California Energy Innovation:

Achieving 100 Percent Zero Carbon Energy While Maintaining Reliability

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Table of Contents

Executive Summary
Of
California Energy Innovation: Achieving 100 Percent Zero Carbon Energy While Maintaining Reliability

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Introduction: Over the past two decades California has emerged as a leader in the drive to combat climate change. This has been especially apparent in the state's efforts to transition to clean energy generation. The state has established ambitious goals that require more clean energy generation and a transition away from energy generated by natural gas. However, the state must be more strategic in its planning in order to ensure that energy is reliably delivered. To achieve this, the state will have to use diverse technology that can store energy for times of the day and year where shortfalls from renewables may occur.

In 2002, the state created the Renewable Portfolio Standard (RPS) in an effort to require more clean energy generation. The requirements for clean energy procurement continued to get more ambitious throughout this period, and ultimately led to the state passing a law that requires 100 percent of energy procured be from zero carbon resources by 2045. This is the most ambitious proposal to date and is shaping California's energy portfolio.

What is the problem and why the state should intervene: The RPS clearly limits the energy resources that are eligible to be consider "renewable". As a result, the state has disproportionately built out wind and solar energy, opposed to other clean sources such as large hydro or nuclear power. The problem is that the sun does not always shine and the wind does not always blow which can lead to shortfalls. Currently, the state relies on natural gas powerplants to maintain reliability during such shortfalls. California should intervene because loss of power is unacceptable to Californians. There can be significant political and health consequences when people lose power. The state has established these requirements, therefore it has a duty to ensure that the transition is done effectively and efficiently. It must ensure that negative externalities such as unreliability do not occur.

Alternatives that could enhance reliability: To reduce the risk of shortfalls and reliability, California must encourage diverse technologies to store energy. This report focuses on two alternatives that can reduce shortfalls and provide reliability. The first is utility scale battery storage. This would collect excess solar energy generated throughout the day and use it when generation tapers off as the sun sets. The second alternative is investment in green hydrogen which can be used as long duration storage. This can also be generated from excess solar energy and can be stored for later use.

Conclusion: It is important that California succeeds in its efforts to transition to a 100 percent zero carbon grid and that reliability is not sacrificed in doing so. The state must consider a diverse portfolio of technologies to maintain reliability and uphold its climate goals.

INTRODUCTION

Over the past two decades, California has dramatically changed the how we generate electricity. The effects of climate change continue to plague our world and the state has risen to be a leader by enacting climate policies that mitigate climate change. While this has been a laudable, and necessary, step to curb the impact of climate change, it has had some negative externalities that must be addressed. The problem is that climate change and a shift to renewable energy has made California's energy grid unreliable. Unfortunately, a lack of reliability in the energy grid can have dire consequences for those who see their power shut off. We have grown accustomed to seeing lights turn on every time that we flip our switch, and to take this away from people is unacceptable.

This report aims to inform legislators, legislative staff, and other stakeholders of how policies passed over last two decades, paired with ever-worsening effects of climate change, have rendered our energy grid less reliable during times of extreme weather. By looking at policies that have been enacted, and the negative externalities that arose because of these changes, we can then explore ways to utilize diverse technologies that simultaneously uphold clean energy goals and maintain reliability. While problems in the energy space can be vast, this report will focus on electrical generation. I will explore how increased renewables, lack of diversity in energy generation, and climate change have created shortfalls of energy during times of high energy usage. The goal is to explore alternative energy options that can be pursued in the future which achieve *both* reliability and renewable goals.

The issue of renewable and reliable energy is of extreme importance to legislators and stakeholders. Over the past two decades, the Legislature has set numerous goals to achieve zero carbon emitting electrical grid but did so without a detailed plan of how to do so. Now as energy reliability becomes a greater concern, legislators must also approach this from a political angle because if power continues to be unreliable, they will ultimately be held responsible for the shortfalls. That much is clear when Assemblymember Bill Quirk, a Democrat from Heyward said, "So the last time we didn't keep the lights on, at the beginning of the century, in 2002, we lost a governor… but you know who's going to get blamed for this, if it doesn't happen? It's us Dems, and it should be. We're in control in the Capitol. We will get blamed if the lights go out."[i] In this report I will explore how energy reliability has played a political role in the past and why comments like Assemblymember Quirk's are so poignant.

I will provide a brief explanation of how our state has gotten into the predicament that we find ourselves in by explaining the evolution of climate policies that laid the groundwork for clean energy generation goals. I will include an overview of legislation that passed and has set ambitious renewable goals in the energy sector, along with other policies passed that could increase strain on the grid in future years. I will then provide an overview of various alternatives that the state could pursue to diversify its energy portfolio and provide more reliability. Unfortunately, it is beyond the scope of this brief policy briefing to provide a comprehensive overview of all types of energy generation, however, I will identify projects that I believe will have the greatest impact.

BACKGROUND

Energy policy has been a hot topic in California policy for over two decades, but as with any other issue area, it has evolved as time progressed. In the late 1990s and early 2000s there was a push by state lawmakers to deregulate the energy sector in the state. AB 1890, by former Assembly Republican leader Jim Brulte, was passed to create the Independent Service Operator (ISO) in the state which would be charged with overseeing energy generation. Up to that point, the three largest utilities essentially had a monopoly over energy generation, transmission, and distribution, which they had used this power to increase their rates to be 50% higher than the rest of the nation.[ii] This legislation placed a cap on electric rates until the utilities were able to fully divest from their plants. In 2002, SDG&E was the first investor-owned utility (IOU) to fully divest all of their plants which lifted the price cap. This caused electricity rates to skyrocket, and some consumers saw their electricity bills triple.[iii] Even before SDG&E fully divested their plants, the state was in the midst of a generation crisis when unexpected heat wave hit California with temperatures reaching up to 103 degrees in San Francisco and 97,000 people in the Bay Area lost power because of a lack of supply. This trend of blackouts would continue for years.

The main problem with deregulation is that it authorized customers to purchase energy from any entity in the state and those corporations' primary focus was profit, not reliability. Some corporations would manipulate their prices and create artificial shortfalls at peak load times. Enron would regularly take plants offline and caused rolling blackouts in the state for millions of customers, with one instance occurring on January 17, 2001 when they took a powerplant offline due to phony repairs.[iv] The rolling blackouts ultimately had major political consequences. Gray Davis, who was the Governor at the time, was heavily criticized for his lack of action to address this issue and when he finally came together with the Legislature to devise a solution in the budget, California already saw millions of people suffer from blackouts, SDG&E filed for bankruptcy, and PG&E was not far behind. On October 7, 2003, Gray Davis was recalled by the voters of California and became the first governor in state history to be removed from his position.

Arnold Schwarzenegger was elected to succeed Governor Davis in the 2003 recall election. Schwarzenegger appealed to Californians because he branded himself as "fiscally conservative and socially liberal".[v] He entered the Governor's office as a new kind of Republican, one who accepted the reality that climate change exists and he became a champion in the fight against it. He was not plagued with the problem of energy reliability like Gray Davis because additional powerplants had been built to maintain reliability through funding approved by the outgoing Davis administration. This allotted Governor Schwarzenegger the opportunity to focus of the impact that energy generation has on the environment unencumbered by the threats of unreliability.

Governor Schwarzenegger ultimately signed numerous Executive Orders and bills to combat climate change. Executive Order S-12-05 for example, required state agencies to reduce energy usage and encouraged consumers and businesses to do the same. This reduced energy usage to the point that Californians only used 6,700 kilowatt hours of electricity per year, compared to the average American who uses

12,000.[vi] Most notably, he was instrumental in the passage of AB 32 which established the state's cap and trade program. Though this landmark program impacts all businesses in the state and significantly reduces GHG emissions, it has an outsized impact in energy generation. In 2022, electrical distribution utilities accounted for 50% of the total credits allotted.[vii] While this did not directly reduce energy reliability, it acted as a market catalyst which caused energy generation to shift to less reliable renewable sources, such as wind and solar.

In years to come after the passage of AB 32, the Legislature and the Governor continued to build on their efforts to combat climate change and increase procurement of clean energy. The path to clean energy began in 2002, when Senator Byron Sher introduced SB 1078, a bill that required the IOUs to increase their renewable energy procurement by 1% each year until they reach 20%, which must be reached no later than 2017. This also created the Renewable Portfolio Standard (RPS) which is the program that outlines the targets for clean energy procurement. The RPS only includes certain renewable resources to be considered RPS eligible, such as solar, wind, geothermal, small hydroelectric dams, and biopower facilities.[viii] This does not include nuclear power or large hydroelectric dams. Enactment of the RPS is important because it has been a large driver in making wind and solar power so prolific, to the point that the state may be over reliant on them as an energy source. Later in this report I will explain why this may be problematic, but it is important to note the role that the RPS plays in energy generation sources and the impact that they may have on reliability.

In the two decades following the landmark 2002 legislation, the Legislature built upon the targets that were created in SB 1078, each time making them more ambitious. What began as a requirement that 20% of energy procured be renewable by 2017 evolved into something much more. In 2017, Senate Pro-Tem Kevin De Leon introduced SB 100 which was titled "The 100 Percent Clean Energy Act of 2018". This bill was, and continues to be, the most ambitious proposal in the clean energy space and built upon previously established goals. Most importantly, SB 100 requires that 100% procurement of energy in the state be from zero-carbon resources. This bill was signed by then Governor Jerry Brown on September 10, 2018.[ix] Two years prior, Governor Brown had issued "objectives for 2030 and beyond" in his state of the state address which included an increase of 50% renewables by 2030. Governor Brown admitted that this was a "tall order" because it would require the complete transformation of the state's electric grid, and transportation system, along with enormous innovation.[x] Governor Brown understood that, while increasing renewables is vital, the transition must be done thoughtfully and collaboratively. This emphasizes the need for the state to diversify its energy generation sources and energy storage while progressing towards the 100% renewable energy requirement that was established in SB 100.

While this background captures the beginning of California's path to clean energy, and the most recent and ambitious requirement, there were multiple other bills that incrementally increased the targets. Table 1 provides an overview of legislation passed that increased the state's renewable goals and shows how these goals became more ambitious over time. Over the span of two decades, California completely transformed how it plans to generate energy in the future. While these efforts promote environmental goals, I will show that there are certainly negative externalities that have arisen out of this shift. In the next

section, I will explain some of these negative externalities which have resulted in a less reliable energy grid.

Table 1: Overview of Legislation Passed in California's Path to 100% Clean Energy

Bill	Author/year	Brief description
SB 1078	Sher (2002)	Required IOUs to increase renewable energy procurement by 1% each year until they reach 20% by 2017. Created the Renewable Portfolio Standard (RPS)
SB 107	Simitian (2006)	Accelerated the 20% renewable requirement established in SB 1078 by seven years
SBX1 2	Simitian (2011)	Expanded the renewable requirements to all sales of energy, and no longer limits the program to IOUs. Establishes the following renewable requirements: 20% by December 31, 2013, 25% by December 31, 2016, and 33% by December 31, 2020
SB 350	De Leon (2015)	Required that 50% of procured energy in California be renewable by 2030
SB 100	De Leon (2017)	Increased the 2030 goal to 60% and requires 100% of procured energy in California be renewable by 2045
SB 846	Laird (2022)	Established higher interim targets from renewables between 2022 and 2045. Requires 90% of procured energy be renewable by 2035 and 95% by 2040

WHAT IS THE PROBLEM AND WHY SHOULD GOVERNMENT INTERVENE?

As California increases renewable energy generation to phase out natural gas energy generation, several problems have been illuminated. This section will focus on some of the negative externalities of current renewables and how they could reduce reliability without additional investments by the state to support them. Reliability means the ability to meet energy demand at all points of the day and throughout the year, even during unprecedented extreme weather events. The problem is that as California approaches key statutory milestones that require greater renewable energy generation, the state could be susceptible to energy shortfalls if certain steps are not taken. More specifically, over the next 13 years, as California's renewable energy requirements reach 90% by 2035, the state could see energy shortfalls at certain times of day or during extreme weather events if diversification and energy storage efforts are not maximized.

To date, California has heavily invested in wind and solar technologies to bolster its renewable energy portfolio. This section will explore the problems that currently exist with wind and solar and how these technologies are susceptible to shortfalls. The following section of this policy brief will explore various technologies that can support wind and solar and help uphold both the state's renewable energy goals while providing reliable energy to California residents.

In addition, this section will explore how the state must consider other factors, such as climate change, and how it impacts energy consumption and generation. First, I will focus on the impact that climate change has had on the energy consumption and how it has increased the demand for energy by more frequent heatwaves. I will then explain how climate change is also simultaneously reducing the supply of energy through more frequent droughts. Next, I will discuss new regulations that will increase the strain on the energy grid, which could exacerbate the state's current problem by significantly adding more energy demand. While this section illuminates some of the problems around current renewables, it is important to note that the technologies discussed are key components to a 100% renewable future, however, without diversification and storage, they can lead to unreliability. It is also important to note that the state is making efforts in this space to ensure that the grid remains reliable during this transition. While this problem is serious, the sky is not falling, and Californians are not likely to be thrown back into the dark ages. The Legislature and the Governor have already demonstrated their ability to be nimble and adjust energy goals to ensure that the lights stay on. This brief is meant to inform of the vulnerabilities that exist and could be exacerbated absent a thoughtful plan to account for potential shortfalls. The primary goal is to successfully transition to a renewable electric grid, while maintaining reliability. Lastly, this section will explore why government should intervene. This will focus on a collaborative partnership between the public and private sectors to achieve the common goal of reliable and renewable energy.

OVERRELIANCE ON WIND AND SOLAR POWER

The creation of the RPS increased renewable energy resources in the state; however, the technologies primarily deployed are not always able to be drawn upon when energy is needed. Indeed, the state has disproportionately built out wind and solar power infrastructure as opposed to other renewable energy options. This is evident through CARB's data on electric generation in 2021. While wind and solar only accounted for 11.4% and 14.2% respectively of the power generated in the state, they hold a disproportionate share of renewable energy generated under the RPS.[xi] According to that data, solar power accounts for 42% of renewable energy generated in 2021, and wind accounts for 34%. When combined, wind and solar account for 76% of renewable energy generated in California. That is a significant amount of energy that cannot be generated at any point in time. Table 2 shows the data from CARB on total electricity generated in the state amongst all sectors in 2021, and Figure 1 represents the breakdown of renewables generated in the same year.

Figure 1: Breakdown of Renewable Energy Generated in California - 2021

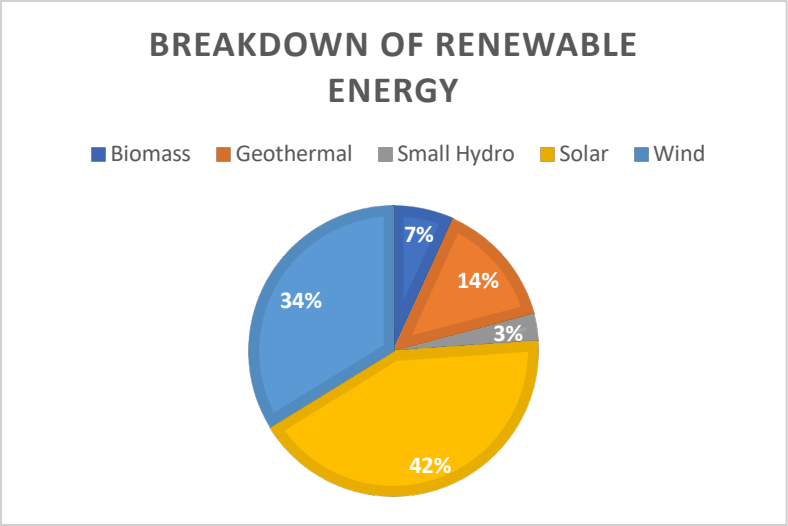


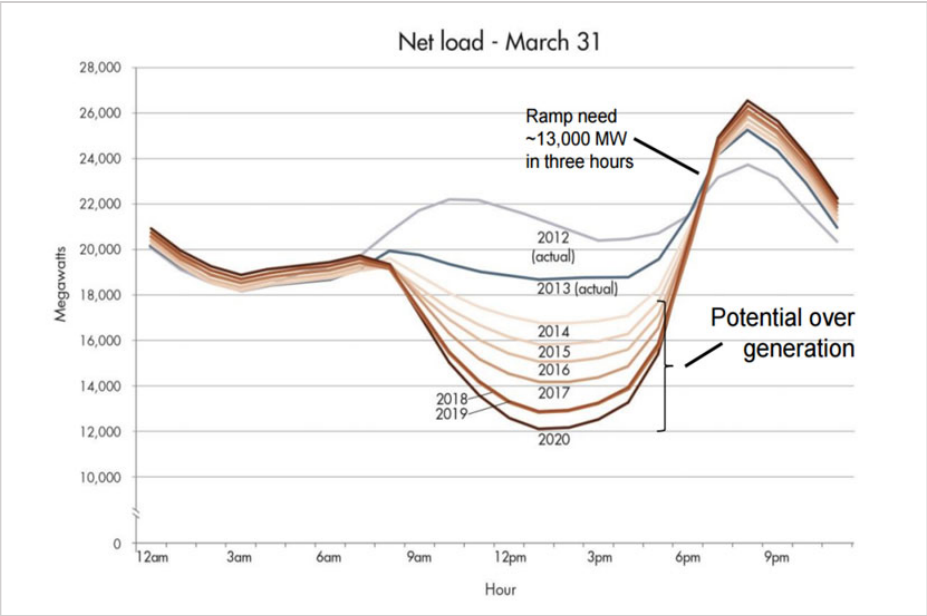
Table 2: Total Energy Generation in California – 2021

Energy Type	Total GWh	Percentage of California Power Mix
Coal	8,272	3.0%
Natural Gas	105,356	37.9%
Oil	37	0.0%
Other (Waste heat/Petroleum Coke)	465	0.2%
Nuclear	25,758	9.3%
Large Hydro	25,656	9.2%
Unspecified	18,887	6.8%
Total Non-Renewable Energy	**184,431**	**66.4%**
Biomass	6,271	2.3%
Geothermal	13,214	4.8%
Small Hydro	2,835	1.0%
Solar	39,458	14.2%
Wind	31,555	11.4%
Total Renewables	**93,333**	**33.6%**
Total System Energy	**277,764**	**100.00%**

Unfortunately for clean energy generation, the sun does not always shine and the wind does not always blow. An overreliance on solar and wind power could cause less reliability in the energy space. To be clear, I am not saying that wind and solar power are ineffective and should not be pursued. These sources of power are an important part of a 100% clean energy future; however, they must be part of a diverse portfolio of energy generation and storage. If the state continues to rely on wind and solar so heavily, it could find energy supply once again falling short of demand. This was evident in the 2021 when California experienced rotating blackouts. In fact, the final root cause analysis conducted by the CPUC indicated this as one of the major root causes. The analysis stated that the transition to renewables has not kept pace to ensure there are sufficient resources to meet demand in early evening hours.[xii] Essentially, in the evening as solar energy generation reduced and demand peaked, there were not sufficient energy resources to maintain reliability. More detail on the 2021 blackouts is provided in the following subsection on climate change and energy consumption.

While wind generation unreliability is easy to understand because the wind is not guaranteed to blow at any point of the day, solar energy generation is a bit more complex. Solar energy is produced throughout the day when the sun is shining, meaning that all solar energy production ceases after the sun goes down. Unfortunately, that coincides with peak energy usage times. Overreliance on solar power creates challenges for utilities to balance supply and demand of energy. This is best displayed on the infamous “duck curve” graph that is displayed in Figure 2.

Figure 2: Duck Curve Graph



The duck curve shows average energy consumption throughout the day and how that coincides with energy generated by solar panels. Between the hours 9:00 AM and 6:00 PM, there is an overgeneration of electricity because consumer demand is far lower than the supply. As consumers complete their typical workday and come home at around 5:00 or 6:00 PM, they begin consuming more electricity by using high energy consuming appliances such as washers, dryers, dish washers, air conditioners, etc. This puts significant strain on the grid. The increase in energy usage coincides with the sun setting and, depending on the time of the year and the part of the state, that can even be before consumers get home from work. Over the three-hour period between 6:00 and 9:00 PM, the demand for electricity increases by 13,000 megawatts (MW), which a significant amount to generate. This shows that one of the primary problems with overreliance on solar energy, without additional storage technologies, is a massive gap in energy generation making it unable to meet the needs of consumers. Currently, this has not been an issue because natural gas powerplants and other unrenewable technologies that have yet to be phased out make up the shortfalls. As the state moves closer to its 100% renewable goals, it is imperative that we consider the duck curve and the implications that it can have on energy shortages when consumption is at its peak.

In addition to time-of-day constraints that exist in solar energy generation, we must also consider time of year constraints. Solar generation in the summer differs greatly from generation in the winter because winter days are significantly shorter. For example, in Sacramento on December 21, 2022, this year's winter solstice, the sun will rise at 7:20 a.m. and will set at 4:48 p.m.[xiii] Compared to the summer solstice on June 1, 2022 in the same region, aka the longest day of the year, the sun rose that day at 5:41 a.m. and set at 8:33 p.m.[xiv] That is a difference of 5 hours and 24 minutes of sunlight between the two most extreme daylight periods of the year. These shorter days mean that solar energy systems will run for less time each day during the winter and therefore will generate less electricity.[xv] Granted, Californians consume far less energy in the winter, approximately 30-

31,000 megawatts, than they do in the summer, approximately 37-38,000 megawatts.[xvi] Despite consuming less energy in the winter, energy storage and generation diversification is still necessary because the decrease in supply of solar energy must be made up in some other form. The state is currently investing in storage technologies to account for this daily and seasonal reductions in energy generation, which I will cover in the 'Alternatives' section of this policy brief.

CLIMATE CHANGE INCREASING DEMAND

Combatting climate change has been one of the driving factors for increasing renewable power generation in the state. Unfortunately, this wicked problem has made the transition even more difficult because it has created extreme weather events that have impacted the demand for energy. While climate change emphasizes the need to transition to clean energy generation, it has also made the transition even more complicated. Although extreme weather events and rolling blackouts in California are relatively rare, recent events can serve as a warning to policymakers of the negative effects that they can have, which can influence policy making and implementation. Delivering reliable energy is imperative and cannot be taken lightly. State leaders have acknowledged this, most notably in response to the blackouts in 2020, Governor Gavin Newsom stated that "we failed to predict and plan these shortages, and that is simply unacceptable."[xvii] Moreover, in the context of transitioning to renewable energy, the Governor emphasized that "we cannot sacrifice reliability as we move forward in this transition."[xviii] This subsection provides an overview of climate change induced extreme weather events that occurred in 2020, and the implications that they had on the grid. This emphasizes the challenges that the state could face in the future as it grapples with increasing renewables and providing reliability as climate change increase the demand for electricity in extreme events.

On August 14-15, 2020, the California Independent System Operator (ISO) was forced to institute rotating blackouts across the state because there was not enough energy supply during a heat wave that impacted the western states. This affected 492,000 customers on the 14th, and 321,000 customers on the 15th.[xix] In response to a request from Governor Newsom, the California Public Utilities Commission (CPUC) conducted a final root cause analysis of the blackouts and they concluded the major root causes of the blackouts.

The CPUC determined that a major contributing factor was that climate change induced extreme heatwave across the western U.S caused demand for electricity to exceed supply.[xx] This put significant strain on the electric grid and ultimately resulted in an insufficient amount of power to service the state. To accommodate the lack of supply, the ISO had to institute rolling power outages where customers were without power anywhere between 8 and 150 minutes. These outages were done intentionally by the ISO and were spread amongst customers in a rotating manner to ensure that no one group of customers were without power for an extended period. Had ISO not instituted these blackouts the balance of the electrical system would have been off-balance which could have resulted in a much more catastrophic shutdown of the entire electrical system.[xxi]

Unfortunately, experts expect that climate change induced heatwaves will continue to occur. Since the mid-1900s, the Earth's global temperature has risen 0.9°C as of 2017.[xxii] This has caused natural disasters to be more devastating and overall temperatures to be

hotter. In cases such as the 2020 heatwave, a period that is already difficult to accommodate increased power supply was made even more difficult. Inability to maintain a reliable electric grid can have dire effects on human health during heatwaves because if people have their power shut off, they are not able to cool their homes. A study conducted by Guriguis et. al. showed that between 1999 and 2009, hospital admissions increased by 7% in California on peak-heatwave days.[xxiii] Over that period, there were 11,000 excess hospitalizations due to extreme heat. With the issue of increased heatwaves, it is imperative that electrical power is reliable because unreliability could come at a significant human cost.

CLIMATE CHANGE REDUCING GENERATION

In addition to adding more strain on the grid, climate change has also reduced some electricity generation that the state has traditionally relied on in the hot summer months, specifically, hydroelectric power. Climate change has caused less rain to fall in the winter months and has resulted in the period from 2000-2018 to be the second driest 19-year period in the U.S. Southwest in the past 1,200 years.[xxiv] In addition to less rainfall, increased temperatures have also reduced the amount of snowpack in the Sierra Nevada. This reduction has caused snow to melt at a much faster rate which leaves the state with reduced snowmelt in the hot season.[xxv] While this impacts many different sectors, it significantly impacts energy generation because it reduces the amount of water stored in reservoirs that are used to generate hydroelectric power.

Combined, large and small hydroelectric power facilities made up 10.2% 2021 electric generation in the state.[xxvi] Decreased rainfall and snow melt as a result of climate change can cause reservoir storage capacity to be reduced to the extent that they are not able to generate hydroelectric power. In fact, that happened in August 2021 when Lake Oroville's reservoir levels were decreased below the minimum levels needed to generate power, the first time that had ever happened since the dam was built in 1967.[xxvii] Extended droughts, reduced rainfall, and fast melting snowpack threaten the viability of future hydroelectric power and could contribute to increased unreliability in energy generation. While hydroelectric power has traditionally been one of the most reliable forms of renewable energy, climate change is causing it to be less reliable at times when reliability is desperately needed.

INCREASED STRAIN ON THE GRID

As I have explained previously, California is susceptible to energy shortages because of extreme weather events as a result of climate change. This has shown that even at the state's current level of energy consumption, it has been difficult to maintain reliability and we have had to resort to using energy generation facilities that are harmful to the environment. As the state transitions away from natural gas, recent regulations that have been passed could ultimately increase the strain on the electrical grid.

On August 25, 2022, CARB approved a regulation to accelerate California's electric vehicle sales. This regulation requires that 100% of new car sales be zero emission vehicles by 2035.[xxviii] The impetus of this regulation is clear, which is reducing global warming emissions in the transportation sector, the largest source of emissions in the state. While transitioning to zero-emission vehicles is an important step to combatting climate change, requiring 100% of new car sales be zero emission will almost certainly create additional strain on the state's grid. This must be considered as the state

simultaneously transitions to renewable energy. A report by the California Energy Commission in 2017 forecasted future energy demand as the state adopts more electric vehicles. At their highest estimate of 3.9 million EVs on the road by 2030, the CEC estimated that the increase in demand would jump from less that 1,000 GW in 2017 to over 30,000 by 2030.[xxix] That is a significant increase in energy consumption for an electrical grid that is already struggling to meet demand. This was evident during the state's most recent heatwave in August, 2022, when the ISO issued a "Flex Alert" which called on Californians to reduce energy consumption for 3 days from the hours of 4 to 9 PM.[xxx] In this flex alert, ISO states that Californians should avoid charging electric vehicles while the Flex Alert is in effect. Considering that currently EVs only make up 12% of vehicles sold in California in 2021, it is concerning the impact that this can have on the grid when EV sales are increased to 100%.[xxxi]

In addition to increasing EVs in the state, CARB has moved to ban natural gas heaters and water heaters.[xxxii] This would require residents, to install zero emission replacements when replacing old heaters and water heaters. These regulations would likely add additional strain on energy consumption, especially when you consider that California's population is roughly 39.5 million people.[xxxiii] While phasing out natural gas in the state is an important step to combatting climate change, these factors must also be part of the energy generation conversation as the state moves to 100% clean energy by 2045. Regulations that will add strain to the grid and increase energy demand should be considered in the state's future energy plans because it must be able to accommodate increased generation, while reducing the forms of generation that it has used in the past.

WHY GOVERNMENT SHOULD INTERVENE

With all of the difficulties that the state faces, a natural question is why or if California should get involved? Is it necessary or appropriate for the state to help solve these issues, or should it be left to the private sector, i.e., the state's IOUs? For decades, California has been a leader in the fight against climate change. The state has played a role on the national stage and has bilateral agreements with 18 different nations on actions to combat climate change.[xxxiv] Governor Newsom has, on multiple occasions, touted California as a world leader in passing climate measures, most recently in response to the passage of a climate bill package at the end of the 2022 session.[xxxv] As the state expresses its commitment to combatting climate change, it must also commit its resources to ensure these efforts are successful. To date, California has done that and has dedicate money to various state agencies to support clean energy programs. Most recently in 2022, the state budget allocated $4.3 billion to address stress on the state's grid and provide reliability. Given that California leaders have long recognized and committed the state to moving to clean energy it should intervene because the private sector cannot accomplish this on its own without a significant impact to ratepayers. The state's early intervention will help alleviate short term costs and ease the transition to 100% renewables.

In addition, California has some responsibility to the residents of the state to intervene because it has established these requirements on the private sector. The state has a responsibility to Californians to ensure that this transition is done efficiently and effectively. If California does not do that then potential negative externalities could occur, such as a state has a responsibility to residents to ensure

that the implementation of these requirements do not harm its residents. The state is already involved and will continue to do so, but it is important that these investments are used tactically and promote the state's ambitious goals.

ALTERNATIVES THAT COULD PROVIDE MORE RELIABILITY

While challenges exist in California's path to 100% zero carbon energy generation by 2045, there are promising solutions that can help the state attain is ambitious goals while maintaining energy reliability. Harnessing existing and evolving technology in energy storage and developing diverse energy generation options could help the state to accommodate the shortfalls that currently exist when solar energy tapers off in the evenings and is reduced in the winter and help alleviate the pressures when extreme weather events occur. The key to success is preparation. It is important to note that the state's energy goals differentiate between "renewable energy" and "zero carbon". Renewable energy is defined under the RPS and includes specific technologies, whereas zero carbon includes technologies that, while they may rely on natural resources that are finite and not renewable, they do not emit climate harming carbon and therefore are not contributing to climate change. This distinction is important because the 100 Percent Clean Energy Act of 2018 requires energy procurement to be 100% zero carbon by 2045, therefore leaving more technology options open. The state's RPS goals require that 95% of energy be renewable by 2040. This leaves a 5% gap in energy generation that will allow for energy procurement to be zero carbon and non-renewable.

An example of zero carbon energy generation that is not renewable is nuclear energy. Nuclear uses uranium, a depletable resource, to generate energy. Currently, nuclear energy accounts for 9.3% of California's total energy generation (see table 2). This could be an option to fill the 5% gap under SB 100. However, there are various problems and hurdles surrounding nuclear energy that make it a difficult energy source to continue. While nuclear energy is an important component of the state's current energy portfolio and has potential to be a clean energy source in the future, I will not focus on it in this policy brief as an alternative. The scope, the politics, regulations, history, and controversy of this energy source are too expansive to be included under the confines of this policy brief. Nevertheless, it is worth mentioning the role that it currently plays and the potential that it has as a clean energy source.

This section focuses on alternatives that the state can pursue to mitigate the problems that we have seen in our current expansion of renewables. While there are many different types of technology that exists in the market for energy generation, in the interest of brevity I will only cover two alternatives. Both of these alternatives focus on energy storage. First, I will explain how battery storage can harness excess energy generated from rooftop solar during non-peak energy times of the day and be distributed as generation tapers off when the sun goes down. Second, I will explore how hydrogen can play a role in long duration storage and can be deployed quickly in extreme weather events or during periods of the year when solar energy generation is reduced.

The above-mentioned alternatives can help to mitigate shortfalls and disperse energy more reliably and equitably throughout the day. If

adopted, they could ease the transition away from natural gas energy and more efficiently deploy renewables. With the expectation that California continues to build out solar and wind energy generation, these options provide opportunities to store excess energy that is generated and deploy it when it is needed the most. Lastly, some of these technologies are burgeoning and will continue to become more prolific as the state transitions to a 100% zero carbon grid. This creates possibility that the alternatives that I describe become more cost-effective and efficient in the future as they are brought to a greater scale. While they may currently be less cost effective to implement, that may change (and in the case of battery technology it already has changed) as more research is done and the industry continues to evolve. To that end, the state should continue to invest in technologies to power the grid and provide reliable clean energy in the future because that investment could be an important factor to driving down the cost as these markets are brought to greater scale in the future.

BATTERY STORAGE

Accommodating time of day and time of year shortfalls in solar energy generation has required an open-minded approach to renewable technologies that can provide energy reliability. Notably, storage has been at the forefront of this discussion, and battery technology has been promoted by CAISO as a key part of the state's strategy going forward to maintaining energy reliability after the sun sets.[xxxvi] In an effort to bolster the state's energy storage, most recently California's budget included $140 million in one-time General Fund investment for long duration storage products, including battery storage. While there are two types of battery storage for energy (one being personal battery storage in an individual's home and the other being grid scale storage) this analysis will focus on grid scale storage because it has the potential to power thousands of homes and is a concentrated investment that the state and the private sector can make, while personal storage is an individual effort for homeowners.

Battery storage is a key component to addressing the problems shown on the duck curve (see Figure 2, discussed previously) whereby solar energy production tapers off as consumer demand increases. Batteries can be charged during the day while solar panels generate more energy than consumers demand. This stored energy can then be deployed as the sun sets and solar panels cease to generate energy. As seen in Figure 2, there is a 13,00 MW increase in demand between approximately 6:00 PM and 9:00 PM, coinciding with reduction in solar energy generation. During this period, energy stored in batteries could be utilized to fill the gap and ensure that consumer demand is met.

To date, California has made significant strides in increasing battery storage and with 3,163 mw of battery storage, the state leads the nation in utility-scale battery storage.[xxxvii] Over the past two years, California has built out its battery storage capacity, and has set the stage for future investments in this space. Most notably, in 2021 the California's largest battery storage facility finished its second phase of construction at Moss Landing.[xxxviii] Moss Landing is an excellent example of how California can harness new technology and retrofit existing infrastructure to increase renewable energy distribution. Originally constructed in the 1960s as a natural gas power plant, it has been converted to now be the largest battery storage plan in the state.[xxxix] This facility's lithium-ion batteries can store up to 400 MW of energy that can power approximately 300,000 homes for four hours.[xl]

Moss Landing is an example of the potential that utility scale battery storage can have, as well as the potential pitfalls that it poses. Within a matter of four months between September 2021 and February 2022, this facility experienced two safety incidents that involved batteries overheating which resulted in temporary shutdown of the facility.[xli] The facility was ultimately brought back online to its full capacity in July 2022. This incident at the state's largest storage facility underscores the reality that battery technology is still developing and is susceptible to setbacks that can bring it offline. Unfortunately, lithium-ion batteries can overheat and catch fire, which ultimately could bring large portions of, if not entire storage facilities offline for an extended period. Losing key storage facilities during certain times of the day could make it more difficult in the future for the state to ensure energy reliability.

In addition to possible equipment failures, another key issue with battery storage is the scale needed to serve the entire state. According to the CEC, 49,000 MW of battery storage will be needed to meet the goals set out in SB 100 by 2045. To put that in perspective, Moss Landing stores up to 400 MW, and cost the facility's owner, Vistra Corp., around $400 million to build out.[xlii] In order to achieve the necessary battery storage projected by the CEC, California would need approximately 122 additional storage facilities the size of Moss Landing.

I recommend that the state continue to provide funding to subsidize battery storage and work with utilities to build out this infrastructure. Building 122 additional battery storage facilities is a massive infrastructure project and an opportunity for California partner with stakeholders and invest in its energy future. Fortunately, market drivers have made battery technology significantly more affordable, and the price of lithium-ion batteries continues to decrease. The price of lithium-ion batteries has declined by 91% between 1991 and 2021. More importantly, the price for utility scale batteries decreased by 70% between 2015 and 2018, representing that as the market further builds out battery technology, the price continues to decrease.[xliii] That translates to a decrease in cost for one battery with a capacity of one kilowatt-hour storage from $7500 in 1991 to $181 in 2018.[xliv] As the market develops this technology it is reasonable to expect that the price, efficiency, and safety of battery storage will continue to improve.

HYDROGEN

Another technology that California could use to store energy and deploy it when shortfalls occur is hydrogen. The benefit of hydrogen is that when it is used to generate electrical power in in a fuel cell it is clean energy that only emits water vapor and warm air.[xlv] In addition, hydrogen can be used as long duration storage which is defined as any system able to discharge energy output for 10 or more hours.[xlvi] While this is promising in the clean energy space and can help accommodate energy shortfalls, especially in the winter when solar generation is reduced, it does have some challenges.

Production of hydrogen is a bit more complicated than large scale batteries. First, not all hydrogen production is environmentally friendly. Hydrogen is produced in multiple ways, with some methods being completely free of GHG emissions, while others emit GHGs in production. Production methods of hydrogen have been color coded to differentiate these types of hydrogen. For example, black and brown hydrogen is produced by burning coal. Grey hydrogen is produced by using natural gas. Currently, grey hydrogen is the most common process of producing hydrogen and has a high

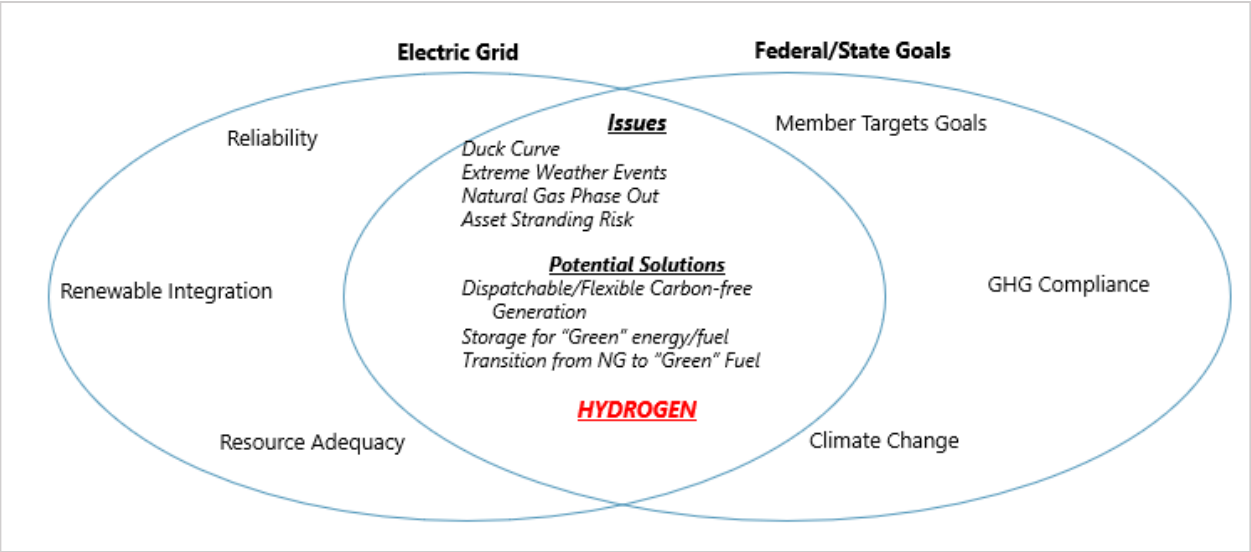
ratio of CO2 emissions which is harmful to the environment.[xlvii] While there are other colors of hydrogen, the focus of this section, and the policy alternative being proposed, will be on green hydrogen which is produced from renewable energy sources such as wind and solar to create hydrogen.[xlviii] In addition, this section will only focus on the use of hydrogen to generate clean power, even though this technology is being explored in other sectors such as transportation.

Much like battery storage, green hydrogen production helps to maximize the excess energy that is produced by wind and solar during non-peak hours of the day and store it for later use. Essentially, surplus electricity generated through solar and wind can be used at a facility to create hydrogen through a process called electrolysis. Electrolysis uses electricity to split water into hydrogen and oxygen elements by using a machine called an electrolyzer.[xlix] The hydrogen is then captured and stored as a gas or a liquid to be deployed at a later time. To make this a reality, large volumes of hydrogen will need to be generated and currently the industry has not been built out to the scale needed.

The federal government and the state have both made significant investments in hydrogen. The federal infrastructure bill passed in 2022 included $8 billion to the U.S. Department of Energy to create hubs of hydrogen producers and consumers and accelerate the use of hydrogen as an energy resource. California has made significant investments in renewable hydrogen production and between 2008 and 2021, the CEC has invested $242 million to support hydrogen research and development projects. Moreover, the $140 million for long duration storage projects that was included in the state's 2022 budget can also be used for hydrogen. This has helped fund investments such as the Lodi Energy Center which is owned by the Northern California Power Agency that is blending 45% hydrogen with natural gas to generate power.[l] Despite using some natural gas to generate power, the hydrogen blend at this facility dramatically reduces emissions while propelling the technology forward. This facility is also supported by PG&E which has launched a study to examine the potential use of hydrogen as a renewable resource and the feasibility of using existing natural gas infrastructure to transmit hydrogen.[li] Investments such as these are key components to increasing hydrogen efficiency and creating opportunities for the state to utilize existing natural gas infrastructure in its clean energy future.

Figure 3 is a Venn diagram derived from an NCPA presentation to the CEC on the Lodi Energy Center and shows how hydrogen can be a potential solution to achieve reliability and integrate renewables while achieving federal and state climate goals.[lii] This shows how hydrogen can help address problems that have arisen through the phasing out of natural gas, the tapering off of solar energy in the evening which is shown in the duck curve, and energy shortfalls that result from extreme weather events.

Figure 3: NCPA diagram on opportunity for hydrogen



To study how hydrogen can help maintain reliability while upholding the state's climate goals the California Senate has established the Select Committee on Hydrogen Energy to explore this technology and the benefits that it poses to the state. On March 3, 2022, the Select Committee held an informational hearing on the progress of the hydrogen industry where various stakeholders presented information.[liii] During this hearing, various stakeholders provided reasons why hydrogen is a technology that could help maintain electric reliability. A representative from AltaSea, an organization that joins in public-private collaboration to advance climate sustainability, explained that hydrogen differs from battery storage as it does not degrade over time. While batteries become less effective as they age, stored hydrogen does not deplete until it is used. This, paired with the possibility of utilizing existing infrastructure, could make hydrogen a more cost-effective solution for energy storage that isn't afflicted by reduced storage capacity, such as with batteries.

Hydrogen offers California an opportunity to account for shortfalls that wind and solar experience seasonally when less energy is generated. In addition to the short-term shortfalls that the state experiences after the sun sets, hydrogen can also be deployed during the winter months when solar farms generate less solar energy because the sun shines for shorter lengths throughout the day.[liv] This is an important planning method that, if paired with other storage technologies such as batteries, could provide more reliability when other renewable energy generation tapers off. In addition, hydrogen offers a flexible deployment option when the state faces extreme weather events. These events are unanticipated and can cause a severe spike in energy usage, such as the events seen in 2020. Stored hydrogen can be quickly deployed and could help accommodate energy shortfalls in these events, maintaining reliability.

While California has been committed in its effort to increase hydrogen production and has made significant investments, it is imperative that the state continues to support this technology. When brought to scale, the cost of production will likely be significantly reduced. An example of success in the state's investment in hydrogen is a recent grant that the CEC awarded

to SoCal Gas for hydrogen research. SoCal Gas' project aims to reduce the cost of hydrogen production to $1.39 per kilogram,[lv] compared to the current cost of $16.80 per kilogram.[lvi]

While hydrogen is a tool that can be used to increase energy reliability, it is important that production is cost-effective. Investment from the state and the federal government could help support these projects and bring the cost of production and storage down, therefore providing another option for energy storage. California should continue to support projects like this and utilize existing resources to partner with the private sector to expand hydrogen. During the March 3 Senate Select Committee hearing the Office of the UC President presented and discussed how the UC could partner with the state to advance hydrogen.[lvii] Already, UC Irvine and UCLA have partnerships with utilities to advance green hydrogen and the UC system is a national leader in hydrogen research and development. Continued support for the UC system could leverage California's extensive investment in higher education to develop hydrogen technology that can be quickly deployed to provide energy when shortfalls occur. Just as the costs of utility scale batteries has reduced as production has increased, the same market concept can be expected with hydrogen production. The state can play an important role in jumpstarting this industry which could further develop this technology and ultimately serve as an important tool in creating a zero-carbon grid.

CONCLUSION

California has made an ambitious commitment to combatting climate change. The state has been a leader in transitioning away from dirty and depletable resources and adopting a new system that is renewable and environmentally sustainable. The statutory changes over the past two decades have made California a leader in the world in clean energy transition. While this is laudable, it is ambitious. The stakes are very high because combatting climate change is incredibly important as it is a direct threat on the future of our world. California needs to succeed in this transition and needs to do it effectively. If the state fails to do so, it could become a cautionary tale of transitioning away from reliable, albeit dirty, sources of energy to renewables which could discourage other governments from doing so in the future.

To succeed in this transition, the state must assess current shortfalls in the energy space and diversify its portfolio in order to maintain reliability. Currently, wind and solar are disproportionately represented in California renewable energy portfolio. While these sources of energy generation are important to a 100% zero-carbon energy grid, they do have vulnerabilities which could result in energy shortfalls and reduced reliability. As we continue to progress in our clean energy efforts, it is imperative that the state leverage multiple options to maximize clean energy generation. Storage projects such as battery storage and green hydrogen are options that can utilize excess energy that is generated throughout the day by wind and solar and deploy it during times of the day/year when that energy generation tapers off or is significantly depleted, and in extreme weather events that unexpectedly increase consumer demand for energy.

Continued investment by the state in diverse projects will be key in ensuring reliability. California has a responsibility to its residents to deliver reliable energy. If it does not the cost to

residents and the state could be significant, in addition to the damage that could be done to the clean energy movement. Creating a 100% zero-carbon energy system requires significant planning and investment. It requires ingenuity and diversity. Investments in the alternatives described above are only a small component of this future; however, they are important to maintaining reliability in a 100% clean energy future. California must be thoughtful and deliberate in its approach because failure is not a viable option.

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