL, 2012.

[51] For example, 2011 Total System Power data show large hydropower provided 13 percent of generation for California. http://energyalmanac.ca.gov/electricity/total_system_power.html.

To build on synergies and avoid working at cross purposes across sectors, the Governor has set an economy-wide goal of 80 percent reduction in GHGs by 2050.[52] For planning purposes within the electricity sector, one pathway toward achieving the economy-wide goal is to aim for 80 percent reduction in GHGs within the electricity sector. However, achieving this vision poses a tremendous challenge for California and the Western United States. Williams et al. (2012) demonstrate that without an economy-wide 80 percent reduction goal, GHG emissions outside of the energy sector could grow substantially. Other studies (Hyman et al., 2002[53], Fujino et al. 2012[54]) suggest that reductions outside the energy sector (including electricity, natural gas, and transportation) could be accomplished at lower costs, potentially decreasing the need for deeper cuts in the energy sector.

Additional Considerations

The studies discussed above provide a good framework for considering how to achieve the 2050 GHG reduction goal, but additional considerations need to be addressed. For example, recent measurements of ambient methane in California[55] suggest that the ARB's GHG inventory may be underestimating total methane emissions. In addition, measurements of carbon 14 in methane[56] in ambient air strongly suggest, at least in the Los Angeles region, that most of the observed "excess" or "fugitive" methane comes from fossil fuels.[57] Other analyses point to the natural gas system as the main source of methane, caused by leakages somewhere in the extraction, transmission, distribution, or end use of natural gas in California.[58,59] The emissions are potentially high enough to substantially diminish the comparative advantage of natural gas in relation to other fossil fuels from a climate perspective. However, the U.S. Environmental Protection Agency recently released its new Inventory of U.S. Greenhouse Gas Emissions and Sinks[60] which includes an overall 20 percent reduction of annual emissions from the U.S.

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[52] http://www.gov.ca.gov/news.php?id=17472 .

[53] Hyman, R. C., J. M. Reilly, M.H. Babiker, A. De Masin, H. D. Jacoby. (2002). Modeling non-CO2 greenhouse gas abatement. Environmental Modeling and Assessment. 8: 175-186.

[54] Fujino, J., Nair, R., Kainuma, M., Masui, T., & Matsuoka, Y. (2012). Multi-gas mitigation analysis on stabilization scenarios using AIM global model. The Energy Journal, (Special Issue# 3), 343-354.

[55] Methane, a potent greenhouse gas, was measured in ambient air in a tall tower in California (Zhao et al., 2009; Seongeun et al., 2011), using research aircrafts (Wennberg et al. 2012), and ground level monitoring stations (Hsu et al., 2010).

[56] Carbon 14 is an isotopic form of carbon that slowly decays with time. Carbon in methane (CH_4) associated with fossil fuels does not include this form of carbon.

[57] Townsend-Small A, Tyler SC, Pataki DE, Xu X, and Christensen LE (2012). Isotopic measurements of atmospheric methane in Los Angeles, California, USA reveal the influence of "fugitive" fossil fuel emissions. Journal of Geophysical Research. 117, D07308, doi: 10.1029/2011JD016826.

[58] Wennberg, P. O., W. Mui, D. Wunch, E. A. Kort, D. R. Blake, E. L. Atlas, G. W. Santoni, S. C. Wofsy, G. S. Diskin, S. Jeong and M. L. Fischer. 2012. On the Sources of Methane to the Los Angeles Atmosphere. Environmental Science & Technology. 46: 9282–9289.

[59] Peischl, J et. al. 2013. Quantifying sources of methane using light alkanes in the Los Angeles basin, California. Journal of Geophysical Research: Atmospheres. DOI: 10.1002/jgrd.50413.

[60] U.S. EPA. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2001 (April 2013). http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html

natural gas system as a result of reduced estimates of methane emissions associated with hydraulic fracturing. Cost effective emission reduction options seem to be available for the natural gas sector[61] as well as mechanisms to recover and use methane to produce electricity and heat.[62] Ongoing and forthcoming studies will provide more information about fugitive methane emissions and explore ways to cost effectively reduce them from California's natural gas system.

Another consideration is how California's portfolio of renewable technologies can increase or minimize needs for flexible capacity. This is discussed in the section on integration issues.

Electrification of the transportation sector will likely have profound impacts on the electricity sector. While Wei et al. (2013) assume electric vehicles will be charged over night, there is considerable uncertainty about charging behavior. Charging behavior uncertainties include: when vehicles will be charged, the prevalence of fast charging technologies, and the geographic dispersion of electric vehicle charging. The Energy Commission is engaged in RD&D to address some of the volatility and stresses electric vehicles may have on the grid.

In addition, while the studies discussed above emphasize electrification of the transportation and industrial sectors, other pathways should also be explored. For example, rather than electrifying the heating sector, it may be possible to expand the use of solar technologies to meet heating and cooling demand in the residential and industrial sectors. In the transportation sector, hydrogen or biogas – rather than just electrification – could reduce GHG emissions.

Consideration should also be given to disadvantaged and low income communities in urban and rural areas that bear a disproportionate burden from air pollution, disease, or other effects from burning fossil fuels. Although criteria pollutants from in-state electricity generation are relatively small, the pollution is concentrated in disadvantaged communities and those communities are disproportionately exposed to emissions from goods transport.[63] Deploying renewables in disadvantaged communities can provide local benefits by helping to increase employment opportunities as discussed further in the Renewable Energy Generation section. Also, the state must explore how to ensure that disadvantaged and low-income communities most impacted by the effects of air pollution can participate in the electrification of the transportation system and realize its benefits.[64]

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[61] Natural Gas STAR Program. http://www.epa.gov/gasstar/methaneemissions/index.html

[62] International Energy Agency, Energy Sector Methane Recovery and Use: the Importance of Policy, 2009.

[63] Transcript of Energy Commission Lead Commissioner Workshop on Evaluating and Capturing Benefits of Renewable Energy for California, April 12, 2012, comments by Laura Wisland, Union of Concerned Scientists, p246.

[64] California Energy Commission, 2012. *2012 Integrated Energy Policy Report Update*. Publication Number: CEC-100-2012-001-CMF. http://www.energy.ca.gov/2012publications/CEC-100-2012-001/CEC-100-2012-001-CMF.pdf

Climate change considerations coupled with market forces and existing regulatory requirements will be a major driver of how the energy system will evolve during the 37 years between now and 2050. As in the past, air quality requirements may also exert considerable influence. For example, to attain federal air quality standards, the South Coast Air Quality Management District will need to cut emissions of oxides of nitrogen (NO_x) by about 80 percent from 2010 levels by 2023, and almost 90 percent by 2032. Similar levels of emissions reductions are likely needed in the San Joaquin Valley (CARB, 2012).

Setting an Interim Target to 2050

Recognizing the uncertainty surrounding technological, economic and socioeconomic changes over the next several decades, state agencies should pursue a set of GHG emission reduction strategies to achieve the 2050 goal rather than relying on a single strategy. There are multiple ways to transform the electricity and natural gas sectors to meet the 2050 goal. Although all pathways pose significant challenges and it is unknown which pathway will be successful, reaching the goal will be easier if the state has more options. The loading order provides a guiding principle for energy policy in California to help guide investments.

Setting interim goals can help ensure progress. For example, if by 2030-2035 the state hasn't made breakthroughs in energy storage, advancing efficiency in existing buildings, and electrifying the transportation sector, then the state will need to re-evaluate its efforts to reduce GHGs.

The Pacala and Socolow framework provides a way to break down the daunting task of reducing GHG emissions by 80 percent into manageable pieces.[65] By dividing expected emission reductions into "wedges" – various actions that collectively meet the overall goal – they establish a diversified portfolio to help manage uncertainty and reduce risk. A downside of this framework is that it can provide the false impression that the solution is easy.[66] Also this framework does not account for interactions between emission reduction efforts or the need for sequencing such as pursuing energy efficiency first, followed by electrifying the transportation sector, and then decarbonizing electricity generation. Recognizing these limitations, the wedge concept provides a useful framework for discussing pathways to reduce GHG emissions.

For California, wedges of GHG emissions reductions in the electricity sector address both energy demand and supply. Below is an overview of the vision, challenges, and

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[65] Pacala, Stephen W., and Robert H. Socolow, 2004: Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies. Science, 305, doi:10.1126/science.1100103 968-972. http://www.princeton.edu/mae/people/faculty/socolow/Science-2004-SW-1100103-PAPER-AND-SOM.pdf.

[66] Davis, Steven; Cao, Long; Caldeira, Ken; Hoffert, Martin. *Rethinking Wedges*. Environmental Research Letters. 2013 IOP Publishing LTD. http://iopscience.iop.org/1748-9326/8/1/011001.

recommendations for each wedge. For each wedge, innovation is needed to achieve deep GHG emission reductions, suggesting that RD&D will be critical.

Demand-Side

Demand-side wedges as proposed in this working paper are efforts to increase energy efficiency, demand response, and CHP. In addition to benefits such as reducing costs and criteria pollutants, lowering energy demand reduces the state's burden to develop non-GHG emitting energy sources to meet its energy needs.

Energy Efficiency

California's energy policies have long emphasized energy efficiency, and much of the legislation enacted over the past two decades requires the state to meet its energy needs first with energy efficiency and demand-side resources. Similarly, the first priority in any plan to dramatically cut GHG emissions should be to increase energy efficiency, consistent with the loading order.

California's Building Energy Efficiency Standards are one of the primary strategies to increase energy efficiency and set a path toward the goal for ZNE new residential buildings by 2020 and ZNE new commercial buildings by 2030.[67] Also, there will be ongoing needs and opportunities to optimize building standards beyond these target dates, including: adjusting mix of measures and performance tradeoffs as incremental costs come down and/or shift; incorporating new energy efficiency and DG technologies; adapting the code to more fully reach the more challenging building sectors; minimizing the off-ramps and exceptions to compliance; and simplifying compliance. Further, there may be a need to add water, transportation fueling infrastructure, and/or land use issues to the code. The Energy Commission's *2007 IEPR* emphasized the importance of the building standards to achieve ZNE levels, with a tiered approach being used to achieve ZNE in future standards. The base tier is the traditional mandatory standard that increases in stringency with every code cycle, while additional tiers are voluntary and represent a "reach" standard for advanced levels of energy efficiency. The intent is to give industry and the marketplace a framework to differentiate highly energy-efficient buildings from standard buildings and to pilot these enhanced features to see how well they work before determining which of the measures should be included in future mandatory standards.[68]

The development of appliance efficiency standards is another strategy for reducing energy use in both new construction and existing buildings. Although permanently installed equipment and appliances account for the bulk of building energy use, consumer electronics and other devices that are plugged into outlets ("plug load")

[67] In 2007, the CPUC adopted four specific programmatic goals known as the "Big Bold Energy Efficiency Strategies" which in addition to the ZNE goals included transformation of heating, ventilation, and air conditioning to ensure that its energy performance is optimal for California's climate and giving all eligible low-income customers the opportunity to participate in the low income energy efficiency program by 2020.
[68] http://www.energy.ca.gov/title24/2013standards/background.html.

represent a growing percentage of building energy consumption and must be addressed to achieve ZNE buildings.

In addition to savings from efficiency standards for new construction, there is significant opportunity for savings in existing buildings. Of California's 13 million existing buildings, more than half of residences and more than 40 percent of commercial buildings were built before 1978, when the state first implemented the Building Energy Efficiency Standards.[69] This leaves open opportunities to significantly decrease energy use in the existing housing market using energy efficiency measures.[70] Even with the continuous improvement of the state's Building Energy Efficiency Standards, there is still significant potential to achieve cost-effective savings within buildings constructed in the 1980s and early 1990s. Assembly Bill 758 (Skinner, Chapter 470, Statutes of 2009) requires the Energy Commission to develop and implement a program to achieve cost-effective energy savings in the state's existing residential and nonresidential building stock (AB 758 Program).[71] As identified in the AB 758 action plan development process, energy assessments - particularly when done at the time a building or unit is sold or by a predetermined future certain date - as well as broad public energy use disclosure requirements are effective ways to encourage the reduction of energy use in existing buildings.

Efficiency programs administered by California's utilities are another key element of achieving energy efficiency gains. Additionally, the CPUC approved pilot Regional Energy Networks to give local governments an opportunity to develop a track record as energy efficiency program administrators, a role traditionally held by the IOUs. Regional Energy Networks are aimed at addressing broad geographic areas to achieve deep energy efficiency savings through various tools including financing. The Energy Commission's *2007 IEPR* determined that a statewide efficiency target should be set at 100 percent of economic potential and achieved through a combination of utility and non-utility programs coordinated at the state level by the Energy Commission and the CPUC. The Energy Commission, in consultation with the CPUC and the public utilities, identifies all potentially achievable cost-effective electric and natural gas efficiency potential and establishes 10-year statewide efficiency targets for achieving this potential every four years.

Other opportunities to advance energy efficiency, include a renewed focus on achieving the goals in Executive Order B-18-12 requiring state buildings to become more energy efficient, using Proposition 39 (The California Clean Energy Jobs Act) funds for energy efficiency and clean energy generation projects in schools (K-12) and community

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[69] Brook M., B. Chrisman, P. David, T. Ealey, D. Eden, K. Moore, K. Rider, P. Strait, G. D. Taylor, and J. Wu. July 2011. *Draft Staff Report: Achieving Energy Savings in California Buildings (11-IEP-1F).* California Energy Commission, Efficiency and Renewables Division. Publication number: CEC-400-2011-007-SD.

[70] J. Hodgson, J. Thach, M. Fung, May 2008, *Carbon Footprint of Single-Family Residential New Construction*, California Building Industry Association, http://www.cbia.org/go/cbia/?LinkServID=311F6C70-DB43-4FE7-841A9BAEFCB09228&showMeta=0.

[71] http://www.energy.ca.gov/ab758/.

colleges, and potentially allocating cap-and-trade auction revenues toward existing energy efficiency programs.

Energy Efficiency Challenges

Challenges for increasing efficiency include program participation, cost, and market saturation. Participation in efficiency programs can fluctuate from year to year depending on economics, incentive amounts, and what efficiency measure will "sell" in a given year. Also, even in good economic times many homeowners, landlords, and commercial/industrial property owners are unwilling to spend significant amounts of money on efficiency despite evidence of savings. Making efficiency products attractive enough to entice prospective customers to invest is an ongoing challenge for all of the utilities.

Deploying affordable and effective energy efficiency improvements in all of California's diverse buildings will be a major challenge. Millions of energy upgrades need to be initiated in existing buildings to meet the state's efficiency and GHG reduction goals, which will involve sizeable investments and program coordination for all building types in all regions of the state. California-specific studies of potential GHG emission reductions from energy efficiency assume very deep retrofits of all existing buildings, including all rented space in the residential and commercial sectors. A challenge for rental properties in particular is that building owners have no incentive to pay for efficiency upgrades since it is their tenants who benefit from reduced monthly energy bills (this problem is referred to as a "split incentive"). Because it applies to rented spaces, the AB 758 program has the opportunity to positively impact low-income and disadvantaged communities by increasing employment opportunities and energy savings in those areas. Implementation of the AB 758 Program will need to include close collaboration between partners, stakeholders, and key market actors to transform the market, level the playing field, and convince building owners and decision makers to take action, including resolving critical uptake issues such as the split incentive.

To reach ZNE, a renewable energy source must be integrated into homes and buildings. Cost-effectively integrating renewable energy generation into residential and non-residential buildings will be a challenge and is a concern for adding requirements to Title 24 Building Standards. Steadily increasing plug loads also pose a challenge to meeting the ZNE building goals. If not controlled, the current plug load trajectory could affect meeting the ZNE buildings goals in California by 2020 and is estimated to be about 40 percent of the energy use of a ZNE building.[72] The U.S. Energy Information Administration's 2011 Annual Energy Outlook projects an increase in plug loads of 60 percent from 2010 to 2030, dwarfing traditional categories like lighting and HVAC.[73] As other building loads shrink, plug load will represent a greater portion of overall energy use and make it challenging to achieve significant reductions in building energy

[72] *The Electric Program Investment Charge: Proposed 2012-14 Triennial Investment Plan*, California Energy Commission Report, CEC-500-2012-082-CMF, November 2012, pages 53-54.

[73] http://www.aceee.org/files/proceedings/2012/data/papers/0193-000302.pdf.

consumption. Minimizing plug load, therefore, will be critical to meeting California's ZNE goals.[74]

Challenges for reducing GHG emissions from appliances include the slow turnover rate of products such as refrigerators or HVAC that are not replaced with regular frequency, with resulting market saturation that can affect participation in utility efficiency programs. Also, as electricity-using products become increasingly more efficient, incremental savings diminish and efficiency program costs increase.

One of the biggest challenges to meeting ZNE goals is that California and all other states are preempted from adopting appliance efficiency standards that are more stringent than those covered by federal law. This preemption has been in place since 1987 and prevents California from pursuing energy efficiency standards to aggressively drive down energy consumption for appliances, such as refrigerators, freezers, clothes washers, clothes dryers, dishwashers, air conditioners, heat pumps, furnaces, boilers, water heaters, showerheads, faucets, toilets, light bulbs, lighting fixtures, distribution transformers, pool pumps, motors, consumer audio and video equipment, and battery chargers, that are covered by the preemption. The preemption also affects the building energy efficiency standards because California is prohibited from setting energy budgets for buildings, based on efficiency for air conditioners, furnaces, water heaters and lighting equipment that is any higher than the federal minimum standard. The federal minimum standards are based on a single efficiency level for each type of equipment that is shown to be cost effective for "average" climate conditions in the U.S. and precludes California from setting building standards that are climate-matched, even when higher efficiencies are cost effective by a wide margin. Changing the federal preemption requirements, which have been strongly supported by Congress since their inception, would likely be extremely difficult.

Energy Efficiency Recommendations

Meeting California's efficiency goals will require creative ideas addressing existing building upgrades, new home construction, appliance efficiency, and the perception of efficiency. Building on the recommendations in the 2011 Integrated Energy Policy Report, actions needed are identified below.

Existing Buildings

- There needs to be considerable focus on increasing the efficiency of the existing building stock. The draft action plan for the AB 758 Program proposed three categories of strategies to help California achieve its energy efficiency and GHG emission reduction goals in existing buildings: no regrets strategies, voluntary pathways, and potential mandatory approaches. After considering all information presented at a series of public workshops and in written comments, the Energy

[74] http://www.energydataweb.com/cpucFiles/pdaDocs/904/California_ZNE_Technical_Feasibility_Report_Final.pdf

Commission will finalize the action plan and consider it for adoption in 2014. The CPUC will consider this action plan in the update of their Energy Efficiency Strategic Plan.

New Buildings

- The Energy Commission should adopt triennial updates of mandatory and reach standards to achieve ZNE standards for newly constructed homes by 2020 and newly constructed commercial buildings by 2030.
- The Energy Commission and CPUC should coordinate future IOU "new construction-related" programs with the Energy Commission's efforts to meet the ZNE goals through triennial updates of mandatory and reach standards. By offering incentives for achieving reach standards, providing technology demonstration and development, and conducting pilot programs for demonstrating ZNE solutions, new technologies and building practices will be integrated into upcoming triennial updates of the Title 24 Building Standards and into the market place quicker and with more success.

Appliance Standards

- The Energy Commission, in collaboration with other states, California utilities, and energy efficiency and appliance standards advocacy groups, should intervene in U.S. DOE proceedings to represent the interests of California regarding the upgrade of federal appliance efficiency standards.
- The Energy Commission should continue to engage with the U.S. DOE proceedings to develop common test methods and appliance efficiency databases.
- The Energy Commission should adopt appliance and reach standards that focus on reducing plug loads to enable California's ZNE goals to be achieved.
- The Energy Commission should continue implementation of Public Resources Code section 25402 which requires the Commission to "reduce the wasteful, uneconomic, inefficient, or unnecessary consumption of energy, including the energy associated with the use of water."

Compliance with Building and Appliance Standards

- The Energy Commission should develop regulations to implement SB 454 (Pavley, Chapter 591, Statutes of 2011), which allows the Energy Commission to adopt an enforcement process for violations of appliance efficiency regulations and impose civil penalties of up to $2,500 for each violation, to increase compliance with the Appliance Standards.
- The Energy Commission and CPUC should jointly pursue improved compliance with the Building Energy Efficiency and Appliance Standards.

Research and Development

- The Energy Commission and the CPUC should collaborate on research to advance technologies and strategies, as well as identify the most cost-effective opportunities for new appliance standards. The Energy Commission and the CPUC should also reevaluate existing standards and identify the most cost-effective opportunities for updates that will achieve greater energy savings.

- The Energy Commission and the CPUC should collaborate on research to advance technologies needed to achieve ZNE building standards and successfully implement the AB 758 Program; improve efficiency of existing technologies; develop and demonstrate advanced technologies, integrated products, and strategies; encourage adoption through utility incentive programs or building energy efficiency codes; and understand the role of consumer behavior and motivations.

Demand Response

Along with energy efficiency, demand response is the first resource in California's loading order of preferred resources. Demand response is different from energy efficiency in that demand response is a temporary reduction in energy use in response to a signal from the utility or system operator such as a price signal or emergency alert. Current demand response programs are used to reduce peak demand on the electric system, but future demand response programs are anticipated to have more flexibility, such as reducing or *increasing* demand in response to the system needs. Demand response can help integrate intermittent renewables into the electricity system, improve load management to help deal with increasing or shifting load, avoid the need to build additional new fossil generation and transmission, give customers more options to manage their bills, and lower overall electric system costs. However, demand response is not yet a mainstream market resource, particularly in the residential sector, despite extensive groundwork by the Energy Commission, CPUC, and California ISO over the past decade.

California's Energy Action Plan II set a target of meeting 5 percent of peak demand with price responsive demand response in 2007.[75] A 2009 analysis by the Federal Energy Regulatory Commission indicates that by 2019 California could achieve as much as 17 percent of peak demand reduction through demand response if residential customers were defaulted to dynamic rates with the enabling technologies to control dispatch of electricity to the California ISO's wholesale energy markets.[76]

California has come close to achieving the 5 percent demand response goal through traditional reliability programs intended to address system emergencies that can only be triggered under limited circumstances. While reliability demand response is necessary for grid stability, it is not flexible enough to provide integration services for intermittent resources (discussed further in the Renewable Energy Integration section). For example, reliability demand response is generally available 24 hours after customer

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[75] California Energy Commission and California Public Utilities Commission, *Energy Action Plan II*, September 2005, http://www.energy.ca.gov/energy_action_plan/.

[76] FERC, *A National Assessment of Demand Response Potential*, Prepared by the Battle Group, Freeman, Sullivan & Co., and Global Energy Partners, LLC., June 2009. California state profile, pp. 91.

notification, but to help integrate intermittent resources, demand response needs to be reliably available within relatively short timeframes such as 30 minutes of being called upon. The California ISO is developing a roadmap of strategies to more fully realize the benefits of demand response and energy efficiency in contributing to reliable, efficient management of the grid while reducing the need for conventional generating sources.[77] The Energy Commission has considered the findings of the roadmap in developing recommendations to advance DR in the 2013 IEPR.[78]

Demand Response Challenges

Lack of consumer awareness is a major barrier to increased consumer participation in demand response. Outside of the large commercial, industrial, and agricultural pumping sectors, the term “demand response” has little meaning to most residential and small commercial customers. This is largely due to the fact that many of these customers have never been on demand response programs[79] or time-varying rates; therefore, many are not aware of the connection between their use of electricity and system reliability and costs. Customer education about all aspects of demand response programs needs to be improved. In addition, more information is needed regarding what will motivate mass market customers to participate in demand response opportunities. Customers and demand response providers also need transparent and easily accessible information to determine the value of demand response.

Non-residential customers who do participate in demand response are not always able to respond to signals for load reductions, depending on their capabilities and the frequency of the signals. The risk of penalties for non-performance is a major concern of customers who are considering participation, yet the absence of penalties in a program raises concerns that the demand response may not be reliable and therefore cannot be counted on for planning purposes. Participants also need to be convinced that the financial incentives are high enough to offset any potential losses in production or services that could or will occur when they drop load. However, financial incentives for the programs are limited to ensure that the programs are cost-effective for utility ratepayers who fund the programs. Finding the appropriate balance between these perspectives is a continuous challenge.

The disconnect between retail and wholesale rates is also a barrier. Most customers today neither know nor pay the market price of wholesale power. This has led to the creation of demand-side programs in the retail market designed to work around the

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[77] California ISO Demand Response and Energy Efficiency Roadmap: Making the Most of Green Grid Resources, Draft, June 12, 2013, http://www.caiso.com/Documents/Draft-ISODemandResponseandEnergyEfficiencyRoadmap.pdf

[78] http://www.energy.ca.gov/2013publications/CEC-100-2013-001/CEC-100-2013-001-LCF.pdf

[79] Residential and small commercial customers have participated in air conditioner cycling programs. In 2012, residential customers in SDG&E and SCE territories participated in Peak Time Rebate programs for the first time.

absence of price information. Customers and demand response providers need to accurately calculate the value of their demand response capability.

Demand response remains mostly in the retail market as a demand-side resource. From the system operation perspective, lack of demand response participation in the California ISO wholesale energy market is a major challenge. Until demand response is bid and dispatched into California ISO wholesale energy markets, it is not actively competing against energy bids by supply-side resources. The implementation of direct participation rules by the CPUC, as described earlier, will enable demand response to be bid into the California ISO market by utilities, third party demand providers, or customers themselves (if they meet certain eligibility criteria). The Renewable Energy Integration section provides further discussion on demand response.

Demand Response Recommendations

- The Energy Commission has analyzed the technical, economic, market, and policy barriers to the use of demand response to support reliability and help integrate renewable resources as part of the *2013 IEPR*. The Energy Commission worked closely with the CPUC and the California ISO in conducting this analysis. As part of this effort, the Energy Commission has identified five strategies to advance DR: resolve Rule 24 Issues and enable DR participation in the California ISO market, develop pilot test market products, resolve regulatory barriers, continue the collaborative process among the Energy Commission, CPUC, and the California ISO, and gain customer acceptance of DR. To support the expansion of DR in California, state agencies should continue pursuing the strategies set forth in the 2013 IEPR.
- Further RD&D is needed to document and better understand customer response to demand response programs and dynamic prices, develop pilot programs to assess the impact potential of different incentives and customer strategies, and demonstrate and validate the capability of automated demand response to provide ancillary services and support integration of higher levels of renewable generation.

Combined Heat and Power

By 2030, California will also need widespread use of efficient CHP and combined cooling, heating, and power (CCHP) systems, especially systems fueled by biogas and waste heat-to-power systems. Governor Brown has called for 6,500 MW of new CHP capacity by 2030.[80]

CHP and CCHP systems can displace boilers and air conditioners in industrial, residential, commercial, district, public, and university settings. They can also be offered as standard features in new developments. CHP can complement renewable and alternative power systems in helping California meet its ZNE buildings goals by

[80] http://www.jerrybrown.org/sites/default/files/6-15%20Clean_Energy%20Plan.pdf.

providing baseload power for district energy or smart grid systems (smart grid is discussed further in the Integrating Renewable Generation and Distribution sections of this working paper). In addition, CHP systems can be used in emergency situations by operating separately from the electric grid, providing a dependable local energy source for critical services, such as hospitals, universities, grocery stores, hotels, data centers, housing complexes, waste, and water treatment centers.[81]

Recent technological advancements hold promise for CHP to help reduce GHG emissions by 2030 and beyond. Reciprocating engines are expected to continue to play an important role for small-scale systems (5 MW and below) despite current challenges related to complying with strict emissions regulations. Emerging systems that will help CHP meet emission regulations include dual stage catalyst systems where NOx and CO are treated in separate stages, advanced air-fuel control systems for ultra-low NOx emissions, and the integration of a partial oxidation gas turbine with a reciprocating engine.[82]

Advances in other clean energy technologies, such as fuel cells and microturbines, will help commercialize these technologies by the target years. In particular, stationary fuel cell technology is showing significant improvements in lowering overall costs, improving durability, and increasing fuel flexibility, particularly for the 2050 timeframe. Hydrogen production, storage, and fueling are also expected to improve and advance deployment of clean fuel cell technology. Emerging, clean burning, microturbine applications increase their flexibility and versatility, allowing for expanded deployment of the technology.[83]

CHP Challenges

Currently, CHP developers must pay non-bypassable charges to compensate their local utility for their “departing load” from the utility.[84] These charges deter investment in CHP and are expected to increase as utilities seek to recover costs from infrastructure and procurement investments and other costs of business.

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[81] In 2012, during the massive power outage on the East Coast after Hurricane Sandy, facilities including hospitals, universities, and some residential buildings were able to keep their power, heat, and critical equipment running because they had CHP systems.

[82] Examples of these technologies are found at the 2012 Public Interest Energy Research Annual Report at http://www.energy.ca.gov/2013publications/CEC-500-2013-013/CEC-500-2013-013-CMF.pdf) and the 2012 Natural Gas Research, Development, and Demonstration Report at http://www.energy.ca.gov/2013publications/CEC-500-2013-008/CEC-500-2013-008.pdf.

[83] Examples of these technologies are found at the 2012 Public Interest Energy Research Annual Report at http://www.energy.ca.gov/2013publications/CEC-500-2013-013/CEC-500-2013-013-CMF.pdf) and the 2012 Natural Gas Research, Development, and Demonstration Report at http://www.energy.ca.gov/2013publications/CEC-500-2013-008/CEC-500-2013-008.pdf.

[84] Note, customer generation departing load that is smaller than 1 MW and is eligible for incentives under the CPUC’s Self Generation Incentive Program are exempt from these charges, pursuant to CPUC Decision 03-04-030.

Standby and demand charges can also be costly to projects that have occasional operational issues and go offline for maintenance or other reasons, since going offline for just one fifteen-minute period triggers a demand charge that lasts an entire month. CHP also incurs a demand charge if a fault on the utility system causes the host's CHP system to trip off.

The costs of complying with local NOx emission standards, state GHG standards, and cap-and-trade pose additional challenges to project viability. While advancements in RD&D will help address emission standards, cap-and-trade adds uncertainty about the price of energy from CHP.[85] Under CHP power purchase agreements, the CHP user receives a fixed percentage discount relative to the alternative cost of power from the utility, but that alternative power price is uncertain under cap-and-trade.

Interconnection processes also present both timing and financial challenges. CHP and biomass developers use synchronous generators which often trigger an interconnection requirement to install a mechanical device that shuts the generator down in two seconds if a disturbance is detected. This equipment and the associated communication and control equipment are very expensive and present a significant cost barrier. Finding alternate ways to ensure the safe and reliable operation of these types of generators will be critical for projects using synchronous generators.

Cost issues are further compounded by the likely sunset over the next five years of the financial incentives CHP currently receives. For example, the CPUC's Self Generation Incentive Program ends in 2016, with funding levels declining annually until then.

For fuel cells, further innovation is needed to develop a lower cost fuel cell over the next 15 years. RD&D is needed to find a breakthrough that will reduce fuel cell costs.

Also, some large CHP developers face uncertainty about their ability to secure long-term utility contracts, which provide secure revenue streams for exported electricity. These revenue streams are necessary to attract large upfront capital investments in new facilities. The CHP market is largely shaped by the CPUC's 2010 settlement agreement that created a new Qualifying Facility/CHP Program focused on CHP benefits and GHG emissions reductions with the following goals: (1) IOUs will procure a minimum of 3,000 MW of CHP, and (2) the IOUs will reduce GHG emissions consistent with ARB's 2008 Climate Change Scoping Plan.[86] The 3,000 MW target is expected to be met by 2015 and will likely consist of new contracts for existing CHP (with a contractual exception for San Diego Gas & Electric).[87] Although the GHG reduction goal may require additional CHP solicitations and procurement, there is uncertainty about whether long term contracts will be offered after 2015.

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[85] Hedman, Bruce, Ken Darrow, Eric Wong, Anne Hampson. ICF International, Inc.2012. *Combined Heat and Power: 2011-2030 Market Assessment.* California Energy Commission. CEC-200-2012-002.

[86] http://www.cpuc.ca.gov/PUC/energy/CHP/settlement.htm

[87] CHP Program Settlement Agreement Term Sheet, 5.0 MW Targets, IOUs' MW Targets, 5.1.1. http://www.cpuc.ca.gov/PUC/energy/CHP/settlement.htm.

Finally, CHP is primarily a baseload resource but needs to be dispatchable to help the state address load balancing needs. On December 3, 2012 the California ISO, with assistance from the Energy Commission, implemented its revised tariff definition of regulatory must-take generation related to CHP resources by making it more applicable to facilities capable of producing electricity in conjunction with their industrial processes and thermal energy uses. This new definition allows CHP resources to establish a capacity level eligible for regulatory must-take generation scheduling priority with any remaining capacity eligible for dispatch into the market.[88] Moving forward, the utility system needs a mix of baseload, peaking, and intermediate load following resources to maintain reliable operations.

CHP Recommendations

- Efforts should be made to ensure that new and existing CHP is appropriately valued under future regulatory amendments to California's cap-and-trade program.
- Evaluate potential opportunities to incentivize the development of new bottoming-cycle CHP within existing state programs and the development of new CHP in state and other public facilities. Pursue opportunities on public facilities include development at hospitals and waste water treatment plants throughout California, but particularly in Orange County and San Diego County due to the closure of San Onofre.
- The CPUC, in collaboration with the Energy Commission, should examine and clearly define the interconnection rules for CHP facilities interested in expanding their systems and dispatch capabilities within an existing contract.
- Further RD&D is needed to advance ultraclean emission technologies, reduce costs, integrate emerging, clean CHP technologies in diversified applications, and demonstrate CHP applications using biomass and other feedstocks.

Energy Supply

In addition to significant demand-side measures described above, meeting the 2050 goal requires dramatically cutting GHG emissions from energy generation. Options to decarbonize electricity generation include: renewable energy generation, geothermal energy generation, renewable DG, solar space and water heating, natural gas coupled with CCUS, and nuclear energy.

[88] Regulatory must-take generation, https://www.caiso.com/informed/Pages/StakeholderProcesses/CompletedStakeholderProcesses/Regulatory-Generation.aspx.

Renewable Energy Generation

The RPS is the principal driver of investment in new renewable energy generation capacity for California. Also, as a separate but related policy, Governor Brown set a target of adding 8,000 MW of centralized large-scale renewable facilities by 2020. Distributed renewable generation is discussed separately below. In 2012, California served about 22 percent[89] of retail sales with renewable energy. Unlike many other jurisdictions, California does not include large-scale hydroelectric generation in its renewable energy policies and calculations.

According to Governor Brown, "[w]hile reaching a 33 percent renewables portfolio standard will be an important milestone, it is really just a starting point - a floor, not a ceiling." Williams et al. 2012 puts the maximum penetration of renewable sources[90] of energy serving California by 2050 at 74 percent; at the national level, others have estimated as much as 80 percent.[91] The *2012 IEPR* Update calls for a study to be completed in 2014 of the feasibility of up to 50 percent RPS-eligible energy goal for 2030. Assembly Bill 327 gives the CPUC the authority to require electricity retail sellers to procure eligible renewable energy resources in excess of the 33 percent RPS procurement requirements. In support of discussions relating to the increase of renewable energy generation in California, the California ISO should study the integration requirements needed to support an electricity portfolio that is 50 percent renewable. Studies of a higher renewable energy portfolio should analyze operational issues, costs and GHG savings.

Others are exploring the possibility of meeting all their electricity needs with renewable energy and a growing number of communities in California are setting 100 percent renewable energy targets including Palo Alto, Lancaster, Marin County, San Francisco, San Jose, Santa Barbara, and parts of the city of Los Angeles.[92] These communities are not isolated from the grid and use the grid as storage when they have over or under generation of renewable energy. The California High Speed Rail Authority has committed to using 100 percent renewable energy for powering the rail system which will connect mega regions of the state from Sacramento to San Diego. The ultimate

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[89] Energy Commission staff estimate, based on data from the Renewable Net Short data, http://www.energy.ca.gov/2013publications/CEC-200-2013-001/CEC-200-2013-001.pdf for 2012 and the Preliminary California Energy Demand Forecast , June 2013 http://www.energy.ca.gov/2013_energypolicy/documents/2013-05-30_workshop/spreadsheets/

[90] This includes electricity generation from large hydropower units. Note that the California Renewables Portfolio Standard of 33 percent by 2020 would represent much higher levels of renewables if generation from large hydropower units is considered. Currently generation from large hydro does not count towards the 33 percent target.

[91] NREL (National Renewable Energy Laboratory). (2012). Renewable Electricity Futures Study. Hand, M.M.; Baldwin, S.; DeMeo, E.; Reilly, J.M.; Mai, T.; Arent, D.; Porro, G.; Meshek, M.; Sandor, D. eds. 4 vols. NREL/TP -6A20- 52409. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/analysis/re_futures/

[92] Go 100% Renewable Energy, http://go100percent.org/cms/.

goal is a net-zero system that procures and produces enough renewable energy to offset the energy it uses from the grid.[93]

Renewable generation includes both distributed, small-scale applications (discussed below) and utility-scale facilities. For utility-scale generation, emphasis can be placed on instate development with potential for greater local co-benefits such as local job creation, or a west-wide system striving for a regional, least-cost energy dispatch of an increasingly low- and zero-emission fleet. The current 33 percent RPS emphasizes developing renewable resources within California, but if greater emphasis is placed on regional, west-wide development, California could achieve higher renewable generation targets at lower costs and greater GHG savings.

The grid must be adaptable to handle changes in climate and energy use while maintaining reliability, minimizing land use impacts, and meeting AB 32 and other environmental goals in a cost effective manner. The California ISO conducts an annual transmission planning process covering a 10-year planning horizon, currently through 2022. The transmission plan provides a comprehensive evaluation of the California ISO's transmission grid to identify upgrades needed to successfully meet California's policy mandates, in addition to examining conventional grid reliability requirements and projects that can bring economic benefits to consumers. Approved and pending transmission projects put California in a good position to deliver the renewable generation required to meet the 33 percent RPS, and higher levels by 2030. SCE stated, however, that challenges with building and permitting new transmission lines may hinder the development of these approved projects, potentially causing a delay in reaching their 33 percent RPS requirement.[94] In addition to setting aggressive renewable generation targets, Governor Brown also calls for a dramatic reduction in the permitting time for transmission infrastructure.[95]

An energy imbalance market (EIM) can reduce the need for new transmission with increasing use of intermittent renewables (EIM is further discussed in Renewable Energy Integration section). If renewable levels in 2030 stay closer to 33 percent, or if greater emphasis is placed on developing DG in 2030, then less transmission may be needed, or some may be deferred. The actual transmission needs are highly dependent on the amount, location, and timing of generating resources and load.

Renewable Energy Generation Challenges

The *2011 IEPR* and the *2012 IEPR* Update provide in-depth discussions of the challenges in moving from a century-old system dominated by fossil fuels to one that is "renewable-centric." The challenges include issues relating to planning, permitting and the environment; transmission; integration; investment and financing; cost; research and

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[93] http://www.hsr.ca.gov/Programs/Green_Practices/operations.html
[94] Before the CPUC, Southern California Edison Company's (U 338-E) Final 2012 Renewables Portfolio Standard Procurement Plan, Public Version, Rulemaking 11-05-005, November 29, 2012.
[95] *Clean Energy Jobs Plan*, Governor Jerry Brown, http://gov.ca.gov/docs/Clean_Energy_Plan.pdf.

development; environmental justice; local government coordination; and workforce development. The discussion below touches on some of these challenges.

The DRECP effort is identifying areas for development of renewable resources as well as for conservation and mitigation in the Mojave and Colorado Desert regions.[96] Once complete, the DRECP will offer an approach to addressing the challenges associated with planning, permitting and the environmental review process of renewable energy development in California. California's desert regions are attractive to renewable energy developers. As of April 2013, the CPUC had approved utility contracts with renewable projects in the DRECP area that are estimated to encompass roughly 130,000 acres.[97] The DRECP will provide for species and habitat conservation on a 22 million-acre swath of federal and private land, while accommodating the development of up to 20,000 MW of additional renewable energy generating and transmission capacity by 2040. The DRECP will provide for sufficient renewable energy development in the planning area to help achieve federal and state energy and climate goals, while also achieving conservation goals under the Natural Community Conservation Planning Act and federal Endangered Species Act.

Another example of challenges with recent trends in renewable development is the large portion of California's new RPS-eligible facilities that use photovoltaic energy without storage. A 2012 study by Lawrence Berkeley National Laboratory showed that as the use of solar resources increases, the system's net peak will shift to later in the evening when solar generation wanes. This ultimately reduces the value of solar without storage as it is not available to serve the evening peak load,[98] and analysis by California ISO shows that it leads to steeper ramp requirements to meet the evening peak (see Renewable Energy Integration section, Figure 4). Going forward, a more balanced portfolio will be needed to displace the use of fossil fuel for a broader set of energy services, including baseload, load-following, and peaking electricity.

Increasing amounts of wind and solar resources without on-site storage are requiring changes in grid operation and infrastructure to integrate growing amounts of variable generation (see discussion of Renewable Energy Integration below). The GHG benefits of increased renewable energy will vary depending on how well generation matches demand and the extent to which gas-fired electricity generation is needed. Going forward, California may encounter an upper bound on the amount of variable generation that can be accommodated by geographic diversity, demand response, improved

[96] http://www.drecp.org/.

[97] Estimates prepared for the DRECP, Capacity is from the CPUC's RPS Project Status Table (March 2013) available at: http://www.cpuc.ca.gov/PUC/energy/Renewables/index.htm. Assumes 7 acres/MW for solar, 40 acres/MW for wind.

[98] Andrew Mills and Ryan Wiser, June 2012, Changes in the Economic Value of Variable Generation at High Penetration Levels: A Pilot Case Study of California. http://emp.lbl.gov/sites/all/files/lbnl-5445e.pdf.

forecasting, and other non-GHG integration services needed to maintain system reliability and maximize GHG benefits.[99]

Disadvantaged communities often look to the potential benefits of renewable energy in terms of air quality and job creation. While renewable generation is a tool to provide broad air quality benefits, it does not, however, necessarily displace local fossil plants. Power plants that provide local reliability services and support the grid must continue to operate, and so adding renewable energy locally may actually displace fossil generation located many miles away.[100] Also there is currently a lack of "green collar" employment opportunities and renewable projects in disadvantaged communities in urban and rural areas. Further deployment of renewable technologies and energy efficiency upgrades in such areas can help increase employment opportunities.[101]

Renewable Energy Generation Recommendations

Increasing renewable energy will require changes in the procurement and planning processes to ensure that the mix of renewable energy resources provides high value to California's electricity system. Below are highlighted recommendations from the *2012 IEPR Update*:[102]

- California's electricity planning efforts need to improve and expand. Energy planning is not simply a question of engineering and how to plan for and integrate more renewable resources. It must also addresses economic and equity issues that will require increased involvement by a large and diverse group of stakeholders. Actions to maximize the benefits of renewable energy must include modifying procurement practices to develop a higher-value portfolio that includes not just lower-cost projects but also those that provide integration services, encourage investment in disadvantaged communities, create jobs in California, and provide value to the state as a whole. Long-term planning must also provide the policy certainty needed by the market to encourage new investments and focus future investments in clean technology innovation.

- There are major planning challenges associated with moving from a generating fleet largely composed of dispatchable resources, which can be ramped up or

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[99] Kyle Siler-Evans, Inês Lima Azevedo, M. Granger Morgan, and Jay Apt; Regional Variations in the Health, Environmental, and Climate Benefits of Wind and Solar Generation; PNAS 2013 110 (29) 11768-11773.

[100] Transcript of Energy Commission Lead Commissioner Workshop on Evaluating and Capturing Benefits of Renewable Energy for California, April 12, 2012, comments by Arne Olson, Energy and Environmental Economics, pp. 26-27.

[101] California Energy Commission, 2012. *2012 Integrated Energy Policy Report Update*. Publication Number: CEC-100-2012-001-CMF. http://www.energy.ca.gov/2012publications/CEC-100-2012-001/CEC-100-2012-001-CMF.pdf

[102] California Energy Commission, 2012. *2012 Integrated Energy Policy Report Update*. Publication Number: CEC-100-2012-001-CMF. http://www.energy.ca.gov/2012publications/CEC-100-2012-001/CEC-100-2012-001-CMF.pdf

turned off on demand, to one that includes large amounts of variable renewable resources that cannot. Integrating these resources will require a combination of complementary resources, as discussed in the Renewable Energy Integration section below.

- California must address how to fund clean energy investments. The state will need to leverage federal tax credits, federal and private funding, and build on investments made through utility procurement programs, the ARRA, and the private sector. Funding for renewable energy and efficiency projects is expected to be available as a result of Proposition 39, and other funding sources such as cap-and-trade proceeds may provide additional opportunities.
- Cutting-edge RD&D is needed to produce the next generation of clean energy technologies. Targeted research and development can reduce the costs and environmental impacts of renewable technologies, help create new businesses and jobs, and attract investment capital to the state. To continue this work, implementation of the EPIC program is imperative.
- As California works to achieve its renewable energy goals, its actions must send appropriate price signals to help shape investments and influence behavior. At the same time, rate design must be fair, sustainable, and include mitigation measures for those who are disadvantaged. Actions should also lower the cost of renewables and reduce impacts on electric rates.
- California's energy system has disproportionately affected many of the state's disadvantaged communities, which may not be in line to receive many of the benefits of increasing renewable development throughout the state. Actions to promote renewable energy must also ensure that the costs and benefits of renewable development are fairly distributed.

Further action is needed to advance renewable energy, including:

- To help move toward an electricity system that primarily uses non-GHG emitting generation sources, the state should evaluate policies for ensuring continuing post-2020 reductions in the carbon intensity of electricity generation. Studies conducted should consider impacts on GHG emissions, as well as maximizing the value of renewable energy generation through cost-benefit assessments that include costs associated with integration, permitting, interconnection, and impacts on retail electricity rates.

Geothermal

Geothermal energy – heat from the Earth – comes from steam, water, or other hot underground fluid that is accessed by drilling wells in a process similar to drilling for oil. The hot fluid or steam is a carbon-free resource that can be used directly in heating applications, or can be converted into electricity by using steam to rotate a generating turbine. California has a unique abundance of geothermal resources that vary from low-temperature resources that can be used directly for district heating, aquaculture, and recreational uses to moderate- and high-temperature resources that can be used to produce electricity. With the exception of the Central Valley and the upper northwest part of the state, geothermal resources and features, such as hot springs, have been found throughout California.[103]

Geothermal electrical production is generally located in or near areas with identified resources referred to as Known Geothermal Resource Areas (KGRAs).[104] KGRAs include the larger production areas at The Geysers KGRA in northern California, several KGRAs in Imperial County in southern California, and the Coso Hot Springs KGRA on the eastern side of the Sierra Nevada. The United States Geological Survey (USGS) estimates the mean electric power generation potential from the state's identified moderate-temperature[105] and high-temperature[106] geothermal resources to be 5,404 MW.[107] In addition, increased exploration and improvements in exploration and production technologies may yield significant additional electrical generation potential from undiscovered or unconventional geothermal resources, such as enhanced geothermal systems (EGS). The USGS has estimated the mean electric power generation potential from undiscovered resources in California to be 11,340 MW, with an additional 48,100 MW potential from EGS.[108]

With an installed geothermal capacity of 2,732 MW,[109] California currently leads both the nation and the world in the production of electricity from geothermal energy. Thirty-three additional geothermal electrical production projects (ranging from prospect development to resource production and power plant construction) are under development in California, with planned added capacity up to 1,061 MW and an estimated resource capacity of up to 1,827 MW.[110] Geothermal projects often need extensive resource exploration, characterization, and development work at the front end and can be very capital and time intensive, possibly taking several years at each development phase. However, if all of the existing thirty-three projects under development are successfully completed in the next 10-15 years, California could potentially reach more than 3,800 MW of installed geothermal electrical capacity by 2025-2030.

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[103] California Division of Oil, Gas, and Geothermal Resources, 2002. *Geothermal Map of California*, 2002. Map Number S-11. ftp://ftp.consrv.ca.gov/pub/oil/maps/Geothermal/MapS-11.pdf

[104] Title 14, Code of Federal Regulations, Section 3200. Definitions. "Known Geothermal Resource Area (KGRA) means an area where BLM determines that persons knowledgeable in geothermal development would spend money to develop geothermal resources".

[105] 90 to 150 degrees Celsius (C) [194 to 302 degrees Fahrenheit (F)]

[106] Greater than 150 degrees C (302 degrees F)

[107] United States Geological Survey, 2008. *Assessment of Moderate- and High-Temperature Geothermal Resources of the United States*, 2008. Fact Sheet 2008-3082. Table 1. http://pubs.usgs.gov/fs/2008/3082/pdf/fs2008-3082.pdf

[108] Ibid.

[109] Geothermal Energy Association, 2013. *2013 Annual US Geothermal Power Production and Development Report*, April 2013, page 20. http://geo-energy.org/pdf/reports/2013AnnualUSGeothermalPowerProductionandDevelopmentReport_Final.pdf

[110] Ibid. Estimated resource capacity is the estimated amount of electricity recoverable from a geothermal resource, while the planned added capacity is an estimate of the portion of a geothermal resource that a developer plans to develop/use for electrical production.

In addition to the moderate-temperature and high-temperature resources suitable for electrical production, California has abundant lower temperature geothermal resources that could be used for small scale distributed generation and co-generation in connection with oil and gas[111,112] or mining operations, as well as for direct use applications and cascading, a practice where geothermal fluid is reused in a series of lower temperature applications.

In its Annual Energy Outlook 2013, the United States Energy Information Administration (EIA) estimated national renewable energy capacity growth from 2011 to 2040 based on oil and natural gas economics, market trends, regulatory influences, and a reference case developed for the assessment. EIA projected that nationally, geothermal capacity would more than triple from 2011 to 2040.[113] Although California currently leads the nation in geothermal capacity, development in other western states is accelerating and could account for a significant amount of the projected national growth in geothermal capacity. If economic and technical challenges can be overcome, however, California could develop significantly more geothermal electrical capacity from the estimated identified and undiscovered geothermal resources in the state. Imperial Irrigation District projects that the Salton Sea alone could have as much as 2,500 MW of economic geothermal potential.[114]

Geothermal Challenges

Geothermal power offers a number of operational benefits over variable energy resources such as wind and solar. With steady well production, geothermal plants can provide reliable power with highly efficient use of transmission capacity due to initial capacity factors ranging from 75 – 97 percent,[115,116,117,118] while binary geothermal plants can also provide flexible power and ancillary services by controlling the flow and pressure of fluids in the plant. Possible integration and ancillary services include

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[111] United States Department of Energy, 2012. *Geothermal Technologies Program Coproduction Factsheet*, DOE/EE-0699, February 2012. http://www1.eere.energy.gov/geothermal/pdfs/gtp_coproduction_factsheet.pdf

[112] Glassley, W.E., et al, 2013, *Geothermal Energy Potential from Oil Fields in the Los Angeles Basin and Co-Located Renewable Resources*, GRC Transactions, Vol. 37, 2013.

[113] U.S. Energy Information Administration, 2013. *Annual Energy Outlook 2013 with Projections to 2040*, April 2013. DOE/EIA-0383(2013),
Page 74. http://www.eia.gov/forecasts/aeo/pdf/0383(2013).pdf

[114] Imperial Irrigation District, *Salton Sea Revenue Potential Study – Final*, December 2013, http://www.iid.com/Modules/ShowDocument.aspx?documentid=8464.

[115] Richard, C., 2013. *Interpretation of U.S. Geothermal Industry Data Analysis of Capacity, Net Production, and Efficiency Trends: 2002-2011*. Page 639, GRC Transactions, Vol. 37, 2013.

[116] Kagel, A., et al, 2007. *A Guide to Geothermal Energy and the Environment*. Geothermal Energy Association, April 2007. Page 8, Table 1. http://geo-energy.org/reports/environmental%20guide.pdf

[117] International Energy Agency, 2010. Renewable Energy Essentials: Geothermal. http://www.iea.org/publications/freepublications/publication/Geothermal_Essentials.pdf

[118] U.S. Energy Information Administration, 2013. *Levelized Cost of New Generation Resources in the Annual Energy Outlook 2013*, January 2013. Page 4, Table 1. http://www.eia.gov/forecasts/aeo/er/pdf/electricity_generation.pdf

regulation up and down, spinning and non-spinning reserve, load following, and supplemental reserve.[119]

However, these benefits of geothermal power are not fully valued because the added costs of system integration, capacity, and ancillary services required by solar and wind are not included in renewable energy pricing for power purchase agreements. For example, under the 2011 RPS Solicitation, the CPUC required that a “zero” adder be used for integration costs in evaluating bids.[120] This, along with the large upfront capital costs for exploration and development, can make geothermal less attractive and competitive in the California energy market. Greater appreciation of geothermal energy’s ancillary benefits may lead to better pricing of geothermal in power purchase agreements structured under the CPUC RPS Program. Furthermore, as discussed in the 2012 Integrated Energy Policy Report, integration costs (e.g. ramping, regulation) and capacity-related services provided by renewable resources are not included in the CPUC’s procurement practices. This is problematic in that it prevents the procurement of a “least direct costs” portfolio. Actions to maximize the benefits of renewable energy include modifying procurement practices to develop a higher-value portfolio that includes not just lower-cost projects but also those that provide integration services, reduce the risk of forest fires that damage transmission lines, encourage investment in disadvantaged communities, create jobs in California, and provide value to the state as a whole.

Before executing power purchase agreements and starting power plant construction, geothermal developers must conduct resource exploration and development activities, including drilling exploration and production wells, to identify the characteristics and extent of the resource. These exploration and drilling activities are high-risk and represent a major capital cost for geothermal projects, requiring long lead times, expensive equipment, and technical expertise. The average cost for a single production well can range from $1-$5 million, depending on well depth and resource conditions.[121] High temperatures and corrosive geothermal steam and fluid conditions also require costly specialized materials for drilling and power plant construction. Improvements in non-drilling exploration technologies for resource assessment, such as geological, geophysical, and seismic survey methods, along with advances in drilling technologies and construction materials, can help reduce the costs associated with resource exploration, confirmation, and development.

[119] Geothermal Energy Association, 2013. *The Values of Geothermal Energy: A Discussion of the Benefits Geothermal Power Provides to the Future U.S. Power System*, October 2013. Page 11. http://geo-energy.org/reports/Values%20of%20Geothermal%20Energy%20Draft%20Final.pdf

[120] California Public Utilities Commission, 2011. *Decision Conditionally Accepting 2011 Renewables Portfolio Standard Procurement Plans and Integrated Resource Plan Supplements*, Decision 11-04-030, April 14, 2011.

[121] Shevenell, L., 2012. *The Estimated Costs as a Function of Depth of Geothermal Development Wells Drilled in Nevada*. Page 126, Table 4, GRC Transactions, Vol. 36, 2012. http://www.atlasgeoinc.com/wp-content/uploads/Costs-GRC-2012.pdf

Lastly, increased exploration for undiscovered geothermal resources in the state would greatly expand resource use opportunities. Potential targets for exploration include areas outside of designated KGRAs with existing thermal features or conditions that may be consistent with geothermal systems and/or elevated subsurface temperatures.

Geothermal Recommendations

- The utilities and the CPUC should adopt changes to procurement practices for renewable energy generation such that procurement decisions consider an expanded suite of renewable energy benefits.
- Using geothermal power's potential as a flexible resource should be encouraged and its ancillary benefits to the grid should be recognized in power pricing agreements.
- Research is needed to further develop technologies and tools for remote sensing, surface, and downhole investigations and reservoir modeling to reduce the costs of geothermal exploration and development. Advances in materials engineering for high temperature and corrosion tolerant plant and well components can also reduce construction and maintenance costs. Innovative geothermal research, development, and demonstration projects in these areas should be supported with increased funding opportunities that can also leverage funding from other sources.
- Funding should also be provided for increased exploration to identify undiscovered geothermal resources.

Renewable Distributed Generation

Governor Brown set a target of adding 12,000 MW of renewable DG (20 MW or less) by 2020 as part of meeting the overall 33 percent RPS goal. The Energy Commission is tracking progress of the many programs in place that are helping the 12,000 MW by 2020 goal for renewable DG, including self-generation and wholesale renewable generation facilities 20 MW or smaller. In the IOU service territories, the following programs help achieve this goal: the CPUC's California Solar Initiative, Self Generation Incentive Program, and Renewable Auction Mechanism; the Energy Commission's New Solar Homes Partnership and Emerging Renewables Program (now closed); IOU solar projects; IOU feed-in tariff programs (AB 1969, SB 32, SB 1122); SCE Renewables Standard Contracts; and utility solar photovoltaic (PV) programs and RPS contracts for projects 20 MW or smaller. The following publicly-owned utility programs also help to achieve this goal: publicly-owned utility SB 1 programs; publicly-owned utility SB 32 feed-in tariff programs; and publicly-owned utility RPS contracts with projects 20 MW or smaller. As of August 2013, if all DG programs are fully subscribed by 2020, California will have more than 9,000 MW of renewable DG. If current programs succeed in transforming the market for renewable DG, much of the additional future capacity needed to achieve the goal could occur through market mechanisms.

As discussed in the Energy Efficiency section, DG is needed to meet the state's ZNE goals. To achieve ZNE, the amount of energy provided by on-site renewable energy sources equals the amount of energy used by the building over a typical year.

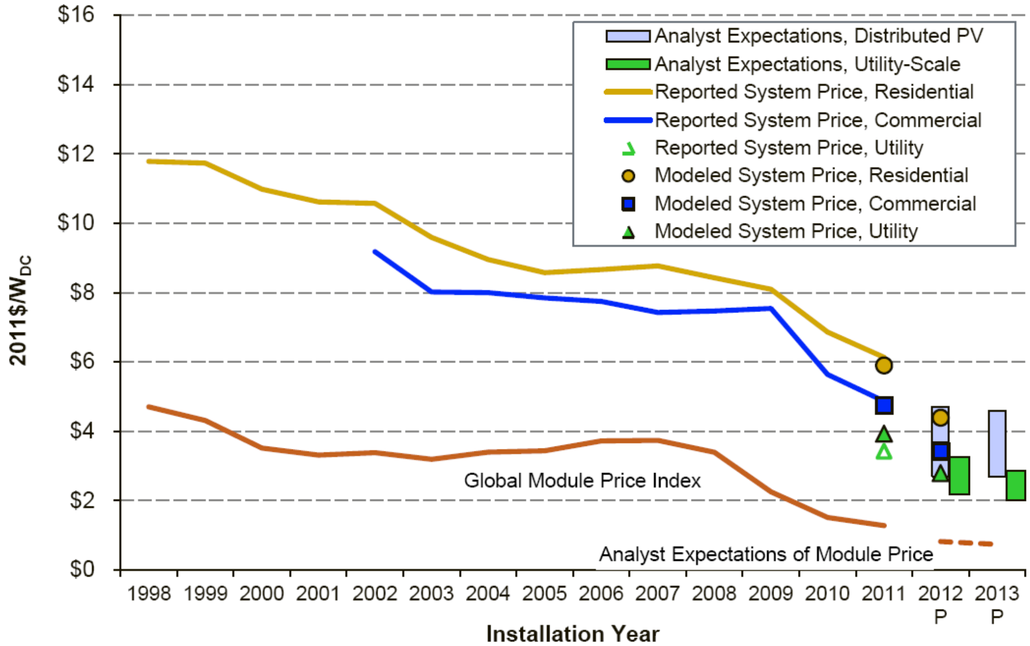
Currently, the pace of DG deployment on new homes is rapidly increasing as indicated by requests for New Solar Homes Partnership incentives. As new home construction in California emerges from the housing market crisis, the pace of requests for incentives from New Solar Homes Partnership is growing quickly. For example, the reservation amount dropped from about $27.9 million in 2008 to about $18.3 million in 2009 with the housing crisis. In 2010, it started to climb back up and in 2012, the reserved amount was almost $47 million.[122] If New Solar Homes Partnership activity in the first 2 months of 2013 continues, the Energy Commission would see reservation requests totaling approximately $75 million for the year.

PV costs have historically been high compared to other energy sources, but have sharply declined in recent years. A study by Bloomberg noted that in late 2011, prices for PV modules fell below the $1.00/W mark; moving towards the benchmark of $1.00/W installed cost for PV systems, which is often regarded in the PV industry as marking the achievement of grid parity for PV.[123] As shown in **Figure 3,** analysis at the U.S. DOE SunShot Initiative show declines in modules and system prices.

[122] http://www.gosolarcalifornia.ca.gov/about/nshp.php, last updated April 15, 2013.

[123] Morgan Bazilian, IjeomaOnyej, Michael Liebreich, Ian MacGill, Jennifer Chase, Jigar Shah, Dolf Gielen, Doug Arent, Doug Landfear, and Shi Zhengrong; Bloomberg Energy Finance; Re-considering the Economics of Photovoltaic Power; http://about.bnef.com/white-papers/re-considering-the-economics-of-photovoltaic-power-a-co-authored-white-paper-on-pv-economics/

Figure 3. U.S. DOE Sunshot: Historic, Recent, and Projected Photovoltaic Pricing Trends (November 2012)



Source: U.S. DOE, November 2012. SunShot: Photovoltaic (PV) Pricing Trends: Historical, Recent, and Near-Term Projections. http://www.nrel.gov/docs/fy13osti/56776.pdf.

Moving forward, California could choose to embrace a high renewable DG policy that supports a large number of communities choosing to pursue 100 percent RPS-eligible renewable targets. Such a pathway should be coupled with policies to develop a portfolio of technologies and renewable resources that provide distribution and transmission grid stabilizing services needed to maintain safety and reliability. For example, California already supports several projects that demonstrate the use of community scale DG to assist with renewable integration issues and grid reliability. The Energy Commission funded over twenty community renewable energy projects which demonstrate the cost-efficient integration of high-penetrations of renewable energy within a given community based on locally-available renewable energy potential. To the extent that systems are designed to provide self-generation only and store excess generation on-site, the impact of high levels of DG on California's distribution and transmission grids can be reduced.

Renewable Distributed Generation Challenges

Many of the challenges and recommendations discussed in the Renewable Energy Generation section also apply to renewable DG. A challenge unique to DG, however, is the need to modernize the distribution system to accommodate large volumes of DG. Meeting the Governor's goal of 12,000 MW of DG by 2020 requires the distribution system to be modernized and this need would increase if renewable DG policy targets are increased. A study by KEMA prepared for the Energy Commission examines experience in Germany and Spain to integrate large amounts of renewable DG and identifies potential distribution system upgrades that may be needed in California.[124] A study by the Resnick Institute[125] looks at the challenges of maintaining grid stability, reliable energy supplies, and affordability as the energy system becomes increasingly more distributed with millions of new participants that will affect power supply and demand. Meanwhile, the grid is conveying increasing amounts of electricity from inherently intermittent and difficult to predict solar and wind resources. Possible electrification of the transportation and industrial sectors will further strain the distribution system.

A fundamental issue is that the distribution system was designed to move electricity in one direction: from central station power plants, through the transmission system, to substations, and finally to consumers. Changes and upgrades in both transmission and distribution infrastructure will be needed as concentrations of renewable DG increase, especially if the amount generated greatly exceeds minimum load at the local level or if the project is participating in a wholesale procurement program. New protection and control systems are required to avoid damaging the system in the event that DG exceeds local demand and flows backward into circuits or substations. The amount of upgrades needed will be affected by whether cost-effective storage options are available in conjunction with increasing levels of DG.

Updating legacy utility systems, however, will take time, planning, and financial investment. However, California's distribution system planning lacks transparency and is not well coordinated with other planning processes such as the Long Term Procurement Plan (LTPP), transmission planning, DG procurement programs, or smart grid deployment plans. This is expected to result in interconnection delays, lost opportunities to deploy DG strategically, and increased costs.

Similar to large-scale renewables, renewable DG creates integration challenges, as discussed below in the Renewable Energy Integration section. This is compounded by the fact that DG is not visible to the California ISO. As DG deployment increases, large daily swings in the net load (load minus intermittent generation) are expected with overgeneration during the day and a sharp drop at night when PV no longer produces energy. Also, fluctuations in PV generation output due to changes in cloud cover can appear as sudden additions or drops in load that need to be managed to maintain grid reliability. Looking to 2050, California will need a fully integrated smart grid enabling grid operators to monitor the distribution system in real-time using advanced sensors, system monitoring devices, and a well developed communication system.

Another way to accommodate high penetrations of DG is to develop self-generating, electrically isolatable microgrids. For example, the University of California, San Diego uses a microgrid and provides a demonstration site to test advances in DG and

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[124] Corfee, K., D. Korinek, C. Hewicker, M. Pereira Morgado, H. Ziegler, J. Zillmer and D. Hawkins, KEMA. 2011. *Distributed Generation in Europe*. California Energy Commission. Publication Number: CECV400V2011V011. Sacramento, Calif.

[125] Resnick Institute Report, Grid 2020 Towards a Policy of Renewable and Distributed Energy Resources, September 2012, http://www.gridwiseac.org/pdfs/grid_2020_resnick_report.pdf

communication and control management systems. The university's microgrid contains a portfolio of local energy demand and clean energy generation systems, including energy storage, electric vehicle charging, CHP, and various renewable technologies.[126] Other promising applications are facilities with very high reliability needs such as prisons, military bases, data centers, and remote locations, such as Borrego Springs.

Although PV cell costs have rapidly declined and PV is becoming increasingly cost-effective, the cost of interconnection to the distribution grid can be high. Similar to the challenge of interconnecting utility-scale renewable generation, the location of a renewable DG project can have a significant effect (negative or positive) on the cost and speed of both utility interconnection and local government permitting processes.

Electricity rate design is another concern related to costs. California's current residential tiered rate design – in which the per-kilowatt-hour rate increases in blocks as electricity consumption rises – is intended to drive efficiency but does not fully capture the fixed cost of providing electricity service. Most residential ratepayers do not understand the tiered block rates and block rates do not necessarily help low-income consumers.[127] Under current rate design, as energy efficiency and DG increase, more of the fixed costs will be spread amongst a smaller ratepayer base. The CPUC is currently exploring these issues in its proceeding, Rulemaking12-06-013.[128]

A related challenge is uncertainty around the continuation of net energy metering (NEM), a billing arrangement which allows customers who install solar PV and other RPS-eligible DG facilities to receive a credit for excess energy that is fed back to the utility. NEM enables customers to use the full output of variable DG technologies, such as solar PV facilities, without having to fully consume the system output in real time. Similarly, NEM supports the development of ZNE buildings. However, under NEM, utilities recover little or no fixed costs from residential customers. This is because, as discussed above, current rate design attempts to recover fixed costs through volumetric charges for residential customers. In October 2013, E3 provided a report to the legislature on these issues.[129]

Subsequently, rate reform legislation, Assembly Bill 327 (Perea, Chapter 611, Statutes of 2013), was signed by the Governor on October 7, 2013 that will have implications on

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[126] California Energy Commission, January 9, 2013, "Energy Commission Awards More than $1.8 million for UC San Diego microgrid Projects." http://www.energy.ca.gov/releases/2013_releases/2013-01-09_UCSD_nr.html.

[127]Transcript of Energy Commission Lead Commissioner Workshop on Retail Rate and Cost Issues with Renewable Development, May 22, 2012, comments by Severin Borenstein, UC Energy Institute, http://www.energy.ca.gov/2012_energypolicy/documents/2012-05-22_workshop/2012-05-22_transcript.pdf

[128] CPUC, *Order Instituting Rulemaking on the Commission's Own Motion to Conduct a Comprehensive Examination of Investor Owned Electric Utilities' Residential Rate Structures, the Transition to Time Varying and Dynamic Rates, and Other Statutory Obligations,* Rulemaking 12-06-013, June 28, 2012, http://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/169782.PDF.

[129] http://www.ethree.com/documents/CSI/CPUC_NEM_Draft_Report_9-26-13.pdf.

NEM going forward and could affect any analysis of societal benefits. Among many other requirements, the bill extended the sunset date for NEM to July 1, 2017 and directed the CPUC no later than December 15, 2015 to develop a standard contract or tariff for customer generation projects. Implementation of these aspects of the bill may have implications of the cost-effectiveness of NEM as well as ratepayer costs and benefits.

Renewable Distributed Generation Recommendations

- The recommendations highlighted from the *2012 IEPR* Update in the Renewable Energy Generation section also apply to DG. Additionally, the *2012 IEPR Update* calls for building transparency into the distribution system planning. Distribution planning should integrate information on increasing quantities of DG while maintaining reliability, controlling costs, and reducing emissions.

Other actions needed include:

- Coming to a timely resolution and implementing reforms being addressed by the CPUC to "ensure that the interconnection process is timely, non-discriminatory, cost-effective, and transparent" (Rulemaking 11-09-011) are needed to help advance DG.
- The CPUC and the Energy Commission should work with the California ISO to determine what operational communication and control technologies are needed to provide greater visibility and respond to dispatch instructions from both the California ISO and utilities.
- The CPUC should ensure the timely implementation of AB 327 NEM requirements.

Renewable Energy Integration

As more variable renewable electricity generating resources like wind and solar are added to California's electricity resource mix, it becomes more challenging for the system operator to balance supply with demand and maintain reliability. Wind and solar output can rise or drop from moment to moment, across hours, and over days or months. Solar resources begin production after sunrise, peak in early afternoon, and more or less shut down at sunset. Wind patterns vary considerably over seasons and locations, but generation commonly peaks at night during the summer. While wind and solar have daily patterns that complement each other on average, actual production varies. A study by the Resnick Institute highlights critical engineering, economic, and policy issues that must be addressed to ensure a successful transition to an electrical system in which renewable and DG are increasingly deployed.[130]

[130] Resnick Institute Report, Grid 2020 Towards a Policy of Renewable and Distributed Energy Resources, September 2012, http://www.gridwiseac.org/pdfs/grid_2020_resnick_report.pdf

Currently, natural gas fired and hydroelectric power plants are the primary mechanism for integrating renewable resources to match supply and demand in real time. Assembly Bill 1257 (Bocanegra, Chapter 749, Statutes of 2013) requires the Energy Commission to determine the role of natural gas-fired generation as part of a resource portfolio, identify strategies and options to take advantage of natural gas as a low-emission resources, and optimize the role of natural gas as a flexible and convenient end use energy source. As part of that analysis, the Energy Commission is required to do a life-cycle GHG emissions study of the natural gas sector every four years. The 2015 Integrated Energy Policy Report will include this analysis. By 2050, the state should only use natural gas to integrate renewable resources, when it is coupled with CCUS. Currently gas resources typically have more than 300 starts and stops per year and operate about 40% of the time. Over time there are likely to be more start-ups and less overall operational. Renewable developers of geothermal and biomass should strive to design their facilities to compete economically in providing these services rather than only functioning as a baseload operation.

Maintaining reliable operation of the electricity system with a high level of intermittent resources will require integration services including regulation to follow real-time ups and downs in renewable generation, voltage, or frequency; ramping generation to follow swings in wind or solar output; spinning reserves that are standing by and ready to connect to the grid; replacement power for outages; and strategies to deal with over-generation conditions. It will also require complementary fast-response generation, energy storage, and demand response that can be turned up and down as needed.

Another consideration is that the mix and distribution of resources in California's renewable energy portfolio will affect integration requirements. For example, the thermal inertia of the fluids in a solar thermal electric power plant allows the generator to avoid sudden drops in energy generation when there is cloud cover. Also, broad geographic placement of PV can help mitigate the need for integration services associated with central station PV.[131] Some renewable powered facilities – such as variable speed hydropower, geothermal energy, and dispatchable biopower generation – can provide load following services, although the economics have not been favorable to date (and biomass supply is likely to be limited by increasing demand in the transportation sector). Another option is to curtail generation at times of overgeneration, but this has not been pursued thus far because it would put project financing at risk. Also, technologies can effectively be co-located to provide integration benefits as demonstrated in Braedstrup, Denmark. Although a potentially costly example, the city combined a solar thermal heating with a CHP plant, a borehole geothermal heat pump, and an electric boiler to provide district heating. The combination allows the district heating system to help integrate intermittent wind energy resources and stabilize the grid.[132]

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[131] Mills, Andrew and Ryan Wiser, Ernest Orlando Lawrence Berkeley National Laboratory, *Changes in the Economic Value of Variable Generation at High Penetration Levels: A Pilot Case Study of California,* June 2012, http://eetd.lbl.gov/EA/EMP.

[132] http://www.solar-district-heating.eu/NewsEvents/News/tabid/68/ArticleId/216/Braedstrup-Solar-Park-in-Denmark-is-now-a-reality.aspx.

Wide deployment of storage technologies, increased demand response, and expanded energy imbalance markets should be the primary mechanisms for meeting integration needs by 2050. Improved forecasting tools, and advancements in a smart grid will also help.

- **Storage:** While taking steps to minimize integration needs, the state must also advance energy storage technologies to help integrate increasing amounts of renewable resources. Storage technologies can be applied on the transmission and distribution system. Storage can help maintain a reliable and efficient transmission grid, providing voltage support to reduce flicker, frequency response by automatically injecting energy into the grid, and grid stability by supplying immediate energy to stop oscillations and improve grid dampening. Storage can also provide load-following capabilities to manage frequent and wide variations in solar and wind energy due to their fast ramp rates (MW power delivered per minute). Some storage technologies such as compressed air and pumped storage have higher ramp rates than conventional gas generation.[133] With smart inverters, storage can also potentially provide a service similar to inertia needed to maintain grid reliability that is currently provided with natural gas facilities.[134]

  Energy storage covers a wide range of emerging technologies, and while pilot project testing has been scaling up, pumped hydro is the only storage technology with extensive use in the field. Emerging storage technologies include flywheels, supercapacitors, batteries, and compressed air systems. Efforts are focused on putting more energy in a smaller package, at a lower price.

  Each energy storage technology has unique characteristics. Flywheels have historically been costly to install and have been used as "power devices", with high power output compared to energy capacity, resulting in brief discharge durations on the order of 15 minutes. Research is ongoing to produce flywheels with dramatically lower costs per kWh of energy capacity and with greater capacity to discharge over several hours. Supercapacitors have dramatically dropped in cost over the past decade and are an emerging energy storage technology capable of very high ramp rates, giving them a potential role in PV output stabilization. Batteries can have various chemistries and are typically capable of scaling up very cost-effectively, giving them a promising role in grid-level storage, but they have yet to be widely validated and verified for utilities. Conventional compressed air energy storage often requires underground caverns, limiting the technology's potential, but state of the art research is ongoing to create modular and more cost-effective aboveground systems.

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[133] 2011. *Renewable Power in California: Status and Issues*. California Energy Commission, December 2011, Publication No. CEC-150-2011-002-LCF-REV1.

[134] 2011. *Renewable Power in California: Status and Issues*. California Energy Commission, December 2011, Publication No. CEC-150-2011-002-LCF-REV1.

Vehicle-to-grid is another important storage option. Vehicle-to-grid applications allow for the bidirectional flow of electricity between plug-in electric vehicles (PEVs) and the grid, introducing the possibility of using PEV batteries as energy storage. With the development of vehicle-to-grid communications, PEVs can absorb energy during times of low demand or over generation and can then provide energy stored in the vehicle battery back into the grid during times of peak demand or when the grid is stressed. This application will benefit both utilities and vehicle owners as grid operators can use the PEVs as a resource to manage and stabilize the grid, while providing PEV owners the ability to sell electricity back to the grid, effectively reducing the cost of owning an electric vehicle.

The 2009 study by E3[135] suggested that an additional 12,000 MW of storage would be needed for a high renewable case with 74 percent renewable generation, 6 percent nuclear, and 20 percent other (including large hydropower, natural gas, and unspecified imports). Even with a high CCUS scenario (47 percent CCUS, 7 percent nuclear, 36 percent renewable, 10 percent other), the authors roughly estimate that 8,000 MW of storage would be needed, with more storage required if higher amounts of renewable energy comes online. California currently has about 1,200 MW of storage on line.[136] In October 2013, the CPUC adopted an energy storage procurement framework and design program which requires the IOUs to procure 1,325 MW of energy storage by 2024.[137]

- **Demand Response:** Currently, the utilities' demand response programs are included in the retail market but do not directly participate in the wholesale market through which the California ISO manages the grid. The programs also lack specific geographic presence targeted to locational needs, and are not visible or dispatchable by the California ISO. Such qualities are necessary to provide integration services.

  Demand response can best facilitate renewable integration via flexible, fast-response automated load control, auto-DR. Flexible demand response has the potential to displace the fossil generation that would otherwise be needed to maintain grid stability as a greater portion of generation is provided by renewable resources. The Energy Commission's research has demonstrated the technical feasibility of using auto-DR to maintain grid power quality at costs lower than traditional generation. Existing retail demand response programs are not designed to meet intermittent resource balancing needs and new flexible, fast-responding demand response programs must be designed and implemented.

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[135] E3, November 2009, *Meeting California's Long-Term Greenhouse Gas Reduction Goals*, http://ethree.com/public_projects/greenhouse_gas_reduction.html.

[136] 2011. *Renewable Power in California: Status and Issues*. California Energy Commission, December 2011, Publication No. CEC-150-2011-002-LCF-REV1.

[137] CPUC; Decision Adopting Energy Storage Procurement Framework and Design Program, October 17, 2013; http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M078/K912/78912194.PDF.

- **Energy Imbalanced Market:** A proposed energy imbalance market (EIM) between the California ISO, PacifiCorp, and NV Energy will help advance renewable integration and has a target implementation date of October 2014. The benefits of an EIM include dispatching energy every five minutes, providing real-time visibility across all balancing authorities, balancing load and resources in real-time with least cost generation, avoiding congestion, and taking advantage of geographical diversity of load and resources. Upon successful implementation of the EIM, the California ISO plans to offer EIM to additional participants throughout the West.
- **Forecasting:** Another mechanism for integrating renewable electricity generation is improved weather and operational forecasting tools. High-accuracy forecasting and modeling of intermittent PV and wind, especially for large power plant installations, will be a necessary tool for grid operators to minimize the operating reserves and standby capacity needed to ensure grid stability. Improved forecasting models will help to alert grid operators of upcoming ramp events, or sudden increases or decreases in energy production. In combination with widely-deployed energy storage, demand response, and fast-ramping natural gas power plants, state-of-the-art PV and wind forecasting could be a useful tool to integrate renewables into the California grid at the lowest cost.[138]
- **Smart Grid**: Finally, widespread deployment of a smart grid is needed to integrate increasing amounts of renewable DG. "Smart grid" refers to a distribution system that allows information from a customer's meter to flow in two directions: both inside the house to thermostats, appliances, and other devices, and from the house back to the utility. Smart grid can include a variety of operational and energy measures like smart meters, smart appliances, renewable energy resources, energy efficiency resources, demand response, and energy storage.[139] A smart grid can help coordinate renewable generation and storage on the supply-side with demand response for customer loads, increasing the value of each of these services.

Renewable Energy Integration Challenges

The surge in renewable generation with variable production profiles will accelerate through 2017, including as much as 7,000 MW of variable central station resources and a significant share of the 8,700 MW of DG needed to reach the State's goal of 12,000 MW by 2020. A majority of these resource additions will be solar photovoltaic which typically is a resource that peaks at noon. Intermittent renewable resources that increase the minute-to-minute and hourly variability of the electric system require more ancillary services and ramping capabilities for the grid to operate reliably. **Figure 4** demonstrates how renewable resource additions beginning in the 2013 – 2014 timeframe will significantly change the net load curve that the California ISO will be

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[138] National Renewable Energy Laboratory. May 2010. *Western Wind and Solar Integration Study*. Prepared by: GE Energy. NREL/SR-550-47434.

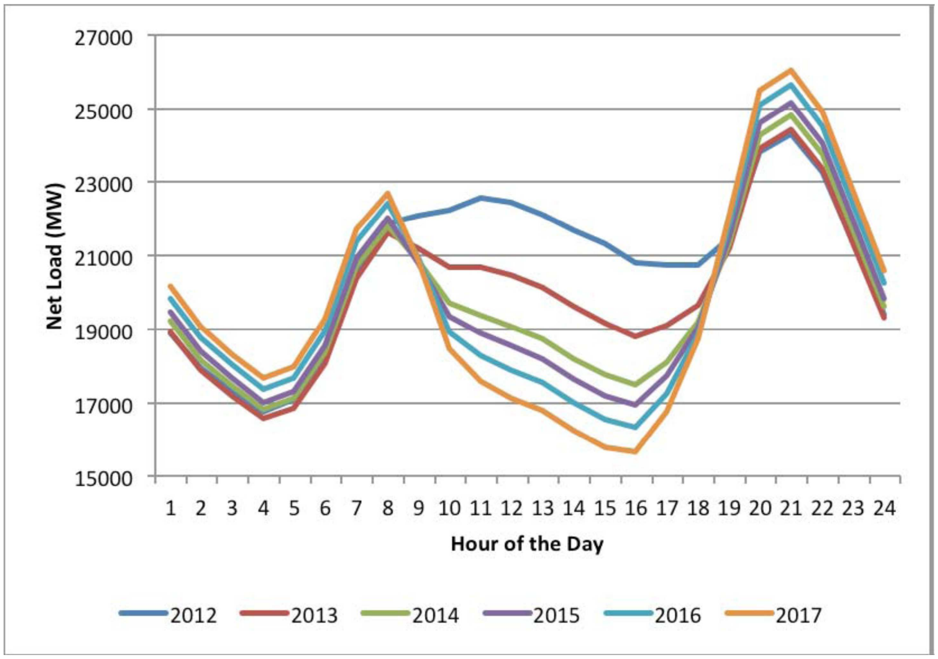
[139] 2011. *Renewable Power in California: Status and Issues*. California Energy Commission, December 2011, Publication No. CEC-150-2011-002-LCF-REV1.

managing.[140] A net load curve is constructed by subtracting the intermittent renewable – wind and solar – from the loads of the entire system. The California ISO's balancing authority will have a very different net load curve by as soon as 2014 because of the large amounts of solar being added. **Figure 4** shows for a particular day in March that the late afternoon ramp will increase much faster than the existing morning ramp. It is possible that over-generation will occur even at times when demand is high because the output of renewable generation is not well correlated with the shape of the load for all seasons of the year. For example, solar photovoltaic production peaks at noon and in March declines rapidly in the late afternoon, while the system is peaking later in the evening from 8:00 – 9:00 PM. Since most renewables have been contracted on a "must take" basis and generally are not curtailed, the electricity system may not have enough ramp down capacity to compensate for the energy produced during the middle of the day from solar resources. This would lead to over generation during the late morning and early afternoon hours. Many expect the non-renewable resources in the system will require more flexibility to compensate for the presence of large amounts of solar production and the variability of wind generation. Flexibility implies dispatchible resources that can meet short but steep load ramps, frequent starts and stops to address intra-hour variability, and increased requirements for regulation services.

Effectively integrating large proportions of renewable resources include simultaneously pursuing several potential solutions: (1) dramatically increased deployment of energy storage technologies that meet integration needs, (2) advanced demand response, (3) additional energy efficiency to reduce loads selectively during the day, (4) improved forecasting of loads and intermittent power production, and (5) advanced development of the smart grid to address system balancing at the distribution system level. Integrating intermittent resources also requires increased operational flexibility and market mechanisms that align with new operating requirements to ensure that enough fast-response and flexible resources are available.

[140] California Independent System Operator, February 26, 2013, *Comprehensive Forward Capacity Procurement Framework.*

Figure 4. Illustrative Change in Net Load Curve Using Load Shapes and Production Profiles From 3/22/2013



Source: California Energy Commission, Electricity Supply and Analysis Division (ESAD).

The current barriers to the deployment of energy storage primarily relate to cost, a need for a market for energy storage products, and lack of operational experience with many energy storage technologies. Energy storage could be a major game changer, but significant scientific breakthroughs are still needed to achieve the crucial very high ramp rates and long discharge times. As additional research is funded, pilots are conducted, and the market shakes out over the next several years, the optimal type, timing and placement of various storage technologies will become clearer. Some may be small-scale and associated with DG, while others may be coupled with specific generation sources or generally on the grid. Energy storage will need regulatory/market design intervention to help new battery technologies achieve commercial deployment.

Deployment of demand response to provide load balancing services at scale will require a sustained effort to develop the necessary policies and markets along with customer engagement on a much greater scale than has been achieved historically. A challenge to using demand response for integration services is making the changes needed for California's demand response programs to meet the California ISO's standards for reliability products and be able to participate in the California ISO's wholesale markets. The necessary advanced metering has largely been deployed, but further work is needed to deploy technologies that enable the California ISO to control energy use. Widespread use of auto-DR technology is likely to be essential to success, but adequate pricing will be needed to achieve customer acceptance.

Other challenges include the need for fully dynamic residential rates in which costs vary minute by minute or hourly. Dynamic pricing opportunities lag under the AB 1X (Keeley, Chapter 4, Statutes of 2001) legislative constraints on residential rate design, a lack of consensus on how the rates should be applied to residential customers, complexities of utility rate cases, and difficulty in attracting non-residential customers to current rate offerings. Further customer education about all aspects of demand response programs is needed as well as additional information about what will motivate mass market participation in demand response opportunities.

A challenge for improved forecasting is that a number of differing forecasting models are used to predict performance on discrete timescales: minutes ahead, hours ahead, and days ahead. Challenges include integrating forecasting tools and achieving higher spatial and temporal resolution to better predict performance of intermittent renewable resources across all timescales.

While the discussion above focuses on utility-scale renewables, renewable DG poses many of the same load balancing challenges as discussed in the section on Renewable Distributed Generation Challenges. While planning and building has been underway to construct the wires, poles and substations for transmission needed for central station generation, solutions are less advanced on the distribution side. Deployment of a smart grid that is electronically and digitally able to communicate and optimize electricity generation, transmission, distribution, and customer systems is needed.

Renewable Energy Integration Recommendations

The volume of variable energy generation development, largely solar, expected over the next decade creates a number of challenges that can be addressed by measures outlined below:

- Develop a forward procurement mechanism to provide flexible, dispatchable generation resources including natural-gas or biomethane-fired generation, that can ramp up and down quickly and often. Fully leverage demand response, energy storage, and other distributed technologies by designing market mechanisms that allow these resources to compete on a level playing field to provide integration services.[141]
- Expand participation of regional balancing authorities in the California ISO/PacificCorp Energy Imbalance Market, which provides a low cost, low risk means of achieving operational efficiency and flexibility needed for greater penetration of intermittent renewable resources. By providing frequent and automatic dispatching of the diversity of loads and resources across the entire Western region, an EIM allows integration of higher levels of wind and solar resources.

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[141] California Energy Commission, 2012. *2012 Integrated Energy Policy Report Update*. Publication Number: CEC-100-2012-001-CMF. http://www.energy.ca.gov/2012publications/CEC-100-2012-001/CEC-100-2012-001-CMF.pdf

- Implement storage procurement targets adopted by the CPUC in October 2013 to encourage the cost-effective deployment of energy storage, consistent with Assembly Bill 2514 (Skinner, Chapter 469, Statutes of 2010).
- Advance RD&D to maintain reliability and cost-effectively integrate increasing solar, wind, and other renewable energy generation. In particular, RD&D is needed for energy storage on a state and federal level. Research should also include improvement of forecasting capabilities and models for solar and wind, expansion of smart grid technologies, and development of microgrids.

Bioenergy

Biomass can be used for various energy applications, including transportation fuels, heat production, and electricity generation. “Bioenergy” is the general term for energy produced from biomass and includes electricity (biopower), renewable gas (biogas, biomethane, or synthetic natural gas), and liquid transportation fuels (biofuels). Biomass sources include California’s agricultural, forest, and urban waste streams. Bioenergy can provide a pathway to low-carbon fuels that can directly replace fossil fuels in California’s existing infrastructure.

A report by the California Council of Science and Technology[142] found that substantial amounts of low-carbon biofuels are required to meet 2050 GHG reduction goals, even with optimistic efficiency, electrification, and implementation of other renewable energy sources. The study found that gaseous biofuels will be required for some heavy industry and for integrating intermittent electricity generation from renewable sources such as wind and solar.

The use of biomass residues benefits a wide range of stakeholders including farms, dairies, forestry, food processors, public works, and waste management. Benefits include reductions in business costs, community waste, local pollution, wildfire risk, and fossil GHG emissions. These benefits vary depending on location and biomass resource type.

Traditionally, biopower was dominated by existing solid-fuel biomass facilities. In the last few years, biopower provided about 30 percent of the renewable electricity generated in California, but many of these facilities became economically unsustainable with the decline of the timber industry in California and many have shut down. Operating capacity for solid-fuel biomass peaked in 1990 at about 800 MW[143] and there is currently about 650 MW still in operation.[144] The next generation for using solid-fuel biomass is thermochemical conversion technologies that produce a methane and hydrogen rich gas which can then be used to generate electricity or offset on-site

[142] Youngs, Heather and Somerville, Christopher R., California Council on Science and Technology, California’s Energy Future – the Potential for Biofuels, May 2013.

[143] http://www.nrel.gov/docs/fy01osti/28805.pdf.

[144] California Energy Commission QFER database, ERFP database, and staff outreach to facility operators. Does not include capacity from in-state coal facilities co-firing with biomass. No data is available on actual biomass capacity at these facilities.

propane use. Currently there are only three known projects operating in California, all under 1 MW. However, the next generation of in-state biopower facilities could provide significant amounts of dispatchable capacity if local distribution challenges can be overcome.

However, new biogas-to-power projects continue to be developed.[145] Biogas is a flexible energy resource that can be used as a direct replacement for natural gas or propane in electricity, transportation, and heating applications.[146] Conditioned biogas, or biomethane, that is cleaned to pipeline quality requirements can be delivered through existing utility natural gas pipelines for use in existing residential or industrial appliances, to generate electricity, or as a transportation fuel.

In the future, micro-sized anaerobic digester technologies could be integrated into homes, or more likely multifamily dwellings, to produce biogas from food, human, and some green wastes onsite. This gas could then be used to operate gas appliances such as water heaters, furnaces, or fuel cells. Gas clean-up technologies are not yet commercially viable for on-site end-use applications.

Although debate continues on the most efficient and beneficial use of biomass, in the short term the most economically and technically viable use may be biopower production. In most cases, the greatest GHG benefit may come from using biomass in CHP applications to produce electricity and heat. However, CHP applications may not exist within a reasonable distance from biomass resources. Biofuel demand is also growing, although in remote areas it can be challenging to find an off-taker for transportation biofuels.

In the long term, demand for alternative transportation fuels could greatly increase with conversion of biomass to liquid fuels for transportation applications likely to outpace demand for electricity generation. Given short and long-term bioenergy demand and the ability of processed biogas to offset natural gas use in both the electrical and transportation sectors, state policy has placed a priority on actions to promote development of sustainable biogas production facilities.[147]

Bioenergy Challenges

Although biopower has been a large part of California's renewable supply, its potential to provide sustainable renewable energy is limited by available feedstocks.[148] With

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[145] Energy Commission staff analysis of data compiled from the U.S. EPA Landfill Methane Outreach Program and the Energy Commission's QFER database. Biogas is a methane rich gas produced from the thermochemical or biochemical conversion of biomass. Generally, projects include anaerobic digester and landfill gas projects.

[146] Some applications require treatment to remove moisture, carbon dioxide, and other contaminants.

[147] *2012 Bioenergy Action Plan.* http://www.resources.ca.gov/docs/2012_Bioenergy_Action_Plan.pdf.

[148] This is also true for the carbon benefit of a biomass resource. If the biomass is harvested from a forest specifically for bioenergy production, there is a long-term temporal shift in when the carbon benefit will be realized. Some estimates range from 30 years to over 100 years. Biomass resources that are residuals

California's emphasis on low-carbon transportation fuels and renewable energy, the state must develop criteria that ensure biomass use in California continues to be sustainable and beneficial. Guidelines, such as the sustainability standards developed for the Energy Commission's Alternative and Renewable Fuel and Vehicle Technology Program,[149] will be necessary to ensure biomass collection is sustainable into the future and to preserve the GHG benefit of the resource.

Because of competing needs for biomass in electricity, transportation, and other applications, the state may need to explore the development of bioenergy crops to generate biomass. Energy crops play an important role in developing low-carbon biofuels but can have life cycle impacts such as water use, land use changes, and loss of food production which can affect a feedstock's overall GHG reduction value. Consistent with the *2012 IEPR Update* recommendation to identify priority renewable energy development zones in California, consideration should be given to the effects of development on the environment and electrical system, areas with high unemployment, and disadvantaged communities that are identified by Cal/EPA as required by Senate Bill 535 (De León, Chapter 830, Statutes of 2012).[150] In the case of production of biofuels from algae, co-location with existing facilities that emit CO_2 would be ideal.

Biogas upgraded to biomethane can be a direct replacement for natural gas, with the most efficient means of transport being through utility natural gas pipelines. However, there are many technical and economic challenges that must be addressed to achieve commercial development of this resource in California. Technical challenges include lack of commercialized biogas cleanup technologies and unknown biogas quality standards.[151] Economic challenges include distance of biomass resources to pipeline infrastructure, the dispersed nature of biomass,[152] and the lack of a fully commercialized biogas industry.

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from other processes such as milling or food processing have carbon benefits that are accrued quickly because the carbon stored in the living matter was going to be released into the atmosphere anyway.

[149] Muench, Tobias. Final Regulation Language Alternative and Renewable Fuels and Technologies Program Title 12 California Code of Regulations Sections 3100--3108, Regulations, California Energy Commission, Publication Number CEC-600-2008-013-F, April 2009.

[150] Senate Bill 535 requires the Cal/EPA to identify disadvantaged communities, "…based on geographic, socioeconomic, public health, and environmental hazard criteria, and may include, but are not limited to, either of the following: (a) Areas disproportionately affected by environmental pollution and other hazards that can lead to negative public health effects, exposure, or environmental degradation. (b) Areas with concentrations of people that are of low income, high unemployment, low levels of homeownership, high rent burden, sensitive populations, or low levels of educational attainment.

[151] These standards are currently under development by the CPUC under Rulemaking 13-02-008.

[152] In most cases, biomass resources cannot support the development of a large facility without transporting material great distances. This increases the cost of the resource and diminishes the economic feasibility of the project. Small facilities are expensive because current technologies and deployment techniques do not scale down economically.

Bioenergy Recommendations

- Solving the cost allocation challenge for biomass collection and distribution will require development of non-ratepayer-funded mechanisms to mobilize sustainably available sources of biomass feedstock. Various agencies in the Bioenergy Interagency Working Group would play a role, including, California Department of Forestry and Fire Protection, ARB, CalRecycle, and the Natural Resources Agency.
- Biomass goals should continue to be aggressive but also consider sustainable biomass yield, greenhouse gas impacts, reduction of climate risk and increased forest health and resilience, waste reduction, air and water quality benefits, recycling, composing, and environmental protection. Various agencies in the Bioenergy Interagency Working Group would play a role, including California Department of Forestry and Fire Protection, ARB, CalRecycle, and the Natural Resources Agency.

- Further work is needed to analyze existing state and federal forest and wildland protections to ensure that biomass use will not increase net long-term GHG emissions. Building on the recommendation in the *2012 Bioenergy Action Plan* to establish sustainability standards for forest biomass feedstock, the state should develop a uniform state sustainable forest-biomass usage policy.

- The Bioenergy Interagency Working Group should identify an appropriate funding source for developing a statewide programmatic Environmental Impact Report for thermochemical conversion technologies using biomass. The Environmental Impact Report should focus on streamlining the environmental review process for SB 1122-type projects.

- Consistent with the recommendation in the *2012 IEPR Update*, the CPUC should modify procurement practices to develop a higher-value portfolio. Procurement decisions should consider an expanded suite of renewable energy benefits, including RPS-eligible facilities that can provide dispatchable and reliable power, integration benefits, reduction in forest fires that threaten public health and safety and damage transmission lines, reduction in transmission and distribution costs, increased investment in disadvantaged communities, and creation of green jobs.

- The Energy Commission should continue research, development, and demonstration of biogas-to-biomethane technologies and projects that inject biomethane into California's natural gas pipelines. The priority should be research that provides needed data identifying constituents of concern for additional feedstock sources not identified in the ARB and Office of Environmental Health Hazard Assessment staff report *Recommendations to the California Public Utilities Commission Regarding Health Protective Standards for the Injection of Biogas into the Common Carrier Pipeline*.[153] Second, the Energy

[153] http://www.arb.ca.gov/energy/biogas/biogas.htm.

Commission should fund research and development of small-scale biogas conditioning technologies.

Solar Space and Water Heating

For electric space and water heating, the state supports solar thermal applications as an alternative to electricity. Solar thermal applications are more environmentally appropriate and less expensive than using electricity to heat space or water. Solar space heating is passive solar and has been a key part of California's building codes since their inception in 1978. Another example of state support is the CPUC's CSI-Thermal Program launched in 2010 to provide rebates to IOU customers who install solar thermal systems to replace water-heating systems powered by electricity or natural gas. The CPUC allocated $350.8 million to advance solar water heating through direct financial incentives to retail customers, training for installers and building inspectors, and a statewide marketing campaign.[154] Solar thermal technology applications include residential and commercial hot water applications as well as industrial heating applications, including food processing[155] and enhanced oil recovery.

Similarly, geothermal or ground source heat pumps offer opportunities to use the heat exchange capacity of the earth to increase the efficiency of heating and cooling systems. The technology uses the earth as a heat source in the winter and a heat sink in the summer and can be applied to residential and non-residential buildings. The Energy Commission, in consultation with the CPUC, cities, counties, special districts, and other stakeholders, evaluated the barriers and strategies of geothermal heat pump/ground loop technology as part of the *2013 IEPR*.

While many studies suggest industrial electrification and electrifying space and water heating as a necessary pathway to achieving the 2050 GHG reduction goal, solar thermal provides a better option for serving heating needs. Further, the effort to nearly eliminate GHG emissions from the electricity sector will be compounded by electrifying sectors currently served with natural gas, whereas efforts to increase efficiency and renewable fuels in the gas sector will advance meeting the state's GHG reduction goals. To the extent that solar thermal can displace natural gas use for heating, it will reduce the need to shift heating load to the electricity sector.

Solar Space and Water Heating Challenges

Limited consumer acceptance hinders widespread application and use of solar space and water heating. There is a lack of consumer awareness about solar water heating (SWH) systems and their energy savings and environmental benefits. Solar space and water heating are not perceived as standard heating options. Also, there is a lack of awareness that the industry is mature with widely recognized uniform technology

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[154] http://www.cpuc.ca.gov/PUC/energy/Solar/swh/.

[155] Rebecca Milczarek, Ph.D , "Solar Thermal: Exploring the World's Oldest (and Newest) Food Processing Technology," Presented at the UC Solar Research Symposium in Davis, California. May 2, 2013.

standards. Consumers are concerned about installation quality, system performance, and ease of maintaining the system.

The economics are also a barrier, with high upfront costs and long paypack periods. Also, the installation and maintenance costs are higher than conventional heating systems.

Retrofitting existing buildings can be challenging as structural issues may prevent installation. Also, tree shading and obstructions on the roof (vents, package units, skylights, exhaust fans, chimneys, etc.) may impede installation, and roof installations may void roof warranties. Finally, efficiency is diminished when solar systems are not fully integrated with the design of the building or if not properly installed.

Rental buildings pose additional challenges to widespread deployment of solar thermal space and water heating. Similar to the difficulty with installing energy efficiency upgrades in rental buildings, the building owner typically does not pay the energy bills and has little incentive to pay the upfront costs to install an energy saving technology such as solar water heaters.

Finally, further technological innovation is needed. For example, there is a need to develop combined solar hot water/heating systems that are highly energy efficient, easy to operate and maintain, and are lower cost than maintaining and operating separate hot water and heating systems. Technology advancements are also needed to develop alternative materials, technologies and manufacturing techniques; make systems more modular; develop integration of solar collectors into building surfaces; and develop of collectors that cover a wider range of temperatures.

Solar Space and Water Heating Recommendations

- Continue rebates for SWH, space heating, and solar cooling applications to improve price competitiveness.
- Increase targeted marketing and outreach to increase consumer awareness and adoption of SWH and solar space heating.
- Increase efforts to develop better workforce training to help ensure proper installation, improve performance, and increase the number of qualified installers. Additional training and education is needed for architects, engineers, designers, building owners, facility managers, consultants, and installers.
- Further RD&D is needed to increase efficiency, performance, and reliability; lower manufacturing, installation, system, and maintenance costs; develop combined space and water heating systems; develop solar collectors that are integrated into building surfaces; and to better understand consumer behavior.

Natural Gas with Carbon Capture Utilization and Storage

The rapid development of renewable electric generation with intermittent output is increasingly displacing gas-fired generation, aside from where gas-fired generation is needed for integration and reliability services. Current natural gas facility designs are being adapted to serve an integration function, which means steeper ramping and multiple stops and starts (over 300 per year). All this must be accomplished within the strict parameters of criteria air pollutants regulations. Technology improvements and new market tariffs will be needed to encourage gas plants with the attributes most useful to California's grid.

If CCUS technology becomes cost-effective, natural gas units can become a de-carbonized resource. It is not clear when alternatives such as demand response, storage, or dispatchable renewable generation will become cost-effective and available on a large enough scale to provide low-carbon integration services. The ultimate aim, as discussed in the Renewable Energy Integration section of this working paper, is by 2050 to use natural gas coupled with CCUS to integrate renewable resources and provide other reliability services.[156]

CCUS has the potential to reduce emissions throughout the electricity and transportation sectors. Projects should facilitate development of CO_2 storage verification methodologies (including options for utilization), promote new energy infrastructure development, and provide platforms for testing technology advances to address California's strategic priorities to lower costs for clean energy, save water, and assure sustainability and reliability of the electric grid and the state's natural resources.

A California Council on Science and Technology study[157] suggests that the 2050 GHG reduction goal cannot be met without widespread deployment of CCUS on stationary industrial sources with large CO_2 emissions, such as power plants and oil refineries. Attaining this scenario will require accelerating the rate of CCUS commercialization and market adoption over the next 35 years. However, as noted previously, the study does not consider solar for industrial applications of process heat and cooling.

CCUS research and projects worldwide indicate that CO_2 can be stored safely in the Earth's subsurface long enough to address CO_2 reduction goals. CCUS research and development in California – funded for the last decade by the U.S. DOE (through the West Coast Regional Carbon Sequestration Partnership[158] and funds from ARRA) and by PIER programs – contributes to this assessment. Commercial-scale demonstration

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[156] "Utilization" refers to a policy of using excess CO2 in productive commercial applications that provide inherent storage of CO2 away from the atmosphere (for example, by binding it in a long-lived product such as a building material) first before storing whatever remaining CO2 that cannot be used economically.

[157] *California's Energy Future – The View to 2050: Summary Report*, California Council on Science and Technology, May 2011.

[158] WESTCARB was established in 2003 and is one of seven research partnerships co-funded by the U.S. Department of Energy to characterize regional carbon sequestration opportunities and conduct technology validation projects; http://www.westcarb.org/.

of CCUS on key California point sources such as natural gas combined cycle power plants, refineries, and cement plants, as well as utilization options such as CO_2-enhanced oil recovery, are a vital next step to gaining real-world experience specific to California.

The Hydrogen Energy California (HECA) project is a CCUS project in California undergoing permitting. The project is a planned integrated gasification combined cycle plant with production of hydrogen, electricity, urea-based fertilizer, and CO_2 for enhanced oil recovery (by agreement with Occidental Petroleum). In addition, the Calera Corporation is currently operating a pilot carbon capture facility adjacent to the Moss Landing natural gas-fired power plant in Monterey County. In capturing CO2 and other emissions from the power plant's flue gas, Calera's process uses a carbonate mineralization technology, resulting in a solid that can be sold as an aggregate or replace a portion of the cement in concrete blends.[159]

Infrastructure components for CCUS include CO_2 capture facilities at emission sources, pipelines for transport, and injection and monitoring wells at storage sites. CO_2 pipeline networks that connect regions with multiple large CO_2 sources with suitable storage or utilization sites are seen as the most cost-effective transportation option. Enabling pipeline construction may require state policies on rights-of-way acquisition, incentives, or other ways to encourage investment in CCUS project development.

Carbon Capture, Utilization, and Storage Challenges

One major policy challenge for CCUS is determining the transitional role of natural gas between now and 2050. Natural gas units are normally long-lived capital investments and can be kept running for thirty to forty years with proper maintenance. California's natural gas-fired plants have become more efficient over the past decade largely due to fleet turnover and produce more electricity per therm of gas. Plants can change functions over time, providing energy and balancing services in the first few years, then being used primarily as a source of capacity as they age. However, once the investment in a new natural gas facility is made, there is an economic interest in its continued operation and any new zero-carbon energy source must compete with it.[160]

For CCUS to support California's 2050 GHG reduction goal, a combination of technical and regulatory advances must occur at a steady pace over the next ten years. Cap-and-trade incentivizes CCUS investments at gas plants as a way to reduce or avoid the expense of purchasing offsets and allowances. As California reduces its future carbon cap, gas generation without CCUS will face ever increasing GHG offset and allowance costs. Additional demonstration and commercial projects for major types of industrial

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[159] http://www.arb.ca.gov/cc/etaac/meetings/102909pubmeet/mtgmaterials102909/basicsofcaleraprocess.pdf

[160] Harvy, Hal; Orr, Franklin Jr; Vondrich, Clara. *A Trillion Tons*. The American Academy of Arts & Sciences, 2013.

and natural gas power CO_2 point sources (either existing or newly built) in conjunction with a robust RD&D program will address both needs.

Another potential CCUS challenge is induced seismicity. CCUS involves injecting and storing fluid at very high pressure underground beneath a layer of caprock, which has the potential to generate or amplify seismic activity.[161] Induced seismicity could become a barrier to implementation of CCUS for two reasons—the risk of damage to people and property and the risk of fracturing the caprock thereby releasing the stored CO2. However, the level of risk is not well-known at this time.

New commercial-scale CCUS projects must be added annually over the next several decades to reduce GHG emissions to 80 million metric tons or less by 2050. At least 10 million metric tons of CO_2 emissions must be removed annually between 2030 and 2050 but with each year of delay in implementing GHG reduction technologies, the required removal rate increases. Given that commercial-scale power and industrial projects may take more than a decade to become operational, timely actions to assure deployment of CCUS technologies on a variety of emissions sources is imperative for California to stay on course for the 2050 goal.

Carbon Capture, Utilization, and Storage Recommendations

- Policy actions are needed in the near-term to incorporate CCUS into the portfolio of accepted compliance technologies – especially the development of accounting and regulatory methodologies – to promote a greater number of CCUS projects capable of achieving the substantive emissions reductions to meet 2050 goals. Policies that support a sustainable and predictable value for CO_2 and that clarify how storage and utilization fulfill compliance requirements are critical to enabling CCUS technologies. Policy and regulatory barriers and recommendations for solutions are discussed in detail in a 2010 report by the California Carbon Capture and Storage Review Panel.[162]

Further RD&D is needed to:

- Facilitate a public/private partnership to demonstrate capture, utilization, and geologic storage of at least one hundred thousand tons per year of CO_2 as a GHG mitigation measure to verify regulatory frameworks and quantification methodologies.
- Demonstrate and validate the grid support co-benefits of operating CO_2 capture systems for natural gas power plants in a manner that maximizes the aggregate value of peak power production, spinning reserve capacity, and GHG emissions reduction.

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[161] National Research Council, Committee on Induced Seismicity Potential in Energy Technologies. 2013. Induced Seismicity Potential in Energy Technologies. The National Academies Press, Washington, DC. 300 pp.

[162] http://www.climatechange.ca.gov/carbon_capture_review_panel/documents/2011-01-14_CSS_Panel_Recommendations.pdf.

- Demonstrate the capabilities of new and emerging CO_2 capture technologies and utilization options that reduce costs; energy and water use; and provide economic benefits through new low-carbon products, such as plastics and building materials.
- Demonstrate and validate sustainable land management practices for forests, rangelands, wetlands, and agricultural lands that maximize the collective value of economic productivity, carbon storage, and wildfire control, while meeting goals for biodiversity and habitat preservation, soil conservation, and water quality.

Nuclear

Nuclear power is another potential option for producing electricity without generating GHGs, although nuclear power is not included in California's loading order and California law prohibits the construction of new nuclear facilities unless specific nuclear waste disposal requirements are met. In 1976, the California Legislature required that a new nuclear facility can only be permitted if the Energy Commission finds that the federal government has identified and approved a demonstrated technology for the:[163]

- Construction and operation of nuclear fuel rod reprocessing plants, and
- Permanent disposal of nuclear waste.

As neither of these conditions has been met, the law effectively created a moratorium on the construction of new nuclear power plants in California, and no new nuclear plants have been constructed in California in more than 30 years. The law exempted California's two existing nuclear facilities, Diablo Canyon Power Plant (Diablo Canyon) and San Onofre, from the new requirements.[164]

California's electricity mix uses nuclear energy from two facilities: Diablo Canyon in California and the Palo Verde in Arizona. California had also received nuclear power for over 40 years from San Onofre until it went offline in January 2012. In June 2013, SCE announced plans to permanently retire San Onofre.[165] Since San Onofre went offline, energy utilities and the state have worked to provide Southern California with reliable electric power and those efforts will continue. Nuclear power provided about 18 percent of California's in-state electricity generation in 2011, but this dropped by half to about 9 percent in 2012 with the outage of San Onofre (these figures do not include imported electricity).

The operating licenses for Diablo Canyon Power Plant (DCPP) Units 1 and 2 are set to expire in 2024 and 2025, respectively. Licenses to operate DCPP Units 1 and 2 would be extended until in 2044 and 2045, respectively, if approved by the NRC. Even if DCPP is relicensed for another 20 years to run until the mid 2040's, the aging power

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[163] Legislative Analyst's Office, http://www.lao.ca.gov/ballot/2011/110306.aspx .
[164] Legislative Analyst's Office, http://www.lao.ca.gov/ballot/2011/110306.aspx .
[165] http://www.edison.com/pressroom/pr.asp?id=8143

plant will ultimately need to be retired. Diablo Canyon is not expected to be operating in 2050.

While the retirement of Diablo Canyon has limited implications for meeting local reliability needs[166], San Onofre was a key provider of reliability services in both the Los Angeles Basin and San Diego areas. Transmission upgrades, synchronous condensers, energy efficiency, demand response, and some conventional generation in Orange and San Diego Counties will contribute to replace San Onofre in the near term, providing reactive power and reducing the need for additional local capacity.[167] The amount of flexible, dispatchable capacity needed in the Los Angeles Basin to replace San Onofre and facilitate the system-wide integration of intermittent renewable resources is the subject of the CPUC's 2012 LTPP and Resource Adequacy proceedings. In addition, the California ISO's transmission planning process is looking into transmission options for replacing generation for San Onofre.

Nuclear Challenges

The *2011 IEPR* took a close look at nuclear power in California after the March 2011, earthquake and tsunami that knocked out power and emergency electrical equipment at the Fukushima Daiichi nuclear plant in Japan. Japan suffered a 9.0 magnitude earthquake, resulting in reactor meltdowns, explosions, fires, and widespread radioactive contamination. Although such a high magnitude quake and tsunami is not thought to be possible near Diablo Canyon or San Onofre, the Fukushima incident heightened concerns about seismic and tsunami hazards for California's coastal nuclear plants and nuclear plants worldwide.[168]

If breakthroughs are made to address a permanent solution to nuclear waste and if new facilities can be located in seismically safe areas, new nuclear facilities may be constructed in the 2030 or 2050 timeframes to meet California's electricity needs. However, even if these tall hurdles are overcome, the state will still need other resources to address load balancing needs. Nuclear power plants have very slow start up periods, little operational flexibility, and significant reliability consequences when they trip off line. Heavy reliance on nuclear would likely require comparable amounts of storage and flexible units.

Nuclear Recommendations

- The Energy Commission as coordinator of the High-Level Nuclear Waste Repository Technical Advisory Group on Yucca Mountain, should continue to

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[166] 2012-2013 Transmission Plan, California ISO http://www.caiso.com/Documents/BoardApproved2012-2013TransmissionPlan.pdf.

[167] For Summer 2013 efforts to mitigate the impact of the absence of San Onofre, see "Briefing on Summer 2013 Outlook and Update on SONGS Mitigation Planning," presentation to the California ISO Board of Governors Meeting, March 20-21, 2013.

[168] France estimates a nuclear disaster could cost them up to $580 Billion. http://www.reuters.com/article/2013/02/07/us-france-nuclear-disaster-cost-idUSBRE91603X20130207.

collaborate and coordinate with potentially affected state agencies[169] to monitor the federal waste management program and represent California's interests regarding potential impacts in any licensing proceeding for a permanent high-level nuclear waste repository to protect California's interests regarding potential impacts to the state.

- The Energy Commission, as coordinator of the California Nuclear Transport Working Group[170], should continue to collaborate and coordinate with potentially affected state agencies[171] to participate in U.S. DOE and western regional planning activities[172] to ensure safe and event-free nuclear waste transportation.
- The Energy Commission, as coordinator of the California Nuclear Transport Working Group, should continue to collaborate and coordinate with potentially affected state agencies to participate in U.S. DOE used fuel disposition campaigns and western regional planning activities for removal of stranded used fuel and greater-than-Class-C low-level radioactive waste from shutdown nuclear power plant at Rancho Seco, San Onofre, and Humboldt Bay.
- Since San Onofre went offline in 2012, energy utilities and the state have worked to provide Southern California with reliable electric power. With the retirement of San Onofre, continued efforts are needed to develop a long-term plan that ensures reliability for decades to come. The Governor requested leadership from the following state energy agencies to develop this long-term plan: the California ISO, Energy Commission, CPUC, South Coast Air Quality Management District, San Diego Air Quality Management District, State Water Resources Control Board, SCE, and SDG&E.

Section 4: Energy Sector Priorities

Following the loading order, the table below provides a list of priority recommendations to put California on a trajectory to meet the 2050 GHG reduction goal. Overall, a clear focus is needed on increasing energy efficiency in existing buildings, advancing storage to integrate renewable resources, advancing CCUS, and supporting RD&D to advance innovation.

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[169] California Attorney General's Office, Department of Conservation-California Geological Survey, Department of Water Resources, Department of Fish and Wildlife-Office of Spill Prevention and Response, Department of Public Health-Radiologic Health Branch, Department of Toxic Substances Control, California Department of Parks and Recreation- Natural Resources Division.

[170] Established in 1989 to advise California Interagency Nuclear Waste Task Force and coordinate California's preparation for federal nuclear waste shipments; the group initially focused on transuranic waste shipments, but was later expanded to include spent fuel and other large quantity radioactive material shipments.

[171] California Office of Emergency Services, California Environmental Protection Agency, California Highway Patrol, Department of Public Health-Radiologic Health Branch, California Department of Transportation, California Public Utilities Commission-Rail Safety and Operations Branch, Department of Fish and Wildlife-Office of Spill Prevention and Response.

[172] Western Governors' Association Waste Isolation Pilot Plant Transportation Advisory Group and Western Interstate Energy Board High-Level Nuclear Waste Committee.

Energy Efficiency	• Focus is needed on increasing the efficiency of the existing building stock. There should be expeditious implementation of the draft action plan for the AB 758 Program once finalized. • The Energy Commission should adopt triennial updates of mandatory and reach standards to achieve ZNE standards for newly constructed homes by 2020 and newly constructed commercial buildings by 2030. • The Energy Commission and CPUC should coordinate future IOU "new construction-related" programs with the Energy Commission's efforts to meet the ZNE goals through triennial updates of mandatory and reach standards. • Intervene in U.S. DOE proceedings to represent the interests of California regarding the upgrade of federal appliance efficiency standards. • The Energy Commission should continue to engage with the U.S. DOE proceedings to develop common test methods and appliance efficiency databases. • The Energy Commission should adopt appliance and reach standards that focus on reducing plug loads to enable California's ZNE goals to be achieved. • Continue to reduce the wasteful, uneconomic, inefficient, or unnecessary consumption of energy, including the energy associated with the use of water. • The Energy Commission should adopt an enforcement process for violations of appliance efficiency regulations and impose civil penalties to increase compliance with the Appliance Standards. • The Energy Commission and CPUC should jointly pursue improved compliance with the Building Energy Efficiency and Appliance Standards. • The Energy Commission and the CPUC should collaborate on research to advance technologies and strategies, as well as identify the most cost-effective opportunities for new appliance standards and updates to appliance standards. • The Energy Commission and the CPUC should collaborate on research to advance ZNE building standards and the 758 Program once finalized; improve efficiency of existing technologies; develop and demonstrate advanced technologies, integrated products, and strategies; encourage adoption through utility incentive programs or building energy efficiency codes; and understand consumer behavior.
Demand Response	• Implement the action plan for advancing demand response that is part of the *2013 IEPR*.
Combined Heat and Power	• Efforts should be made to ensure that new and existing CHP is appropriately valued under future regulatory amendments to California's cap-and-trade program. • Evaluate potential opportunities to incentivize the development of new bottoming-cycle CHP within existing state programs and the development of new CHP in state and other public facilities. Pursue opportunities on public facilities include development at hospitals and waste water treatment plants throughout California, but particularly in Orange County and San Diego County due to the closure of the San Onofre. • The CPUC, in collaboration with the Energy Commission, should examine and clearly define the interconnection rules for CHP facilities interested in expanding their systems and dispatch capabilities within an existing contract. • Further RD&D is needed to advance ultraclean emission technologies, reduce costs, integrate emerging, clean CHP technologies in diversified applications, and demonstrate CHP applications using biomass and other feedstocks.

Renewable Energy	• California's electricity planning efforts need to improve and expand. Actions to maximize the benefits of renewable energy must include modifying procurement practices to develop a higher-value portfolio that includes not just lower-cost projects but also those that provide integration services, encourage investment in disadvantaged communities, create jobs in California, and provide value to the state as a whole. • California must address how to fund clean energy investments. • Cutting-edge RD&D is needed to produce the next generation of clean energy technologies. • As California works to achieve its renewable energy goals, its actions must send appropriate price signals to help shape investments and influence behavior. At the same time, rate design must be fair, sustainable, and include mitigation measures for those who are disadvantaged. Actions should also lower the cost of renewables and reduce impacts on electric rates. • California's energy system has disproportionately affected many of the state's disadvantaged communities, which may not be in line to receive many of the benefits of increasing renewable development throughout the state. Actions to promote renewable energy must also ensure that the costs and benefits of renewable development are fairly distributed. • To help move toward an electricity system that primarily uses non-GHG emitting generation sources, the state should evaluate policies for ensuring continuing post-2020 reductions in the carbon intensity of electricity generation. Studies conducted should consider impacts on GHG emissions, as well as maximizing the value of renewable energy generation through cost-benefit assessments that include costs associated with integration, permitting, interconnection, and impacts on retail electricity rates.
Geothermal	• The utilities and the CPUC should adopt changes to procurement practices for renewable energy generation such that procurement decisions consider an expanded suite of renewable energy benefits. • Using geothermal power's potential as a flexible resource should be encouraged and its ancillary benefits to the grid should be recognized in power pricing agreements. • Research is needed to further develop technologies and tools for remote sensing, surface, and downhole investigations and reservoir modeling to reduce the costs of geothermal exploration and development. • Funding should also be provided for increased exploration to identify undiscovered geothermal resources.
Distributed Renewable Energy	• The recommendations highlighted from the *2012 IEPR Update* in the Renewable Energy Generation section also apply to DG. • Build transparency into the distribution system planning to integrate increasing quantities of DG while maintaining reliability, controlling costs, and reducing emissions. • Resolve and implement interconnection reforms in a timely manner. • Determine what operational communication and control technologies are needed to provide greater visibility and respond to dispatch instructions from both the California ISO and utilities.
Integrating Renewable	• Develop a forward procurement mechanism designed so that all resources, demand response, energy storage, distributed technologies and natural gas

Resources	power plants can compete to provide integration services. • Expand participation of regional balancing authorities in the California ISO/PacificCorp EIM, which provides a low cost, low risk means of achieving operational efficiency and flexibility needed for greater penetration of intermittent renewable resources. • Implement storage procurement targets adopted by the CPUC in October 2013 to encourage the cost-effective deployment of energy storage. • Promote RD&D for renewable integration, particularly on storage.
Bioenergy	• Explore all mechanisms to fund biomass collection and distribution. • Develop aggressive biomass-use goals. • Develop standards for sustainable forest biomass use. • Develop a programmatic environmental impact report focused on streamlining the environmental review process for SB 1122-type projects. • Modify procurement practices to develop a higher-value biopower portfolio. • Increase the research and development for projects that inject biomethane into California's natural gas pipelines.
Solar Space and Water Heating	• Continue rebates for SWH, space heating, and solar cooling applications. • Increase targeted marketing and outreach to increase consumer awareness and adoption of SWH and solar space heating. • Increase efforts to develop better workforce training to help ensure proper installation, improve performance, and increase the number of qualified installers. Additional training and education is needed for architects, engineers, designers, building owners, facility managers, consultants, and installers. • Continue RD&D to help bring down costs, increase reliability, and advance technology innovation.
Natural Gas with Carbon Capture Utilization and Storage	• Policy actions are needed to promote CCUS projects. Policy and regulatory barriers and recommendations for solutions are discussed in detail in a 2010 report by the California Carbon Capture and Storage Review Panel. • Facilitate a public/private partnership to demonstrate capture and geologic storage of at least one hundred thousand tons per year of CO2 to verify regulatory frameworks and quantification methodologies. • Demonstrate and validate the grid support co-benefits of operating CO2 capture systems for natural gas power plants in a manner that maximizes the aggregate value of peak power production, spinning reserve capacity, and GHG emissions reduction. • Demonstrate CO2 capture technologies and utilization options that reduce costs, energy and water use, and provide economic benefits through new low-carbon products, such as plastics and building materials. • Demonstrate sustainable land management practices for forests, rangelands, wetlands, and agricultural lands that maximize the collective value of economic productivity, carbon storage, and wildfire control, while meeting goals for biodiversity and habitat preservation, soil conservation, and water quality.
Nuclear	• Monitor the federal waste management program and represent California in any licensing proceeding for a permanent high-level nuclear waste repository to protect California's interests regarding potential impacts to the state. • Participate in U.S. DOE and western regional planning activities to ensure safe

	and event-free nuclear waste transportation. • Participate in U.S. DOE used fuel disposition campaigns and western regional planning activities for removal of stranded used fuel and greater-than-Class-C low-level radioactive waste from shutdown nuclear power plant sites in Rancho Seco, San Onofre, and Humboldt Bay. • Since San Onofre went offline in 2012, energy utilities and the state have worked to provide Southern California with reliable electric power. With the retirement of San Onofre, continued efforts are needed to develop a long-term plan that ensures reliability for decades to come.

Section 5: Conclusions

In conclusion, California must do nothing less than transform its energy system to meet the 2050 GHG reduction goal. This will be a monumental undertaking, but one that is technically achievable. The policies laid out in this working paper break down the problem into its key components: reducing energy demand and decarbonizing energy supply. A diversified suite of policy options must be pursued in part because it is unclear what technological or other breakthroughs may happen in the coming decades, and because a multi-faceted approach makes each element more achievable. Reducing demand with energy efficiency, demand response, and CHP lessens the burden to reduce GHGs on the energy generation side. Although the future energy generation mix is unknown, this working paper lays out a vision for decarbonizing California's electricity generation mix using a portfolio of strategies which include: a decrease in the cap on carbon emissions, an increase of clean technologies, increased use of solar thermal to displace natural gas and electricity, and the use of some natural gas-fired electricity with CCUS along with storage and demand response to help maintain reliability of the grid. Whether nuclear continues to be part of the state's electricity mix is also unknown and depends in part on whether a permanent solution to nuclear waste is developed and if plants can be located in seismically safe areas. Despite the uncertainties, California must move forward to find innovative solutions to the difficult problem of meeting the state's energy needs while dramatically reducing GHG emissions. Increased research and development will be critical to success and areas of focus include energy efficiency, storage for renewable integration, and CCUS. Transforming the energy sector will require partnerships at the state, federal and local level and with industry, businesses, environmental groups, environmental justice groups, and Californians statewide.