SOUTH COAST
AIR QUALITY
MANAGEMENT DISTRICT

Energy Outlook

2016 AQMP WHITE PAPER

NOVEMBER 2015

South Coast Air Quality Management District

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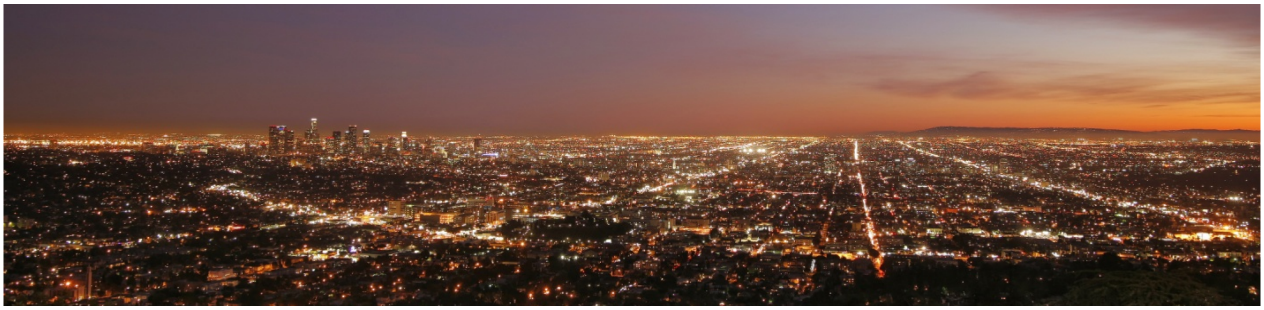


I. Purpose

In order to attain federal ambient air quality standards for ozone and $PM_{2.5}$ in the South Coast Air Basin (Basin), and to achieve the state's GHG reduction targets, transformational changes regarding how we select and use energy resources are essential. The Energy Outlook White Paper Workgroup was assembled to assist staff in the development of a white paper that provides insight and analysis on a range of topics that impact the energy sector and air quality within the Basin. The range of topics and analysis, in part, cover:

- Review of the energy resource choices within the AQMP planning horizon;
- Identification of potential demand, supply, and infrastructure needs for energy sectors based on existing and proposed regulations, policies, and programs;
- Review of emerging technologies that impact efficiency and reliability;
- Scenario analysis based on input from other working groups for various energy sectors;
- Energy infrastructure; and
- Recommended actions for coordinated efforts among the public agencies, fuel providers, and consumers for the scenarios analyzed.

II. Background

The 2016 Air Quality Management plan will largely focus on a NOx heavy reduction strategy to achieve the 2023 and 2031 federal ozone standard deadlines in the Basin. Additional but limited reductions of VOCs are needed to help achieve the federal ozone standards, and reductions of both NOx and VOCs will reduce levels of fine particulate matter being formed within the atmosphere. In addition to reducing these criteria pollutants, significant reductions in greenhouse gas (GHG) emissions are needed to achieve the State GHG targets, and to develop pathways for others in the nation and the world to limit atmospheric levels of GHGs below thresholds that lessen the potential for catastrophic climate change impacts.

Within California, many different policies, regulations, market-based mechanisms and incentives are in place and/or are being implemented that impact the types of energy supplied and used, how energy is used, and the emissions associated with energy generation and use. Policies and regulations previously enacted for air quality improvement have had an impact on the types of energy supplied and used in the Basin. As an example, the amount of coal use for electricity production in California has declined from a peak of 1,363 tons in 1993 to 539 tons in 2012[1]. This partially is a result of the Emission Performance Standard established by SB 1368 in 2006, which does not allow an increase in generating capacity of a facility that exceeds 1,100 lbs. CO_2 per MWh[2]. Similar GHG emissions limits are being implemented under the EPA's Clean Power Plan and will result in fuel switching of several coal power plants nationally. The sources of energy in California will continue to change as a result of the rapid development of new technologies and renewables, needs to protect public health from air pollution, and initiatives such as Governor Brown's new targets to reduce fossil fuel usage by 50%, increase renewable power generation to 50%, and increase efficiency within existing buildings 50% by 2030.

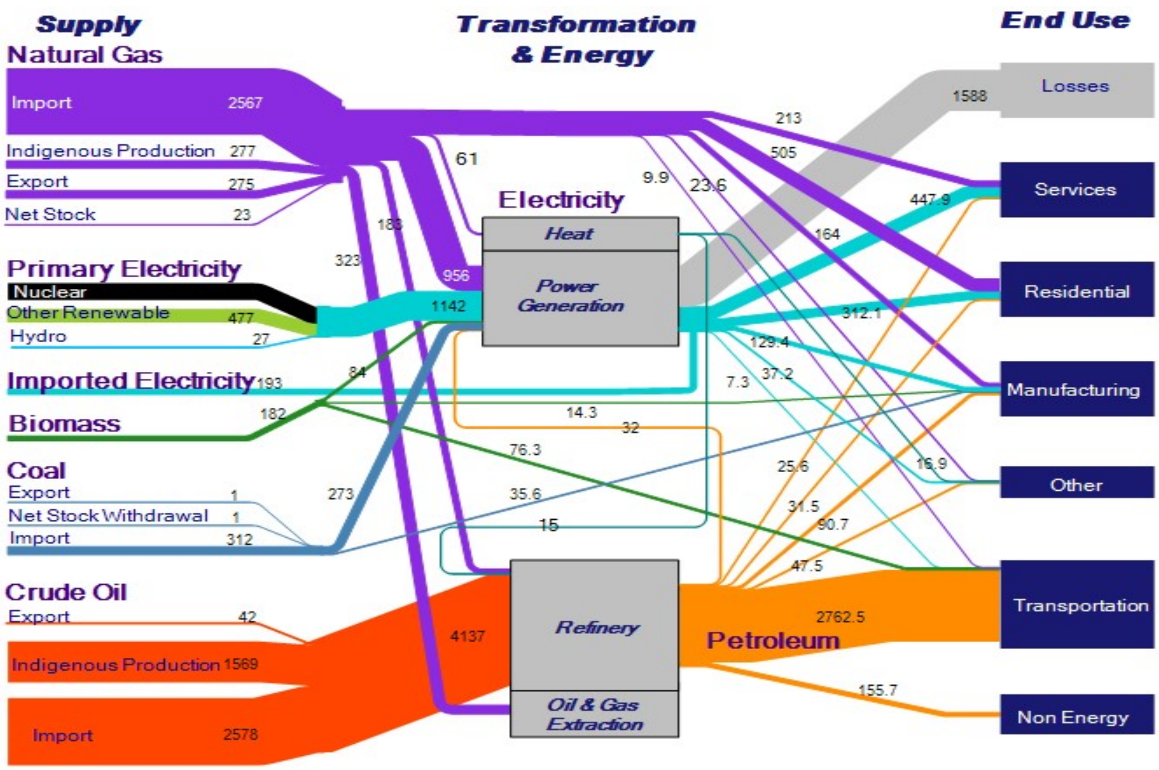


FIGURE 1

2008 California Energy Flow in Trillion BTUs[3].

The energy supply and consumption pathways for California in 2008 are shown in Figure 1. These energy pathways show a clear split of energy supply vs. end use, with liquid petroleum fuels primarily used in transportation, whereas, stationary non-transportation end uses utilize gaseous, solid, nuclear, and renewable energy sources. These historical energy flows have relatively little energy crossover between the stationary and transportation sectors. Newer technologies, declining renewable energy costs, changing and volatile fossil energy prices, along with newly implemented policies and regulations are resulting in the traditionally separated transportation and stationary energy sectors becoming more integrated and economically coupled. The changes in energy supply and the increase in cross sector energy demand will create benefits and potential costs for the use of each energy type along with potential impacts on criteria pollutant, toxic, and GHG emissions.

Additionally, the energy losses within the overall energy system are high. Energy losses relating to power generation are shown in Figure 1 to be 62% of the total primary energy used to generate electricity (not including losses associated with imported electricity generation). These losses are a result of inefficiencies within technologies to generate energy that result in waste heat. Also shown in Figure 1, the difference between energy inputs into the refinery sector and petroleum outputs result in 25% losses in energy also as a result of waste heat production. Not shown in Figure 1 are the significant energy losses that occur within the stationary and transportation end uses of electricity, natural gas, and petroleum. Within the transportation sector these losses are typically around 80% to the heat losses associated with the widespread use of internal combustion drive train technologies[4].

New renewable energy policies, implementation of new technologies and the enhanced energy efficiency efforts being undertaken in California are driven, in part, by the need for significant reductions in greenhouse gases and will also result in significant criteria pollutant reductions. Since NOx emissions largely do not have a naturally occurring source in the Basin, except for biomass burning sources, the entire inventory of NOx emissions is the direct result of combustion sources and the properties of the fuel and end use technologies. Additionally, a large majority of VOC and GHG emissions in the Basin also result from either fugitive or combustion emissions resulting from our energy choices. In 2011, the SCAQMD Governing Board adopted the SCAQMD Air Quality Related Energy Policy which guides the SCAQMD in integrating air quality and GHG reductions along with Basin energy issues in a coordinated manner[5]. The Energy Outlook white paper in part further implements the policies and actions within the SCAQMD Air Quality Related Energy Policy. To further reduce Basin emissions while providing clean reliable energy sources, transformations of the traditional energy infrastructure will be needed as new technologies that have zero and near zero emissions and renewable energy sources are increasingly implemented.

III. Emissions by Energy Type

Shown below in Figure 2 are the NOx emissions from the 2012 AQMP inventory resulting from different types of energy use. The diesel and gasoline fuels (consumed primarily for transportation) result in the highest NOx emissions. Even as fleet turnover to lower emission vehicles occurs in the transportation sector and further reductions are achieved for stationary sources, the 2016 AQMP baseline inventory projects that the Basin will not achieve NOx levels sufficient to achieve the 2023 and 2031 ozone standard, without significant further reductions of NOx.

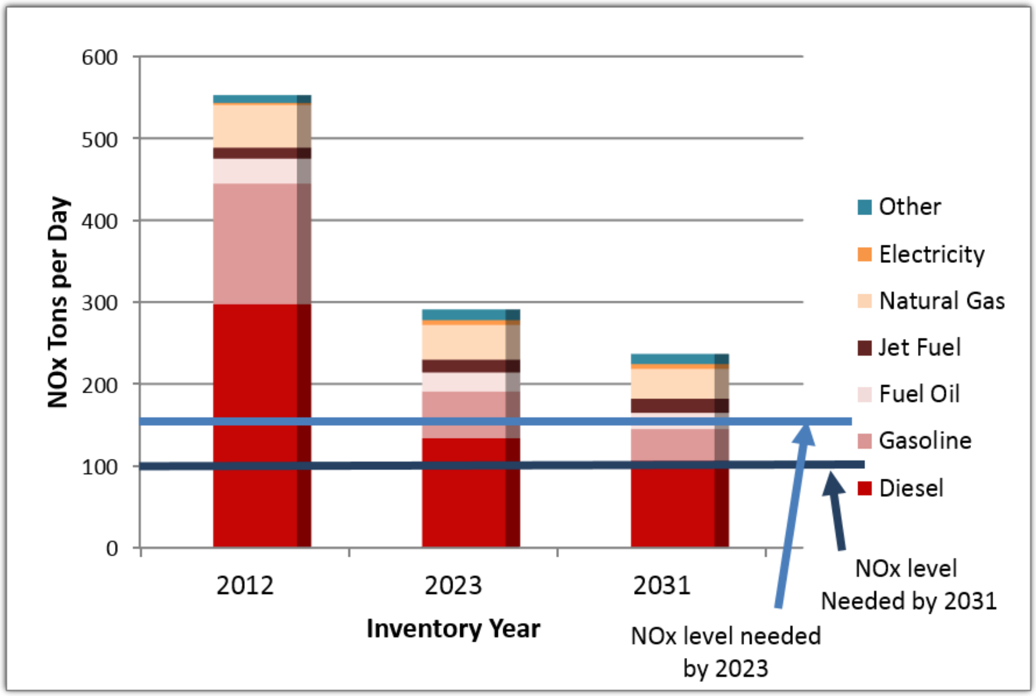


FIGURE 2

NOx Annual Average Emissions Inventory by Fuel Type (*2016 AQMP inventory*)

The carbon dioxide emissions in the Basin associated with fossil fuel combustion are directly linked to the carbon content in the fuels and the amount of fuels used. As shown in Figure 3 the 2008 Basin carbon dioxide emissions were over 134 million metric tons. This emission estimate does not include fuels used to generate power that is imported into the Basin or the impact of many of the GHG policies and regulations that have come into effect since the 2012 AQMP analysis.

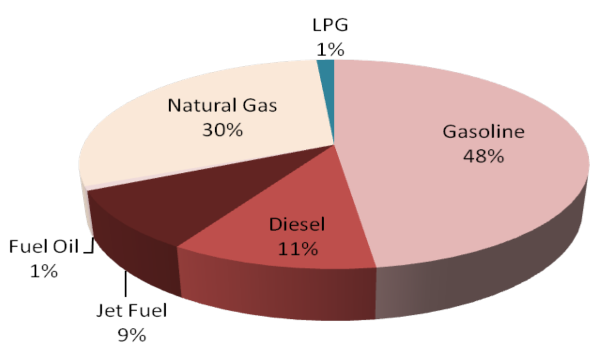


FIGURE 3

Greenhouse Gas (CO_2) Emissions in 2008 by Fuel Type (Total 134 MMT CO_2, *2012 AQMP*)

IV. Policies and Regulations Impacting Energy Use in California

There are several federal, state, and local regulations and policies that impact energy usage in California. Table 1 provides a partial list of policies and regulations which have been recently enacted or proposed at the different levels of government.

TABLE 1

Policies and Regulations Impacting Energy Use in California

Policy Objective	Level of Government	Name	Goal
Air Quality	Federal	Clean Air Act	Achieve health based standard levels of criteria and toxic pollutants along with protecting public health from ozone depleting substances and greenhouse gases.
GHG Reduction	Federal	Clean Power Plan	Reduce GHG emissions from new, modified and existing power plants
Fuel Standard	Federal	Energy Independence and Security Act of 2007	36 billion gallons of renewable transportation fuel by 2022.
Truck GHG Reductions	Federal	Phase 2	Increases fuel economy of trucks and trailers starting for model year 2021.
Petroleum Reduction	State	California State Alternative Fuels Plan, Governors Target	Reduce petroleum use in to 15% below 2003 levels by 2020; 50% reduction in petroleum fuel use by 2030.
ZEV Mandate	State	California Executive order B-16-2012	1 million EVs by 2023 and 1.5 million by 2025.
Vehicle Efficiency	State	Pavley Standards AB 1493	Increase vehicle efficiencies and reduce GHG emissions.
GHG Reduction	State	AB32, California Global Warming Solutions Act Governor Targets	Reduce GHG emissions to 1990 levels by 2020, 40% below 1990 levels in 2030, and 80% below 1990 levels by 2050.
GHG Reduction	State	Cap and Trade	Reduce GHG emissions from stationary facilities and fuel providers.
Renewable Power Generation	State	Renewable Portfolio Standard Governors Target, SB 350	33% renewable electricity generation by 2020 and target of 50% renewable power generation by 2030.
Building Efficiency Standards	State	Title 24, Governors Target, SB 350	Net zero energy new residential construction by 2020, net zero energy commercial construction by 2030, increase in existing building efficiency 50% by 2030.
Emissions Performance Standard	State	SB 1368	Establish base load generation to not exceed 1,100 lbs CO_2/MWh.
Coastal water protection	State	Once Through Cooling	Eliminate use of once through ocean water cooling by coastal power plants. Protection of coastal waters and marine life.
Energy Storage Mandate	State	AB2514	1.3GW storage mandate by 2020.
Large Stationary Emissions Reductions	Local	Regional Clean Air Incentives Market (RECLAIM)	Declining Allocations and Credit trading program within Basin for NOx and SOx reductions from large stationary sources.
Electrical system reliability	State/Local	AB 1318	Needs assessment report evaluates electrical system reliability needs of the South Coast Air Basin.

V. Energy Landscape

Over the past decade the energy landscape in the United States has changed dramatically. This is largely the result of an increase in domestic fossil fuel production from implementing unconventional recovery techniques such as fracking. As a result the United States is requiring less imported energy to match consumption and, by around 2028, is projected to recover as much fossil energy as consumed, Figure 4[6]. However, there are many potential environmental issues and concerns associated with unconventional recovery techniques and the transport of fuel from increased domestic energy production. These concerns, in-part, include the potential for groundwater contamination, wastewater disposal, and emissions associated with well production.

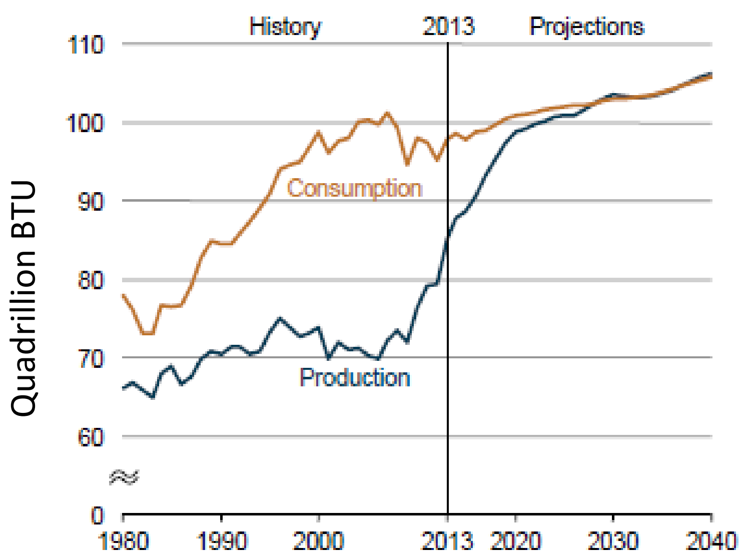


FIGURE 4

Historical and Projected United States Domestic Energy Production and Consumption[6]

At the same time, renewable energy is also being more widely implemented and integrated with new technologies in transportation, energy storage, distributed energy, and demand side management[7]. One of the most significant changes in the renewable landscape has been the dramatic drop in costs for solar power generation as shown in Figure 5. Under the California Solar Initiative, the installed costs for rooftop photovoltaic (PV) systems have dropped 50% over the last 7 years to a recent average below $5 per watt.

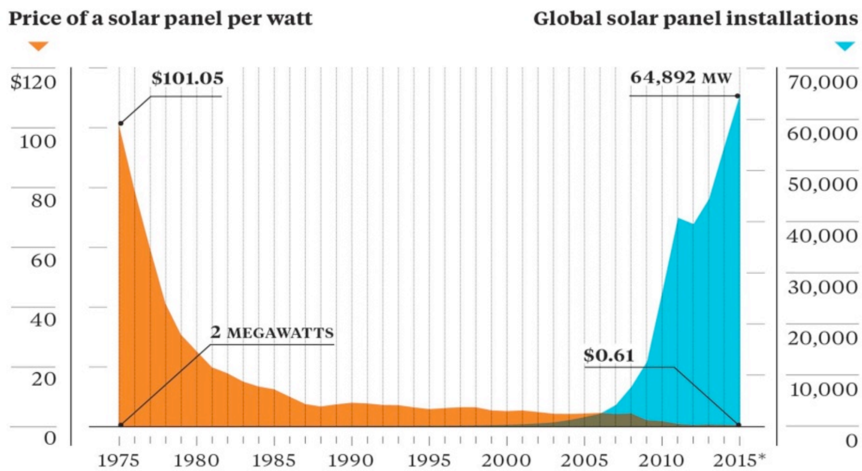


FIGURE 5

Solar Panel Prices and Installations over Time (*Source: Bloomberg Markets*[8])

The increase in production of oil and gas within the United States has also led to declining prices. These changes, new technologies, along with new policies and regulations are changing the energy landscape within the Basin. Current and upcoming issues and technologies for each energy sector that may result in emissions impacts are discussed below.

a. Electricity

Background

The electricity energy sector is reliant on many different types of fossil and renewable energy sources to meet electrical load demands in real time. A stable grid relies upon the delicate balancing of matching generation with demand, traditionally accomplished by using large central power plants connected to transmission grids operated by grid balancing agencies such as the California Independent System Operator (CAISO). These large transmission grids help supply localized distribution grids operated by utilities to supply end use customers. The traditional generation and distribution system meets electricity demand increases through large central power plants and peaking generation units. The need to balance generation capacity with peak demand periods, occurring during the daytime during the summer months, requires excess generating capacity that often sits idle. For instance, peaking generator units typically provide the excess generating capacity when needed, but have low capacity factors (utilization factors) around 5% and do not operate as efficiently as larger combined cycle base load power plants[9].

The traditional one way flow of electricity from large power plant to passive end use creates additional expenses for ratepayers based on the need for excess infrastructure and generating capacity. A version of the simplified traditional utility model with large plants supplying end users is still somewhat in place within California, but started changing with state demand side programs being implemented by the CEC and DOE in the 1970's. These programs started the process of adjusting end user demand to help minimize the amount of electrical infrastructure needed to maintain the electrical grid. The early demand side management regulations implemented by the CEC, include building energy standards under Title 24 and appliance efficiency standards. End use efficiency programs along with other demand side measures have helped lower and leveled the per capita electricity consumption in California while also reducing the amount of new power plants needed (*see Residential and Commercial Energy White Paper*).

Electricity pricing structures also reduce electricity demand during peak demand periods. Many large electricity consumers are billed largely based on time of use and for on-peak power demand. Under this pricing structure electricity rates vary substantially during the highest usage hours of the summer months. Time of use rate structures have recently become available to residential customers as utility smart meters have been implemented. To help shave energy during peak demand periods, many utilities have created demand response programs that provide financial benefits to customers that install equipment to shave energy use during high demand periods.

The electricity sector in Southern California is undergoing rapid changes with the unexpected shutdown of the San Onofre Nuclear Generating Station along with the repowering of coastal generating plants to meet the state's requirements of the Once-Through-Cooling (OTC) Policy. At the same time, other mandates requiring implementation of more renewable power generation and increasing the amount of electric cars in California are quickly creating additional demands on the electricity system.

POWER CONTENT LABEL

ENERGY RESOURCES	2013 SCE POWER MIX (Actual)	2012 CA POWER MIX**
Eligible Renewable	**22%**	**15%**
-- Biomass & waste	1%	2%
-- Geothermal	9%	4%
-- Small hydroelectric	1%	2%
-- Solar	1%	1%
-- Wind	10%	6%
Coal	6%	8%
Large Hydroelectric	4%	8%
Natural Gas	28%	43%
Nuclear	6%	9%
Other	0%	0%
Unspecified sources of power*	**34%**	**17%**
TOTAL	**100%**	**100%**

* "Unspecified sources of power" means electricity from transactions that are not traceable to specific generation sources.

** Percentages are estimated annually by the California Energy Commission based on the electricity sold to California consumers during the previous year.

For specific information about this electricity product, contact Southern California Edison. For general information about the Power Content Label, contact the California Energy Commission at 1-800-555-7794 or www.energy.ca.gov/consumer.

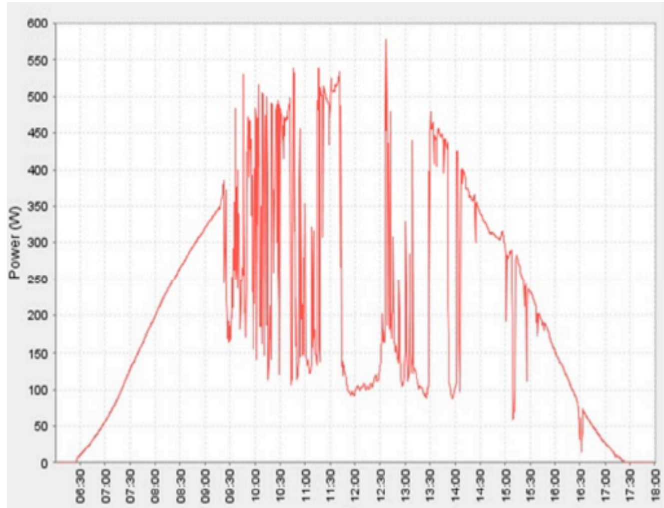
FIGURE 6

Power Content Label for Southern California Edison's Power Supply Mix in 2013

Under AB162, utilities are required to disclose the percentage of power from different generation sources that they supply to customers as they progress toward supplying at least 33% energy from renewable generation sources by 2020. As shown in Figure 6, SCE in 2013 supplied 22% from qualifying renewable resources and is currently on track to achieve the 33% target in 2020. In 2003, the Energy Action Plan implemented the states preferred resources for electrical loading order which places priority, respectively, on demand side management, renewable generation, and lastly, additional fossil fuel powered generation[10]. Other regulations such as California's GHG Cap and Trade Program provide market incentives that promote increased generation efficiencies and the use of renewable fuels.

FIGURE 7

Daily Power Output from Solar Panel Array showing Generation Intermittency from Passing Clouds (*Courtesy UC, Irvine*)



As higher percentages of variable and intermittent renewable resources are integrated into the electrical grid, matching generation with demand becomes increasingly difficult with traditional grid systems, and can make the electrical grid less reliable. The addition of large amounts of renewable generation often requires resources that can balance the short term intermittency. For photovoltaics and wind generation, this often results from intermittent cloud cover (*Figure 7*) and varying wind speeds, respectively. Additional resources must be implemented to balance large variable renewable power sources on the larger transmission and utility distribution electrical grids. Figure 8, shows the actual and projected net generation demand that is required from fossil generation as more wind and solar power are projected to be added to the CAISO transmission electrical grid. Referred to as the "Duck Curve", due to its shape, the primary impact of adding more solar generation requires the output from fossil generation units to significantly decline or idle during the peak daylight hours. The generation units, however, must be quickly dispatchable not only to help balance potential renewable generation intermittency, but also be capable and ready to

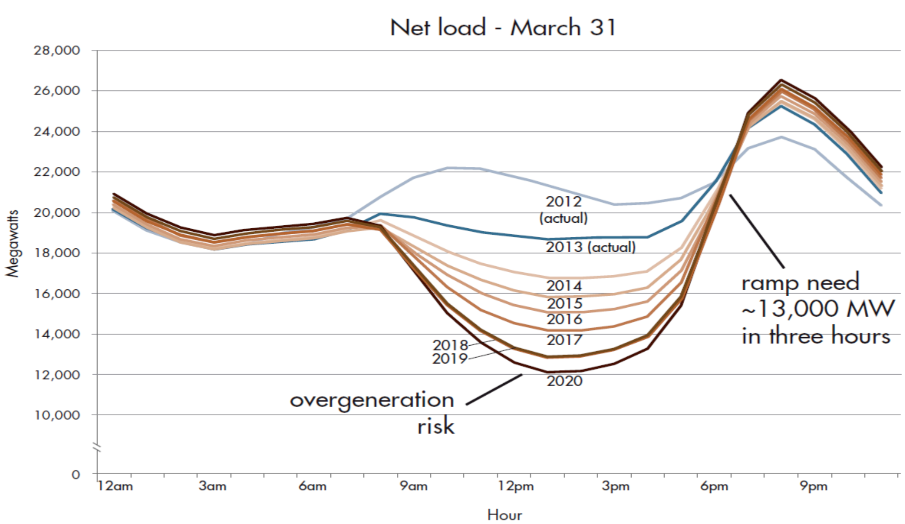


FIGURE 8

"Duck Curve" represents the Net Load which shows the variability in demand and supply that CAISO must balance with controllable flexible resources. The net load represents the load that must be met with flexible and dispatchable resources. The net load subtracts the variable renewable generation from the end user demand. (*Source CAISO*) provide the rapid generation ramp needed as the sun sets and system load increases into the evening.

Currently, peaking generation plants and synchronous condensers are being utilized to help provide the flexible and dispatchable resources that help integrate renewable resources into the electrical grid. The peaking generation units help support renewable resources by having fast ramp rates and response times, but negate some of the GHG emissions benefits of using renewables by maintaining reliance on fossil generation. Additionally, increasing the number of startup events along with ramping needs results in slightly higher criteria pollutant emissions from peaking generation units than have been observed from these generators in the past (refer to: UCI Professor Jack Brouwer April 15th Energy Outlook Workgroup Presentation[11]).

As a result of changes in power plants such as San Onofre closure, along with the planned closure and repowering of additional Southern California coastal power plants, there is a need for voltage support on the local distribution networks. Smaller generating plants and other distributed energy resources are being implemented in a newer grid structure that provides more resilience and less reliance on large traditional generation, and operates with less infrastructure redundancy. Additionally, a change under CPUC Rule 21 is being made to start allowing smart inverters attached to rooftop solar installations to provide grid support services such as voltage support. Allowing the large amounts of rooftop solar inverters to help provide other grid service needs other than energy helps provide cleaner more reliable grid power. In California most inverters installed with rooftop solar panel systems are smart inverters; however, the grid services capabilities, such as voltage support, has been disallowed under outdated grid interconnection requirements that are currently under review[12]. Allowing smart inverters to provide grid services has already been implemented in Europe.

New Technologies and Adapting to a Changing Grid Landscape

As mentioned earlier, the traditional electric grid management paradigm has been to add additional generation to match demand with end use customers being passive consumers. It has been shown that demand side management is much less costly than adding generation and provides greater utilization of existing resources[13,14,15]. Demand side management is increasingly becoming more important as higher amounts of power are derived from renewable generation making it more difficult to match generation with demand[16]. Southern California Edison is undertaking a preferred resources pilot program within Orange County that is studying which types of demand side management resources can help alleviate infrastructure needs, in part, due to the San Onofre shutdown[17]. Large amounts of renewable power during low demand periods have recently resulted in periods of over-generation that led to negative wholesale market prices[18]. New technologies are rapidly being developed and implemented that provide flexible resources to help manage any excess power generated from renewable resources along with reduced load during times of peak demand or high net load ramping needs[16].

To help balance end user demand with generation, households and businesses are increasingly relying on energy management systems that help reduce peak demand charges, can participate in demand response events, and better manage energy loads with onsite generation and occupancy needs. One example of these technologies in the residential sector has been the implementation of Wi-Fi connected smart thermostats that help reduce heating and cooling energy use by using occupancy sensors along with weather forecasts. Other technologies are beginning to utilize utility smart meters with cellular phones to incentivize participation in demand response events (e.g. Ohmconnect.com). These systems also can be registered with utility demand response programs and are being developed to integrate with other electricity end uses.

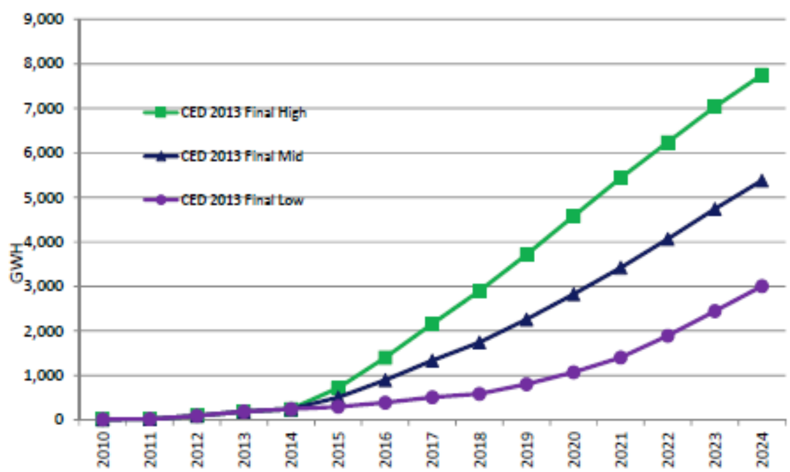


FIGURE 9

Projected Energy Needs by Electric Vehicles in California (*High, Mid, and Low Scenarios*)[19].

One of the largest challenges facing the electricity sector will be integrating increasingly large amounts of power and energy demands from an increasingly electrified transportation sector (*Figure 9*). Traditionally, as shown in Figure 1, the transportation sector primarily has relied on liquid fuels and has been separated from the electricity sector. Original implementation designs for the existing electrical infrastructure did not incorporate energy or power requirements for transportation. As increasing numbers of electric vehicles become reliant on the electrical grid for energy needs, incorporating electric vehicles into the grid can be done in a manner that actually helps provide needed grid resources. Demonstrations are being done with managed charging of electric vehicles that synchronize with grid resource needs during periods of over generation and peak usage. Existing utility rules are being reviewed to also allow electric vehicles to provide other ancillary grid services such as frequency regulation, voltage support and reactive power. Managing electric transportation charging in this manner may be done by the site host, local utility, and/or system integrator. Collectively, plugged in electric vehicles can provide significant grid resources when intelligently integrated with the grid. If unmanaged, the integration of transportation energy needs onto the electrical grid will create additional infrastructure needs without benefits to grid stability.

Incorporating large amounts of energy storage will help integrate increasing amounts of renewable generation, better manage demand charges and help reduce infrastructure costs for electric vehicle chargers. Energy storage systems can be deployed on the larger transmission grid, the local utility distribution grids, and behind the meter applications. Several different technologies are being utilized for energy storage systems which include: batteries, fuel production, flywheels, pumped hydro, and compressed air. Currently the most widely used storage systems utilize different battery chemistries along with using second life electric vehicle batteries. The costs for batteries for both vehicle and stationary storage applications have been shown to be steadily dropping, however, it is often difficult to reliably determine and compare recent prices without a standard methodology. Thus, there is a need to establish a battery price index or energy storage price index as these technologies become more widely used[20].

Grid scale energy storage systems are starting to be implemented that replace the need for peaking generation plants. These systems have several advantages over peaking generation units in that they have high utilization capacity factors, zero emissions, and are easier to site. As more renewable generation is integrated, and over generation becomes more prominent, the excess power may be used to electrolyze water to form hydrogen and oxygen. The hydrogen can then be stored nearby and used for transportation applications, power generation, integrated into the natural gas pipelines, and/or used to develop synthetic fuels. The application of hydrogen in natural gas pipelines is being demonstrated in Europe.


The World's Biggest Battery Is Being Built For Southern California's Grid

AES is building a 400 MW-hour lithium-ion battery for SCE as an alternative to gas peaker plants.

Eric Wesoff
November 12, 2014

The world's biggest battery is coming to California.

Last week, Southern California Edison (SCE) revealed the winners of a massive 250-megawatt energy storage procurement round, one that could set new

Greentechgrid: Nov. 2014

Behind the meter storage systems are being used to help offset peak demand charges, provide backup power when needed, integrate vehicle chargers with existing infrastructure, and off grid applications. As many residences and businesses are under time of use utility rates, the storage systems can provide arbitrage opportunities for the residents and businesses to utilize low electricity costs during off peak hours and use the stored power during high priced periods "on-peak" [21]. Behind the meter applications also include backup power and in many applications may reduce or eliminate the need for backup generation units and, when coupled with renewable generation under high utility rates, may become a cost effective technology for off grid solutions[22].

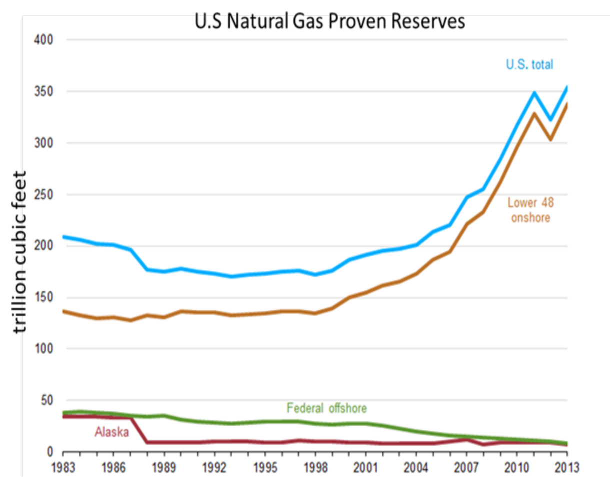


FIGURE 10

Increase in U.S. Natural Gas Proven Reserves over Time[6].

b. Natural Gas

Within the United States the natural gas supply has gone from a possible need for imports to that of ample supply and declining prices. This is a result of technological developments in exploration, drilling, and well stimulation that have increased recoverable reserves within the United States (*Figure 10*). The increase in supply and resource base has driven natural gas prices down to a recent $3 per thousand cubic feet in May 2015, 60% lower than in May 2008 when reserves started to dramatically increase. In 2008, an estimated $3 billion worth of natural gas was consumed in the residential and commercial sectors Basin wide.

In the Basin, the natural gas distribution infrastructure provides the primary fuel used for electricity generation along with cooking and heating needs in the residential and commercial sectors and process heating in the industrial sector (*Figure 11; also see Residential and Commercial White Paper*). Within California, the majority of non-renewable power generation derives from natural gas powered generation. This is, in part, due the increased generating efficiency that natural gas combined cycle power plants provide over traditional steam boilers that helps provide overall emission benefits relative to other fuel choices[9]. Additionally, natural gas when combusted has lower particulate matter formation relative to other fuels with complex carbon molecules. This property allows for lower particulate matter emissions than other fuel choices and, when used in heavy duty transportation applications, does not have the associated toxicity of diesel fuel combustion.

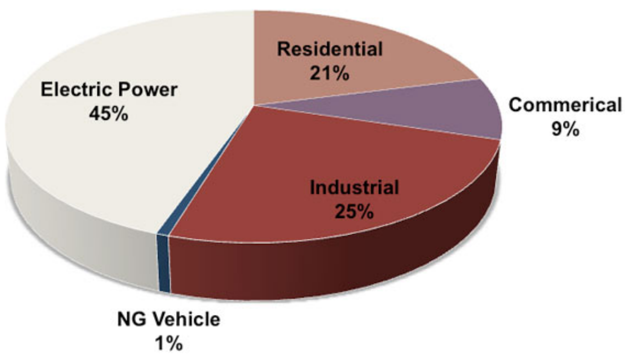


FIGURE 11

California Natural Gas Demand by Sector in 2012 (*CEC Energy Almanac*)

Natural gas has an existing pipeline infrastructure that makes it easily transportable, is often a lower energy cost option, and can often provide GHG and criteria emissions benefits over petroleum and coal. However, methane, the primary component in natural gas, has a long atmospheric lifetime of 10 to 14 years, whereas, other hydrocarbons have atmospheric lifetimes from hours to days. Therefore, the fugitive releases of methane within the Basin do not contribute to photochemical production of ozone or secondarily formed particulate matter as result of short residence times in the Basin and long atmospheric lifetimes. However, on a global scale, the atmospheric levels of methane do contribute to increased global background levels of ozone as well as being a potent GHG.

Using natural gas can provide reduced end use carbon dioxide emissions as a result of methane having a higher hydrogen to carbon molecular ratio than every other hydrocarbon. Combustion of methane therefore releases less CO_2 on a weight per weight basis relative to other hydrocarbons[23]. However, the direct end use GHG emission benefits from natural gas can be negated or reversed from upstream fugitive releases of methane into the atmosphere. Further efforts and research are needed to minimize


NATURE'S SONG

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Temecula and Calimesa are participating in a new recycling program that turns food waste into natural gas. Your town might be next.

Closing the food waste cycle

Press Enterprise; Aug 18, 2015

fugitive methane emissions along the entire natural gas production, distribution, and end use chain[24]. Due to the high climate forcing impacts from methane, the fugitive emissions of methane need to be better understood and further incorporated into the lifecycle analysis.

The greatest GHG benefits from methane use are realized from renewable sources. There are many different supply streams of renewable methane that include landfills, wastewater treatment plants, and food waste and manure digesters. Difficulties recovering renewable sources of methane include the implementation of clean and efficient systems that separate methane from other impurities in a cost effective manner. The SCAQMD Clean Fuels program along with other state agencies' programs have helped develop and demonstrate technologies to clean up renewable methane waste streams for power generation and transportation uses. Although these technologies are being implemented, it is currently unclear how much renewable methane might be cost-effectively recovered within the Basin from the many different waste streams.

New Technologies and Uses

The natural gas distribution system in California is slightly constrained during the winter month periods when more natural gas is required for heating purposes[25]. During these months underground storage helps provide natural gas during peak demand periods. Much like electricity generation constraints during peak summer demand periods, the natural gas pipelines require a similar balancing technique during times of high usage in the winter months. Within Southern California, there is currently over 140 billion cubic feet of underground storage using depleted reservoirs that help balance Basin natural gas needs between seasons of high use and high prices with seasons that have lower prices and lower natural gas demands.

As mentioned earlier, methane use in California will increasingly be derived from renewable sources. Several technologies will likely become more prominent; these include[11,26]:

- Technologies, such as pressure swing adsorption that help scrub the natural gas from different waste streams.
- Developing natural gas from excess renewable power generation (power to gas).
- Increasing use of natural gas for stationary and transportation fuel cells.
- Using oxy generation systems for combustion processes without pollutant emissions.
- Ultra low NOx heavy duty compressed natural gas (CNG) engines.

c. Liquid Fuels

In the Basin, the primary use of liquid petroleum fuels is for transportation purposes. In 2008 over 7.3 billion gallons of gasoline and 1.4 billion gallons of diesel were consumed within the Basin with a combined estimated cost of $32 billion dollars (2012 AQMP). Of all the different energy types, the gasoline and diesel fuels often have more significant price volatilities as a result of variations in global crude prices, refinery capacity issues, and overall supply for California blended fuels[4] as shown in Figures 12 and 13. Supply issues for California reformulated gasoline can result in prices for California gasoline being decoupled from crude oil market prices and gasoline prices in the rest of the nation, Figure 13.

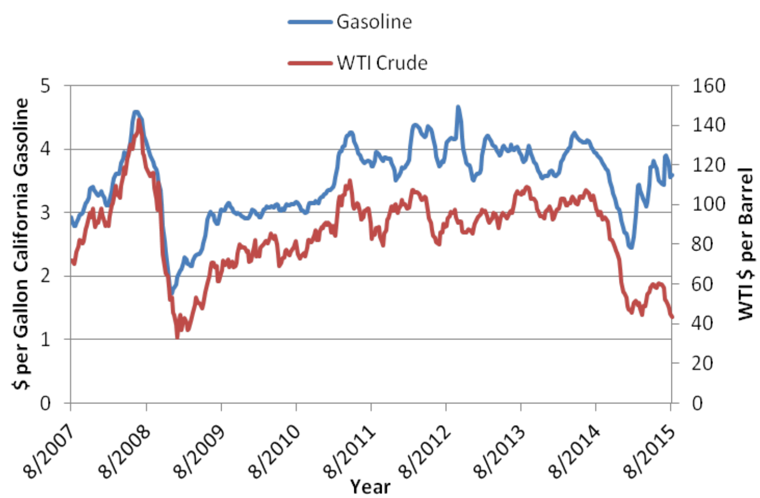

FIGURE 12

Average Weekly Market Price between a Gallon of California Gasoline and WTI Crude
(*CEC Energy Almanac and EIA*)

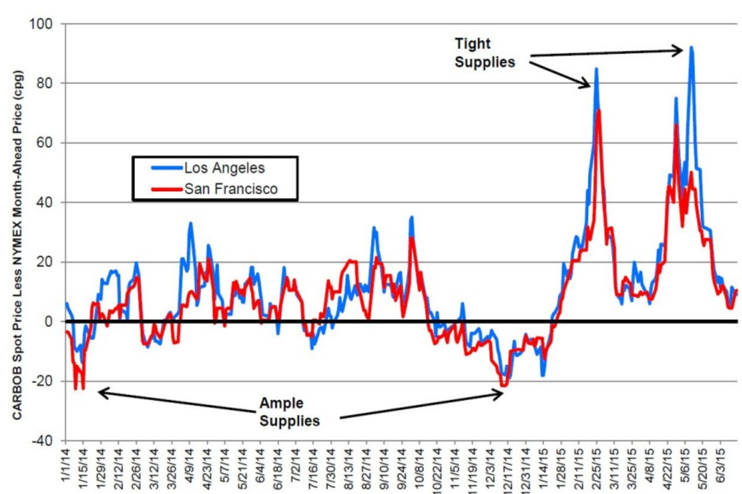

FIGURE 13

Recent High Market Premium (in cents) on California Reformulated Gasoline Blendstock for Oxygenate Blending (CARBOB) minus the NYMEX national price
(*CEC Petroleum Watch July 15, 2015*)

As previously shown in Figure 2, the use of liquid fuels currently result in the highest emissions of NOx and is the largest contributor to GHG emissions within the Basin. A large transformation is needed within engine technologies to lower NOx emissions from transportation sources. As shown in Figure 2, diesel use results in significant NOx emissions, particularly within the heavy duty and off-road engine categories. As outlined within the Goods Movement, On-Road and Off-Road white papers, new technologies are needed to improve engine emissions and drive train efficiencies to reduce NOx along with GHG levels[27].

Continued use of liquid fuels will increasingly require climate friendly fuel use pathways that, in part, include more efficient end use technologies. Overall GHG emissions need to be considered, not only at the tailpipe but also by using a full well to wheels emissions analysis that accounts for fuel production and distribution. This is currently implemented within the Low Carbon Fuel Standard (LCFS) to determine the carbon intensities of different fuels by reviewing the lifecycle analysis of bio-fuels along with other low carbon intensity alternative fuels. A similar analysis can also consider the associated lifecycle emissions of criteria and toxic pollutant emissions but is currently not part of the LCFS program. Unfortunately, the majority of bio-fuels produced still have a positive GHG impact and the upstream emissions associated with traditional oil and gas recovery are still relatively uncertain[28]. The use of bio-fuels can provide a partial solution to GHG reductions, particularly in applications that don't have alternative technologies available such as aircraft. However, the limited availability of fuel feed stocks, land use considerations, weather variability, and potential negative impacts upon food prices are all issues that should be addressed as bio-fuels develop as part of the solution in reducing GHG emissions.

d. Other Energy Choices

As newer technologies such as fuel cells become more widely available for power generation and transportation, the supply of alternative energy sources will become more important. Partially discussed in earlier sections, these energy sources will include renewable fuels such as biodiesel, ethanol, and waste woody biomass. Some of these renewable fuels may be produced from algae that sequester CO_2 from power plant emissions that are then converted back into fuels used again at the power plant (*See: SoCal Gas, Ron Kent's April 15th Energy Outlook Workgroup Presentation*[26]).

Other energy supply choices that will be produced from different feed stocks and energy sources are fuels that do not occur naturally in pure form such as hydrogen and dimethyl ether (DME). The production of these fuels will help provide emission benefits but may also be produced to help integrate increasingly larger percentages of renewables onto the electrical grid, provide renewable energy streams for transportation, and use existing infrastructure for transport and delivery.

In 2015 the first fuel cell vehicles for purchase were introduced in California from Toyota and Hyundai. As these vehicles are being introduced, supplies of hydrogen and fueling infrastructure is needed to support their operation. Using hydrogen as an energy source produces water as a byproduct in fuel cell applications.

Additionally, the fugitive release of hydrogen into the atmosphere does not have an impact on climate, criteria pollutants, or toxic risk.

Although the end uses of hydrogen are generally considered zero-emission, the sources of hydrogen fuel and the associated emissions to generate hydrogen can vary significantly. Currently, the largest supply of hydrogen within California comes from steam reformation of hydrocarbons. Methane currently is widely used as the hydrocarbon source for production of hydrogen; however, other compounds such as methanol have been utilized for onsite reformation and fuel cell systems. Unfortunately the reformation process emits CO_2 as a byproduct which can be mitigated by using renewable sources, or possibly by future carbon capture technologies such as algae systems.

Production of hydrogen can also occur through the electrolysis of water. As mentioned within the electricity section, the implementation of renewable generation will result in periods of overproduction relative to real time demand. Rather than curtail the production of power, the excess energy can also be stored by producing fuels. Hydrogen generated during periods of excess power through electrolysis of water, referred to as "power to gas", can be utilized by fuel cells during periods of high electrical demand or within the transportation sector. During the electrolysis process, hydrogen and oxygen are produced, and the oxygen might also be recovered and used at nearby peak generation units using zero-emission oxy combustion technologies (*see natural gas emerging technologies section*). Additionally, the hydrogen produced renewably through this process might eventually be blended with natural gas and added into the distribution pipelines. It is also possible to use the hydrogen produced with waste CO_2 streams to produce synthetic natural gas along with other hydrocarbons.

While it is currently not possible to track the amount of hydrogen being produced from different sources within the Basin, the implementation of both stationary and transportation fuel cells along with implementing clean pathways to develop large quantities of hydrogen needs to be closely monitored and supported.

VI. Scenario Analysis

Studies have been conducted to show how new technologies can help achieve both air quality and climate goals. For example, there have been several studies conducting "back casts" on the state energy sectors to identify potential pathways to achieve the 2050 GHG targets [29,30,31]. Achieving the GHG state targets will have the co-benefit of criteria pollutant reductions. The scenario case shown in Figure 14 uses the 2016 AQMP baseline inventory and applies two variations of the Governor's 2030 target reductions of 50% reduced petroleum use, a 50% increase in existing building energy efficiency, and a 50% renewable portfolio standard. Under SB 350, the 50% increase in building efficiency and 50% renewable energy production by 2030 are being set into law. The potential impact on NOx reductions from these targets is represented as Scenario #1 in Figure 14. Further implementing the 50% reduction in fossil fuels in addition to the other two targets, represented as Scenario #2 in Figure 14, results in the largest potential NOx reductions. In both scenarios, a linear implementation of the 50%

targets is assumed along with a linear and proportional reduction in criteria pollutants applied to the forecasted inventory years (2012, 2023, and 2031).

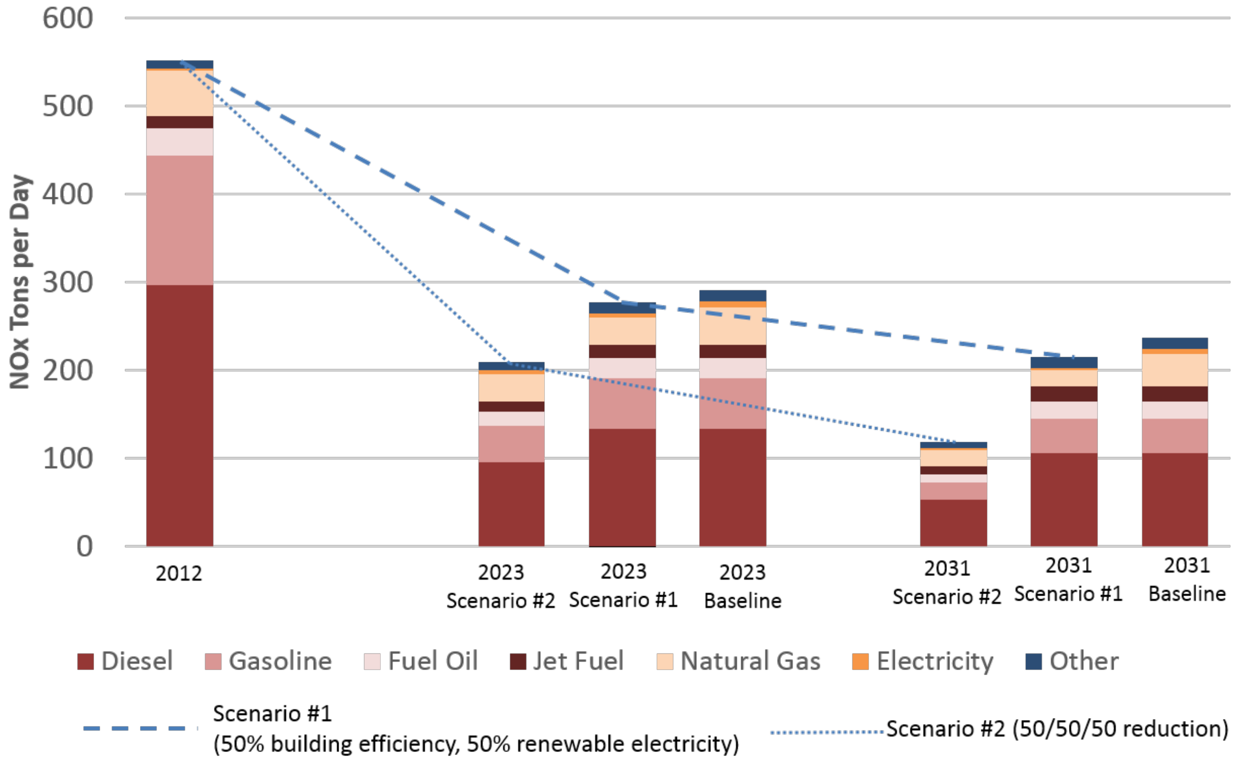

FIGURE 14

Potential Impact on 2016 AQMP Inventory from Scenarios Implementing 50% Reduction in Existing Building Energy Usage, 50% Renewable Power, and in Scenario #2, 50% Fossil Fuel Reduction by 2030. Dashed Lines show Reductions in NOx from Applied Scenarios over 2016 Baseline Inventory

In Figure 15, the two "50% reduction" scenarios are shown again in relation to the NOx levels needed for attainment and 2016 AQMP baseline inventory. The two scenarios shown in Figure 15 provide the potential for significant NOx reductions, but do not meet the projected NOx carrying capacities for ozone attainment in 2023 and 2031. Further NOx reductions will be needed above and beyond these scenarios designed primarily to make progress towards the state's 2030 GHG targets. However, the NOx reductions that might be achieved through the Governor's 50/50/50 targets provide significant progress towards the ozone standards.

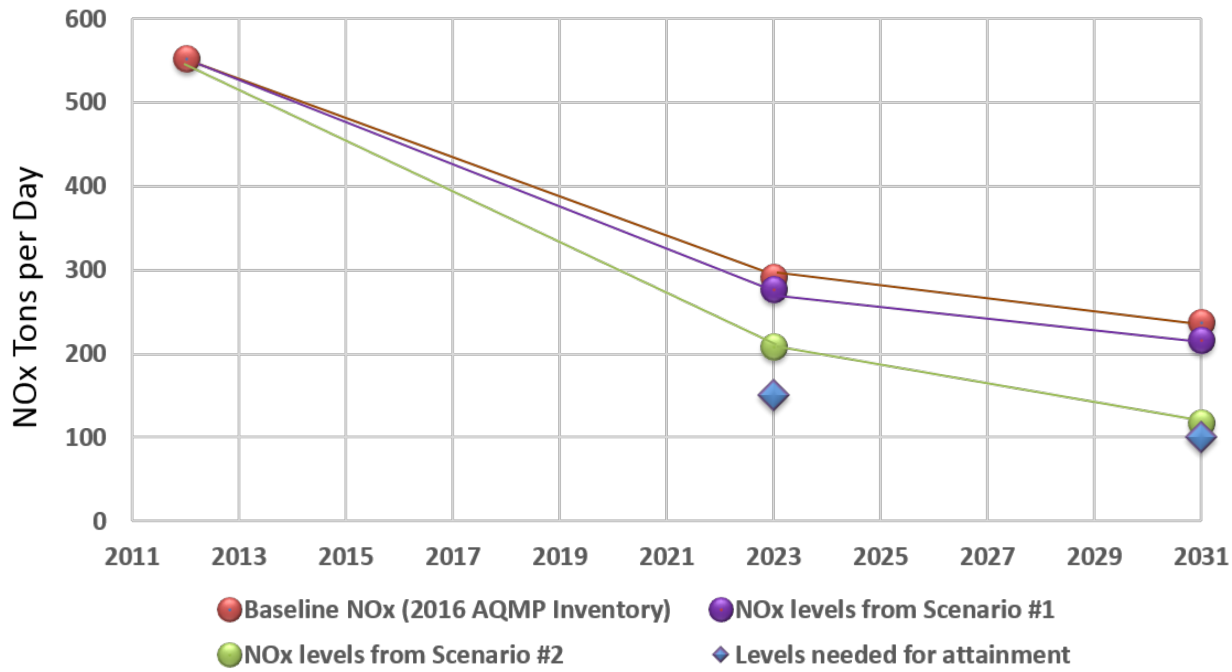

FIGURE 15

Basin NOx Levels showing Projections for Future Years from 2016 AQMP Inventory (red), Future NOx levels with Scenario #1 50% Increase in Building Efficiency and Renewable Power Generation by 2030 (purple), Scenario #2 showing Significant NOx Reduction when 50% Fossil Fuel Reduction is included. Diamonds (blue) show NOx Levels Needed for Attainment of Federal Ozone Standards.

VII. Findings and Recommendations for 2016 AQMP

Southern California is facing challenges in providing its residents with clean air, clean and sufficient supplies of water, affordable and reliable energy, and efficient transportation options. The traditional energy landscape is rapidly changing to incorporate new technologies that alleviate resource challenges, are adaptable to match changing demand profiles, and provide more efficient use of energy with fewer emissions. To increase resilience and provide leadership in reducing greenhouse gas emissions while addressing looming air quality deadlines, the changes occurring within the energy sector are providing opportunities and pathways to achieve these goals.

As part of the 2016 AQMP, staff is recommending consideration of the following actions:

Electricity:

- Monitor the implementation of increasingly large electrical energy demand from electric transportation. Promote the demonstration and development of technologies that minimize the emission impacts of adding electric transportation while reducing infrastructure needs.
- Support the development of a battery price index and/or energy storage index to provide clarity on recent storage prices.
- Support development and demonstrate energy storage applications and the benefits they can have on reducing the need for additional fossil generation units and/or increased start up/ shutdown/ramping of existing peaking units.
- Review and develop programs for increased demand side management implementation and for technology development with an additional focus on emission benefits.

Natural Gas:

- Further study the potential supply of renewable natural gas from applicable waste streams, such as waste water treatment plants, in the Basin.
- Implement new technologies such as fuel cells that use reformation and can provide high efficiencies through combined heat and power applications. Use these technologies to help integrate the transportation sector, to provide grid services, and as a potential replacement for backup generation units.
- Work with utilities and other energy developers to review the integration of the natural gas system with power generation and the further implementation of renewables.
- Assess the development of oxy combustion power generation systems.

Liquid Fuels

- Consider criteria pollutants in the well to wheels lifecycle analysis of fuels. This analysis would include criteria and toxic emissions associated with flaring at well sites, processing, and delivery.
- Promote the development of renewable fuels that provide criteria pollutant emission reductions as well as GHG benefits.

Other Fuels

- Support the development of an index that monitors of the amounts of hydrogen used in transportation along with a price tracking monitor for costs associated with different hydrogen producing technologies.
- Continue to demonstrate and promote renewable energy sources that provide criteria pollutant reductions as well as GHG reductions.

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