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Holland & Knight References (2 of 11)

The attached document is the second of 11 separate uploads that contain the references cited in Holland & Knight's DEIR Comment Letter.

Additional submitted attachment is included below.

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ENERGY INSTITUTE BLOG

Rooftop Solar Inequity

California's distributed solar policy hurts the poor. It really is that simple.

California regulators and legislators are diving back into Net Energy Metering (NEM) policies, debating how much customers with their own solar systems should receive for producing electricity. Since the 1990s, customers have been paid nearly the full retail price for electricity they export to the grid. With residential prices **about double (https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a)** any other western state, that means California regulators offer a sweet deal to solar households. And it's getting sweeter every year as our electricity prices rise.

As **numerous (https://energyathaas.wordpress.com/2018/09/17/the-electricity-price-isnt-right/) EI (https://energyathaas.wordpress.com/2021/03/08/ensuring-equity-in-californias-energy-transition/) blogs**

(https://energyathaas.wordpress.com/2021/04/05/californias-billion-dollar-energy-bill-question/) and **research (https://ei.haas.berkeley.edu/research/papers/WP294.pdf)** have **pointed out (https://haas.berkeley.edu/wp-content/uploads/WP314.pdf)**, however, California retail prices are 2-3 times higher than the actual cost avoided when a rooftop system pumps kilowatts into the grid. The retail prices are so high, because they are paying for massive fixed costs, expenses that don't decline when a household exports solar power to the grid. These include most transmission and distribution costs, wildfire mitigation (think cutting trees and bushes around power lines), compensating past victims of wildfires, paying for energy efficiency programs, subsidizing electricity for low-income customers, and making early investments in new renewable technologies to help them get a foothold.

(https://energyathaas.files.wordpress.com/2020/02/solar.jpg)

When a household installs solar in the service areas of the three California investor-owned utilities (PG&E, SCE and SDG&E), the customer saves 20-30 cents for every kilowatt-hour their system produces, but the utility costs only **go down by 7-9 cents (https://haas.berkeley.edu/wp-content/uploads/WP314.pdf)**. (Studies that reach similar conclusions **here (https://www.cpuc.ca.gov/uploadedFiles/CPUC_Website/Content/Utilities_and_Industries/Energy/Reports_and_White_Papers/Feb%202021**

%20Utility%20Costs%20and%20Affordability%20of%20the%20Grid%20of%20the%20Future.pdf), here (https://haas.berkeley.edu/wp-content/uploads/WP294.pdf), and here (https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M363/K013/363013287.PDF) — none paid for by entities with a financial stake in the answer). The extra 10-20 cents are avoided by that household, but those fixed costs still have to be paid. So rates go up for everyone else.

It has been well documented – and surprises no one – that households with solar **are disproportionately wealthy (as well as disproportionately white)** (https://emp.lbl.gov/publications/residential-solar-adopter-income-and). So, when a customer installs solar, their share of the fixed costs are shifted to other ratepayers who are poorer on average. Net Energy Metering hurts the poor. It's that simple.

(https://energyathaas.files.wordpress.com/2015/05/topazsolarfarm.jpg)

"But wait," comes the voice of a residential solar advocate, "it's more complicated than that." And then comes a checklist of reasons why maybe it's not a cost shift onto the poor after all.

- **"That 7-9 cent utility savings calculation doesn't account for the societal benefit from rooftop solar power being clean and local, and displacing**

conventional generation that burns fossil fuels." *Actually, the calculation does account for reduced pollution, using recent estimates of the damage from both criteria pollutants and greenhouse gases. In fact, that number overstates the benefits of putting solar on rooftops, because the primary alternative these days isn't burning more fossil fuels. It's installing more large-scale wind and solar plants, which are 3-5 times cheaper according to the* ***latest*** (https://www.lazard.com/perspective/levelized-cost-of-energy-and-levelized-cost-of-storage-2020/) *Lazard independent analysis.* **("But the cost of CO2 emissions in your analysis is only $50/ton. It should be far higher."** *California has a very clean grid these days, so even doubling the cost of CO2 to $100/ton barely adds another cent to the societal value. And, the real alternative crowded out by new rooftop solar going forward is new large-scale solar and wind, which also produces no CO2.* **"But rooftop generation is closer to where the power is used so it saves on distribution costs."** *Except, the most credible estimates of those savings* ***are*** (https://energyathaas.wordpress.com/2018/06/25/does-rooftop-solar-help-the-distribution-system/) ***tiny*** (https://energyathaas.wordpress.com/2020/09/28/what-can-distributed-generation-do-for-the-grid/) *compared to the cost difference.)*

(Source: computerworld.com)

(https://energyathaas.files.wordpress.com/2021/01/netmetering5.jpg)

- **"What about the recent Clack et al [study (https://www.vibrantcleanenergy.com/wp-content/uploads/2020/12/WhyDERs_TR_Final.pdf)](https://www.vibrantcleanenergy.com/wp-content/uploads/2020/12/WhyDERs_TR_Final.pdf) that concludes distributed energy resources would lower the cost of reaching grid decarbonization goals?"** *A full discussion of the details of this study will have to wait for another blog, but (1) it models OPTIMIZED adoption of distributed energy resources, not the "save money by not paying utility fixed costs" incentive that is driving distributed solar installation in California, (2) it models solar plus storage, which accounted for just 5% of systems installed in 2019 (the most recent year for which Lawrence Berkeley Lab has put out data), (3) it does not model storage without rooftop solar, which would be interesting given that most of the benefits seem to come from the storage, and (4) it is a consulting report paid for by the rooftop solar industry (That doesn't mean that the conclusions are incorrect, but any industry-financed study should be looked at with additional skepticism).*
- **"Low income customers aren't hurt by the cost shift, because they get a special low rate, the California Alternative Rate for Energy (CARE)."** *Except CARE is, by law, a 30%-35% discount off the standard rate. So, when the cost shift pushes up the standard rate, it pushes up the CARE rate by 65%-70% as much. Not quite as bad, but still a cost shift onto the poor. And CARE only protects households with incomes less than 200% of poverty, which for a family of 4 is currently $53,000 per year. You aren't in poverty if you are slightly above that income, but in California you sure aren't making ends meet without a struggle.*

[(https://energyathaas.files.wordpress.com/2018/04/catinnovationfig1_2.jpg)](https://energyathaas.files.wordpress.com/2018/04/catinnovationfig1_2.jpg)

- **"Low income customers live in neighborhoods with greater exposure to local pollution from conventional electricity generation, which rooftop solar allows us to shut down."** *Except what is keeping fossil plants alive in California isn't a lack of solar. It's the need to balance supply and demand. There is now so much solar on our grid that we have plenty of supply during the times when rooftop panels are cranking out juice. What we need in order to shut down those neighborhood fossil plants is resources that can balance the system when solar wanes – storage, dispatchable renewables (hydro, geothermal), imports from other areas, and/or reductions in demand.*
- **"Rooftop solar is not the primary reason our rates are so high."** *That's true, those fixed costs mentioned above are the biggest factors. Except it is getting less true every year. NEM has made solar so lucrative for customers that well over half of all the solar on residential rooftops at the end of 2019 was installed in the previous four years (and by all accounts installations continued to accelerate in 2020). The cost shift from all that solar is growing at a disturbing rate. In 2019,* ***it accounted for*** (https://haas.berkeley.edu/wp-

content/uploads/WP314.pdf) *4.5 cents of SDG&E's 29 cent average residential price (2.5 cents of 26 cents for PG&E, 1.4 cents of 21 cents for SCE).*

- **"Utilities are cynically playing the equity card. They only care about increasing their own profits."** *Maybe, except the utilities are not the only, or even the loudest, voices calling for major reduction in the cost shift from NEM. The two most venerable California electricity consumer advocate organizations are leading the charge. (Here are links to the arguments made by* ***The Utility Reform Network*** **(https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M371/K664/371664446.PDF)** *and the* ***CPUC's Public Advocates Office*** **(https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442468355)***). One of the foremost environmental groups,* ***Natural Resources Defense Council*** **(https://www.nrdc.org/experts/mohit-chhabra/rooftop-solar-california-ready-take-next-step)***, is also on board. The other leading enviro groups – Environmental Defense Fund and Union of Concerned Scientists – are staying mum, but certainly aren't defending NEM as it currently works in California.*

- **"Solar may have been a high-income choice in the past, but a growing share of panels are now going to the poor."** *It indeed is not as overwhelmingly tilted as it was a few years ago, but it's still very tilted.* ***This*** **(https://eta-publications.lbl.gov/sites/default/files/solar-adopter_income_trends_final.pdf)** *report from Lawrence Berkeley National Lab finds that the median income of 2019 California solar adopters was about $120,000 versus* ***$78,105*** **(https://www.statista.com/statistics/205778/median-household-income-in-california/#:~:text=In%202019%2C%20the%20median%20household,state%20was%2070%2C489%20U.S.%20dollars.)** *for all households. That gap is down from about $140,000 versus*

> *$54,238 in 2010, which was practically the solar stone age. So the gap is closing, but not quickly. New installations today are still much more common among the wealthy than among low and middle income (LMI) customers, in part because LMI families are less likely to own their homes and, if they do, they have smaller roofs. Even if LMI households were someday represented proportionately among solar adopters, the LMI community as a whole would still be hurt by NEM. That's because households that install solar still pay way more than the 7-9 cents per kWh that the system as a whole saves. So the losses that other ratepayers have to cover are greater than the gains to the households that install the solar. Like customers at a casino, some people go home happy, but as a group they lose money.*

Sometimes a regressive cost shift really is just a regressive cost shift. It actually is that simple.

If state leaders still want to prioritize rooftop solar, they could avoid shifting costs onto low and middle income households (and also avoid discouraging electrification with sky-high rates) by subsidizing rooftop systems directly, and transparently, with a program covered by the state budget. Better yet, follow the recent design changes for **EV subsidies (https://cleantechnica.com/2020/01/05/california-offers-up-to-9500-to-purchase-a-used-or-new-electric-vehicle-focus-on-lower-income-motorists/)**: limit the rebates to households below a certain income threshold and/or to houses below a certain valuation. I would still rather see the money go to more cost-effective efficient-scale renewables, but direct subsidies may be a solution that everyone fighting for a low-carbon future can grumble about equally.

I still tweet mostly energy news/research/blogs @BorensteinS .

Keep up with Energy Institute blogs, research, and events on Twitter @energyathaas

Suggested citation: Borenstein, Severin. "Rooftop Solar Inequity" *Energy Institute Blog*, UC Berkeley, June 1, 2021, **https://energyathaas.wordpress.com/2021/06/01/rooftop-solar-inequity/** **(https://energyathaas.wordpress.com/2021/06/01/rooftop-solar-inequity/)**

Severin Borenstein

VIEW ALL

Severin Borenstein is E.T. Grether Professor of Business Administration and Public Policy at the Haas School of Business and Faculty Director of the Energy Institute at Haas. He has published extensively on the oil and gasoline industries, electricity markets and pricing greenhouse gases. His current research projects include the economics of renewable energy, economic policies for reducing greenhouse gases, and alternative models of retail electricity pricing. In 2012-13, he served on the Emissions Market Assessment Committee that advised the California Air Resources Board on the operation of California's Cap and Trade market for greenhouse gases. He chaired the California

19 thoughts on “Rooftop Solar Inequity” >

This argument that roof-top solar and net metering are the culprit for raising rates and cost shifting burden to the poor doesn’t make much sense. Following its logic, if instead of solar, a California home or business chooses to reduce its electricity usage by installing energy efficient appliances, LEDs, or simply turning off lights they would still be responsible for hurting the poor. Following its logic, the solution would be to encourage middle- and upper-income Californians to use more electricity so as to shift the fixed cost burden back.

Of course, these are silly ideas. One of the greatest success stories of the past 30 years is the ability of our state to reduce our energy intensity through technological advance and implementation of energy efficient devices and strategies, including roof-top solar. For purpose of the equity argument, the only difference between roof-top solar and other electricity saving measures is that roof-top solar has been tremendously successful. This success should be embraced and built on, rather than punished.

Mr. Borenstein identifies the real culprit early on: high fixed costs associated with the old central utility model which is increasingly poorly adapted to our state’s changing climate. Roof-top solar cannot be blamed for the devastation and cost of electricity transmission line induced fires or for the ongoing costs of crude mitigation strategies such as public safety power shut-offs. In fact, roof-top solar, coupled with battery storage, will be the solution that many Californians opt for.

Our electricity rate structures that attempt to cover these high fixed costs with energy usage-based rates are out of synch. Unfortunately, all Californians will need to bear the cost burden of the central utility legacy. We need to do this in a fair and equitable manner with a basis in logic: customers should not be singled out just because they decided to save electricity using solar as opposed to some other energy savings device or not at all.

Over the past 50 years, we've seen resistance to saving electricity from companies, bureaucracies, and individuals trained and invested in the old utility model. In the 1970s, it was energy efficiency. Today, its roof-top solar. All parties need to come together and establish a new regulation and rate making paradigm that works for all Californians. Let's embrace and take advantage of the opportunity that falling costs of small scale solar and storage present to address our climate challenges rather than engage in Texas style scapegoating.

Mac Moore

Yes, as Mac Moore points out, it is true that anyone who installs energy efficiency equipment and uses less energy shifts some of the burden of fixed costs to everyone else. A socialized cost, which has been bearable, is not silly but a demonstrate that we value that usage reduction. And there will continue to be such cost socialization as long as embedded costs are recovered through usage based charges. Rooftop solar with NEM is just much more efficient at making that shift because you get paid for surplus energy production, you don't just reduce your own usage. And if you have TOU rates the usage reduction (apart from the surplus energy) better targets the periods to which more costs have been allocated.

The phenomenon will not be eliminated by instituting demand charges — rooftop solar reduces peak demand as well as energy usage — although I don't think there is an NEM effect on demand charges. It's not even completely eliminated by instituting customer charges, since you'll have some cord-cutting (albeit not much). The phenomenon would only be eliminated by getting rid of the embedded costs. I htink that would require either accelerated depreciation (a greater near-term rate increase) or disallowance — THAT would be a "new ratemaking paradigm" but I don't see it coming about without scapegoating much greater than "Texas style".

What impact does residential solar have on reducing peak demand during the summer AC season, and thus the need for investment in peak demand generation capacity?
What impact does residential solar PLUS STORAGE have on reducing peak demand during the summer AC season, and thus the need for investment in peak demand generation capacity?

Right. The bugaboo about renewable generation has always been storage. When rooftop solar began, the peak was much earlier and the solar was a good thing. Now that that there is a lot more solar, the peak has moved later. So now they incentivize people (with resources) to have storage with their solar and that is what many of us do.

I personally am happy with having distributed storage subsidized because I can get some insurance for the unreliability of the grid that way, but that is wrong answer. Unfortunately it is the only kind of anwer the politic seems to allow. California's solar policy hurts the poor not because we incentivize too much, but because we make the remaining ratepayers pay for it instead of the State as a whole. We need to provide the correct incentive to get whatever the desired public benefit is and then pay for it ourselves.

Some would argue that we incentivize too much and that our solar infrastructure is over built. A reasonable question to ask, but if we have renewable generation objectives that we are not meeting, then we don't have to do too much studying. Maybe there are smarter ways to get the amount we want. We could Big Brother it with regulation. The State could build it and own it. But those don't seem very attractive options. If we want the private sector to do something that is otherwise not believed to be cost effective we must incentivize it.

"California's distributed solar policy hurts the poor. It really is that simple."

A point that can't be emphasized enough, Severin – both from a social equity standpoint, and one that recognizes the value of simplicity.

In energy circles, the prevailing view seems to be that complexity can solve the problem of climate change – that if we have enough sources of clean energy, if the wind blows when the sun doesn't shine and vice versa; if we can convert solar power to hydrogen to power the grid at night; if large generation plants can be replaced by many smaller ones, it will somehow add up to a total solution.

Anyone with experience in physics or engineering will recognize that, in practice, the sum of parts always ends up being more problematic than the whole. Inefficiency, maintenance, and added expense are proportional to the complexity of any mechanical or energy system. And it's not just California's distributed solar policy – Germany's Energiewende can take credit for its host having the most expensive electricity of any non-island country (and a grid that, like ERCOT, came perilously-close to crashing in February).

"What we need in order to shut down those neighborhood fossil plants is resources that can balance the system when solar wanes – storage, dispatchable renewables (hydro, geothermal), imports from other areas, and/or reductions in demand. "

There isn't much evidence even all of those proposed remedies together would suffice. Lithium-ion storage is three orders of magnitude too expensive and short-lived to be practical. Existing geothermal/hydro resources are mostly spoken for.

CPUC is counting heavily on imports to take the place of Diablo Canyon's output after 2025. Like after the closure of San Onofre, however, they will likely be coal- and gas-fired electricity from other western states, greenwashed under the heading of "unspecified sources of energy". I don't think anyone would argue closing neighborhood fossil plants by importing electricity from over-the-border fossil plants qualifies as a satisfactory solution.

"The retail prices are so high, because they are paying for massive fixed costs…these include most transmission and distribution costs, wildfire mitigation…compensating past victims of wildfires…paying for energy efficiency programs, subsidizing electricity for low-income customers, and making early investments in new renewable technologies to help them get a foothold."

Investing in renewable technologies is a fixed cost? No doubt solar, wind and gas developers would like to think so. But in truth, it's no more fixed than another cost you left out: charging customers $4.5 billion to decommission a state-of-the-art, zero-carbon nuclear plant with 40 years of remaining service life. The fix is in on both, thanks to a governor with everything to gain, and LMI electricity customers with everything to lose.

Very well said, and spot on. Thank you Carl
Jim Harlan

There are zero up front cost solar options for home owners. There are also grid level solar plant investments available to those who would rather cast their lot in renewables that way.

Why would one chose to spend extra money every month to voluntarily subsidize grid level renewable generation for no personal monetary benefit, when they can install rooftop solar on their house, get paid retail with a 5-15 year payback, and their neighbors have to make up the addition cost? The incentives are counter productive, if the goal is decarbonization.

"And, the real alternative crowded out by new rooftop solar going forward is new large-scale solar and wind, which also produces no CO2."
Two issues arise with this statement. First, like with any generation resource, manufacturing, installing, maintaining and decommissioning rooftop solar does produce CO2. Solar and wind often also come with disproportionate environmental costs that are not yet fully embedded in net metering credits. Second, if the subsidies you highlight in your article were eliminated and net metering only paid the time-differentiated avoided costs,how likely is it that either rooftop

or large-scale solar and wind would economically remain a preferred resource? Adding more solar to an already afternoon surplus and wind to a late evening surplus might be expected to generate a declining avoided cost.

Azmat is right that when a fixed cost has to be allocated to a shrinking demand the unit price goes up. But that's not what's happening here; in addition to the denominator of the calculation increasing, the numerator is reduced by payments to departing load (think about how that would apply to the PCIA!).
Here's a numerical example. Suppose $360 of costs are allocated to 1000 units of demand; you get a unit cost of 36 cents. If 100 units of demand leave the system, then the 900 remaining units each have an allocated cost of 40 cents. But if those 100 departing units not only avoid paying the price, but get it paid to them, the unit cost increases to 45 cents – the increase itself more than doubles (900*.45 + 100*(-.45) = 360).
Now, the surplus rooftop solar energy injected to the grid is supplying something, namely energy. If the energy component of the rate represents the downward marginal cost of that energy it is a perfectly reasonable amount to pay for the surplus solar energy. But the surplus solar energy is not supplying any capacity unless it is offsetting load growth. The "duck curve" effect implies that there is no peak period load growth on the margin to offset. And, even if capacity were smoothly divisible – an assumption we make whenever we use the phrase "marginal cost of capacity" – the incremental and decremental marginal costs are not equal; the decremental cost is basically zero.

Very interesting and thought provoking article, Severin. Thank you.

Sometimes the truth hurts, although I do believe that the more rationale solar players in the residential marketplace are no longer leading with "you can make a bunch of money selling your excess electricity to the grid". And yes, not all grids are equal. The carbon intensity of different electric grids in different parts of the country vary, and, as you point out, the carbon intensity of the California Grid varies by time of day.

As residential storage becomes increasingly affordable and a standard offering, and as EV adoption increases it will be interesting to see how the underlying grid economics evolve. A rational and reasonable approach to NEM policy development for California is critical to the build out of an equitable 21st century electric grid.

They rob banks because that is where the money is.
When the State wants to incentize people to invest in somthing with societal benefits (e.g. in solar), they are going to attract people with capital. Guess what, that means it is people of higher incomes who will take advantage of it. If the State didn't want that outcome, it should not have done that kind of incentive program, but having done it, it should honor those deals in good faith. Much of the incentive for doing it comes from the high cost of electricity. (While the overall kW cost has been going up over the years, the NEM tariff has been getting steadily worse for rooftop solar as the original deals had a huge peak-to-off peak ratio which was more aligned with solar production.)

The problem comes from the fact that the burden for the grid incentives falls on the ratepayers. Infrastructure benefits the entire economy–not just the direct users. In the US we mostly pay for infrastructure through taxes not fees. We have FREEways not toll roads, in the main. If we wanted to decrease road building by incentivizing people to live close to where they work or ride-share, would we put increasing tolls on those who couldn't as we succeeded? That is as dumb as raising rates to pay for people to put on rooftop solar.

When I calculated solar for me, it was a 7-yr payback, which meant it was a good but not great investment. If NEM rates go down, the payback lenthens(or even goes away). If we want non-Thunbergians to invest, then we have to make it worth their while or not bother. That is the economics part. The equity part comes in when we consider how it is paid for.

The original sin here was paying for efficiency incentives from ratepayer funds. We were too clever in the "cost of conserved energy" and handling through the PUC rather than the legislature. That logic allowed us to waive our hands and call what is clearly a supply-side technolgy (i.e. solar) the same thing.

Rooftop solar is not a cost-effective choice for the consumer on its own. If it is societal benefit, then society must either do it directly, madate it or provide enough incentive to make it cost-effective. Society should not care who does the investing as long as the societal benefits accrue Societal benefits are normally paid for from the general fund, not user fees. This article mearly confuses that simple logic by mixing other issues.

Isn't the larger story – and culprit – the inherent inequities by how those 'fixed' costs are allocated in the first place? Recognizing that rate-making is always more complicated than the simple equations, isn't is also fair to say that allocating the fixed costs disproportionately on the poorer customers the regressive policy that should be addressed first (and to greater effect)? I'm hardly economically disadvantaged (and do not have solar) and yet my small home with no air conditioning pays the same proportion of 'fixed' costs as the mega-home across the street, even though their contribution to overall system costs (by using vastly more power during periods of high-cost peak power) is vastly higher than mine. Vastly. Why is the cost-shift question always framed around solar? For those of you who claim so much concern for the disadvantaged, how come there is never any concern about, for example, the air conditioner cost shift? Every one (and more) of the affluent homes you seem to be concerned about having solar unfairly subsidizing also have huge peak hour air conditioning loads (with or without solar) that is an order of magnitude more of an impact on overall system 'fixed' costs that we all pay for equally (and regressively). Air conditioning (and other large load that correlate with high-cost peak moments) should be far more concerning to those that profess to be concerned about the protecting the disadvantaged.

All new-tech, solar and EV, shift costs to those who cannot 'afford' to switch. Perhaps the same happened when the national highway system shifted train and bus riders to cars. The fixed costs of trains/buses didnt change much, but ridership went down, so fares had to increase. EVs [if not already so] should pay state taxes by miles driven. Rooftop solar should get credit only for the incremental production savings to the utility for generation-avoided at that time. [electrons are instantaneous, so technology CAN figure these easily].
Is this not similar to tax-reduction for the high-income shifting the tax burden [and-or reduction in services, that then become fee-based] for the rest.

The utility rates [option cost] for solar homes should be based on the HIGHEST draw from the grid.

Residential Solar-Adopter Income and Demographic Trends: 2021 Update

Galen Barbose, Sydney Forrester, Eric O'Shaughnessy, and Naïm Darghouth

April 2021

This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under Solar Energy Technologies Office (SETO) Agreement Number 34158 and Contract No. DE-AC02-05CH11231.

BERKELEY LAB

U.S. DEPARTMENT OF ENERGY

Report Outline

1. Introduction

- Overview and key findings
- Data sources and geographic coverage

2. Solar-Adopter Income Trends

- Temporal and geographic trends
- Solar-adopter incomes compared to the broader population
- Low-to-moderate income (LMI) shares of solar adopters
- Income trends based on:
  - Third-party ownership (TPO)
  - Installer
  - Battery-storage pairing
  - Multi- vs. single-family housing

3. Other Socio-Economic Trends for Solar Adopters

- Home value
- Credit score
- Education
- Occupation
- Rural vs. urban
- Race and ethnicity
- Age

4. Conclusions

5. Appendix

Overview

Report describes income- and other demographic trends among U.S. residential solar photovoltaic (PV) adopters

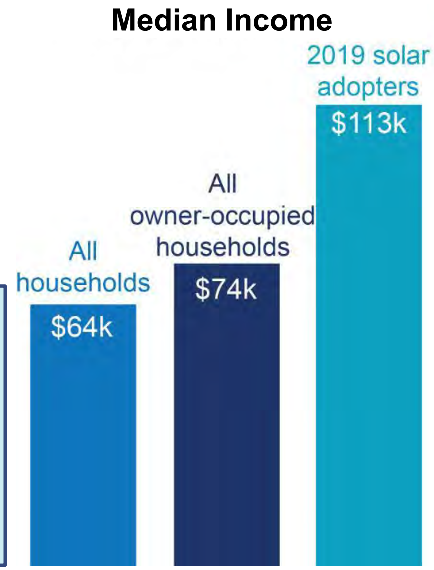
- Pairs Berkeley Lab's *Tracking the Sun* dataset and other sources of PV addresses with *household-level* income and demographic data: unique in both its level of market coverage and granularity
- Updates and expands previous reports with data on adopters through 2019 and an expanded range of demographic trends, beyond the prior focus primarily on income
- Intends to be descriptive and data-oriented; complements and informs other ongoing work at Berkeley Lab surrounding issues of solar energy access and equity, including:
  - An online data visualization tool that allows users to further explore the underlying dataset in this report
  - In depth analyses around drivers and potential solutions to solar energy adoption inequities
  - Institutional support to organizations working on solar energy access and equity

For further information on related research at Berkeley Lab, see:
solardemographics.lbl.gov

High-Level Findings

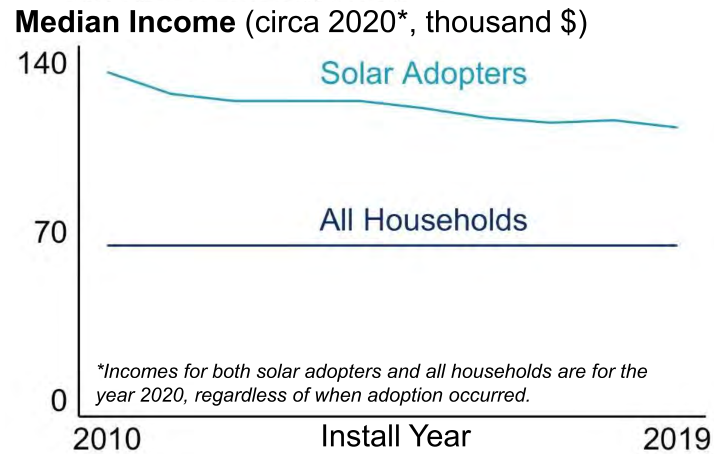
Solar adopter incomes vary considerably, but are generally higher than population averages

- The median solar adopter income was about $113k/year in 2019, compared to a U.S. median of about $64k/year
- The skew toward high incomes is particularly stark among adopters that own their systems and for those with paired solar-plus-storage systems



Low- and Moderate-Income Adoption
While solar adoption skews toward high-income households, low- and moderate-income households are also adopting. In 2019, about 42% of adopters earned less than 120% of their area's median income. (120% is a threshold sometimes used to include both low and moderate income)

Over time, solar adopters increasingly resemble the broader population



- The difference in income between solar adopters and the broader population fell from $72k/year in 2010 to $49k/year in 2019, at the median
- Solar adopters have become more reflective of the broader population in terms of education levels, race, and occupation
- These trends reflect the effects of falling solar prices and the emergence of policies and business models that support broader adoption, among other factors

Solar adopters vary along other demographics

Compared to the broader population, solar adopters tend to:

- Live in higher-value homes
- Have higher credit scores
- Have more education
- Live in majority-white block groups
- Be older
- Work in business and finance-related occupations

Data Sources

PV Street Addresses & System Data

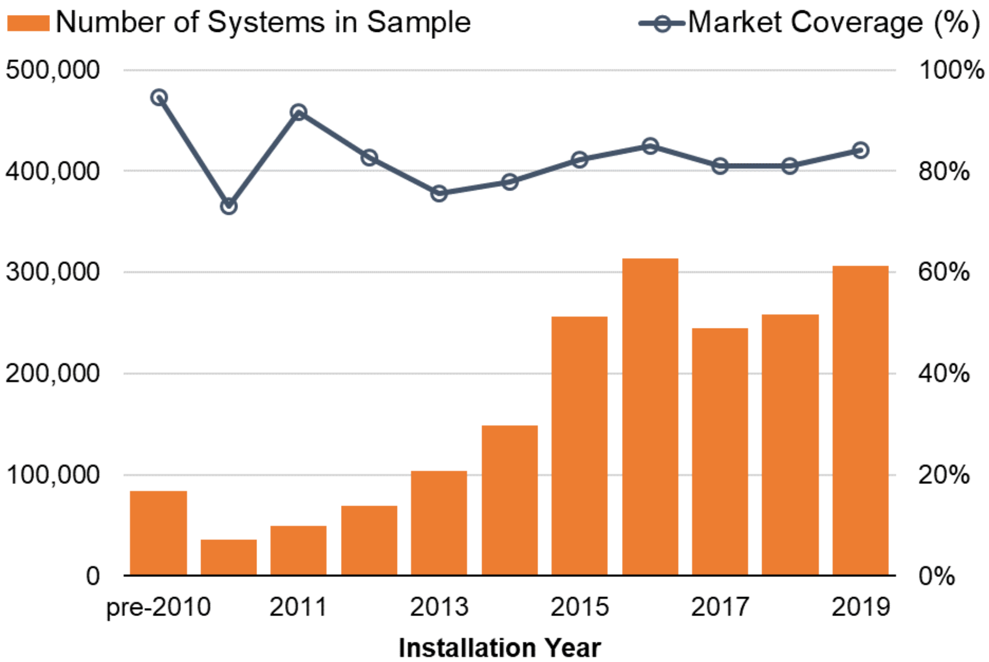
- Berkeley Lab's ***Tracking the Sun*** dataset: Primary data source; includes addresses and other data for roughly 1.5 million systems, obtained primarily from utilities and state agencies
- **BuildZoom** and **Ohm Analytics**: Purchased PV permit datasets; provide a supplementary source of PV street addresses for roughly an additional 400,000 systems

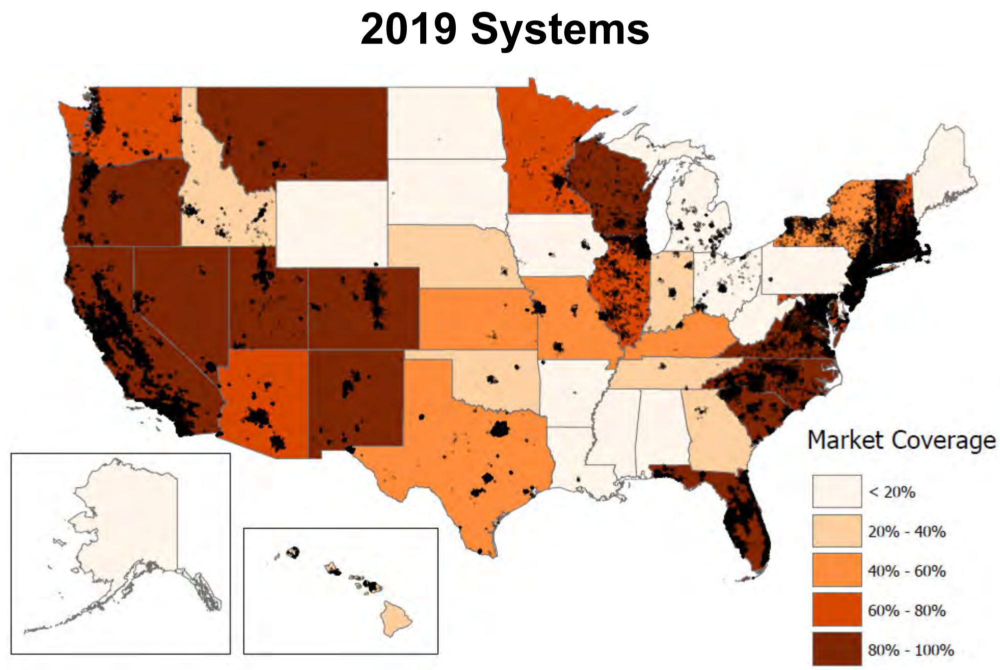
Income & Other Socio-Economic Data

- **Experian ConsumerView**: Purchased dataset providing modeled household-level income estimates for solar adopters and for population as a whole; as well as household data on other socio-economic attributes
- **U.S. Census** and **Bureau of Labor Statistics**: Used for comparison purposes to characterize demographics of total U.S. population

See appendix slides 38-39 for further details on income and other socio-economic data sources

Sample Coverage





Sample consists of **1.9 million systems**, covering **82%** of all U.S. residential systems through 2019 and **84%** of systems installed in 2019

See appendix slides 40-41 for further details on sample sizes

General Points on the Data and Descriptive Approach

- We focus here on national and state-level trends, with an emphasis on PV systems installed in 2019; additional data, including county- and Census tract-level trends, as well as data for earlier years, are available through Berkeley Lab's online data visualization tool
- Temporal trends are shown starting from 2010; data are available for earlier years but tend to be noisy, due to small sample size, and are heavily dominated by California
- Income estimates from Experian are based on the first quarter of 2020, regardless of the date of installation, and thus represent current incomes, rather than incomes at the time of adoption
- For all state-level figures, we present trends only if the underlying sample consists of at least 100 systems and at least 10% market coverage for the applicable state and year; see appendix slide 40
- Sample sizes vary across different elements of the analysis, depending on the underlying data sources and completeness of the associated data fields; see appendix slide 41 for details
- All comparisons of solar adopter incomes to Area Median Incomes (AMI) are based on household size; as used throughout this report, "Area" refers to the applicable U.S. Census Core-Based Statistical Area or county (for rural areas)

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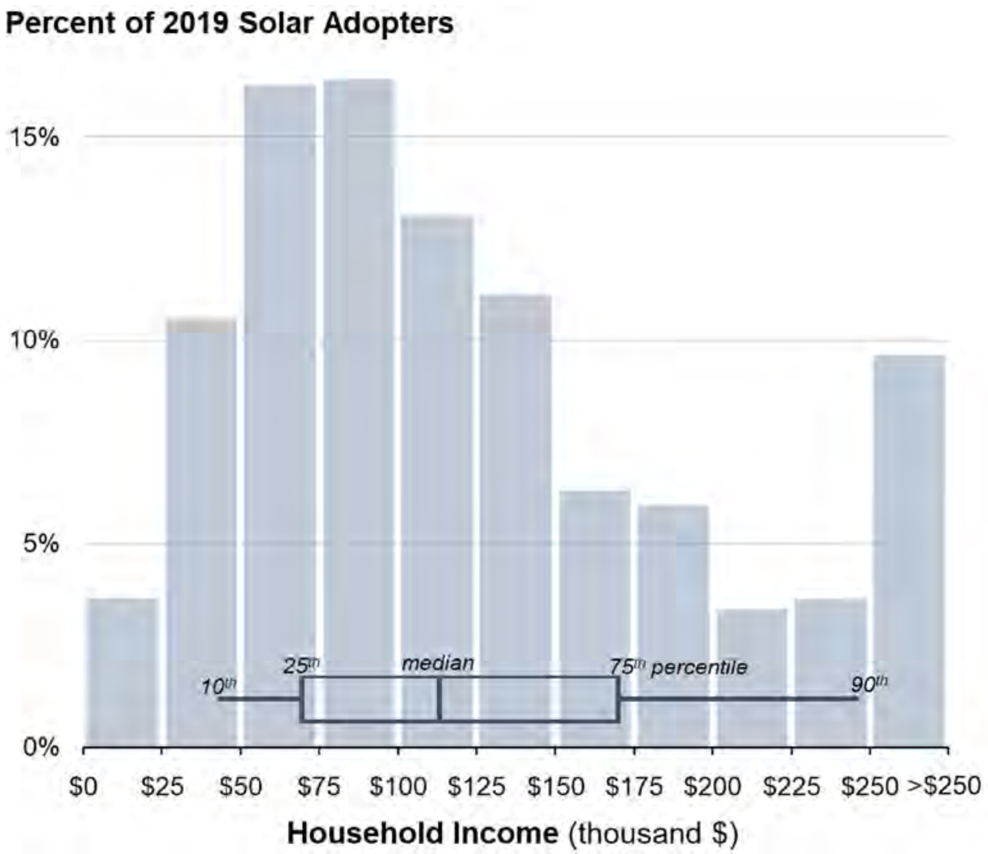
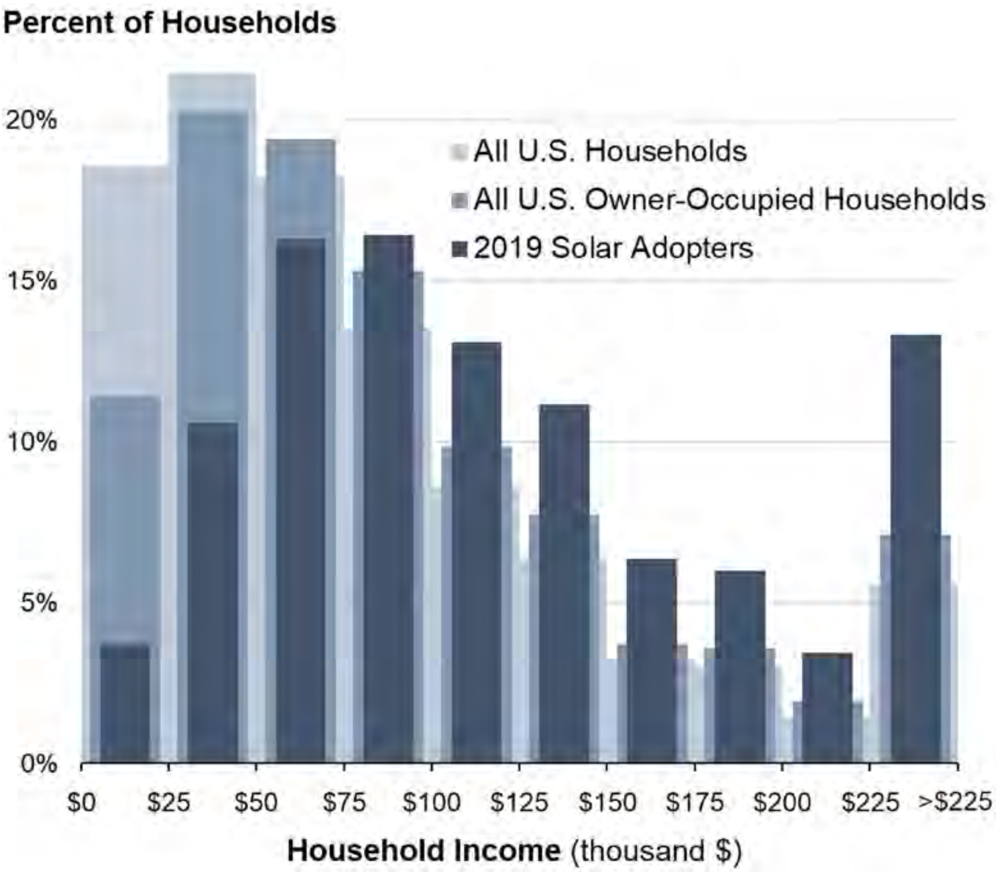
Solar-Adopter Income Trends

Solar-Adopter Income Distribution



- Solar-adopter household (HH) incomes span all income ranges
  - Distribution peaks at $50-100k, but with a long upper tail
- Median solar-adopter HH income was $113k in 2019
  - Half of 2019 solar adopters (the 25-75th percentile range) had incomes of $69-170k
  - While the large majority (10-90th percentile range) fell between $42-247k

Solar-Adopter Incomes Compared to Total U.S. Population



- Solar-adopter incomes skew high relative to the population at large
  - Median income of all U.S. HHs is $64k, compared to $113k for 2019 solar adopters
  - Disparities are most pronounced at the low and high ends of the income spectrum
  - The next set of slides provide a more refined set of metrics to characterize the degree of skew
- Skew is less pronounced if comparing to only owner-occupied households (OO-HHs)
  - Median income of all OO-HHs is $74k
  - Solar adopters in this study are almost entirely OO-HHs (due to owner-control of rooftop, owner/tenant split incentive)

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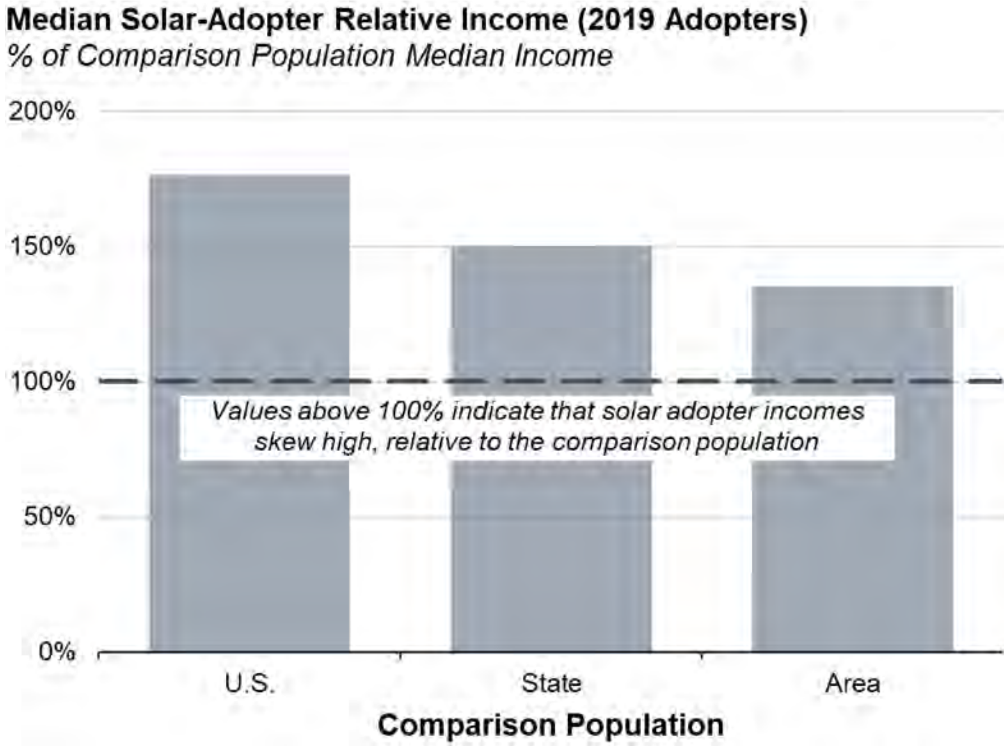
Solar-Adopter "Relative Income"



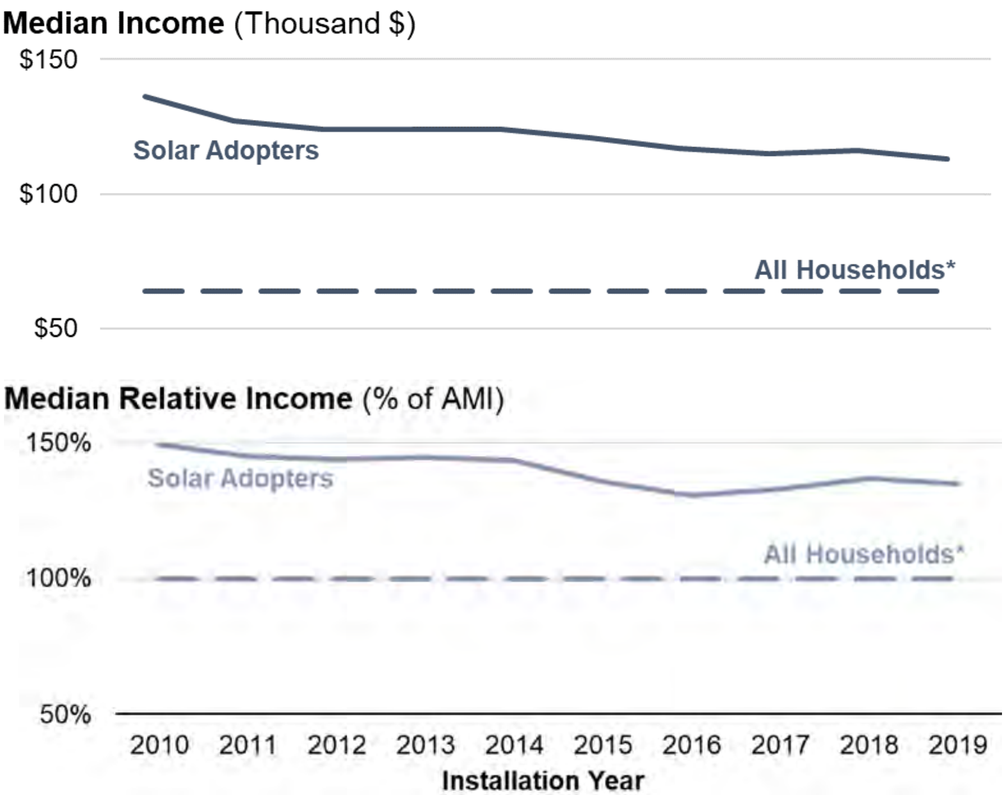
Note: To calculate these values, we first calculate each solar adopter's household income as a percentage of the median household income for each comparison population, and then take the median of those percentage values across all solar adopters.

Relative Income: Solar adopter HH income *as a percentage* of the median income of all HHs

- Provides a simple metric to characterize the degree to which solar adopter incomes differ from the rest of the population
- Can be based on comparison populations at different geographical scales: here we compare to national, state, and area medium incomes
- Solar-adopter incomes skew high, regardless of how broadly defined the comparison region, though the skew is smaller the more localized the comparison

Going forward, we default to Area Median Income (AMI) as the basis for calculating relative incomes

Solar-Adopter Income Trends over Time



**The flat lines for "All Households" reflect incomes in Q1 2020 and simply serve as a reference level for the solar-adopter incomes, which are based on the same timeframe.*

- Solar adoption has been slowly migrating toward lower incomes over time
- We see this in terms of both absolute and relative incomes, though the trend in relative incomes has flattened in recent years
- Long-term trends reflect some combination of:
  - Falling PV prices
  - Maturing PV markets
  - Expansion of PV financing options
  - Programs targeting LMI households
- Recent trends impacted by shifting market share of TPO, as shown later in slide 20

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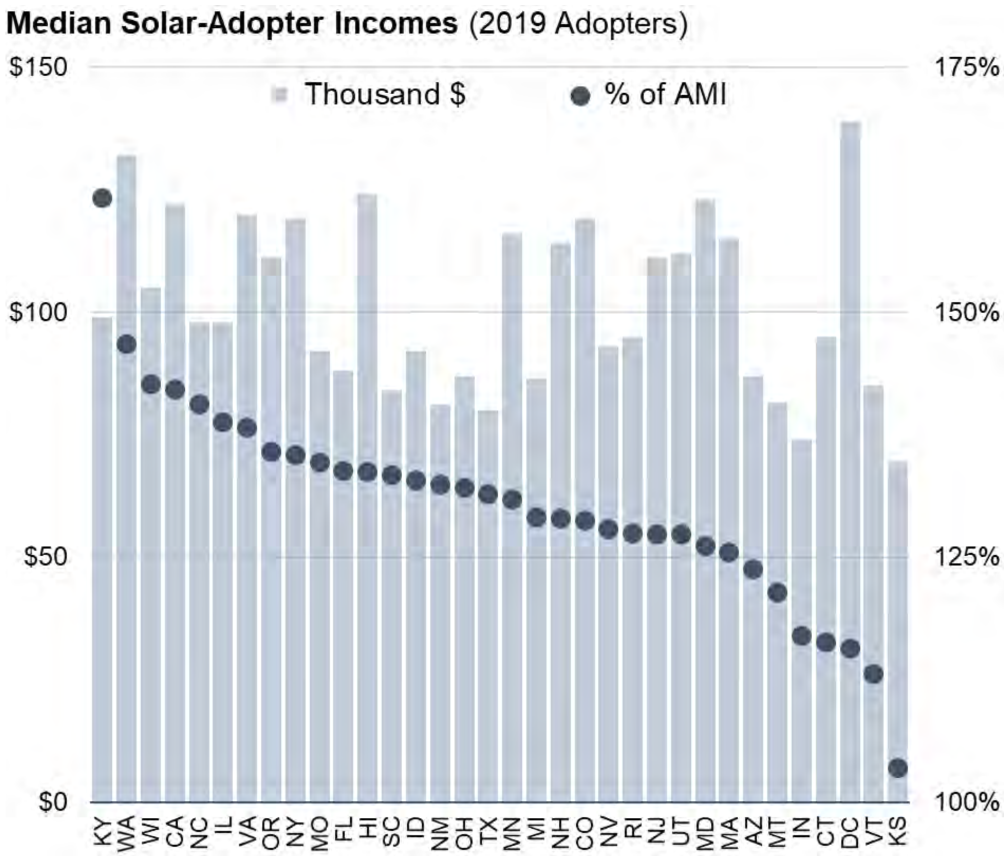
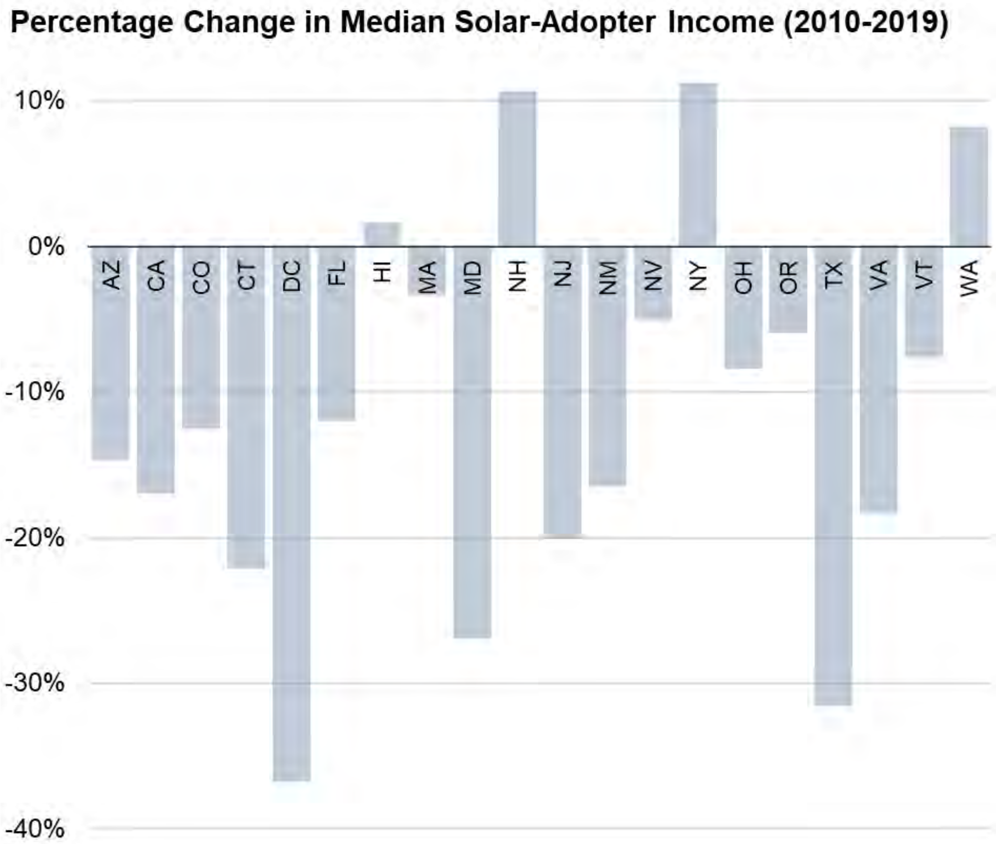
Solar-Adopter Income Trends across States



- Solar-adopter median incomes vary widely across states, as expected, given general differences in income levels across states
- All states exhibit some skew toward higher incomes, with median relative incomes typically ranging from 120-140% of AMI
- Some of that variation (especially at the extremes) may be idiosyncratic, though may also reflect fundamental drivers, such as:
  - Relative levels of solar market maturity
  - Solar policies and programs
  - Availability of financing
  - Income inequality within the broader population

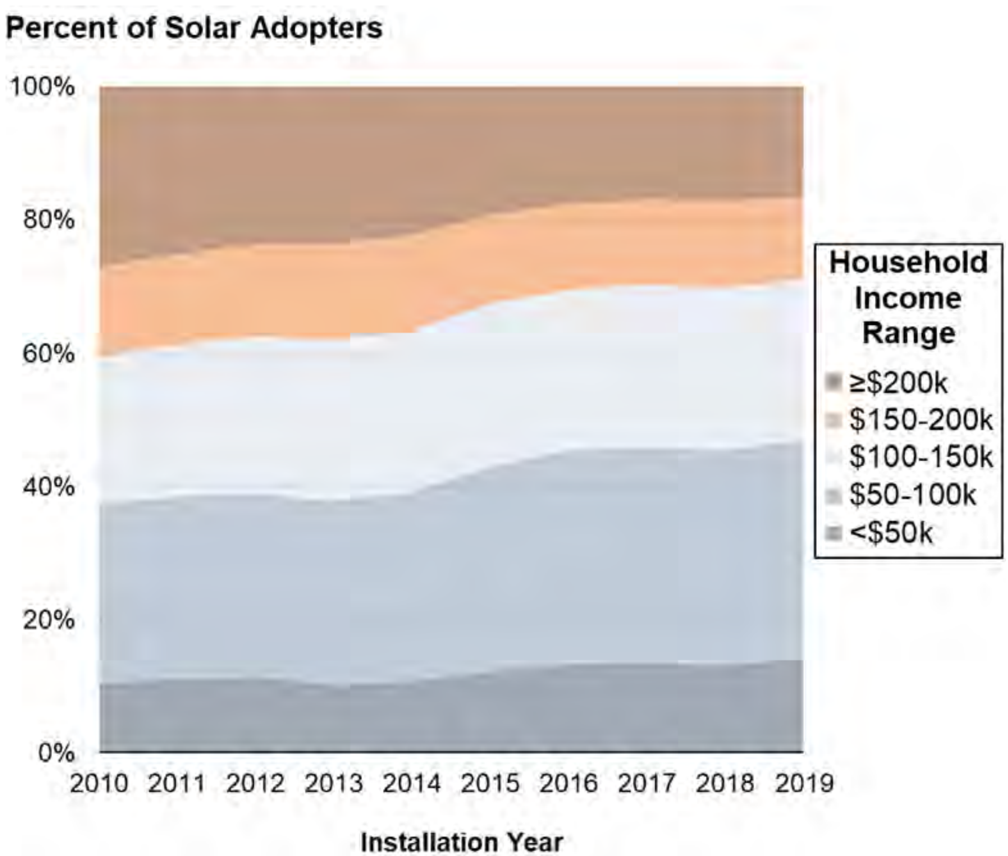
Solar-Adopter Income Trends over Time by State

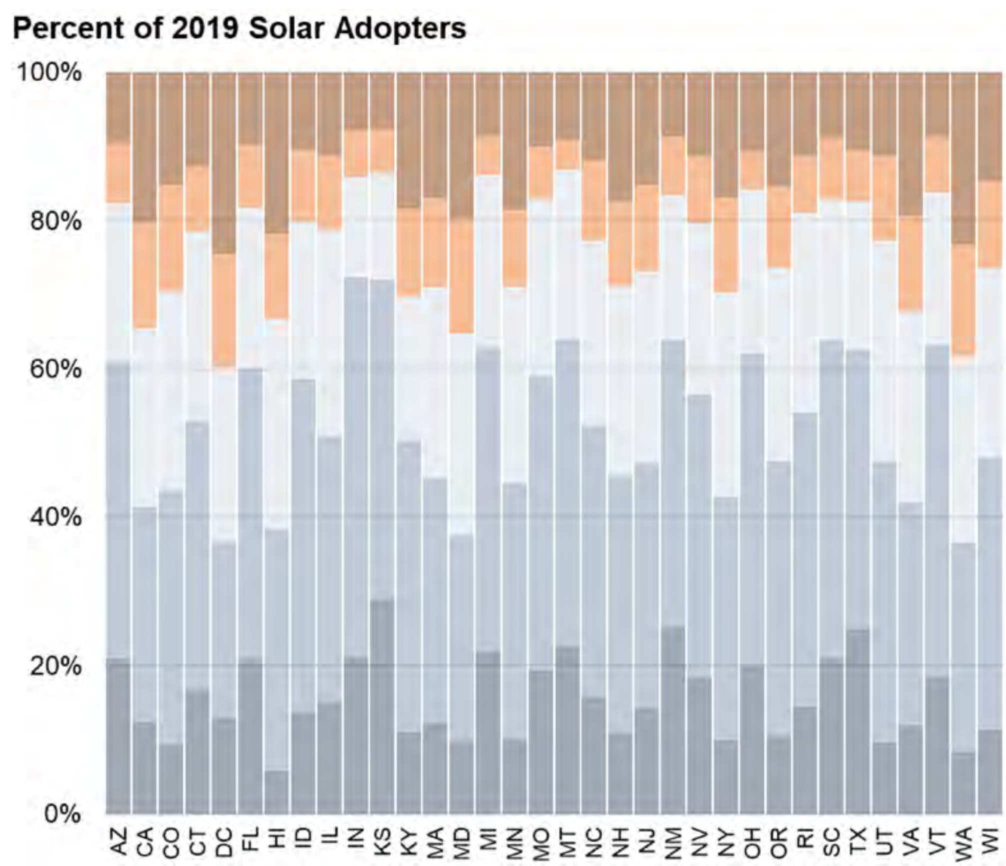


- Virtually all states show a trend toward lower income adopters over time, with generally about a 5-20% drop in median adopter incomes over the 2010-2019 period
- Though not shown here, similar trends occur at the county-level as well
- Trends reflect both *deepening* and *broadening* of solar markets (O'Shaughnessy et al. 2021)
  - ***Deepening***: Solar adoption within existing markets progressively moving toward lower incomes
  - ***Broadening***: Solar adoption expanding into previously under-served, lower-income areas within each state

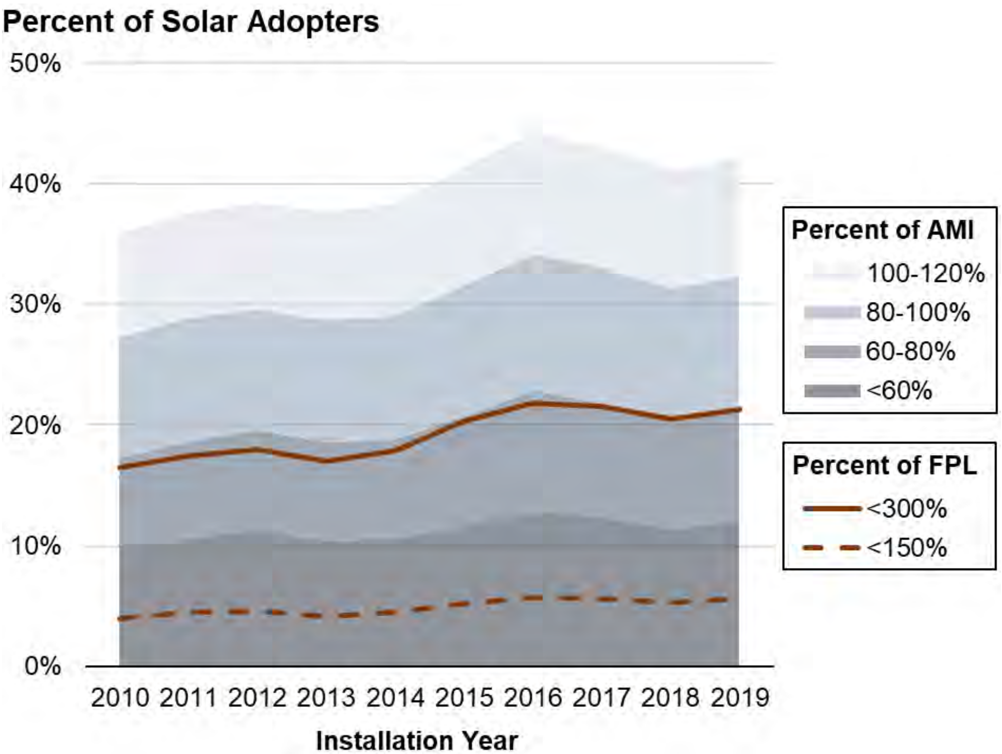
Solar-Adopter Income Distributions over Time and by State

Similar trends to median incomes, but highlighting the spread in adopter incomes





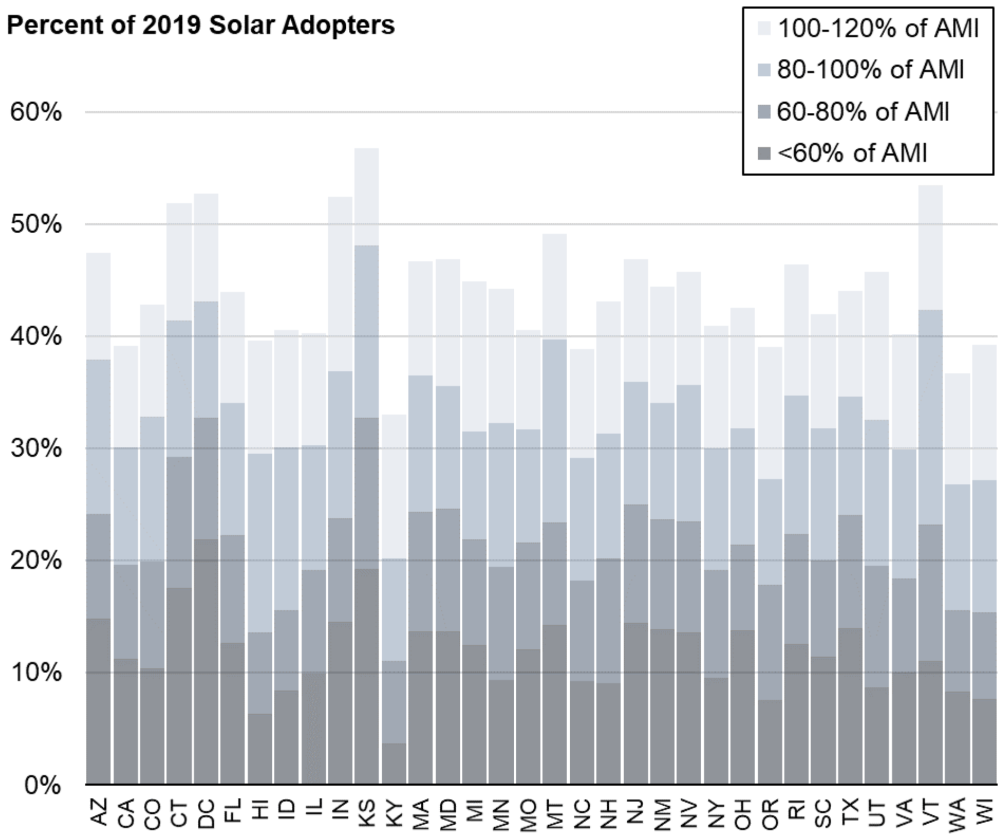
LMI Share of U.S. Solar Adopters over Time

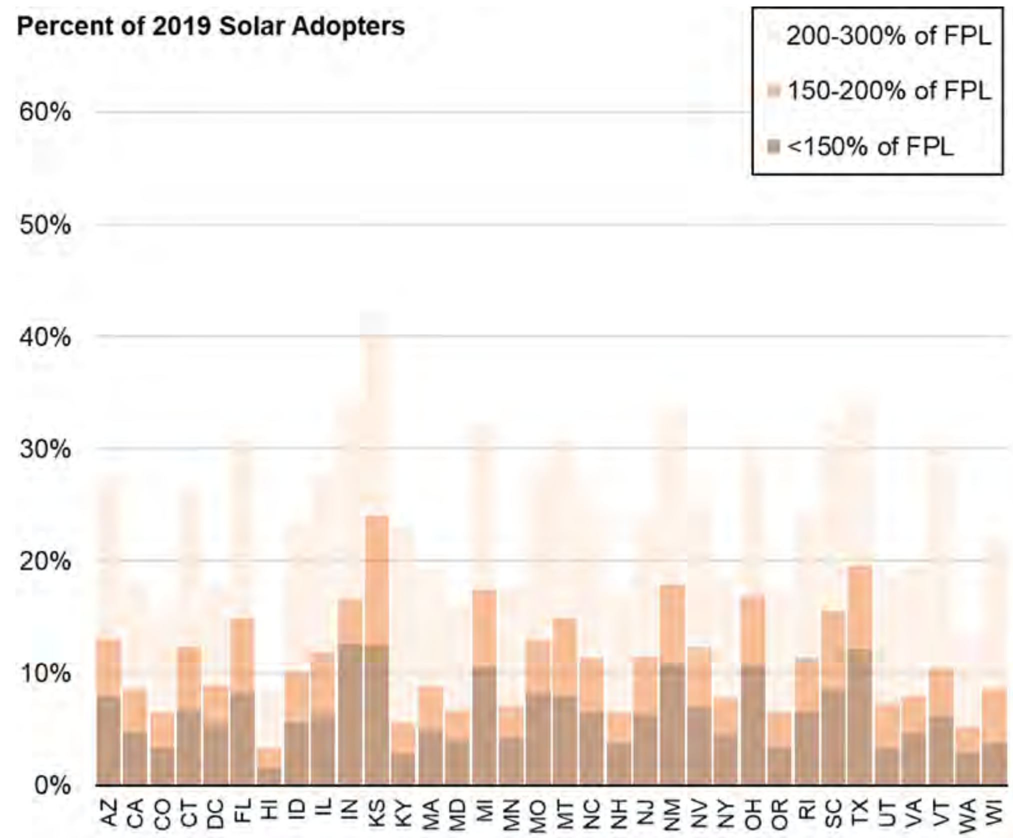


Notes: Both AMI and FPL vary by household size. For a family of three, the FPL for the contiguous 48 states was $21,330 in 2019.

- Various income metrics and thresholds can be used to define “low-to-moderate income” (LMI):
  - 150% of Federal Poverty Level (FPL) is common, especially in federal programs
  - 80% of AMI is also frequently used
  - Higher thresholds (e.g., 300% of FPL, 100-120% of AMI) are sometimes used to include “moderate” income
- Regardless of how its defined, LMI shares of U.S. solar adopters are trending up over time
  - Consistent with earlier trends in absolute income levels, and notwithstanding some variability in changes year-over-year
- Across all U.S. solar adopters in 2019:
  - **AMI:** 21% were <80% of AMI, 42% were <120% of AMI
  - **FPL:** 6% were <150% of FPL, 21% were <300% of FPL

LMI Share of Solar Adopters by State





Solar-Adopter Income Trends by Segment

- Beyond looking at how solar-adopter incomes vary over time and geography, we can also evaluate differences by market segment
- Here, we focus on several segmentations:
  - Third-party vs. host-owned systems
  - Differences across solar installers
  - PV systems installed with battery storage vs. stand-alone PV systems
  - PV systems installed on multi-family vs. single-family homes
- Each comparison is based on the subset of the sample for which data on the relevant segmentation are available (see slide 41 for applicable sample sizes)
- Comparisons are made primarily in terms of relative incomes, though the same basic trends apply in terms of absolute income levels as well

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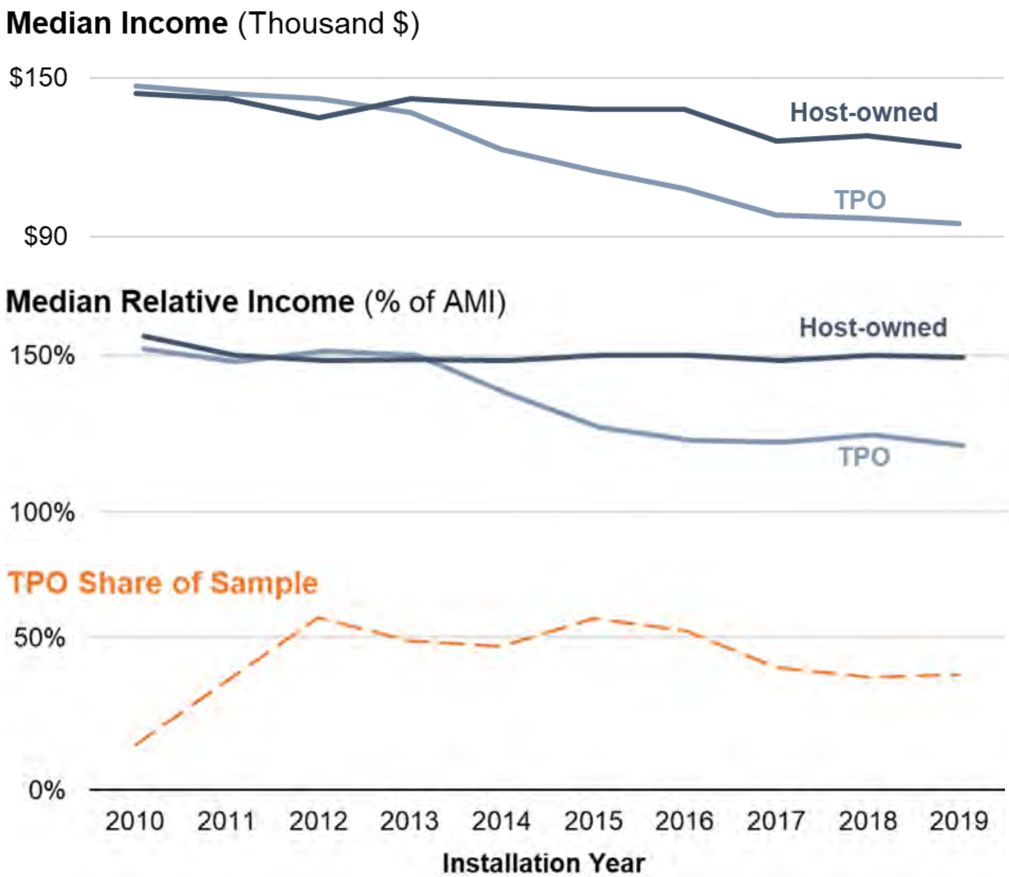
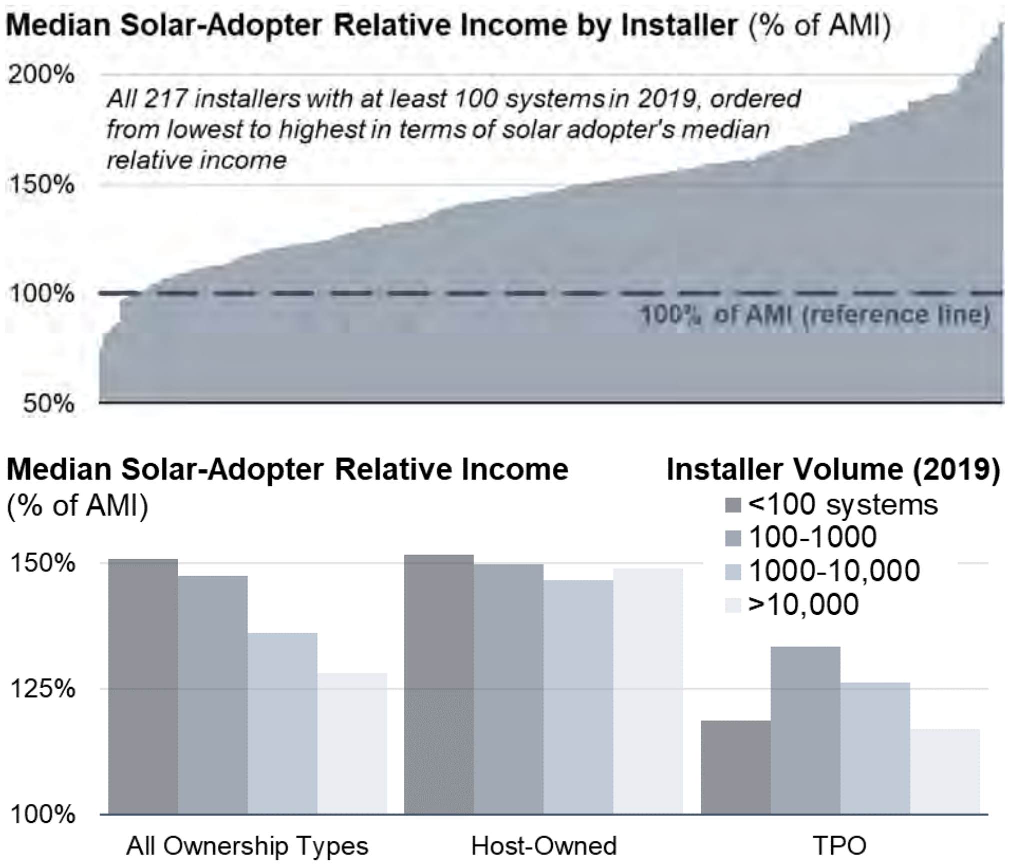
Third-Party vs. Host-Owned Systems



- Solar adopter incomes for third-party owned (TPO) systems are presently lower, and have declined much more significantly over time, compared to host-owned systems
  - Though not shown here, state-level comparisons generally exhibit the same basic trends
- O'Shaughnessy et al. (2021) found that TPO has driven adoption by lower income HHs
- Implication is that the general trend toward lower income solar adopters, observed earlier, can be substantially attributed to TPO
- The recent decline in TPO market share has likely dampened the overall trend toward lower income solar adopters

Installer-Level Trends



- Solar-adopter relative income varies considerably across installers, though virtually all skew higher than AMI
- Among the small set of installers (8 firms) with median incomes below AMI are several with business models focused specifically on LMI
- Larger volume installers exhibit lower relative income, primarily because they tend to more heavily favor TPO
- Among host-owned systems, installer size has no bearing on relative income; among TPO systems, the relationship is ambiguous (relative incomes are generally lower the larger the installer, except for the smallest installers)

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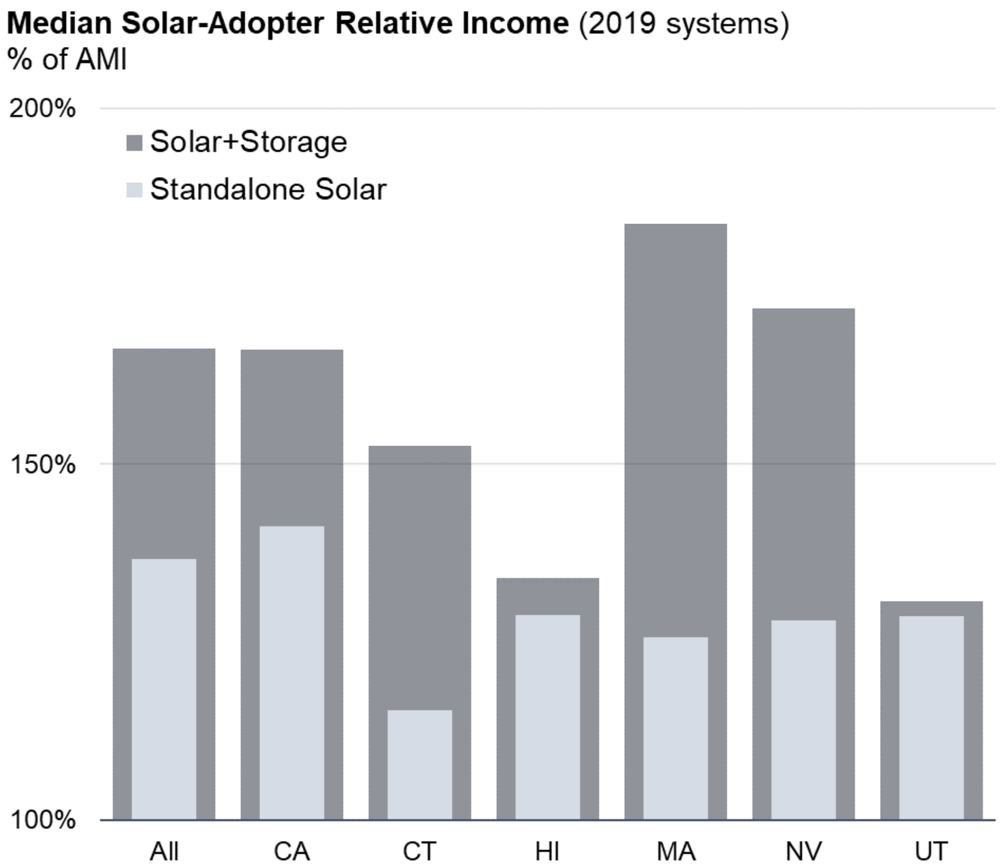
Paired Solar+Storage vs. Stand-alone Solar



- Roughly 4% of the PV systems in the sample were paired with storage in 2019, but that rate is growing (Barbose et al. 2021)
- Paired solar+storage systems typically cost about 30% more than stand-alone PV systems, for standard system sizes
- Not surprisingly, given the price differential, solar+storage adopters tend to have higher incomes (roughly 22% higher) than stand-alone solar adopters
- The solar+storage sample is dominated by CA, but the general trend in income differences between paired vs. stand-alone systems is consistent across other states as well

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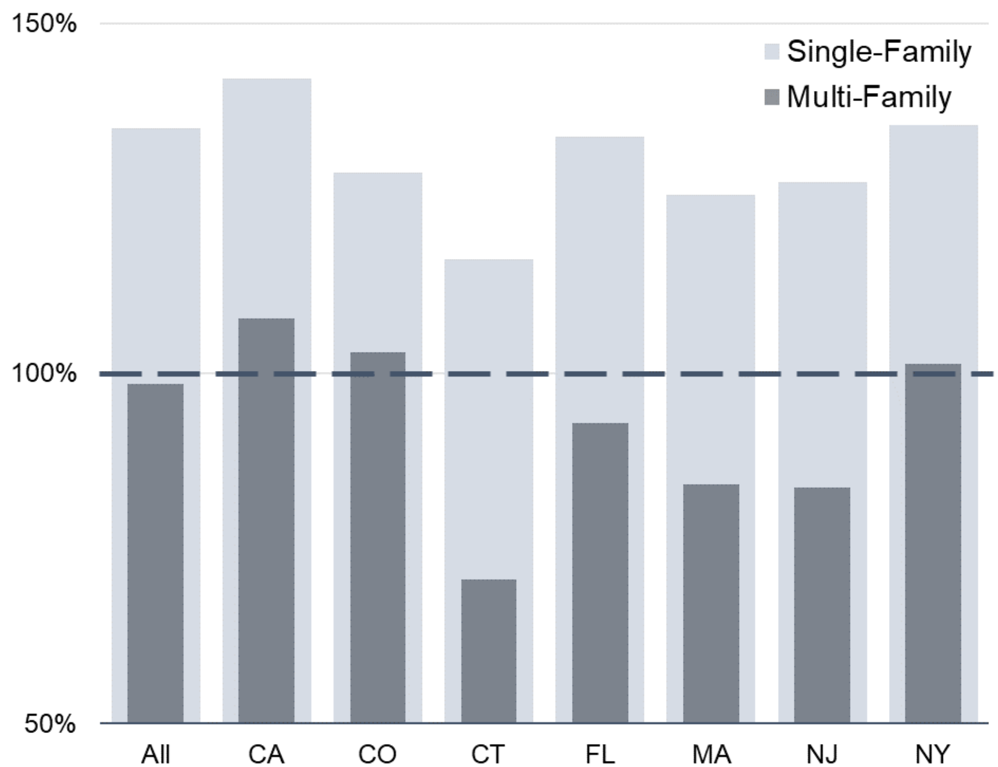
Multi-Family vs. Single-Family

Median Solar-Adopter Relative Income (2019 systems)
% of AMI



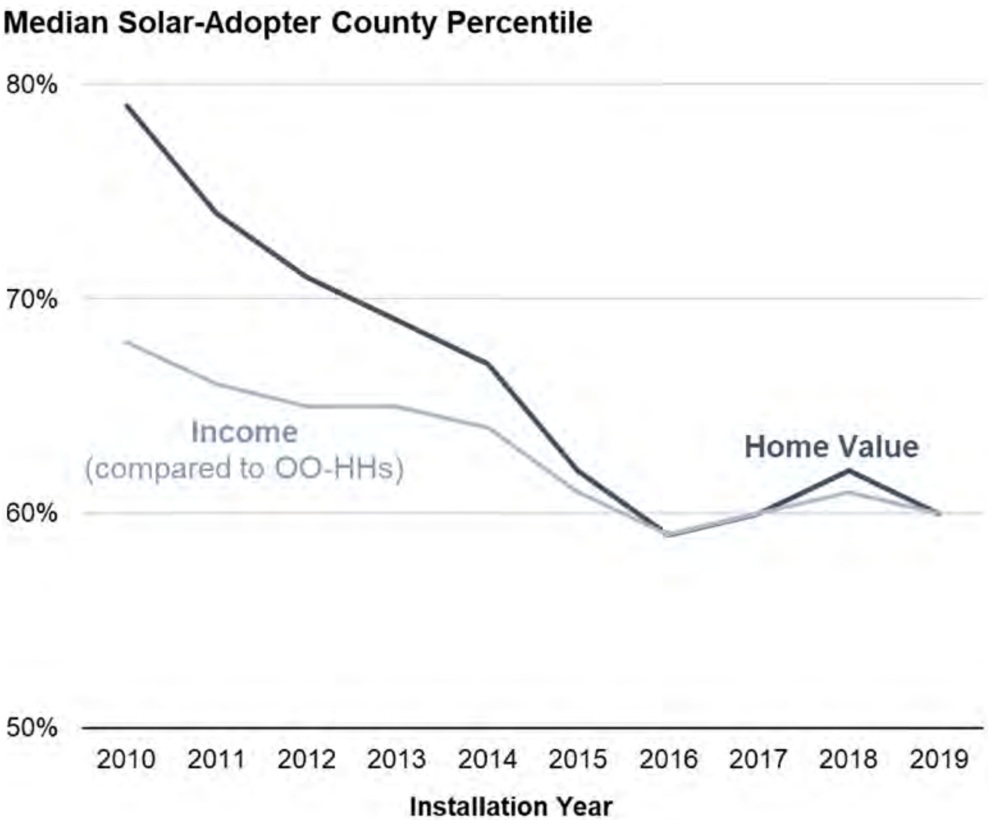
- Roughly 2% of all solar systems in the 2019 sample were installed on multi-family buildings
  - Most are owner-occupied; includes condos
- Multi-family solar adopter incomes are considerably and consistently below those of single-family adopters
- Across all multi-family systems in the dataset, incomes are roughly equivalent to AMI, but are well below AMI in several states
- Data on participation in income-qualifying solar programs is incomplete, but suggests higher participation by multi-family than single-family households, though still a minority overall
  - In CA, 20% of multi-family vs. 1% of single-family solar adopters participated in LMI programs

Other Socio-Economic Trends for Solar Adopters

Approach to Describing Other Socio-Economic Trends

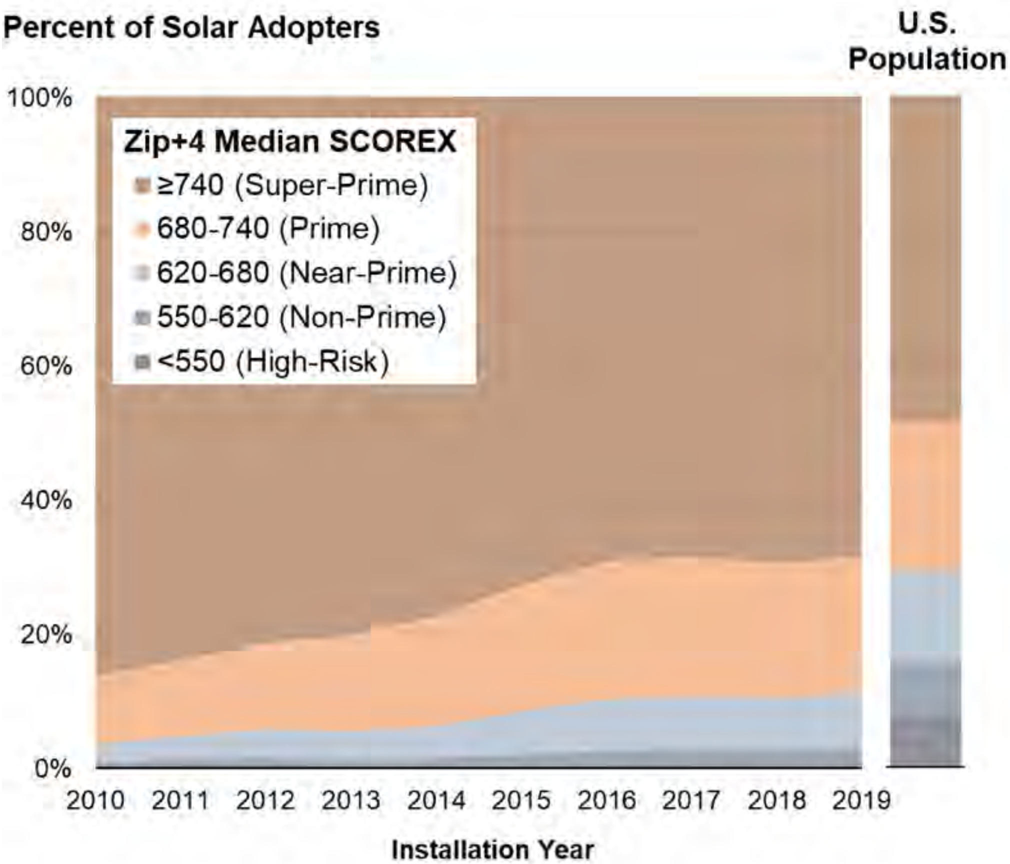
- Going beyond household income, we describe trends in other demographic and financial attributes of solar adopters (*see slides 38-39 for details on these variables*):
  - Home Value
  - Credit Scores
  - Education Level
  - Occupation
  - Rural vs. Urban
  - Race and Ethnicity
  - Age
- Trends describe the distribution of solar adopters nationally, changes over time, and comparison to the broader (in most cases, total U.S.) population
- Many of these trends illustrate a consistent theme: solar adopters more closely resembling the broader US population over time, but still exhibit some skew
- Some of these attributes may be correlated to income, leading to parallel trends

Home Value



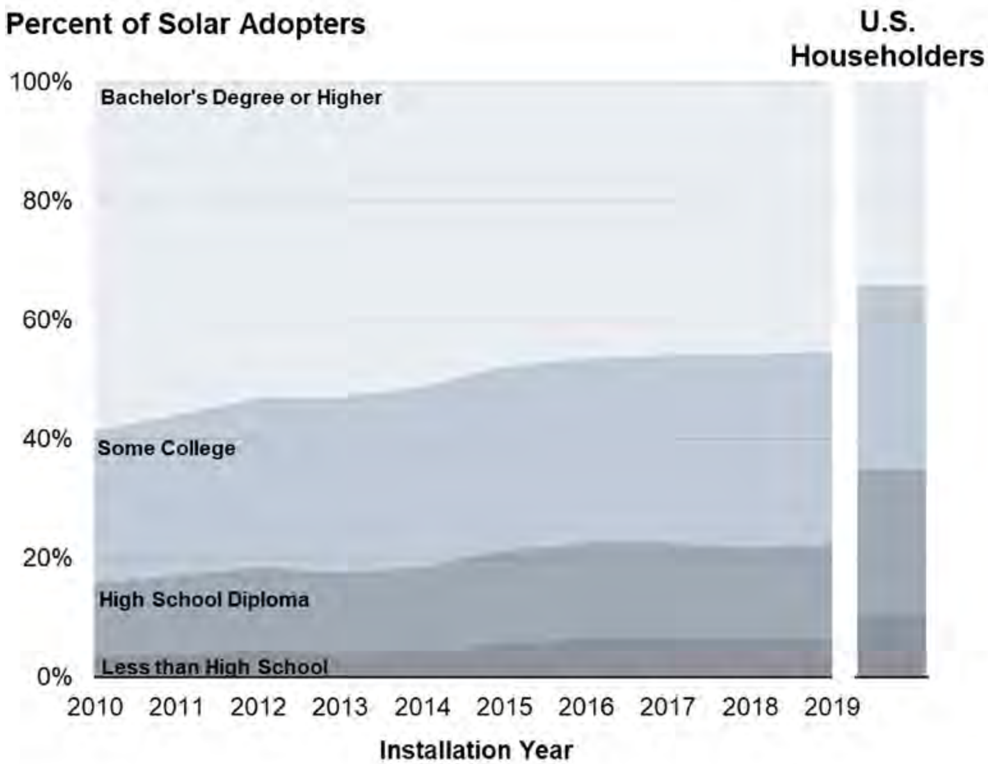
- Home value provides a measure of household *wealth*, as distinct from income—albeit only for households that own their home
- Solar-adopter home value data are expressed as a *percentile* of all homes in the same county (a different metric for expressing relative value)
- Solar-adopter home values are generally higher than others in the same county (above the 50th percentile), though that skew has declined substantially over time
- And has converged to resemble the skew in income among owner-occupied households (OO-HHs)
- A more comprehensive metric of wealth is needed to fully assess how solar adopters compare to the broader population, which includes renters

Credit Scores



- Due to privacy issues, credit score data consist of median values for all individuals in each solar adopter's zip+4, rather than individual or HH-level scores
- Solar adopters skew toward higher credit-score zip+4s, with a disproportionately large share of Super-Prime and virtually none with credit scores in the lower two groups—no doubt highly related to home ownership
- The skew has diminished over time as solar adopters within the middle tiers (Prime and Near-Prime) have comprised a larger share, though that trend has flattened in recent years

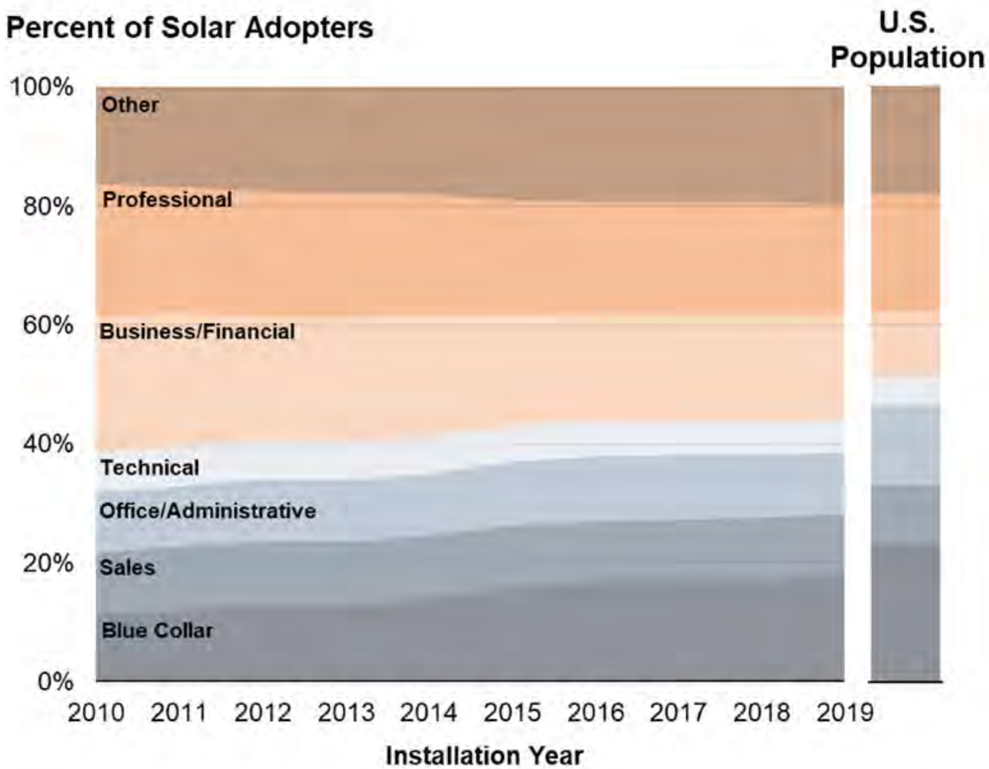
Education Level



Notes: Education level for each solar adopter is based on the highest known education level among adult household members, and for the U.S. population is based on the education level of householders.

- Almost half (45%) of all solar adopters in 2019 had a bachelor's degree or higher, while 22% had a high school diploma or less, and the remainder in between
- Solar-adopter educational levels are generally higher than the population at large, where 34% have at least a bachelors degree and 35% have no more than a high school diploma
- That skew has diminished somewhat over time: in 2010, 59% of solar adopters had a bachelors degree, while 16% had no more than a high school diploma
- As with income, the trends in educational levels have flattened in recent years

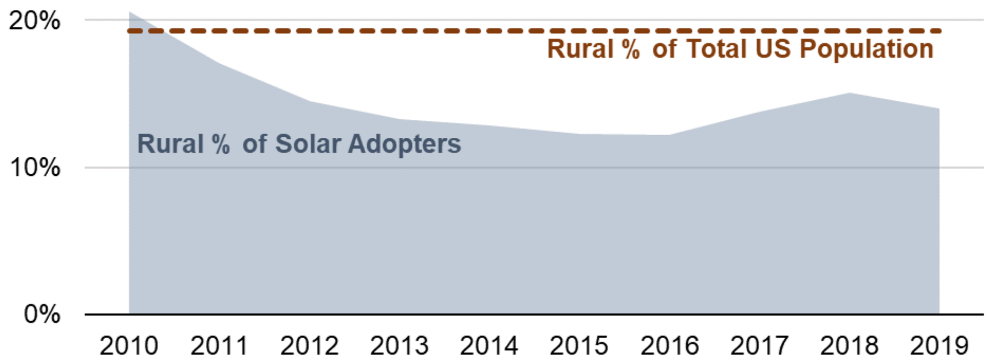
Occupation

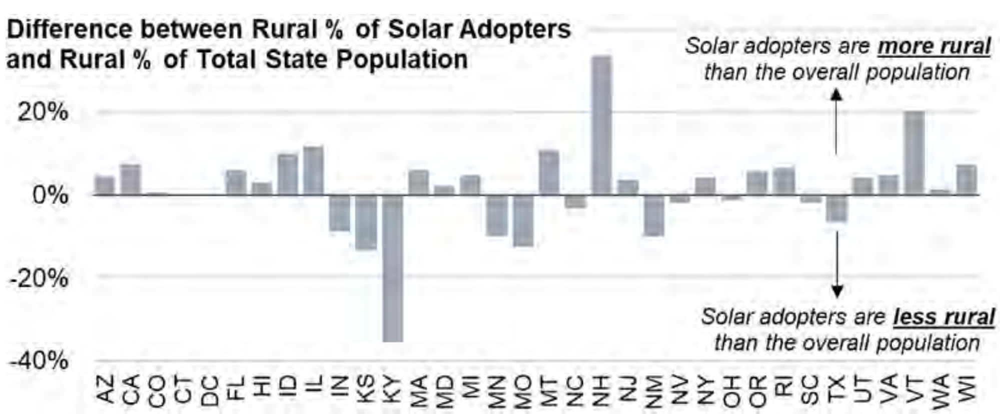


Notes: Occupation statistics for solar adopters are based on all adult household members. Statistics for U.S. population are based on data from the U.S. Bureau of Labor Statistics, consolidated and mapped on to the Experian's occupational categories.

- Similar shares of 2019 solar adopters came from professional, business & financial, and blue-collar occupational categories, as well as the catch-all "other" category
- Compared to the broader U.S. population, solar adopters are over-represented by business & financial occupations and under-represented by blue-collar occupations
- However, that skew has diminished greatly over time, as blue-collar occupations comprise increasingly larger shares of new adopters

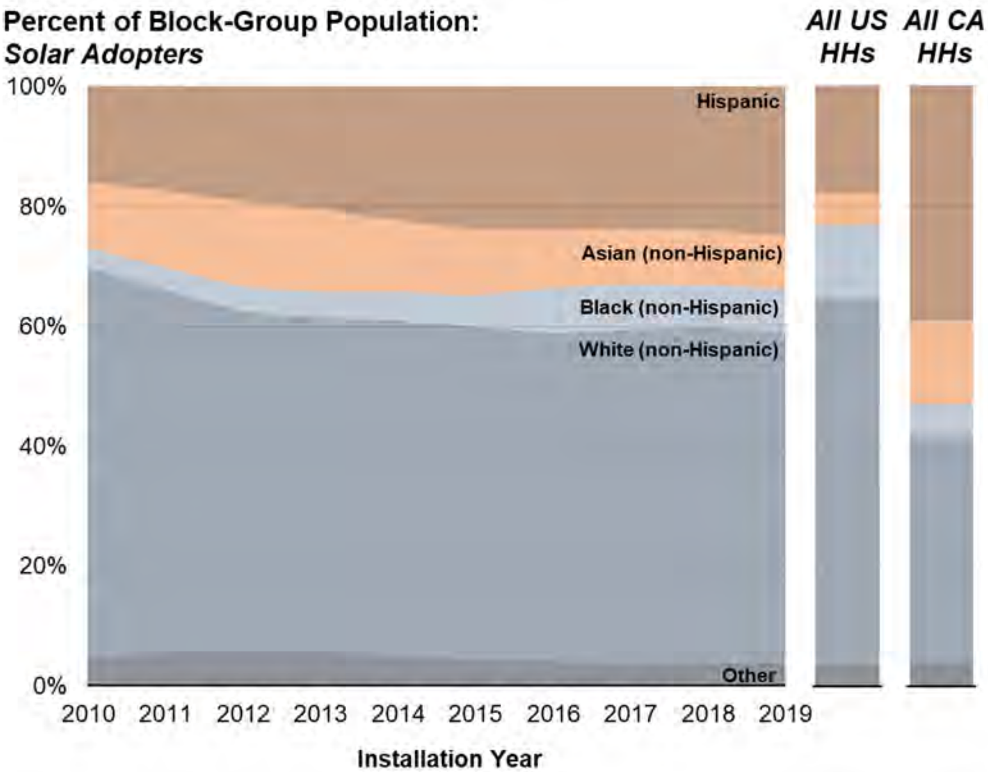
Urban vs. Rural





- U.S. Census defines “rural” vs. “urban” areas based on population density; urban areas often include surrounding suburbs/exurbs
- Solar adopters are slightly less rural than the U.S. as a whole: 14% of solar adopters in 2019 vs. 19% of the total U.S. population
- Temporal trend is mixed: solar adopters were less rural in 2019 than in 2010, but trends have shifted over the intervening years
- National trends reflect the fact that solar adoption skews towards less rural states
- At the individual state level, solar adopters may be more or less rural than the state as a whole (if anything, they tend to skew rural)

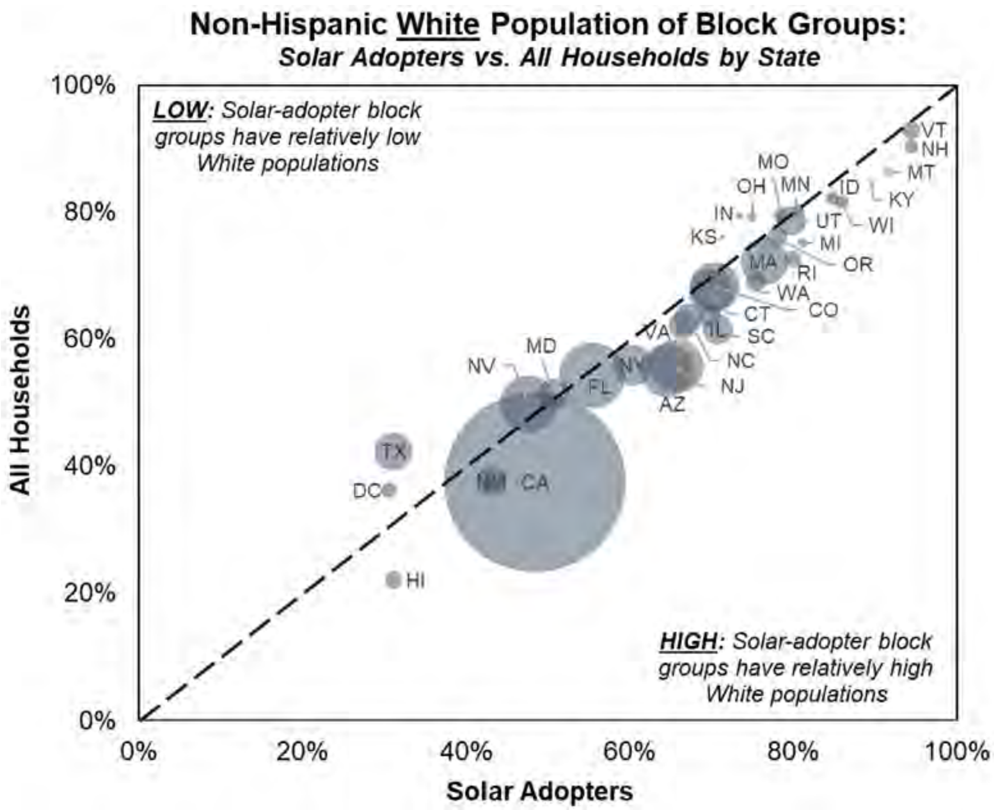
Race and Ethnicity:
National Trends



Notes: To construct the figure, each household (solar adopter or otherwise) is assigned the racial/ethnic composition of its block group, and the values plotted are the averages across all applicable set of households.

- Data on race and ethnicity of individual solar adopters were unavailable for this study; we instead characterize solar adopters based on the composition of their block group
- Compared to all U.S. households, solar adopters live in block groups with larger Hispanic and Asian populations, and with correspondingly smaller White or Black populations
- To a significant degree, this reflects broad geographical trends in solar adoption: specifically, roughly half are in CA, which has relatively large Hispanic and Asian populations

Race and Ethnicity:
State-Level Differences in Non-Hispanic White Population



Notes: The size of the bubbles represents the solar-adopter sample size. See the previous slide for a description of how the plotted values were calculated.

- State-level comparisons show that solar adopters generally skew towards block groups with relatively high White population
- The figure compares the percentage of the block group population that is White (non-Hispanic) for solar adopters vs. all households in each state
- As shown, in most states, solar adopters skew toward block groups with larger White populations (i.e., are below the diagonal line)
- In CA, the disparity is relatively high: solar adopters live in block groups where, on average, 48% of the population is White, compared to 38% for all HHs in the state

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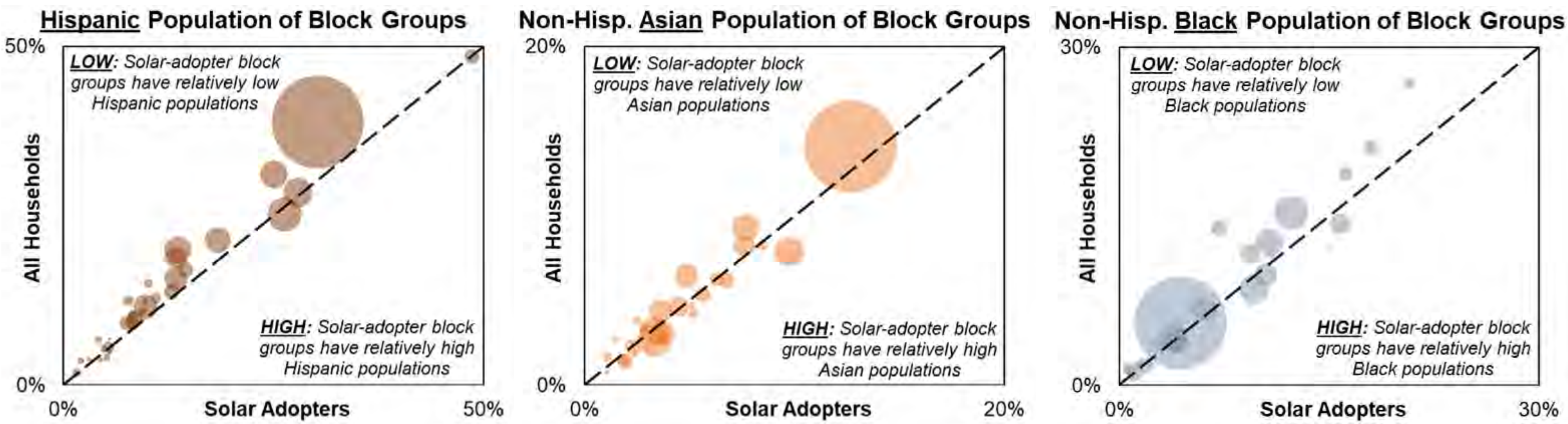
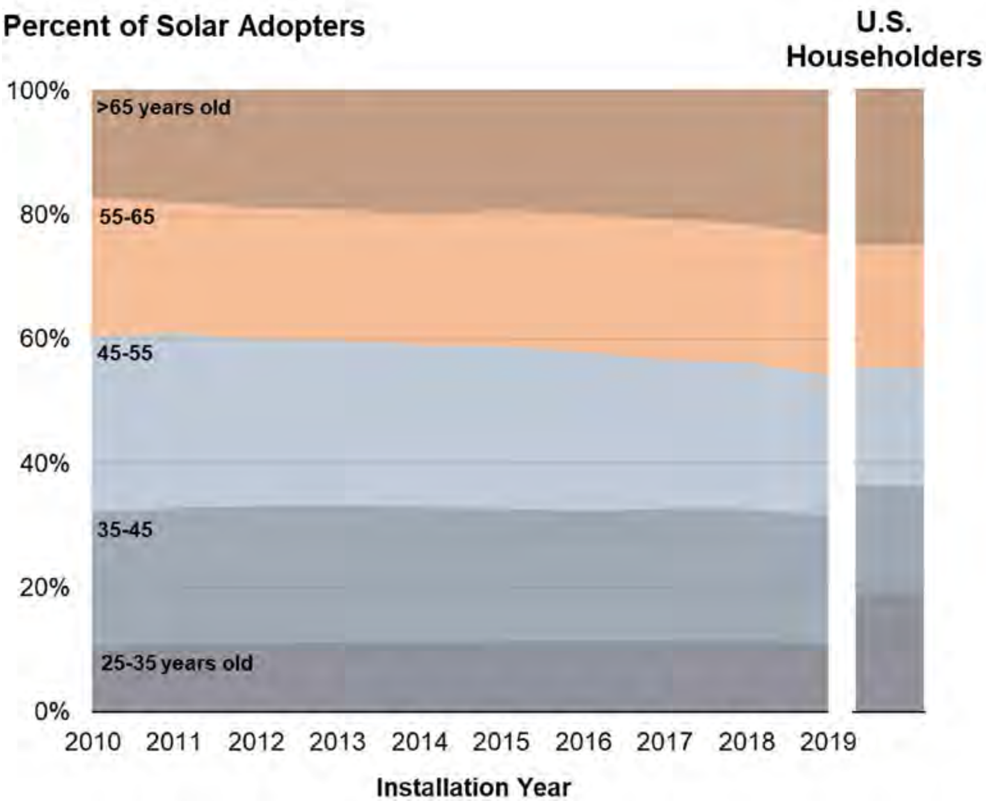
Race and Ethnicity:
State-Level Differences in Hispanic, Black, and Asian Populations



- Solar adoption generally skews toward block groups with relatively low Hispanic and Black populations, with somewhat larger and more consistent disparities for Hispanic populations
- In contrast, solar adoption skews toward block groups with relatively high Asian populations in most states (roughly two-thirds), though not in California, and the skew is much smaller than that observed for non-Hispanic White populations on the previous slide

Age



Notes: Ages for solar adopters are based on the primary household member, adjusted to reflect age at the time of adoption, and for the U.S. population are based on the householder.

- As a general matter, solar adopters skew slightly older than the broader population (comparing among adults 25+)
- This is largely due to under-representation among the youngest group (25-35), which is not surprising, given lower home ownership rates and incomes
- The most notable shift over time has been an increasing share of solar adopters within the oldest age group (65+), which had previously been under-represented
- That trend is consistent with growing technology acceptance (less perceived risk), and likely fueled by greater availability of financing (key for individuals on fixed-incomes)

Conclusions

Conclusions

- Solar adopters are heterogeneous in terms of their income and demographics
- Solar adopters diverge from the general U.S. population in many ways, skewing, for example, toward higher income, more urban, and more educated households
- Those differences are diminishing over time, albeit slowly
- The degree of disparity between solar adopters and the broader population varies significantly across states, and also tends to be smaller the more localized the comparison
- We highlight the role of third-party ownership in driving some of these trends, and speculate about other potential drivers, but further analysis would help to better understand the underlying dynamics—especially around the effects of policy interventions aimed at addressing adoption inequities

Appendix

Key Experian Data Elements Used in this Analysis

- **Estimated Household Income**: The total estimated income for a living unit, incorporating several highly predictive individual and household level variables. The income estimation is determined using multiple statistical methodologies to predict the income estimate for the living unit.
- **SCOREX PLUS** : Predicts the likelihood of future serious delinquencies on any type of account. Due to limitations related to the Federal Fair Credit Reporting Act, data provided for each address represent the corresponding Census block medians, rather than the credit score of the specific individual or household.
- **Date of Birth/Combined Adult Age:** Date of Birth is acquired from public and proprietary files. These sources provide, at a minimum, the year of birth. The birth month is provided where available. Estimated ages are acquired from proprietary data sources and Experian models which estimate the adult age.
- **Dwelling Type:** Each household is assigned a dwelling type code based on United States Postal Service (USPS) information; could be either Single Family Dwelling Units, Multi-Family, Marginal Multi Family, P.O. Boxes, or Unknown.
- **Occupation Group:** Compiled from self-reported surveys, derived from state licensing agencies, or calculated through the application of predictive models.
- **Individual Education:** Compiled from self-reported surveys, derived based on occupational information, or calculated through the application of predictive models.

Key Public Data Elements Used in this Analysis

- **U.S. Census American Community Survey 5-Year Data (2014-2018):** Educational attainment by householder (Table B25013); Hispanic or Latino origin by race – population (Table B03002); Age of householder (Table B25007)
- **U.S. Census 2010** Urban-rural classification: Rural, urban, and urban cluster populations by state; and definition by latitude/longitude for classification of solar adopters
- **Bureau of Labor and Statistics:** Occupational Employment Statistics Survey, May 2019

State Sample Sizes: *TTS=Tracking the Sun, BZ=BuildZoom, Ohm=Ohm Analytics; Market Coverage based on comparison to Wood Mackenzie's Solar Market Insight report*

State	All Years					2019 Installations				
	TTS	BZ	Ohm	Total	Market Coverage	TTS	BZ	Ohm	Total	Market Coverage
AK	0	1	0	1	0%	0	0	0	0	0%
AL	0	2	0	2	2%	0	0	0	0	0%
AR	88	39	0	127	10%	0	27	0	27	5%
AZ	0	26,616	52,873	79,489	53%	0	1,252	12,512	13,764	70%
CA	981,359	47,200	0	1,028,559	96%	141,764	11,762	0	153,526	97%
CO	0	23,063	28,845	51,908	84%	0	1,034	10,461	11,495	100%
CT	37,651	1,247	0	38,898	94%	9,247	293	0	9,540	100%
DC	4,445	500	0	4,945	88%	889	301	0	1,190	70%
DE	0	966	0	966	15%	0	66	0	66	12%
FL	3,760	13,368	31,120	48,248	94%	894	4,377	15,231	20,502	100%
GA	0	124	0	124	13%	0	35	0	35	27%
HI	0	46,428	0	46,428	57%	0	1,398	0	1,398	38%
IA	0	273	0	273	9%	0	81	0	81	10%
ID	0	3,290	0	3,290	55%	0	848	0	848	32%
IL	7,092	173	0	7,265	74%	4,315	103	0	4,418	67%
IN	0	61	350	411	17%	0	4	202	206	30%
KS	0	69	301	370	77%	0	11	93	104	46%
KY	0	41	203	244	33%	0	18	91	109	40%
LA	0	1,888	0	1,888	12%	0	12	0	12	1%
MA	88,661	2,775	0	91,436	90%	9,660	883	0	10,543	77%
MD	0	9,577	38,613	48,190	73%	0	849	3,815	4,664	79%
ME	0	0	0	0	0%	0	0	0	0	0%
MI	0	1,292	1	1,293	19%	0	448	0	448	16%
MN	1,070	2,797	0	3,867	82%	0	746	0	746	65%
MO	0	399	1,812	2,211	26%	0	41	826	867	48%
MS	0	0	0	0	0%	0	0	0	0	0%

State	All Years					2019 Installations				
	TTS	BZ	Ohm	Total	Market Coverage	TTS	BZ	Ohm	Total	Market Coverage
MT	0	253	675	928	61%	0	11	339	350	80%
NC	12,212	1,022	0	13,234	99%	3,472	421	0	3,893	90%
ND	0	8	0	8	47%	0	1	0	1	13%
NE	0	122	0	122	56%	0	29	0	29	31%
NH	6,258	14	0	6,272	83%	847	9	0	856	77%
NJ	107,726	244	1	107,971	99%	13,293	26	0	13,319	88%
NM	20,381	1,086	0	21,467	99%	3,671	623	0	4,294	100%
NV	49,337	2,506	1	51,844	100%	14,708	609	0	15,317	100%
NY	71,619	2,743	0	74,362	61%	7,762	135	0	7,897	51%
OH	2,042	694	0	2,736	56%	59	334	0	393	19%
OK	0	18	110	128	17%	0	2	94	96	35%
OR	16,444	2,674	0	19,118	100%	1,158	833	0	1,991	100%
PA	5,980	1,908	0	7,888	30%	0	402	0	402	8%
RI	6,813	0	0	6,813	100%	1,487	0	0	1,487	88%
SC	0	819	11,735	12,554	64%	0	125	2,104	2,229	80%
SD	0	2	0	2	9%	0	1	0	1	6%
TN	0	224	0	224	15%	0	30	0	30	21%
TX	1,362	26,388	1	27,751	45%	49	6,885	0	6,934	44%
UT	13,031	4,516	0	17,547	48%	3,977	304	0	4,281	92%
VA	9,323	387	0	9,710	100%	3,599	158	0	3,757	98%
VT	12,326	3	0	12,329	100%	1,527	0	0	1,527	100%
WA	7,018	4,866	1,928	13,812	70%	1,144	113	777	2,034	70%
WI	3,284	207	0	3,491	81%	852	83	0	935	100%
WV	0	0	0	0	0%	0	0	0	0	0%
WY	0	25	0	25	4%	0	19	0	19	7%
US	1,469,282	232,918	168,569	**1,870,769**	**82%**	224,374	35,742	46,545	**306,661**	**84%**

Sample Sizes by Analysis Element

Vary depending on data availability and unit of observation

Analysis Element	Unit of Observation	Sample Size	
		2019	All Years
Income (single-family)	Household	306,658	1,870,718
TPO vs. host-owned	Household	207,670	1,318,524
Installer name	Household	170,391	n/a
With or without storage	Household	186,839	n/a
Multi- vs. single-family	Household	312,836	n/a
Home Value	Household	258,079	1,555,724
Credit Score	Household	306,660	1,870,745
Education	Household	306,658	1,870,718
Occupation	Individuals	708,984	4,601,798
Urban vs. Rural	Individuals	902,298	5,860,654
Race/Ethnicity	Household	299,700	1,822,326
Age	Household	192,824	1,240,172

General Notes:

- With the exception of the multi- vs. single-family comparison, all other elements of the analysis are based only on single-family solar adopters
- The unit of observation for most analysis elements is the household, but for several elements (occupation and urban vs. rural), data for the overall U.S. population are available only at the individual level. In those cases, solar adopters summary statistics are based on all individuals in each household in order to allow for comparison to the U.S. population.
- Analysis elements related to TPO, installer name, and battery storage are based almost entirely on solar adopter addresses from Tracking the Sun

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QuickFacts

California

QuickFacts provides statistics for all states and counties, and for cities and towns with a ***population of 5,000 or more***.

Table

PEOPLE

Population	
Population estimates, July 1, 2019, (V2019)	39,512,223
Population estimates base, April 1, 2010, (V2019)	37,254,519
Population, percent change - April 1, 2010 (estimates base) to July 1, 2019, (V2019)	6.1%
Population, Census, April 1, 2020	39,538,223
Population, Census, April 1, 2010	37,253,956
Age and Sex	
Persons under 5 years, percent	6.0%
Persons under 18 years, percent	22.5%
Persons 65 years and over, percent	14.8%
Female persons, percent	50.3%
Race and Hispanic Origin	
White alone, percent	71.9%
Black or African American alone, percent (a)	6.5%
American Indian and Alaska Native alone, percent (a)	1.6%
Asian alone, percent (a)	15.5%
Native Hawaiian and Other Pacific Islander alone, percent (a)	0.5%
Two or More Races, percent	4.0%
Hispanic or Latino, percent (b)	39.4%
White alone, not Hispanic or Latino, percent	36.5%
Population Characteristics	
Veterans, 2015-2019	1,574,531
Foreign born persons, percent, 2015-2019	26.8%
Housing	
Housing units, July 1, 2019, (V2019)	14,366,336
Owner-occupied housing unit rate, 2015-2019	54.8%
Median value of owner-occupied housing units, 2015-2019	$505,000
Median selected monthly owner costs -with a mortgage, 2015-2019	$2,357
Median selected monthly owner costs -without a mortgage, 2015-2019	$594
Median gross rent, 2015-2019	$1,503
Building permits, 2020	106,075
Families & Living Arrangements	
Households, 2015-2019	13,044,266
Persons per household, 2015-2019	2.95
Living in same house 1 year ago, percent of persons age 1 year+, 2015-2019	87.1%
Language other than English spoken at home, percent of persons age 5 years+, 2015-2019	44.2%
Computer and Internet Use	
Households with a computer, percent, 2015-2019	93.0%
Households with a broadband Internet subscription, percent, 2015-2019	86.7%
Education	
High school graduate or higher, percent of persons age 25 years+, 2015-2019	83.3%
Bachelor's degree or higher, percent of persons age 25 years+, 2015-2019	33.9%
Health	
With a disability, under age 65 years, percent, 2015-2019	6.7%
Persons without health insurance, under age 65 years, percent	8.9%
Economy	
In civilian labor force, total, percent of population age 16 years+, 2015-2019	63.3%
In civilian labor force, female, percent of population age 16 years+, 2015-2019	57.5%

All Topics

Median household income (in 2019 dollars), 2015-2019

Total accommodation and food services sales, 2012 ($1,000) (c)	90,830,372
Total health care and social assistance receipts/revenue, 2012 ($1,000) (c)	248,953,592
Total manufacturers shipments, 2012 ($1,000) (c)	[illegible]
Total merchant wholesaler sales, 2012 ($1,000) (c)	666,652,186
Total retail sales, 2012 ($1,000) (c)	481,800,461
Total retail sales per capita, 2012 (c)	$12,665
Transportation	
Mean travel time to work (minutes), workers age 16 years+, 2015-2019	29.8
Income & Poverty	
Median household income (in 2019 dollars), 2015-2019	**$75,235**
Per capita income in past 12 months (in 2019 dollars), 2015-2019	$36,955
Persons in poverty, percent	11.8%

BUSINESSES

Businesses	
Total employer establishments, 2019	966,224
Total employment, 2019	15,516,824
Total annual payroll, 2019 ($1,000)	1,077,175,621
Total employment, percent change, 2018-2019	1.9%
Total nonemployer establishments, 2018	3,453,769
All firms, 2012	3,548,449
Men-owned firms, 2012	1,852,580
Women-owned firms, 2012	1,320,085
Minority-owned firms, 2012	1,619,857
Nonminority-owned firms, 2012	1,819,107
Veteran-owned firms, 2012	252,377
Nonveteran-owned firms, 2012	3,176,341

GEOGRAPHY

Geography	
Population per square mile, 2010	239.1
Land area in square miles, 2010	155,779.22
FIPS Code	06

About datasets used in this table

All Topics

Median household income (in 2019 dollars), 2015-2019	

Value Notes

Estimates are not comparable to other geographic levels due to methodology differences that may exist between different data sources.

Some estimates presented here come from sample data, and thus have sampling errors that may render some apparent differences between geographies statistically indistinguishable. Click the Quick Info icon to the row in TABLE view to learn about sampling error.

The vintage year (e.g., V2019) refers to the final year of the series (2010 thru 2019). *Different vintage years of estimates are not comparable.*

Fact Notes

- **(a)** Includes persons reporting only one race
- **(c)** Economic Census - Puerto Rico data are not comparable to U.S. Economic Census data
- **(b)** Hispanics may be of any race, so also are included in applicable race categories

Value Flags

- **-** Either no or too few sample observations were available to compute an estimate, or a ratio of medians cannot be calculated because one or both of the median estimates falls in the lowest or upper int open ended distribution.
- **F** Fewer than 25 firms
- **D** Suppressed to avoid disclosure of confidential information
- **N** Data for this geographic area cannot be displayed because the number of sample cases is too small.
- **FN** Footnote on this item in place of data
- **X** Not applicable
- **S** Suppressed; does not meet publication standards
- **NA** Not available
- **Z** Value greater than zero but less than half unit of measure shown

QuickFacts data are derived from: Population Estimates, American Community Survey, Census of Population and Housing, Current Population Survey, Small Area Health Insurance Estimates, Small Area Income and F Estimates, State and County Housing Unit Estimates, County Business Patterns, Nonemployer Statistics, Economic Census, Survey of Business Owners, Building Permits.

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CEC-057 (Revised 1/21)

NOTICE OF PREPARATION

NOTICE OF PREPARATION OF AN ENVIRONMENTAL IMPACT REPORT FOR THE 2022 AMENDMENTS TO THE ENERGY CODE

The California Energy Commission (CEC) is the lead agency under the California Environmental Quality Act (CEQA) and will prepare an environmental impact report (EIR) for the proposed 2022 amendments to the Building Energy Efficiency Standards contained in the California Code of Regulations, Title 24, Part 6 (Energy Code).

In accordance with California Code of Regulations, Title 14, section 15082, the CEC has prepared this notice of preparation (NOP) to inform agencies and interested parties that an EIR will be prepared for the above-referenced project. The purpose of an NOP is to provide sufficient information about the project and its potential environmental impacts to allow agencies and interested parties the opportunity to provide a meaningful response related to the scope and content of the EIR, including mitigation measures that should be considered and alternatives that should be addressed (Cal. Code Regs., tit. 14, § 15082[b]).

The CEC has the exclusive authority to adopt energy efficiency standards for buildings, which are located in the Energy Code. Public Resources Code section 25402, subdivisions (a) and (b) establish that the CEC shall periodically prescribe, by regulation, statewide building energy efficiency standards to reduce wasteful, uneconomic, inefficient, or unnecessary consumption of energy. The Energy Code includes the energy efficiency requirements applicable to newly constructed buildings and additions and alterations to existing buildings.

Submitting Comments

Pursuant to California Code of Regulations, Title 14, section 15082(b), your response must be sent no later than 30 days after receipt of this notice, although you are encouraged to submit them sooner. You may submit comments electronically through the CEC's electronic commenting feature on the CEC's webpage at https://efiling.energy.ca.gov/EComment/EComment.aspx?docketnumber=19-BSTD-03.

A full name, email address, comment title, and either a comment or an attached document (.doc, .docx, or .pdf format) is mandatory. After a challenge response test used by the system to ensure that responses are generated by a human user and not a computer, click on the "Agree & Submit Your Comment" button to submit the comment to the CEC's Docket Unit.

You are encouraged to use the electronic filing system described above to submit comments. If you are unable or do not wish to submit electronically, a paper copy of your comments, including the docket number 21-BSTD-02 and indicating "2022 Energy Code Update CEQA Documentation" may be sent to:

Docket Unit
California Energy Commission
Docket No. 21-BSTD-02
1516 9th Street, MS-4
Sacramento, CA 95814

Or, email them to docket@energy.ca.gov

Please note that your e-comments, emails, written letters, any attachments, and associated contact information (for example, address, phone number, and email address) become part of the viewable public record. Additionally, this information may become available via internet search engines.

If you have any questions or need additional information on how to participate in CEC's review of the proposed project, please contact Peter Strait at peter.strait@energy.ca.gov.

The project location, description, and potential environmental effects are summarized below.

Project Description

The Warren-Alquist Act establishes the CEC as California's primary energy policy and planning agency. Public Resources Code sections 25213, 25402, 25402.1, 25402.4, 25402.5, 25402.8, and 25910 mandate and/or authorize that the CEC adopt rules and regulations, as necessary, to reduce the wasteful, uneconomic, inefficient, or unnecessary consumption of energy and water in new residential and new nonresidential buildings.

One of the ways the CEC satisfies this requirement is through the Energy Code. The Energy Code includes the energy efficiency requirements applicable to newly constructed buildings and permitted additions and alterations to existing buildings. The CEC updates the Energy Code on a three-year cycle as part of the California Building Standards Code.

The current project is the latest triennial update to the Energy Code. The proposed amendments, if adopted, would be incorporated into the 2022 edition of the Energy Code and become effective on January 1, 2023. The CEC is proposing the following amendments to the Energy Code:

- Revise the prescriptive compliance path available for building projects to include only heat pump technology in specific circumstances;
- Revise the "standard design" used for the modeling-based performance compliance path available for building projects to establish the performance baseline based on heat pump technologies in specific circumstances;
- Improve existing residential energy efficiency standards for solar photovoltaic systems, including battery storage, and associated compliance options;
- Add new prescriptive solar photovoltaic and battery requirements for the following newly constructed nonresidential building types: high-rise multifamily, hotel-motel, tenant-space, office, medical office or clinic, restaurant, grocery store, retail store, school, and theater/auditorium/convention center buildings;
- Add new requirements that mixed fuel buildings be electric ready, meaning that electrical connections and other features needed to allow use of non-combustion equipment options are installed at the time of initial construction;
- Establish new energy efficiency standards for lighting, envelope, and space conditioning systems serving controlled environment horticulture spaces;
- Improve energy efficiency standards for commercial and industrial process loads, including, computer room air conditioning, refrigerated areas, fan systems, compressed air systems, and steam traps;
- Improve nonresidential and multifamily efficiency standards for building envelopes (e.g., exterior walls, windows, roofs, and floors), fan and duct systems, HVAC controls, boilers and service water heating systems, indoor and outdoor lighting systems, and grid integration equipment such as demand responsive controls;
- Improve minimum standards for residential kitchen ventilation;
- Update and enhance requirements relating to duct sealing and ventilation; and
- Make numerous minor revisions to existing provisions to improve the clarity of the regulations.

Project Location

The project is a change to building design and construction requirements that are applicable statewide.

Potential Environmental Impacts

While the Energy Code relates to new construction, it does not cause new construction to occur within the state. The Energy Code also does not regulate where such construction occurs nor does it change the application of zoning laws, land use restrictions, or any other laws that affect the siting of specific building projects.

Rather, the Energy Code is a set of design and construction requirements that apply once a decision to begin a construction project has been made and a building permit requested (i.e., the Energy Code provides conditions attached to the permit to construct a given improvement). The Energy Code sets design and construction standards for specific building components to ensure the building achieves a minimum level of overall energy efficiency. For example, the Energy Code may require that installed HVAC equipment meet minimum federal standards for equipment efficiency and that associated ducting be appropriately sealed and insulated. As such, adopting amendments to Energy Code requirements does not directly cause any changes to the environment. Its effects are indirect, as builders and manufacturers respond to new requirements.

Rather, improvements in energy efficiency act to lower a building's wasteful use of energy, thus avoiding potentially negative impacts that would otherwise have occurred. The majority of efficiency improvements considered in the proposed amendments to the Energy Code do not increase the amount of ground disturbance needed for a given building nor change the type or character of equipment or materials installed into the building as a part of its construction. Nevertheless, CEC has identified three areas where a potentially significant environmental impact may exist:

- An increase in greenhouse gas emissions is theoretically possible but not expected. The proposed Energy Code encourages heat pump technology, which reduces on-site gas combustion for space and water heating equipment. Heat pump equipment relies on use of refrigerants for its operation, as do air conditioners. Many of the most common refrigerants have a high global warming potential (see https://ww2.arb.ca.gov/resources/documents/high-gwp-refrigerants), meaning that refrigerant leakage, should it occur during transport, installation, operation, or disposal, could result in increased greenhouse gas emissions. While mixed-fuel buildings will still be constructed using the performance compliance approach, the removal of gas alternatives in the prescriptive pathway and the need to achieve modified performance targets can be reasonably anticipated to incentivize additional use of heat pump technologies that would not otherwise occur, with an expected commensurate increase in the use of necessary refrigerants.

  The use of refrigerants substitutes for continuous on-site combustion of gas during operation of space and water heating equipment, thus reducing combustion-related emissions and potentially increasing those from refrigerants. This substitution is not expected to lead to a significant increase in net greenhouse gas emissions attributable to building space heating and water heating needs, though staff acknowledges that there is a possibility than an environmental impact may nonetheless exist and intends to investigate this area in the EIR.

- Replacement of combustion of natural gas at the building site with heat pump technologies has a significantly lower emissions tradeoff than has historically been the case, making it reasonable to expect a net reduction in emissions. While use of utility-provided electricity means that overall fuel efficiency, inclusive of transmission losses, can be lower than the fuel efficiency of on-site equipment, this is counterbalanced by the fact that heat pump equipment is more efficient than combustion equipment (having coefficients of performance of two and above, meaning that they provide twice or more energy as heating than they consume as electricity). Further, California has made (and is mandated to continue making) significant strides to decarbonize its electricity system by converting to renewable sources, such that it is reasonable to expect that the relative advantages of heat pump technologies will increase over time.

Staff is not aware of any substantial evidence that fuel substitution would have a direct or a cumulatively considerable environmental impact on criteria pollutant emissions or greenhouse gas emissions, though staff acknowledges that there is a possibility that an environmental impact may nonetheless exist and intends to investigate this area in the EIR.

Lastly, staff has also identified a possibility of a cumulative impact occurring as this project encourages transition to electric equipment serving new space and water heating needs at the same time that other projects encourage transition to electric equipment serving transportation needs. Staff intends to investigate whether this context creates any potentially significant impacts.

- A significant increase in hazards and hazardous materials is possible but not expected, because the proposed Energy Code would incorporate battery storage systems into nonresidential system requirements. Battery storage equipment relies most commonly on use of lithium ion batteries for their operation. The requirement to include these systems in specified buildings can be reasonably anticipated to require routine transport of lithium ion batteries to such construction projects. Lithium ion batteries are regulated as a hazardous material under the U.S. Department of Transportation's Hazardous Materials Regulations (HMR; 49 C.F.R., Parts 171-180). (See https://www.phmsa.dot.gov/lithiumbatteries.)

  Lithium ion batteries are ubiquitous throughout consumer and commercial products, and compliance with existing federal laws allows them to be safely transported, used, and recycled. The marginal increase in routine transport, use, and disposal of such batteries needed to install building battery storage systems is not expected to lead to a significant increase in risk or to pose a significant hazard to the public or the environment, though staff acknowledges that there is a possibility that an environmental impact may nonetheless exist and intends to investigate this area in the EIR.

Staff has identified that this project will have either no or less-than-significant impacts in the following environmental topic areas: aesthetics, agriculture and forestry resources, biological resources, cultural resources, energy, geology and soils, hydrology and water quality, land use and planning, mineral resources, noise, population and housing, public services, recreation, transportation and traffic, utilities and other service systems, tribal cultural resources, and wildfire.

Responsible and Trustee Agencies

Any adoption of building standards by any state agency is subject to approval by the California Building Standards Commission, making them a responsible agency for this project.

Staff is not aware of any significant environmental impacts for which another California agency would be a trustee agency.

Alternatives

The EIR will consider a reasonable range of potentially feasible alternatives to the project. In addition to a no project alternative. The EIR will likely consider project alternatives that do not change provisions relating to use of heat pump equipment or add requirements for battery storage systems.

2021 SB 100 Joint Agency Report

Achieving 100 Percent Clean Electricity in California: An Initial Assessment

Gavin Newsom, Governor
March 2021 | CEC-200-2021-001

SB 100 Joint Agency Principals
Chair David Hochschild, California Energy Commission
Chair Mary Nichols, California Air Resources Board
Commissioner Liane Randolph, California Public Utilities Commission
Commissioner Andrew McAllister, California Energy Commission

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Finally, the joint agencies would also like to acknowledge the contributions and insights provided by California's balancing authorities, as well as the Disadvantaged Communities Advisory Group (DACAG). These contributions were essential in developing the analytical framework for SB 100, the interagency report, and recommendations for follow-up work.

PREFACE

The SB 100 Joint Agencies

The California Energy Commission's primary functions include forecasting electricity and natural gas demand for state planning, siting and licensing thermal power plants 50 megawatts or greater, investing in energy innovation, setting the state's appliance and building energy efficiency standards, and planning for and directing state response to energy emergencies. The CEC also publishes the Integrated Energy Policy Report, which provides an assessment of major energy trends and issues facing California's electricity, natural gas, and transportation fuel sectors.

The California Public Utilities Commission regulates services and utilities, protects consumers, safeguards the environment, and assures Californians' access to safe and reliable utility infrastructure and services. The essential services regulated include electric, natural gas, telecommunications, water, railroad, rail transit, and passenger transportation companies. The CPUC does resource planning for 80 percent of California's electric grid through the Integrated Resource Planning proceeding and implements programs such as the RPS, efficiency incentives, transportation electrification investments, customer solar, and building decarbonization.

The California Air Resources Board's mission is to promote and protect public health, welfare, and ecological resources through effective reduction of air pollutants while recognizing and considering effects on the economy. CARB is the lead agency for climate change programs and oversees all air pollution control efforts in California to attain and maintain health-based air quality standards.

The Climate Imperative

In 2020, Californians witnessed the impacts of climate change as never before. The state experienced its hottest August on record — the month ranked third hottest across the United States. On August 16, Death Valley, reported a high temperature of 130 degrees Fahrenheit. If verified, this would be the hottest August temperature ever recorded for the United States and among the hottest temperatures recorded on Earth. In September, Woodland Hills hit 121 degrees F, the hottest temperature ever recorded in Los Angeles County.

Along with record-breaking heat came a record-breaking fire season. The 2020 wildfire season was the largest in history, burning more than 4 million acres and shattering the previous record set in 2018. Five of the six largest wildfires in California history occurred in 2020 and the August Complex Fire was the single largest fire, having burned over 1 million acres. The 2020 fire season took 33 lives, and more than 10,400 structures were destroyed.

> ***"The debate is over around climate change. Just come to the state of California. Observe it with your own eyes"*** — Governor Newsom noted during a September 2020 press conference following a tour of the destruction of the North Complex Fire.

Without drastic mitigation measures, climate change-related events will continue to become more frequent, catastrophic, and costly. And the impacts are often disproportionately borne by the state's most vulnerable and disadvantaged populations.

California is only one piece of the climate solution. But as the fifth largest economy in the world, the state has an outsized role in demonstrating to other states and countries that a clean energy future is not only possible, but beneficial to the well-being of its residents and the economy. Moving to a clean electric grid is a foundational step that will unlock and support economywide opportunities to achieve carbon neutrality and address the most catastrophic impacts of climate change.

ABSTRACT

The *2021 SB 100 Joint Agency Report* (2021 Report) includes a review of the policy to provide 100 percent of electricity retail sales and state loads from renewable and zero-carbon resources in California by 2045. The report assesses various pathways to achieve the target and an initial assessment of costs and benefits. The report includes results from capacity expansion modeling and makes recommendations for further analysis and actions by the joint agencies.

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EXECUTIVE SUMMARY

Senate Bill 100 (SB 100)

The 100 Percent Clean Energy Act of 2018 (Senate Bill 100, De León, Chapter 312, Statutes of 2018) is a landmark policy that establishes a target for renewable and zero-carbon resources to supply 100 percent of retail sales and electricity procured to serve all state agencies by 2045. The bill also increases the state's Renewables Portfolio Standard (RPS) to 60 percent of retail sales by December 31, 2030 and requires all state agencies to incorporate these targets into their relevant planning.

The statute calls upon the California Public Utilities Commission (CPUC), California Energy Commission (CEC), and the California Air Resources Board (CARB) to use programs under existing statutes to achieve this policy and issue a joint policy report to the Legislature by January 1, 2021, and every four years thereafter. The report shall be completed as part of a public process and include specified information relating to policy implementation.

SB 100 is an Ongoing Effort

The analysis in the 2021 Senate Bill 100 Joint Agency Report (2021 Report) is intended to be a first step in an iterative and ongoing effort to assess barriers and opportunities to implementing the 100 percent clean electricity policy. This report includes system modeling to provide directional insights into what a 2045 portfolio of renewable and zero-carbon resources may look like, as well as the associated costs and resource build rates (the average amount of new generation required each year) required to achieve such a portfolio. The analysis builds on the modeling and assumptions used for CPUC's integrated resource planning and considers California's overarching priorities on energy, climate, equity, and public health.

Initial findings suggest that the goals of SB 100 are achievable, though opportunities remain to reduce overall system costs. This report presents various scenarios to meet the 100 percent clean electricity target with existing technologies, as well as alternative scenarios that explore additional factors. All these scenarios require additional analysis. The preliminary findings are intended to inform state planning and are not intended as a comprehensive nor prescriptive roadmap to 2045. As discussed in Chapter 4, future work will delve deeper into critical topics such as system reliability and land use and further address energy equity and workforce needs.

A robust public process informed the 2021 Report. The joint agencies held a year-long series of public workshops to solicit comments on the report's scope, analysis, and process. The agencies consulted with the California balancing authorities — which balance supply and demand and maintain electric frequency on the grid — as required by SB 100. The agencies also consulted with the Disadvantaged Communities Advisory Group, which consists of members from and representing disadvantaged communities and advises the CEC and CPUC on energy equity issues.

Moving to 100 Percent Clean Electricity

California has long led the nation and the world in setting ambitious renewable energy and climate policies, working toward a clean economy that is healthier and more just. The state now aims to achieve carbon neutrality by 2045 and net negative emissions thereafter

Decarbonizing the electric grid is imperative to achieve economywide carbon neutrality. The Renewables Portfolio Standard (RPS) has been a primary driver for increasing clean electricity generation, requiring the state's electric utilities to make renewable energy sources like solar and wind an ever-greater percentage of their power base. Although California is ahead of schedule in meeting its 33 percent renewable energy target by 2020 and on track to achieve 60 percent renewable energy by 2030, deep decarbonization of the electricity sector to meet climate change objectives will require continued transformational change in the state's electric system.

As California enters a new climate reality and moves toward a majority renewable grid, the state's planning processes likewise need to evolve to meet the needs of all Californians who depend on safe, affordable, and reliable electricity every day. Effectively integrating 100 percent renewable and zero-carbon electricity and achieving carbon neutrality in the state by 2045 will require rigorous analysis of implementation considerations, as well as coordinated planning across state agencies. While there remains work to do, achieving 100 clean electricity is a core pillar in the transition to a clean energy economy enjoyed by all Californians.

Benefits of 100 Percent Clean Electricity

In addition to serving as a central policy in the state's efforts to address climate change, successful implementation of SB 100 can benefit residents across the state by:

Improving Public Health

Implementing SB 100 is expected to reduce criteria air pollution emissions as renewable and zero-carbon resources replace fossil fuel in generating electricity. Today, more than 28 million Californians live in areas that exceed the federal health-based standards for ozone and fine particulate matter ($PM_{2.5}$). Disadvantaged communities (see glossary for definition) will reap the highest health benefits from the phaseout of fossil fuels in generating electricity; half of the state's natural gas power plants are in communities that rank among the 25 percent most disadvantaged.

The public health benefits are expected to grow substantially throughout the state as the transition from fossil fuels to clean electricity accelerates in transportation and buildings. Increased conversion of cars, trucks, and buses, as well as home appliances to electric technologies can improve health and reduce mortalities associated with air pollution across the state.

Advancing Energy Equity

The joint agencies are committed to ensuring the benefits of cleaner, more efficient energy are enjoyed by all Californians, including those in low-income and disadvantaged communities, as well as tribal and rural communities. To ensure equitable outcomes, SB 100 will need to be implemented in ways that help these communities overcome barriers to clean energy, including:

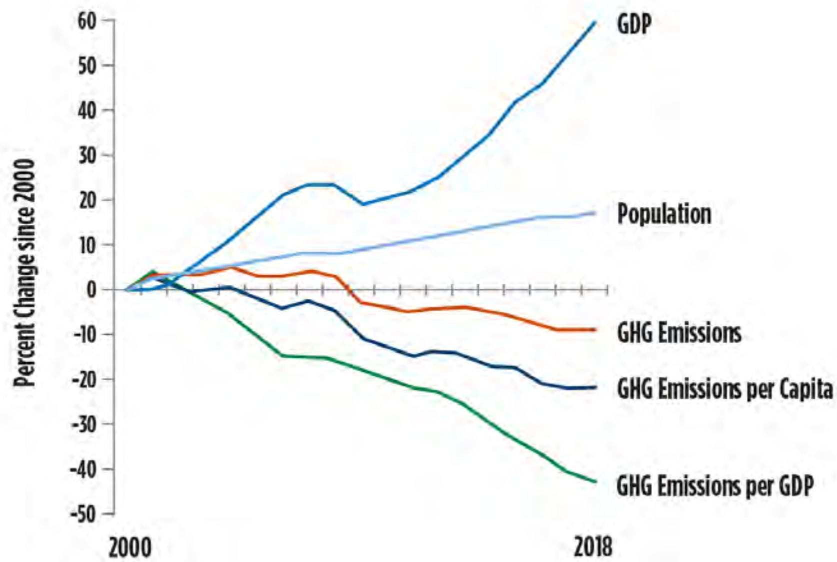
- Keeping electricity affordable, with an emphasis on vulnerable populations and households that pay a disproportionately high share of their household income on energy.
- Reducing air pollution from local power plants, particularly in communities that experience a disproportionate amount of air pollution.
- Strengthening communities' ability to function during power outages and enjoy reliable energy in a changing climate.
- Funding of training for high-quality jobs and careers in the growing clean energy industry.

Supporting a Clean Energy Economy

As a clean energy leader boasting one of the world's largest economies, California has shown that economic growth and environmental protection are not mutually exclusive. For decades, the state has reduced GHG emissions while growing its economy at a rate that has consistently outpaced the U.S. national average.

California's policies have spurred innovation and created markets for renewable energy, energy efficiency, energy storage, low-carbon fuels, and zero-emission vehicles. The state is a leader in patent registrations across all major clean technology (cleantech) categories and California's companies have received more than 50 percent of all U.S. venture capital investment in cleantech.

Figure 1: Statewide Trends of Emissions and Indicators (2000–2018)



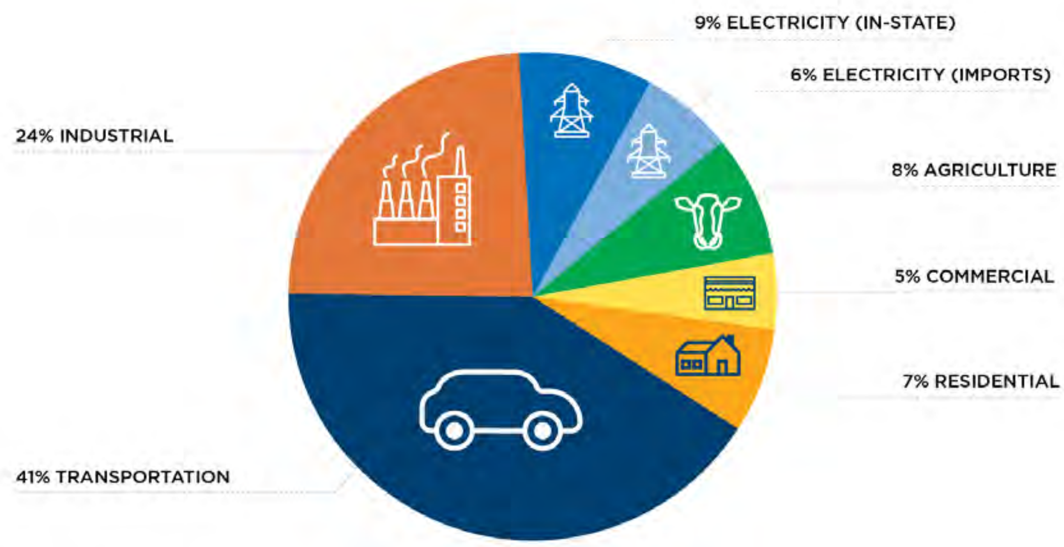
Source: CARB Emissions Inventory

As of 2020, California had more than 530,000 clean energy jobs, more than half the total energy-related jobs in the state. While the global COVID-19 pandemic has dramatically affected California's energy sector, clean energy jobs remain an important component of the state's economy. SB 100 provides an opportunity to create more high-quality clean energy jobs and increase diversity in the state's clean energy workforce.

A Cornerstone of California's Clean Energy Efforts

Successful implementation of SB 100 alone will not achieve statewide carbon neutrality, but it is pivotal to the success of California's climate-fighting efforts that collectively can reach the target. A clean electricity grid can serve as a backbone to support the decarbonization of transportation, buildings, and some industries. Together, with the electricity sector, these sectors account for 92 percent of the state's GHG emissions.

Figure 2: California GHG Emissions by Sector



Source: CARB Emissions Inventory

SB 100 sits within a portfolio of related key clean energy efforts to reduce climate and air pollution emissions while maintaining a reliable and affordable electric grid. These efforts include:

- **Transportation Electrification** — While the transportation sector remains among the state's biggest decarbonization challenges, California has already positioned itself as a leader in clean transportation with more than 566,000 zero-emission vehicles (ZEVs) on the road and nearly half of the total U.S. ZEV sales. Building on this success, Governor Gavin Newsom issued an executive order in September 2020 requiring all new passenger car and truck sales to be zero-emission by 2035. This transformation will require close coordination and planning across the electric and transportation sectors.
- **Building Decarbonization** — The construction of and conversion to zero-emission buildings has rapidly emerged as a key decarbonization strategy in recent years. State agencies are assessing pathways to reduce emissions from this important sector and considering implications of migrating more building energy uses, such as space and water heating, to the electric grid.
- **Energy Efficiency** — Prioritizing cost-effective energy efficiency measures remains critical as the state moves toward 100 percent clean electricity. Taking steps to reduce energy demand can offset the need for additional generation capacity, saving customers money while reducing land-use and other environmental impacts associated with the construction of new generation facilities.

- **Load Flexibility** — Load flexibility — the ability to shift electricity consumption to other parts of the day — is critical to supporting grid reliability, especially in a high-renewables future, and reducing the total cost of the electric system. The state has efforts underway to research and implement a variety of load flexibility applications.
- **Research and Innovation** — Given the urgency of achieving an electricity system powered by renewable and carbon-free electricity, continued prioritization of research and development of new and more cost-effective solutions is imperative. State agencies are also working to ensure these investments benefit all Californians.

2021 Report Analysis and Findings

The analysis for this report used the RESOLVE California model, a capacity expansion model developed by Energy and Environmental Economics, Inc. (E3). The RESOLVE model produces a least-cost resource portfolio, given policy and reliability constraints. The modeling inputs and assumptions build upon previous state efforts, including the CPUC's Integrated Resource Planning (IRP) 2045 Framing Study, and were informed through public and stakeholder comments.

The analysis examines estimated resource requirements and cost impacts of various SB 100 implementation pathways. Although capacity expansion is an important tool, it is just the first step in a series of modeling phases to develop reliable portfolios that meet all applicable policy objectives. Further analysis is needed to evaluate topics such as reliability and land use and better reflect equity, workforce, and additional planning and implementation considerations.

Modeled Scenarios

While the primary focus of this report is to analyze scenarios based on established cost and performance data and the joint agencies' interpretation of SB 100, the joint agencies recognize the importance of analyzing outcomes beyond these assumptions to support broader energy and climate planning and public health efforts. As such, scenarios are broken into two categories, "core scenarios" and "study scenarios," described below. A 60 percent RPS scenario was also modeled and used as a counterfactual, or reference baseline, to evaluate the impacts of the 100 percent clean electricity policy.

Core Scenarios

The "core scenarios," shown **Table 1**, modeled for the 2021 Report are consistent with the joint agencies' interpretation of the statute and include only commercialized technologies with publicly available cost and performance data.

Table 1: SB 100 Core Scenario Classification List

Scenario Classification	Scenario Description
SB 100 Core Scenario	Includes retail sales and state loads; high electrification demand; all candidate resources available
SB 100 Core, Demand Sensitivities	Change: demand scenarios or load shape
SB 100 Core, Resource Sensitivities	Change: candidate resource availability

Source: CEC, CPUC, and CARB. Developed by consensus

Study Scenarios

The "Study Scenarios," shown in **Table 2**, are exploratory analyses that examine outcomes outside the scope of the joint agencies' interpretation of the SB 100 policy. They are intended to provide additional information for consideration and support broader state energy, climate planning, and public health efforts. Study scenarios should not be interpreted as asserting the state's ability or intention to regulate beyond the interpreted scope of SB 100.

Table 2: Study Scenario Classification List

Scenario Classification	Scenario Description
Expanded Load Coverage	Adds storage and system losses to included loads; high electrification demand; all candidate resources available. Demand and resource sensitives were also analyzed.
No Combustion	No conventional combustion resources included (fossil and biomass based); retires all in-state combustion resources by 2045.
Zero Carbon Firm Resources	Adds generic zero carbon firm resources to candidate resources as a proxy for emerging zero-carbon technologies.
Accelerated Timelines	Accelerates 100% target to 2030, 2035, and 2040.

Source: CEC, CPUC, and CARB. Developed by consensus

Zero-Carbon Resources Modeled

SB 100 does not define "zero-carbon resources," and the state had no legal definition prior to the bill becoming law. For modeling, the joint agencies interpreted "zero-carbon resources" to mean energy resources that either qualify as "renewable" in the most recent Renewables Portfolio Standard (RPS) Eligibility Guidebook or generate zero greenhouse gas emissions on site.

Only commercialized technologies with vetted and publicly available cost and performance data and an anticipated pipeline of development were included for the core scenarios. Moreover, the joint agencies excluded energy resources from some or all scenarios if the use of these resources would have significant negative effects on public health or the environment or were otherwise at odds with state policies and priorities. Excluded technologies may be included in future SB 100 analyses if assessments change. Staff will update modeling as emerging technologies become commercialized.

Table 3 lists technologies that could meet the SB 100 criteria for renewable and zero-carbon resources, as interpreted by the joint agencies. The list is not prescriptive but rather used to evaluate potential SB 100 implementation strategies.

Table 3: Generation Technologies Included in Modeling

Technology	Eligibility Basis	Scenarios
Solar PV	RPS	Core and Study
Solar Thermal (existing only)	RPS	Core and Study
Onshore Wind	RPS	Core and Study
Offshore Wind	RPS	Core and Study
Geothermal	RPS	Core and Study
Bioenergy	RPS	Core and Study
Fuel Cells (using green hydrogen)	RPS	Core and Study
Small Hydro (existing only)	RPS	Core and Study
Large Hydro (existing only)	Zero-Carbon	Core and Study
Nuclear (existing only)	Zero-Carbon	Core and Study
Generic Firm Dispatchable Resource	Zero-Carbon	Study Only
Generic Firm Baseload Resource	Zero-Carbon	Study Only

Source: CEC, CPUC, and CARB. Developed by consensus

Technologies that could meet the zero-emissions criteria but have other barriers to development were excluded from modeling for the reasons listed in **Table 4**.

Table 4: Considered Technologies Excluded From Modeling

Technology	Reason for Exclusion
New in-state nuclear	State effectively has a moratorium on new in-state nuclear power plants under the Warren-Alquist Act.
Drop-in renewable fuels (green hydrogen and biomethane)	Technology for synthetic drop-in renewable fuels not yet commercially available in California or inadequate cost and supply data for modeling or both. Inadequate supply potential for biomethane in the power sector.
Natural gas generation with carbon capture and sequestration	Lack of cost and performance data for 100 percent carbon capture.
Coal-fired generation with carbon capture and sequestration	Incompatible with the state's public health priorities and lack of cost and performance data for 100 percent carbon capture.
New small hydroelectric generation	Inadequate data on new capacity cost and resource availability for modeling purposes.
New concentrating solar power	Lack of proposed new development and high cost relative to other solar resources.
New large hydroelectric generation	Limited development feasibility at this time and environmental concerns.

Source: CEC, CPUC, and CARB joint agency consensus

Modeling Results

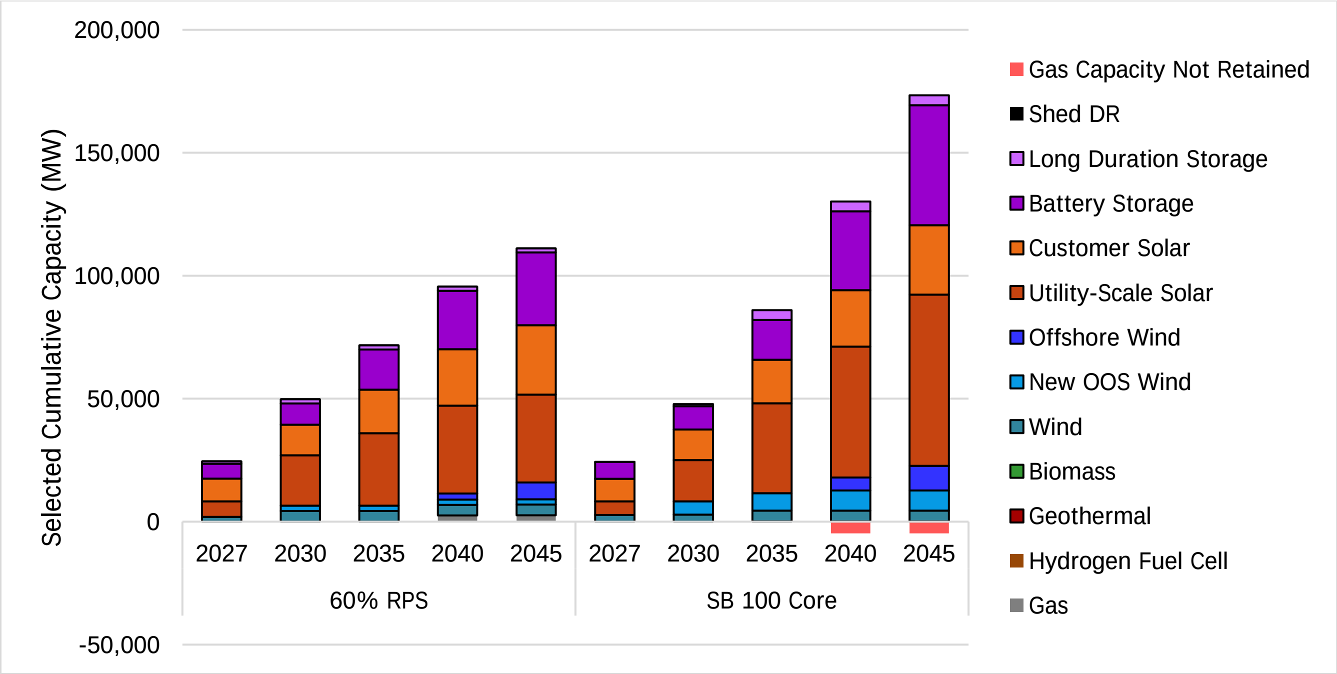
All scenarios modeled for the 2021 Report result in significant capacity additions. However, numerous factors affect the total resource need, overall system costs, and makeup of a 2045 resource portfolio. Select modeling results are shown below. For complete results, see Chapter 3.

Core Scenarios

SB 100 Core Scenario

Figure 3 shows cumulative capacity additions for the 60 percent RPS and SB 100 Core scenarios. The SB 100 Core scenario shows an approximate tripling of generation resources relative to today's installed capacity, which is driven by the conversion to clean electricity resources and growing electricity demand.

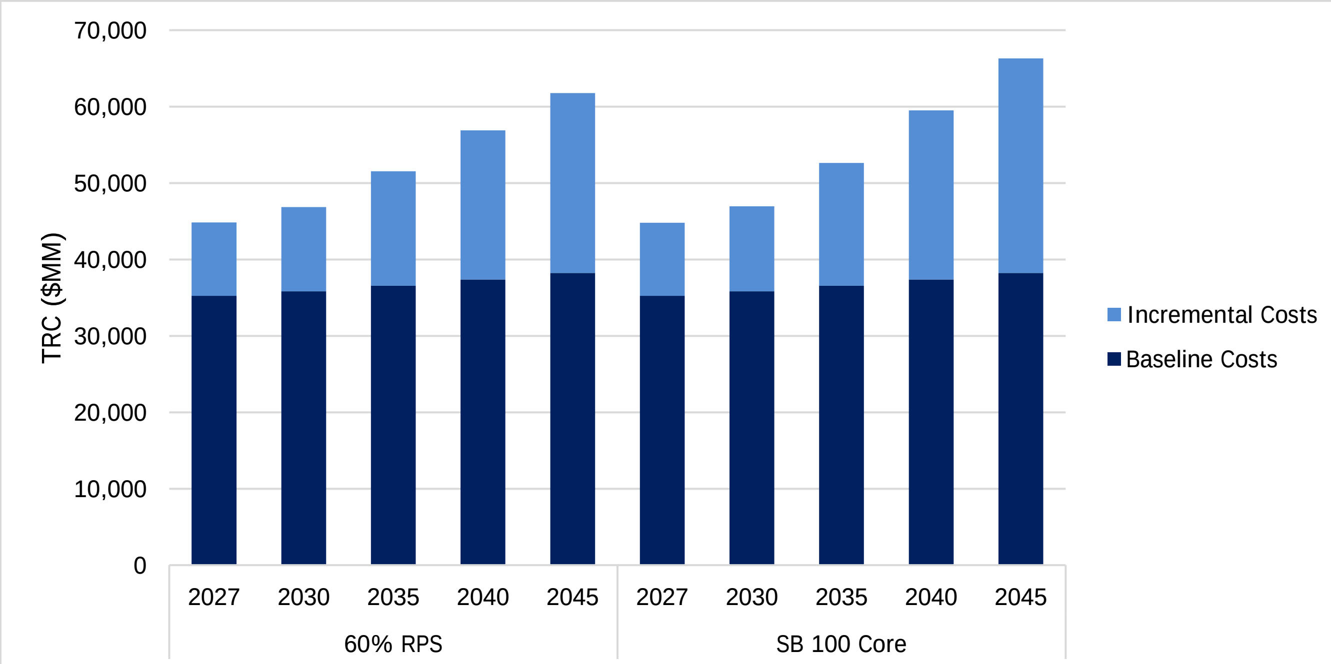
Figure 3: Cumulative Capacity Additions for SB 100 Core Scenario and 60 Percent RPS Reference Scenario



Source: CEC staff and E3 analysis

The SB 100 Core scenario results in nearly $4.5 billion in additional annual total resource cost (TRC) in 2045, or a 6 percent increase over the 60 percent RPS reference, as shown in **Figure 4**. Investments in renewables, storage and transmission constitute the primary differences in costs. All costs presented are directional and require further analysis.

Figure 4: Total Resource Cost of the 60 Percent RPS and SB 100 Core Scenarios

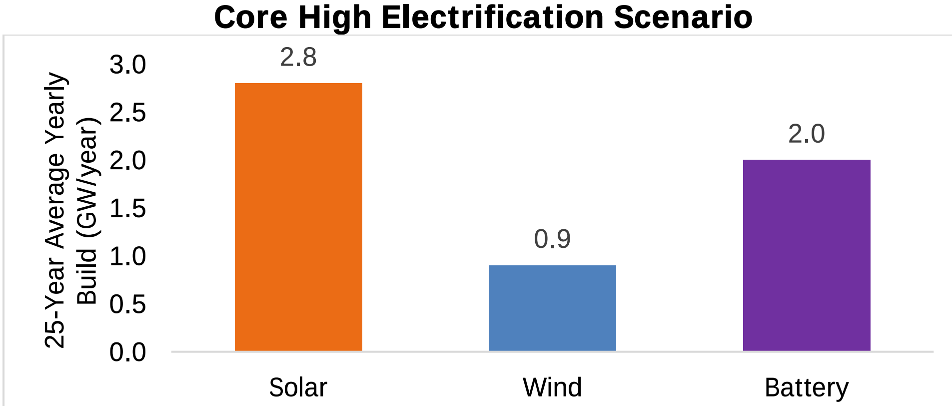


Source: CEC staff and E3 analysis

Given the magnitude of the capacity additions, the average build rates provide important implications for implementing the 100 percent clean electricity goal. Build rates can indicate whether there could be bottlenecks in supply-chain or regulatory and permitting processes, resulting in barriers to procurement of new clean energy generation.

Over the last decade, California has built on average 1 gigawatt (GW) of utility-scale solar and 300 MW of wind per year, with a maximum annual build of 2.7 GW of utility-scale solar and 1 GW of wind capacity. As shown in **Figure 5**, the SB 100 Core Scenario requires 25-year average build rates consistent with or greater than the single-year historical build rates.

Figure 5: Average Resource Build Rates for Solar, Wind and Batteries in the SB 100 Core High Electrification Scenario

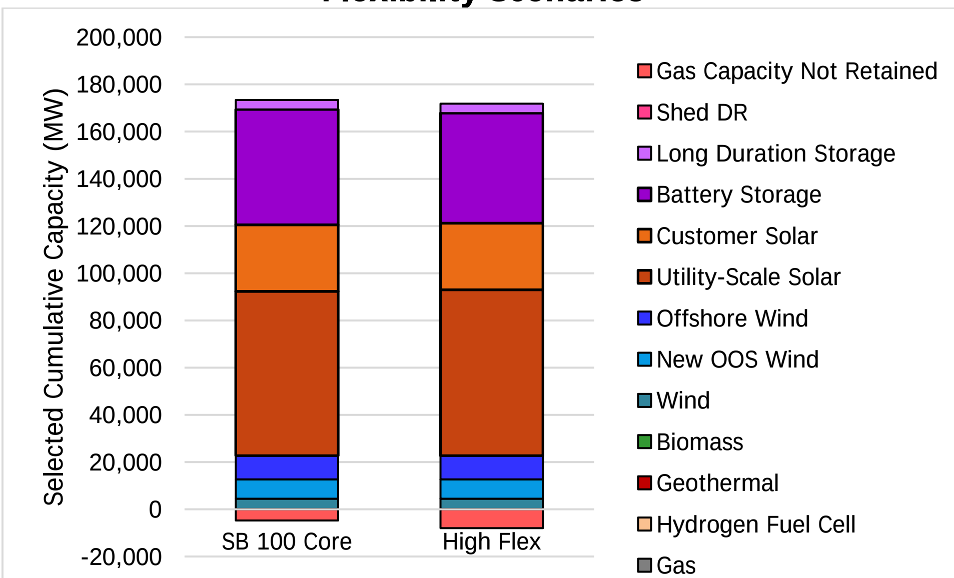


Source: CEC staff and E3 analysis

SB 100 Core: High Flexibility Scenario

The shape and flexibility of electricity loads can significantly impact cost and resource build. While RESOLVE cannot at this time explicitly model load flexibility, a high flexibility scenario was developed with a modified load shape and reduced resource adequacy requirement to represent a future with greater load flexibility. As shown in **Figure 6**, the High Flexibility Scenario results in 2.7 GW avoided battery storage build and a decrease in economic gas retention by 3.3 GW compared to the SB 100 Core Scenario, with the same annual electric energy demand. The High Flexibility Scenario also results in nearly $1 billion of annual supply cost savings in 2045, compared to the SB 100 Core Scenario.

Figure 6: Cumulative Capacity Additions in 2045 for the SB 100 Core and High Flexibility Scenarios



Source: CEC staff and E3 analysis

Study Scenarios

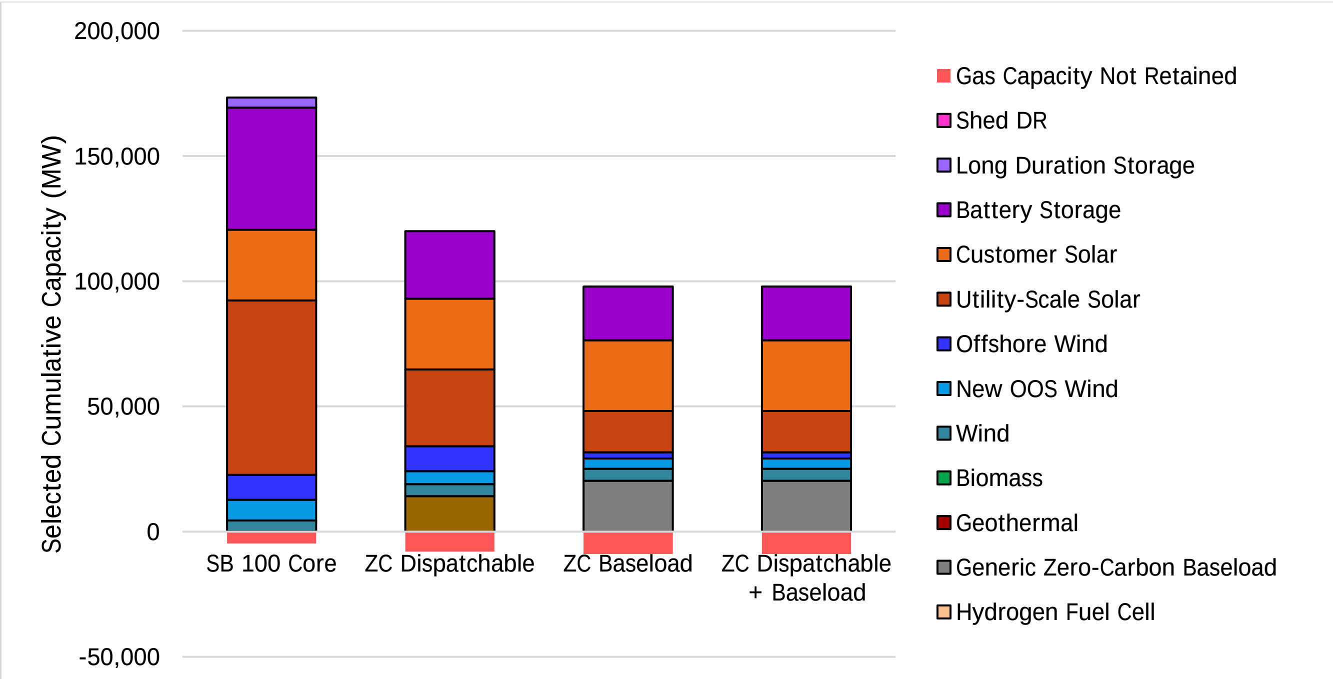
Study: Generic Zero-Carbon Firm Resources Scenario

A number of emerging zero-carbon technologies could play an important role in achieving the 100 percent renewable and zero-carbon electricity target. However, due to high uncertainty in the available cost and performance data of pre-commercialized technologies, some technologies were not included in the core scenarios. Instead, the joint agencies included study scenarios to begin to evaluate the potential impact of commercialization of cost-competitive, zero-carbon firm resources.

The “generic dispatchable” resource and “generic baseload” resource included in these scenarios could represent a wide variety of emerging technologies, such as natural gas with 100 percent carbon capture, 100 percent green hydrogen combustion, or other renewable fuels, if they are able to achieve the modeled cost profiles. The study scenarios could also indicate the effects of higher-cost existing resources achieving the modeled cost profiles.

In scenarios where either the generic dispatchable resource, generic baseload resource, or both are included as a candidate resource, the model selects about 15 GW of either or both resources in total, as shown in **Figure 7**. The inclusion of the lower-cost zero-carbon firm resources significantly lowers the utility-scale solar and battery storage selected in the model and reduces TRC in 2045 by $2 billion, or about 3 percent.

Figure 7: Cumulative Capacity Additions for the SB 100 Core and Generic Zero-Carbon Firm Resource Scenarios in 2045



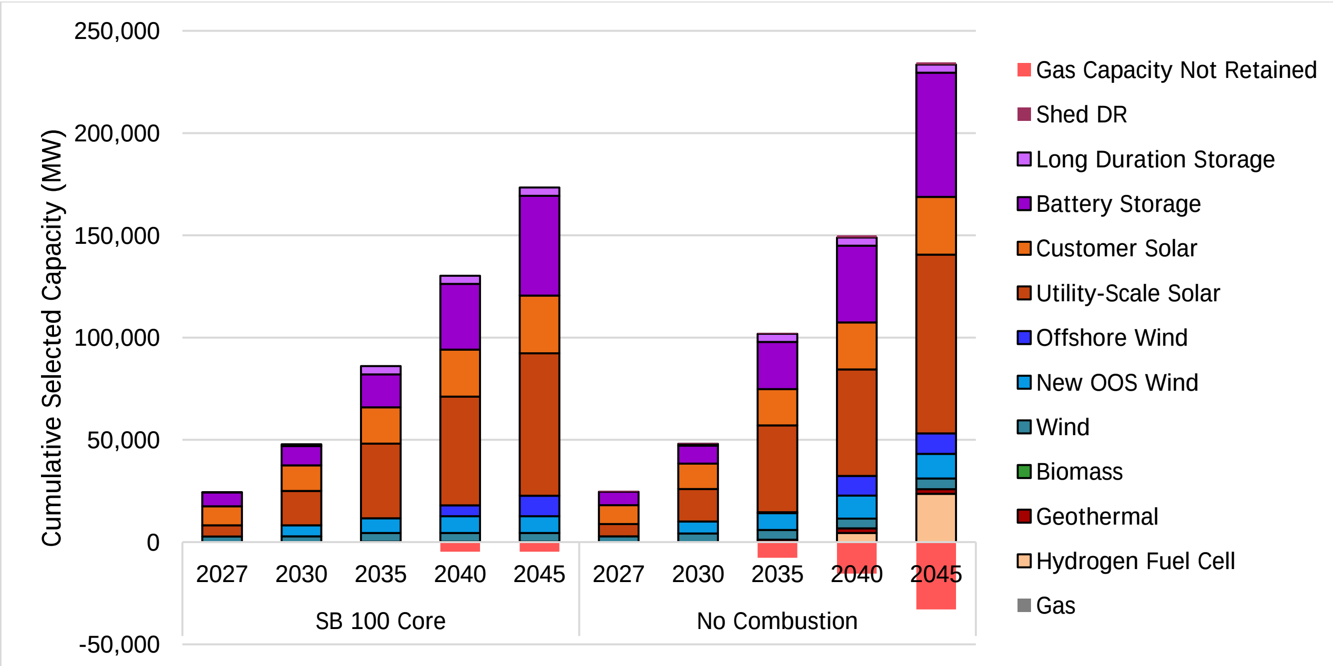
Source: CEC staff and E3 analysis

Study: No Combustion Scenario

SB 100 does not preclude combustion resources from being a part the state's resource portfolio. However, studying scenarios in which combustion resources are expressly retired can inform pathways to significantly reduce criteria pollutants and toxic air contaminants from electricity generation. To that end, the No Combustion Scenario retires all combustion resources by 2045, and no combustion resources are available as candidate resources.

With the retirement of all combustion resources, 61 GW of additional capacity is selected compared to the SB 100 Core Scenario, including 25 GW of hydrogen fuel cells, as shown in **Figure 8**. Given the significant capacity additions in the No Combustion Scenario, there is an increase annual TRC by $8 billion, or about 12 percent, compared to the SB 100 Core Scenario.

Figure 8: Cumulative Capacity Additions for the SB 100 Core and No Combustion Scenarios



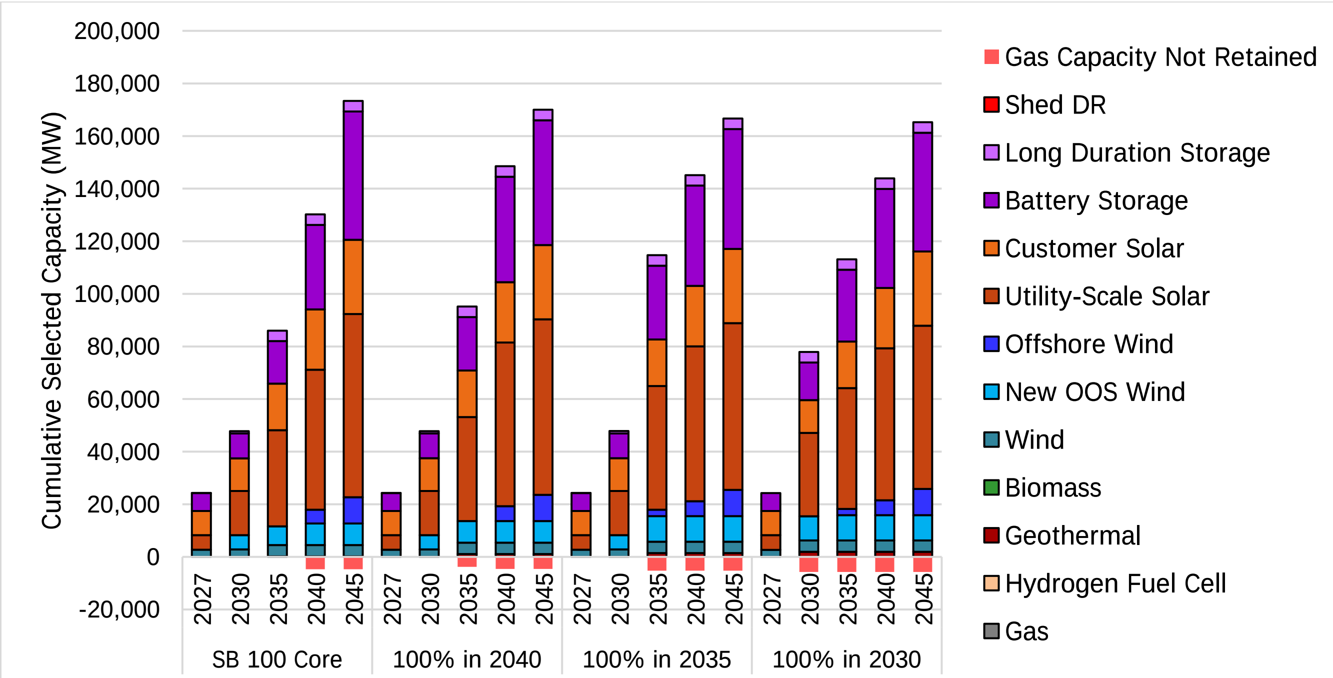
Source: CEC staff and E3 analysis

Study: Accelerated Timeline Scenarios

The final set of study scenarios examine the impacts of accelerating the 100 percent renewable and zero-carbon target to 2030, 2035, and 2040. Each accelerated timeline scenario shows a significant jump in resource build in the 100 percent target year, while the 2045 portfolio remains similar across scenarios, as shown in

Figure 9. The final set of study scenarios examine the impacts of accelerating the 100 percent renewable and zero-carbon target to 2030, 2035, and 2040. Each accelerated timeline scenario shows a significant jump in resource build in the 100 percent target year, while the 2045 portfolio remains similar across scenarios, as shown in **Figure 9**.

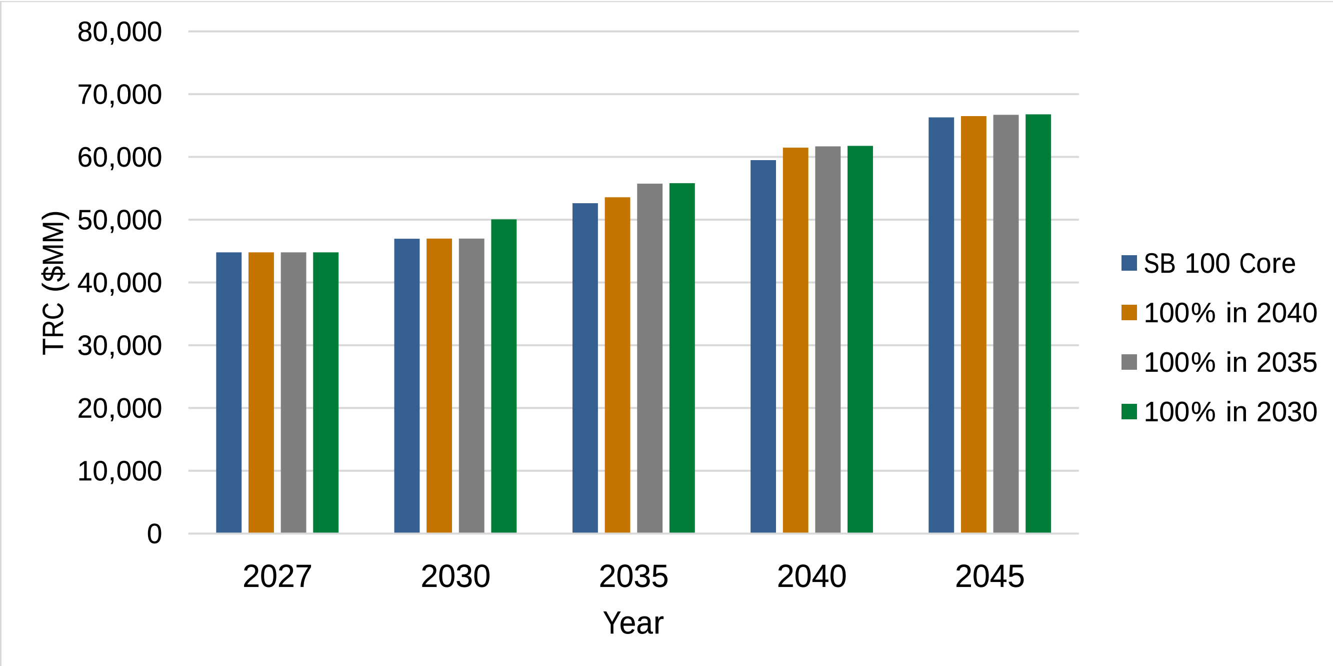
Figure 9: Cumulative Capacity Additions for the SB 100 Core (2045 SB 100), 100 Percent in 2040, 100 Percent in 2035, and 100 Percent in 2030 Scenarios



Source: CEC staff and E3 analysis

Each accelerated timeline scenario results in increased annual TRC compared to the SB 100 Core scenario for every modeled year except 2027, as shown in **Figure 10**. In general, the TRC shows a significant jump in the year the 100 percent target is set to be achieved. By 2045, the accelerated scenarios result in less than a 1 percent increase in TRC relative to the SB 100 Core scenario.

Figure 10: Total Resource Costs for the SB 100 Core, 100 Percent in 2040, 100 Percent in 2035, and 100 Percent in 2030 Scenarios



Source: CEC staff and E3 analysis

Key Takeaways From Modeling

1. SB 100 Is Achievable

Initial analysis demonstrates that SB 100 is technically achievable, though additional analysis is needed to evaluate reliability and other factors more comprehensively. The preliminary modeling in this report suggests the total resource cost of achieving SB 100 is about 6 percent higher than a 60 percent RPS future in 2045. This cost may be lower if the cost trends for renewables continue to fall faster than projections. Cost reductions and innovation in zero-carbon technologies, as well as load flexibility and energy storage development, can further reduce implementation costs.

- **Increased Resource Diversity Lowers Overall Costs**

  Resource portfolio diversity, both technological and geographical, generally lowers total resource costs. Nearly all out-of-state or offshore wind resources are selected when made available, and even a modest amount of load flexibility can reduce battery storage requirements, decrease gas capacity and lower total costs. If zero-carbon firm technologies can reach a cost of about $60/megawatt-hour (MWh), they could reduce system costs by an estimated $2 billion annually in 2045.

- **Gas Capacity Is Retained for Reliability Needs, but Cost Reductions and Innovation in Zero-Carbon Firm Resources and Storage May Reduce Gas Capacity Needs**

  Natural gas capacity is the most economic option to provide capacity for reliability needs with current resource assumptions and demand scenarios. Cost reductions and innovation in zero-carbon firm resources and storage may reduce the amount of gas generation needed. Further analysis is needed to evaluate costs associated with maintaining an aging gas fleet operating in a high-renewables system.

2. **Sustained Record-Setting Build Rates Will Be Required to Meet SB 100 in a High-Electrification Future**

   The need for a significant amount of new generation resources is driven by the 100 clean electricity target and increasing electricity demand to achieve economywide decarbonization. The projected record-setting resource development rates needed have implications for workforce needs, land-use planning, technology supply chains, and regulatory and permitting processes that must be considered for implementing SB 100 successfully.

3. **Goals Beyond SB 100 May Be Achievable but Require Additional Analysis**

   The study scenarios are beyond the scope of SB 100. However, they provide directional insight to inform the state's energy and climate planning efforts and contribution toward environmental and public health goals.

   Eliminating all in-state combustion resources results in a significant increase in the amount of storage and zero-carbon firm resources selected by the model to replace natural gas capacity. This scenario adds an estimated $8 billion to annual system costs in 2045 compared to the SB 100 Core scenario. Further analysis could identify public health benefits, particularly in disadvantaged communities where a disproportionate amount of combustion resources is located. This analysis may estimate the relative public health benefits along with the additional costs.

   Accelerating the SB 100 timeline to achieve the 2045 target by 2030, 2035, or 2040 results in increased total resource costs and required additional capacity in the target year. All scenarios resulted in similar annual resource costs and resource portfolios by 2045.

4. **Current SB 100 Analysis Is Directional, and Further Analysis Is Necessary**

   This analysis is the first step in an ongoing effort to evaluate and plan for the SB 100 policy. Further analysis is necessary to determine reliability of the portfolios, better capture the impact and value of resources that are either not represented or not well valued in the current modeling framework — including long-duration storage, hybrid resources, demand-side resources, load flexibility, and emerging technologies, such as green hydrogen and natural gas with 100 percent carbon capture and sequestration — as well as assess local community impacts.

Next Steps for Analysis

The analysis in the 2021 Report is intended to be a first step in an iterative and ongoing effort to assess barriers and opportunities to implementing the 100 percent clean energy policy. The modeling of this report provides directional insights into what a 2045 portfolio of renewable and zero-carbon resources may look like, as well as the associated costs and resource build requirements to achieve such a portfolio. Topics for additional assessment include:

- ***Reliability***: The joint agencies plan to evaluate resource portfolios developed in this report in a multistep process to ensure reliability for all hours of the year in line with state planning requirements while meeting clean energy and climate goals.
- ***Emerging Technologies and Innovation***: Future analyses will be updated to incorporate market trends and aim to better evaluate the potential impact of emerging resources, such as offshore wind, long-duration energy storage, green hydrogen technologies, and demand flexibility.
- ***Land-Use and Environmental Impacts:*** The joint agencies plan to review methods to include land-use impacts in system modeling and assess needs to update previous land use studies to reflect the increased resource requirements of SB 100.
- ***Non-Energy Benefits (NEBs) and Social Costs:*** Emerging cost analysis tools and methods may better integrate social costs and NEBs. Stakeholders recommended the joint agencies integrate at least the following NEBs and social costs into SB 100 planning:
    - Land-use impacts
    - Public health and air quality
    - Water supply and quality
    - Economic impacts
    - Resilience

Additional Considerations for Implementation

As the SB 100 scenarios are refined in the future, additional factors must be considered in planning for SB 100 implementation and coordination with complementary proceedings and programs:

- ***Equity:*** Steps must be taken to ensure equitable implementation of SB 100 and benefit communities in a meaningful and measurable way.
- ***Affordability:*** Meeting the 100 percent clean electricity target will likely require substantial new investments in the electric system, which may have impacts on electricity rates for consumers. Further analysis is required to better understand how these costs will be factored into rates that directly affect consumers.
- ***Safety:*** California is assessing how to address numerous new risks associated with electric and gas infrastructure and how to pay for needs including system maintenance, hardening, repurposing, upgrades, or retirement. State planners must incorporate

safety challenges in long-term planning and identify approaches to decarbonization that enhance public safety.

- *Electric System Resilience:* Cost-effective achievement of the 100 percent clean electricity target requires that investments in electricity generation and infrastructure consider climate change impacts. State agencies are also exploring options for clean backup power when there are disruptions to the grid.
- *Addressing Barriers to Project Development:* The analysis indicates that resources with lengthy permitting requirements and development times will be necessary, necessitating long lead-time planning. Stakeholders raised concerns about delays, which may need to be addressed to meet the SB 100 target.
- *Collaboration Across Western States:* There are opportunities for increased coordination and market development to ease importation and integration of additional renewable energy facilities and take advantage of the geographic diversity of loads and resources.

Recommendations

Following the results of the 2021 Report analysis and comments from stakeholders and the public, the joint agencies propose a number of key recommendations to support the implementation of SB 100 and inform long-term planning, which are summarized below.

Areas for Further Study in the 2025 SB 100 Report

1. **Perform a comprehensive reliability assessment as the next step in the modeling process.**

   Additional modeling is needed to evaluate whether the projected portfolios meet system reliability requirements. Projected portfolios can be adjusted as needed in an iterative process to ensure reliability requirements are met and inform the state's long-term system planning.

   The CEC and CPUC are assessing resource availability to complete this modeling ahead of the next report. The joint agencies will continue to consult with the California balancing authorities when developing the tools and metrics for this analysis.

2. **Continue to assess the role and impacts of emerging technologies and nongeneration resources.**

   Future analyses should be updated to reflect market trends, including changes in price, the commercialization of new technologies, and updates to total resource potential. Furthermore, the joint agencies should continue to evaluate and consider ways to better assess the impacts of less-proven technologies that could significantly impact a 2045 resource mix and total cost.

3. **Analyze projected land-use impacts of scenarios and opportunities to reduce environmental impacts.**

   The CEC is developing tools to better assess the total land area required to implement SB 100, areas where new resources could be located, and relative environmental impacts. As state agencies work to better quantify the carbon stored in natural and working lands, these areas must also be incorporated into electricity land-use planning. Closer collaboration with other state agencies, tribal governments, local and regional jurisdictions, and stakeholders, to plan for development will be important to balance clean electric grid infrastructure needs with efforts to restore, conserve, and strengthen natural and working lands.

4. **Define and include social costs and non-energy benefits (NEBs) in future analyses.**

   The joint agencies will continue evaluating available modeling tools and metrics to capture non-energy benefits and social costs in future SB 100 analyses, including those for:

   - Land-use impacts
   - Public health and air quality
   - Water supply and quality
   - Economic impacts
   - Resilience

5. **Continue to study opportunities and impacts related to achieving the 100 percent clean electricity target before 2045.**

   The joint agencies plan to continue analysis of the 2030, 2035, and 2040 scenarios in future SB 100 report analyses.

Process and Engagement for SB 100 Reports

6. **Convene an annual joint agency SB 100 workshop in years between reports.**

   Hosting an annual workshop will support alignment between agencies on relevant topics and proceedings and enhance continuity between SB 100 reports. These workshops will also provide an opportunity for joint agency leadership and staff to hear from stakeholders and the public on topics related to SB 100 progress.

7. **Align future SB 100 planning with findings and outcomes from relevant state efforts.**

   The joint agencies aim to incorporate findings and outcomes from other relevant efforts in future SB 100 reports. Relevant efforts include:

   - The CEC's energy demand forecasts, including electrification trends and updates for extreme climate event planning.

- Transmission planning and development.
- Reliability planning, including possible updates to resource adequacy requirements.
- Electric system resilience planning.
- Assessments from CPUC's Integrated Resource Planning, CEC's Integrated Energy Policy Report, and CARB's Scoping Plan.

8. **Consult with advisory groups to guide equitable planning and implementation.**

   The DACAG and other environmental justice, health, and equity stakeholders provided valuable input for this report. For the 2025 SB 100 Report, the joint agencies plan to continue and build upon this collaboration to help ensure SB 100-related efforts benefit all Californians.

9. **Retain and expand upon best practices for community outreach and accessibility.**

   The joint agencies worked to ensure broad access to the 2021 Report process by holding workshops across the state, conducting significant outreach by phone, email, and social media, and offering remote attendance options for all workshops. The agencies will retain these best practices for the 2025 SB 100 Report while exploring additional methods to maximize participation and access to meeting information and materials for California residents.

Supporting Achievement of the 100 Percent Target

10. **Continue state support for research and innovation in clean energy technologies.**

    Continued investments in research and innovation can accelerate technology performance and cost improvements that can make progress toward the SB 100 goal easier and faster and reduce costs to electricity ratepayers. California's research and innovation programs, including the Electric Program Investment Charge (EPIC), will continue to catalyze advancements to support the cost-effective implementation of SB 100. The state's ongoing collaboration with cleantech incubators, research labs, and private investment firms will be critical to leveraging state funding in innovation.

11. **Continue to prioritize energy efficiency and load flexibility to minimize total implementation costs.**

    Prioritizing cost-effective energy efficiency and load-flexibility measures remains critical as the state moves toward a 100 percent clean electricity future. Taking steps to reduce energy demand can offset the need for additional generation capacity, saving Californians money, while reducing land-use and other environmental impacts associated with the construction of new facilities.

12. **Identify and address bottlenecks in project permitting and development.**

    Because SB 100 implementation is projected to require sustained record-setting construction rates, barriers to project development need to be addressed early and comprehensively. The CEC and CPUC should engage with stakeholders — including developers, utilities, balancing authorities, local governments, and community organizations — to better understand specific barriers and advance strategies to address them.

13. **Promote workforce development programs that focus on high-quality job creation.**

    Implementation of SB 100 creates a significant opportunity to support California companies, benefit local economies, and create family-sustaining jobs while optimizing climate outcomes. The joint agencies should continue collaborating with the California Workforce Development Board (CWDB) to identify strategies and best practices to support an equitable clean energy workforce and high-quality job creation, including findings from CWDB's 2020 report, Putting California on the High Road. The agencies should also seek the expertise of the DACAG workforce subcommittee.

CHAPTER 1: Background

Clean Energy Efforts Across the Nation

In 2018, California became the second state, after Hawaii, to establish a 100 percent clean electricity target. Today, 17 states, plus Washington D.C. and Puerto Rico, have adopted similar policies, along with more than 200 cities and counties.[1] More than one-third of Americans, or roughly 111 million residents, live in a state or community committed to 100 percent clean electricity.[2]

The SB 100 joint agencies engage with the other committed states and entities through the 100 Percent Clean Energy Collaborative, established by the Clean Energy States Alliance, to promote knowledge-sharing and updates on implementation efforts.

Decades of Climate Leadership

California has long led the nation and the world in setting ambitious renewable energy and climate policies, working toward a clean economy that is healthier and more just. The state became a global leader in climate policy with the passage of the California Global Warming Solutions Act of 2006,[3] which requires a reduction of statewide GHG emissions to 1990 levels by 2020.41F[4] California met the target four years early and continues to accelerate decarbonization economywide.

1 Clean Energy States Alliance. 100% Clean Energy Collaborative - Table of 100% Clean Energy States https://www.cesa.org/projects/100-clean-energy-collaborative/table-of-100-clean-energy-states/, and UCLA Luskin Center for Innovation. November 2019. *Progress Toward 100% Clean Energy in Cities and States Across the U.S.* https://innovation.luskin.ucla.edu/wp-content/uploads/2019/11/100-Clean-Energy-Progress-Report-UCLA-2.pdf.

2 Ibid.

3 California Global Warming Solutions Act of 2006 (Assembly Bill 32, Núñez, Chapter 488, Statutes of 2006).

4 For more information, see the link to the California Air Resources Board AB 32 Overview Webpage, http://www.arb.ca.gov/cc/ab32/ab32.htm.

Table 5: California's Key Greenhouse Gas Reduction Policies

Year	Policy	Description
2006	AB 32 (Núñez)	Reduce statewide GHG emissions to 1990 levels by 2020.
2006	SB 1368 (Perata)	Prohibits long-term investments in baseload power plants[5] with GHG emission rates higher than those of natural gas combined-cycle generation.
2015	SB 32 (Pavley)	Reduce statewide GHG emissions to 40 percent below 1990 levels by 2030.
2015, 2005	Executive orders B-30-15 and S-3-05	Reduce statewide GHG emissions to 80 percent below 1990 levels by 2050.
2018	Executive Order B-55-19	Achieve carbon neutrality no later than 2045 and maintain net negative emissions thereafter.

Source: CEC staff

Putting a Price on Carbon

California launched a Cap-and-Trade Program in 2012 to ensure its climate goals are achieved cost-effectively. It places a firm, declining cap on the largest sources of GHG emissions, such as large power plants, importers of electricity, industrial plants, and natural and transportation fuel suppliers.

The program covers 80 percent of the state's GHG emissions and creates a powerful economic incentive for significant investment in cleaner, more efficient technologies. Companies covered by the program have flexibility to reduce emissions onsite or use allowances bought at state-administered auctions or from another company with excess allowances. All covered entities in the Cap-and-Trade Program are subject to existing air quality permit limits for criteria and toxic air pollutants.

The California Climate Investments initiative spends the auction revenue on projects that further reduce greenhouse gas emissions, strengthen the economy, and improve public health and the environment. Cumulatively, the program has invested $6.3 billion in these projects.[6]

5 Those intended to run constantly at near capacity levels.

6 State of California - California Climate Investments Data Dashboard Web page https://www.caclimateinvestments.ca.gov/cci-data-dashboard.

Increasing Renewable Energy Generation

The Renewables Portfolio Standard (RPS), established by law in 2002,[7] has been a primary driver for increasing clean electricity generation. The law and subsequent amendments require the state's electric utilities to make renewables an ever-greater percentage of their power base. SB 100 expands the RPS and requires 60 percent of electricity retail sales to be met by eligible renewable resources by December 31, 2030.

The CPUC implements and administers RPS compliance for California's retail sellers of electricity, which include investor-owned utilities (IOUs), electric service providers (ESPs) and community choice aggregators (CCAs). The CEC oversees enforcement of RPS procurement requirements of public owned utilities (POUs) and is responsible for the certification of eligible renewable energy resources.

Eligible Renewable Energy Resources[8]
For RPS compliance, generation must be procured from certified facilities, which include: • Solar • Wind • Geothermal • Biomass, such as crop residues, forest waste, and landscape trimmings • Biomethane from landfills and organic waste digesters • Small hydroelectric • Fuel cells using renewable fuel or qualifying hydrogen gas

State efforts have also supported rapid growth of the distributed solar industry. The California Solar Initiative of 2006[9] was particularly successful. The $3.4 billion, decade-long effort created a self-sustaining solar market. Thousands of home and business owners earned rebates by installing solar energy systems through the suite of incentives of the initiative.

7 Senate Bill 1078 (Sher, Chapter 516, Statutes of 2002) created the RPS with an initial target of 20 percent renewable electricity by 2017, citing an opportunity to "promote stable electricity prices, protect public health, improve environmental quality, stimulate sustainable economic development, create new employment opportunities, and reduce reliance on imported fuels." The CPUC regulates RPS rules for California's retail sellers of electricity. The California Energy Commission (CEC) administers the certification of electrical generation facilities as eligible renewable energy resources and regulates RPS requirements for public owned utilities. For more information, see CPUC RPS Program website and CEC RPS Program website.

8 For more information see California Energy Commission. *Renewables Portfolio Standard Eligibility Guidebook, Ninth Edition (Revised)*. Publication Number: CEC-300-2016-006-ED9-CMF-REV. January 2017. https://efiling.energy.ca.gov/getdocument.aspx?tn=217317.

9 Senate Bill 1 (Murray, Chapter 132, Statutes of 2006), Senate Bill 1 (Murray, Chapter 132, Statutes of 2006).

In 2018, the CEC adopted a building energy efficiency code[10] requiring most new homes to have solar photovoltaic systems (or be powered by a solar array nearby) starting January 1, 2020. With continuing cost declines, solar is now cost-effective for new home construction across the state. In 2019, California reached the milestone of 1 million solar rooftop installations.[11]

Key Renewable Energy Policies

Table 6: Key Renewable Energy Legislation

Year	Policy	Description
2002	SB 1078 (Sher)	Established RPS program and target of 20 percent renewable energy in state's electricity mix by 2017
2006	SB 1 (Murray)	Codified California Solar Initiative, a $3.4 billion decade-long program to create a self-sustaining solar market
2006	SB 107 (Simitian)	Accelerated the 20 percent RPS target from 2017 to 2010
2011	SB X1-2 (Simitian)	Added RPS target of 33 percent by 2020
2015	SB 350 (De León)	Adds RPS target of 50 percent by 2030, a doubling of energy efficiency by 2030, and steps to ensure all Californians, including those in the most vulnerable communities, realize benefits of a clean energy economy
2018	SB 100 (De León)	Increases RPS mandate to 60 percent by 2030 and set a 2045 target for renewable and zero-carbon resources to supply 100 percent of retail sales and electricity procured for all state agencies.
2018	2019 Building Energy Efficiency Standards	Requires solar photovoltaic systems on new homes starting in 2020

Source: CEC staff and California Legislative Information

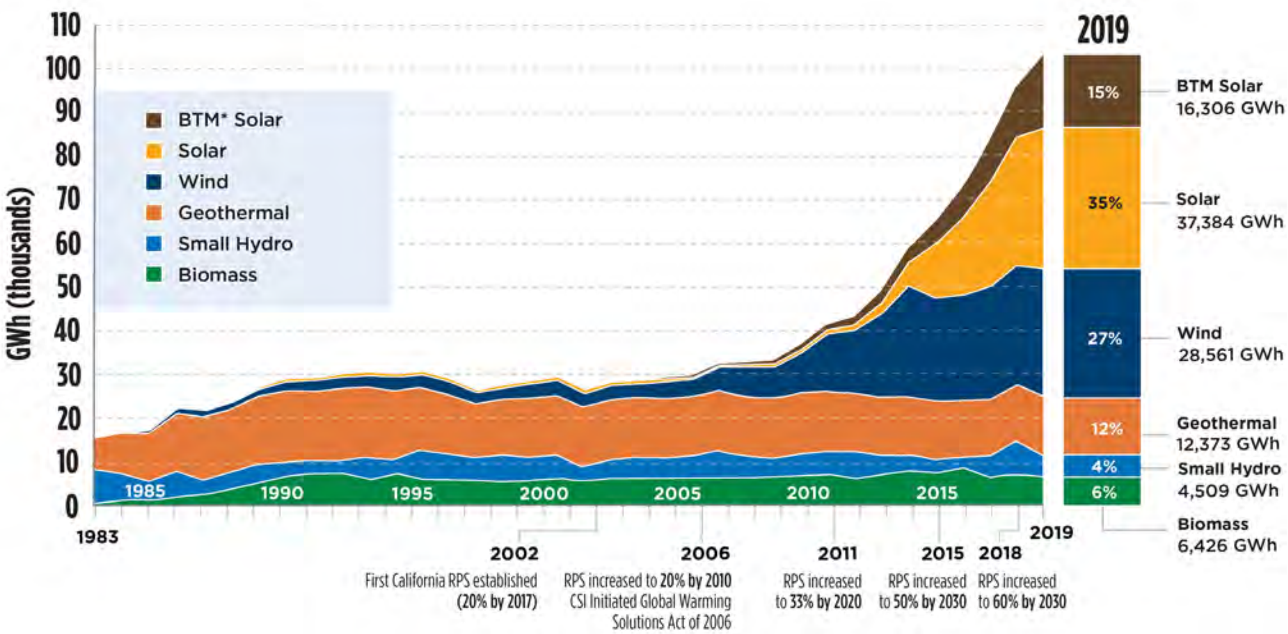
10 See CEC 2019 Building Energy Efficiency Standards Web page https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2019-building-energy-efficiency.

11 California Solar +_Storage Association, December 12, 2019. *California Celebrates Reaching One Million Solar Roofs Milestone; New Focus On "One Million Solar Batteries" Goal*. Link to article titled California Celebrates Reaching One Million Solar Roofs Milestone; New Focus On "One Million Solar Batteries" Goal https://calssa.org/press-releases/2019/12/12/california-celebrates-reaching-one-million-solar-roofs-milestone-new-focus-on-one-million-solar-batteries-goal.

The effects of these policies can be seen in

Figure 11. In the past five years, solar generation has increased more than 350 percent, and behind-the-meter (BTM) solar resources have more than doubled.

Figure 11: Total Renewable Generation Serving California Load by Resource Type



Source: CEC Tracking Progress – Renewable Energy, February 18, 2020, [Link to CEC Tracking Progress – Renewable Energy](https://www.energy.ca.gov/sites/default/files/2019-12/renewable_ada.pdf), https://www.energy.ca.gov/sites/default/files/2019-12/renewable_ada.pdf.

Benefits of 100 Percent Clean Electricity

Improving Public Health

Statewide, more than 28 million Californians live in areas that exceed the federal health-based standards for ozone and fine particulate matter ($PM_{2.5}$).[12] Implementation of SB 100 is expected to reduce these emissions as renewable and zero-carbon resources replace fossil fuels in generating electricity. Prioritizing this transition in disadvantaged communities will reap the highest public health benefits. Today, half of the state's natural gas power plants are in communities that rank among the 25 percent most disadvantaged.[13]

12 CARB. Workshop Discussion Draft: 2020 Mobile Source Strategy. September 30, 2020. https://ww2.arb.ca.gov/sites/default/files/2020-09/Workshop_Discussion_Draft_2020_Mobile_Source_Strategy.pdf.

13 Physicians, Scientists, and Engineers for Healthy Energy. Research brief: Natural gas power plants in California's disadvantaged communities. April 2017. https://www.psehealthyenergy.org/wp-content/uploads/2017/04/CA.EJ_.Gas_.Plants.pdf.

Public health benefits are expected to grow substantially throughout the state as the transition from fossil fuels to clean electricity accelerates in transportation and buildings. Cars, trucks, and buses are leading sources of air pollution in California. Research has shown that Latinos, African Americans, and low-income communities are exposed to substantially higher levels of vehicle pollutants than other demographic groups.[14]

Air pollution from heating and cooking with natural gas also poses a significant public health risk. Natural gas appliances emit several harmful air pollutants, including carbon monoxide, nitrogen oxides (NOx), particulate matter, and formaldehyde. Researchers with the UCLA Fielding School of Public Health recently explored the link between these appliances and various acute and chronic health effects, such as respiratory illness, cardiovascular disease, and premature death. They found that if all residential gas appliances in California were immediately replaced with clean electric alternatives, the reduction of outdoor NO_X and $PM_{2.5}$ would result in 354 fewer deaths over a year.[15]

The compound health effects of air pollution were recently highlighted when researchers at the Harvard University T. H. Chan School of Public Health found that higher levels of the tiny, dangerous $PM_{2.5}$ particles in air were associated with higher death rates from COVID-19.[16] Dr. Aaron Bernstein,[17] interim director at the school's Center for Climate, Health, and the Global Environment, said the findings are particularly important for people in poor neighborhoods and communities of color: "Higher death rates [from COVID-19 infection] that have been observed among the poor and people of color in the United States reflect existing health and economic inequalities that both contribute to, and result from, greater exposure to air pollution."[18]

Advancing Energy Equity

California's energy and environmental efforts focus on low-income and "disadvantaged communities," a state designation for low-income census tracts that suffer additional burdens, such as poor health, high unemployment and poor air or water quality. The joint agencies are committed to ensuring the benefits of cleaner, more efficient energy are enjoyed by all

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14 Union of Concerned Scientists. "Inequitable Exposure to Air Pollution from Vehicles in California (2019)" January 28, 2019. https://www.ucsusa.org/resources/inequitable-exposure-air-pollution-vehicles-california-2019.

15 UCLA Fielding School of Public Health. *Effects of Residential Gas Appliances on Indoor and Outdoor Air Quality and Public Health in California*. April 2020. https://ucla.app.box.com/s/xyzt8jc1ixnetiv0269qe704wu0ihif7.

16 *Science Advances Magazine*. "Air pollution and COVID-19 mortality in the United States: Strengths and limitations of an ecological regression analysis" Volume 6, No. 45, November 4, 2020. https://advances.sciencemag.org/content/6/45/eabd4049. More recently, CARB is funding two studies to examine the impacts of chronic air pollution exposure on the risk, progression, and severity of COVID-19.

17 Dr. Bernstein, an assistant professor at Harvard Medical School, was not involved in the study.

18 Harvard T. H. Chan School of Public Health, Coronavirus and Air Pollution Web page, https://www.hsph.harvard.edu/c-change/subtopics/coronavirus-and-pollution/.

Californians, including those in low-income and disadvantaged communities, as well as tribal and rural communities.

To ensure equitable outcomes,[19] SB 100 will need to be implemented in ways that help these communities overcome barriers to clean energy, including:

- Keeping electricity affordable, with an emphasis on vulnerable populations and households that pay a disproportionately high share of their household income on energy.
- Reducing air pollution from local power plants, particularly in communities that experience a disproportionate amount of air pollution.
- Strengthening their ability to function during power outages and enjoy reliable energy in a changing climate.
- Funding of training for high-quality jobs and careers in the growing clean-energy industry.

Disadvantaged Communities Advisory Group
The Clean Energy and Pollution Reduction Act of 2015 (SB 350) called for the formation of this group to ensure that disadvantaged communities, including tribal and rural communities, benefit from clean energy and pollution reduction initiatives. The 11-member group meets several times a year to review CEC and CPUC clean energy programs and policies. Members are either from or represent disadvantaged communities. In 2018, the DACAG adopted an Equity Framework[20] that can serve as a guide for SB 100 program design, outreach, and workforce development efforts. During the development of this report, the group also formed a subcommittee focused on SB 100. The subcommittee and other environmental justice and equity organizations provide valuable insights on ways to ensure energy equity as the state advances toward a clean energy future.

Supporting a Clean Energy Economy

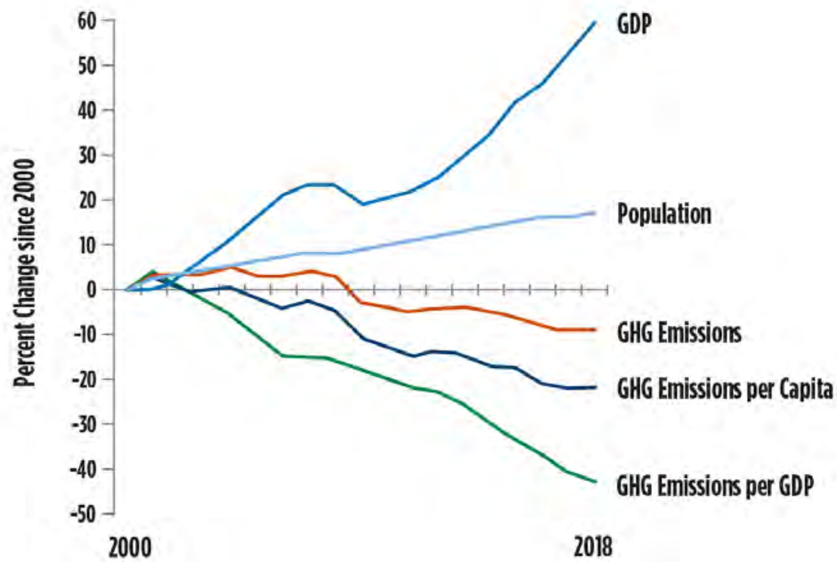
As a clean energy leader boasting one of the world's largest economies, California has shown that economic growth and environmental protection are not mutually exclusive. For decades,

19 "Equity" is defined as reducing disparities between different populations. Environmental equity, then, is (at least in part) about ensuring disadvantaged populations have equitable access to clean energy and other "environmental goods/services." Economic equity in this clean energy context, would therefore aim to ensure disadvantaged workers have equitable access to high-quality clean energy jobs or careers.

20 Disadvantaged Communities Advisory Group, Equity Framework, https://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/UtilitiesIndustries/Energy/EnergyPrograms/Infrastructure/DC/DAC%20AG%20Equity%20Framework%20(Revised).pdf.

the state has reduced GHG emissions while growing its economy at a rate that has consistently outpaced the U.S. national average.[21]

Figure 12: Statewide Trends of Emissions and Indicators (2000–2018)



Source: CARB[22]

California's policies have spurred innovation and created markets for renewable energy, energy efficiency, energy storage, low-carbon fuels, and zero-emission vehicles. The state is a leader in patent registrations across all major clean technology (cleantech) categories, with 3.5 times more patents than the next highest state, Texas.[23] Patents in energy storage, a key technology to achieving SB 100 goals, increased more than 65 percent from 2017 to 2018.[24]

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21 Bureau of Economic Analysis. "Gross Domestic Product by State, 2nd Quarter 2020." Released October 2, 2020. https://www.bea.gov/data/gdp/gdp-state.

22 California Air Resources Board. GHG Emission Inventory Graphs https://ww2.arb.ca.gov/ghg-inventory-graphs.

23 Next10.org. 2019 California Green Energy Innovation Index, 11th Edition. October 2019. https://www.next10.org/sites/default/files/2019-10/2019-california-green-innovation-index-final.pdf.

24 Next10.org. 2019 California Green Energy Innovation Index, 11th Edition. October 2019. https://www.next10.org/sites/default/files/2019-10/2019-california-green-innovation-index-final.pdf.

In addition, California's companies have received more than 50 percent of all U.S. venture capital investment in cleantech.[25]

As of 2020, California had more than 530,000 clean energy jobs,[26] more than half of the total energy-related jobs in the state. The cleantech companies range from start-ups to large manufacturers in the fields of renewable energy, grid modernization, energy storage, energy efficiency, and clean vehicles.[27] Most of these jobs require workers skilled in the construction trades and crafts.[28] Examples include performing building energy retrofits, solar and wind system installation, electric vehicle charging equipment installation, and battery storage maintenance and repair.

The global COVID-19 pandemic has dramatically affected California's energy sector. The cleantech industry has suffered some of largest job losses since social distancing and other precautions took hold in March 2020. During the first three months, the clean energy workforce declined by 20 percent, roughly 110,000 jobs.[29] The latest available data shows jobs slowly increasing from June through October, yet net losses remained at more than 76,000 jobs.

A Cornerstone of California's Clean Energy Efforts

Successful implementation of SB 100 alone will not achieve statewide carbon neutrality, but it is a cornerstone of California's climate-fighting efforts that collectively can reach the target. A clean electricity grid can serve as a backbone to support the decarbonization of transportation, buildings, and some industries that, together with the electricity sector, account for 92 percent of the state's GHG emissions.

25 Next10.org. *2020 California Green Energy Innovation Index, 12th Edition*. December 2019. https://www.next10.org/sites/default/files/2020-12/2020-california-green-innovation-index-final_0.pdf.

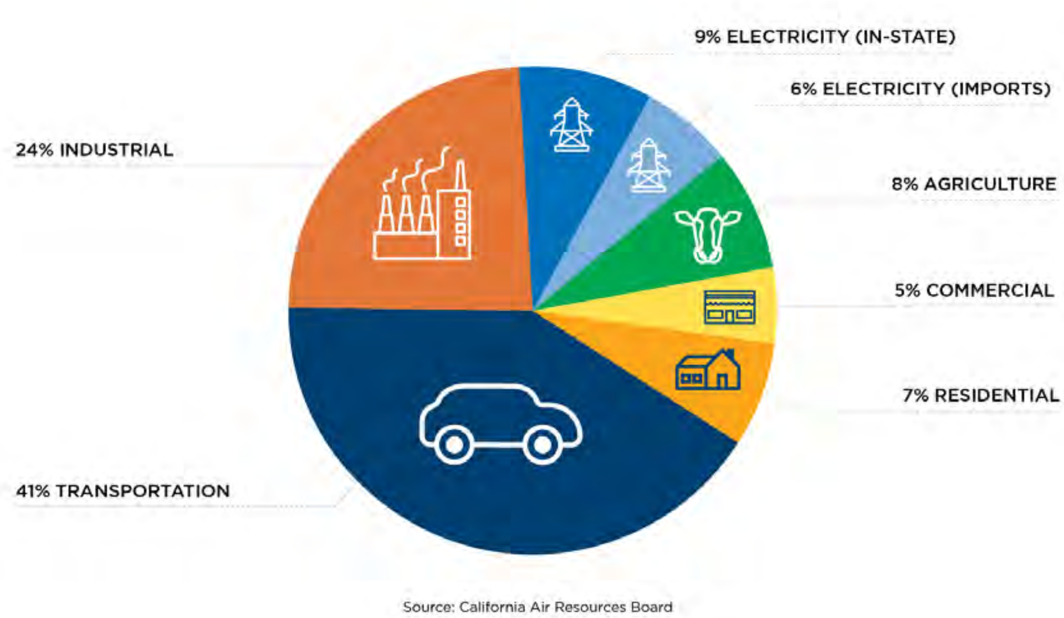
26 E2.org. Clean Jobs California 2020. June 25, 2020. https://e2.org/reports/clean-jobs-california-2020/.

27 The Clean Jobs California 2020 Report, sponsored by the CEC and CPUC, details employment demographic data from more than 4,500 energy employers in the last quarter of 2019.

28 According to E2, one in five construction workers are employed in clean energy, 43 percent of solar and wind energy jobs are in construction, and nearly 6 in 10 energy efficiency employees work in construction. Source: Clean Jobs America. April 2020. https://e2.org/wp-content/uploads/2020/04/E2-Clean-Jobs-America-2020.pdf.

29 BW Research Partnership. Clean Energy Employment Initial Impacts from the COVID-19 Economic Crisis, October 2020. November 12, 2020. https://e2.org/wp-content/uploads/2020/11/Clean-Energy-Jobs-October-COVID-19-Memo-Final.pdf.

Figure 13: California GHG Emissions by Sector



Source: CARB Emissions Inventory[30]

SB 100 sits within a portfolio of related key clean energy efforts to reduce climate and air pollution emissions while maintaining a reliable and affordable electric grid. These include:

Transportation Electrification

The transportation sector remains the largest source of GHG emissions in California, responsible for 50 percent of the state's climate-altering pollution.[31] Vehicle exhaust also accounts for 80 percent of smog-forming gases and other air pollutants linked to premature deaths from respiratory and heart disease.[32] Economywide, GHG emissions have been decreasing in recent years, but transportation emissions have largely increased since 2013 and remain the state's biggest decarbonization challenge.

In 2018, Governor Edmund G. Brown Jr. established by executive order[33] a target of 5 million zero-emission vehicles (ZEVs) on California roads by 2030. The order also called for the

30 California Air Resources Board. GHG Emission Inventory Graphs https://ww2.arb.ca.gov/ghg-inventory-graphs.

31 When including emissions associated with production and refining of fossil fuels for transportation.

32 California Air Resources Board. 2016 Mobile Source Strategy Web page https://ww2.arb.ca.gov/resources/documents/2016-mobile-source-strategy.

33 Governor Edmund G. Brown, Jr. Executive Order B-48-18, January 26, 2018. https://www.ca.gov/archive/gov39/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/index.html.

installation of 250,000 publicly available electric vehicle charging ports and 200 hydrogen fueling stations by 2025. In September 2020, Governor Gavin Newsom expanded this goal when he issued an executive order[34] requiring that all new cars and passenger trucks be zero-emission by 2035 and all medium- and heavy-duty vehicles on the road be zero-emission by 2045.

These targets are ambitious, but California has already positioned itself as a leader in clean transportation. Many state programs are encouraging more motorists to shift to zero-emission vehicles, including:

- CPUC-approved investments in building more charging ports.
- CARB's Clean Vehicle Rebate Project, which has provided nearly $900 million in rebates to ZEV buyers[35]
- A CARB program that gives vehicle fuel producers credits toward meeting the state's Low Carbon Fuel Standard by funding the installation of fast (direct current) electric vehicle chargers and hydrogen fuel stations.
- CEC's Clean Transportation Program, which invests up to $100 million annually to accelerate the development and deployment of ZEV chargers and advanced clean transportation technologies.

Today, California has more than 566,000 ZEVs on the road and more than 763,000 cumulative ZEV sales — nearly half of all ZEV sales in the nation. The state also home to 34 ZEV-related manufacturers.[36] In 2019, electric vehicles became the state's second-largest export, valued at more than $7 billion.[37]

Despite these major advancements, big challenges lie ahead on the road to 100 percent zero-emission transportation. Primarily, the charging infrastructure must be greatly expanded to support many electric vehicles.

Having so many more vehicles tapping the state's electricity system will require closely coordinated planning between the power and transportation sectors. It will also create new green jobs and opportunities for innovators. Through a process known as vehicle-grid integration, electric cars help manage loads on the grid. Standardized, smart charging

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34 Governor Gavin Newsom. Executive Order N-79-20. September 23, 2020. https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-text.pdf.

35 Center for Sustainable Energy (2020). California Air Resources Board Clean Vehicle Rebate Project, Rebate Statistics. https://cleanvehiclerebate.org/eng/rebate-statistics.

36 CEC Analysis, includes ZEV, ZEV component, and ZEV infrastructure manufacturers and employers.

37 United States Census Bureau. Foreign Trade: State Exports from California Web page https://www.census.gov/foreign-trade/statistics/state/data/ca.html.

technologies will make it easy for drivers to charge up with enough energy for their trips at the least possible cost.

Building Decarbonization

Another significant source of California's GHG emissions are those linked to everyday use of buildings, mainly natural gas heating and cooking. Decarbonizing energy use in new and existing buildings has recently emerged as a key climate-fighting strategy. In July 2019, Berkeley became the first U.S. city to ban natural gas in new buildings.[38] As of December 2020, 41 California cities have passed ordinances to either ban natural gas or favor electric heating.[39]

Assembly Bill 3232 (Friedman, Chapter 373, Statutes of 2018)[40] requires the CEC to identify and evaluate ways to reduce the GHG emissions of buildings by 40 percent below 1990 levels by 2030. The assessment will compare costs of different decarbonization pathways, estimate effects on the electricity grid, and recommend state actions.[41] Preliminary findings suggest switching from gas to highly efficient electric appliances such as heat pump water and space heaters is an effective strategy. A final report is planned for release in 2021.

The CPUC recently authorized $435 million through 2024 to spur the clean building technologies market.[42] Programs under development include:

- BUILD (Building Initiative for Low-Emissions Development): Provides incentives for installation of decarbonizing technologies such as heat pumps in all-electric, low-income new construction.
- TECH (Technology and Equipment for Clean Heating): Provides incentives to manufacturers and training for installers of low-emission space and water heaters in early stages of market development.

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38 City of Berkeley. Ordinance No. 7,672–N.S. Adding a New Chapter 12.80 to the Berkeley Municipal Code Prohibiting Natural Gas Infrastructure in New Buildings Effective January 1, 2020 https://www.cityofberkeley.info/uploadedFiles/Planning_and_Development/Level_3_-_Energy_and_Sustainable_Development/2019-07-23%20Item%20C%20Prohibiting%20Natural%20Gas%20Infrastructure.pdf.

39 Sierra Club. California's Cities Lead the Way to a Gas-Free Future https://www.sierraclub.org/articles/2020/12/californias-cities-lead-way-gas-free-future.

40 Assembly Bill 3232 https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB3232.

41 CEC. 2019. *2019 California Energy Efficiency Action Plan.* CEC-400-2019-010-CMF. Link to Final Commission Report: 2019 California Energy Efficiency Action Plan, https://efiling.energy.ca.gov/GetDocument.aspx?tn=231260&DocumentContentId=62914.

42 See "Fact Sheet – Heat Pump Water Heater Incentive Programs," available for download at the CPUC Building Decarbonization Web page https://www.cpuc.ca.gov/buildingdecarb/.

Energy Efficiency

California has been a global leader in energy efficiency for more than 40 years, beginning in the 1970s with the CEC's adoption of the nation's first energy conservation standards for buildings and appliances. Since 1990, these standards have saved Californians more than $100 billion in utility costs.[43]

Today's standards cover much of the home and work environments, from computers to lighting, toilets, faucets, water heaters, insulation, windows, and household appliances. New buildings are becoming increasingly energy-efficient as the CEC updates and improves standards, about every three years. A home built under 2019 standards, for instance, will use 53 percent less energy than one built under 2016 codes.

The CPUC oversees hundreds of utility ratepayer-funded programs across the state to improve compliance with building and appliance codes and encourage businesses, industries, and homeowners to use new technologies that exceed the standards. In 2019 alone, these programs saved more than 2,700 GWh of electricity and 84 million therms of natural gas — enough to power 328,000 homes for a year.

Load Flexibility on the Electricity Grid

Load flexibility — the ability to shift electricity use to other parts of the day — is critical to maintaining a reliable and affordable supply of electricity. Load flexibility can also reduce GHG emissions by maximizing electricity use when grid power is least polluting.

The CPUC and CEC are laying the groundwork for automating load flexibility by taking steps to implement time-dependent electricity rates and moving forward a range of additional actions including:

- Building Energy Efficiency Standards (Energy Code): The 2019 Energy Code provides compliance credit for battery storage systems and heat pump water heaters that meet specific load flexibility requirements.
- Load Management Standards: These are designed to increase flexibility of demand through rates, storage, and automation — minimizing costs and improving reliability.
- CalFlexHub: The California Flexible Load Research and Deployment Hub is a new CEC program to fund research, development, and deployment of flexible demand technologies.
- Flexible Demand Appliance Standards:[44] The CEC is developing standards that would require specified appliances sold in California to include flexible-demand technologies

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43 California Energy Commission. California Energy Commission Tracking Progress - Energy Efficiency. September 2018. https://www.energy.ca.gov/sites/default/files/2019-12/energy_efficiency_ada.pdf.

44 Under Senate Bill 49 (Skinner, Chapter 697, Statutes of 2019) https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200SB49.

that enable operations to be scheduled, shifted, or curtailed to help reduce GHG emissions and maintain system reliability at lowest cost.

- Vehicle-Grid Integration (VGI): The CPUC and CEC are working with other state agencies and stakeholders to assess opportunities and develop policies that support VGI, which will allow owners of battery-electric vehicles to program smart charging in a way that helps balance demand and supply on the grid.

Research and Innovation

Since 2012, California ratepayers have invested more than $1 billion in emerging technologies that help make energy more affordable, reliable, and environmentally sustainable. EPIC, California's flagship electricity R&D program administered by the CEC, invests more than $130 million annually to support the development of emerging clean energy technologies. Moving forward, EPIC will continue to catalyze advancements to support the cost-effective implementation of SB 100 in:

- Renewable and zero-carbon generation.
- Long-duration energy storage.
- Energy efficiency.
- Electric load flexibility.

State agencies are working to ensure the benefits of these investments benefit all Californians. As much as 65 percent of EPIC technology demonstration projects are in disadvantaged and low-income communities, surpassing the 35 percent target set by Assembly Bill 523 (Reyes, Chapter 551, Statutes of 2017).[45]

45 Assembly Bill 523 (Reyes, Chapter 551, Statutes of 2017) https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB523.

Removing Carbon From the Atmosphere

In the 2015 Paris Agreement, scientists agreed that carbon neutrality — the point at which the removal of carbon pollution from the atmosphere equals or exceeds emissions — must be achieved by midcentury to stabilize the climate.[46] Three years later, Governor Brown issued an executive order that California become carbon neutral by 2045. To reach that target, state leaders are going beyond GHG emissions reduction measures. They are taking steps to remove greenhouse gases from the atmosphere are store them underground — a strategy known as "carbon capture and sequestration," as shown in **Figure 14**. In October 2020, Governor Newsom directed CARB to set a science-based target for removal of carbon from "natural and working lands," primarily agricultural.[47]

While engineered carbon removal technologies may also be an important tool, sequestering carbon on land including farms and ranches costs less and improves soil health and crop production. Using cover crops, reducing tillage, and applying compost and other organic matter are among the methods that strengthen the ability of the soil to store carbon.[48] California's Healthy Soils Initiative, a collaboration of state agencies, funds demonstration projects and financially assists farmers and ranchers in putting soil-improving practices to work on their lands to sequester carbon and reduce GHG emissions. The program is funded by revenue from the state's cap-and-trade auctions.[49]

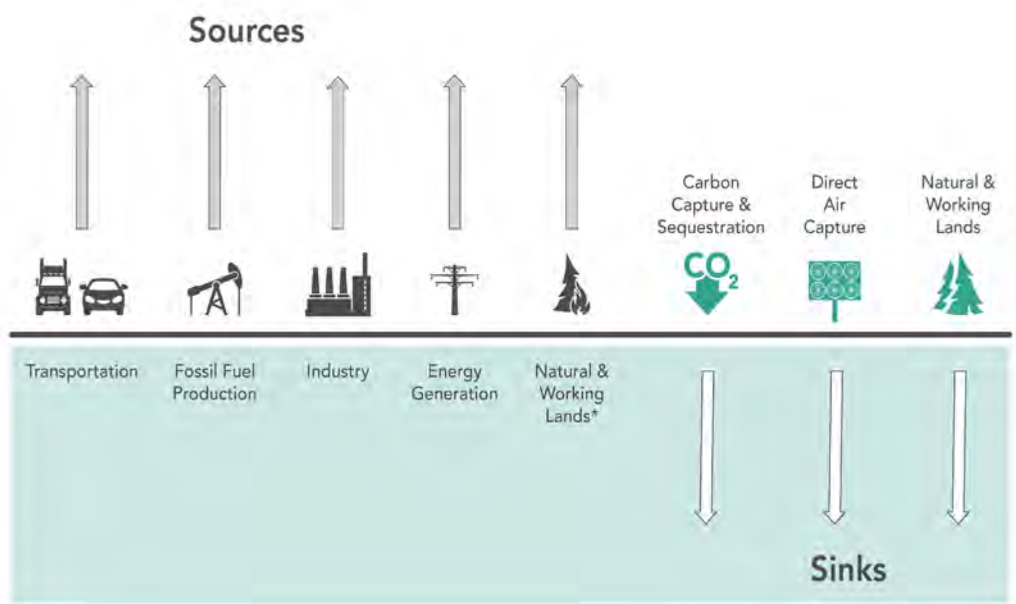
46 United Nations. Paris Agreement, Article 4.1. December 12, 2015. https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf

47 Governor Gavin Newsom. Executive Order N-82-20. October 7, 2020. https://www.gov.ca.gov/wp-content/uploads/2020/10/10.07.2020-EO-N-82-20-signed.pdf.

48 California Climate Investments. *2020 Annual Report to the Legislature on California Climate Investments Using Cap-and-Trade Auction Proceeds*. March 2020. https://ww2.arb.ca.gov/sites/default/files/classic/cc/capandtrade/auctionproceeds/2020_cci_annual_report.pdf; and Kat Kerlin, UC Davis, "A Climate Change Solution Beneath Our Feet." May 15, 2017. "Soil sequesters carbon through a complex process that starts with photosynthesis. A plant draws carbon out of the atmosphere and returns to the soil what isn't harvested in the form of residue and root secretions. This feeds microbes in the soil. The microbes transform the carbon into the building blocks of soil organic matter and help stabilize it, sequestering the carbon." https://climatechange.ucdavis.edu/news/climate-change-solution-beneath-feet/.

49 California Department of Food and Agriculture, Office of Environmental Farming & Innovation. Healthy Soils Program Web page. https://www.cdfa.ca.gov/oefi/healthysoils/.

Figure 14: Midcentury Carbon Neutrality



Natural and working land emissions include wildfire, disease, land and agricultural management practices, and other sources.

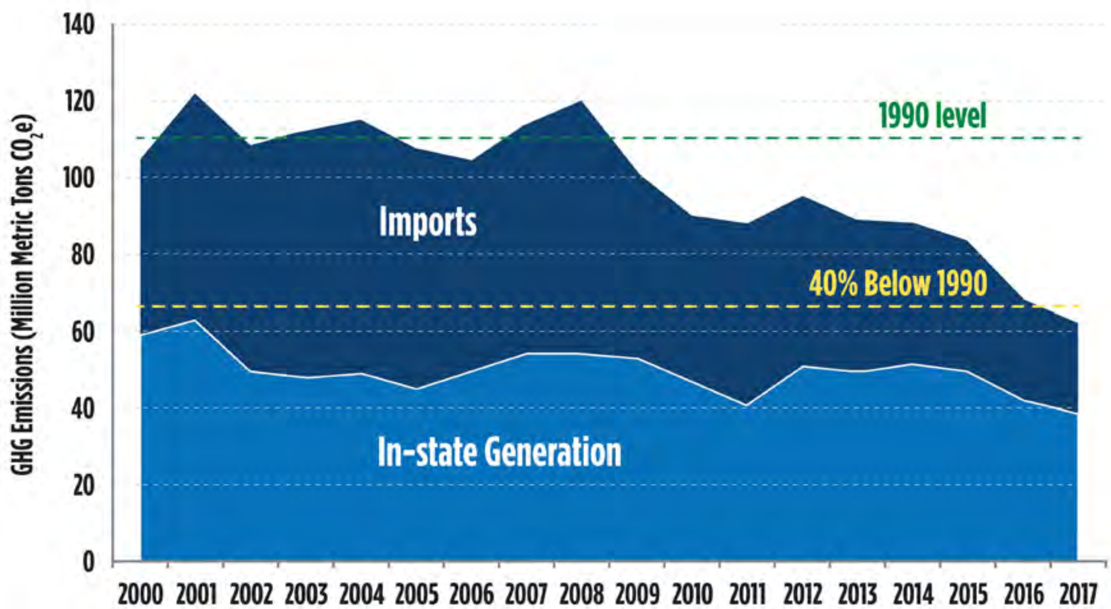
Source: CARB.

California's Electric Grid Today

Declining Emissions

GHG emissions from power generation have dropped by more than 40 percent since 2000, as shown in **Figure 15**. The declines are largely attributable to increased use and reduced cost of renewable energy, particularly solar, the state's energy efficiency standards, and greatly reduced use of coal-fired power plants. Although emissions are on an overall downward trend, the availability of hydroelectric power can significantly affect GHG emissions levels in wet versus dry years.

Figure 15: The Electricity Sector Has Significantly Reduced GHG Emissions Since the Turn of the Century



Sources: California Air Resources Board and CEC staff analysis, December 2019

Increasing Clean Generation

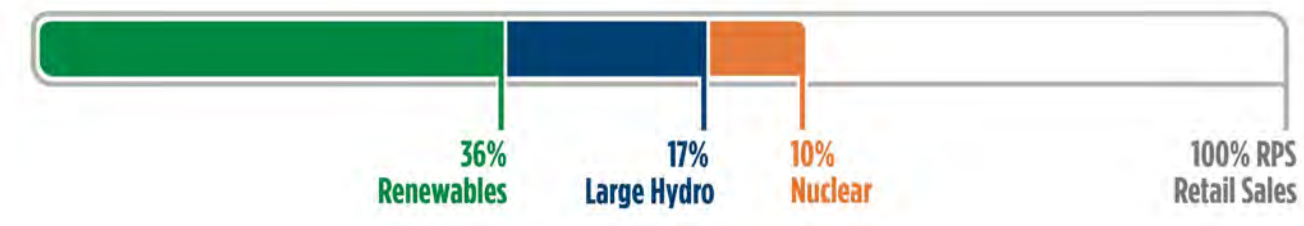
The proportion of California's electricity from renewable sources has increased dramatically since the establishment of the Renewables Portfolio Standard in 2002. Preliminary data show the state exceeded the 2020 target of 33 percent in 2019 with a total of 36 percent of retail sales supplied by eligible renewable energy resources.[50]

In 2019, nearly two-thirds of California's electricity came from carbon-free sources,[51] as shown in **Figure 16**. By 2025, out-of-state coal generation is projected to be eliminated from the state's resource mix altogether. The grid also is using less natural gas because of the increasing amount of renewable sources, In the near term to midterm, however, natural gas generation will continue to play a critical role in ensuring grid reliability.

50 California Energy Commission. California Energy Commission Tracking Progress – Renewable Energy. February 2020. https://www.energy.ca.gov/sites/default/files/2019-12/renewable_ada.pdf.

51 For purposes of the GHG inventory, these include solar, wind, large and small hydropower, and nuclear.

Figure 16: 63 Percent of 2019 Retail Sales From Nonfossil Resources



Source: CEC, Tracking Progress, 2020

The increasing integration of renewable resources into the grid is changing system planning and operations. With the growth in intermittent renewables, system operators need generators with flexible capabilities to balance supply and demand. The swift rise in solar and wind power coming onto the grid has resulted in more frequent instances of oversupply during the middle of the day, when the sun is brightest. In certain times of the year, the daily net load — the difference between forecasted load and expected electricity production from variable generation resources — is lower during the midday then quickly ramps up.[52]

Although several tools are available to rapidly adjust supply and demand, natural gas power plants provide about 75 percent of the flexible capacity of the grid (the ability to quickly ramp energy production up or down to match supply and demand). While some natural gas power plants are retiring, others are still needed to maintain grid reliability as more renewable power enters the system. In the long term, other resources such as demand-side management and storage are essential to maintaining reliability while integrating high penetrations of renewables. This need can also be supported through increased coordination and the evolution of markets in the western region, which are already helping better integrate renewables.

Overview of California's Electricity System

Agency Oversight

California has several energy organizations with different electricity related responsibilities:

- **The CEC** is the state's lead energy policy and planning agency. The CEC's primary functions include forecasting electricity and natural gas demand for state planning, siting and licensing thermal power plants 50 MW or greater, investing in energy technology, setting the state's appliance and building energy efficiency standards, and planning for and directing the state's response to energy emergencies. The CEC also publishes the *Integrated Energy Policy Report*, which assesses major energy trends and issues facing California's electricity, natural gas, and transportation fuel sectors.

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52 California Independent System Operator. Fast Facts: What the Duck Curve Tells Us About Managing a Green Grid. 2016. https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf.

- **The CPUC** regulates services and utilities, protects consumers, safeguards the environment, and assures Californians' access to safe and reliable utility infrastructure and services. The essential services regulated include electric, natural gas, telecommunications, water, railroad, rail transit, and passenger transportation companies. The CPUC does resource planning for 80 percent of California's electric grid through the IRP proceeding and implements programs such as the RPS, efficiency incentives, transportation electrification investments, customer solar, and building decarbonization.
- **CARB's** mission is to promote and protect public health, welfare, and ecological resources through effective reduction of air pollutants while recognizing and considering effects on the economy. CARB is the lead agency for climate change programs and oversees all air pollution control efforts in California to attain and maintain health-based air quality standards.
- **City, county, and tribal governments** also influence statewide energy decisions and have permitting authority for transmission lines, thermal power generators under 50 MW and nonthermal power generators, including solar and wind operations on nonfederal lands.

Load-Serving Entities (LSEs)

California's electric load is met through a variety of LSEs, which serve retail customers.[53] The primary LSEs are the following:

- **Investor-owned utilities (IOUs)** provide transmission and distribution services to all electric customers in their service territory. The utilities also provide generation service for "bundled" customers, while "unbundled" customers receive electric generation service from an alternate provider, such as a community choice aggregator (CCA). California's electric IOUs are Pacific Gas and Electric, Southern California Edison, and San Diego Gas & Electric.
- **Publicly owned utilities (POUs),** or municipal utilities, are publicly financed and controlled by citizen-elected governing boards. The Los Angeles Department of Water and Power and Sacramento Municipal Utility District are among the largest POUs that together serve about 27 percent of the state's electricity demand.
- **Community choice aggregators (CCAs).** Growing numbers of California communities have formed these local agencies to buy electricity on behalf of their residents and businesses, often aiming to provide lower rates and greener electricity than offered by the default utility. CCAs are a relatively new type of load-serving entity

53 CPUC. California Customer Choice: An Evaluation of Regulatory Framework Options for an Evolving Electricity Market. August 2018. https://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Utilities_and_Industries/Energy_-_Electricity_and_Natural_Gas/Cal%20Customer%20Choice%20Report%208-7-18%20rm.pdf.

and have grown rapidly, projected to serve about 38 percent of the load within IOU service territories by 2022.[54]

- **Electric service providers (ESPs),** or direct access providers, are nonutility entities that market electric service directly to customers. However, the customer load service by ESPs is set at a limited amount. Like CCAs, ESPs must comply with resource adequacy, RPS, and IRP requirements overseen by the CPUC.

Grid Balancing

California's grid is divided into five balancing authority areas. The following balancing authorities balance supply and demand and maintain electric frequency on the grid. The authorities are:

- California ISO, which manages about 80 percent of the state's flow of electricity.
- Los Angeles Department of Water and Power.
- Balancing Authority of Northern California.
- Imperial Irrigation District.
- Turlock Irrigation District.

Western States Coordination

California is part of a larger integrated electricity system called the Western Interconnection, which includes all or parts of 14 western states as well as Alberta, British Columbia, and Baja California. Several of these jurisdictions have also adopted clean energy goals or standards,[55] expanding opportunities for market development and knowledge-sharing on integrating increasing amounts of renewable generation.[56]

In 2014, the California ISO initiated the Western Energy Imbalance Market (EIM), a real-time wholesale energy trading market with PacifiCorp as its first member.[57] The EIM manages

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54 CalCCA. 2010-2020: A Decade of CCA in California. May 1, 2020. https://cal-cca.org/celebrating-10-years-of-cca-in-california/.

55 For details on states with clean energy or renewable goals or standards, see the Link to State Policy Climate Maps at https://www.c2es.org/content/state-climate-policy/ or the CESA 100% Clean Energy Collaborative - Table of 100% Clean Energy States at https://www.cesa.org/projects/100-clean-energy-collaborative/table-of-100-clean-energy-states/.

56 These entities are described in the CEC's Western Energy Planning Fact Sheet at https://www.energy.ca.gov/sites/default/files/2019-06/Western_Energy_Planning.pdf.

57 The Western Energy Imbalance Market (EIM) is a real-time wholesale energy trading market that enables participants anywhere in the West to buy and sell energy when needed. The EIM platform balances fluctuations

congestion on high-voltage transmission lines to maintain grid reliability, supports integration of renewable resources, and makes excess renewable energy available to participating utilities at low cost rather than turning the generating units off.

The EIM has grown to 11 member entities, and another 11 plan to join by 2023, which will account for 82 percent of the load in the Western Interconnection.[58] This market is credited with achieving $1.18 billion in savings from increased operational efficiencies and a 1.3 million MWh reduction in curtailment of renewable energy.[59] There is interest in building off the EIM's success, including with the California ISO's Extended Day-Ahead Market (EDAM) Initiative.[60] The EDAM initiative, which is still in the early stages, aims to improve renewable integration and market efficiency through day-ahead scheduling and unit commitment across a larger area.

California is engaged with several other regional government and industry groups to ensure its energy interests are represented. They include:

- Western Electricity Coordinating Council: A nonprofit corporation that promotes bulk power system reliability and security in the Western Interconnection.
- Western Interstate Energy Board: An organization of 11 western states and three western Canadian provinces that promotes coordinated development of energy policies.
- Western Interconnection Regional Advisory Body: Created by western governors under the Federal Power Act to provide advice on grid reliability to the Federal Energy

in supply and demand by automatically finding lower-cost resources to meet real-time power needs. The EIM manages congestion on high-voltage transmission lines to maintain grid reliability and supports integrating renewable resources. Further, it enhances reliability by increasing operational visibility across electricity grids. In addition, the market makes excess renewable energy available to participating utilities at low cost rather than turning the generating units off.

58 The entities and their dates of entry include the following: PacifiCorp (2014), NV Energy (2015), Arizona Public Service (2016), Puget Sound Energy (2016), Portland General Electric (2017), Idaho Power (2018), Powerex (2018), the Balancing Authority of Northern California/Sacramento Municipal Utility District (2019), Seattle City Light (2020), and Salt River Project (2020). Entities and their planned dates of entry include Los Angeles Department of Water and Power (2021), Northwestern Energy (2021), Turlock Irrigation District (2021), Public Service Company of New Mexico (2021), Balancing Authority of Northern California Phase 2 [Modesto Irrigation District, City of Redding, City of Roseville, and Western Area Power Administration–Sierra Nevada Region] (2021), Avista Utilities (2022), Tucson Electric Power (2022), Tacoma Power (2022), Bonneville Power Administration (2022), Xcel Energy – Colorado (2022), and El Paso Electric (2023).

59 California ISO, Western EIM Benefits Report, Fourth Quarter 2020, January 29, 2021, available at https://www.westerneim.com/Documents/ISO-EIM-Benefits-Report-Q4-2020.pdf.

60 Link to Extended Day-Ahead Market Initiative information on the California ISO's Web page http://www.California ISO.com/informed/Pages/StakeholderProcesses/ExtendedDay-AheadMarket.aspx.

Regulatory Commission, the North American Electric Reliability Corporation, and the Western Electricity Coordinating Council.

- Western Governors' Association: An instrument of the governors of 19 states and 3 U.S. territories for bipartisan policy development, information exchange, and collective action on issues of critical importance to the western United States.

Planning for a Midcentury Grid

Designing for a Changing Climate

California's electric grid must meet the state's clean energy goals while maintaining reliability and affordability, protecting public health and the environment, and distributing benefits of clean energy to all Californians — all in the face of fiercer and more frequent wildfires, droughts (reduced hydropower availability), and heat waves (higher loads from air conditioning). Meeting the state's goals also requires scientifically informed, flexible, and adaptive strategies to increase energy sector resilience to climate stressors, with particular attention to high fire threat areas and vulnerable populations. Future investments in electric generation, storage, distribution, and transmission must be designed and operated for a changing climate.

Changes in Supply and Demand

Planning a midcentury grid requires accommodating the variable nature of solar, wind and hydroelectric power; the increasing integration of renewable generation from utilities and customers; and increasing loads from building and transportation electrification. With the right policies, technologies, and price signals, a surge in all-electric vehicles and buildings can not only be accommodated, but could potentially support grid reliability.

August 2020 Rolling Blackouts Highlight Planning Needs

On August 14 and 15, 2020, the state experienced rotating outages during an extreme heat wave that spread across the West. An analysis[61] developed jointly by California ISO, CPUC, and CEC found a series of factors contributed to the emergency:

- The extreme, climate change-induced heat wave resulted in electricity demand exceeding supply; the existing resource planning processes are not designed to fully address an extreme heat wave like the one experienced in mid-August.
- Resource planners have not kept pace with the rapid rise of solar and wind power on the grid, resulting in insufficient supply to meet the high demand in the early evening in extreme conditions.

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61 California ISO, CPUC, and CEC. *Final Root Cause Analysis –: Mid-August 2020 Extreme Heat Wave*. January 13, 2021., January 13, 2021, http://www.caiso.com/Documents/Final-Root-Cause-Analysis-Mid-August-2020-Extreme-Heat-Wave.pdf.California ISO, CPUC, and CEC. *Preliminary Root Cause Analysis – Mid-August 2020 Heat Storm*. http://www.caiso.com/Documents/Final-Root-Cause-Analysis-Mid-August-2020-Extreme-Heat-Wave.pdf.

- Some practices in the day-ahead energy market exacerbate supply challenges when the grid is under high stress.

The heat wave that persisted from August 14 through 19 brought temperatures 10 to 20 degrees Fahrenheit above average. During this period, California experienced four out of the five hottest August days since 1985. Typically, California's hot daytimes in the summer are offset by cool evenings. During the extreme heat events, however, the high temperatures persisted into the evening and overnight, and air conditioners drove up electricity demand beyond normal.

The extreme heat also pinched electricity supply. Natural gas power plants ran less efficiently, and fewer imports of electricity were available as other western states also endured the extreme heat. At the same time, high clouds covered parts of California, reducing solar generation.

Heats waves of such severity and compounding factors are no longer outside the realm of planning contingencies. State agencies are busy recalibrating electricity supply and demand planning to more accurately reflect the increasing risk of extreme weather events.

SB 100: A Foundation for California's Clean Energy Future

SB 100 provides a tremendous opportunity for state agencies to collaboratively plan for a midcentury grid. As California moves toward a majority renewable grid in a changing climate, the state's planning processes likewise need to evolve to meet the needs of all Californians who depend on safe, affordable, and reliable electricity. Effectively integrating 100 percent renewable and zero-carbon electricity and achieving carbon neutrality by 2045 will require coordinated planning across state agencies, local governments, and electric utilities.

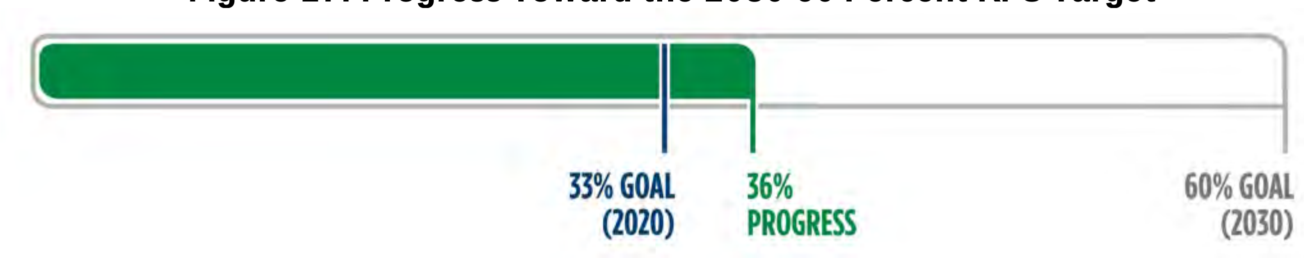
CHAPTER 2:
SB 100 Overview and Report Development Process

100 Percent Clean Electricity by 2045

The 100 Percent Clean Energy Act of 2018 (Senate Bill 100, De León) is California's keystone climate mitigation policy to drastically reduce greenhouse gas emissions in the power sector and help make California's economy carbon neutral by 2045.[62] SB 100:

- Sets a December 31, 2045 target for eligible renewable and zero-carbon energy resources to supply 100 percent of California's electricity to consumers and state agencies.[63]
- Increases the state's Renewables Portfolio Standard to 60 percent of electricity retail sales by December 31, 2030, and raises interim procurement requirements by amounts consistent with this increase.
- Requires that the joint agencies — CPUC, CEC, and CARB — use existing programs to achieve this policy and issue the Legislature a report on the implementation of the law by January 1, 2021, and every four years thereafter.

Figure 17: Progress Toward the 2030 60 Percent RPS Target



Source: CEC 2020, Tracking Progress – Renewable Energy, https://www.energy.ca.gov/sites/default/files/2019-12/renewable_ada.pdf

62 Governor Jerry Brown's September 10, 2018 Executive Order No. B-55-18, a complement to SB 100, states: "A new statewide goal is established to achieve carbon neutrality as soon as possible, and no later than 2045, and achieve and maintain net negative emissions thereafter. This goal is in addition to the existing statewide targets of reducing greenhouse gas emissions."

63 Public Utilities Code Section 454.53 https://codes.findlaw.com/ca/public-utilities-code/puc-sect-454-53.html.

State Agency Requirements

Under SB 100, the CPUC and CEC, in consultation with CARB, must ensure California's transition to a zero-carbon electric system is consistent with the Commerce Clause (which describes an enumerated power listed in the United States Constitution) and does not cause greenhouse gas (GHG) emissions to increase elsewhere in the western grid.

In addition, all state agencies must:

1. Maintain the safety and reliability of the electric system.
2. Prevent the implementation of the law from causing "unreasonable impacts" to customers' utility rates and bills, taking into "full consideration" the economic and environmental costs and benefits of clean electricity.
3. To the extent feasible and authorized under law, take actions to reduce greenhouse gas emissions in other economic sectors (industrial, commercial, agricultural, residential, transportation) to ensure equity between those sectors and the electricity sector.[64]

SB 100 Reports

SB 100 specifies that the joint agency reports be informed by public participation and consultation with California balancing authorities. The reports shall include:

1. A review of the 100 percent clean electricity policy focused on electricity technologies, forecasts, transmission, reliability, affordability, and environmental and public safety protection.
2. An evaluation of the potential effects of the law on electricity system reliability, statewide and local.
3. Anticipated costs and benefits to utilities and ratepayers (electric, gas, and water).
4. Identification of barriers to implementing the policy and benefits of achieving it.
5. Alternative scenarios to achieve the policy, with estimated costs and benefits.

SB 100 also emphasizes the need to benefit disadvantaged communities.[65] The joint agency reports consider how the implementation of the law affects disadvantaged communities, as well as tribal and rural communities.[66]

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64 Public Utilities Code Sections 399.11–399.33, 454.51, 454.52, 9621, and 9622.

65 This definition derives from CalEPA's CalEnviroScreen, a tool that identifies census tracts disproportionately burdened by and vulnerable to multiple sources of pollution. https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-30. In April 2017, CalEPA released its list of disadvantaged communities for SB 535.

66 For more detail, see the Disadvantaged Communities Advisory Group Equity Framework, https://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/UtilitiesIndustries/Energy/EnergyPrograms/Infrastructure/DC/DAC%20AG%20Equity%20Framework%20(Revised).pdf.

2021 Report Scope

This report examines implications of the 100 percent clean electricity policy under SB 100. Chapter 3 provides preliminary assessments of resource needs and projected costs of various implementation pathways.

The exploration builds on the modeling and assumptions used for CPUC's Integrated Resource Planning and considers California's overarching priorities on energy, climate, equity, and public health.

This report is neither a comprehensive nor prescriptive roadmap to 2045. As discussed in Chapter 4, future reports will delve deeper into critical topics such as system reliability and land use and further address energy equity and workforce needs.

Figure 18: SB 100 Joint Agency Coordination Process

Source: CEC, CPUC, and CARB. Developed by consensus

Public Engagement

The joint agencies held a year-long series of public workshops to solicit comments on the scope, analysis, and process of the report. A September 2019 kickoff workshop in Sacramento was followed by regional scoping workshops in Fresno, Redding, and Diamond Bar in Los

Angeles County and two technical workshops on the scenario modeling.[67] The agencies also held workshops on the draft modeling results and draft report.

The CEC conducted the outreach by email, phone, social media, and agency listservs. Most workshops had hundreds of attendees. The Draft Modeling Results Workshop drew nearly 400 participants via Zoom. The joint agencies received hundreds of comments at the workshops and online through the SB 100 docket.

Table 7: SB 100 Workshop Summary

Activity	Date
Kickoff Workshop (Sacramento)	September 5, 2019
Scoping Workshop 1: Central Valley (Fresno)	September 30, 2019
Scoping Workshop 2: Northern California (Redding)	October 25, 2019
Scoping Workshop 3: Southern California (Diamond Bar)	October 29, 2019
Technical Workshop (San Francisco)	November 18, 2019
Modeling Inputs & Assumptions Workshop (Sacramento)	February 24, 2020
Draft Modeling Results Workshop (Remote Only)	September 2, 2020
Draft Report Workshop (Remote Only)	December 4, 2020

Source: CEC, CPUC, and CARB

Consultation With Balancing Authorities

In September 2019, the joint agencies initiated consultation with the balancing authorities,[68] as required by SB 100.[69] The balancing authorities staff suggested inputs and assumptions for modeling the pathway scenarios and participated in the workshops as panelists. They were

67 For a complete record of the SB 100 report proceeding and public comments, see the SB 100 Joint Agency Report Webpage at https://www.energy.ca.gov/sb100 and the SB 100 docket at https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=19-SB-100.

68 “Balancing authorities” are responsible for balancing electricity supply with demand to ensure the generation, transmission and distribution of electricity all working reliably to meet California’s energy needs. California’s balancing authorities include the California Independent System Operator, Los Angeles Department of Water and Power, the Balancing Authority of Northern California, Imperial Irrigation District, and Turlock Irrigation District.

69 Public Utilities Code section 454.53 (d)(2) states: ”In consultation with all California balancing authorities, as defined in subdivision (d) of Section 399.12, as part of a public process, issue a joint report to the Legislature by January 1, 2021, and at least every four years thereafter.”

particularly informative on wildfire threats and the future reliability of the state's electricity system in a changing climate.

Kickoff Workshop

September 5, 2019, Sacramento

State Resources Secretary Wade Crowfoot and Alice Reynolds, the Governor's Senior Energy Advisor, stressed the importance of SB 100 in helping the state meet its climate goals. The agency principals for the report[70] discussed the need to align the clean electricity goals of SB 100 with state efforts to decarbonize California's economy as a whole and ensure a safe, reliable, and equitable energy future for all Californians.

The workshop prompted a wide variety of oral and written comments (19 stakeholders made oral comments at the workshop, while 17 commenters submitted written comments following the workshop), including requests that the 2021 Report include the roles of energy conservation and storage, synergies between the electricity sector and other economic sectors, near-term system reliability needs, and a definition of "zero-carbon resource" that does not preclude nuclear power and large hydroelectric generation.[71]

Regional Scoping Workshops

- Central Valley, September 30, 2019, in Fresno
- Northern California, October 25, 2019, in Redding
- Southern California, October 29, 2019, in Diamond Bar

At each workshop, a diverse panel of local leaders and experts fielded questions on energy equity, grid reliability, and land use.[72] More than 150 attendees attended each workshop, either in person or online, and more than 100 sets of written comments were received.

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70 CEC Chair David Hochschild, CARB Chair Mary Nichols, CPUC Commissioner Liane Randolph, and CEC Commissioner Andrew McAllister.

71 Commenters also cited a letter submitted to the Senate Daily Journal stating the bill language was intended to include all existing carbon resources currently under contract, such as nuclear and large hydro resources.

72 The Central California Scoping Workshop occurred in Fresno on September 30, 2019. A stakeholder panel included representatives of Turlock Irrigation District, San Joaquin Valley Latino Environmental Advancement and Policy Project and Leadership Counsel for Justice and Accountability. The Northern California Scoping Workshop occurred in Redding on October 25, 2019. A stakeholder panel included representatives of Blue Lake Rancheria, Redding Electric Utility, the American Wind Energy Association California Caucus, the Balancing Area of Northern California, and the California Independent System Operator. The Southern California Scoping Workshop occurred in Diamond Bar on October 29, 2019. A stakeholder panel included representatives of California Environmental Justice Alliance, Port of Long Beach, the Los Angeles Department of Water and Power, and Imperial Irrigation District.

Commenters asked that the state's definition of "zero-carbon resource" include electricity from large hydroelectric dams, small modular nuclear power plants, hydrogen-based power, and bioenergy resources. They also stressed energy equity, workforce training, consumer protection, and greater system reliability as wildfires become fiercer and more frequent.

Technologies and Scenarios Workshop

November 18, 2019, San Francisco

Staff with the three agencies presented a framework for modeling SB 100 implementation scenarios and evaluating the associated costs, benefits, and impacts. They proposed to leverage existing modeling analyses, such as the 2018 Deep Decarbonization in a High Renewables Future: Updated Results from the California PATHWAYS Model[73] and the SB 100 2045 Framing Study for the CPUC IRP,[74] and include the publicly owned utility perspective.

Staff presented the "RPS+" interpretation of "zero-carbon resources" — technologies that are RPS-eligible or have zero onsite emissions — and a "zero-combustion" interpretation recommended by environmental justice advocates. Stakeholders overwhelmingly supported the former interpretation.

In addition to the 20 panelists and public commenters who spoke at the workshop, 26 stakeholders submitted written comments. Comments included requests for consideration of:

- All types and durations of energy storage.
- Natural gas-fired resources with carbon capture and sequestration.
- Hydrogen and fuel cell technologies.
- Implications of an energy storage accounting that excludes losses.
- Grid reliability risk analysis.

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73 Mahone, Amber, Zachary Subin, Jenya Kahn-Lang, Douglas Allen, Vivian Li, Gerrit De Moor, Nancy Ryan, Snuller Price. 2018. *Deep Decarbonization in a High Renewables Future: Updated Results from the California PATHWAYS Model*. CEC. Publication Number: CEC-500-2018-012. Link to Deep Decarbonization in a High Renewables Future: Updated Results from the California PATHWAYS Model https://www.ethree.com/wp-content/uploads/2018/06/Deep_Decarbonization_in_a_High_Renewables_Future_CEC-500-2018-012-1.pdf.

74 See the 2045 Framing Study results starting in Appendix A on slide 145 of the CPUC Energy Division's November 6, 2019 *2019-20 IRP: Proposed Reference System Plan*. https://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/UtilitiesIndustries/Energy/EnergyPrograms/ElectPowerProcurementGeneration/irp/2018/2019%20IRP%20Proposed%20Reference%20System%20Plan_20191106.pdf.

Modeling Inputs and Assumptions Workshop

February 24, 2020, Sacramento

Three panels of experts discussed implementation of SB 100 and related implications for electricity rates, grid reliability, land use, workforce development, environmental justice, and energy equity. In addition to the panelists, 17 stakeholders provided public comments. More than 30 written comments were also received following the workshop.

Stakeholders reiterated requests for a more inclusive definition of “zero-carbon” energy resources that considers their land-use impacts. Others commented on the modeling — including assumptions, limitations, and scenarios — and the use of modeling results in developing policy recommendations.

Modeling Results and Implications Workshop

September 2, 2020, Online

CEC staff summarized the modeling study and detailed the results.[75] The modeling consultant, E3, joined staff in fielding audience questions. The workshop then broke out into panels on three topics: energy resource build requirements, grid planning implications, and energy equity and workforce considerations.

The agencies received more than 100 written comments after the workshop. Many favored accelerating the SB 100 target to 2030 and stressed the importance of maintaining grid reliability as the state transitions to 100 percent clean electricity. Other commenters stressed:

- Careful land-use planning to minimize environmental impacts.
- New transmission infrastructure.
- Energy production cost modeling to assess reliability.
- Modeling improvements to better refine technology costs, attributes, and performance.
- Energy equity, non-energy benefits, and affordability of electricity.

Draft 2021 Report Workshop

December 4, 2020, Online

CEC staff summarized the draft report, providing an overview of modeling results and updates made after the draft results workshop, areas for further analysis, additional considerations, and joint agency recommendations.

Stakeholder comments focused on the need to assess the reliability and operational feasibility of the scenarios, inclusion of non-energy benefits and social costs into the analytical

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75 As background, the joint agencies released two documents: the August 31, 2020 SB 100 Joint Agency Report Modeling Framework and Scenarios Overview and the Inputs & Assumptions: CEC SB100 Joint Agency Report.

framework, and requests to change technology assumptions and add technologies into future modeling.

Additional Outreach and Engagement

Clean Energy States Alliance (CESA)

The joint agencies exchange knowledge and ideas with their counterparts in 18 other states and entities in the United States (District of Columbia and Puerto Rico) that have 100 percent clean electricity and carbon neutrality goals. They engage through the 100% Clean Energy Collaborative, run by the Clean Energy States Alliance, a nonprofit coalition of public agencies and organizations working to advance clean energy.

In a May 2020 CESA webinar, CEC Chair David Hochschild discussed California's 100 percent clean energy policy and how other states could benefit by adopting a similar goal.

On July 21, 2020, staff with the CEC and an official with the New Jersey Board of Public Utilities presented on integrating energy equity considerations into 100 percent clean energy policy and implementation, generating interest in deeper discussion within the collaborative.

Disadvantaged Communities Advisory Group and Equity Stakeholders

In advance of the Modeling Inputs and Assumptions workshop, CEC staff presented an overview to the DACAG, the formal body that advises the CEC and CPUC on energy equity issues. Members moved to establish DACAG's SB 100 subcommittee to more closely track and assume responsibility for proceeding comments. In addition, the joint agencies included environmental justice and equity representatives on workshop panels to discuss implementation considerations.

The DACAG and a separate group of community and environmental justice organizations later submitted letters[76] urging the joint agencies to analyze at the local level how SB 100 implementation will affect communities' public health, land use, economic well-being, and air and water quality. The letters also urged consideration of communities' cumulative burdens resulting from the COVID-19 pandemic and the growing number and severity of heat waves and wildfires, particularly in under resourced communities that already bear the brunt of pollution.

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76 See RE: SB 100 Joint Agency Report: Charting a path to a 100% Clean Energy Future Docket #: 19-SB-100, June 12, 2020, https://efiling.energy.ca.gov/GetDocument.aspx?tn=233461&DocumentContentId=65990; and RE: SB 100 Joint Agency Report, Docket #: 19-SB-100, August 21, 2020, https://efiling.energy.ca.gov/GetDocument.aspx?tn=234415&DocumentContentId=67287.

Other Western States

On October 8, 2019, CEC staff gave a presentation titled "Senate Bill 100: Toward Zero-Carbon Electricity" at a meeting of the Joint Committee on Regional Electric Power Cooperation-Western Interconnection Regional Advisory Body.

Statutory Interpretation for Modeling

To model SB 100 implementation scenarios, the joint agencies needed to interpret the meaning of "zero-carbon resources"[77] in the law and determine the electric loads subject to the policy.

Zero-Carbon Resources Interpretation

SB 100 does not define "zero-carbon resources," and the state had no legal definition before the bill becoming law. The joint agencies interpreted "zero-carbon resources" to mean energy resources that either qualify as "renewable" in the most recent RPS (Renewables Portfolio Standard) Eligibility Guidebook[78] or generate zero greenhouse gas emissions on site.[79] SB 100 workshops and documents refer to these criteria as "RPS+".

Additional Criteria for Modeled Resources

Staff further limited the pool of modeled resources to those meeting the following criteria:

- Alignment with state policies and priorities
    - Staff excluded energy resources from some or all scenarios if the use of these resources in generating electricity would have significant negative effects on public health or the environment or were otherwise at odds with state policies and priorities.
- Technology readiness and resource availability
    - Only commercialized technologies with vetted and publicly available cost and performance data were included for core scenarios. Moreover, only technologies that have an anticipated pipeline of development were included. (For example,

77 Senate Bill 100 (De León, Chapter 312, Statutes of 2018, 454.53 [a]), revises state policy in "that eligible renewable energy resources and zero-carbon resources supply 100 percent of all retail sales of electricity to California end-use customers and 100 percent of electricity procured to serve all state agencies by December 31, 2045. https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB100.

78 California Energy Commission. *Renewables Portfolio Standard Eligibility Guidebook, Ninth Edition (Revised)*. Publication Number: CEC-300-2016-006-ED9-CMF-REV. January 2017. https://efiling.energy.ca.gov/getdocument.aspx?tn=217317.

79 For modeling, this list does not acknowledge de minimis emissions associated with included technologies. SB 100 compliance programs would need to establish clear requirements for qualification as a zero-carbon generation resource.

although solar thermal is a well-proven renewable technology, little development is anticipated at this time, primarily because it cannot compete with solar photovoltaic on cost.)

- Generic firm zero-carbon resources were included in the exploratory study scenarios to illustrate the possible impact of emerging resources such as green hydrogen generation and natural gas generation with carbon capture if they are able to achieve specified costs.
- Excluded technologies may be included in future SB 100 analyses. Staff will update modeling as emerging technologies become commercialized.

Technologies Included in Modeling

Table 8 lists technologies that could meet the SB 100 criteria for renewable and zero-carbon resources, as interpreted by the joint agencies. The list is not prescriptive, but rather for evaluating potential SB 100 implementation strategies. This list may be updated for future SB 100-related modeling.

Table 8: Generation Technologies Included in Modeling

Technology	Eligibility Basis	Scenarios
Solar PV	RPS	Core and Study
Solar Thermal (existing only)	RPS	Core and Study
Onshore Wind	RPS	Core and Study
Offshore Wind	RPS	Core and Study
Geothermal	RPS	Core and Study
Bioenergy	RPS	Core and Study
Fuel Cells (green H_2)	RPS	Core and Study
Small Hydro (existing only)	RPS	Core and Study
Large Hydro (existing only)	Zero-Carbon	Core and Study
Nuclear (existing only)	Zero-Carbon	Core and Study
Generic Firm Dispatchable Resource[80]	Zero-Carbon	Study Only
Generic Firm Baseload Resource[81]	Zero-Carbon	Study Only

Source: CEC, CPUC, and CARB. Developed by consensus

80 For example, natural gas with 100 percent carbon capture and sequestration or 100 percent drop-in renewable fuels.

81 For example, low-cost geothermal or imports of emerging nuclear generation technologies.

Zero-Carbon Resources Not Modeled

Technologies that could meet the zero-emissions criteria but have other barriers to development were excluded from modeling for the reasons listed in **Table 9** and discussed in more detail below.

Table 9: Considered Technologies Excluded From 2020 Modeling

Technology	Reason for Exclusion
New in-state nuclear	State effectively has a moratorium on new in-state nuclear power plants under the Warren-Alquist Act.[82]
Drop-in renewable fuels[83] (green hydrogen and biomethane)	Technology for synthetic drop-in renewable fuels not yet commercially available in California or inadequate cost and supply data for modeling or both. Inadequate supply potential for biomethane in the power sector.
Natural gas generation with carbon capture and sequestration	Lack of cost and performance data for 100 percent carbon capture.
Coal-fired generation with carbon capture and sequestration	Incompatible with the state's public health priorities and lack of cost and performance data for 100 percent carbon capture.
New small hydroelectric generation	Inadequate data on new capacity cost and resource availability for modeling.
New concentrating solar power	Lack of proposed new development and high cost relative to other solar resources.
New large hydroelectric generation	Limited development feasibility at this time and environmental concerns.

Source: CEC, CPUC, and CARB joint agency consensus

82 California Energy Commission. January 2020. Warren-Alquist Act 2020 Edition, Sections 25524.1 and 25524.2. Publication Number: CEC-140-2020-001. https://ww2.energy.ca.gov/2020publications/CEC-140-2020-001/CEC-140-2020-001.pdf.

83 Green electrolytic hydrogen and synthetic methane are gaining breakthroughs and cost reductions as "drop-in" or replacement fuels in natural gas-fired power plants and potential zero-carbon dispatchable generation resources.

New In-State Nuclear

Since 1976, California law[84] has prevented the permitting of new nuclear fission power plants until adequately safe technologies exist for fuel rod reprocessing and disposal of high-level nuclear waste. Until these conditions can be satisfied, expansion of new in-state nuclear generating capacity is infeasible.

Imported nuclear power could be considered a zero-carbon resource, but uncertainty in cost projections for new nuclear projects excluded this resource from the core scenarios.

Drop-In Renewable Fuels

Green electrolytic hydrogen, synthetic methane, and biomethane are gaining breakthroughs and cost reductions as “drop-in” or replacement fuels in natural gas-fired power plants and potential zero-carbon dispatchable generation resources.

Hydrogen can be blended with natural gas to reduce emissions in the near term, and industry aims to eventually use 100 percent hydrogen fuel in retrofitted gas plants. Hydrogen can also be synthesized into renewable methane as a drop-in fuel. The Los Angeles Department of Water and Power is exploring the conversion of its Intermountain Power Plant in Utah to 30 percent hydrogen by 2025 and eventually 100 percent hydrogen fuel.

Fully converted plants could significantly affect the 2045 energy portfolio. However, staff excluded the drop-in fuels in this round of modeling because of inadequate publicly available cost and performance data, including costs to produce and transport the fuels. The generic zero-carbon resources modeled in the study scenarios could serve as proxies for these technologies if they are able to reach the specified price point.

Staff excluded biomethane because of the higher value in the other sectors.

Natural Gas Generation With Carbon Capture and Sequestration (CCS)

There are growing interest and investment in natural gas generation with CCS to provide more flexibility and reliability in the state’s electricity grid. However, technological and economic barriers to full decarbonization of fossil fuels remain high. Partially decarbonized resources (that is, with less than 100 percent of onsite carbon emissions captured and stored) did not meet the joint agencies’ criteria for zero-emission technologies.

The generic zero-carbon flexible resource modeled in the study can serve as a proxy for the effect natural gas with 100 percent CCS might have on the 2045 portfolio at the specified price point.

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84 California Energy Commission. January 2020. Warren-Alquist Act 2020 Edition, Sections 25524.1 and 25524.2. Publication Number: CEC-140-2020-001. https://ww2.energy.ca.gov/2020publications/CEC-140-2020-001/CEC-140-2020-001.pdf.

Coal-Fired Generation With CCS

Coal-fired generation with CCS also faces significant technical and economic barriers. Furthermore, the agencies have significant public health concerns regarding the use of coal-fired power plants, even with total carbon capture. Coal-fired plants emit 84 of the 187 hazardous air pollutants identified by the U.S. Environmental Protection Agency (EPA).[85] Of the suite of toxic metals present, the arsenic and mercury in solid coal combustion commonly pose the greatest public health risk because of the associated prevalence and high toxicity. The same is true of the prevalence of polycyclic aromatic hydrocarbons (PAHs) and related precursors in solid petroleum-based fuels (for example, coal). While gas-fueled combustion may also produce toxics, the amounts and toxicity are less impactful than coal combustion. Coal combustion also emits criteria pollutants and related precursors at higher levels than natural gas combustion.[86]

Coal extraction, transport, and storage, and waste storage are associated with additional health and environmental impacts.[87] Further, coal miners suffer from respiratory health issues, including black lung disease, and are at high risk for workplace fatalities.[88]

New Small Hydroelectric Generation

The modeling included current operations as zero-carbon resources, but there are inadequate resource potential and planned development for inclusion as a candidate resource in this round of modeling.

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85 U.S. EPA. Air Toxics Standards for Utilities: Utility MACT ICR Data. Part I & II: Final draft (version 2) of selected EU MACT ICR response data (excludes facility contact information), including; All Part I (General Facility Information); and All Part II (Fuel Analysis and Emission Data); including all Hg CEMs data. Available at https://www3.epa.gov/ttn/atw/utility/utilitypg.html.

86 SO_2 emission rates from coal plants far exceed those from natural gas plants, even with best available control technology. Sources: (a) U.S. EPA. RACT/BACT/LAER Clearinghouse (RBLC) Basic Information. Available at https://www.epa.gov/catc/ractbactlaer-clearinghouse-rblc-basic-information. (b) Emission levels from Intermountain Power Generating Station Unit 3. Air pollution controls include low NOx burners, over fire air, selective catalytic reduction, baghouse/fabric filter, wet flue gas desulphurization, and use of low sulfur coal. Accessed August 4, 2020, from U.S. EPA RACT/BACT/LAER Clearinghouse (RBLC) at https://www.epa.gov/catc/ractbactlaer-clearinghouse-rblc-basic-information. (c) South Coast Air Quality Management District. Huntington Beach Energy Project Final Determination of Compliance. 2016. Numbers represent controlled, steady-state emission levels. Available at https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=12-AFC-02C.

87 EIA. *Coal Explained: Coal and the Environment*. Available at https://www.eia.gov/energyexplained/coal/coal-and-the-environment.php.

88 CDC. The National Institute for Occupational Safety and Health. *Mining Topic: Respiratory Diseases*. Available at https://www.cdc.gov/niosh/mining/topics/RespiratoryDiseases.html.

Concentrating Solar Power (CSP)

Solar thermal power plants with CSP technology, which use mirrors to collect the sun's energy, represent a small share of California's renewable generation. Because of the higher costs relative to solar photovoltaic and wind energy, there is limited development potential, and solar thermal plants were ruled out of the modeling study. Concerns regarding the environmental impacts of CSP projects — including avian mortality from power tower flux and evaporation ponds[89] — have also been a barrier to development, though recent technological and operation changes have reduced the mortality.

New Large Hydro Generation

While hydroelectric generation is considered a zero-carbon resource, the potential for developing costly new water diversions and dams with large environmental impacts is too small for this resource to be included in the modeling study.

Stakeholder Comments on Zero-Carbon Resource Definition

Many commenters supported the "RPS+" criteria for selecting energy resources in the study, and many urged the joint agencies to keep eligibility broadly defined to allow resource innovation and diversity.

The agencies carefully considered the high number of comments in favor of including or excluding specific technologies and made changes where appropriate. For a full list of technologies, inputs, and assumptions used for 2020 modeling, refer to the SB 100 Inputs & Assumptions document.[90]

Electricity Loads Subject to SB 100

SB 100 speaks only to retail sales and state agency procurement of electricity. The joint agencies interpret this to mean that other loads — wholesale or nonretail sales and losses from storage and transmission and distribution lines — are not subject to the law. The modeling reflects this interpretation.

The loads subject to SB 100 are therefore the total of the utility supplied retail sales and the state agency procurements — effectively the Department of Water Resources' (DWR) purchases of electricity to run the State Water Project pumping plants. The pump load is the largest consumer of electricity in California.

As shown in blue in **Figure 20,** these loads accounted for roughly 82 percent of total state consumption in 2018. The joint agencies considered the remaining loads to be outside the

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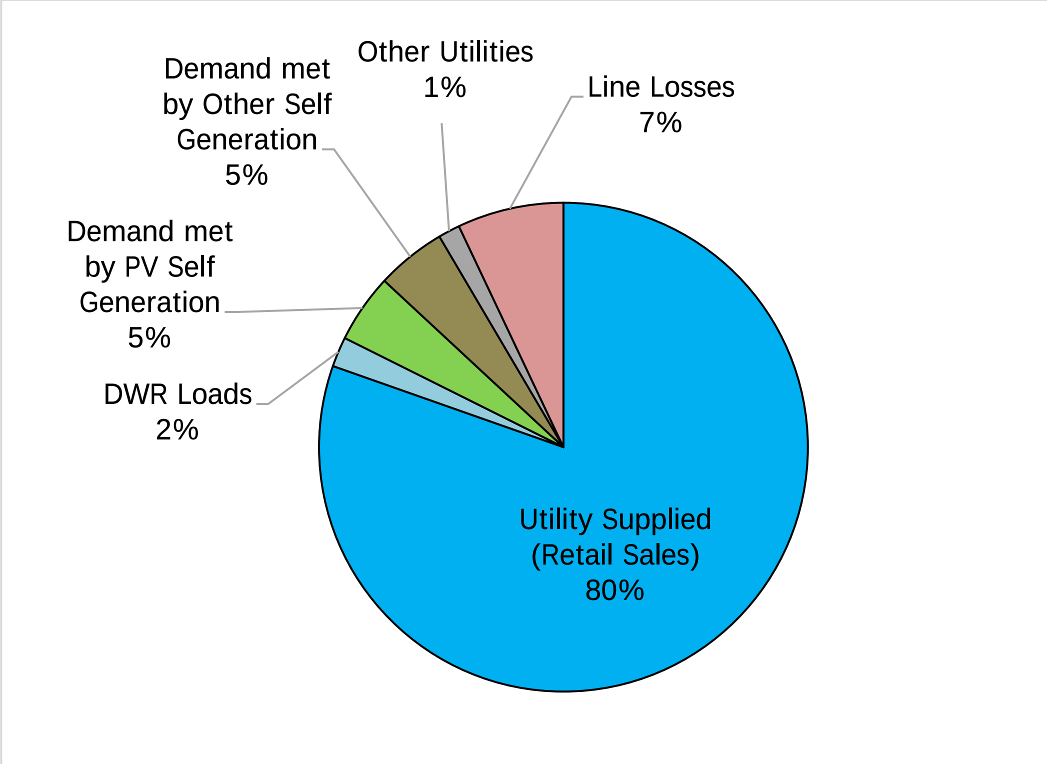
89 California Energy Commission staff. October 2016. *Final 2016 Environmental Performance Report of California's Electrical Generation System*. CEC. Publication Number: CEC-700-2016-005-SF. https://efiling.energy.ca.gov/getdocument.aspx?tn=214098.

90 E3. Inputs and Assumptions: CEC SB100 Interagency Report. June 2020. https://efiling.energy.ca.gov/getdocument.aspx?tn=234532.

scope of the 2045 goal of the law. Solar self-generation accounted for an additional 5 percent of total consumption in 2018.

Figure 19: 2018 California Electricity Loads



Source: 2019 California Energy Demand and the Quarterly Fuels and Energy Report Demand filings

The modeled scenarios also reflect assumptions made about electricity demand. The joint agencies analyzed a reference demand case using an extrapolation from the 2019 Integrated Energy Policy Report California Energy Demand Forecast,[91] as well as high electrification, high biofuels, and high hydrogen scenarios — building off the analysis in the 2018 Deep Decarbonization in a High Renewables Future report.[92]

Several stakeholders commented on the scope of loads covered SB 100. As noted above, the law states “that eligible renewable energy resources and zero-carbon resources supply 100%

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91 California Energy Commission. February 2020. *2019 Integrated Energy Policy Report*. CEC. Publication Number: CEC-100-2019-001-CMF. https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2019-integrated-energy-policy-report.

92 Energy and Environmental Economics, Inc. June 2018. *Deep Decarbonization in a High Renewables Future.* California Energy Commission, https://ww2.energy.ca.gov/2018publications/CEC-500-2018-012/CEC-500-2018-012.pdf.

of retail sales of electricity to California end-use customers and 100% of electricity procured to serve all state agencies by December 31, 2045."

Commenters favoring inclusion of system losses interpreted "supply" to include the upstream generation needed to deliver the retail sales of electricity.

After careful consideration, the joint agencies determined "supply" to mean only retail sales and state loads — an interpretation consistent with the state's Renewables Portfolio Standard.

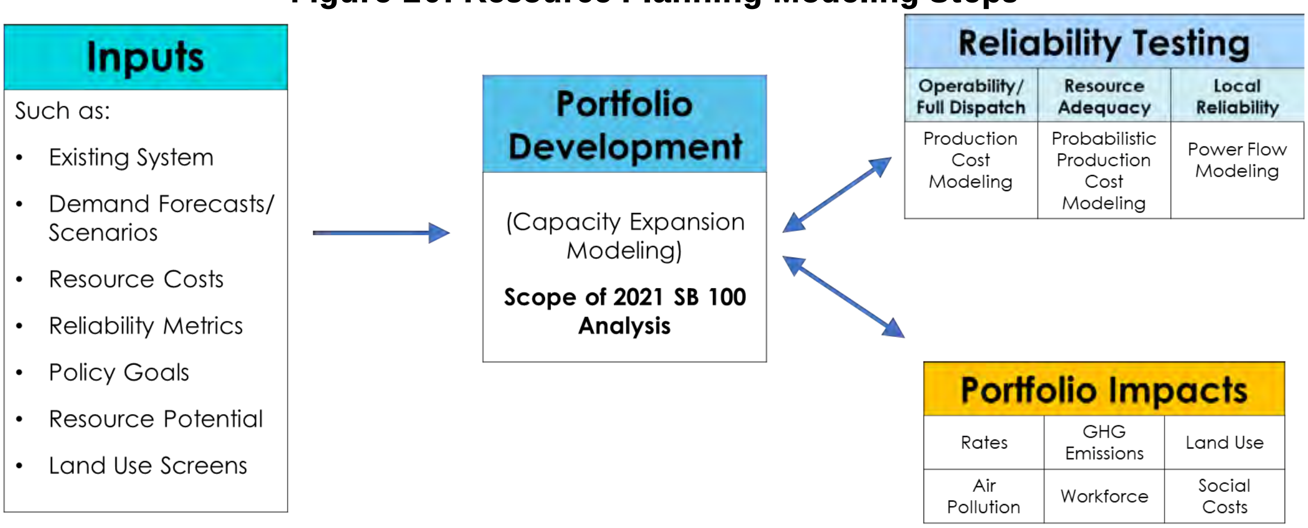
CHAPTER 3: Capacity Expansion Modeling and Discussion

Modeling Scope

The 2021 Report uses capacity expansion modeling as a first step in evaluating the 2045 policy. Capacity expansion modeling optimizes new resource investments over the planning horizon, given the policy and reliability constraints. Typically, simplifications are necessary in capacity expansion modeling due to the computational complexity of optimizing resource selection over a long time horizon. Thus, resource planning typically includes multiple modeling steps to evaluate the reliability of the developed portfolios, as shown in **Figure 21**.

Ideally, in a statewide, long-term analysis such as SB 100, production cost modeling (to test operability and verify resource dispatch) and probabilistic production cost modeling (to determine resource adequacy) would also be completed. Comprehensive studies also evaluate the relevant environmental, economic, and societal impacts of the portfolio. If any assessments do not meet the reliability constraints or policy objectives, the portfolio or capacity expansion model would be adjusted and reassessed.

Figure 20: Resource Planning Modeling Steps



Source: CEC staff

All portfolios presented in this report are directional and intended to inform and complement ongoing analysis within the joint agencies. A comprehensive reliability assessment is not included in this first report; so the portfolio composition and associated costs may change after a more rigorous analysis is completed. Quantitative evaluation of environmental, health, and other societal impacts are also not included in the scope of the 2021 Report.

The modeled zero-carbon candidate resources represent a subset of possible resources that could qualify as “zero-carbon.” Only commercialized resources with established and vetted publicly available cost and performance data, as well as an anticipated development pipeline, were included in the core modeling scenarios, as described in Chapter 2: SB 100 Overview and Report Development Process. Drop-in renewable fuels that could partially decarbonize a generating unit were not included as these generating resources do not meet the "zero-carbon resource" criteria of emitting zero or negligible greenhouse gas (GHG) emissions. Generating resources operating on 100 percent renewable fuels were not included due to lack of established and vetted cost and performance data. Generic zero-carbon firm candidate resources[93] were included in a set of study scenarios and could indicate the potential impact of 100 percent renewable fuels at a specific cost point.

The study includes two types of scenarios, which are described in the Scenario Framework section of this chapter:

- Core scenarios, which reflect the joint agencies' interpretation of the 2045 target in SB 100
- Study scenarios, which are outside the joint agencies' interpretation of the 2045 target in SB 100 and provide information to further support California energy and climate planning and public health considerations

Modeling Framework

Modeling Tools

The 2021 Report modeling builds on existing studies, namely the CPUC Integrated Resource Planning (IRP) 2045 Framing Study, as presented in the 2019–21 IRP cycle.[94] The 2045 Framing Study provided guiding information about the state's long-term policy goals for the IRP's 2030 Reference System Plan. While the 2045 Framing Study is the basis for the SB 100 analysis, the version of the RESOLVE model used for the 2021 Report differs from the version used for the 2019–20 IRP cycle. The framework and modeling assumptions were updated to align with the goals of the 2021 Report. Some key changes are noted in the next section.

RESOLVE California Model

The RESOLVE California model is a capacity expansion model developed by Energy and Environmental Economics, Inc. (E3) The RESOLVE model produces a least-cost resource

93 "Firm resources" are generating resources that can generate electricity at any given time. Examples of zero-carbon firm resources include geothermal, biomass, hydroelectric, and nuclear power.

94 CPUC Energy Division. [2019-20 IRP: Proposed Reference System Plan](https://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/UtilitiesIndustries/Energy/EnergyPrograms/ElectPowerProcurementGeneration/irp/2018/2019%20IRP%20Proposed%20Reference%20System%20Plan_20191106.pdf). November 6, 2019. https://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/UtilitiesIndustries/Energy/EnergyPrograms/ElectPowerProcurementGeneration/irp/2018/2019%20IRP%20Proposed%20Reference%20System%20Plan_20191106.pdf. The modeling for this report has been prepared by E3 for the joint agencies. This report is separate from any work E3 is doing for the California Public Utilities Commission. However, the joint agencies will continue work together to implement SB 100, which will be informed by the findings and modeling in this report.

portfolio, or selection of new electricity generating resources, required to meet an assumed future electric demand by optimizing the net-present value of capital investments and operational costs under policy and reliability constraints.

RESOLVE contains two modules, investment and operational, that co-optimize for the least-cost resource portfolio. The RESOLVE optimization directly captures the linkages between investment decisions and system operations in a single stage. The operational module simulates hourly resource dispatch over a representative 37 independent days for each year modeled in the planning horizon. The investments and operations within the planning horizon are modeled under several potential constraints, including Renewables Portfolio Standard policy, GHG emissions, resource adequacy constraints to maintain reliability, and operational restrictions on generators and resources.

The resource adequacy constraint ensures there is sufficient capacity to meet the system resource adequacy requirement, or capacity requirement, in each modeled year using a net qualifying capacity approach for thermal generators, and an effective load carrying capacity (ELCC) approach for renewables and storage resources.[95] The system resource adequacy requirement is 115 percent of typical peak load.[96] Further reliability analysis for the selected portfolios is necessary and planned for future work, as described in Chapter 4 of this report.

Several changes were made from the CPUC 2019 IRP version of the RESOLVE model for the 2021 Report, including:

- Increasing the geographic footprint from the California ISO to include all balancing authority areas in California.
- Updating baseline resources to reflect the supply provided by additional balancing authority areas included in the geographic footprint.
- Updating the resource cost assumptions to the reflect the most current datasets available at the time of modeling. Details on cost assumptions are described in the Resource Assumptions section and in the Input and Assumptions documentation.

95 "Effective load carrying capability" (ELCC) is the increment of load that could met by the resource while maintaining the same level of reliability. The ELCC of a variable renewable energy resource is based on the capacity coincident with peak load and the profile and quantity of existing variable renewable energy resources. For a detailed description of ELCC implementation in RESOLVE, see page 87 of the Inputs and Assumptions documentation.

96 As stated in the *Final Root Cause Analysis: Mid-August 2020 Extreme Heat Wave*, *Final Root Cause Analysis: Mid-August 2020 Extreme Heat Wave* , *Preliminary Root Cause Analysis: Mid-August 2020 Heat Storm*, the CEC and CPUC recognize that planning for a combination of a 1-in-2 peak with a 15 percent planning reserve margin may not be enough in a high renewables system, particularly when combined with the increasing impacts of extreme heat events, such as those experienced by California and the Western United States in 2020. Any changes to the current resource adequacy and reliability planning processes will be reflected in future assessments.

- Removing the GHG constraint to evaluate the impact of the 100 percent clean electricity policy without the impact of a potentially more stringent constraint.[97]
- Adding hydrogen fuel cells to the candidate resource options. Hydrogen was assumed to be produced off-grid by electrolyzers powered by renewables.
- Expanding the out-of-state (OOS) wind potential to 12 gigawatts (GW) and offshore wind potential to 10 GW.
- Changing how storage is constrained to a feasible dispatch pattern by placing a daily cycling limitation on battery energy storage and removing storage losses from the load portion of the compliance accounting method. For more details, please refer to the Inputs and Assumptions documentation.

Limitations of RESOLVE

Although capacity expansion modeling is an important tool, it is just the first step in a series of modeling phases to develop reliable portfolios that meet all applicable policy objectives. While RESOLVE does include a planning reserve margin constraint to represent system capacity needs, this constraint is not a substitute for probabilistic modeling to calculate a loss of load expectation or similar metrics.

There are specific limitations with RESOLVE that have implications for the modeling results:

- RESOLVE optimizes California as one zone. It does not reflect the impacts of separate balancing authority or load-serving entity requirements or policy objectives or evaluate local reliability needs. Furthermore, the model does not address land-use and spatial constraints that could limit the areas that are assumed by the model to be available for renewable or zero-carbon energy development.
- RESOLVE independently simulates dispatch for 37 representative days of any modeled year. These representative days, sampled from historical meteorological data from 2007 through 2009, are assigned weights to create a reasonable representation of the complete distribution of potential conditions in a full 8,760-hour (the number of hours in a year) simulation. While this representation is sufficient for the primary function of RESOLVE, capacity-expansion modeling, a model with more geographic and temporal granularity is necessary to simulate full dispatch operations and determine the reliability of the selected portfolio.
- RESOLVE includes minimal demand-side resource options for selection. This version of RESOLVE includes customer-side solar and shed demand response (DR). Resources such as energy efficiency, shift DR, and customer-side battery storage are not

97 The CPUC IRP version of RESOLVE includes a 2030 GHG constraint to reflect the SB 350 requirement of planning to meet an electric sector GHG target. The 2045 Framing Study also includes a GHG constraint reflective the 80 percent economywide reduction in GHG emissions by 2050 scenarios. A GHG constraint may be more stringent than the statutory requirements in SB 100 and were removed to best evaluate the 2045 statutory goal. The 2030 GHG emissions for all scenarios are within the established 2030 GHG range.

candidate resources. As such, a sensitivity exploring the potential value of load flexibility was included in the analysis.

- As configured for this study, RESOLVE optimizes only storage resources within each modeled 24-hour day, so as long duration storage resources cannot be optimized across days and are thus not fully valued by the model. Tool development is underway to better evaluate the benefits of and compare types of long-duration storage in RESOLVE.[98] RESOLVE also does not represent hybrid resources, such as solar plus battery storage.

Finally, the analysis presented in this report does not include uncertainty or risk analysis. Given the limitations of the current modeling paradigm, all scenarios and results are intended to provide directional information and serve as a foundation for future analyses.

Inputs and Assumptions

Resource Assumptions

Supply-side candidate resources for selection in the optimization include renewable and zero-carbon resources (as described in Chapter 2), gas resources, storage resources, and transmission resources. Demand-side candidate resources for selection include customer-side solar, customer-side storage, and shed demand response.

RPS-eligible and zero-carbon resources that can be selected as candidate resources include utility-scale solar, wind resources — which are divided between in-state wind, out-of-state wind on new transmission (OOS wind), and offshore wind (OSW) — geothermal, biomass, and hydrogen fuel cells. Solar and wind resources are counted toward the system resource adequacy requirement based on an ELCC approach, as described on page 87 of the Input and Assumptions documentation. Gas resources include combustion turbine and combined-cycle gas turbine generators. Existing gas resources can also be economically retired by the model.

The costs for all generating resources are based on the National Renewable Energy Laboratory (NREL) 2019 Annual Technology Baseline (ATB), except hydrogen fuel cells, which are based on the Department of Energy's Hydrogen Analysis Project. Resource costs are shown in

Figure 22.[99] Hydrogen is assumed to be produced off grid by electrolyzers powered by renewables.

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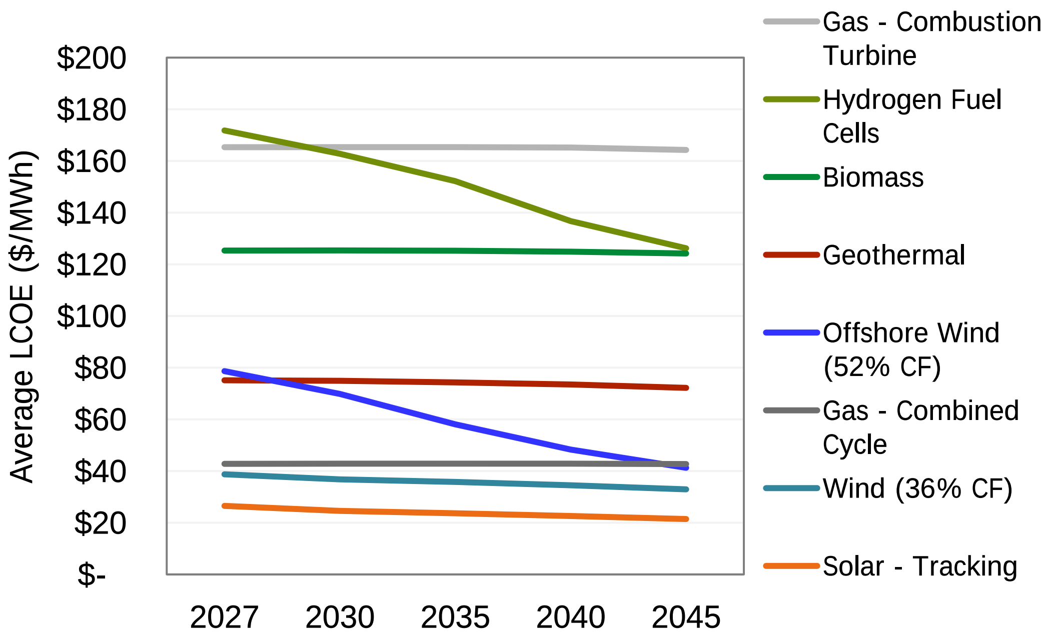
98 California Energy Commission. GFO-19-308- Assessing Long-duration Energy Storage Deployment Scenarios to Meet California's Energy Goals, https://www.energy.ca.gov/solicitations/2020-01/gfo-19-308-assessing-long-duration-energy-storage-deployment-scenarios-meet.

99 National Renewable Energy Laboratory. NREL 2019 Annual Technology Baseline Web page, https://atb.nrel.gov/electricity/2019/; and U.S. Department of Energy. DOE H2A Analysis Web page, https://www.hydrogen.energy.gov/h2a_analysis.html.

Figure 21: Implied Levelized Cost of Energy (LCOE) of Average Technologies (2016$/MWh)



Source: CEC staff and E3 analysis

Several storage resources are available for selection by the model, including lithium-ion battery storage and long-duration storage, which is modeled as pumped hydroelectric energy storage. The model can select the duration for each storage resource. Long-duration storage capacity is limited to 4,000 MW.[100] Storage resources are counted toward the resource adequacy requirement based on an ELCC approach, as described on page 89 of the Input and Assumptions documentation. Storage resource costs are based on Lazard's Levelized Cost of Storage Analysis 5.0 and supplemented by NREL's Solar and Storage Report.[101]

For more information on resource assumptions, see the Inputs and Assumptions documentation.

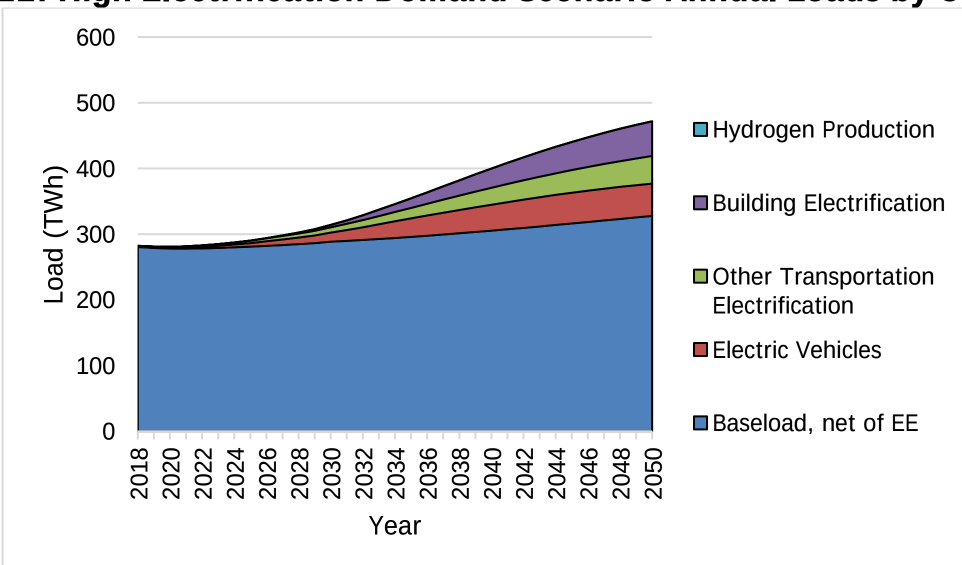
100 Long duration storage is generally considered storage resources that can sustain maximum output for 8 hours or longer.

101 Lazard. November 2019. Lazard's Levelized Cost of Storage Analysis- Version 5.0, https://www.lazard.com/media/451087/lazards-levelized-cost-of-storage-version-50-vf.pdf; and National Renewable Energy Laboratory. November 2018. 2018 U.S. Utility-Scale Photovoltaics Plus-Energy Storage System Costs Benchmark, https://www.nrel.gov/docs/fy19osti/71714.pdf.

Demand Scenarios

Demand scenarios are a key driver of resource portfolio development. This study used several demand scenarios, representing a range of future economywide scenarios, developed through the E3 PATHWAYS model. PATHWAYS is an economywide scenario tool used to evaluate potential pathways to meet economywide GHG reduction targets. Like the IRP 2045 Framing Study, this study uses three mitigation scenarios that meet the goal of 80 percent economywide reduction in GHG emissions by 2050[102]: high electrification (**Figure 23**), high biofuels (**Figure 24**), and high hydrogen[103] (**Figure 25**).[104]

Figure 22: High Electrification Demand Scenario Annual Loads by Category



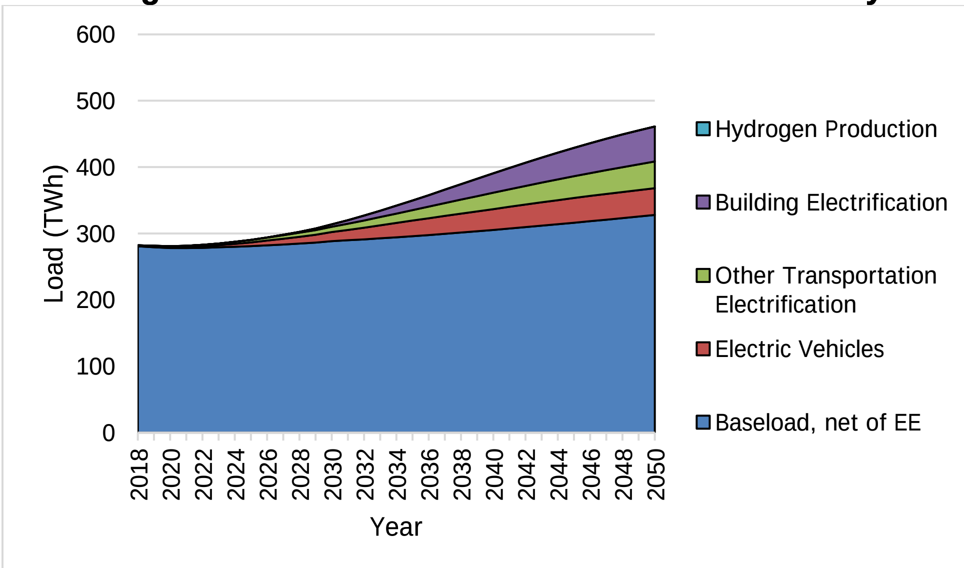
Source: E3 analysis

102 Governor Arnold Schwarzenegger, [Executive Order S-3-05](https://www.library.ca.gov/Content/pdf/GovernmentPublications/executive-order-proclamation/5129-5130.pdf), June 1, 2005, https://www.library.ca.gov/Content/pdf/GovernmentPublications/executive-order-proclamation/5129-5130.pdf.

103 Hydrogen for demand-side end uses (such as vehicles) was assumed to be produced on-grid (in other words, have corresponding electric load), while hydrogen for the supply-side hydrogen fuel cell was assumed to be produced off-grid.

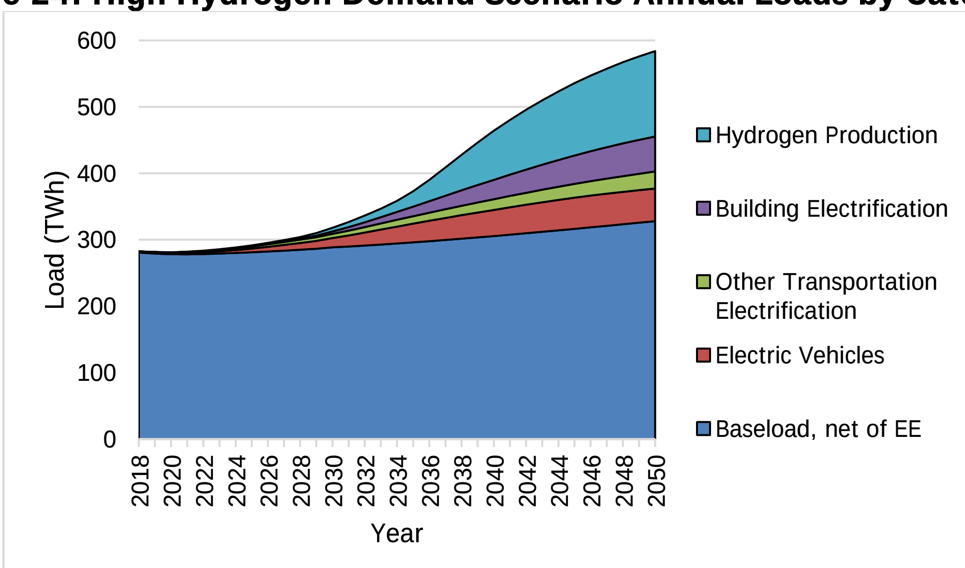
104 Mahone, Amber, Zachary Subin, Jenya Kahn-Lang, Douglas Allen, Vivian Li, Gerrit De Moor, Nancy Ryan, Snuller Price. 2018. *Deep Decarbonization in a High Renewables Future: Updated Results from the California PATHWAYS Model*. California Energy Commission. Publication Number: CEC-500-2018-012. https://ww2.energy.ca.gov/2018publications/CEC-500-2018-012/CEC-500-2018-012.pdf.

Figure 23: High Biofuels Demand Scenario Annual Loads by Category



Source: E3 analysis

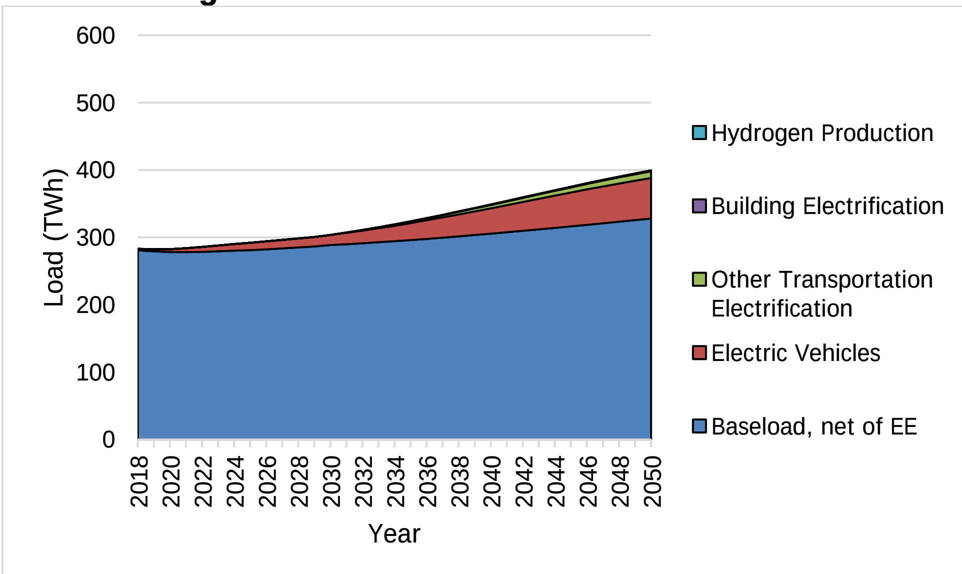
Figure 24: High Hydrogen Demand Scenario Annual Loads by Category



Source: E3 analysis

Moreover, the study used a reference scenario developed to align with the 2019 California Energy Demand Forecast through 2030 and an extrapolation of that forecast through 2045,[105] as shown in **Figure 26**.

Figure 25: Reference Demand Scenario



Source: E3 analysis

Each of the demand scenarios includes a significant increase in demand from 2020, ranging between a 22 percent increase by 2045 in the reference scenario and an 87 percent increase in the high hydrogen scenario.

With the substantial growth in annual loads by 2045, each scenario shows a near doubling of resource adequacy requirements compared to present day, as shown in **Figure 27**.[106]

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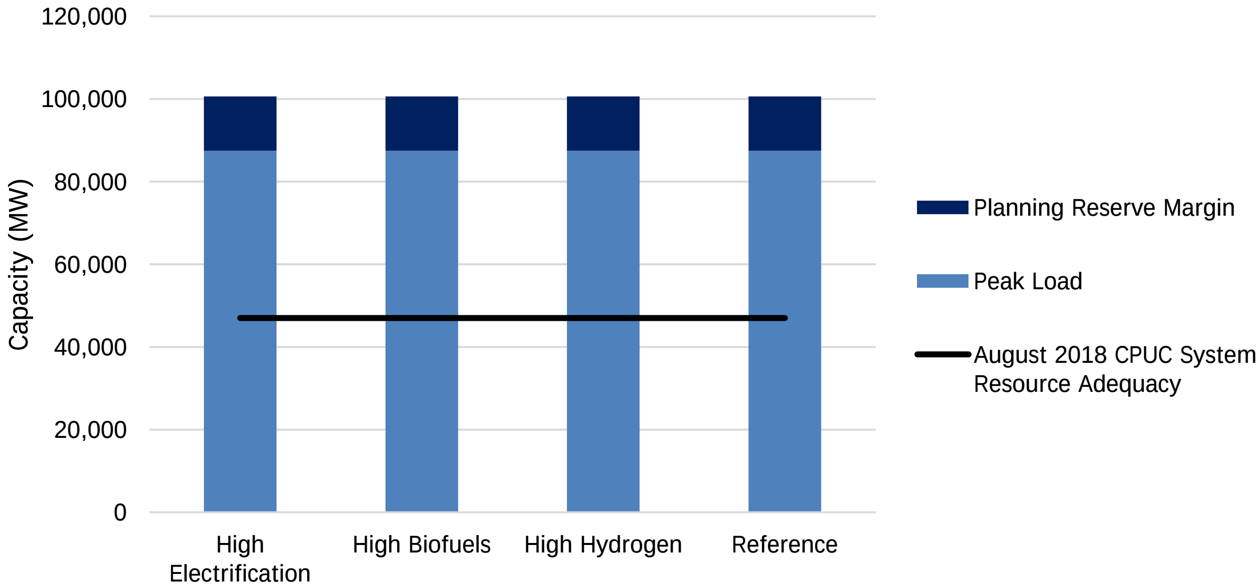
105 California Energy Commission. February 2020. *2019 Integrated Energy Policy Report*. CEC. Publication Number: CEC-100-2019-001-CMF. https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2019-integrated-energy-policy-report.

106 The RESOLVE reliability module resource adequacy requirement is peak load plus a 15 percent planning reserve margin; this reserve margin value is a user-configurable input variable. Figure 7 references the August 2018 CPUC System Resource Adequacy resource total. This number represents the capacity requirement for roughly 80 percent of state loads. Publicly owned utilities have separate resource adequacy processes.

Figure 26: 2045 Resource Adequacy Requirement for the High Electrification, High Biofuels, High Hydrogen, and Reference Demand Scenarios



Source: CEC staff and E3 analysis

Additional information about the demand scenarios and demand assumptions can be found in the Input and Assumptions documentation.

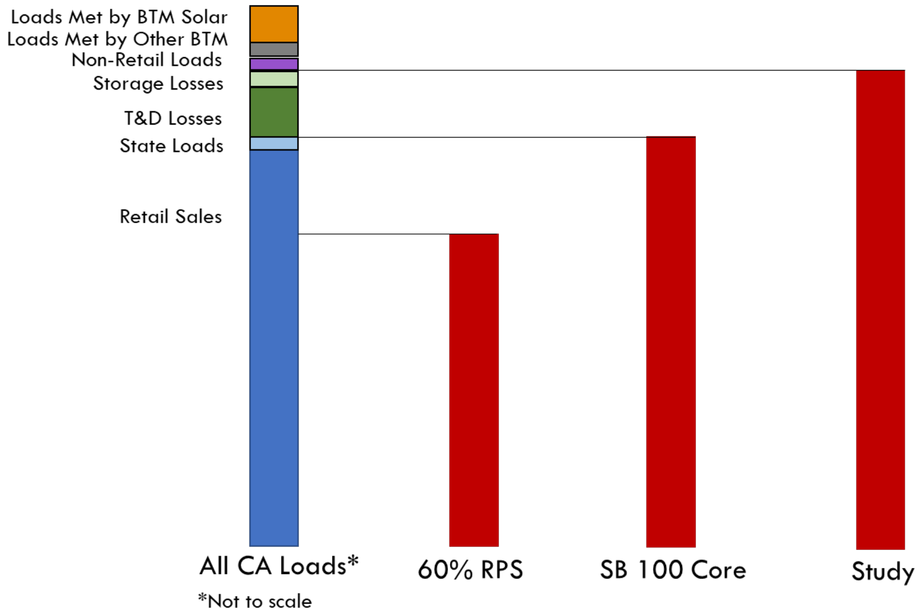
Zero-Carbon Load Coverage

Three zero-carbon load coverage targets, as illustrated in **Figure 28**, were considered in this study:

- A "60 percent RPS" load coverage target with a constant 60 percent of retail sales being met by RPS-eligible resources through 2045. This load coverage target acts as a counterfactual — or reference — to evaluate impacts of the 2045 100 percent clean electricity target.
- The "SB 100 core" load coverage target is consistent with the joint agencies' interpretation of SB 100, and 100 percent of retail sales plus state agency loads in 2045 are met by zero-carbon generation. Interim years include a linear zero-carbon target from 2030 to 2045.
- The "study" load coverage target goes beyond the joint agencies' interpretation of SB 100, and 100 percent of retail sales, state loads, transmission and distribution losses, and storage losses in 2045 are met by zero-carbon resources. Interim years include a linear zero-carbon target from 2030 to 2045.

All scenarios include a 60 percent RPS target in 2030 as required by SB 100.

Figure 27: 2045 Zero-Carbon Load Coverage Targets



Source: CEC, CPUC, CARB. Developed by consensus.

Scenario Framework

SB 100 states that the joint agency report shall include "alternative scenarios in which the policy ... can be achieved and the estimated costs and benefits of each scenario." Furthermore, the statute requires the 2021 Report to include "a review of the policy ... focused on technologies, forecasts, then-existing transmission, and maintaining safety, environmental and public safety protection, affordability, and system and local reliability."

The modeling included in this report evaluates the costs and benefits of various technological pathways to meet the 2045 target, while acknowledging that costs, performance, and availability of commercialized technologies will change over the next 25 years. Future modeling will be updated accordingly.

While the primary focus of this report is to analyze scenarios based on established cost and performance data and the joint agencies' interpretation of SB 100, the joint agencies recognize the importance of analyzing outcomes beyond these assumptions to support broader energy and climate planning and public health considerations. As such, scenarios are broken into two categories, "core scenarios" and "study scenarios."

Core Scenarios

The "Core Scenarios" modeled for the 2021 Report are consistent with the joint agencies' interpretation of the statute and, therefore, include the proposed loads subject to SB 100 (retail sales plus state agency loads) in the zero-carbon target. Generation applied toward meeting the zero-carbon target includes generation from resources that meet the zero-carbon criteria as described in the Modeling Scope section of this chapter.

The scenarios reflect a central, “SB 100 Core Scenario,” with the default assumptions of the SB 100 Core Load Coverage Target, High Electrification Demand Scenario, and all candidate resources available for selection by the model. Sensitivities then explore the effect of changing specific assumptions. Core scenarios are listed in **Table 10**.

Table 10: SB 100 Core Scenario Classification List

Scenario Classification	Scenario Description
60% RPS (Counterfactual)	60% RPS through 2045
SB 100 Core Scenario	Core Load Coverage; High Electrification Demand; All candidate resources available
SB 100 Core, Demand Sensitivities	Change: Demand Scenarios or Load Shape
SB 100 Core, Resource Sensitivities	Change: Candidate Resource Availability

Source: CEC, CPUC, and CARB. Developed by consensus.

Study Scenarios

The “study scenarios” are exploratory analyses that examine outcomes outside the scope of the joint agencies’ working interpretation of the SB 100 policy. They are intended to provide additional information for consideration and support broader state energy, climate planning, and public health efforts. Study scenarios should not be interpreted as asserting the state’s ability or intention to regulate beyond the interpreted scope of SB 100. Rather, they are intended to advance an understanding of long-term planning beyond the scope of SB 100. Study scenarios are listed in **Table 11**.

Table 11: Study Scenario Classification List

Scenario Classification	Scenario Description
Expanded Load Coverage	Core Load Coverage plus storage and T&D losses; High Electrification Demand; All candidate resources available
Expanded Load Coverage, Demand Sensitivities	Change: Demand Scenarios
Expanded Load Coverage, Resource Sensitivities	Change: Candidate Resource Availability
Zero Carbon Firm Resources	Add generic zero carbon firm resources to candidate resources as a proxy for emerging zero-carbon technologies
Accelerated Timelines	Accelerate 100% target to 2030, 2035, and 2040
No Combustion	No conventional combustion resources included (fossil and biomass based); retire all in-state combustion resources by 2045

Source: CEC, CPUC, and CARB. Developed by consensus.

Preliminary Results

The initial SB 100 modeling resulted in the following key findings:

- SB 100 is achievable and will require significant resource capacity to meet the 2045 target and increasing electric demand.
- Gas capacity is maintained for resource adequacy, although gas generation decreases by half compared to a 60 percent RPS future.
- SB 100 reduces electric sector GHG emissions to around 24 MMT CO_2 in 2045 in a high-electrification future.
- Demand is a significant driver of new resource needs.
- Demand flexibility reduces total new resource needs and total supply cost.
- Cost-competitive zero-carbon firm resources would reduce total resource needs and total system costs.
- A no-combustion scenario appears technically achievable and results in significant new capacity and increased total resource cost compared to the SB 100 core scenario.

Central Core and Study Scenario Results

All scenarios modeled result in significant capacity additions. **Figure 29** shows the cumulative capacity additions, plus the assumed new customer-side solar, for three scenarios with different zero-carbon load coverage targets, 60 percent RPS (60 percent of retail sales), SB 100 core (100 percent of retail sales and state loads), and study (core loads plus system losses) with high-electrification demand. Across all scenarios, the customer-side solar included is a modeling input, representative of projected customer-side solar adoption. No additional customer-scale solar was selected in the optimization.

In the 60 percent RPS scenario, 73 GW if utility-scale capacity is added by 2045, including:

- All 4.3 GW of assumed available in-state wind.
- 2.2 GW of out-of-state wind.
- 36 GW of utility-scale solar.
- 30 GW of battery storage.
- 1.7 GW of pumped storage.
- 440 MW of shed DR.
- 2.6 GW of new gas generation.

While the RPS target remains at 60 percent after 2030, increased electricity demand in the high-electrification demand scenario still drives the need for a significant amount of additional renewable energy resources, storage, and some gas resources.

In the SB 100 core scenario, 145 GW of utility-scale capacity additions are selected by 2045, including:

- All 4.3 GW of assumed available in-state wind.
- All 10 GW of assumed available offshore wind.
- All 4 GW of assumed available long-duration storage.
- 8.2 GW of out-of-state wind.
- 70 GW of utility-scale solar.
- 135 MW of geothermal.
- 49 GW of battery storage.

Moreover, the model economically retires 4.7 GW of gas capacity.

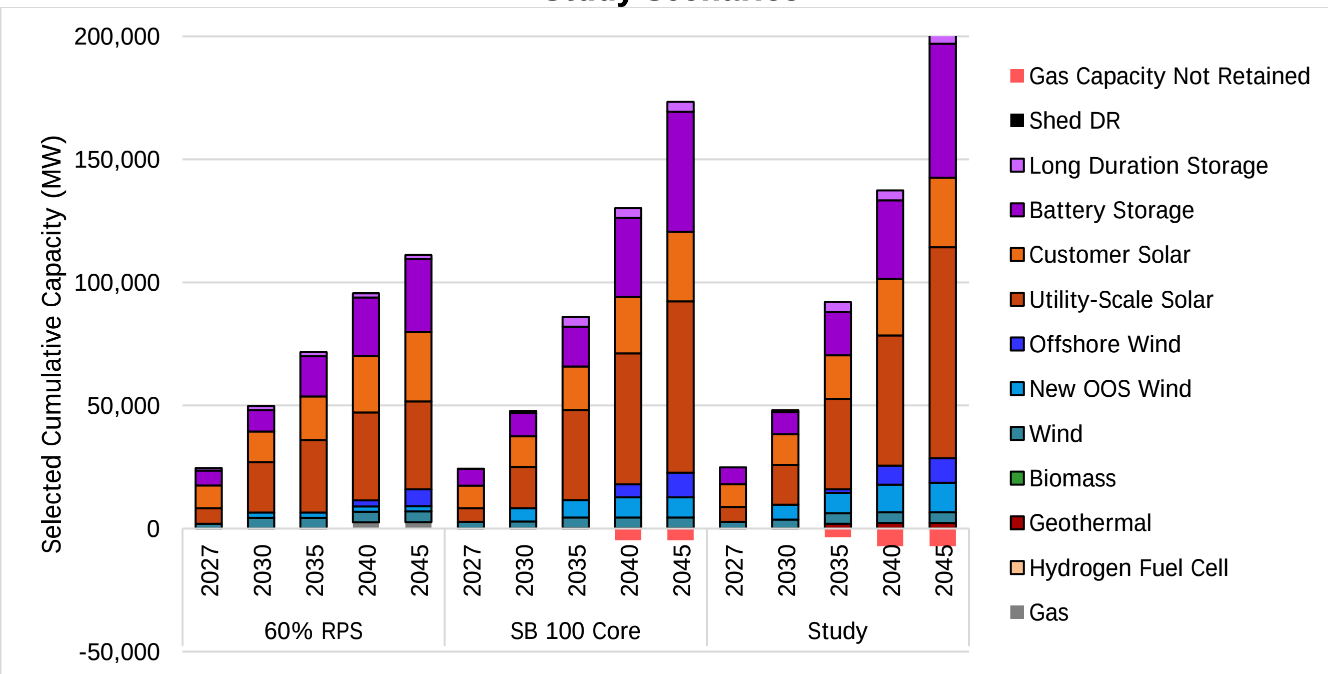
In the study scenario (expanded load coverage), 173 GW of utility-scale capacity additions are selected by 2045, including:

- All 4.3 GW of assumed available in-state wind.
- All 10 GW of assumed available offshore wind.
- All 4 GW of assumed available long-duration storage.
- 11.9 GW of out-of-state wind.

- 86 GW of utility-scale solar.
- 2.3 GW of geothermal.
- 55 GW of battery storage.

Furthermore, the model economically retires 7.2 GW of gas capacity.

Figure 28: Cumulative Capacity Additions for the 60 Percent RPS, SB 100 Core, and Study Scenarios

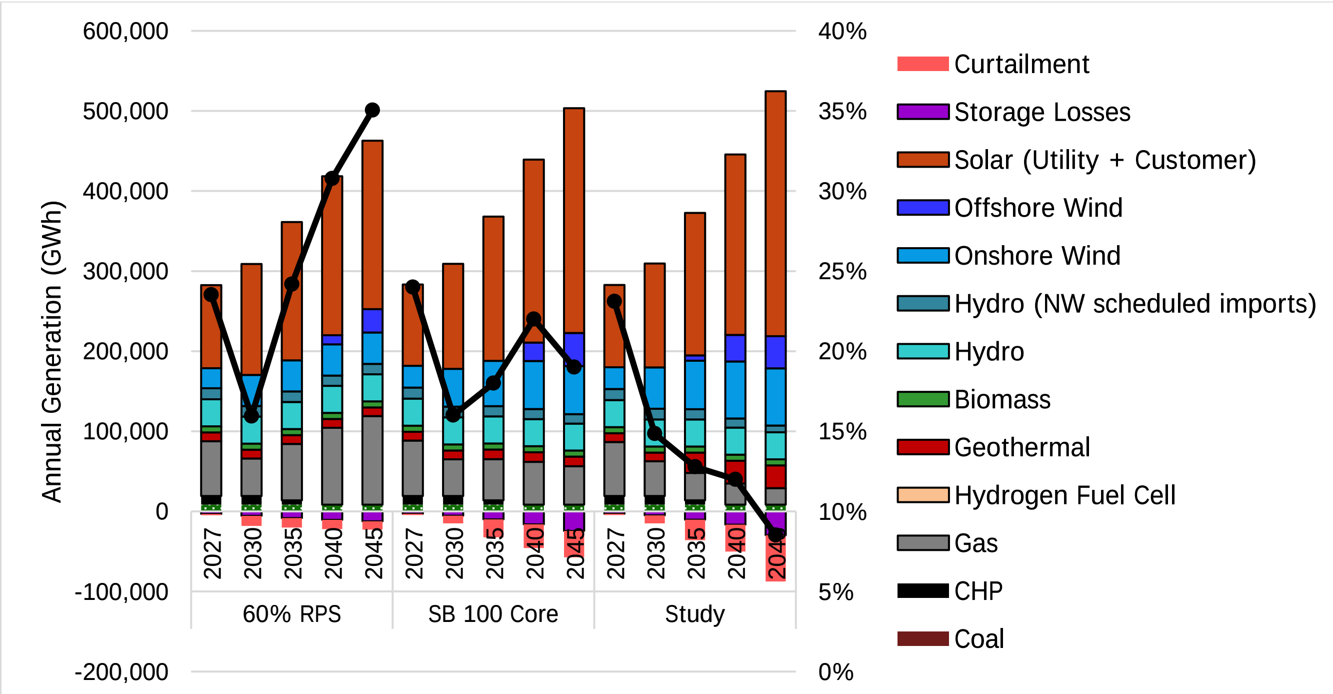


Source: CEC staff and E3 analysis

The annual generation in each of the scenarios increases significantly over the modeled years, as shown in **Figure 30**. In the 60 percent RPS scenario, gas generation and the gas fleet capacity factor increase between 2030 and 2045 (that is, gas generator are run more often). On the other hand, in both the SB 100 core and study (expanded load coverage) scenarios, gas generation and gas fleet capacity factors decrease between 2027 and 2045.

Renewable curtailment increases with the stringency of the zero-carbon target. In 2045, curtailment reached 2 percent in the 60 percent RPS scenario, 7 percent in the SB 100 core scenario, and 11 percent in the study (expanded load coverage) scenario.

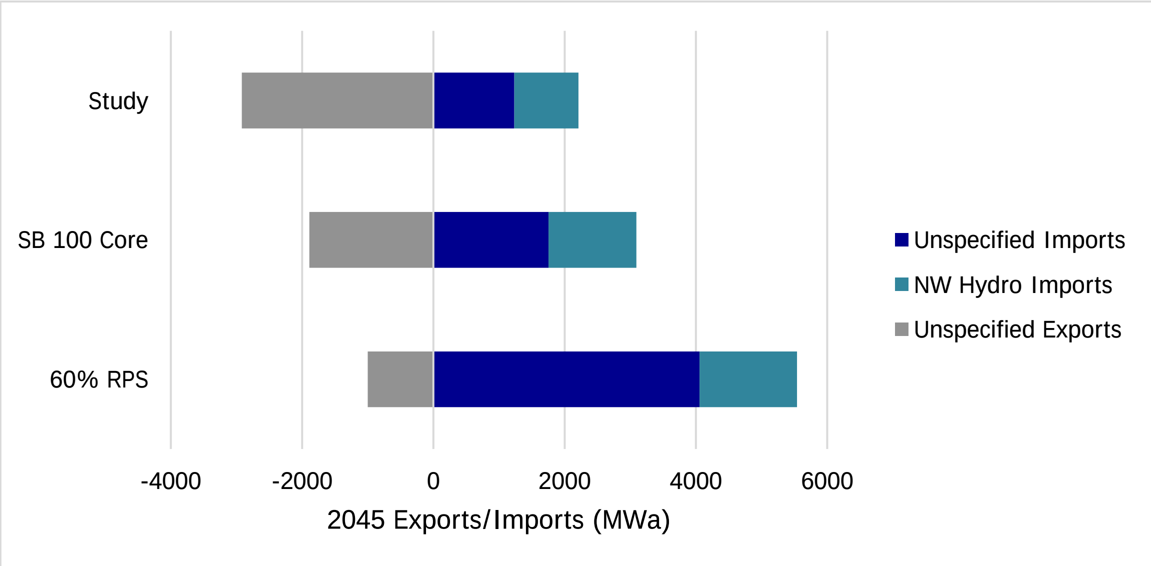
Figure 29: Annual Generation for the 60 Percent RPS, SB 100 Core, and Study Scenarios



Source: CEC staff and E3 analysis

As shown in **Figure 31**, as the stringency of the zero-carbon target increases, average imports decrease and average exports increase.

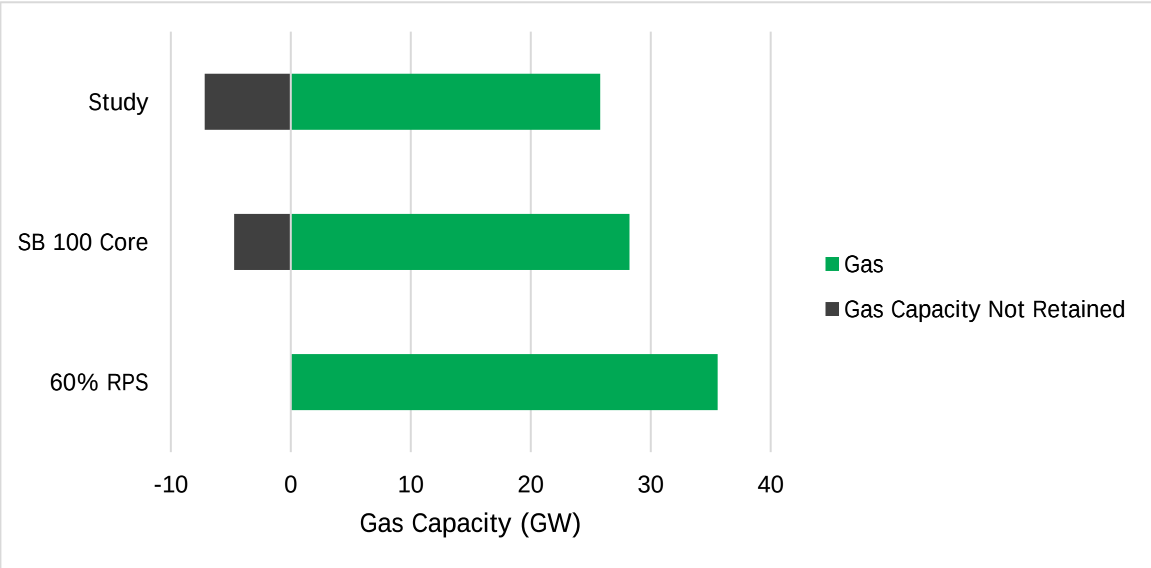
Figure 30: Average Imports and Exports in 2045 for the 60 Percent RPS, SB 100 Core and Study Scenarios



Source: CEC staff and E3 analysis

While both the SB 100 core and study (expanded load coverage) scenarios show decreases in gas generation, much of the gas fleet is retained, as shown in **Figure 32**.

Figure 31: Total Installed (Existing and New) and Retired Gas Capacity for the 60 Percent RPS, SB 100 Core and Study Scenarios



Source: CEC staff and E3 analysis

This analysis assumes no additional gas generators retirements beyond those planned at the time of modeling.[107] Additional retirements before the first modeled year would likely increase economic gas retention or storage additions or both. Gas maintenance costs are consistent with the NREL ATB's projected fixed operations and maintenance (O&M). Comparison to CPUC resource adequacy reported average contract prices suggest that costs included in NREL's ATB may be an underestimate of gas maintenance costs.[108] Higher than modeled gas fleet maintenance costs may decrease economic gas retention or increase total scenario cost or both.

Significant gas capacity is economically retained to contribute to meeting the system resource adequacy requirements, as shown in **Figure 33**.[109] Comparing across scenarios, despite the significant increase in variable renewable energy nameplate capacity, the ELCC contributions increase relatively little, with a marginal ELCC for solar at 2 percent and a marginal ELCC for wind at 19 percent. In scenarios where the optimization results in more battery storage, there are increases in economic gas retirements. While there is a resource adequacy constraint in the model (i.e., a 15 percent planning reserve margin), a full resource adequacy analysis is necessary to determine whether the portfolios produced are resource adequate.

107 It is assumed the remaining once-through-cooling units retire on the planned retirement schedule. No other gas generators are assumed to retire.

108 California Public Utilities Commission. August 2019. *2018 CPUC Resource Adequacy Report*, https://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Utilities_and_Industries/Energy/Energy_Programs/Electric_Power_Procurement_and_Generation/Procurement_and_RA/RA/2018%20RA%20Report.pdf.

109 Economic retention does not mean gas resources are the only resource that can provide capacity but are the most economic resource to do so in these scenarios, given current inputs and assumptions.