

Chapter 10

Climate and Energy



Significant reductions in greenhouse gases are needed to achieve California's climate targets, presenting challenges for the State's energy and transportation infrastructure. Climate, energy, and transportation strategies have direct impacts on air quality, and the 2016 AQMP control strategy will affect these other objectives. Therefore, understanding the connections and coordination with other agencies is essential. A large majority of criteria pollutant and greenhouse gas emissions result from our transportation and energy choices.

In This Chapter

- Introduction 10-1
Overview of climate change and energy issues
- South Coast Basin Energy Consumption, Emissions, and Projections 10-7
Regional energy and fuel information
- Challenges and Opportunities in Moving Towards 100 Percent Renewable Power 10-14
Grid collaboration, renewable generation, demand response, energy efficiency and energy storage

- Southern California's Energy and Air Quality Future 10-28
Infrastructure and transformation of the energy sector
- References 10-33

Introduction

In September 2011, the SCAQMD Governing Board adopted the SCAQMD Air Quality-Related Energy Policy. This policy integrates energy, air quality, and climate change by explaining how our dependence upon fossil fuels for energy generation and consumption within the Basin results in the emission of criteria

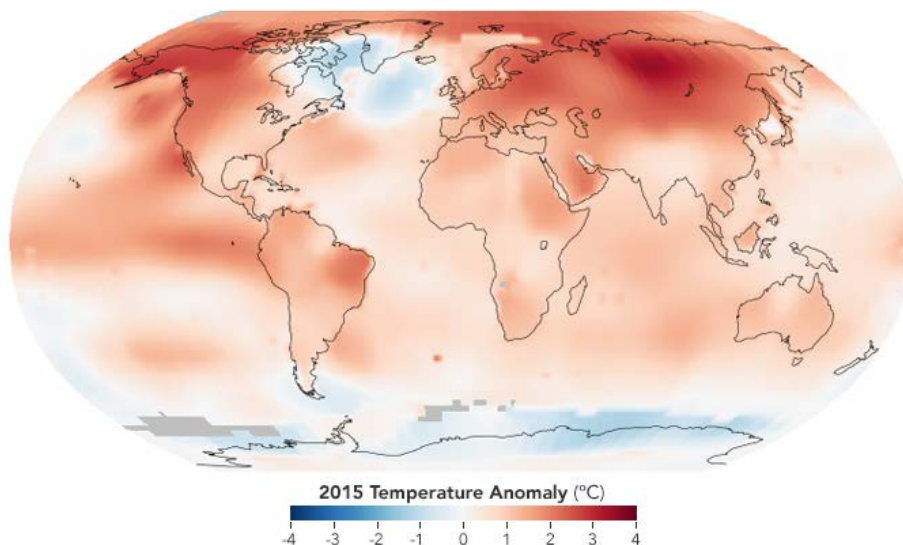


FIGURE 10-1
GLOBAL TEMPERATURE ANOMALIES IN 2015 (NOAA, 2016)

pollutants, toxic pollutants, and greenhouse gases. The Air Quality-Related Energy Policy also articulates ten Policies and ten Actions to ensure clean air by promoting the development of reliable, safe, cost effective, and clean energy. For example, Policy 1 asserts the promotion of zero and near-zero emission technologies through ultra clean energy strategies to meet air quality, energy security and climate change objectives. Action 10 requires that an update of energy usage within the District is provided in each AQMP (SCAQMD, 2011). In addition, during the December 4, 2015 Governing Board hearing, the SCAQMD Governing Board requested a review of technologies and programs that can help reduce energy use, increase availability of renewable energy sources, reduce the need for new fossil fuel-based power generation in the Basin, and incorporate alternatively powered transportation.

The energy projections, technologies, and programs presented here reflect existing District policies and planning efforts. However, many newly adopted programs, as well as those under development and within the proposed 2016 AQMP control measures, will have impacts on future energy usage in California that are not yet fully accounted for in future energy use projections. In addition, ten white papers that preceded the development of the 2016 AQMP, covered an array of sectors and topics, including a survey of technologies and policies that can help achieve a zero and near-zero emission future, were integral to the development of this chapter as well as the 2016 AQMP (SCAQMD Energy Outlook White Paper). Two of the white papers were focused on energy usage in the Basin and highlighted the importance of energy and climate change objectives from other agencies in helping reduce air pollution, showing the importance of collaborative planning efforts. The Residential and Commercial Energy white paper provided an assessment of the energy usage, age of buildings, review of existing efficiency programs, and future energy usage scenarios within the Basin's commercial and residential sectors. The Energy Outlook white paper reviewed the types of energy use, focused on different end use sectors, reviewed

new technologies and the changing energy environment, and provided future emissions scenario analysis as future energy and climate change targets are achieved.

In the U.S., “criteria air pollutants,” are those with health based air quality standards that set allowable concentrations of six substances in ambient air, and are regulated under the federal Clean Air Act as well as California State law. They include ozone, particulate matter (PM), carbon monoxide (CO), lead, nitrogen dioxide (NO_x), and sulfur dioxide (SO_x). Volatile organic compounds (VOCs), ammonia, and NO_x are also regulated as ozone and PM precursors. Control strategies in this AQMP rely on a combination of available and advanced technologies along with efficiency improvements to attain the ambient air quality standards. Additionally, many of the control measures combine planning efforts for climate change, transportation, and the energy sector to achieve multiple co-benefits. As later shown, the primary sources of criteria and greenhouse gas emissions are direct and indirect energy use within the Basin.

Criteria pollutants and greenhouse gases (GHGs) are often treated separately by different regulations. However, certain air pollutants are both climate forcers and criteria pollutants. Additionally, there are interactions between climate and criteria pollutants within the atmosphere. These interactions often worsen the impacts from greenhouse gases and increase background levels of criteria pollutants. An example of this interaction is the atmospheric fate of the GHG methane. While methane persists in the atmosphere for 10 to 14 years, its atmospheric lifetime is impacted by criteria pollutants (Prather, 2007). As methane reacts within the atmosphere, it acts like a VOC and increases background tropospheric ozone levels. Over the past 12 years, global methane emissions have increased over 30 percent, which also increased background levels of tropospheric ozone (Turner, 2016). Increasing background tropospheric ozone makes achieving air quality standards more difficult. Lastly, tropospheric ozone is also one of the strongest and significant short lived climate pollutants (Intergovernmental Panel on Climate Change [IPCC] AR5, 2013).

Climate Change

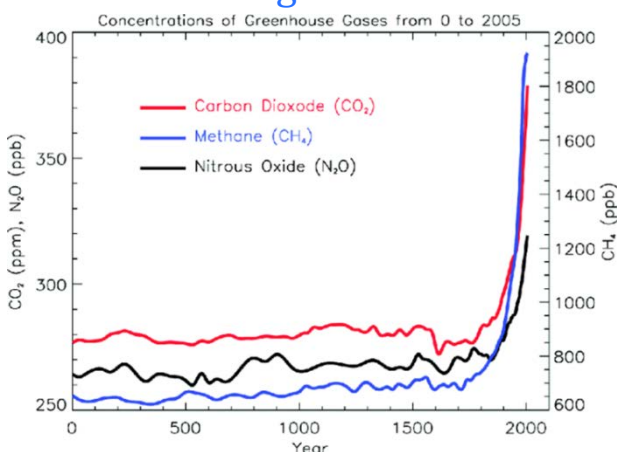


FIGURE 10-2
ICE CORE RECORD ALONG WITH ATMOSPHERIC MEASUREMENTS
OF METHANE, CARBON DIOXIDE, AND NITROUS OXIDE
(Thomas Karl, 2009)

The earth’s atmospheric greenhouse effect is essential for life on this planet. Greenhouse gases in the earth’s atmosphere absorb outgoing infrared radiation, keeping us at a comfortable average global temperature of 60 °F. An absence of GHGs in earth’s atmosphere would result in an average surface temperature of 0 °F. The earth’s natural carbon cycle balances GHGs in the atmosphere to stable concentrations over thousands of years. However, this balance has been disrupted over the past 150 years due to mankind’s rapid increase in consumption of fossil fuels for energy, as well as a decline in natural carbon sinks due to human land-use Revolution, fossil fuels previously

sequestered underground have been extracted and burned largely for their energy content, releasing greenhouse gases such as carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O) into the atmosphere at an escalating rate. During the same period, synthetic gases with extremely high global warming potentials, such as chlorofluorocarbon and hydrofluorocarbon refrigerants, were developed and released into the atmosphere. In addition, human activity has led to a decline in natural carbon sinks such as forests and wetlands, which have been removed so the land could be used for agriculture, mining and, and the growth of cities and towns.

The rapid expansion of fossil fuel-based energy, the emission of synthetic gases, and the depletion of our natural carbon sinks have drastically increased the level of GHGs in the earth's atmosphere and depleted stratospheric ozone. This results in changing global weather patterns, such as more extreme storms, higher average temperatures, and more prolonged periods of drought. In addition, half of the additional CO₂ emitted into the atmosphere over this time was absorbed by the earth's oceans, leading to an increase in ocean acidity. These changes, along with other human-caused environmental impacts, have some ecologists and geologists terming the geologic epoch in which we live, "the Anthropocene Period", in which human activities have started to significantly impact global ecology and ecosystems (University of California, 2015).

Since the beginning of the Industrial Revolution, GHG concentrations in the atmosphere have increased exponentially (see Figure 10-2). As shown in Figure 10-3, average global temperatures have been increasing with some variation since the 1950's. The highest yearly average global temperature, since instrumental temperature record keeping began in 1880, was observed in 2015 (NOAA, 2016). The 2015 record average temperature broke the previous average record temperature by 0.23 °F, the widest margin documented. NOAA's recent temperature data also confirmed that July 2016 was not only the record warmest July ever, but the hottest month ever on record, in agreement with NASA data (NASA Earth Observatory, 2016).

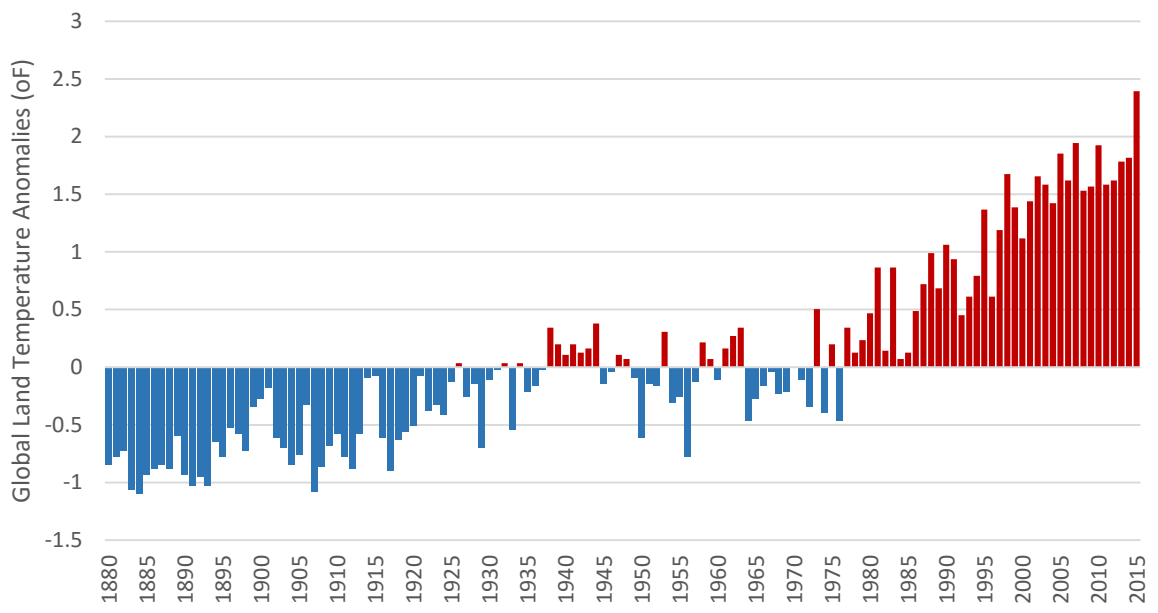
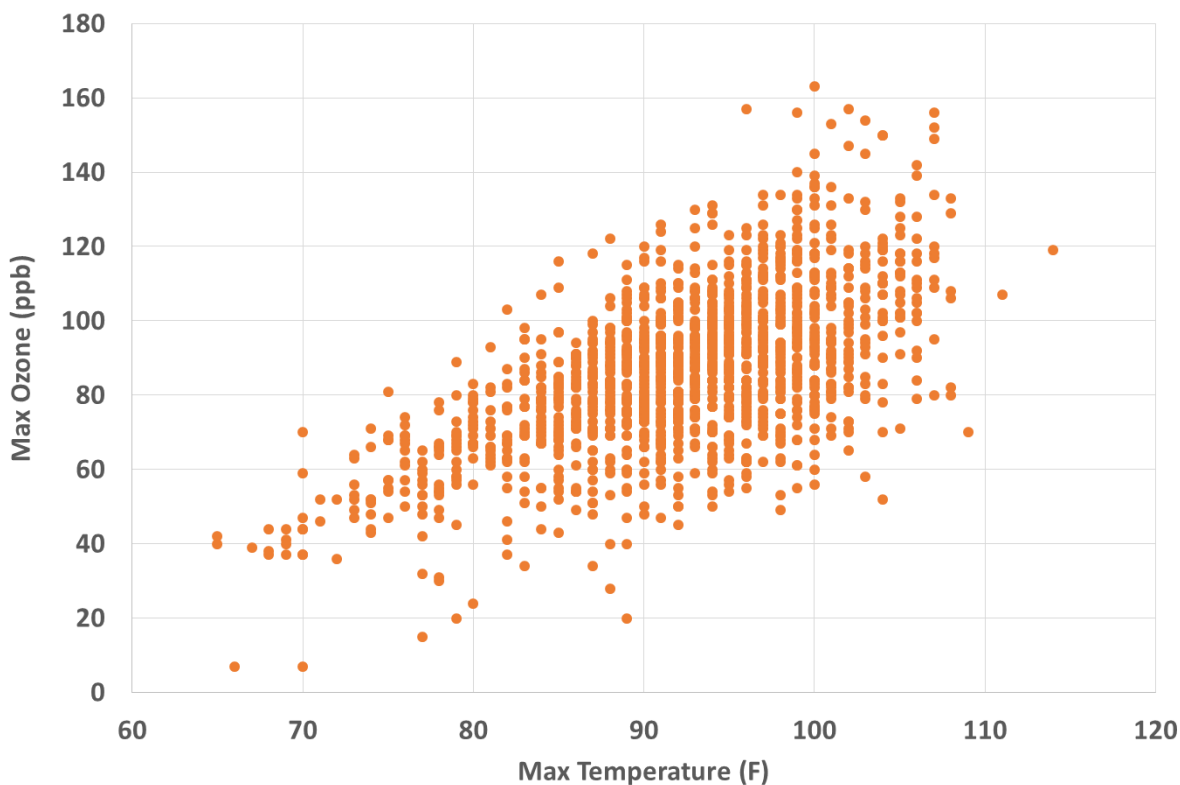


FIGURE 10-3
 GLOBAL TEMPERATURE ANOMALIES (I.E. DEPARTURE FROM REFERENCE VALUE OR LONG-TERM AVERAGE) FOR LAND WITH RESPECT TO 20TH CENTURY TEMPERATURE AVERAGE (*NOAA, n.d.*)

Even if GHG emissions were significantly curtailed today, there would continue to be climate change impacts for decades to come due to the past accumulation and slow removal processes of greenhouse gases in the earth’s atmosphere. The projected impacts include extreme weather variability, rising ground-level temperatures, sea level rise, and depleted water resources. In addition, future projections of increased extreme heat events in Southern California could result in more days exceeding the ground-level ozone standard. Ground-level ozone in the Basin forms through a chemical reaction between NOx and VOCs in the presence of sunlight. The correlation of the peak hourly temperature and peak hourly ozone measurements is shown in Figure 10-4 for the SCAQMD San Bernardino monitoring station. This increase of ozone with temperature is often referred to as the “climate penalty.” Additionally, increased emissions of criteria pollutants from developing countries along with higher atmospheric levels of methane have resulted in increasing levels of global background ozone, which makes it more difficult to achieve ozone standards in urban areas (Cooper, 2011) (IPCC, 2013).

Ozone and Temperature Correlation: SCAQMD San Bernardino Monitoring Station

**FIGURE 10-4**

CORRELATION OF ONE-HOUR OZONE MAXIMUM CONCENTRATION WITH ONE-HOUR MAXIMUM TEMPERATURE DURING SUMMER MONTHS FROM YEARS 2004 TO 2015 MEASURED AT SCAQMD SAN BERNARDINO MONITORING SITE

Many GHGs undergo slow atmospheric reactions and/or uptake through biological processes or other removal mechanisms. To minimize these predicted greater future impacts of climate change and associated catastrophic weather events, the world must quickly limit its collective GHG emissions. Following a “business as usual” path without future GHG mitigation efforts could lead to increased average warming that ranges from 2.5 °C to 7.8 °C (4.5 °F to 14 °F) by the end of the century (University of California, 2015). The range of projected temperatures reflects the significant uncertainties associated with predicting future global temperatures, impacts from climate feedback mechanisms, and varying global emission levels. The consequences for each degree of increased temperature include: significant public health impacts, ecological disturbances, and sea level rise, coupled with a declining ability to adapt to these changes. In addition, as temperatures increase so does the intensity of positive feedback mechanisms, such as decreasing surface albedo from melting ice, and increased methane emissions from the thawing of permafrost. If higher levels of warming continue to occur, areas of the earth will become uninhabitable due to heat stress, lack of potable water, vector-borne transmission of disease, and sea level rise inundating coastal lands (Sherwood, 2010) (Pal, 2015). Many ecological consequences are already occurring, such as ocean acidification, species migration, and sea level rise due to ocean warming and associated thermal expansion.

The California Global Warming Solutions Act (AB 32 and SB 32), and related Executive Orders mandate that California reduce emissions to 1990 levels by 2020, 40 percent below 1990 levels by 2030, and 80 percent below 1990 levels by the year 2050. The 2050 target was based on the need to limit global warming to below 2 °C. The 2 °C limit was formally codified in the Copenhagen Accord in 2009 as a global benchmark by which nations have agreed to measure collective success in limiting global warming. The recent 21st Council of Parties (COP-21) in Paris retained the commitment of the world's nations to reduce GHG emissions to the 2 °C threshold, while also recognizing the desirability of pursuing an even lower target. As GHGs accumulate in the atmosphere, climate change impacts become more acute and mitigation of these impacts becomes more intractable, complex, and expensive. For example, future economic costs arising from the impacts of climate change are non-linear with increasing temperatures because these costs recur year-after-year (White House, 2014). Therefore, it is critical that decisions are made expeditiously to develop and implement technologies to reduce GHG emissions alongside reductions of criteria and toxic pollutants. Every year of delay allows increased accumulation of GHGs in the atmosphere, negative health impacts, and, consequently, the need for more aggressive reductions in the future. Within the Basin, use of fossil fuel based energy resources contribute the majority of criteria pollutants, air toxics, and GHG emissions. Efforts to clean the air and meet mandated air quality standards, focused on the adoption of cleaner energy sources, also achieve the co-benefit of reducing GHG emissions, thus helping to meet State and global climate goals. These efforts also provide economic benefits from the new technologies and markets associated with clean low emission technologies.

Energy

The use of energy is a necessity of modern life in Southern California. It powers our economy, our mobility, and our personal comfort, and well-being. In 2012, total energy costs in the Basin were estimated to be over \$57 billion. Currently, energy use for both in-Basin mobile sources and electricity generation for stationary sources is dominated by the combustion of fossil fuels. The combustion of fossil fuels results in the emission of criteria pollutants, air toxics, and greenhouse gases. This results in short-term air quality impacts on health and longer-term climate change impacts from the accumulation of greenhouse gases in the earth's atmosphere.



FIGURE 10-5
(Bloomberg New Energy Finance , 2016)

Beginning in late 2014, global fossil fuel based energy prices dropped sharply and continued to fall. In the past, declining fossil fuel prices have hindered the growth of renewable energy resources. However, over the past two years, renewable energy technologies have also significantly declined in price, making them increasingly cost competitive with traditional fossil fuel-based energy resources (Bloomberg New Energy Finance , 2016).

The declining costs of renewable energy technologies are opening pathways for decarbonizing multiple energy sectors, thus reducing criteria and air toxic pollutants and greenhouse gas emissions, and helping achieve cleaner air and climate stability. However, at this time, most renewable energy technologies are not a direct replacement for traditional fossil fuel based resources for power generation. This is due to the intermittency of many renewable energy resources, outdated regulations and policies governing

energy generation, and necessary upgrades to grid and transmission infrastructure. A key to overcoming these roadblocks is the adoption of integrated energy strategies that achieve GHG emission reductions and commensurate reductions of criteria pollutants and toxic air emissions.

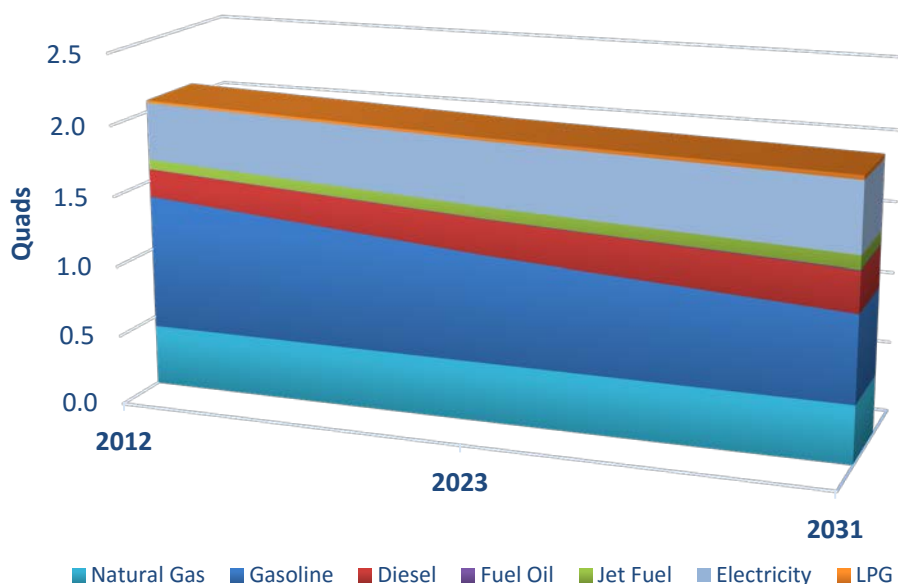
California is already transitioning towards generating power from a higher percentage of cleaner renewable energy sources as later shown in Figures 10-14 and 10-15. This is resulting in improved air and water quality, as well as greater resilience to large price fluctuations of traditional fossil fuel-based energy resources. The emission reduction efforts in California and the Basin have charted a path for the nation and other countries to follow as they also begin to develop new technologies and programs to tackle air pollution and curb GHG emissions while growing a vibrant and resilient economy.

South Coast Basin Energy Consumption, Emissions, and Projections

Energy projections, technologies, and programs presented in this section reflect information derived from many existing policies and other agencies' planning documents. However, many newly adopted programs and those still in development will also have impacts on future energy usage in California and are not yet fully represented in the future energy use projections below.

Energy Consumption Inventory and Projections

In 2012, the end use energy needs of the Basin were 2.1 quads (1 quad = one quadrillion [10¹⁵] British Thermal Units). This is equivalent to over 2 percent of the energy consumption within the United States (U.S.) for approximately 5 percent of the U.S. population (EIA Consumption & Efficiency, n.d.). As shown in Figure 10-6, in 2012, the Basin consumed 0.96 quads of gasoline, over 45 percent of the total Basin energy consumed. End-use electricity and natural gas consumption account for the second and third largest categories of energy consumption in the Basin, principally the result of commercial and residential building usage.



Note: Does not include consumption of natural gas for electricity generation to avoid double counting with electricity end use. Does not include fuel oil and diesel past the 24 nautical mile buffer zone.

FIGURE 10-6

TOTAL END USE ENERGY CONSUMPTION IN QUADS FOR THE BASIN BY FUEL TYPE IN 2012 AND FORECASTED GROWTH

The largest share of energy use in the Basin is devoted to transportation purposes as shown in Figure 10-7. This is the result of several factors related to the region’s dense urban population, development structure, and economy. Southern California has two of the largest maritime ports in the nation. Together, the San Pedro Bay ports of Los Angeles and Long Beach account for nearly 40 percent of all U.S. container imports (on a per twenty-foot equivalent unit (TEU) basis) (U.S. Maritime Administration, 2016). The in-Basin goods movement system includes local distribution networks based on extensive fleets of diesel powered trucks and trains transporting many millions of shipping containers to and through the area. The Basin also has three large airports that include both air and ground transportation. Most importantly, the Basin is home to more than 16 million residents who primarily rely on freeway and road infrastructure for mobility. As a result, the largest end energy use is vehicular gasoline consumption.

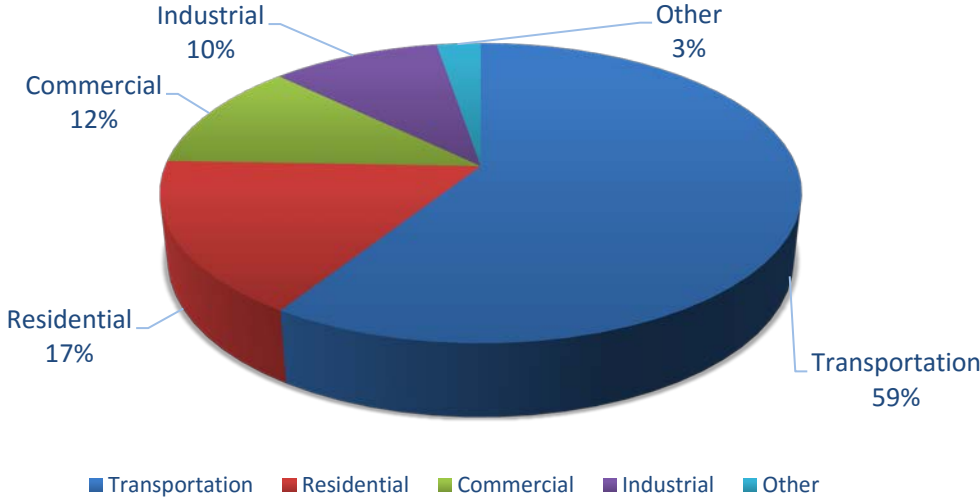
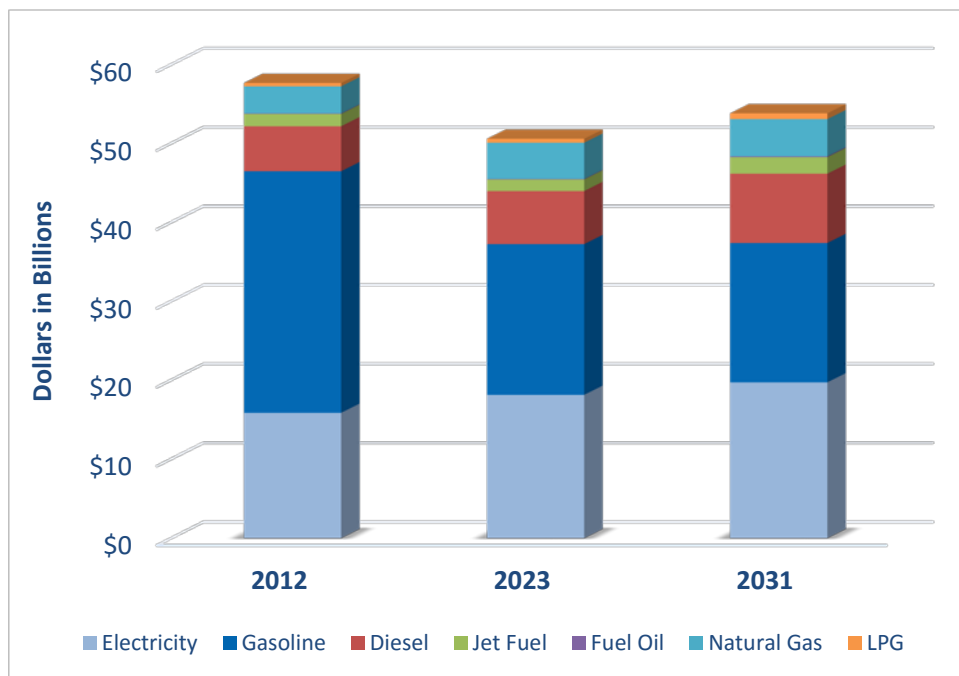


FIGURE 10-7
SHARE OF ENERGY USE IN THE BASIN

In 2012 over \$57 billion was spent on energy costs within the Basin. As shown in Figure 10-8, the cost of energy is expected to decrease in 2023 to \$50 billion and then increase slightly in 2031 to \$53 billion. This trend is consistent with the projected energy prices of the EIA Annual Energy Outlook. As shown in Figure 10-6, the Basin energy usage is projected to decrease slowly from 2.1 to 1.9 quads largely because of improved efficiency in 2031 (i.e., a 0.2 quad decrease between 2012 and 2031) within mobile and stationary sources. Similar to the energy consumption pattern, associated GHG emissions decrease from 127 MMT (million metric tons) CO₂ in 2012 to 105 MMT CO₂ in 2031. This projected decline of GHG emissions by 2030 currently falls short of the statewide target of reducing GHG emissions 40 percent below 1990 levels by 2030. State, federal, and local mandates regarding energy efficiency standards, renewable energy portfolio standards, and the cap-and-trade program will all help to reduce both energy consumption and emissions.

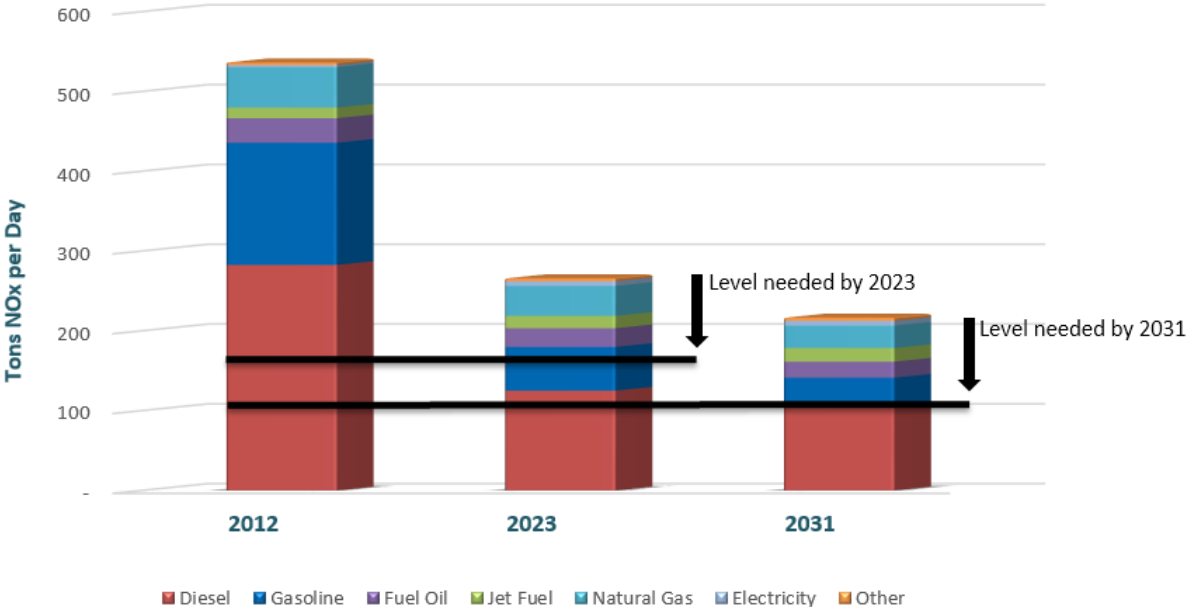


Note: Does not include cost of natural gas for electricity generation to avoid double counting with electricity end use. Prices based on EIA Energy Outlook 2011 reference case for the Pacific except electricity (EIA AEO, 2015).

FIGURE 10-8
DOLLARS SPENT AND PROJECTED ON ENERGY END USE IN 2012 AND FUTURE YEARS IN THE BASIN

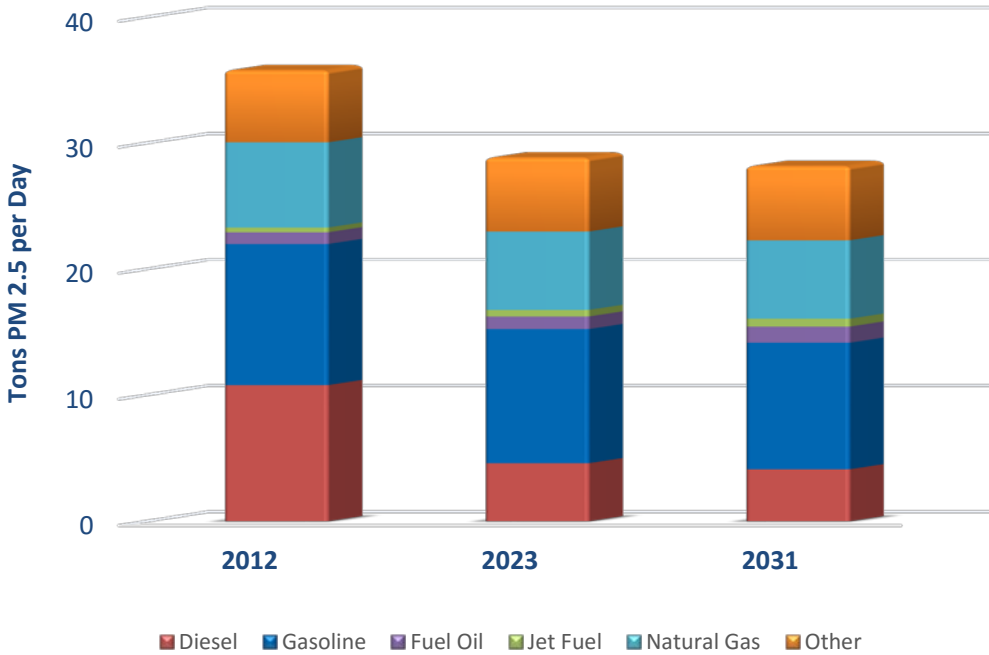
Emissions

Transportation sources account for over 50 percent of in-Basin energy use. These sources are also the main contributor to NO_x emissions (Figure 10-9). Within the transportation sector, diesel-powered sources emit the majority of NO_x. This is largely the outcome of years of effective stationary source and light-duty vehicle controls, the large numbers of diesel vehicles, and the slow rate of fleet turnover for diesel-powered vehicles. Increased fleet turnover, fuel economy standards, diesel repowering and other State regulations are projected to lower NO_x emissions. However, these reductions are not sufficient to achieve the National Ambient Air Quality Standards (NAAQS) ozone standards. Figure 10-10 provides the corresponding data for direct PM_{2.5} emissions by fuel type. Similarly, the majority of PM_{2.5} emissions are attributable to transportation sources.



Note: Other includes Biomass, Landfill Gas, Incinerators, LPG and RECLAIM Other.

FIGURE 10-9
NOX EMISSIONS IN TONS PER DAY BY FUEL TYPE



Note: Other includes Biomass, LPG, Incinerator and Landfill Gas

FIGURE 10-10
PM 2.5 EMISSIONS IN TONS PER DAY BY FUEL TYPE

In 2012, the CO₂ emissions from direct fuel use in the Basin were 127 MMT (see Figure 10-9). These emissions account for 28 percent of the total 459 MMT CO₂ released in California in 2013 (California Greenhouse Gas Emission Inventory - 2015 Edition, n.d.). Transportation fuels dominate the CO₂ emissions in Southern California. CO₂ emissions, shown in Figure 10-9, were developed from recent fuel consumption data and future projections.

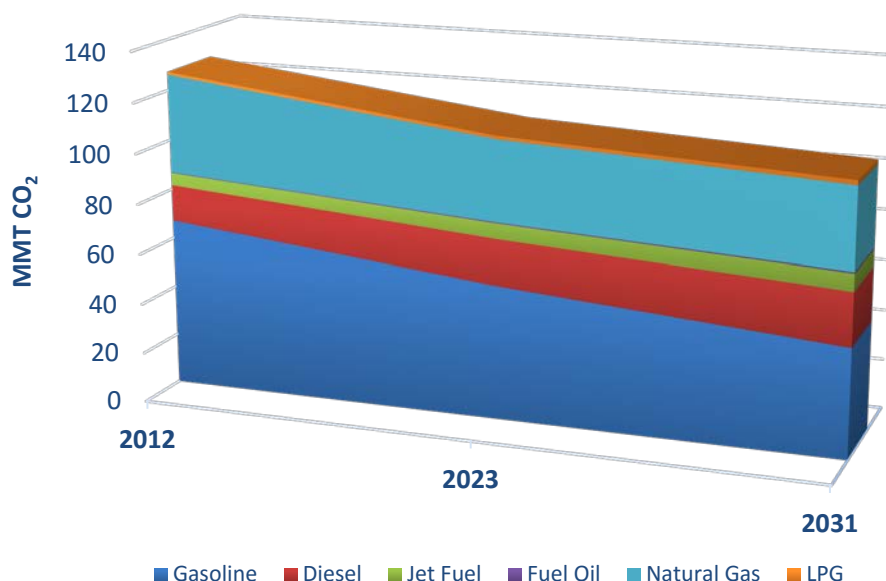


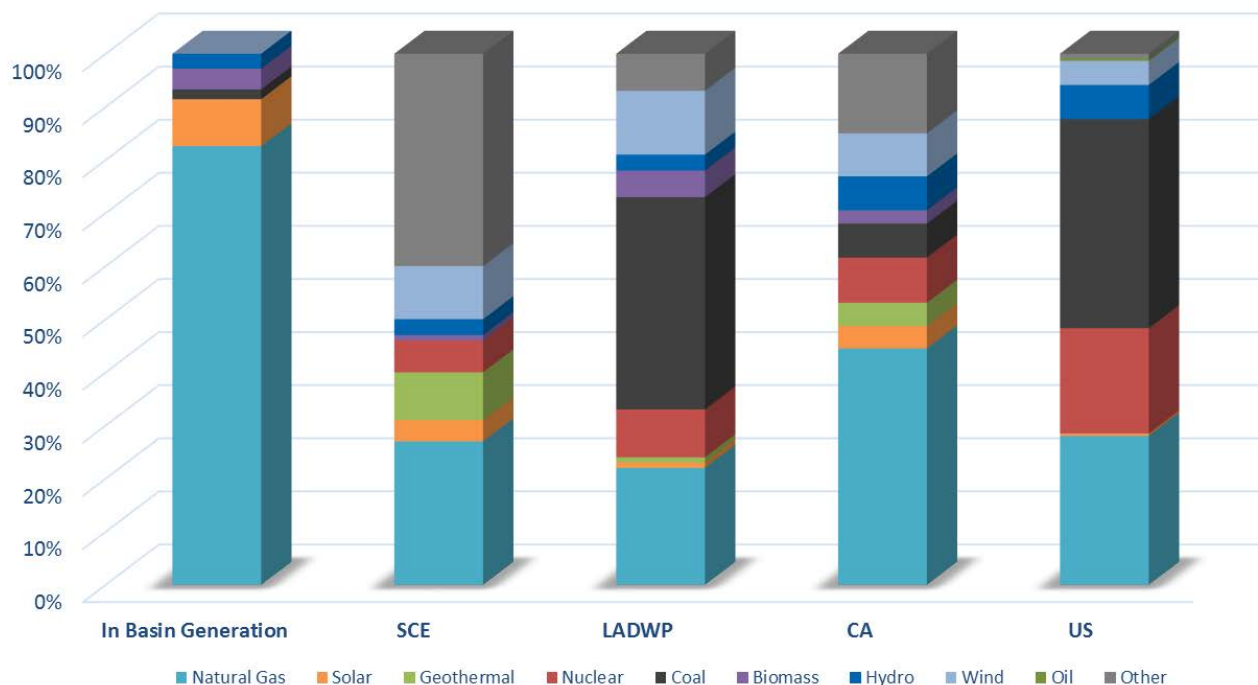
FIGURE 10-11
CARBON DIOXIDE EMISSIONS BY FUEL TYPE

Electricity Sources

In 2012, electricity end use in the Basin accounted for 120,210 gigawatt hours (GWh) of energy usage and 37 percent of the energy end use costs. Electricity generated within the Basin accounted for 45,000 GWh or 37 percent of the total electricity consumed in the Basin (CEC Energy Almanac - QFER and SB 1305 Reporting, n.d.). As of 2012, natural gas-fueled power plants produced the majority of the electricity in the Basin (Figure 10-12) as is the case for most of California; in contrast, the majority of electricity produced in the U.S. is from coal-fired power plants. Figure 10-12 also shows the percentage breakdown of the generation mix for electricity supplied to the Basin from Southern California Edison (SCE) and the Los Angeles Department of Water and Power (LADWP). From 2010 to 2014, the percentage of power used by SCE from coal has been reduced from 7 percent to 0 percent (CEC Utility Annual Power Content Labels for 2014, n.d.). LADWP energy supply from coal has recently reduced from 40 percent to between 28 and 30 percent since the start of divestiture of the Navajo Generating Station in July 2016 (LADWP Comments on Draft 2016 AQMP, 2016).

SB 1368 (CEC SB 1368 Emission Performance Standards, n.d.), and its implementing regulations promulgated by the California Energy Commission (CEC) and the California Public Utilities Commission (CPUC), have explicit constraints on utilities regarding the development of new coal-powered facilities or contracts for coal-powered generation. Due to this legislation, and as the State’s renewable portfolio

standard and cap-and-trade program are implemented, power procurement from coal resources will continue to decline over time.



Note: The SCE and LADWP generation do not represent the total Basin generation and generation outside of the Basin is not subject to SCAQMD regulatory authority. These figures represent purchases of electricity products by California retail suppliers and do not correspond to utility requirements under the California Renewables Portfolio Standard. The "Other" category accounts for unspecified electricity sources.

FIGURE 10-12
ELECTRICITY GENERATING MIX BY TYPE IN 2012

In-Basin Electricity Consumption

As stated above, total electricity end use consumption within the Basin was 120,210 GWh in 2012 and expected to grow to an estimated 144,369 GWh by 2031. This is derived from the net energy loads for L.A. Basin, SCE and LADWP service territories within the CEC California Energy Demand Forecast 2010–2020, and retail supplier power content percentages (QFER CEC-1304 Reporting Database, n.d.) (CEC Utility Annual Power Content Labels, n.d.). The CEC-1304 reporting form collects data from power plants with a total nameplate capacity of 1 megawatt (MW) or more. Electricity consumption is continuing to recover from a decline experienced during the last economic recession. The projected electricity use within the Basin is estimated to grow approximately 20 percent from 2012 to 2031 (an average of 1.1 percent per year). In 2012, an estimated \$15.8 billion was spent on end-use electricity deliveries within the Basin. Based on EIA Annual Energy Outlook 2015 projections, an estimated \$19.7 billion is projected to be spent on electricity in the Basin in 2031.

Challenges and Opportunities in Moving Towards 100 Percent Renewable Power

Worldwide energy consumption accounts for two-thirds of global GHG emissions (International Energy Agency, 2015). Additionally, as shown previously in Figure 10-9, energy consumption accounts for all in-Basin NO_x emissions, along with the majority of VOC and air toxics emissions (SCAQMD, 2015). Over the past century, the energy used by different sectors in the Basin primarily stems from specific fossil fuels: e.g., liquid fuels gasoline and diesel are used in the transportation sector, and natural gas is primarily used for electrical power generation and heating (SCAQMD Energy Outlook White Paper). Currently, California is undergoing a widespread shift in power generation and electrical infrastructure with the advent and adoption of renewable energy technologies. Renewable generation technologies such as solar photovoltaics, wind turbines, and hydrogen fuel cells are becoming more efficient and declining in cost. Solar photovoltaic technologies using crystalline silicon and other established renewable energy technologies do not need significant technological advances to achieve terawatt-scale deployment by 2050 (MIT, 2015). It is also feasible with new technology development, continued price declines, and widespread implementation to have renewable energy sources provide the majority of transportation and stationary energy needs (Jacobson, 2014). Installed costs for solar panels have been declining rapidly as shown in Figure 10-13, and wind energy capacity costs have decreased 75 percent in the past three decades (Trancik, 2015). Renewable energy generation technologies have thus become cost competitive with fossil fuel generation technologies in most locations. However, as discussed above, the renewable generation technologies, must currently still be supplemented by fossil fuel generation due to intermittency, periods of over-generation, along with lack of manageable loads and energy storage (MacDonald, 2016) (Trancik, 2015). The reliance on fossil generation to support renewables is expected to decline as more auxiliary resources are integrated onto the grid.

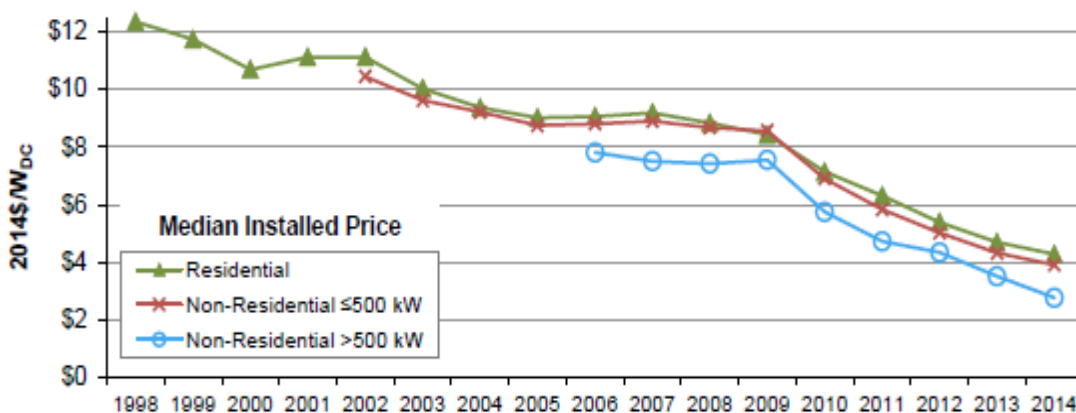


FIGURE 10-13
MEDIAN INSTALLED SOLAR PHOTOVOLTAIC PRICES (*DOE and LBNL, 2015*)

Declining costs in solar and wind resources have made them attractive technologies to increase the amount of renewable power generation globally (Bloomberg, 2016). In California, the majority of new renewable generation has been from solar and wind resources, as shown in Figure 10-14.

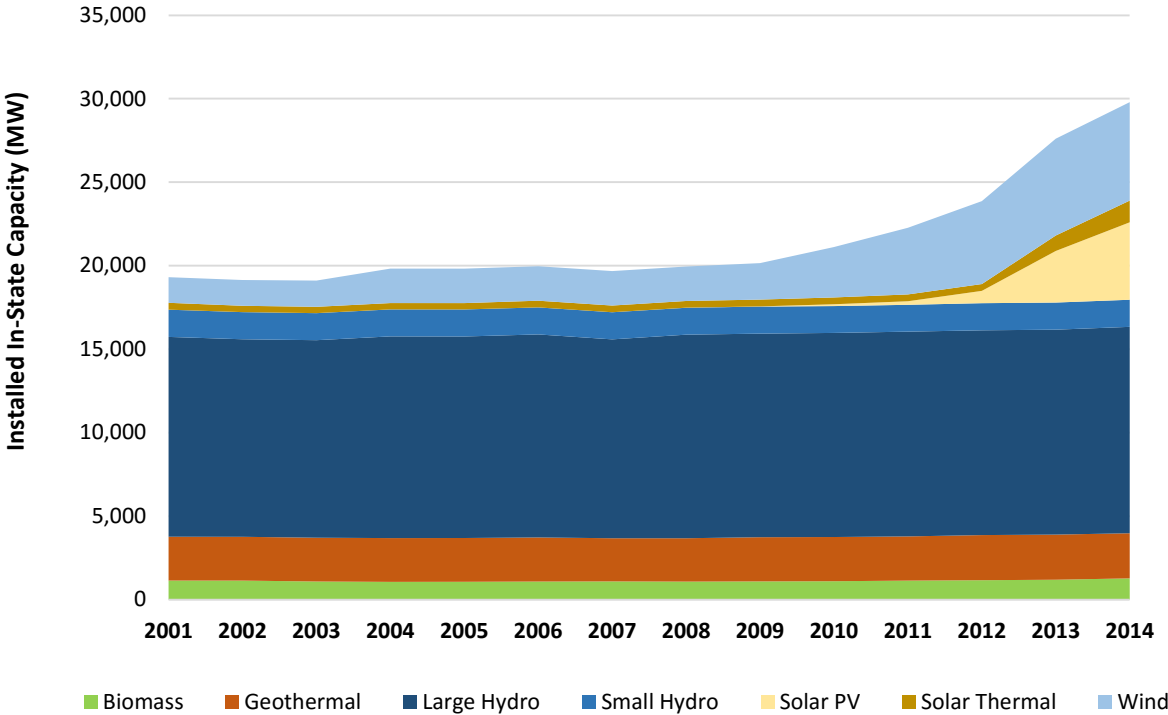


FIGURE 10-14
IN STATE RENEWABLE ELECTRICITY GENERATION BY FUEL TYPE

This shift has been in response to regulatory and policy mandates, as well as technology advancement in energy efficiency and renewable energy. The consumption of electricity is expected to increase through mid-century as alternatively powered vehicles become more reliant upon the electrical grid.

The increase in electricity consumption coincides with increasing requirements to power the grid with renewable power. As the grid shifts to operating with a higher percentage of renewable power, matching generation with demand on short-time scales becomes more complex as a result of intermittency from the renewable resources. Grid balance has historically been maintained by controllable conventional power generating resources. Currently, fossil fuel energy resources such as natural gas are able to ramp quickly to meet spikes in demand and support renewable power intermittency. With the move towards 50 percent of grid power coming from renewable energy resources, the reliance on conventional generating resources will decrease. However, intermittency and demand spikes will need to be met through additional resources that include enhanced regional grid collaboration, a diverse mix of renewable power resources, adjusting electricity loads through demand-side management, stored power, and grid integration of alternatively powered transportation. This will require policy and regulation changes to allow for new power markets, the expansion of efficiency programs and requirements to reduce the need for generation, the development of new energy storage technologies, and utilization of alternatively powered transportation for grid stability.

Increasing Grid Flexibility through Enhanced Regional Grid Collaboration and Increasing Renewable Generation Resource Diversity

California was one of the first states to implement a renewable portfolio standard (RPS) that required investor owned utilities (IOUs) to procure 20 percent of their electricity from renewable resources by 2010. In 2011, Governor Brown mandated a new RPS requiring that 33 percent of the State’s electricity come from renewable resources by 2020. In the summer of 2015, the passage of SB 350 put in place a new RPS mandate to achieve 50 percent renewable energy generation by 2030, with a requirement for longer-term discussions regarding the potential for 100 percent renewable power generation (Crawford, 2015). While these California targets are ambitious, Hawaii is the first state to adopt a 100 percent renewable power target by 2045.

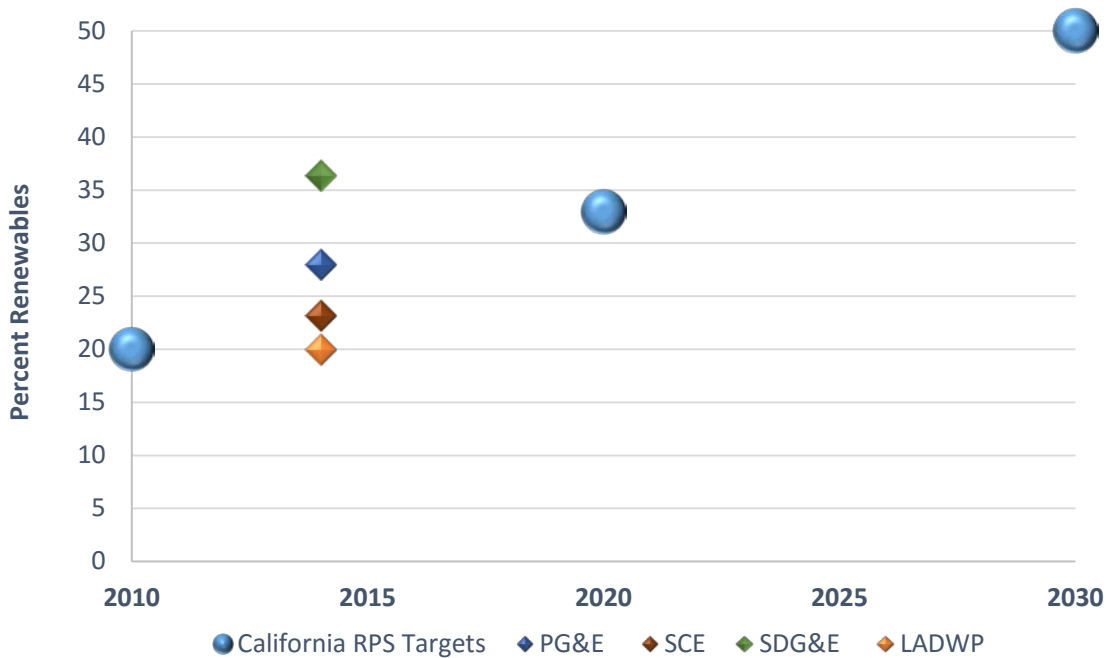
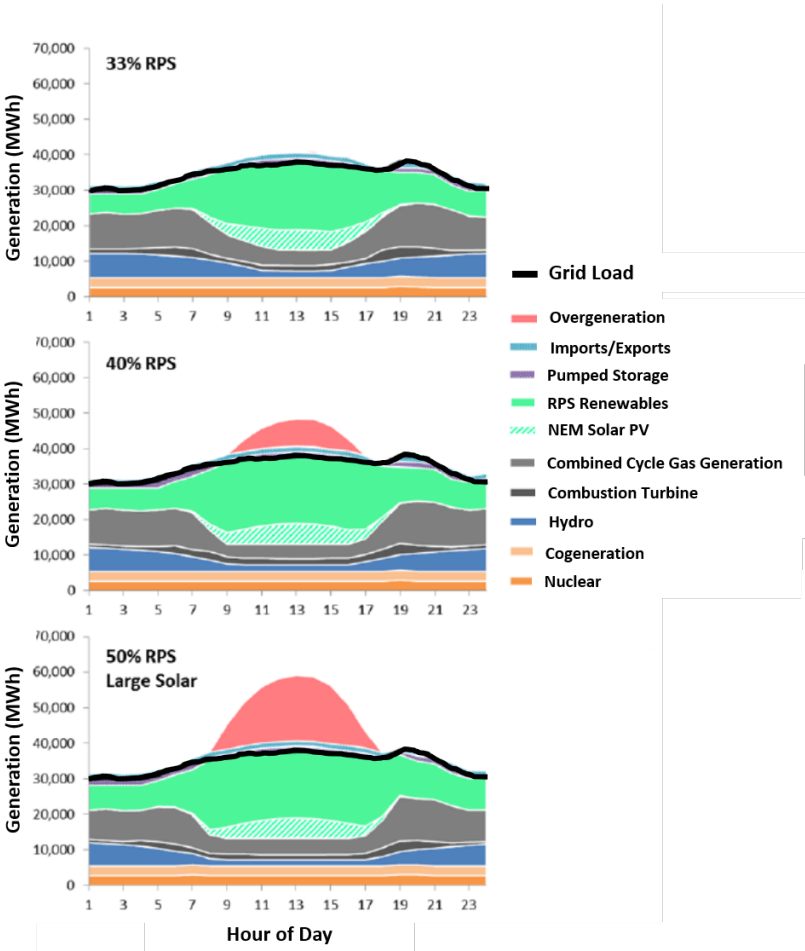


FIGURE 10-15

INCREASINGLY STRINGENT RENEWABLE PORTFOLIO MANDATES FOR CALIFORNIA AND THE LATEST PERCENTAGE OF RENEWABLES AT THE THREE LARGEST INVESTOR OWNED UTILITIES AND ONE PUBLICLY OWNED UTILITY PROCURED TO MEET THE RENEWABLE MANDATES (SOURCE: CPUC BIENNIAL RPS UPDATE JAN. 2016) (SOURCE: CEC UTILITY ANNUAL POWER CONTENT LABELS)

As higher levels of renewable resources power the electrical grid, flexible grid resources, such as energy storage, must be integrated to accommodate the inherent intermittency and over-generation issues. It



is anticipated that California will meet the majority of its 33 percent and 50 percent RPS requirements with additional solar and wind resources. The addition of large amounts of solar is predicted to result in over-generation during periods of peak sunlight, as shown in Figure 10-16, primarily in the fall and spring.

A reliable grid must match load demand with generation supply on a second-by-second basis. Over-generation and the intermittency of renewable power resources create challenges for maintaining this stability. Therefore, the California Independent Operator (CAISO) is initiating procedures to accommodate increasing amounts of solar generation and other renewable power. Figure 10-17 shows the net load profile (net load = total grid load – renewable generation) that traditional generation resources must provide in future years as more solar and wind energy resources are added. Referred

FIGURE 10-16 GRID LOAD RELATIVE TO GENERATION RESOURCES. POWER OVERGENERATION OCCURS WITH HIGHER PERCENTAGES OF RENEWABLES FROM SOLAR AND WIND. THE 50% RPS LEVEL ASSUMES 25% SOLAR AND 15% WIND. (Energy and Environmental Economics, 2015)

to as the “Duck Curve” due to its shape, this illustration of net load shows that adding more solar generation to the grid requires generation from other energy sources to significantly decline or idle during peak daylight hours. However, these conventional generating resources must be able to quickly ramp up to balance renewable power generation intermittency and provide power demand ramping rates as solar resources decline at day’s end. Currently, gas turbine power plants and synchronous condensers are used to meet the supply interruptions associated with renewable power generation. The reliance on these fossil fuel resources to bridge these interruptions negates some of the GHG and criteria emissions benefits achieved from using clean renewable power resources.

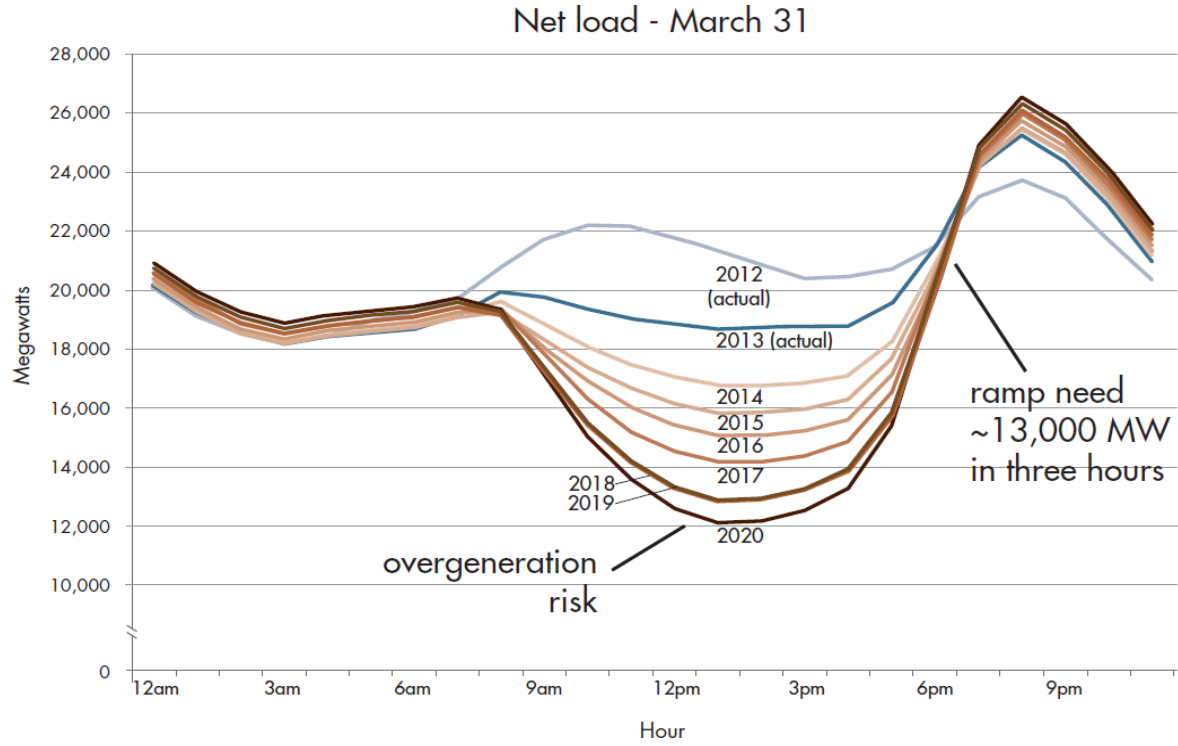


FIGURE 10-17

"DUCK CURVE" REPRESENTS THE NET LOAD FROM FLEXIBLE GENERATION SOURCES THAT CAISO MUST BALANCE ON A TYPICAL SPRING DAY. THE NET LOAD SUBTRACTS THE VARIABLE RENEWABLE GENERATION FROM THE END USER DEMAND. (CAISO, 2016)

Enhanced Regional Collaboration

Linking the electrical grids operated by CAISO with the electrical grids managed by neighboring states’ grid balancing authorities can utilize larger amounts of renewable resources while providing greater reliability and lower energy costs (Energy and Environmental Economics, 2015).

In 2014, CAISO developed a platform for an Energy Imbalance Market (EIM). Initially, the EIM was a collaboration with CAISO and grid operator PacifiCorp. The EIM was developed to increase grid operational efficiencies by (1) providing coordinated planning efforts and renewable resource development; and (2) providing a mechanism to export excess renewable power and import renewable power during periods of over-generation or high load needs. However, CAISO was not allowed to fully participate in the EIM until the passage of SB 350, which permitted CAISO to operate as a regional organization with authority outside of California.

The EIM is facilitating the utilization of renewable resources available in each territory by the other territories. Because these renewable resources vary based on local and sub-regional weather patterns and generation technologies, the over-generation from these resources in their “home territory” can be used to supplement and balance electrical loads in the other territories (see Figure 10-18). For example, the Pacific Northwest has large amounts of wind and hydropower resources. These resources can be used to balance the intermittency of solar power generation in California along with providing renewable resources for peak evening electrical loads.

Because grid load profiles vary throughout the day and the grid operators are located in different time zones, the exchange of power resources within the EIM helps to accommodate these load profile variations. Finally, the ability to tap into the more abundant EIM system resources can support the high

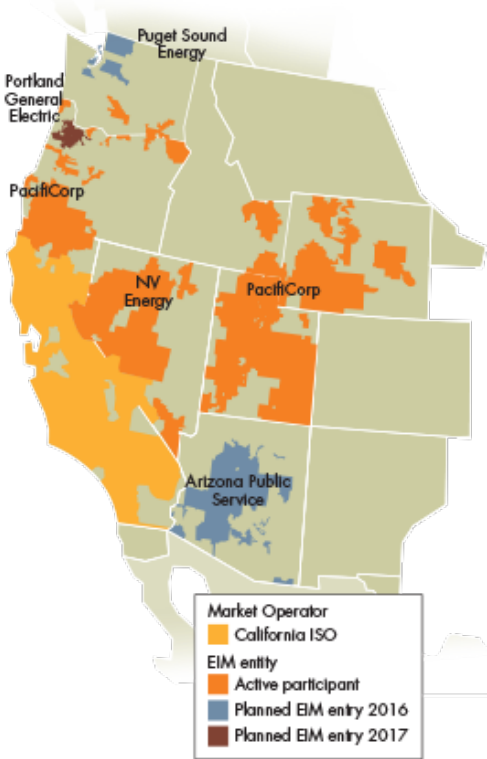


FIGURE 10-18
ENERGY IMBALANCE MARKET (EIM)
PARTICIPATION (CAISO, 2016)

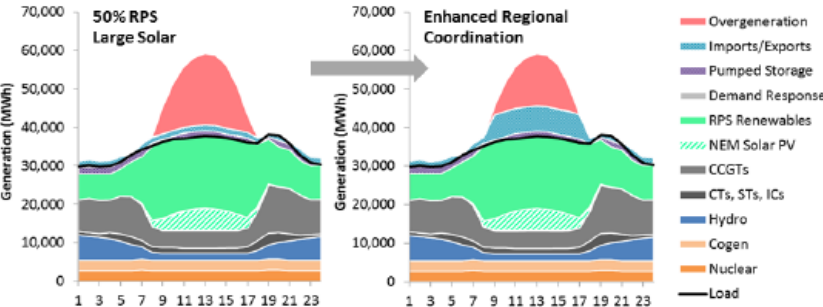


FIGURE 10-19
GRID LOAD WITH AND WITHOUT ENHANCED REGIONAL COORDINATION
(ENERGY AND ENVIRONMENTAL ECONOMICS, INC, 2014)

ramp rates shown in Figure 10-17 and Figure 10-19. Other grid balancing authorities in the western United States have joined the EIM and more are planning to join (Energy and Environmental Economics, 2015). While the EIM market is still relatively new, CAISO will need to avoid the import of coal and other fossil fuel energy resources

utilized by some participating authorities in order to avoid jeopardizing the RPS targets for California.

Increasing Grid Flexibility through Advanced Demand Response and Energy Efficiency Measures

The two most cost-effective ways to avoid the expense of adding power generation and new infrastructure are to increase energy efficiency and to improve grid load management (Rosenfeld, 2009). The avoided use of energy through efficiency measures has been termed “negawatts” by Amory Lovins of the Rocky Mountain Institute (Economist, 2014).

Two of the greatest advantages of implementing energy efficiency measures are that benefits are cumulative and long-lasting.

The California Public Utilities Commission (CPUC) and the California Energy Commission (CEC) have established building efficiency and appliance efficiency standards that became progressively more stringent. California Code of Regulations, Title 24 building efficiency standards, have increasingly strengthened efficiency requirements for new buildings since their adoption in the late 1970’s. The target for new Title 24 standards is zero net energy consumption for new residential construction by 2020 and zero net energy consumption for newly constructed commercial buildings by 2030. The Title 24 building energy standards coupled with State and national appliance energy standards have helped keep per capita energy consumption in California stable and well below national levels since the late 1970’s, (shown in Figure 10-20) along with reducing the need for 12,000 MW of new power generation (Rosenfeld, 2009).

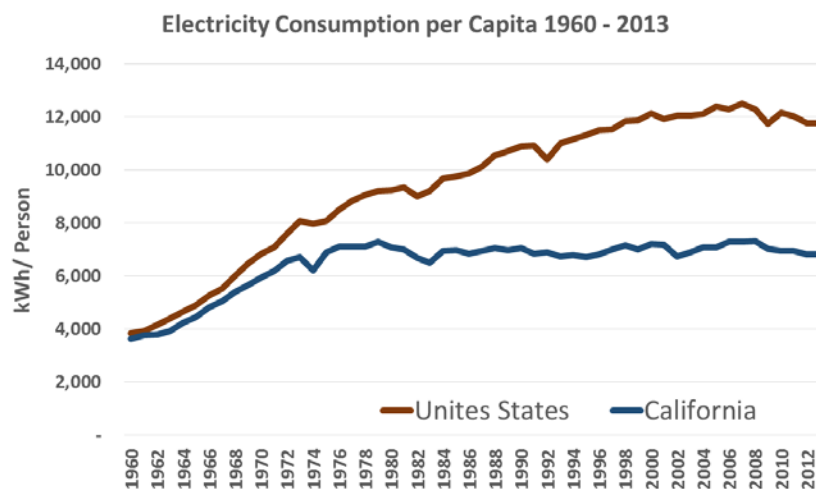


FIGURE 10-20
PER CAPITA ELECTRICITY CONSUMPTION OVER TIME FOR CALIFORNIA AND THE UNITED STATES

Improving the energy efficiency of existing buildings is a huge opportunity to realize additional energy reductions. In Southern California, 64 percent of residential homes were built prior to the adoption of the first Title 24 energy standards (SCAQMD, 2015). Ratepayer programs administered through the CPUC provide rebates for efficiency improvements in existing buildings. While these improvements drive down energy demand, the incentives to perform these retrofits are often not utilized. This is due to barriers to performing efficiency retrofits such as expensive upfront capital costs; lack of awareness of the incentives; the complexity of the retrofit projects; and, the split incentive issue associated with rented buildings whereby retrofit costs are borne by building owners but the benefit of lower energy bills is realized by tenants. The U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, has compiled key resources to help overcome some of these obstacles. In addition, California established a target to double the energy efficiency of existing buildings by 2030 with the adoption of the Clean Energy and Pollution Act of 2015 (SB 350) targets. This will help spur energy efficiency retrofits, as well.

The highest electrical loads generally occur during hot summer days when air conditioner usage spikes. The additional demand is largely met with the power produced by peaking fossil fuel generation units (“peaker plants”). These generation units typically operate with 10 percent utilization rates; therefore, have lower generation efficiencies to help lower capital costs. Since peaker plants operate infrequently, these generating resources often do not utilize the most fuel efficient generating technologies such as incorporating heat recovery steam generators.

To help limit the use and need for additional peaker plants, electrical utility pricing structures help reduce usage during peak periods by employing time-of-use rates. Time-of-use rates increase during peak demand periods, and thus act as a monetary incentive to curtail demand during peak periods. Rather than match grid load demand with additional generation, decreasing end use demand through demand response programs can help change load profiles. Demand response programs incentivize end-use customers to reduce or shift their electricity usage during peak usage demand periods. New technologies such as Wi-Fi enabled thermostats, controllable electric water heaters which can also pull power from the grid to be used as energy storage, and smart phone app-based products, are making load management easier to implement for both utilities and consumers.

As electric vehicles (EVs) become more prevalent, vehicle charging will become an important grid management tool. Intelligently integrating electric transportation charging technologies with the electrical grid is an effective way to provide grid resources. Many EV charging site hosts already have the ability to manage power flows based, in part, on electricity pricing and demand response, allowing the utility to send a signal to customers to cut back on loads during high peak grid demand. Future grid services tied to EV charging are anticipated to include bi-directional power flows, frequency response, and voltage support to enhance grid stability and storage capacity.

Increasing Grid Flexibility through Energy Storage Technologies

The energy landscape is rapidly evolving due to declining costs for generation equipment and the development of new technologies that provide grid and behind-the-meter support services, including energy storage systems.

As discussed above, renewable generation technologies are now well established and cost-effective; however, the technologies that provide ancillary services and grid support to fully integrate renewable power into the grid are still evolving. Renewable power resources are variable. This means that renewable resources may generate more power than is immediately necessary to meet demand, resulting in the need to block and thus lose the excess power from reaching the electrical grid. Another option is to store the additional energy supply. Energy storage technologies help to balance over-generation by storing excess power for later use (Figure 10-21), and by storing energy generated during weak demand periods so that it can be used during peak periods (Figure 10-22). Using energy storage technologies in large grid-scale applications along with smaller behind-the-meter energy storage systems provide flexible resources that reduce reliance on fossil-based generation plants.

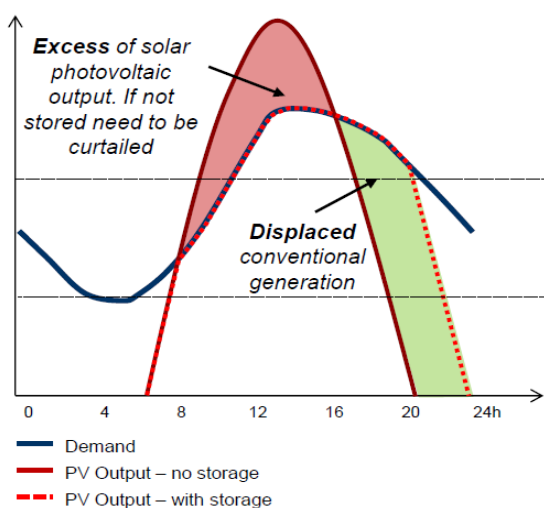


FIGURE 10-21
 USE OF STORAGE TO MATCH TO RENEWABLE GENERATION AND STORE THE EXCESS SOLAR POWER FOR LATER PERIODS *(SBC Energy Institute, 2013)*

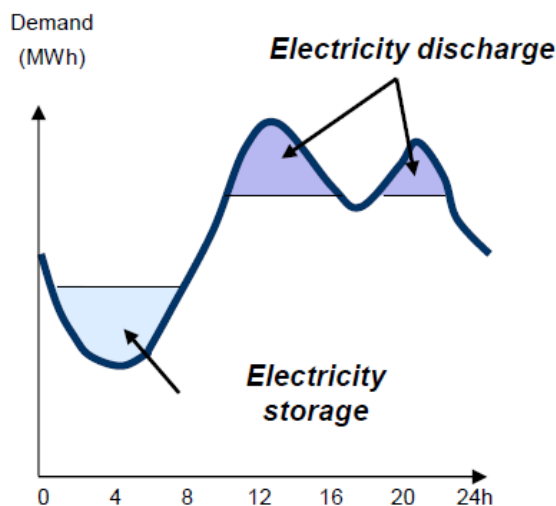


FIGURE 10-22
 EXAMPLE USING STORAGE TO HELP BALANCE ELECTRICAL LOADS FOR END USE ELECTRICITY CUSTOMERS. ELECTRICITY IS STORED DURING LOWER DEMAND PERIODS AND DISCHARGED DURING PEAK USAGE PERIODS. USING STORAGE IN THIS MANNER TAKES ADVANTAGE OF LOWER ELECTRICITY RATES TO PROVIDE POWER AT HIGHER RATE PERIODS. *(SBC Energy Institute, 2013)*

Energy storage systems can utilize different physical processes including thermal, mechanical, electrochemical, and chemical technologies, as shown in Table 10-1. Each storage technology has properties that can provide different types of support services based on their energy storage capacities, discharge rates, and ability to perform other ancillary services such as frequency regulation and voltage support.

TABLE 10-1
STORAGE TECHNOLOGIES GROUPED BY PHYSICAL PRINCIPLES

Mechanical Storage	Thermal Storage	Electrical Storage	Chemical Storage "Power to Gas"
<ul style="list-style-type: none"> -Pumped hydro -Compressed air -Flywheel 	<ul style="list-style-type: none"> -Hot-water storage - Molten salt -Ice and chilled water 	<ul style="list-style-type: none"> -Supercapacitors -Sodium-sulfur batteries -Lithium ion batteries -Vanadium redox-flow batteries 	<ul style="list-style-type: none"> -Hydrogen -Synthetic natural gas -Methanol -Synthetic diesel

Each storage technology has advantages and disadvantages with applications for transmission, distribution, and behind-the-meter power needs. Disadvantages of different storage technologies include costs, discharge rates, ease of installation, and maturity of the technology. Different storage types provide options for different applications, such as long term storage, reactive power, and peak shaving.

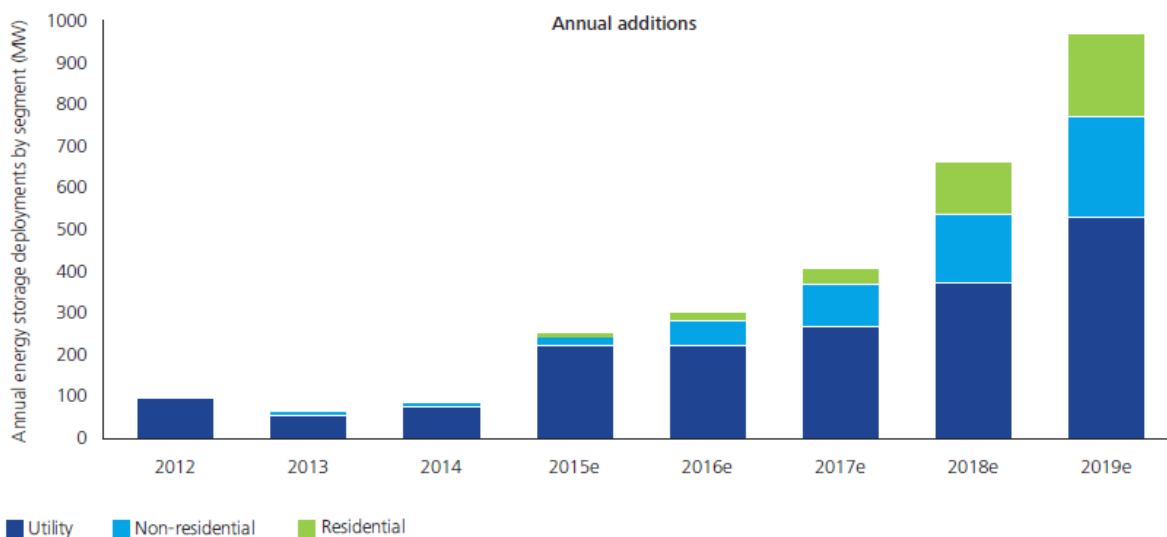


FIGURE 10-23

PAST ENERGY STORAGE DEPLOYMENTS IN U.S BY SECTOR UP TO 2014 AND FUTURE MARKET ESTIMATES TO 2019. FROM 2014 TO 2015 THE MARKET IS ESTIMATED TO HAVE INCREASED BY 185 PERCENT. (SOURCE GREEN TECH MEDIA RESEARCH)

Electricity pricing structures that promote load balancing and State mandates to increase the amount of renewable energy generation are driving the market for energy storage systems, a market that is projected to grow to \$50 billion by 2020. Many energy storage technologies, such as compressed air and power-to-gas technologies, are still under development. However, other energy storage systems, such as lithium batteries, are currently being marketed for behind-the-meter commercial and residential applications as well as large grid applications. Energy storage can be used to lower peak consumption, which reduces load demand charges. Currently the North America cost break-even point for adding battery storage systems for customers paying demand charges is around \$9 per kilowatt and is expected to drop to \$4–5 per kilowatt by 2020 as battery prices continue to drop (McKinsey&Company, 2016).

Grid-level Energy Storage

Grid-level storage systems are the largest energy storage systems. They typically must be at least 1 MW in order to provide useful service at a grid scale, as shown in Figure 10-22. These systems can replace certain peak generating resources (Figure 10-23). This is important from an efficiency standpoint; peak generating resources typically have low utilization rates with flexible generating ranges that are less than total capacity due to idling requirements. In addition, peaker plants are only brought online to meet high peak demand; they sit dormant for most of the year. Battery storage systems would provide numerous valuable grid resources beyond periods of peak demand.

Cost has been a limiting factor in considering a grid storage system over natural gas peaking generation; however, prices for battery storage systems are dropping rapidly with declining battery prices (GTM Research, 2016). In addition, the system controls for grid energy storage are more dynamic than for peak generating resources. In order to ensure the energy stored can meet anticipated demand, the amount of energy storage within the system, discharge rates, and length of discharge, requires a different level of monitoring than peak generating resources. However, more widespread utilization of grid

energy storage systems will soon take place because of new regulations. Under the AB 2514 energy storage mandate, utilities are required to install 1.3 GW of storage within their electrical grids in California. Many of the large power generating companies have already embraced grid-level storage systems, and thus are beginning to help local utilities meet their AB 2514 requirement.



FIGURE 10-24
5 MW GRID LEVEL BATTERY STORAGE USED ON UC SAN DIEGO MICROGRID

Grid storage technologies include molten salt thermal storage coupled with large solar thermal generating plants and large lithium battery container installations, as shown in Figure 10-22. An emerging grid storage technology is vanadium-redox-flow batteries; this system has large storage capacities, a long lifetime, and lower costs but must operate at high temperatures.

Another emerging technology for longer-term storage is “power-to-gas” which consists of energy storage by converting electrical energy to chemical energy in the form of hydrogen. As previously mentioned, the integration of increasingly

higher percentages of solar renewable energy into the grid will result in periods of electricity over-generation. Hydrogen gas can be generated during those periods of excess power through electrolysis of water, addressing renewable intermittency and excess electricity generation. This hydrogen can be used to produce natural gas and liquid fuels, can be converted back to electricity through clean combustion and fuel cells, or used for transportation by vehicles and by fossil fuel-powered electrical generation plants. Additionally, the hydrogen produced renewably through this process may eventually be blended with natural gas and added into the existing distribution pipeline infrastructure. Today, within California, hydrogen is mainly produced through steam reformation of hydrocarbons, primarily methane. However, the reformation process emits CO₂ as a byproduct. The use of electrolysis coupled with solar renewable energy provides a zero-emission hydrogen production solution. Other renewable sources would include steam-reformed biogas and biomass. Together with avoiding renewable energy curtailment, power-to-gas systems can help provide grid stabilization with renewable resources along with long term energy storage.

Hydrogen can be converted back to electricity using stationary fuel cells which have different characteristics compared to conventional power plants, allowing them to better complement the integration of renewable resources and the need to balance variability. The efficiency of conventional thermal power plants decreases when plants are operated at less than design output, thus increasing emissions. In contrast, stationary fuel cells can be operated at lower generation outputs with further increases in efficiency. Moreover, stationary fuel cells, contrary to conventional fossil based plants, have high efficiencies even at small scales. This characteristic makes for a more interesting option to support distributed power generation.

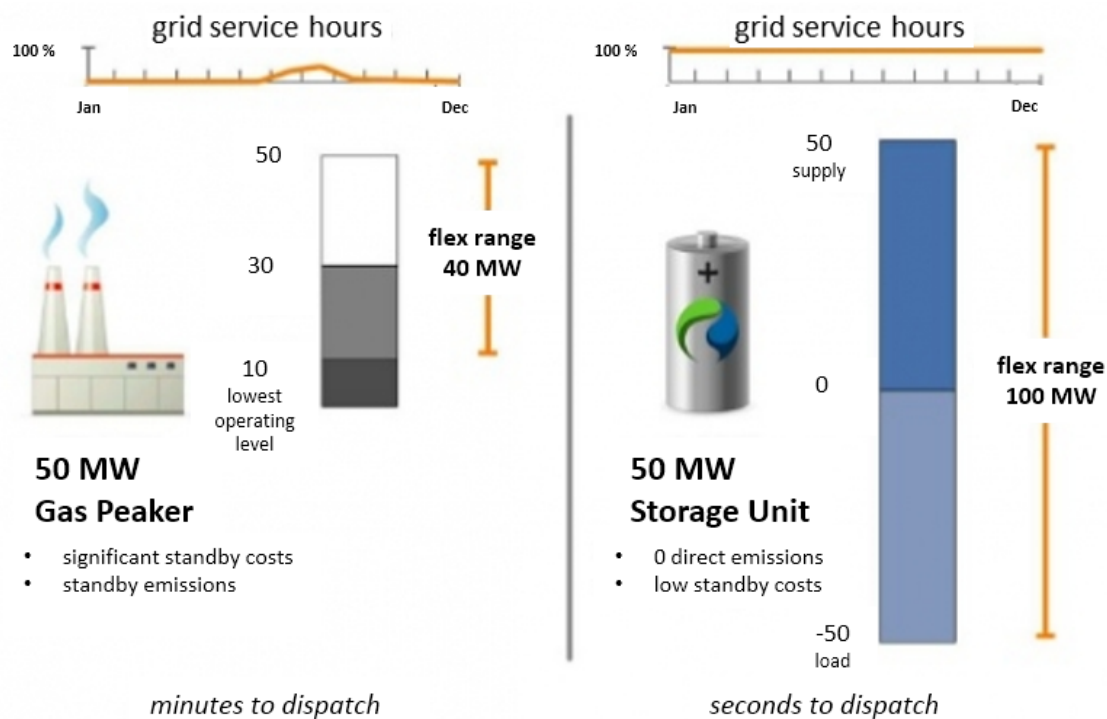


FIGURE 10-25
 COMPARISON OF USING GRID STORAGE IN PLACE OF PEAKING GENERATION UNITS (*Adapted from Greentech Media, 2016*)

Residential and Commercial Storage

Residential and commercial energy storage systems installed “behind the meter” (i.e., on the building owner’s side of the meter) are becoming popular because they can decrease peak demand electrical utility costs, provide backup power, and be used as off-grid systems.

A portion of the utility rates for large commercial sites are typically set during the highest 15-minute peak power consumption during a billing cycle. In addition, many utility charges are adjusted seasonally during peak electrical demand periods. These so-called “high demand charges” have prompted the use of energy storage systems to reduce the highest peak power loads. This is known as “peak shaving” (see Figure 10-20). Under this application, electricity is pulled from the grid during low demand periods, when rates are also typically lower. The energy is stored so that it can later be used during the highest rate periods. Many commercial energy storage companies are installing systems at no cost to facilities that are subject to high demand rates. Under these installations, the electrical cost savings are shared with the storage owner/installer and the site. These arrangements are often referred to as Power Efficiency Agreements (PEAs), and are similar to the Power Purchase Agreements (PPAs) offered by many solar installers. Residential energy storage systems are being used in a similar manner because many California residences are subject to time-of-use rates that vary with peak electrical loads.

Although the market for residential and commercial energy storage systems is still in its infancy, as shown in Figure 10-21, the development of storage technologies for residential and commercial applications is beginning to grow quickly. Increases in electricity rates, coupled with declines in energy storage and

solar power prices, are creating an economic driver for new energy storage system installations. Another reason is the ease with which residential storage systems can be installed, e.g., by simply plugging into an existing wall outlet.

To meet this nascent demand, both established companies and startups are starting to offer energy storage products. Many of the startup companies are focusing on how these storage systems, when coupled with distributed power generation from solar, give the consumer the ability to manage their own energy system. In the near future, combining an energy storage system with on-site solar generation could make tying in to the electrical grid optional for some consumers (Rocky Mountain Institute, 2014). Whether many residences and commercial sites decide to unplug from traditional utility service will likely depend on how the utilities rates are structured and the cost to keep grid connections for unforeseen circumstances.



FIGURE 10-26
TESLA 'POWERWALL' HOME BATTERY

Biogas

As long as traditional power generation plants remain operational and utilize fossil fuels as source energy, the natural gas they use should come from renewable resources, when possible. In the Basin, the waste streams from wastewater treatment plants, dairies, and landfills can be utilized to generate renewable biogas. Generating biogas from these waste streams can, in some instances, reduce emissions from these facilities. Additionally, the biogas can be used by conventional power generating plants, by the transportation sector, and by commercial and residential end users while counting toward renewable mandates. Sourcing biogas from within the Basin can provide new fuel supplies that decrease reliance on existing infrastructure. There is a high potential for biogas production in the Basin, with the four county region representing slightly over 50 percent of the State's biogas availability from landfill gas and waste water treatment plants (CEC PIER Program, UC Davis, 2015). If the energy potential from biogas is developed the resulting natural gas could supply an estimated 7 percent of the Basin's natural gas consumption in 2012 and 8.5 percent of the consumption in 2023.

Policy and Regulation Changes Along with Developing New Power Markets

The electrical power industry is undergoing the most rapid change in a century since the invention and development of electrical utility grids by Thomas Edison and Nicola Tesla. As shown previously in Figure 10-11, the price of solar panels has dropped significantly over time and is expected to continue. As distributed renewable energy becomes more widely available and less costly, the electrical utilities, CAISO, and regulatory agencies will need to develop regulatory mechanisms to incentivize and integrate these resources into the grid and allow the delivery of multiple grid services, such as energy generation, energy storage and voltage support (Solar City Grid Engineering, 2016). To accommodate larger amounts of distributed renewable energy on the grid, many of the rules governing utility markets will need to be amended to allow for additional storage, EV integration, and other flexible resources. Using distributed renewable energy as an infrastructure resource by the utilities will enable a more dynamic and flexible power system than the traditional centralized energy generation system of the past.

To allow for the participation of distributed renewable energy resources in the wholesale energy market, CAISO is developing the Distributed Energy Resource Provider (DERP) market. The DERP market would allow multiple smaller energy resources to be aggregated, and then participate as a single entity in the wholesale power market. The DERP market could provide opportunities for large microgrids, such as those run by universities, to sell power back to an investor-owned utility (IOU). In addition, large buildings such as warehouses could be aggregated together, thus becoming a significant source of power generation.

As a larger percentage of distributed renewable resources power the grid, the need increases for ancillary services such as energy storage and voltage support. For example, the shutdown of the San Onofre Nuclear Generating Station (SONGS) created a significant need for voltage support and reactive power (VAR) in South Orange County. Renewable energy resources typically have smart inverters giving them the ability to provide ancillary services. However, these ancillary services are currently prohibited under CPUC Rule 21. Amending Rule 21 to allow smart inverters to provide ancillary services is currently under review. This opens up the possibility of additional grid ancillary service markets for energy storage; EV charging and storage; and distributed generation.

These changes in energy management could allow further penetration of distributed renewable resources into the energy market without the need for large centralized generation facilities. Some utilities are looking to utilize distributed renewable energy as infrastructure resources in their infrastructure planning needs assessments. For example, SCE perceives distributed renewable resources as large-scale infrastructure solutions within their Preferred Pilot Resources program (Southern California Edison, n.d.).

Southern California's Energy and Air Quality Future

Southern California's energy market has undergone three transformative events within the last two decades: the California Energy Crisis in 2000; the shutdown of the SONGS in 2012; and, the Aliso Canyon natural gas storage leak in 2015 and 2016. While the energy infrastructure in the Basin has proven resilient enough to continue providing power to millions of end-users, these unplanned events have demonstrated the vulnerabilities of traditional centralized generation in an urban region. Encouraged by technical innovation and the declining costs of renewable resources, current planning efforts are now putting a greater focus on the development of distributed renewable energy resources and their essential supporting technologies, along with the continued implementation of efficiency measures.

The development and implementation of distributed energy resources and new technologies, along with heightened energy-efficiency efforts, provide multiple benefits in the Basin. These benefits include criteria and toxic emission reductions, GHG reductions, a resilient energy infrastructure, and significant economic benefits. These economic benefits are achieved, in part, through increased energy diversity; reduced energy costs; jobs for system installation and retrofits; and the creation of new businesses focused on clean technology innovation and production.

In addition to developing a more resilient energy infrastructure and becoming increasingly reliant on renewable resources to power the electrical grid, the transportation sector must also be transformed in order to attain healthful air quality levels standards in the Basin. Transportation and goods movement are the largest energy-consuming sectors in the Basin and employ many of the oldest technologies. Internal combustion engines utilize only 20 percent to 30 percent of the energy content in gasoline or

diesel for mobility; the remaining energy is lost primarily to waste heat. Increased efficiency within the transportation sector would provide a multitude of benefits.

The light-duty transportation sector is subject to several efficiency regulations that dictate fleet fuel efficiency requirements. These regulations include federal fuel-efficiency mandates, Pavley standards, and a State of California Executive Order target to have 1.5 million electric cars on the road by 2025. The technology transition to efficient light-duty vehicles such as hybrids, plug in hybrids, EVs, and fuel cell vehicles is well underway. Incentives available from California and the federal government have resulted in the purchase of 196,500 plug-in hybrids, 106,000 EVs and 635 fuel cell vehicles in the State since 2011 (Plug-in Electric Vehicle Collaborative, n.d.) (Hybrid Cars, n.d.) (California Air Resources Board, 2016); one of the top selling vehicles in



FIGURE 10-27
TOYOTA MIRAI (Toyota, 2016)



FIGURE 10-28
TESLA MODEL 3 (Tesla Motors, 2016)

California is the Toyota Prius hybrid. While these numbers are relatively small compared to overall vehicle sales, some industry analysts are predicting that the adoption of these vehicles may follow an “S” curve adoption rate much like cell phones and computers, as illustrated in Figure 10-29. Supporting these sales projections are declining battery prices, increased range, and less frequent maintenance requirements (Randall, 2016). An indication that EVs may start to show significant sales volumes and follow the “S” curve adoption rate is the 400,000+ (as of April 28, 2016) reservations for the Tesla Model 3 immediately following its recent announcement on March 31, 2016. If sales are completed, this model alone would quadruple the number of pure EVs on the road in the next 18 months.

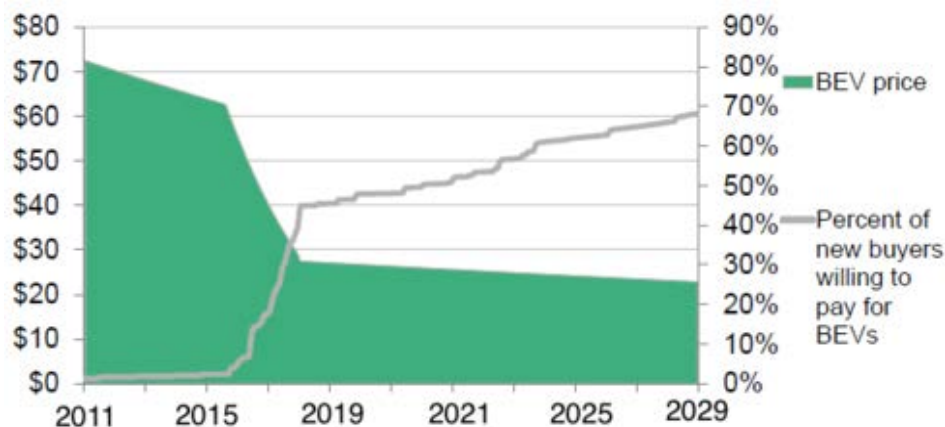


FIGURE 10-29
FORECASTED ADDRESSABLE (AVAILABLE) MARKET FOR BATTERY EV'S WITH 200-MILE RANGE IN RELATION TO BATTERY EV PRICE DECLINES (BATTERY EV PRICES IN THOUSANDS \$) (SOURCE: BLOOMBERG NEW ENERGY FINANCE)

The source energy used by the transportation sector (e.g. gasoline, diesel) has historically differed from the source energy used by stationary sources (e.g. natural gas, electricity). Therefore, the transportation

fueling infrastructure has operated largely independent of the electrical grid. With anticipated widespread adoption of EVs, a large part of the transportation sector will tap into the electrical grid to supply its energy needs. In order to accommodate the acceleration of EV sales and the resultant vehicle charging requirements, the electrical grid must become more dynamic. As the grid adapts to accommodate additional power needs, there is an opportunity to strengthen its resiliency by utilizing EV battery storage. As discussed above, EVs can help control grid loads with strategic charging. When renewable resource over-generation occurs, EVs can pull power from the grid and store this energy in their batteries. Using EV charging as a grid service could be more widely implemented to take advantage of the many potential benefits.

As of July 2016 California had 20 retail hydrogen fueling stations with 14 of those stations located in the Basin, including one at the SCAQMD headquarters in Diamond Bar. Additional infrastructure will have to become available to keep up with anticipated demand and to have a robust network of fueling stations. A complete network of fueling stations will boost vehicle manufacturing, reduce industry risk while lowering cost with economies of scale, and encourage the commercialization of fuel cell vehicles such as the Toyota Mirai, Honda Clarity, and the Hyundai Tucson. The emissions associated with the production of hydrogen for transportation could be mitigated by using renewables such as solar or even steam-reformed biogas instead of the currently used steam reformation of hydrocarbons. SB 1505 (Lowenthal, 2006) mandates that once annual throughput reaches 3,500 metric tons, no less than 33.3 percent of the hydrogen produced or dispensed in California must be from renewable energy resources. Compliance with this mandate will enhance the emissions benefits of fuel cell vehicles. The National Renewable Energy Laboratory 2014 study identified both Los Angeles and Orange Counties as some of the top 5 areas in the U.S. with net availability and potential for hydrogen from waste water treatment plants and landfills.

Transformation of the Energy Sector

The path forward to achieving cleaner air and mitigating climate change requires the continued transformation of the energy sector. The past model of simply adding centralized power generation to accommodate electrical loads is becoming less cost-effective and potentially obsolete. This transformation will include integrating additional renewable resources into the electrical grid; the widespread adoption of zero emission vehicle technologies; the development and implementation of energy storage technologies; increased energy efficiency measures; the use of alternative low-emission fuels; and, the launch of new energy markets to ensure these new technologies flourish. To encourage this transformation and maximize its co-benefits, SCAQMD will engage in the following activities:

- ***Coordinate planning, technology demonstration, and incentive program efforts*** – Agencies such as CEC, CPUC, U.S. EPA, CARB, SCAG, SCAQMD, CAISO, and local agencies leverage their efforts by working together on planning and regulatory efforts. Regulation and action by one agency can potentially conflict with the planning, regulatory and incentive efforts of other agencies. In addition, agencies working in collaboration with the local ports, utilities, and Original Equipment Manufacturers (OEMs) can identify and undertake technology demonstration projects prior to widespread implementation. Working together can better identify and implement incentive-funding programs that help the transition to newer technologies.

- ***Establish Workgroup to Assess Life-Cycle Emissions*** – In assessing technologies for stationary sources, the SCAQMD will convene a workgroup to assess the in-basin life-cycle criteria pollutant emissions related to energy use from technologies and/or other activities such as efficiency improvements. This assessment, in part, will include future energy scenarios that are anticipated as more renewable resources are incorporated into the energy usage within the Basin. The assessments will consider emissions associated with energy time-of-use, impact of higher efficiencies, fuel switching, and future energy and regulatory markets. In addition, the assessments will consider life-cycle GHG emissions, potential toxic impacts or benefits, and utilize experts and materials from other government agencies and universities.
- ***Provide technical and project assistance*** – The SCAQMD in collaboration with other agencies, utilities, OEMs, and stakeholders are able to provide technical assistance to those wishing to implement distributed energy resources, efficiency measures, or new transportation technologies and infrastructure. In addition to providing technical assistance, SCAQMD can help make available incentive programs, tax credits, rebates, credit markets and other financial tools to help project managers leverage funds from multiple sources to assist with infrastructure costs.
- ***Schedule for infrastructure and technology needs*** – Implementing more efficient mobile source technologies will require that the supporting energy infrastructure can accommodate their use. SCAQMD must continue to coordinate with other agencies and utilities on the implementation of transportation infrastructure that accommodates mobile source technologies.
- ***Collaborate and participate in national and international partnerships*** – Working collaboratively with other state, national, and international entities on air pollution reduction efforts, including the development of new technologies to assist in this effort, will leverage information and programs, and transfer knowledge on successes and lessons learned.
- ***Evaluate biogas*** – The technologies to produce biogas from waste streams within the Basin should continue to be further reviewed and coordinated with State agencies that are implementing measures to achieve renewable and waste stream diversion mandates.
- ***Study the “climate penalty”*** – Future climate impacts on air quality must be further studied, taking into account scenarios regarding future projected temperatures, local and global emissions, and weather extremes. The SCAQMD should continue to work with other agencies and researchers to further understand and monitor climate change impacts on air quality.
- ***Integrate a variety of implementation approaches in collaboration with other agencies with focus on the air quality benefits from GHG reduction measures such as renewable energy, smart grid technologies, and efficiency*** – This AQMP is incorporating several control measures to account for criteria pollutant co-benefits from federal, State and local mandates and programs to reduce GHG emissions, increase energy efficiency, along with renewable power sources. These control measures include ECC-01 and ECC-02 which account for co-benefits of greenhouse gas, efficiency, and renewable energy mandates such as AB 32, SB 32, SB 350 and Title 24. Furthermore, control measure ECC-03 will pursue incentive programs to accelerate the

implementation of onsite renewable energy, solar thermal, efficiency measures, along with smart grid applications.

References

- Adapted from Greentech Media. (2016, March 6). *AES Launches Modular Grid Battery Alternative to Peaker Plants*. Retrieved from <http://www.greentechmedia.com/articles/read/AES-Launches-Modular-Grid-Battery-Alternative-to-Peaker-Plants>
- Bloomberg. (2016, April 6). Wind and Solar are Crushing Fossil Fuels: Record Clean Energy Investment Outpaces Gas and Coal 2 to 1. Retrieved from <http://www.bloomberg.com/news/articles/2016-04-06/wind-and-solar-are-crushing-fossil-fuels>
- Bloomberg New Energy Finance . (2016, January 14). Clean Energy Defies Fossil Fuel Price Crash to Atract Record \$329 Billion Gloval Investments in 2015. Retrieved from www.BNEF.com
- CAISO. (2016). Retrieved from <http://www.caiso.com/informed/Pages/EIMOverview/Default.aspx>
- CAISO. (2016). Retrieved from http://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf
- California Air Resources Board. (2016). *2016 Annual Evaluation of Hydrogen Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development*. Sacramento. Retrieved from <http://www.arb.ca.gov/msprog/zevprog/hydrogen/hydrogen.htm>
- California Greenhouse Gas Emission Inventory - 2015 Edition*. (n.d.). Retrieved from California Air Resources Board: <http://www.arb.ca.gov/cc/inventory/data/data.htm>
- CEC Energy Almanac - QFER and SB 1305 Reporting*. (n.d.). Retrieved from http://energyalmanac.ca.gov/electricity/total_system_power.html
- CEC PIER Program, UC Davis. (2015). *An Assessment of Biomass Resrouces in California, 2013*. Retrieved September 2016, from <http://biomass.ucdavis.edu/publications/>
- CEC SB 1368 Emission Performance Standards*. (n.d.). Retrieved from http://www.energy.ca.gov/emission_standards/
- CEC Utility Annual Power Content Labels*. (n.d.). Retrieved from <http://www.energy.ca.gov/sb1305/labels>
- CEC Utility Annual Power Content Labels for 2014*. (n.d.). Retrieved from <http://www.energy.ca.gov/sb1305/labels/index.html>
- Cooper, O. S.-S. (2011, November 18). Measurment of wester U.S. baseline ozone from the surface to the tropopause and assesment of downwind impact regions. *Journal of Geophysical Research*, 22.
- Crawford, C. M. (2015, April 14). Calofornia Power Grid Seen Able to Handle 100% Renewables. *Bloomberg*.
- DOE and LBNL. (2015). *Tracking the Sun VIII: The Installed Price of Residential and Non-Residential Photovoltaic Systems in the United States*. Retrieved from https://emp.lbl.gov/sites/all/files/lbnl-188238_1.pdf

- Economist. (2014, March 1). Negawatt Hour. *Economist*. Retrieved from www.economist.com/news/business/21597922-energy-conservation-business-booming-negawatt-hour
- EIA Consumption & Efficiency. (n.d.). Retrieved from <http://www.eia.gov/consumption/>
- Energy and Environmental Economics. (2015). *Regional Coordination in the West: Benefits of PacificCorp and California ISO Integration*. Retrieved from <https://www.caiso.com/Documents/StudyBenefits-PacifiCorp-ISOIntegration.pdf>
- GTM Research. (2016). *Grid Scale Energy Storage Balance of System Costs Will Decline 41% by 2020*. Retrieved from <http://www.greentechmedia.com/articles/read/grid-scale-energy-storage-balance-of-systems-costs-will-decline-41-by-2020>
- Hybrid Cars. (n.d.). Retrieved from Car Sales Dashboard: <http://www.hybridcars.com/>
- Intergovernmental Panel on Climate Change [IPCC] AR5. (2013). *Climate Change - Physical Science Basis Chapter 8*. Retrieved from <http://ipcc.ch/report/ar5/>
- International Energy Agency. (2015). *Energy and Climate Change: World Energy Outlook Special Report*. IEA. Retrieved from www.iea.org/publications/freepublications/publication/weo-2015-special-report-energy-climate-change.html
- IPCC. (2013). *Fifth Assessment Report (AR5) - Chapter 8. Anthropogenic and Natural Radiative Forcing*. Cambridge U.K. and New York NY USA: Cambridge University Press. Retrieved from <https://www.ipcc.ch/report/ar5/wg1/>
- Jacobson, M. (2014, August). A roadmap for repowering California for all purposes with wind, water, and sunlight. *Energy The International Journal*, Volume 73, 14 August 2014, Pages 875–889. Retrieved from www.elsevier.com/locate/energy
- LADWP Comments on Draft 2016 AQMP. (2016, August 19). Los Angeles Department of Water & Power's Comments on Draft 2016 Air Quality Mangement Plan.
- MacDonald, A. e. (2016, January 25). Future cost-competitive electricity systems and their impact on US CO2 emissions. *Nature Climate Change*.
- McKinsey&Company. (2016, August). *The New Economics of Energy Storage*. Retrieved from <http://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/the-new-economics-of-energy-storage>
- MIT. (2015). *The Future of Solar Energy: An Interdisciplinary MIT Study*. MIT. Retrieved from www.mitei.mit.edu/futureofsolar
- NASA Earth Observatory. (2016, August 21). July 2016 Was the Hottest Month on Record. Retrieved from <http://earthobservatory.nasa.gov/IOTD/view.php?id=88607>
- NOAA. (2016, January). *Global Highlights: Calendar Year 2015*. Retrieved from <http://www.ncdc.noaa.gov/sotc/global/201513>

- NOAA. (n.d.). *Climate at a Glance*. Retrieved from http://www.ncdc.noaa.gov/cag/time-series/global/globe/land/ytd/12/1880-2015?trend=true&trend_base=10&firsttrendyear=1880&lasttrendyear=2015
- NREL. (n.d.). *Methane potential from biogas sources*. Retrieved from <http://www.nrel.gov/gis/biomass.html>
- Pal, J. a. (2015, October 26). Future Temperature in Southwest Asia Projected to Exceed a Threshold for Human Adaptability. *Nature Climate Change*. Retrieved from www.nature.com/nclimate/journal/vaop/ncurrent/full/nclimate2833.html
- Plug-in Electric Vehicle Collaborative*. (n.d.). Retrieved from PEV Sales Dashboard: <http://www.pevcollaborative.org/pev-sales-dashboard>
- Prather, M. (2007). Lifetimes and Timescales in Atmospheric Chemistry. *Phil. Trans. Roy. Soc. A*, 1705-1726.
- QFER CEC-1304 Reporting Database*. (n.d.). Retrieved from California Energy Commission Energy Almanac: http://energyalmanac.ca.gov/electricity/web_qfer/
- Randall, T. (2016, February 25). Here's How Electric Cars Will Cause the Next Oil Crisis: A Shift is Under Way that will Lead to Widespread Adoption of EVs in the Next Decade. *Bloomberg*. Retrieved from <http://www.bloomberg.com/features/2016-ev-oil-crisis/>
- Rocky Mountain Institute. (2014). *The Economics of Grid Defection*. Retrieved from http://www.rmi.org/electricity_grid_defection
- Rosenfeld, P. a. (2009). *A Graph Is Worth a Thousand Gigawatt-Hours How California Came to Lead the United States in Energy Efficiency*. Innovations.
- SBC Energy Institute. (2013). *Leading the Energy Transition: Electricity Storage*. Retrieved from https://www.sbc.slb.com/mwg-internal/de5fs23hu73ds/progress?id=7InAJntVsL-AKnfVrvhFS__K6nhbRP7xOSfGtdtMK8,&dl
- SCAQMD. (2011). *Air Quality Related Energy Policy*. SCAQMD. Retrieved from www.aqmd.gov/home/about/policies/aqmd-air-quality-related-energy-policy
- SCAQMD. (2015). *Multiple Air Toxics Exposure Study (MATES-IV)*. Diamond Bar: SCAQMD. Retrieved from <http://www.aqmd.gov/home/library/air-quality-data-studies/health-studies/mates-iv>
- SCAQMD. (2015). *Residential and Commercial White Paper*. SCAQMD.
- SCAQMD. (n.d.). 2016 AQMP White Papers. Retrieved from <http://www.aqmd.gov/home/about/groups-committees/aqmp-advisory-group/2016-aqmp-white-papers>
- SCAQMD Energy Outlook White Paper. (n.d.). AQMP White Papers. Retrieved from <http://www.aqmd.gov/home/about/groups-committees/aqmp-advisory-group/2016-aqmp-white-papers>

- Sherwood, S. a. (2010, May 25). An Adaptability Limit to Climate Change due to Heat Stress. *Proceedings of the National Academy of Sciences*, 107(27). Retrieved from www.pnas.org/content/107/21/9552.full.pdf
- Solar City Grid Engineering. (2016). *White Paper: A Pathway to the Distributed Grid: Evaluating the Economics of Distributed Energy Resources and Outlining a Pathway to Capturing their Potential Value*. Retrieved from www.solarcity.com/gridx
- Southern California Edison. (n.d.). *Preferred Resources Pilot*. Retrieved from <http://www.edison.com/home/innovation/preferred-resources-pilot.html>
- Tesla Motors. (2016). *Model 3*. Retrieved from <https://www.tesla.com/model3>
- Thomas Karl. (2009). *IPCC WG1-2007 "The Physical Science Basis" Report*. Retrieved from <http://www.enr.gov.nt.ca/state-environment/11-trends-global-greenhouse-gas-concentrations>
- Toyota. (2016, August). *Mirai Fuel Cell Vehicle*. Retrieved from <https://ssl.toyota.com/mirai/>
- Trancik, J. e. (2015). *Technology Improvement and Emissions Reductions as Mutually Reinforcing Efforts: Observations from the Global Development of Solar and Wind Energy*. MIT. Retrieved from www.mitei.mit.edu/news/report-technology-improvement-and-emissions-reductions-mutually-reinforcing-efforts
- Turner, A. D. (2016). A large increase in U.S. methane emissions over the past decade inferred from satellite data and surface observations. *Geophysical Research Letters*, 43. doi:10.1002/2016GL067987
- U.S. Maritime Administration. (2016, April 8). *MARAD Open Data Portal Data & Statistics*. Retrieved from U.S. Waterborne Foreign Trade by U.S. Customs Ports 2000 – 2015: <http://www.marad.dot.gov/resources/data-statistics/>
- University of California. (2015). *Bending the Curve: Ten Scalable Solutions for Carbon Neutrality and Climate Stability (Executive Summary)*. University of California. Retrieved from www.uc-carbonneutralitysummit2015.ucsd.edu/_files/Bending-the-Curve.pdf
- White House. (2014, July). *The Cost of Delaying Action to Stem Climate Change*. Retrieved from www.whitehouse.gov/sites/default/files/docs/the_cost_of_delaying_action_to_stem_climate_change.pdf