Cap-and-Trade and Cost Containment in California

Meredith Fowlie and Brian Holt

California has established a goal of reducing statewide greenhouse gas (GHG) emissions to 40% below 1990 levels by 2030. Policy design choices will play a decisive role in determining what it costs to meet this goal and how these costs will be allocated. To ensure that California's clean energy transition is affordable and equitable, cost-containment and fair cost allocation should be guiding principles.

This chapter underscores the importance of this cost-containment imperative. We begin by discussing the role that a GHG cap-and-trade program can play in keeping the costs of achieving GHG emission targets in check. We show how, **if companion policies are used to incentivize or mandate specific forms of GHG abatement, this can increase overall abatement costs while reducing GHG allowance prices if mandated abatement strategies are relatively costly.**

The second part of the chapter surveys available evidence on current and proposed companion climate policies in California. This available evidence indicates that **some of California's prescriptive policies, including some clean technology subsidies, deliver GHG reductions at a relatively high cost.** Given rising GHG abatement costs and mounting concerns around affordability (see Chapter 1), we argue that it will be important to ensure that prescriptive regulations are implemented in a way that aligns with cost containment objectives along with other policy goals.

Cost-containment advantages of cap-and-trade

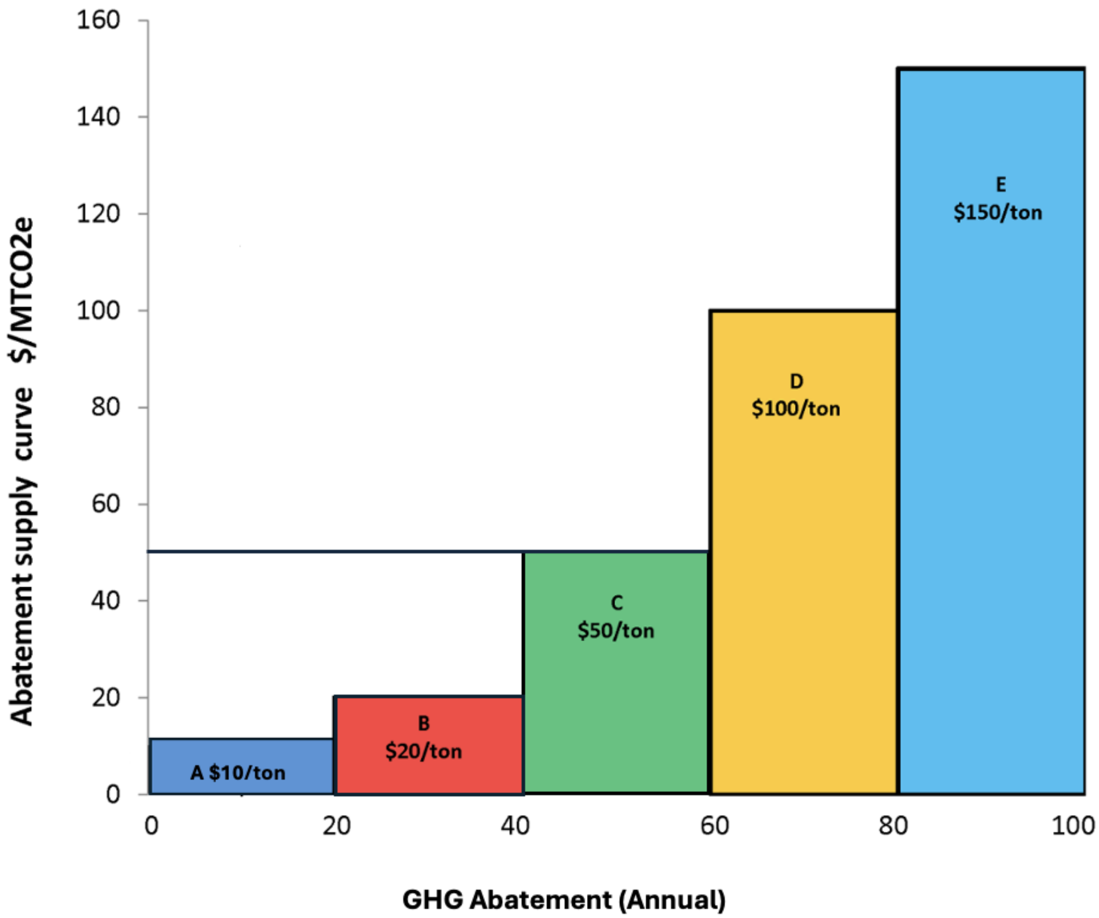
As California pursues deeper GHG reductions, the costs of achieving these reductions are increasing. High costs of living in California, and mounting concerns around affordability, make it important to seek out the most promising and least costly GHG abatement options.

California's GHG cap-and-trade program has been designed to incentivize and coordinate cost-effective GHG reduction abatement. The stylized graphics below illustrate the basic intuition behind how this market-based coordination is designed to work (Figure 1) and how interactions with more prescriptive "companion" policies can impact carbon market outcomes (Figure 2).[1]

The staircase graphic in each figure is meant to represent a stylized set of GHG abatement options (e.g. increased adoption of electric vehicles, accelerated deployment of renewable energy generation, industrial decarbonization) arranged in ascending order of abatement cost. The height

[1] This graphical illustration is based on a 2016 blog post, "Time to Unleash the Carbon Market?", from June, 2016.

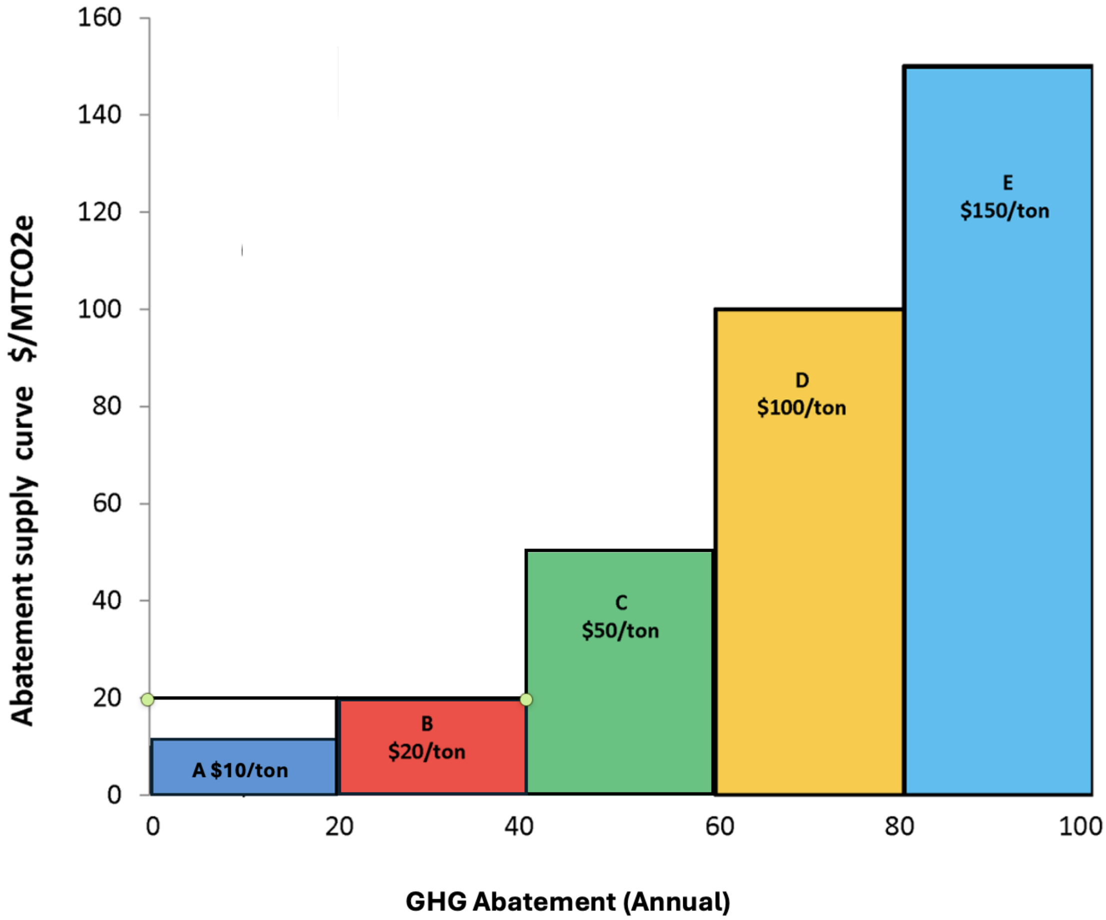
of the blocks measure the cost per ton of CO2 emissions reduced. The width of the blocks measures achievable GHG emissions reductions.



Suppose that California policy makers have set a GHG emissions target that requires a reduction of 60 units below “business as usual” emissions. If a GHG cap-and-trade program was used to coordinate this abatement, the market price would increase until this level of GHG abatement has been supplied by market participants. In this very simple example, a price of $50 delivers the desired GHG reductions. The total abatement cost incurred to meet the target:

A + B + C = (20 x $10) + (20 x $20) + (20X$50) = $1200.

Thus far, we have assumed that the carbon market is the only policy instrument driving GHG emissions reductions into the economy. However, California has historically relied on a combination of carbon pricing and prescriptive policies (e.g. clean technology mandates and subsidies) to encourage GHG abatement. With this in mind, now suppose policy makers mandate the deployment of options A and E to deliver 80% of the desired abatement. Under this scenario, the role of the carbon market is reduced to delivering only the 20 units of abatement (i.e. strategy “B”) required to meet the target.



Under this policy regime which combines prescriptive policies with the carbon market mechanism, the total cost of meeting the emissions target would be:

A + B + E = 20 x \$10 + 20 x \$20 + 20 x \$150 = \$3600.

The market clearing price required to deliver 20 units of abatement is \$20/ton abated. Note that this combination of prescriptive policies with the carbon market increases the overall cost of achieving the GHG reduction target.

This exposition is overly simplistic of course. It ignores tremendous amounts of uncertainty around business-as-usual emissions trajectories, technology costs, etc. But these pictures help to elucidate how interactions between carbon markets and more prescriptive climate policies impact carbon market prices and abatement costs. More specifically, **if companion policies are used to incentivize or mandate specific forms of GHG abatement, this can increase overall abatement costs while reducing GHG allowance prices if mandated abatement strategies are relatively costly.**

This simple example begs the question: *Why would policy makers mandate relatively expensive GHG abatement alternatives?* There are several possible reasons.

First, it can be very challenging for policymakers to anticipate which abatement options will hold the greatest potential in the future. Whereas the graphs above provide a clear snapshot of GHG abatement costs at one point in time, the reality is far less clear - and far more dynamic. Policy makers are working with limited and uncertain information about which abatement options will deliver GHG reductions most cost-effectively going forward. Carbon market mechanisms are designed to respond to evolving technological innovations and market conditions. In other words, a well-functioning carbon market mechanism will coordinate the least cost abatement without knowing in advance what the most promising strategies will be.

Second, policymakers might want to encourage more expensive GHG abatement alternatives that offer significant "co-benefits". The cost per ton metric used in the figures above can be useful for drawing cost comparisons across abatement strategies, but this metric fails to capture other benefits, such as local air quality or biodiversity or technological change. These co-benefits can justify the deployment of strategies that deliver GHG reductions at higher cost per ton.

Third, mandates and regulations provide more ex ante certainty around what types of investments a climate policy will support. More prescriptive policy commitments can be useful in the presence of network effects, and/or in sectors where decarbonization requires capital-intensive, long-lived infrastructure investments. However, this certainty can come at a cost if mandated technologies prove to be less cost effective ex post.

Finally, policymakers may elect to pursue relatively costly prescriptive policies because the benefits generated by these policies tend to be more salient, whereas the costs are less visible (as compared to carbon pricing). Carbon pricing can be politically unpopular because the costs are highly visible, whereas the GHG abatement benefits are hard to directly observe.

How do costs of companion programs compare to allowance prices?

The graphics above illustrate how a reliance on more prescriptive approaches can increase the overall cost of meeting our GHG abatement targets if some (or all) of the prescribed GHG abatement options are relatively costly. California has relied heavily on more prescriptive policies (e.g. renewable energy mandates) and technology-specific subsidies (e.g. rooftop solar subsidies). How do the costs of these policies compare to the market price of GHG allowances?

The costs of more prescriptive policies are not so straightforward to estimate. A detailed empirical analysis is well beyond the scope of this report, so we rely on other studies that have endeavored to construct cost-per-ton measures for specific policies and programs. . Appendix A summarizes some of the available evidence for policy instruments that are currently being used to deliver GHG emissions reductions in California. An important caveat when comparing these estimates: input assumptions and cost accounting approaches vary significantly across studies. These comparisons should be viewed as illustrative versus definitive.

These caveats notwithstanding, the evidence suggests that the ex post realized cost per ton of GHGs avoided varies widely across companion climate policies. In some cases, GHG abatement achieved using prescriptive policies is estimated to be significantly more costly (in terms of dollars spent per ton of CO2 avoided) as compared to the California carbon price (which was around $32/ton in 2023). In contrast, the costs of GHG reductions induced by the California Renewable Portfolio Standard (RPS) look quite low now that solar and wind technology costs have fallen (below $10/ton).

Looking ahead, the 2022 Scoping Plan includes some more ex ante cost estimates for measures considered in Scoping Plan scenarios. Here again, we see significant variation in abatement cost estimates across programs and policies, with many cost estimates significantly exceeding current and forecast GHG allowance prices.

Table 3-11: Estimated cost per metric ton of reduced CO_2e relative to the Reference Scenario for measures considered in the Scoping Plan Scenario (AB 32 GHG Inventory sectors)

Measure	Annual Cost, 2035 ($/ton)	Average Annual Cost, 2022–2035 ($/ton)	Annual Cost, 2045 ($/ton)	Average Annual Cost, 2022–2045 ($/ton)
Deploy ZEVs and reduce driving demand	-171	-99	-103	-122
Coordinate supply of liquid fossil fuels with declining CA fuel demand	60	109	-50	39
Generate clean electricity[a]	101	156	145	161
Decarbonize industrial energy supply	290	217	257	274
Decarbonize buildings	235	230	112	213
Reduce non-combustion emissions	93	94	106	99
Compensate for remaining emissions	745	823	236	485

[a] Note: The denominator of this calculation (2045) does not include GHG reductions occurring outside of California resulting from SB 100. If these reductions were included, this number would be lower.

Conclusion

California's pursuit of greenhouse gas (GHG) emission reductions will require a careful balancing of cost containment and climate ambition. The state's cap-and-trade program offers a powerful tool to minimize the costs of emission reductions by coordinating the most cost-effective abatement options. However, this cost-effectiveness is often overshadowed by the more visible costs of carbon pricing, which can be politically unpopular.

Prescriptive policies deliver more salient GHG reduction benefits. But the hidden costs of these policies can be substantial. A reliance on relatively costly mandates, standards, and subsidies could significantly increase the overall cost of GHG abatement while also putting downward pressure on the GHG allowance price (and thus reducing the incentives to reduce GHG emissions in other parts of the California economy).

We offer the following observations and recommendations to CARB and the legislature.

1. As the state moves forward with it's climate change mitigation efforts, maintaining a focus on cost containment will be essential to ensuring that its clean energy transition remains both affordable and effective. In this respect, re-authorization of the cap-and-trade program has a critical role to play.

2. More prescriptive companion policies can provide important benefits. However, given the imperative to contain and manage the cost impacts of climate action in California, these benefits should be judiciously weighed against the potential costs.

3. In addition to the cost-effectiveness advantages of carbon pricing, the GHG cap-and-trade program generates state revenues. These revenues can be used to address affordability concerns among other objectives. We discuss this topic in more detail in Chapter 1.

Appendix

NB: These calculations are preliminary. Comments encouraged

i. Rooftop solar subsidies

In past years, California has compensated customers who install rooftop solar on their homes (or businesses) at retail rates for excess energy they generate and feed back into the electric grid.

These “net energy metering” (NEM) customers also save money when they consume the electricity their panels produce (versus paying the retail rate for grid electricity). This program has been effective at accelerating the adoption of rooftop solar panels.

To (coarsely) assess the implicit costs incurred when we reduce GHG emissions via investments in rooftop solar PV, we need to estimate both the social value of the electricity generated by PV systems (including the avoided air pollution and climate damages), and we need to estimate the increase in supply costs. A detailed analysis of these benefits and costs is beyond the scope of this report. We provide rough estimates drawn from public data and basic calculations.

Abatement Costs: According to the 2024 Tracking the Sun report, the median installed solar PV system price in 2023 in California was $4.2/W DC for residential solar PV. Using a time horizon of 20 years and a discount rate of 2%, we calculate an annualized cost is $0.26/W DC. If we further assume that a 1 W DC solar panel would generate approximately 1.5 kWh per year, this implies a levelized cost of over $0.17 per kWh.

Of course, the system installation costs incurred by a homeowner can exceed the technology and infrastructure costs. Some of these homeowner costs may be offset by tax credits and subsidies. Transfers from homeowners to rooftop solar PV installers, or transfers from tax payers to rooftop solar adopters, have implications for the allocation of costs. Here, we are focused on estimating the social costs (e.g. technology costs) so that we can assess the empirical analog of the abatement costs incurred to reduce GHGs via rooftop solar adoption and generation.

To estimate the GHG emissions avoided when a rooftop solar PV system generates a kWh of electricity, we use the average marginal emissions intensity in 2023 which is approximately 0.4 tons CO2/MWh (this over-all-hours average likely over-estimates the rate of GHG emissions displacement in daylight hours when solar panels are generating electricity). The marginal cost of grid electricity production in California was around 6 cents/kWh in 2023. Dividing the additional cost per kWh generated using rooftop solar PV (i.e. $0.17/kWh-$0.06/kWh) by the tons of CO2 displaced by solar electricity production, we estimate that it cost over **$270/ton** to reduce a ton of CO2 via investments in rooftop solar.

There are reasons to think that this *under*-estimates abatement costs per ton of GHG avoided. The emissions intensity of the California grid is expected to decrease over the life of these PV sustems (and the quantity of GHG emissions displaced falls). Moreover, because some of the investments in rooftop solar would have happened even absent the subsidy, $270 is a lower bound on the costs GHG’s abatement due to the NEM subsidy.

On the flip side, this approach could *over*-estimate GHG abatement costs insofar as we under-estimate avoided costs. Some benefits not captured in this very simple analysis include the benefits of learning that can reduce technology costs and improve system performance going forward, and the some costs of integrating utility-scale renewables that are not fully captured by the TTS cost estimates.

Energy affordability and incidence:

In Chapter 1 we estimated that the social marginal cost of grid electricity production and consumption in 2023 was approximately \$0.15 per kWh (accounting for pollution costs) while the average residential rate was \$0.34/kWh. In other words, when a rooftop solar system generates a kWh, this avoids a cost of \$0.15, while the system owner avoids paying \$0.34. Thus, inadvertently, this subsidy shifts the burden of recovering significant non-incremental costs onto other grid-connected customers.

The Public Advocates Office recently estimated a "cost shift" of \$8.5 billion in 2024 off of the bills of rooftop solar PV customers and onto the bills of other households.[2] This figure was derived by subtracting the value that solar generation provides to the grid – measured as avoided costs– from the total compensation provided for NEM solar generation. To the extent that owners of solar, or solar and storage systems, are wealthier homeowners, this ends up being a regressive payment from a lower income to a higher income customer base.

In other words, this policy that was designed to incentivize the accelerated deployment of rooftop solar has inadvertently led to significant increases in residential retail electricity rates that are disproportionately impacting renters and lower income.

ii. Renewable Portfolio Standard (RPS)

California's RPS mandates that 60% of grid electricity sales should be sourced from renewables by 2030. To the extent that qualifying renewable resources are more expensive to procure than the generation resources that would otherwise be used, this policy will increase the cost of electricity generation in California.

Cost/ton CO2e avoided: The CPUC tracks RPS and non-RPS procurement expenditures in terms of \$/kWh and annual RPS revenue requirements. RPS procurement costs have fallen at a rate of 13 percent per year between 2007 and 2019. In 2019, the average RPS energy contract price across all technology types was \$28/MWh. As renewable energy technology costs have fallen, so has the above-market premium for renewable energy generation. The average difference in RPS versus non-RPS procurement costs reported by the large investor-owned utilities had dropped to \$0.0028/kWh in 2019 (CPUC, 2020). This translates to a very low cost per ton of GHG abatement (below **\$10/ton CO2e**). We note that this is lower than cost estimates constructed by the California Legislative Analyst's Office. One reason is that we are using current procurement costs which are significantly lower than technology costs incurred in the early years of RPS compliance.

[2] https://www.publicadvocates.cpuc.ca.gov/-/media/cal-advocates-website/files/press-room/reports-and-analyses/240822-public-advocates-office-2024-nem-cost-shift-fact-sheet.pdf

Energy affordability and incidence: Borenstein et al (2021) estimate the retail rate impacts of RPS compliance. On a per kWh basis, these residential rate impacts of RPS compliance are very small. The authors estimate average residential rate impacts per kWh of $0.00, $0.006 and $0.0001 for SDG&E, PG&E and SCE, respectively.

iii. Low carbon fuel standard (LCFS)

The Low Carbon Fuel Standard is designed to decrease the carbon intensity of California's transportation fuel utilization and incentivize the use of low-carbon and renewable alternatives to support climate change mitigation and deliver air quality benefits.

Cost/ton CO2e avoided: California LCFS prices currently exceed **$75/ton CO2e**. The LCFS price has consistently exceeded the GHG allowance price, implying that we have been paying a lot more for GHG reductions under the LCFS program versus the carbon market. These LCFS prices likely under-estimate the costs per ton of CO2e abated due to concerns around additionality of RNG, EV crediting, and the lifecycle-based calculations of GHG content.

Energy affordability and incidence: Complying with the LCFS increases gasoline supply costs and consumer gas prices. In contrast to the cap-and-trade program, which raises revenues that can be rebated to households and firms, the LCFS does not generate revenues for California.

iv. EV subsidies

The Inflation Reduction Act offers California households a $7,500 federal tax credit to incentivize EV adoption. Although this is not currently a California program, Governor Newsom has indicated that California will step in to provide a California ZEV rebate if the incoming Trump Administration follows through on its threat to eliminate the federal tax credit.

A recent paper by Allcott et al. (2024) analyzes the costs and benefits associated with IRA EV tax credits (relative to a baseline with no incentives offered). These authors estimate that IRA EV tax credits have increased annual registrations of US firms' EVs by 37 percent, or 310,000 annually. Compared to pre-IRA policy, IRA EV credits generated an estimated $1.87 of US benefits per dollar spent in 2023, at taxpayer cost of $32,000 per additional EV sold. This per-vehicle cost exceeds the subsidy level because only 23 to 33 percent of credits are additional.

A “global” cost of **$135/ton of GHG** emissions is avoided by these EV subsidies. Because the design of the IRA EV subsidies favors domestic vehicle manufacturers, the estimated *domestic* cost per ton is much lower (**$10/ton**). EV tax credits do not directly impact energy prices because they are funded by federal taxpayers. Accelerated adoption of EVs should reduce volumetric electricity prices in California insofar as increasing demand for electricity spreads fixed cost recovery over a broader base.