

PATHWAY 2045

Update to the Clean Power and Electrification Pathway

November 2019

EXECUTIVE SUMMARY

By 2045, California will undergo a remarkable evolution. Supported by its residents, the state will achieve carbon neutrality to reduce the threat of climate change. This will require substantial decarbonization of all sectors of the economy and will necessitate rigorous planning to keep energy safe, reliable and affordable.

Pathway 2045 examines the energy implications of California's long-term decarbonization goals on both the economy and the electric sector and maps out a feasible and low-cost path to meeting these goals. Pathway 2045 builds on *The Clean Power and Electrification Pathway*,¹ Southern California Edison's 2017 analysis of what will be required to meet 2030 interim goals.

Pathway 2045 concludes that the changes required across California's economy are profound: Decarbonization is achieved through powering 100% of retail sales* with carbon-free electricity, electrifying transportation and buildings and using low-carbon fuels for technologies that are not viable for electrification.

The remaining carbon is sequestered to reach carbon neutrality (Figure 1). Emerging technologies and practices will be required to find the most economical method to remove carbon at this scale.

Electric sector: To economically meet both the 2030 and 2045 decarbonization goals, the electric sector needs to decarbonize more quickly than currently required. By 2045, significant electrification of the state's economy combined with population and economic growth will result in a 60% increase in electricity sales from the grid and a 40% increase in peak load.

Eighty gigawatts (GW) of new utility-scale clean generation and 30 GW of utility-scale energy storage will be required in the next 25 years. Energy storage will be essential because the most cost-effective, carbon-free generation sources — wind and solar — are intermittent. Thirty additional GW of generation capacity and 10 GW of storage will come from distributed energy resources (DERs) including up to 50% of single-family homes in California which, driven by improved economics, building codes and supportive but equitable policies, are projected to have customer-sited solar by 2045.

The grid: The grid must have sufficient capacity and continue to modernize to harness the full potential of DERs. Electrification will further increase customers' reliance on the grid, underscoring the need to build in additional resilience to withstand the more frequent and severe weather conditions due to climate change impacts. Grid hardening efforts today along with system designs that accommodate increasing flexibility and more monitoring should reduce these risks. At the same time, California's leadership in deep decarbonization can be a global model that helps mitigate the further threats of climate change.

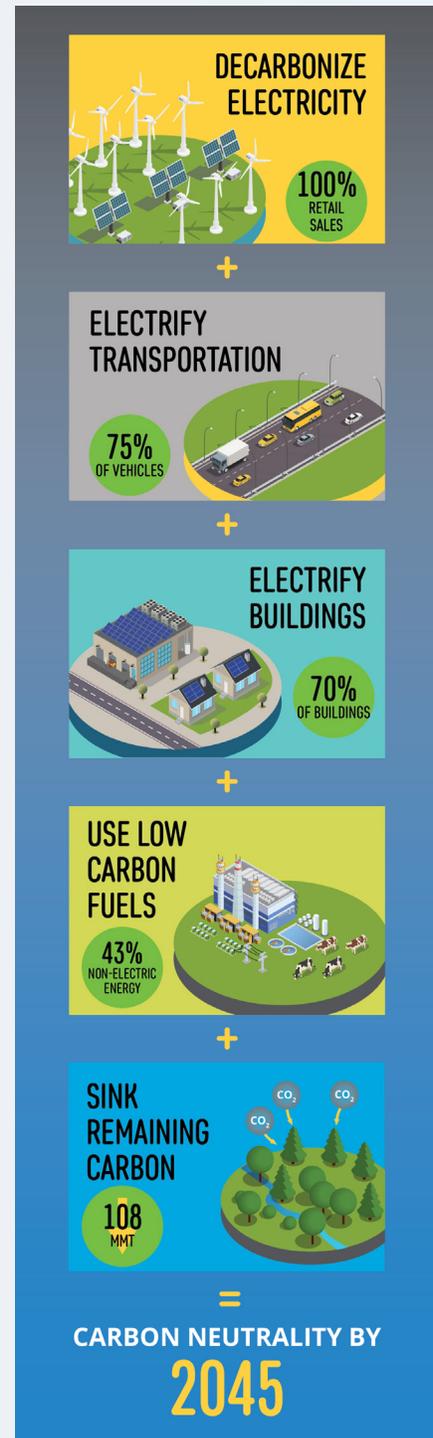


Figure 1: Decarbonization is required across the California economy

* Retail sales is electricity used by individual customers (as opposed to wholesale electricity that is bought, sold and traded in markets).

Natural gas and low-carbon fuels: Services provided by natural gas today, such as supporting electric grid reliability, will still be needed in 2045. Natural gas consumption in 2045 will decline 50% from today, and cost impacts on remaining gas customers will need to be managed. At least 40% of the remaining gas will need to be low-carbon fuels such as biomethane or hydrogen. Other hard-to-electrify sectors such as heavy-duty transportation and some industrial processes will also rely on a combination of natural gas and low-carbon fuels. Research and development is necessary to bring these low-carbon fuels to commercial viability and required scale.

Transportation: Three-quarters of light-duty vehicles, two-thirds of medium-duty vehicles and one-third of heavy-duty vehicles will need to be electric by 2045. Vehicle affordability, product diversity and charging infrastructure availability are needed to accelerate adoption to meet 2030 targets and prepare for 2045.

Buildings: Almost three-quarters of space and water heating needs to be electric by 2045. Given the long life cycles of space and water heating equipment, significant consumer awareness and education need to be supported now to speed adoption. Customers will benefit from the significant efficiency provided by electrification, as well as from energy efficiency and demand response programs that help to lower customer consumption and bills.

The cost and benefits for Californians: The clean energy and grid investments required to meet 2045 goals is a tremendous economic development opportunity for California. Utility-scale generation and storage and the supporting grid represent up to \$250 billion of clean energy and grid investments and include thousands of sustaining craft and skilled jobs.

As California decarbonizes, energy must remain affordable for all of the state's consumers, including our most vulnerable residents. Electrification produces savings for an average household, but late adopters who continue to rely on natural gas for their homes or gasoline for their cars will be increasingly burdened in the transition.

Robust, coordinated and targeted policies are needed to clean the power supply; build, operate and maintain a reliable and resilient grid; and move customers to adopt new technologies and programs. Advancing and scaling up adoption of new technologies will require incentives, regulations and other market transformation policies.

Most importantly, through this transition, all California residents will benefit from greatly reduced greenhouse gas emissions (Figure 2) and new economic opportunities.

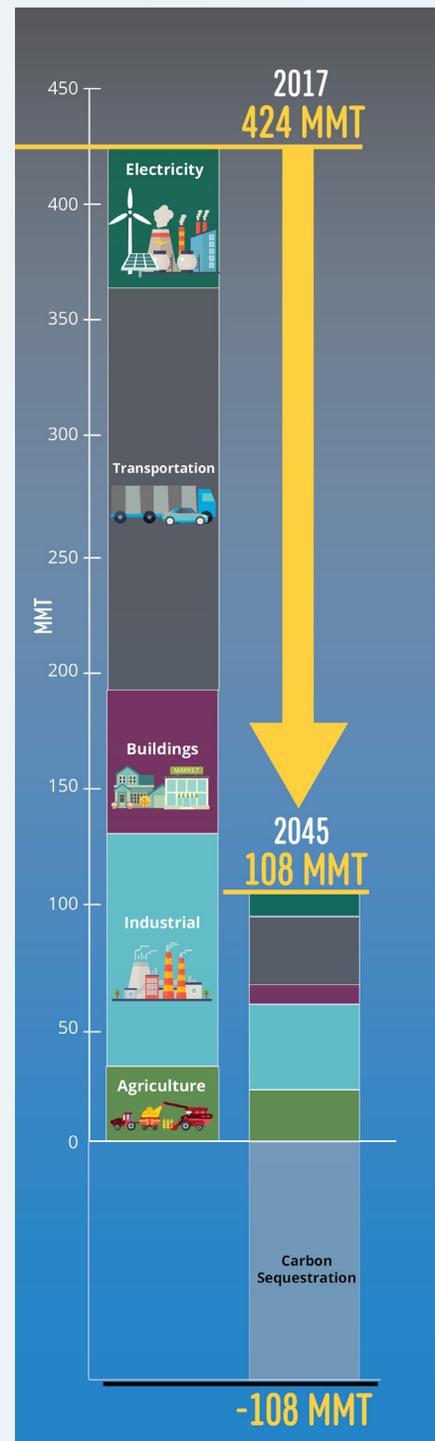


Figure 2: Greenhouse gas emissions reductions to meet California targets (in million metric tons)

“Climate change is the defining issue of our time — and we are at a defining moment.”

Antonio Guterres
United Nations Secretary-General²

INTRODUCTION

California is committed to reducing its greenhouse gas (GHG) emissions and achieving carbon neutrality in 2045 in order to reduce its contributions to climate change. The state’s regulatory and legislative actions are supported by residents, almost two-thirds of whom believe that climate change is already affecting our environment, and more than half of whom think global warming is a very serious threat to California’s future economy and quality of life.³

Pathway 2045 is an in-depth analysis to identify a feasible and economical route to realizing California’s GHG reduction goals (Figure 3) and achieve carbon neutrality in California at the lowest reasonable cost by 2045.

It examines how the economy must transform to meet the state’s goals and the policy, technology and market implications of that transformation. Pathway 2045 updates and extends an earlier SCE analysis, *The Clean Power and Electrification Pathway*,⁴ which focuses on the transition to 2030.

Pathway 2045 concludes that reaching California’s 2045 greenhouse gas goals is possible but will be a significant challenge for the state and requires a near-complete transformation of how the state sources and uses energy across all sectors of the economy. Getting to 2045 goals also requires meeting or exceeding intervening 2030 goals.

In Pathway 2045, economywide GHG emissions decline from 424 million metric tons (MMT) in 2017 to 260 MMT in 2030, and further, to 108 MMT by 2045. This meets the 2030 targeted goal of a 40% reduction from 1990 GHG emissions (Figure 2, page 2) and aligns with the 2050 goal to attain an 80% reduction from 1990 emissions (to 86 MMT).

Economywide decarbonization is achieved through:

- deep decarbonization of the electric sector
- significant electrification of transportation and buildings coupled with advanced energy efficiency
- use of low-carbon fuels for hard-to-electrify applications such as industrial and heavy-duty transportation.

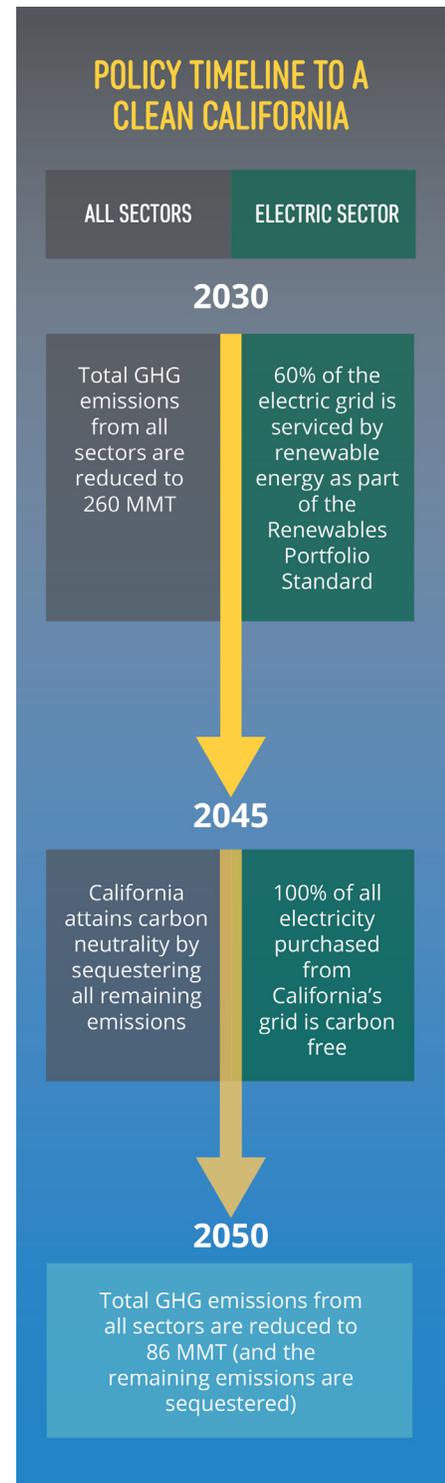


Figure 3: California policy timeline

The remaining carbon is assumed to be sequestered, either biologically or physically, to reach carbon neutrality.

This transition will largely rely on adoption and deployment of currently available technologies. However, commercialization of some emerging technologies will be needed to close the emissions gap.

APPROACH⁵

While a variety of scenarios (including high biomethane and high hydrogen scenarios) could theoretically meet California 2045 decarbonization goals, a high electrification scenario has been found to be among the most feasible and economical.^{6,7} Widespread electrification delivers significant efficiency gains because electric equipment and appliances are more energy efficient than those that rely on fossil fuels.⁸ Improvements in equipment efficiency, energy efficiency (EE) and demand response (DR) programs further lower customer consumption which helps to keep consumer costs affordable (Figure 4).

Pathway 2045 is an electric-led pathway⁹ designed to examine the implications of California’s long-term decarbonization goals on the electric sector and across the economy.

First, a decarbonization analysis identified the most feasible, cost-effective mechanisms to reduce GHGs across sectors of the California economy. Second, a detailed electric sector analysis examined two scenarios to inform the cost estimates and potential trade-offs of resource and grid development: the *Balanced* scenario focuses on both in-state and out-of-state resource development, including out-of-state transmission development, and the *Solar Heavy* in-state scenario, which does not exceed existing California Independent System Operator (CAISO) import limits.¹⁰ The objective of running two scenarios is to provide alternatives, not to conclude at this time that one or the other approach is the preferred path to 2045.

... a near-complete transformation of how the state sources and uses energy across all sectors of the economy.

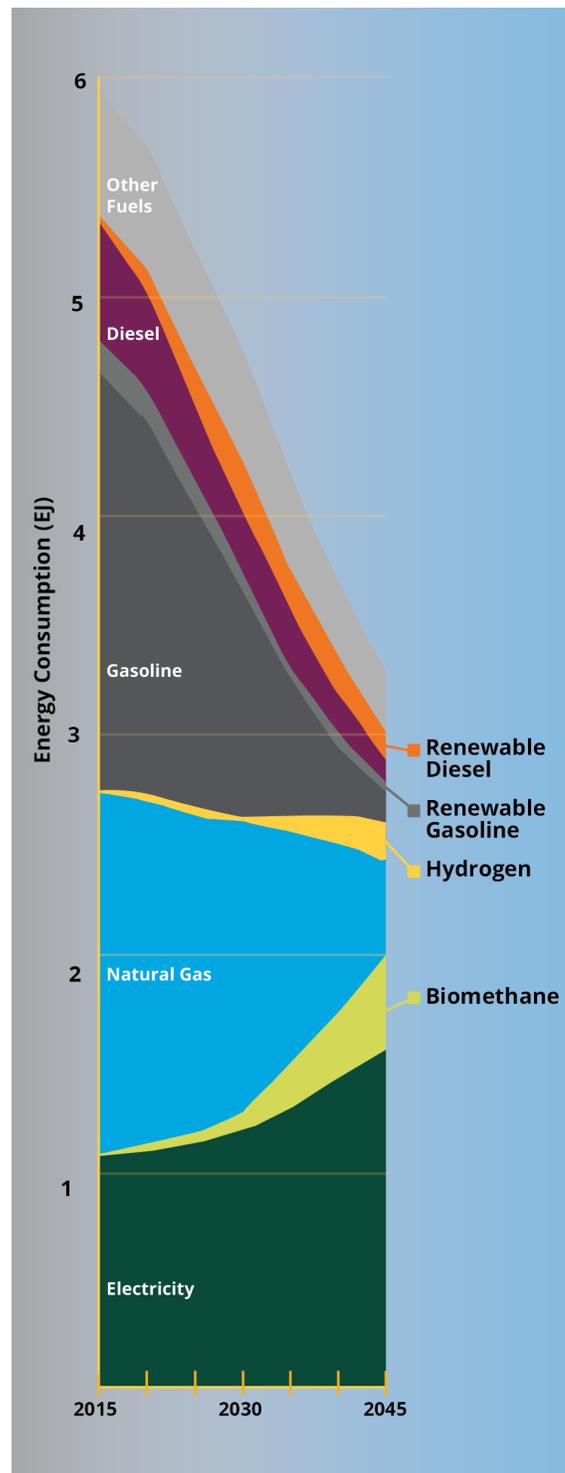


Figure 4: 2045 is powered by energy efficiency, clean energy and fossil fuel reductions

ELECTRIC SECTOR

Deep decarbonization of the electric sector is key for California to reach carbon neutrality, and long-term coordinated electric sector planning is critical.

Shifting energy demand from more carbon-intensive sectors to electricity will significantly increase electricity demand. By 2045, a greater reliance on electricity, combined with population and economic growth, will result in a 60% increase in grid-served electricity consumption (Figure 5) and a 40% increase in peak load. This load growth is a considerable departure from the past two decades of relatively flat demand.

California's SB 100 requires 60% renewable energy by 2030, as defined by the Renewables Portfolio Standard (RPS). RPS does not include all types of carbon-free electricity (it excludes large hydro and nuclear) and the state's energy providers are on track to meet this target. However, given both the 40% GHG reduction goal and the steep resource procurement ramp post-2030 to reach 100% carbon-free retail electric sales by 2045, the electric sector should provide 80% carbon-free electricity by 2030.¹¹

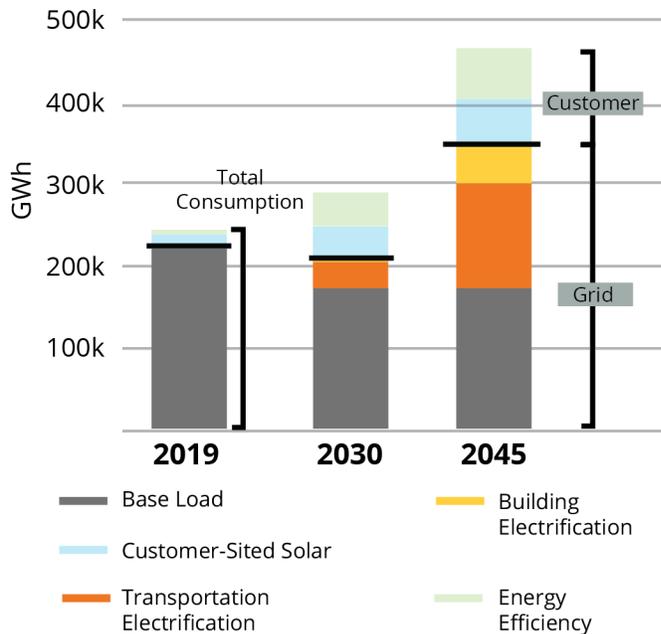
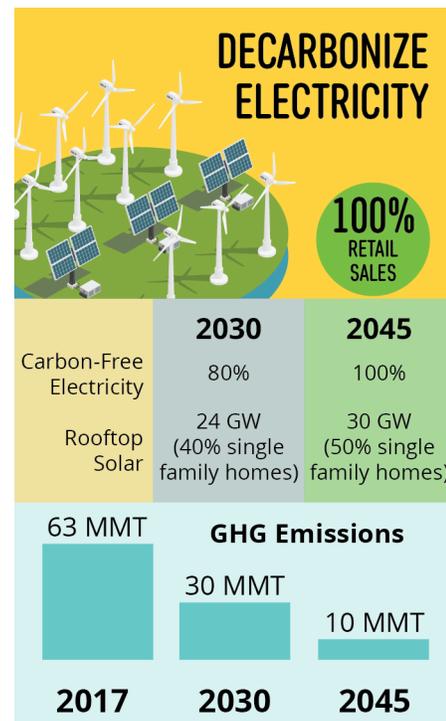


Figure 5: Increased demand is met through grid and customer-sited (distributed) resources



RESOURCE INVESTMENT

By 2045, more than 80 GW of additional utility-scale clean generation and 30 GW of utility-scale energy storage will be needed in CAISO's footprint.

This is an annual development rate two to three times higher than historical levels¹² and represents approximately \$170 billion of clean energy investment. It will require significant procurement and resource management coordination.* Integrated planning across jurisdictions becomes paramount as procurement and planning responsibilities continue to fragment. This level of clean energy investment will be an economic engine for California in the upcoming decades, creating thousands of sustaining craft and skilled jobs in resource development, grid construction and energy management.

* Land use, siting issues and battery supply chain/recycling issues are not addressed in the Pathway 2045 analysis.

As the economy becomes more dependent on electricity as its primary fuel, up to 50% of single-family homes in California are projected to have customer-sited solar, driven by improved economics, building codes and supportive but equitable policies. This will provide approximately 30 GW of generation capacity. Additionally, 10 GW of customer-sited storage is projected by 2045. Grid modernization will need to keep pace to ensure interconnection and interoperability of DERs with the grid.

COMPARATIVE RESOURCE SCENARIOS

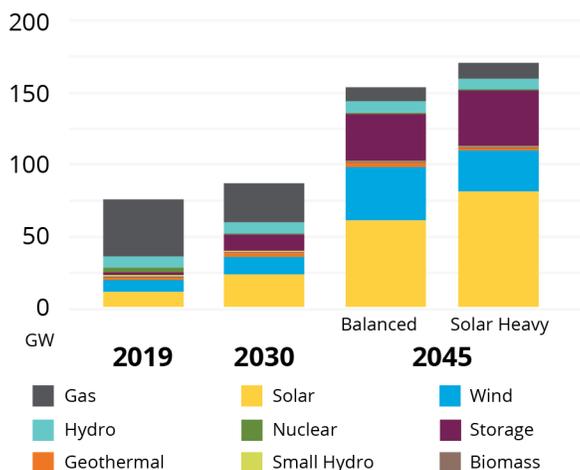
In both the *Balanced* and *Solar Heavy* scenarios, Pathway 2045 demonstrates that the projected need can be met with clean generation technologies that exist today (Figure 6).

The 2045 *Balanced* scenario relies heavily on in-state solar, wind and energy storage resources. California’s abundant resource potential and anticipated technological improvements allow three-quarters of the generation to be developed in state. However, the *Balanced* scenario also sources clean energy, primarily wind, from neighboring states (two-thirds of wind resources added are from out of state by 2045). Out-of-state resources and enhanced integration across state boundaries in the western grid provide greater resource diversity and flexibility but bringing these resources to the CAISO border requires additional transmission investments.

The *Solar Heavy* scenario relies more on new, in-state solar and energy storage and less on out-of-state wind (only half of wind resources added are from out of state by 2045). This scenario requires more resource capacity, but by using more in-state resources, requires less transmission relative to the *Balanced* scenario. Land use constraints that were not modeled in this scenario could limit the amount of in-state development that is feasible.

Both scenarios use longer-duration storage in 2045 compared to the typical four-hour duration used through 2030. Sixty percent of the storage used in the *Balanced* scenario and 70% of the storage used in the *Solar Heavy* scenario have durations of seven hours or greater. This longer storage duration is needed to replace the function of today’s dispatchable generation.

Alternative solutions beyond solar, wind and storage, including offshore wind and advanced geothermal, were included as resource options in both scenarios. However, the costs of these technologies were too high to be selected and will need to be significantly reduced to be competitive.¹³



While the current cost differential between scenarios in 2045 is within 5%, both scenarios have uncertain future costs given the type, location and quantity of resources needed. Decision-making should be based on a holistic approach that considers the complexity and interdependencies among factors such as in-state, land-use constraints, length and difficulty of siting processes, and other states’ policies that may restrict California’s access to their resources.

Figure 6: Comparative capacity mixes (in GWs)

RESOURCE ATTRIBUTES

Resource attributes are the most important elements to consider when planning across decades. For the purposes of this modeling, specific resources were selected that today are predicted to most cost-effectively meet demand in 2045. Pathway 2045 intends to be resource agnostic, however, if a specific technology reveals itself to be more effectual and cost-competitive than what has been modeled, then that technology should be selected in future planning and procurement activities.

GRID INVESTMENT

From 2030 to 2045, grid investments of up to \$75 billion will be required to integrate bulk renewable generation and storage and serve the load growth associated with transportation and building electrification.

Transmission upgrades will be required for generation interconnections within the state and the doubling of CAISO's import capability to source out-of-state renewables. Investments are also required to address the local capacity area issues that occur with the projected retirement of many natural gas plants.

Utility-scale storage is used to balance load and resources and to minimize transmission and distribution upgrades. However, energy storage cannot fully offset traditional grid upgrades given both the significant load growth and the limited charging window offered by bulk solar (Figure 7).

Distribution grid upgrades will be required to meet increased demand and peak loads. Some of these may be offset by DER solutions that can include managed charging and shifting

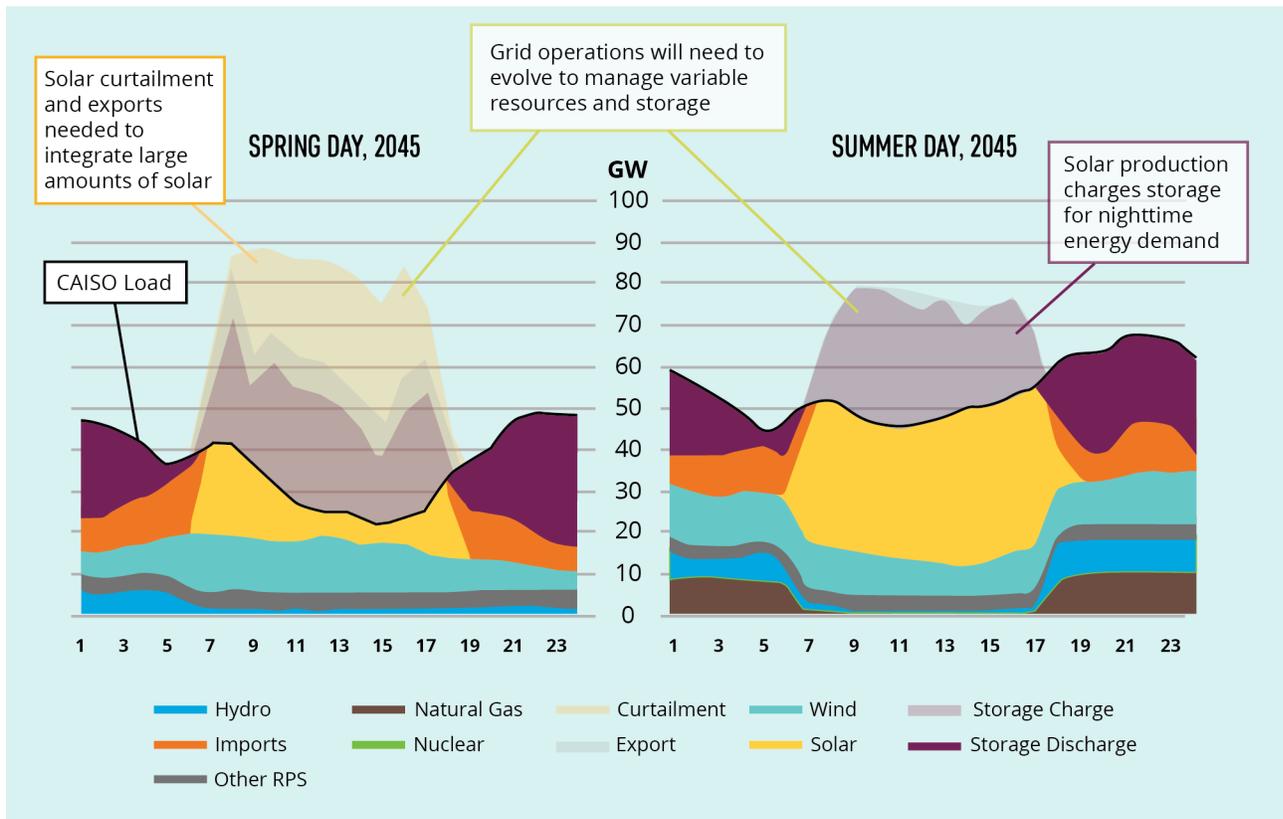


Figure 7: Resource mix of the decarbonized grid

the timing of customer usage through smart homes and other technology advances. Additionally, homes with solar and storage will provide increased load flexibility and resilience, including increased protection from power disruptions.

Customers should always be able to rely on the electric system. This is why new electric system designs and standards must be developed to create a grid that is resilient to more frequent extreme weather events brought on by climate impacts. Building on the grid hardening technologies that are being deployed today (such as the accelerated installation of insulated wire and advances in protection and control technologies) the new grid must include real-time diagnostics that can identify and isolate anomalies and weaknesses, while also facilitating deeper integration of DERs.

GRID OPERATIONS

In 2045, solar and wind will contribute the bulk of the energy supply across most hours of the day and 68% of the annual energy needed to serve grid demand. Natural gas generation, by contrast, will contribute 6% of the annual energy needed to serve grid load and will be used primarily to fill the gaps during high-load or low-renewable-generation periods. Curtailment of solar generation will be required during low-load, high-renewable-generation periods, creating a significant opportunity for storage or load management technologies that can use this excess energy.

With the dominance of intermittent solar and wind and the projected retirement of natural gas plants that provide significant amounts of steady, controllable energy, grid operators will need to evolve their operations to manage storage resources and

flexible customer loads (such as electric vehicles and building systems) to maintain grid stability.* More planning studies are needed to address how to reliably operate a decarbonized grid and to better understand worst-case weather scenarios. California's resource adequacy program, planning standards and energy markets may need to undergo comprehensive reform to manage this new fleet of variable, shiftable resources (Figure 7, page 7).

NATURAL GAS AND LOW-CARBON FUELS

Today, natural gas provides 46% of in-state (CAISO) generation, supplies 90% of the energy used in space and water heating and offers grid services. It provides thermal energy for industrial heating processes and supports combined heat and power services for customers with large energy needs, such as manufacturers, high-rise office buildings and hospitals.

Pathway 2045 shows significant reductions in natural gas use across the economy. However, some natural gas continues to be deployed because removing it completely from the 2045 electricity landscape would significantly increase resource costs. Compared to the *Balanced* scenario, if the remaining 10 GW of natural gas capacity was eliminated from the electric system, average annual resource costs would rise nearly 40% post-2030 to account for increased out-of-state wind, pumped storage and geothermal capacity. Until alternative cost-effective technologies are available to provide grid services and energy during infrequent but expected weather patterns, natural gas generation capacity provides a crucial role in keeping the grid reliable and affordable.

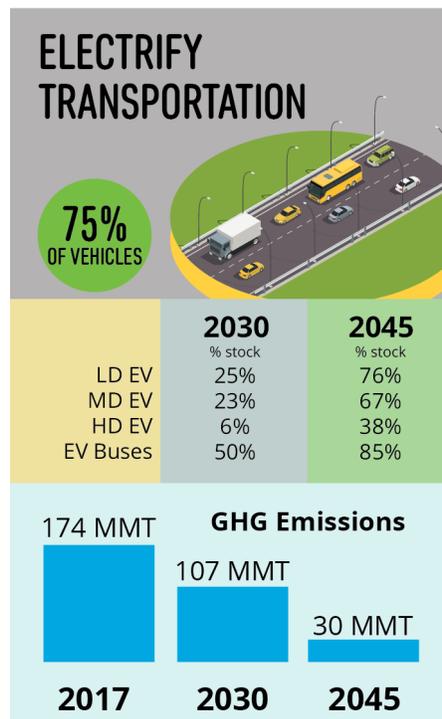
* Key aspects of grid stability include inertia, active and reactive power control, fault ride-through and black start power.

Transitioning away from natural gas use in electric generation and buildings will have the largest impact on reducing overall pipeline gas consumption (50% reduction from today's levels, equivalent to approximately 1,000 billion cubic feet). The industrial sector will consume the largest share of the remaining gas in the system due to hard-to-electrify applications, such as high-temperature industrial processes.

The natural gas that remains will need to be decarbonized through the addition of biomethane and hydrogen. Each of these low-carbon fuels have specific technological and cost challenges. Research and development are needed for these technologies to be commercially viable before 2045. Biomethane production costs and environmental impacts vary significantly with the feedstock and production process used.¹⁴ Hydrogen challenges include high production and transportation costs.

As demand for natural gas declines, fixed infrastructure costs and ongoing system maintenance costs will be spread over a diminishing number of customers. If current investment and cost allocation trends continue, residential and commercial gas rates in 2045 could significantly increase from 2020.^{15,16}

California policymakers will need to examine investment strategies to avoid stranding natural gas investments. Fossil infrastructure needs to be assessed through the lens of future reduced demand, and — when demand cannot be sustained through 2045 — substitute investments in electrification need to be incentivized and cost impacts on remaining gas customers need to be managed.



TRANSPORTATION

Decarbonizing the transportation sector requires widespread vehicle electrification. However, in hard-to-electrify applications, such as ballast tractors or long-haul tractor-trailers that cover hundreds of miles and need to refuel quickly, other technologies including hydrogen and biofuels may also prove important.

RESULTS

Based on current car ownership and usage patterns,* three-quarters of light-duty vehicles, two-thirds of medium-duty and one-third of heavy-duty vehicles, will need to be electric by 2045 (Figure 8, page 10).

* The future of personal vehicle usage is outside the purview of this analysis; hence, this analysis relies on current usage/ownership patterns. The emergence of ride sharing, autonomous vehicles and evolving travel patterns could reduce the number of vehicles needed in 2045, however, it is unclear the impact this may have on vehicle miles traveled.

Transportation electrification will increase electric load by nearly 130 terawatt hours (TWh) — representing more than one-third of the grid-served load. Faster charging rates and higher concentrations of vehicles will require grid upgrades. To minimize these upgrades, vehicles will need to charge in locations and at times that reduce the stress on the grid. While Pathway 2045 does not consider the application of vehicle-to-grid (V2G) technologies, with such a large electric vehicle fleet in 2045, having access to even 5-10% of the vehicle fleet for battery capacity could have a substantial impact on resource needs.

IMPLICATIONS

Achieving 2045 goals is significantly more difficult if interim 2030 goals have not been met. Public awareness of EVs and the benefits associated with them continues to lag.¹⁷

In light-, medium- and heavy-duty vehicle electrification, vehicle model availability and at-scale electric fueling infrastructure continue to be barriers to adoption. Addressing these barriers in the early years is critical to drive technology improvement, product availability and the diversity of the customer base. This in turn can help bring price parity between EVs and internal combustion vehicles by 2030.

There are opportunities for biofuels and hydrogen to play a role in transportation for those medium- and heavy-duty vehicles that are not suitable for electrification. Given that biofuels produce criteria pollutant tailpipe emissions,¹⁸ Pathway 2045 only uses them in hard-to-electrify segments. In this analysis, approximately 1 billion gallons of renewable diesel and biodiesel are consumed in 2045, representing almost 50% of the total diesel fuel consumed.*

Hydrogen could be the fuel source for a material portion of vehicles (Figure 8). However, significant progress, requiring technology improvements, will need to be made in vehicle availability and fuel production and distribution for this result to be realized.

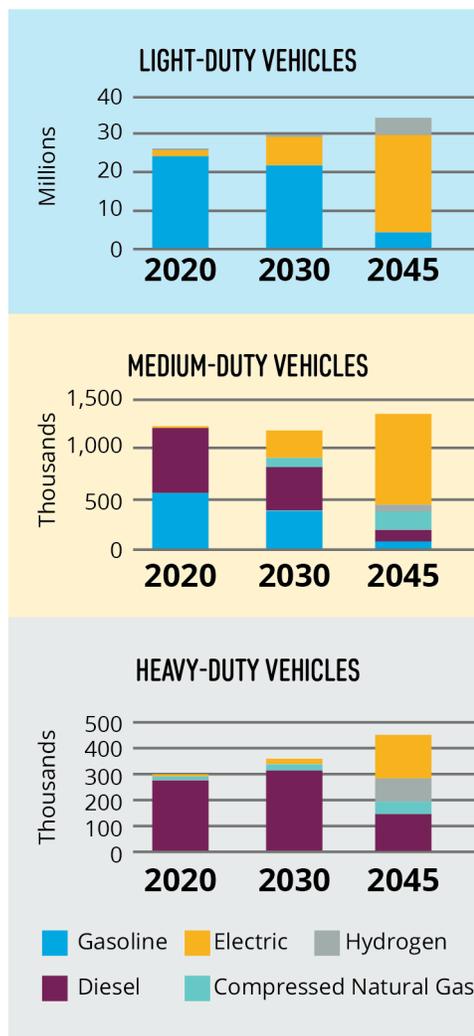


Figure 8: Vehicles by fuel sources

Getting to 2045 is significantly more difficult if interim 2030 goals have not been met.

* Energy Information Administration's Annual Energy Outlook 2019 (AEO2019) projects 2 to 5 billion gallons of renewable and biodiesel to be consumed in the U.S. in 2045. AEO2019 does not contain a scenario with deep decarbonization targets. This would likely show higher demand with increased renewable diesel and biodiesel production to match.



BUILDINGS

GHG emissions from the commercial and residential sectors today are dominated by natural gas for household and commercial business use, such as space heating, cooking and hot water or steam generation.¹⁹ Emissions from building electricity use, such as air conditioning, lighting and refrigerators, are already accounted for in the electric power section of the analysis.

RESULTS

Building electrification today reduces total GHG emissions in single-family homes by 30% to 60% relative to a natural gas-fueled home. As electricity gets cleaner, these reductions are estimated to increase to almost 90% by 2050.²⁰ Continued advances in energy efficiency will reduce the amount of electricity consumed.

Approximately one-third of building space and water heating will need to be electric by 2030 and almost three-quarters by 2045. Building electrification will increase electric load nearly 50 TWh by 2045 — representing almost 15% of the total 2045 grid load. Like transportation, buildings offer an opportunity to provide flexible loads, which can be optimized to use power when it is most efficient and reduces grid upgrade costs. In 2045, California’s grid will continue to be a summer peaking system driven by air-conditioning loads, however space heating electrification during the winter will improve system utilization.²¹

IMPLICATIONS

Achieving customer conversions from natural gas to electric technologies requires customers to understand and realize the benefits of electrification. Electric alternatives and trained technicians to install and maintain them need to be easily available. Challenges with building retrofits in the rental market where owners make investments but tenants see bill savings, will also need to be addressed. Easy-to-access and inclusive financing, incentives and optimized utility pricing must be available to help offset the initial costs of conversion to electric (including panel upgrades) and provide ongoing affordability.

Building electrification helps California meet climate adaptation and equity goals. For builders and buyers, all-electric new homes can reduce building costs when compared to mixed-fuel new homes.²² For residents, especially in vulnerable communities, heat-pump HVAC systems, which provide both air conditioning and heating, can help protect public health as heat waves become more severe and non-air-conditioned homes will be less tolerable.

INDUSTRY

California's industrial sector is diverse — comprising refineries, oil and gas extraction, cement plants, manufacturing and waste. From a technological standpoint, industry presents diverse and difficult decarbonization challenges. Its many subsectors employ a range of industrial processes, many highly energy intensive, heavily reliant on high-carbon raw materials or requiring a large, steady supply of natural gas. While the sector contributes significant GHG reductions to the economy, it also consumes most of the remaining carbon-based fuels. Pathway 2045 does not assess the competitiveness of California industries after GHG abatement actions are taken. This important issue needs to be addressed as California continues to decarbonize.

The industrial sector reduces GHG emissions from 101 MMT CO₂e (CO₂ equivalent) to 74 MMT CO₂e by 2030, and to 37 MMT CO₂e by 2045, through a 40% reduction of methane emissions, a 35% reduction of gasoline production and 70% electrification of HVAC systems, in addition to use of low-carbon fuels for process heat.

CARBON NEUTRALITY

To achieve carbon neutrality, the equivalent amount of GHGs remaining after decarbonization efforts must be removed from the atmosphere. This sequestration process can be achieved through additional natural resources that absorb CO₂ from the atmosphere, such as trees, or through engineered solutions — although most engineered solutions, such as carbon capture and storage and direct air capture, are still nascent technologies. California's natural and working lands

provide one option for sequestration. State action to minimize wildfire threats, restore natural lands and manage agricultural soil will store carbon and enhance the land's resilience to worsening climate impacts.

Affordable carbon sequestration is a significant challenge — and sequestering 108 MMT of CO₂e in 2045 will require deploying every viable resource. California should take a leadership role in this area by piloting new technologies over the next decade.

AFFORDABILITY

Decarbonizing California's economy is only going to be successful if the transition remains affordable to all of California's consumers, including California's most vulnerable residents. The question that California needs to answer is not if it can afford to achieve its long-term decarbonization goals, but what is the most feasible, cost-effective path to do so.

Pathway 2045's economywide net annual incremental costs in 2045 is \$33 billion (in 2019 dollars) relative to a baseline case which does not meet California's GHG reduction targets but includes SB 350 and SB 100. This cost assessment includes the upfront, annualized capital costs and the expected fuel costs net of savings incurred from all GHG abatement mechanisms chosen. It does not include any societal benefits from reduced emissions.

... a decarbonized, electrified world produces energy savings for an average household.

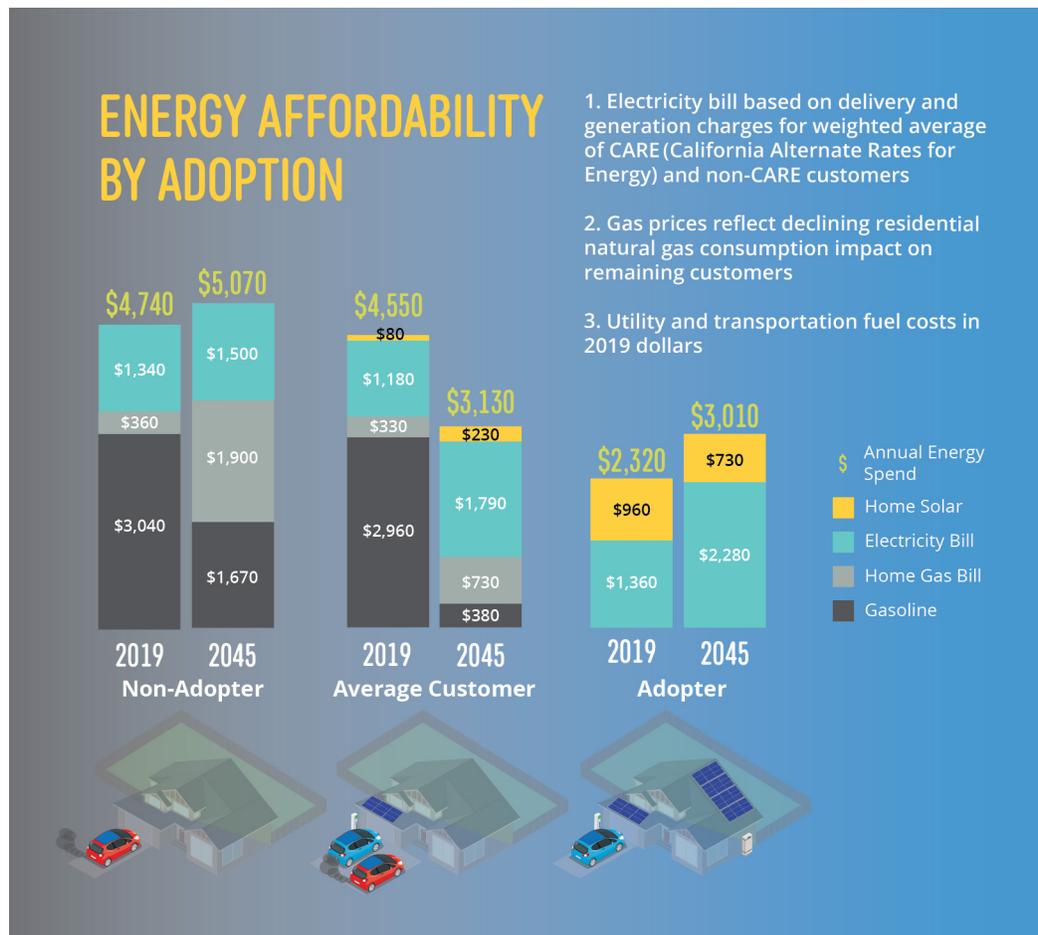


Figure 9: Annual energy costs for residential households (using SCE data)

California must manage the macro-economic costs associated with GHG reduction through thoughtful, coordinated policy and actions that address both the costs of adoption and energy costs post-adoption.

The good news is that, when assuming reasonable cost and efficiency improvements over time,²³ a decarbonized, electrified world produces energy savings for an average household (Figure 9) due in part to significant energy efficiency gains (Figure 4, page 4). While electricity bills increase over time, the energy consumption cost for an average household decreases by one-third by 2045. Household savings are driven by reduced gasoline consumption due to the high market penetration of electric vehicles.

As the economy progresses toward decarbonization, a mixture of clean energy adopters and non-adopters will emerge. Non-adopter energy consumption costs are almost double that of adopters. Over one-third of a non-adopter's energy consumption costs stem from home gas bills by 2045²⁴ because the total natural gas system infrastructure costs are shared among a smaller set of customers. This disparity between adopters and non-adopters needs to be addressed proactively through appropriate policies.

POLICY DIRECTION

While Pathway 2045 charts a long-term course, given the long planning and infrastructure life cycles (Figure 10), clear and robust policy actions in 2020 and the next few years will be pivotal in defining California’s clean energy trajectory.

FOSTER CONSUMER ADOPTION OF END-USE TECHNOLOGY

Adequate and reliable funding for vehicle purchase incentives is required to bolster zero-emission vehicle adoption levels until the markets are self-sustaining. This should be complemented by phased-in regulations for vehicle emissions, air-quality and vehicle technology requirements. Additionally, deployment of public charging infrastructure at scale in the right locations needs to be accelerated through swift regulatory and municipal decisions.

Accessible up-front incentives and financing assistance for purchases and retrofits will incent growth in residential and commercial space and water heating electrification. Updating building codes and standards for new homes by 2025 will be essential.

Targeted and coordinated DER programs and time-of-use rates can be used to encourage customers to reduce energy use at peak times and to invest in behind-the-meter energy storage. Robust programs that reinvigorate energy efficiency and tie it to GHG reduction can support customer adoption of energy saving behaviors and equipment.

ADVANCE CLEAN RESOURCE DEVELOPMENT AND SUPPLY

California’s current path for electric system resource planning makes reaching even 2030 GHG reduction targets challenging. The California Public Utilities Commission (CPUC) Integrated Resource Planning (IRP)

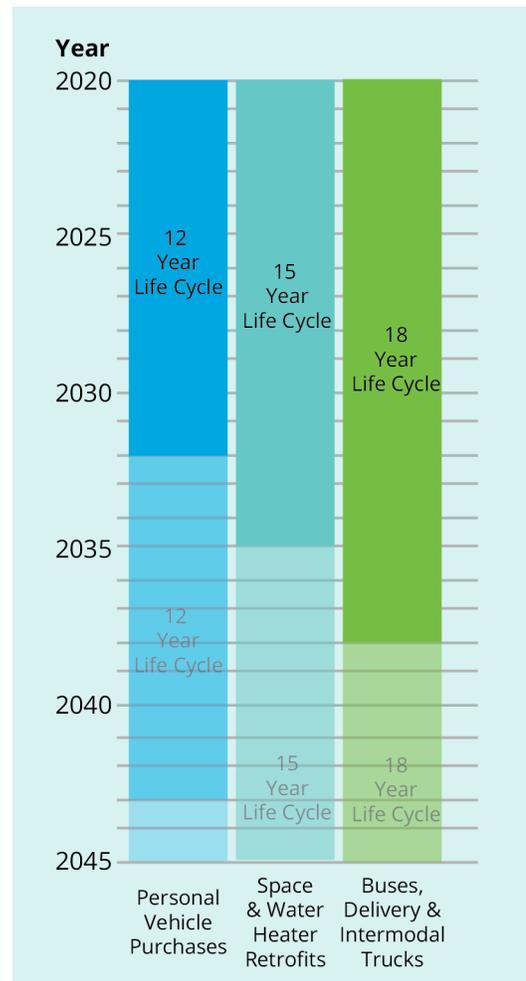


Figure 10: Equipment life cycles

process provides a ripe opportunity for inter-agency coordination to secure the appropriate pace of clean resource development by:

1. California Air Resources Board setting cross-sector GHG reduction targets that mirror the state’s 2030 and 2045 goals,
2. California Energy Commission reflecting appropriate levels of increased electrification and DERs when forecasting load in the Integrated Energy Policy Report, and
3. CPUC adopting enforceable IRPs that require all load-serving entities to preserve reliability while meeting decarbonization goals.

The state must also rationalize current retail choice models with future long-term wholesale procurement requirements and evaluate efficient regional energy markets if in-state development is constrained.

BUILD AND OPERATE RELIABLE AND RESILIENT ENERGY SYSTEMS

Evaluation of cost-effective options for scope and scale of interconnections, capacity upgrades and DER interoperability beyond 2030 must be undertaken in parallel with determination of precise location and volumes of future resource development. This must happen in coordination with resiliency planning for wildfires and climate adaptation. Besides accounting for higher electrification in load forecasts, lengthening the system planning windows will afford more efficient and effective scenario planning for system improvements while maintaining optionality. Approval processes for infrastructure deployment that provide flexibility during licensing, permitting and construction, such as establishing programmatic environmental reviews for suites of infrastructure options, will enhance the utilities' responsiveness to emergent or changing needs.

FILL TECHNOLOGY GAPS

Scalable innovations are needed for:

1. Clean power production, including biomethane and hydrogen technologies,
2. Grid design, analytics and DER integration, and
3. End-use electrification and energy management.

Technological progression to improve performance efficiency, reduce costs and diversify product offerings will be accelerated if government funding along with targeted public-private partnerships prioritize R&D and pilot projects.

PROMOTE EQUITABLE PARTICIPATION

Decarbonization will come with costs, but incentive and pricing policies must target clean power opportunities in vulnerable communities and help prevent any customer group from being disproportionately burdened. It is crucial to assess affordability and cost-effectiveness using the total financial impact of energy, not just electricity costs. Customers who are least able to transition to other fuels must be protected from being stranded with high-carbon costs. Regulatory processes should be initiated that address infrastructure decommissioning and rate structure modifications to provide an orderly transition away from fossil fuels.

The clean energy transition is a tremendous opportunity for California. Helping our workforce develop and evolve by funding programs that increase opportunities in clean energy fields will provide additional avenues to uplift the economy and society.

The state has initiated and implemented many green policies, but much work remains to ensure that an effective policy framework is in place for the clean future Californians seek.

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24. Appendix

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