ENERGY INNOVATION
POLICY & TECHNOLOGY LLC

# RECALIBRATING CALIFORNIA'S CAP-AND-TRADE PROGRAM TO ACCOUNT FOR OVERSUPPLY

*An original quantitative analysis and policy recommendations*

MARCH 2017

By Chris Busch

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## PREFACE

We are actively seeking feedback on our methodology, findings, and recommendations. The underlying assumptions, data, and calculations are available for inspection at the following link: http://energyinnovation.org/wp-content/uploads/2017/03/CapTrade_SupplyDemand_Analysis.xlsx. The author's email address is chrisb@energyinnovation.org.

Energy Innovation: Policy and Technology LLC
98 Battery Street, Suite 202
San Francisco, CA 94111
(415) 799-2176

# EXECUTIVE SUMMARY

For the first time last year, a portion of the current vintage allowances[1] offered in one of the California-Quebec cap-and-trade program's quarterly auctions went unsold. The drop off in volume sold and the variability in demand—which rebounded to 88 percent in the last auction of 2016, only to fall again to 18 percent in the first auction of 2017—have drawn increasing attention from policymakers and the media. This report provides a quantitative analysis of the supply and demand for carbon allowances in the linked California-Quebec cap-and-trade program to help discern the role that temporary or systemic oversupply may be playing.

Cap levels have exceeded emissions in the three years for which empirical data exists (2013-2015), an important causal factor in weak auction demand since current emissions are the most important determinant of demand. This report refers to the situation of demand below supply as "oversupply." Emissions falling faster than expected and resultant demand shortfalls reflect the success of California's overall policy efforts. Beyond successful climate policy, several economic and technological trends have caused California to decarbonize more quickly and cheaply than regulators had expected when they were first designing the cap-and-trade program.

The design of California's cap-and-trade program is better equipped to handle oversupply than any other in the world because of its price floor and holding limits. The price floor sets a pre-determined minimum price the government accepts at auction. Holding limits set numerical restrictions on the amount of allowances any one participant can hold. These design features serve as stabilizers; the price floor ensures a minimum level of stringency today, and holding limits reduce the extent to which current slack in the cap will be carried forward.

The effect of oversupply is coming into sharper focus because of the cap-and-trade program's price floor. The price floor is holding back some allowances from the market since emissions are below the current cap level. Thus, recent auction results are, in part, evidence that the auction price floor is doing its job—providing an automatic adjustment of supply in response to demand signals.

The cap-and-trade program is doing the job it was created to do in the AB 32 Scoping Plan. The program was created as a *supportive policy* to sweep up emission reductions not accomplished

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[1] Allowances are tradable permits to emit carbon, and are the main currency of cap-and-trade program compliance. The program's cap is the sum of allowances issued in each year. Some allowances are distributed for free, and many are sold at quarterly auctions. Allowances sold at auction must receive bids at or above a price floor, known formally as the auction reserve price.

Emitters can use current vintage allowances in the current compliance period or they can be held for use in future compliance periods. The current and second compliance period runs for three years from 2015-2018. Current vintage allowances are distinguished from future vintage allowances not currently usable but sold through advance auctions with the intention of providing a window into market expectations around future prices, which in turn should promote market stability.

through other sector-specific policies like performance standards, thereby providing an incentive for lower-carbon economic activity along with an economy-wide quantitative backstop ensuring the portfolio of climate policies delivers. The state of oversupply indicates that the state is on track to surpass its 2020 emission reduction target.

It is neither an indictment of past market design choices, nor a big surprise, that cap levels that made sense for the 2020 Scoping Plan would change when reconsidered as part of the 2030 Scoping Plan. With some incremental changes, such as those suggested in this report, the program can drive more reductions sooner, to help put the state on the path to the aggressive 2030 target while also providing the more stable revenue that policymakers want.

### *Retrospective analysis*

The analysis carried out in this report has backward-looking and forward-looking elements. First, for the retrospective analysis, we use very detailed data on sources to calculate emissions covered under the program. These historical emissions are shown together with cap levels in past years to 2020 in Figure ES-1.

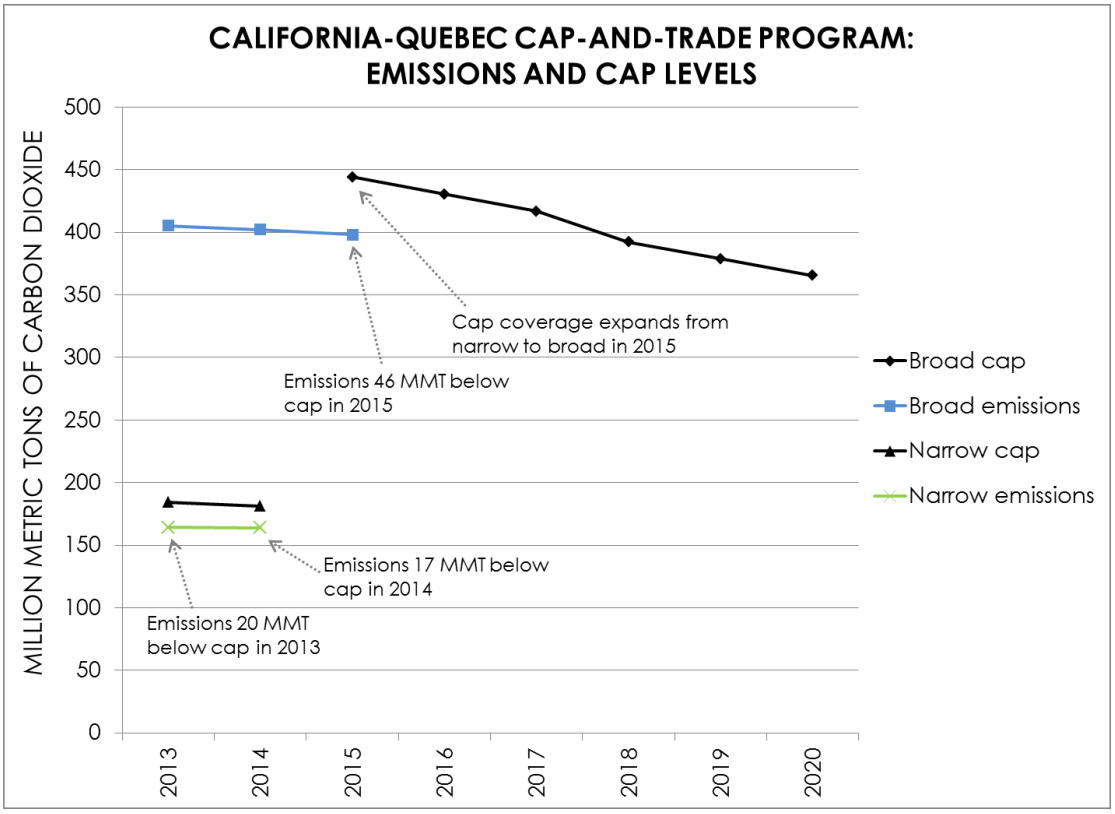


*Figure ES-1. Emissions and cap levels in the California-Quebec linked cap-and-trade program. (Source: Energy Innovation graphic with California and Quebec agency data)*[2]

[2] Data on emissions are taken from mandatory reporting data. Cap levels are taken from regulatory documents. See the Appendix for more details about data and links to help find them.

Figure ES-1 shows that the number of allowances offered (cap level) has exceeded emission levels in every year for which we have data (2013-2015). Such market fundamentals create the conditions necessary for a persistent drop in demand at auction. Demand has also likely been negatively affected by a lawsuit challenging the legality of auctions under the currently approved regulation.[3]

The legal uncertainty created by the pending lawsuit should be distinguished from the need for greater certainty regarding program demands in 2021 and beyond. It is true that stronger confidence about program requirements in 2021 and later could have played a role in driving greater current demand, perhaps allowing the continued sell-out of auctioned allowances at prices above the floor. Nonetheless, current oversupply is a necessary condition for why such long-run demand would be needed to lift allowance prices above the auction floor. Put differently, future scarcity is only needed to lift demand and prices absent current scarcity. Nailing down legal authority for 2021 and later is important: Large investments require long-term policy signals. Yet a proper understanding of program performance so far is a necessary input for current policy debates.

The nature of the program's three-year compliance period may also explain some recent auction dynamics. Emitters must cover 30 percent of their emissions annually, but a full accounting for second compliance period (2015-2017) emissions will not take place until November 1, 2018. Thus, emitters have six upcoming auctions to purchase allowances before final accounting for the current compliance period occurs.

At the same time, active discussions around carbon pricing in Sacramento may be creating a sense of near-term political uncertainty that the program may change even before 2020, with some arguing for replacement with a carbon tax. In this policy environment, emitters may choose to wait and see how the current legislative sessions play out before purchasing the additional allowances needed for the second compliance period.

### *Prospective analysis*

We undertake forward-looking analysis to provide insights into expected future trends for supply and demand. The core analytical method involves bounding likely future outcomes based on high and low demand forecasts. Data show a one percent decline in emissions under the program from 2013-2014, and a 0.8 percent decline from 2014-2015. Thus, the current trend is for emissions under the cap to decline by approximately one percent annually. The high and low demand scenarios add and subtract one percentage point per year, respectively, to the current trend.

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[3] Danny Cullenward and Andy Coghlan. 2016. "Structural oversupply and credibility in California's carbon market," The Electricity Journal 29 (2016) 7–14

1. High demand scenario. This forecasts flat annual emissions (zero percent decline), constant at the 2015 level.
2. Low demand scenario. This forecasts an annual emission decline of two percent.

Our analysis finds that over the remainder of the currently approved regulation period (through 2020) about 82 percent (78-86 percent) of all allowances planned for distribution would be required for compliance by those covered under the combined California-Quebec program. After accounting for free allocation, the analysis indicates demand at auction should be strong enough to produce average sales of approximately 76 percent (71-81 percent) of allowances offered.

Using these demand forecasts, we estimate the value of all the California allowances yet to be distributed through 2020. This is a hypothetical calculation illustrating the total value that might accrue under a 100 percent auction approach. We also present a forecast of revenue for California's Greenhouse Gas Reduction Fund for the remainder of 2017 through 2020. These figures range from $7.6-$8.5 billion and do not account for any advance auctioning of post-2020 allowances. Table ES-1 summarizes these results.

| | High demand scenario | Current trend scenario | Low demand scenario |
|---|---|---|---|
| Emission trajectory under scenario | Flat emissions (0% annual decline) | 1% annual decline | 2% annual decline |
| % of allowances yet to be distributed that would be needed for compliance through 2020 | 86% | 82% | 78% |
| % of allowances slated for auction needed for compliance through 2020 (i.e. minimum expected average for auction sales) under an assumption of 28% free allocation | 81% | 76% | 71% |
| Estimate of revenue for the remainder of 2017-2020 for the Greenhouse Gas Reduction Fund after accounting for free allocation and consignment auctions. Assumes price floor increases from $13.54 this year to $16.36 in 2020. | $8.5 billion | $8.0 billion | $7.6 billion |

*Table ES-1. Demand and revenue under varying emission forecasts. (Source: author's calculations)*

The result of our prospective analysis show that the very low auction sales in the second quarter of 2016 and the first quarter of 2017—with sales of 11 percent[iv] and 18 percent,[v] respectively—would not be sustainable in the long run: Auction sales will have to be much higher for emitters to be in compliance. The notable variability in recent auction demand indicates they are aberrations from a long-term trend, rather than harbingers of a constant state of drastic oversupply. Nevertheless, our work suggests that, absent a strong signal for future demand, current oversupply conditions would suggest auction sales in the range of 70-80 percent are likely on between now and the end of 2020.

Oversupply is more significant when viewed within the lens of the second compliance period alone. If 2016 and 2017 emission reductions continue at the current trends rate, we estimate that emitters will need 200 MMT more allowances for compliance. Yet, at a rate of 70 MMT in current vintage allowances offered per auction, 420 MMT will be on offer at the next six auctions. Thus, it is possible auction sales could remain below 50 percent in upcoming auctions absent increased political and policy certainty.

## *Policy implications*

In comments on the latest auction results, Senator Kevin de Leon said, "We need a program that both reduces pollution and provides stable funding to clean up climate emissions."[vi] The following is a four-part formula for accomplishing these goals:

(1) Lower caps: While the price signal alone is driving reductions, the findings developed in this paper indicate the program can start driving more significant reductions sooner. The state needs to reduce emissions much faster in order to hit its 2030 emissions target. A tighter cap under the cap-and-trade program has a valuable role to play in helping to cost-effectively drive these reductions.

(2) Switch to annual compliance: The three-year compliance period provides significant temporal flexibility that increases the potential for variability in revenue flows. Annual compliance would require a steadier flow of auction purchases and would provide more regular information to the market.

(3) Increase the price floor: The price floor has proved its worth as a guard against insufficient stringency and deserves to be amplified. As part of a two-thirds legislative majority effort, likely increases in program proceeds can be recognized as macro

[iv] May 2016 Summary Results Report: https://www.arb.ca.gov/cc/capandtrade/auction/may-2016/summary_results_report.pdf

[v] February 2017 Summary Results Report: https://www.arb.ca.gov/cc/capandtrade/auction/feb-2017/summary_results_report.pdf

[vi] Statement on Cap-and-Trade Auction Results: http://sd24.senate.ca.gov/news/2017-03-01-statement-cap-and-trade-auction-results

economically-efficient revenue at a time when the state has major investment demands for its clean energy transition, transportation and water infrastructure needs, and more.

(4) Give away fewer free allowances: Every unit given away for free presents an opportunity cost in efficient revenue not earned, and reduces demand at auctions.

# INTRODUCTION

The California-Quebec cap-and-trade program requires businesses regulated under the program to submit allowances to cover their carbon dioxide emissions. The two jurisdictions have linked their cap-and-trade programs: Their allowances are completely fungible and are auctioned together on a common platform with other harmonized program design elements. The amount of allowances created for any particular year equates to the cap level, and are primarily distributed to emitters via government–sponsored quarterly auction.

In 2016, for the first time, some current vintage allowances, i.e. those available for use in the current compliance period (2015-2017), went unsold.[1] While almost all (95 percent) of allowances sold at the February 2016 auction, the fraction sold dropped to 11 percent in May and 35 percent in August. Demand rebounded in November when 88 percent of allowances were snapped up by buyers in the largest current vintage volume sale yet, only to fall again to 18 percent in the first auction of 2017, the most recent at the writing of this paper. While current vintage allowances represent most of those sold at auction, each auction also features a smaller amount of allowances for use in a future compliance period. These advance auctions are intended to provide some early indication of future market prices.

Figure 1 illustrates the recent trend, showing volumes of current and advance auction sales, since California and Quebec began joint auctions in November 2014. The vertical axis on the right-hand side of the figure shows the number of allowances sold. The vertical axis on the left-hand side gives the bid-to-cover ratio, the number of qualified auction bids divided by the number of allowances being offered. Allowances are only sold at auction at or above a set price, the price floor, which increases annually. Qualified bids are those at or above the price floor. Thus, if the bid-to-cover ratio is more than one, demand for allowances exceeded the amount offered at the price floor. If the bid-to-cover ratio is less than one, that means only a fraction of allowances offered were sold.

[1] Auctions of current vintage allowances are distinguished from advance auctions of future vintage allowances, which have been more consistently variable over time.

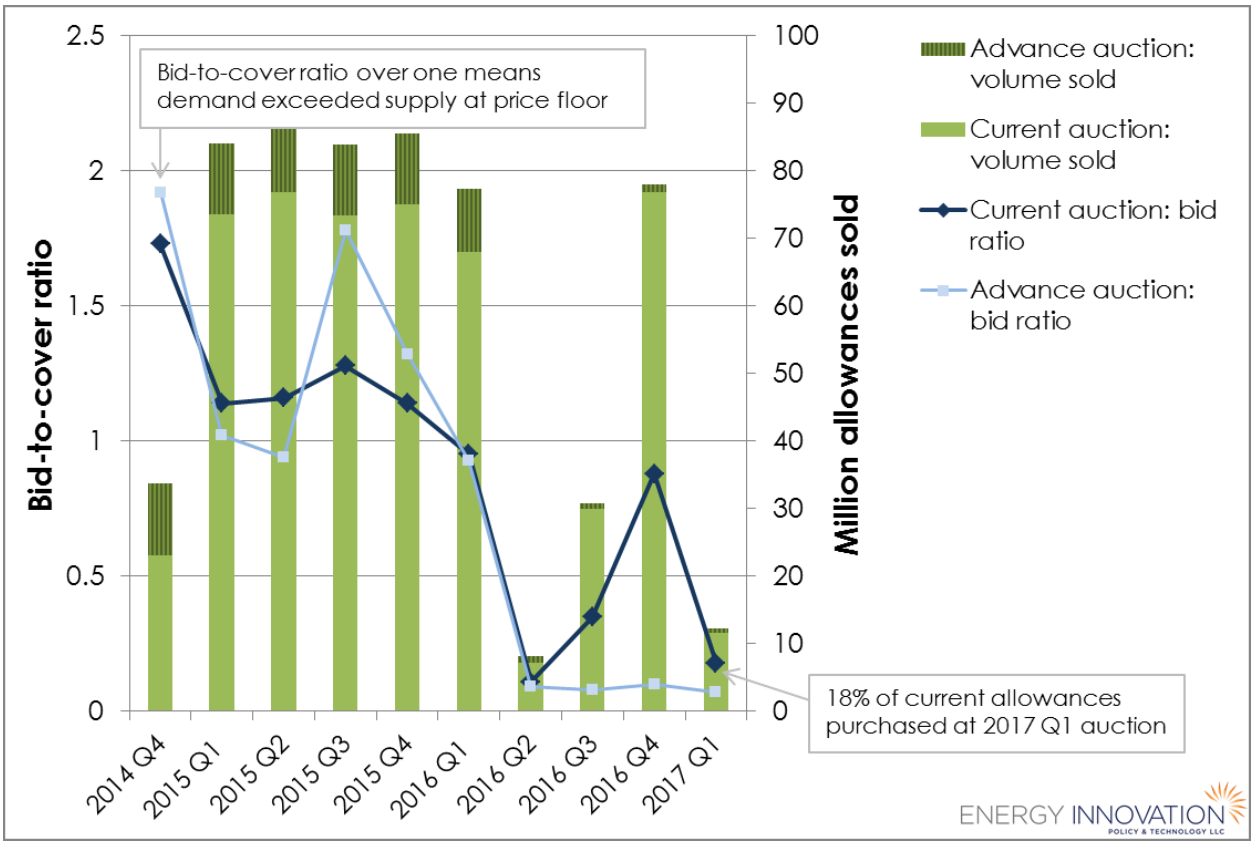


*Figure 1. Bid-to-cover ratios and volumes sold at joint California-Quebec auctions (Source: Energy Innovation graphic with data from California Air Resources Board [2])*

This analysis developed in this report includes a retrospective evaluation of supply and demand using empirical data on emissions and a forward-looking component based on forward looking future forecasts of demand. The retrospective analysis documents clear indications of oversupply in past data and offers insights into how this interacts with other factors to help understand recent auction trends. The prospective analysis develops high and low possible emission trajectories, to explore what to expect about future auctions and to inform policy recommendations.

## RETROSPECTIVE ANALYSIS

The retrospective part of this study is straightforward: The approach involves directly comparing actual emission levels and cap levels for the first three years of the program to reveal the balance of supply and demand. Cap levels directly correspond to supply. Emissions are a foundational driver of demand. Emissions are calculated using very detailed source-level data, submitted by emitters under California and Quebec's mandatory reporting rules.

[2] Most recent and archived auction results here: https://www.arb.ca.gov/cc/capandtrade/auction/auction.htm

Figure 2 shows that the number of allowances issued (cap level) and emission levels in every year for which data exists.

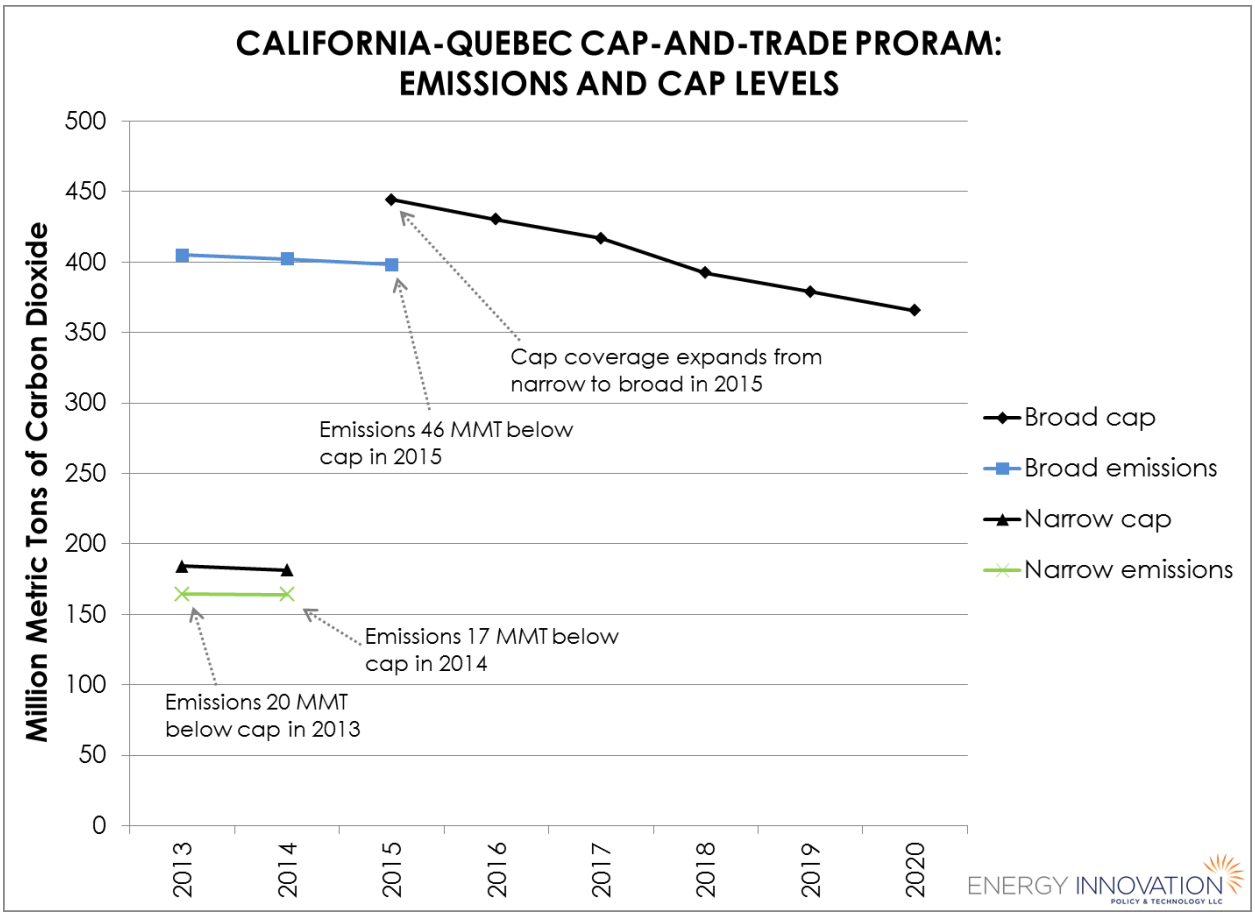


*Figure 2. Emissions and cap levels in the California-Quebec linked cap-and-trade program. (Source: Energy Innovation graphic with California and Quebec agency data)*[3]

Figure 2 shows that the cap levels were above emission levels in 2013, 2014, and 2015. The narrow cap and narrow emissions in 2013 and 2014 refer to the less expansive coverage of the program in these initial years when the program only covered electricity and other large industrial facilities. In 2015, the program expanded to cover transportation fuels and natural gas. Broad cap and broad emissions refer to this full scope of emissions covered and their aggregate emissions.

Demand below supply is almost certainly playing a role in market dynamics, particularly weak demand at auction, yet legal uncertainty has received more attention. Legal observers have argued California's case is on strong footing in regard to the defense of its auctions and

[3] Data on emissions are taken from mandatory reporting data. Cap levels are taken from regulatory documents. See the Appendix for more details about data and links to help find them.

Greenhouse Gas Reduction Fund-approach to spending revenue.[4] However, it is also clear that demand has been affected to some extent by a lawsuit challenging the legality of auctions under the currently approved regulation, which is defined through 2020. Cullenward and Coughlan point to court activity in April 2016 as a potential driver of the drop off in demand from the February to May auctions, when demand for current vintage allowances dropped from 95 percent to 11 percent.[5]

The recent episode of weak demand at 2017's first quarterly auction points to factors other than legal uncertainty at work. Most readings of the court's questioning in January were interpreted as positive for the state's defense of its cap-and-trade program.[6] Secondary market prices jumped more than 20 cents after the hearing, demonstrating increased certainty in the program's legality.[7] However, demand fell again from the fourth quarter of 2016 to the first quarter of 2017.

In addition to oversupply and the current lawsuit, we see a third factor at work in recent auction results. Significant flexibility in the pace of compliance also seems to be contributing to demand fluctuation from quarter to quarter. The program is in the middle of the second (of three) compliance period for cap-and-trade, which runs from 2015-2017 (inclusive). Because large emitters covered under the program have until November 1, 2018 to finalize their submissions of allowances and offsets,[8] an exact accounting of the balance supply and demand in the second compliance period will not be possible until the end of 2018 at the earliest. If the compliance timetable were annual and if supply were below demand, auctions would almost certainly be selling out. This paper's section on policy implications carries out a thought experiment around what 2016 auction results might have looked like with annual compliance rather than three-year compliance periods.

Our interpretation is that a new sense of potential political risk to the program is interacting with the three-year compliance period to produce momentary drops in demand. An active discussion is underway in Sacramento around reforming the state's approach to carbon pricing. Emitters might perceive heightened political risk because powerful policymakers have renewed calls for a carbon tax or fundamental departures from the current approach. It is hard to imagine the state legislature forcing a completely different approach that would require the unravelling of the

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[4] Cara Horowitz. (2016). "Cap-and-trade auctions: Still not a tax," Legal Planet.

[5] Danny Cullenward and Andy Coghlan. 2016. "Structural oversupply and credibility in California's carbon market," The Electricity Journal 29 (2016) 7–14

[6] Also see: Adam Ashton (2017). "Tough Questions," Sacramento Bee. Richard Frank (2017). "California Appellate Court Hears Argument," Legal Planet.

[7] Chris Busch. 2017. "Carbon Prices Rise In California's Cap-And-Trade Program As Legal Certainty Grows," Forbes (February 8)

[8] Offsets are emission reduction credits generated outside of the sectors directly covered by California's cap-and-trade program. They can account for up to eight percent of a capped entity's emissions.

current program design to 2020, and even more difficult to map out how that unwinding would occur.

Greater confidence regarding program demands in 2021 is another aspect of legal certainty receiving attention. It is true that such long-run demand could have played a role in driving greater current demand, perhaps allowing the continued sell-out of auctioned allowances at prices above the floor. Nonetheless, current oversupply is a necessary condition for why such long-run demand would be needed for prices to be above the auction floor.

Long-term demand can keep prices above their minimum levels even in the presence of oversupply. This is illustrated in the case of the European Union's Emissions Trading System, which Appendix 1 discusses as part of a more thorough and technical argument that current oversupply is a necessary condition for post-2020 to determine whether or not all auctioned allowances are sold.

In practical terms, post-2021 legal certainty is an appropriate, and indeed crucial, policy priority. Yet it is important to recognize the role of current oversupply in discussions around what is working and what should change.

# METHODOLOGY FOR PROSPECTIVE ANALYSIS

## DATA

In addition to mandatory reporting data on emissions by sources covered under the program, the second core data source is the most recent compliance instrument report released by the California Air Resources Board (CARB) on January 6, 2017. These compliance reports are updated quarterly by CARB and provide a picture of what emitters are holding (vis-à-vis allowances and offsets), what they have submitted for retirement, and future supply (the number of allowances yet to be put into distribution).[9] We have updated these data with recent auction results, shifting the 6.44 million metric tons (MMT) of emissions sold from future supply to current holdings.

## OFFSETS

The compliance instrument report also covers offsets, which are credits sold from emission reductions projects in sectors not directly capped by the cap-and-trade program, such as agriculture. These have been a contentious element of the cap-and-trade program from the start. A 2008 Union of Concerned Scientists memo showed the initial proposed offset limit of 10 percent of emissions could have yielded all of the intended reductions, substituting direct emissions reductions at capped sources.[10] CARB later reduced the amount of emissions that any particular emitter can cover through offsets to four percent. When the seriousness of the

[9] https://www.arb.ca.gov/cc/capandtrade/complianceinstrumentreport.xlsx. Accessed 10 February 2017

[10] Union of Concerned Scientists. 2008. Notes on Analysis of 10% of Emissions Offset Limit in WCI.

economic recession became clear in 2009, CARB moved to expand offset use somewhat, increasing the level allowed to eight percent, which remains the current level. At the same time, they took about four percent of allowances from under the cap and directed them to the newly created allowance price containment reserve (the Reserve). This swap was intended to maintain stringency while allowing for more cost containment.

In the first compliance period, emitters used about half of their maximum allowable level of offsets, or just over four percent. Carbon allowance prices have remained at the low end of expectations, even though California has the highest auction price floor of any program, which has reduced the need for offsets. CARB has put the onus on buyers to replace offsets that may be invalidated after their purchase through later verification. This creates some additional risk for the use of offsets for compliance, compared to allowances, creating a disincentive for users. It is not a very large disincentive; however, in light of low carbon allowances prices, and political opposition to offsets, it may be significant.

In sum, offsets are a rich topic deserving their own exploration, but this analysis focuses on allowances, which are the largest component driving supply and demand interactions. This analysis assumes a four percent use of offsets, half of the maximum allowed and similar to the use in the first compliance period. The topic is also explored further in the offsets sensitivity section below.

## DEMAND SCENARIO CONSTRUCTION

To forecast future allowance demand, we develop high and low emission scenarios. Emissions within a current compliance period are a fundamental driver of demand. While legal jeopardy can introduce some uncertainty, absent this or other risks to program authority, emissions in a given period will be a lower bound on demand in that period.

Data show an annual decline of one percent and 0.8 percent over the 2013-2014 and 2014-2015 periods, respectively. Thus, the current trend is for emissions under the cap to decline by approximately one percent annually. The high and low demand scenarios add and subtract one percentage point per year, respectively, to the current trend.

1. High demand scenario. This forecasts flat annual emissions (zero percent decline), constant at the 2015 level.
2. Low demand scenario. This forecasts an annual emission decline of two percent.

These future demand scenarios are depicted in Figure 3.

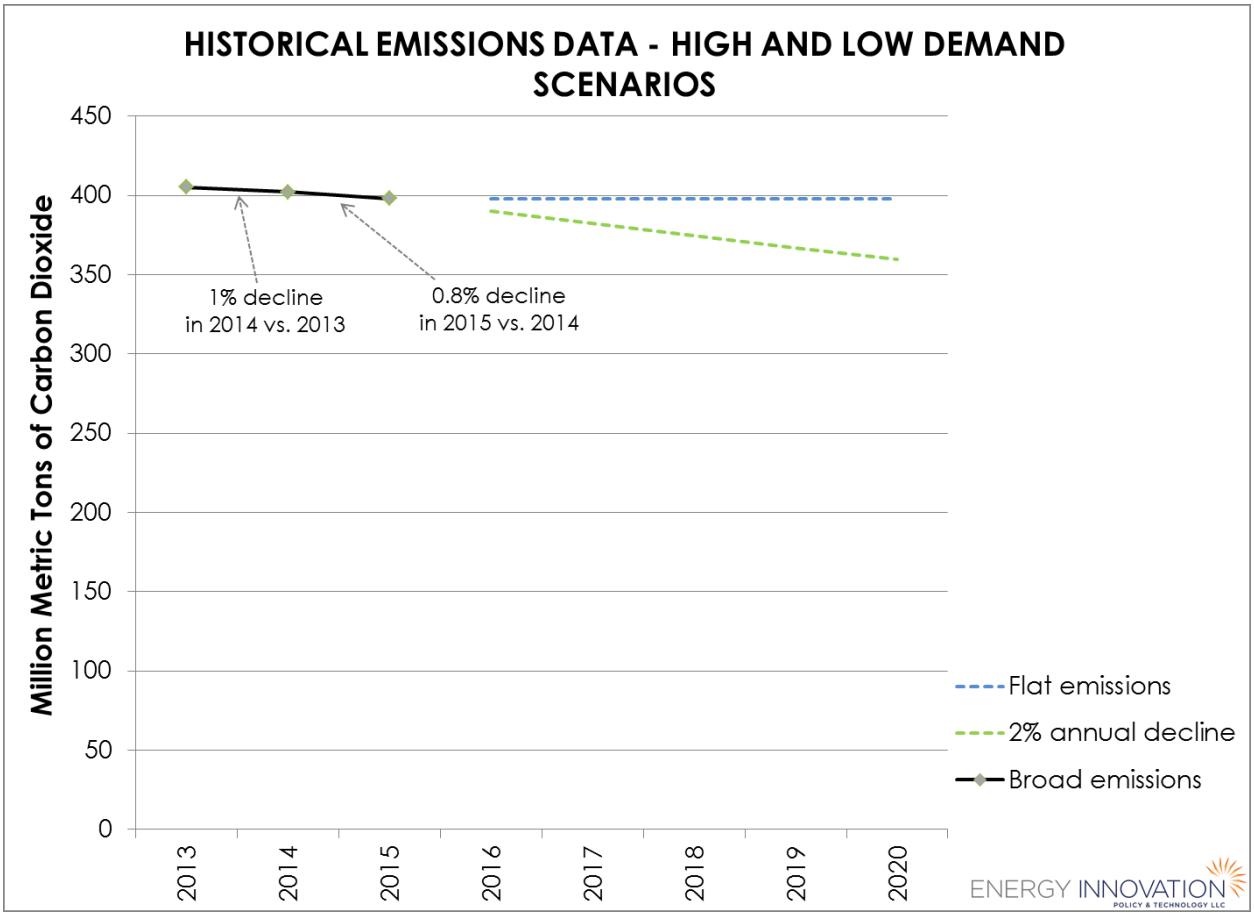


*Figure 3. Historical data and high and low demand scenarios developed for this analysis. (Source: Energy Innovation graphic with data from California and Quebec agencies)*

Our scenarios are most closely related to research entitled *Expecting the Unexpected: Emissions Uncertainty and Environmental Market Design*,[11] which present an econometric analysis of emissions, using top-down inventory data instead of the bottom-up source level data used in this analysis, with independent variables such as like macroeconomic growth, trends in Vehicle Miles Traveled, and availability of hydroelectric power. Their work is different in that it forecasts unconstrained emissions, i.e. the level of emissions that would be expected in the absence of cap-and-trade, whereas this work forecasts constrained emissions under the program.

It is possible to impute confidence intervals from their results using the standard deviations on broad scope emissions reported in Table 4 of *Expecting the Unexpected*. 1.96 standard deviations on either side of the mean coefficient value implicitly define a 95% confidence

[11] Severin Borenstein, James Bushnell, Frank A. Wolak, and Matthew Zaragoza-Watkins. 2016. "Expecting the Unexpected: Emissions Uncertainty and Environmental Market Design," Energy Institute at Haas, Working Paper 274

interval. Four years is the right length of cumulative uncertainty to consider, commensurate with the four future years from today that the analysis contemplates. In reality, we forecast five year of data, but unlike the future, in which true surprises are possible, what the 2016 data reveal will not be a big surprise. There is enough regularity in the trends to say this with strong confidence about the 2016 data. The results of *Expecting the Unexpected* suggest a 95 percent confidence interval of 165 MMT over four years of uncertain (and unconstrained) emissions. The interval implied by our scenario analysis is 116 MMT between the low and high demand scenarios, which equates to 72 percent of the roughly commensurate confidence interval suggested by *Expecting the Unexpected*.

## SUPPLY

CARB's quarterly compliance report[12] details the status of supply adjusted to reflect the 2017 first quarter auction results. This section walks through the parts relevant to allowance supply.

- Allowances held by emitters (first row, Table 1): These are in columns B and C, under entity accounts, General and Compliance. Allowances in the general category are tradable, while those in the compliance allowances are slated for submission and are not available for trading.
- Allowances already retired for second period compliance (second row, Table 1): These are in Column G. To impute the amount retired for use in the second compliance period, we subtract the amount retired in the first compliance period (128.8 million metric tons [MMT] of $CO_2$), found in the 2013-2014 compliance instrument report.[13]
- Future supply (third row, Table 1): Allowances still slated for distribution through the end of the third compliance period in 2020 are found in Column F. The analysis includes the allowances in the "Limited Use Holding Account," Column D, in this category. These are allowances given to electric utilities with the condition they will be sold at future auctions and revenue will be returned to the utilities. Since these allowances will eventually be sold at auction, they are considered part of future supply. Frankly, this categorization decision is a matter of judgement, and different approaches could be considered equally valid, which is why we present more than one framing of this question.

[12] The most recent quarterly compliance instrument report is available at this link. We use the version data January 6ht, 2017. https://www.arb.ca.gov/cc/capandtrade/complianceinstrumentreport.xlsx.

[13] Data on first compliance period: https://www.arb.ca.gov/cc/capandtrade/2013-2014compliancereport.xlsx.

This approach reveals the following current distribution of supply.

| Supply segments | MMT $CO_2$ |
|---|---|
| Allowances currently held by emitters and available for compliance | 915 |
| Allowances already retired for second compliance period | 129 |
| Future supply: allowances still to be distributed through 2020 | 1,450 |

*Table 1. Disposition of allowances for compliance through 2020. (Source: CARB data)*

## FRACTION OF FUTURE SUPPLY FREELY ALLOCATED

To estimate future auction sales and revenue implications, some assumptions are required regarding the fraction of future allowance supply to be given away freely to emitters. To our knowledge, Quebec has not released data with the same level of detail on allocation as California. Therefore, for this aspect of the analysis, a California value for the fraction of freely allocated supply in the future is estimated and applied to the linked program. This likely overstates the amount of free allocation to some degree, for reasons discussed after the California data are profiled below.

The complication of auctioning allowances to utilities in California's electricity sector is introduced in footnote two. These utilities receive free allowances, which they are required to sell at the joint California-Quebec auctions, later receiving the proceeds. The investor-owned utilities are bound to use the funds under rules set by the California Public Utilities Commission. Our analysis treats these allowances sold at auction for electric utilities under consignment as auctioned. Figure 4 distinguishes consignment auctions from general auctions, as it presents an overview of allowance distribution in the California program.

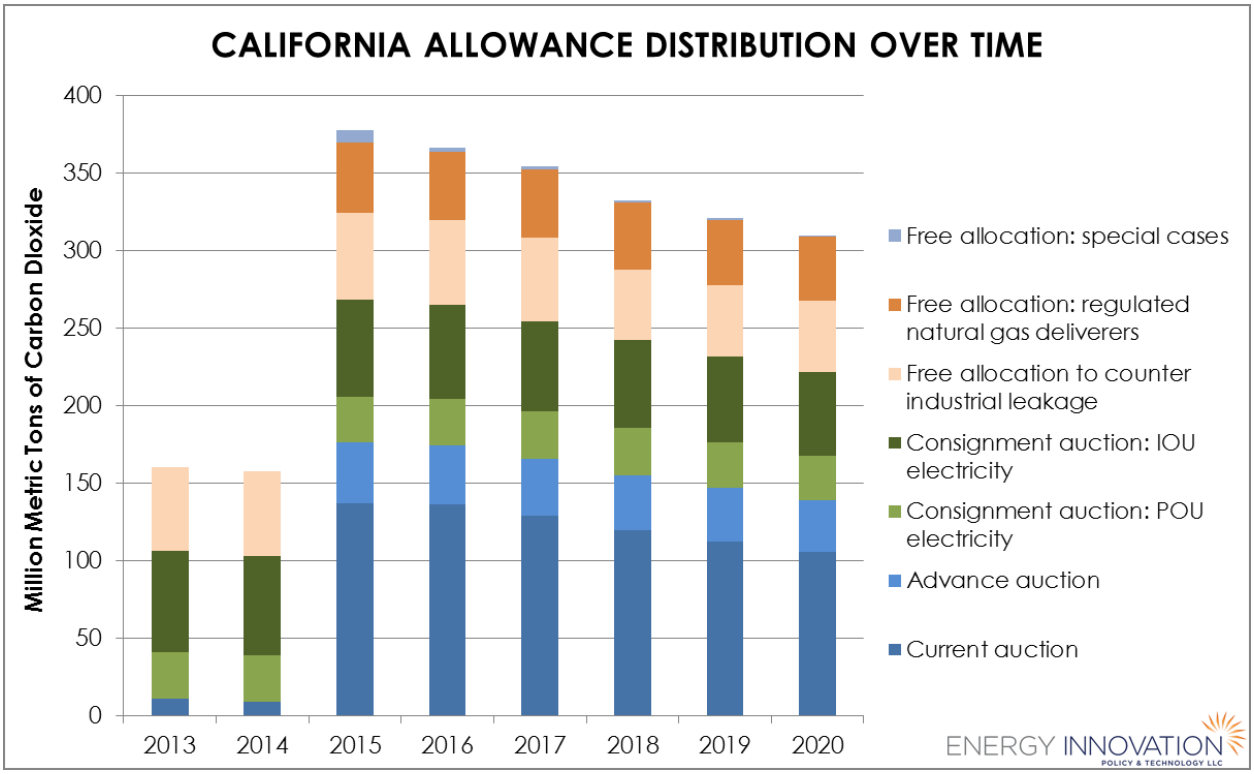


*Figure 4. California allowance distribution over time. (Source: Energy Innovation graphic with data from CARB's State Auction Budget Spreadsheet.)*[14]

Figure 4 shows that auctioning state-owned allowances through current and advance auctions, is the largest single method for allowance distribution and consignment auctions of allowances for electric utilities is the second largest type. Large industrial users (other than electricity generation) receive free allowances for the purpose of "leakage prevention." Leakage refers to the potential for businesses to reduce production in-state, but increase it out-of-state in an effort to avoid a regulation. This segment includes refineries and cement plants. CARB plans to slightly ramp down the rate of free allocation for this segment in the third compliance period, and CARB staff have proposed a more sizable decline in free allocation starting in 2021.

Natural gas delivery companies also receive free allocation, which declines at the same rate as the cap. These natural gas firms operate under public-utility regulation and are required to use the free allocation to keep rates down for customers.

Table 2 details free allocation under California's program in 2015 and 2016.

[14] This graphic includes neither the allowances for the Allowance Price Containment Reserve, which amounts to 122 MMT, cumulative through 2020, nor the allowances set aside and retired under a feature to support the voluntary adoption of renewable energy.

| | 2015 | 2016 |
|---|---|---|
| Broad scope cap (total) | 379 | 367 |
| Free to industrial facilities | 58 | 56 |
| Free to natural gas utilities | 45 | 44 |
| Fraction free to industrial facilities | 15% | 15% |
| Fraction free to natural gas deliverers | 12% | 12% |

*Table 2. Free allocation under California Program in recent years. (Source:* CARB allocation data)

To explore how future free allocation would affect demand at auction and future revenue, we calculate expected percentages going to different uses from 2017-2020.[15] This lists planned free allocation and auctioning with the results in size-ranked order as follows: auctioning (46 percent), consignment auctions for the electric utility sector (26 percent), free allocation to trade-exposed large industry (15 percent), and free allocation to natural gas deliverers (13 percent).

Because Quebec requires all electricity and fuel distributors (including natural gas) to buy their allowances while following the same approach of declining free allocation to trade-exposed industry, using the California estimate of the linked program may overstate the amount of free allocation. To the extent it does, that represents additional future auction demand. The analysis assumes all freely distributed allowances are used, and so every additional free allowance reduces demand at auction by one unit.

## REVENUE EXPECTATIONS IN CALIFORNIA

Revenue is a function of two variables: the number of allowances, and their price. In addition to modeling the current price floor and expected auction results, we also develop some alternative, hypothetical scenarios (i.e. a higher price floor and different levels of auctioning).

We present results using a forecast of the current program price floor, which increases each year by an increment of five percent plus the annual inflation rate assumed at 1.5 percent. We also test a higher price floor, starting at the current at price floor and increasing in 2018 by $3 annually thereafter.

Results are shown for four levels of auctioning: (1) 46 percent, approximating current auction levels with consignment auctions categorized as free allocation, representing funds that currently would flow into the Greenhouse Gas Reduction Fund; (2) 28 percent, approximating current auction levels with allowances sold at auction under consignment treated as auctioned; (3) 85 percent, approximating a situation in which the only free allocation is to industry deemed trade-exposed and at risk of leakage; and (4) zero percent free allocation. One hundred percent auction results are also presented to provide insights into the full value of allowances.

[15] CARB state auction budget spreadsheet: https://www.arb.ca.gov/cc/capandtrade/stateauction.htm.

Parsing the fraction of future California allowance supply listed on the compliance instrument report is a necessary step to exploring possible future revenue from auction sales. The relative size of the cap levels in regulation is used to estimate how many allowances from future supply are California-owned allowances. To attribute California and Quebec ownership to future supply, we find a ratio by dividing the sum of California cap levels in regulation over 2017-2020 by the sum of California and Quebec cap levels in regulation over the same period. This suggests that approximately 85 percent of future supply will be California allowances with 15 percent owned by Quebec.

Advance auctioning of 2021 vintage or later allowances could lead to additional revenue, though this complication is not factored into the analysis. Previous advance auctioning of vintage 2017, 2018, 2019, and 2020 allowances is automatically accounted for in our revenue estimations because the future supply listed on the compliance instrument report takes this into account.

## LIMITATIONS

Like any analytical framework, the one developed in this report has limitations. A list of some of the most important limitations includes:

- The analysis does not factor in plans for Ontario to join the California-Quebec market in 2018. The province has not released the necessary data for inclusion into our analysis. Ontario has released facility-level mandatory reporting data for power plants and large industrial sources, but has not yet provided fuel distributor data. While the linkage with Ontario is not certain, it is expected, and it would be ideal to explore what the implications of this geographic expansion will be.
- The analysis likely overestimates future free allocation, due to uncertainties discussed above.
- Data on allowance holdings aggregate those covered under the program with the third-party investment firms operating in the market. It is not possible to tell what fraction of currently held allowances are owned by regulated emitters, and our estimations about long-run allowance demand and auction demand do not account for third-party investor holdings. Some third-party firms will choose to sell them, and some may decide to hold them in anticipation of higher prices in the future. It is impossible to know how many will re-enter the market. To the extent some do not, this factor biases our results downward and is a reason to expect somewhat higher demand from emitters than we indicate here.
- While the analysis uses current emissions as a proxy for demand, other factors also matter. Legal uncertainty has been discussed, but it is not integrated into the calculations. Long-run expectations about the program's longevity and stringency, as well as expectations regarding technological innovation, also matter.
- Our demand forecast framework takes a simple approach to develop bound the range of likely demand levels. A more sophisticated consideration of future drivers of emission

trends, be they faster economic growth or increased availability of low-emission hydroelectric supply due to rain returning to California would add texture to the high and low demand scenarios. However, it is not clear that complex methods are inherently more accurate than simpler forecasts at predicting future trends.[16]

## RESULTS OF PROSPECTIVE ANALYSIS

This section combines future demand forecasts with cap levels under the linked cap-and-trade program to provide insights into the relative balance of supply and demand with implications for expectations for future demand for allowances, auction sales, and revenue.

### FUTURE DEMAND-SUPPLY BALANCE

Figure 5 shows that emissions have been below cap levels, and demand is likely to remain below cap levels through at least 2018 and until 2021 under the low demand scenario. The figure portrays the expansion of the program from the narrow coverage of the initial cap, which covered the electricity sector and other large industrial facilities in the first period, 2013-2014, to natural gas and transportation fuels in the second compliance period (the "broad scope").

[16] J Scott Armstrong. 2015. "Importance of Simple Forecasting Methods," Wharton Magazine (Sept. 15): "We found that none of the papers provided a balance of evidence that complex forecasting procedures improved the accuracy of forecasts. Moreover, complexity increased forecast errors, by 27 percent on average, in the 25 papers that include quantitative comparisons."

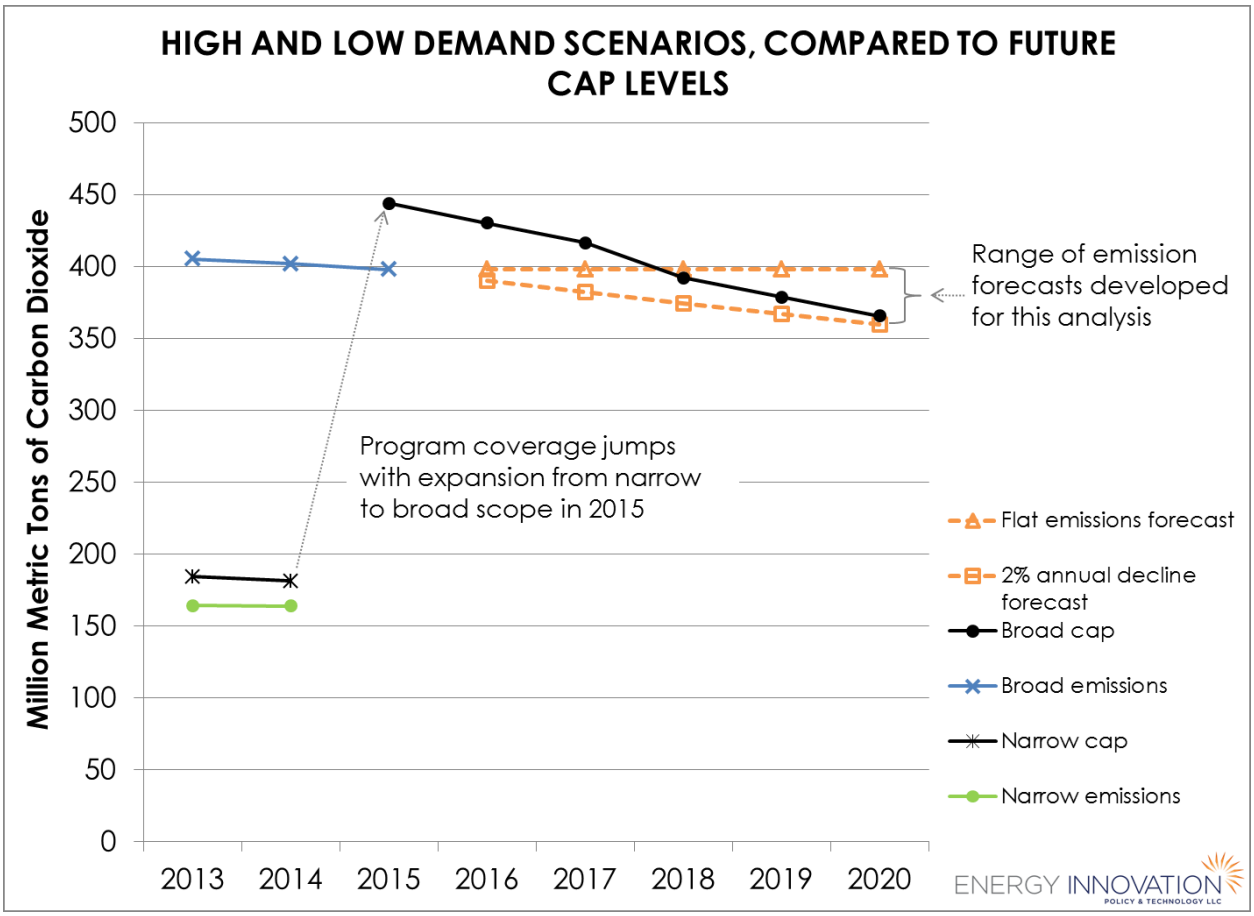


*Figure 5. High and low demand scenarios compared to future cap levels in linked program. (Source: Energy Innovation graphic with California and Quebec data plus author's calculations)*

Table 3 provides some detail regarding supply and demand balance, indicating when estimated demand will exceed supply for a given year (when the cap is expected to be below the emission trajectory). At the extreme, if California's emission reduction pace increases, as modeled in the low demand scenario, supply would remain above demand through 2020.

| | High demand scenario | Current trend scenario | Low demand scenario |
|---|---|---|---|
| Emission trajectory under scenario | Flat emissions (0% annual decline) | 1% annual decline | 2% annual decline |
| First year cap is tighter than current year emissions | 2018 | 2019 | 2021 |
| How much would scenario emissions exceed cap levels in 2020? | 32 MMT | 13 MMT | -6 MMT (emissions remain below cap through 2020) |

*Table 3. Details regarding future demand scenarios in relation to cap levels (Source: authors' calculations)*

Figure 6 illustrates the balance between cumulative remaining demand to 2020 and cumulative remaining supply to 2020 as bounded by the low and high demand scenarios.

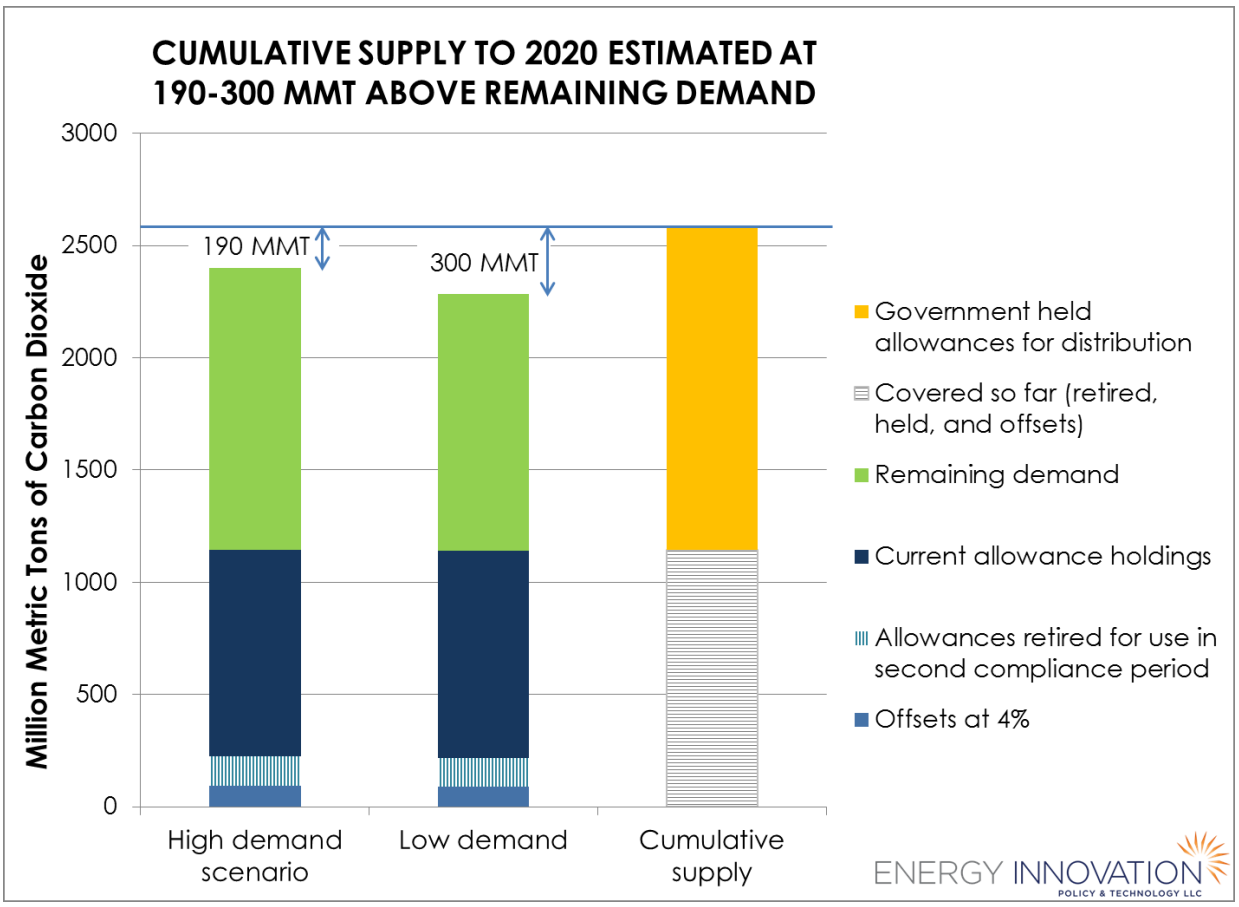


*Figure 6. The difference between remaining demand and supply to 2020. (Source: author's calculations)*

While the oversupply trend is prominent, it is also true that a very large percentage of allowances yet to be distributed will be needed for compliance, and auction demand should be much greater than the levels seen in the second and third quarter auctions in 2016.

| | High demand scenario | Current trend scenario | Low demand scenario |
|---|---|---|---|
| Emission trajectory under scenario | Flat emissions (0% annual decline) | 1% annual decline | 2% annual decline |
| % of future allowance distributions needed for compliance through 2020 | 86% | 82% | 78% |
| % of allowances for auction needed for compliance through 2020 with 28% free allocation | 81% | 76% | 71% |

*Table 4. Allowance and auction demand – cumulative through 2020 – under different emissions scenarios (Source: author's calculations)*

As reported in Table 4, our analysis finds that about 82 percent (between 78-86 percent) of the allowances yet to be distributed will be needed by emitters for compliance. Extending the analysis to enable estimation of demand at future auctions requires the amount of free allocation to be taken into consideration. No emitter will turn away free allocation, reducing the need for auctioned allowances commensurately. Thus, each unit of free allocation puts downward pressure on auction demand. For reasons explained in the methodology section, we explore the implications of 28 percent future free allocation. This assumption combined with other results suggests that future auction sales should average at least 76 percent (71-81 percent) of allowances offered for sale.

There is a striking difference between the long-run trend, reflected in these results, and the low percentage of sales at three of the last four auctions. The market analysts at CaliforniaCarbonInfo.net also conclude that future auction demand will have to be stronger. Before the last auction results were known, Billy Hamshaw and Chandan Kumar commented that results of sales below 20 percent would:

> "[T]rigger a quarterly shortage, though momentarily. So as is the case, a general cumulative shortage of allowances has been triggered for the first time in the history of the market, the deficit is projected at a level of 2.3 million [tons]. However, with two more auctions before the annual surrender and six more auctions before the triennial surrender – the market still has sufficient time to recover in volume before the situation becomes critical for compliance."[17]

[17] CaliforniaCarbonInfo. 2017. "Auction Results: Pre-emptive price shock proved correct with subscription at 18%" (March 2).

Oversupply is more significant when the second compliance period alone is considered, excluding the third compliance period. If 2016 and 2017 emission reductions continue at the current trends rate, we estimate that emitters will need 200 MMT more allowances for compliance in the second compliance period. Yet, at a rate of 70 MMT in current vintage allowances offered per auction, 420 MMT will be on offer at the next six auctions. Thus, it is possible auction sales could remain below 50 percent in upcoming auctions, absent increased political and policy certainty.

## REVENUE EXPECTATIONS IN CALIFORNIA

To date, auctioning of California allowances has generated $4.4 billion for investments through the Greenhouse Gas Reduction Fund. The following calculations explore the expectations around future revenue from California auction sales and under different free allocation assumptions explained in the methodology section. The results are aggregated over the remaining four years of the program, after accounting for free allocation to large industry and natural gas and the portion of allowances.

Table 5 gives results for allowance values at two different price points; the current price floor and a hypothetical floor price that escalates more quickly. It also explores the effect of different levels of free allocation. The first column of results shows the full value of allowances under a hypothetical 100 percent auction approach. The second column (85 percent auction), approximates a policy under which the only type of free allocation is similar to the current allocations to trade-exposed, large industry. The third column (72 percent auction) adds free allocation to natural gas utilities for the purpose of keeping rates down. The fourth column (46 percent auction) would be the closest in approximating expected revenue for the Greenhouse Gas Reduction Fund, based on current allocation and auction structure.

| | Cumulative revenue 2017-2020 at different auction levels | | | |
|---|---|---|---|---|
| | 100% | 85% | 72% | 46% |
| High Demand | | | | |
| at current price floor<br>(starts at $13.54 in 2017 and rises to estimated $16.36 in 2020)[18] | $18 billion | $16 billion | $13 billion | $8.4 billion |
| at hypothetical higher price floor<br>(starts at $13.54 in 2017 and rises $3 per year to $22.54 in 2020) | $22 billion | $19 billion | $16 billion | $10 billion |
| Middle Demand Trend Scenario | | | | |
| At current price floor<br>(starts at $13.54 in 2017 and rises to estimated $16.36 in 2020) | $18 billion | $15 billion | $13 billion | $8.0 billion |
| At hypothetical higher price floor<br>(starts at $13.54 in 2017 and rises by $3 per year to $22.54 in 2020) | $21 billion | $18 billion | $15 billion | $9.7 billion |
| Low Demand Scenario | | | | |
| At current price floor<br>(starts at $13.54 in 2017 and rises to estimated $16.36 in 2020) | $17 billion | $15 billion | $12 billion | $7.7 billion |
| At hypothetical higher price floor<br>(starts at $13.54 in 2017 and rises by $3 per year to $22.54 in 2020) | $20 billion | $17 billion | $15 billion | $9.3 billion |

*Table 5. Estimated California revenue from auctions sales over 2017-2020 (Source: author's calculations)*

## OFFSETS SENSITIVITY ANALYSIS

Offsets are a much smaller slice of overall compliance than allowances. As mentioned, the program allows up to eight percent of an emitter's emissions to be covered through offsets, but

[18] The future escalation in the price floor assumes a 1.5 percent annual inflation rate. This plus five percent equates to an estimated 6.5 percent annual increase in the price floor.

use in the first compliance period was about half of that, 4.4 percent.[19] We will not know how many have been used in 2015 or 2016 until after second compliance period accounting is completed toward the end of 2018. This section carries out some sensitivity analysis around the implications of different levels of offset use, from none to the full eight percent allowed. The effects are shown in Figure 5.

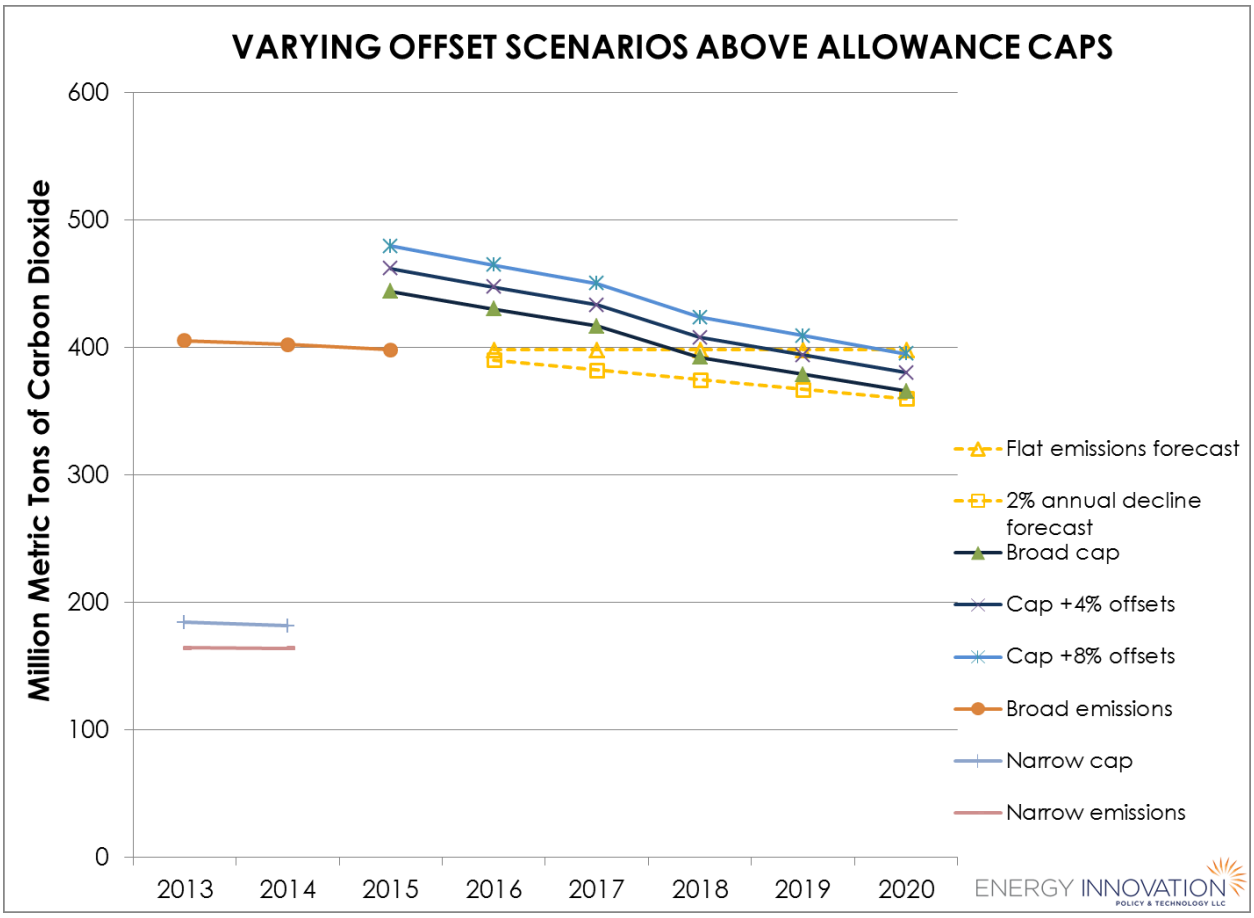


*Figure 7. Illustrating the effect of different levels of offsets use on overall allowable emissions. (Source: author's calculations)*

The potential implications of this maximum theoretical range of offset outcomes are best illustrated when the no offsets (zero percent) case is paired with the flat emissions forecast, and the eight percent offsets case is paired with the two percent annual decline case. These pairings have the effect of strengthening demand in the high demand scenario and weakening it in the low demand scenario.

[19] CARB. *2013-2014 Details of first Compliance Period for ARB's Cap-and-Trade Program.* https://www.arb.ca.gov/cc/capandtrade/2013-2014compliancereport.xlsx

| | High demand (flat emissions) | Current trend demand | Low demand (faster decline) |
|---|---|---|---|
| Offset usage considered | 0% offsets use | 4% offsets use | 8% offsets use |
| % of future allowance distributions needed for compliance through 2020 | 93% | 82% | 72% |
| % of allowances for auction needed for compliance through 2020 with 28% free allocation | 90% | 76% | 62% |

*Table 6. Allowance and auction demand under varying future demand scenarios with offset sensitivity. (Source: author's calculations)*

These extreme offset cases are very unlikely, given the program's performance to date. The latest quarterly compliance instrument report shows emitters holding about 28 million tons' worth of offset credits, making at least some level of offset use going forward almost inevitable unless the program rules change. Given the risks for buyers in using offset credits, the slowness of offset supply to develop, the political criticism offset use has drawn, and relatively low carbon prices, it is also very unlikely that use of the full eight percent of offsets allowable would occur. Nonetheless, this sensitivity analysis provides some insights into the interaction of offsets use with allowance demand.

## POLICY IMPLICATIONS

In comments on the latest auction results, Senator Kevin de León said, "We need a program that both reduces pollution and provides stable funding to clean up climate emissions."[20] Here we propose a four-part formula for accomplishing these goals:

(1) Lower caps
(2) Switch from three-year to annual compliance
(3) Increase the price floor
(4) Give away fewer free allowances.

(1) **Lower caps:** While the price signal alone should be driving some reductions, the fact of the cap above current emissions certainly points to the potential for the cap to be

[20] California State Senate Majority Caucus (2017). *Statement on Cap and Trade Auction Results.* California Senate President pro Tempore Kevin de León (D-Los Angeles). http://sd24.senate.ca.gov/news/2017-03-01-statement-cap-and-trade-auction-results

tighter. Much faster reductions will be needed to hit the state's 2030 emissions reduction target, and cap-and-trade has a valuable role to play in helping cost-effectively drive these reductions. Ambitious reductions in cap-and-trade cap levels as part of the drive to hit the 2030 target would certainly provide the necessary impetus for caps that start driving real emission reductions in the proposed fourth compliance period. However, to achieve Senator de León's goals in the near term—before 2021—steeper cap reductions should be put in place now.

In terms of handling allowance oversupply, CARB is sending the right signal with plans to strengthen the price floor mechanism. In its latest proposed regulatory amendments,[21] CARB staff called for a change to treatment of allowances held back from the market due to insufficient demand at auction. Currently, if prices rise above the price floor for two auctions in a row, CARB will reintroduce at future auctions allowances previously held back because of the floor price. After two years of going unsold, the proposed amendments would send to the Reserve any allowances that were held back because of the auction price floor (only sold at high prices), mitigating that current over supply will inadvertently interfere with efforts to achieve greater stringency in the future.

The policy debate should acknowledge that oversupply has happened in every cap-and-trade program for carbon emissions, including the European Union ETS (EU ETS) and the Northeast U.S. Regional Greenhouse Gas Initiative (RGGI). The combination of holding limits and a price floor will help stabilize and adjust market conditions, as is already happening. Other programs without these design features have had to confront the resulting problems. For example, the EU ETS has neither a price floor nor holding limits, and as a result two billion tons of allowances were banked (held for future use) at the end of the second phase of that program – equivalent to a full years' worth of emissions under the program. The California-Quebec demand shortfall pales in comparison.

Senator de Leon's recent comments also included concerns that the program "may not even be achieving pollution reduction in disadvantaged communities, when that should be our utmost priority." Our findings have implications for the debate about the effects of cap-and-trade on air quality in disadvantaged communities. It is too early to judge how the program will perform in delivering air quality benefits for disadvantaged communities because the cap has not started driving significant reductions.

(2) Switch to annual compliance: Too much flexibility can contribute to large swings in demand. Under the current program, emitters have to cover 30 percent of their emissions annually. A full accounting for second compliance period (2015-2017) emissions will not take place until November 1, 2018. Arguably, this is too much flexibility in light of the multiple other flexibility options, including allowance trading,

[21] CARB Proposed Regulation Order: https://www.arb.ca.gov/regact/2016/capandtrade16/capandtrade16.htm.

banking, borrowing, offsets, and the Reserve. Annual compliance would require steadier submissions and would provide more regular information to the market.

We explore the implications of annual (instead of three-year) compliance periods through a thought experiment exploring what 2016 revenue might have been with annual compliance under different auctioning levels, and compare the actual price floor from last year and an illustrative $20 per ton price. Emissions for 2016 are estimated by applying an annual reduction of one percent compared to source-level data for 2015 from the mandatory reporting rule, finding emissions of 337 MMT, as compared to the California 2016 cap of 367 MMT.

| Auction scenario | 100% auction | 85% auction | 72% auction | 46% auction |
|---|---|---|---|---|
| Tons | 337 MMT | 286 MMT | 246 MMT | 169 MMT |
| Value at $12.73 | $4.3 billion | $3.6 billion | $3.1 billion | $2.1 billion |
| Value at $20 | $6.7 billion | $5.7 billion | $4.9 billion | $3.4 billion |

*Table 7. Some hypothetical insights into what 2016 could have looked like with annual compliance (Source: author's calculations)*

The different auction levels investigated in Table 7 relate to different approaches to allocation. The 85 percent auctioning level reflects a situation in which the 15 percent of allowances are given away for free, roughly equivalent to the amount for the "at risk of leakage, large industry" portion of allowance distribution.

The hypothetical results in Table 7 can be compared with actual auction sales in 2016, shown in Table 8. In total, buyers purchased 168 MMT in allowances (current and advance auctions), which raised about $2.1 billion in total value. The largest share of sales was consigned allowances for electric utilities. The share of "state-owned" allowances, those sold with funds going to the Greenhouse Gas Reduction Fund, added up to 71 MMT with a value of $901 million at $12.73 per ton.

| | Corresponding to auction % | MMT | Value at $12.73 |
|---|---|---|---|
| 2016 California allowances sales at auction | 72% | 168 | $2.1 billion |
| 2016 revenue for Greenhouse Gas Reduction Fund | 46% | 71 | $901 million |

*Table 8. Actual 2016 allowance sales with revenue estimated based on price floor. (Source: author's calculations and CARB data)*

(3) Increase the price floor: The price floor has proved its worth as a guard against insufficient stringency and deserves to be amplified. As part of a two-thirds legislative majority effort, likely increases in program proceeds can be recognized as macro

economically-efficient revenue at a time when the state has major investment demands for its clean energy transition, transportation and water infrastructure needs, and more. Raising the price floor would certainly bolster this source of efficient revenue, as results in Table 5 and Table 7 indicate.

(4) Give away fewer free allowances. Every unit given away for free presents an opportunity cost in efficient revenue not earned, and reduces demand at auctions. Sometimes public interest goals can be furthered through free allocation. Free allocation to natural gas companies to avoid rate increases and leakage are legitimate goals for policies. Yet, the opportunity cost of giving away allowances must be acknowledged.

# CONCLUSION

With this memo, we quantify the extent of the oversupply of allowances—current emissions below cap levels. Emissions and demand are lower than expected for several reasons. First, other policies have reduced emissions more than expected (for example, the renewable portfolio standard had investor-owned utilities hitting 27 percent renewable electricity in their 2016 supply[22]). Second, cap levels were set before the full extent of the 2008-2010 economic recession was appreciated. Third, faster than expected technological innovation has driven down low-carbon technology costs. Fourth, there has been some reshuffling of imported electricity emissions.[23]

When looking at market trends to 2020, our analysis finds about 82 percent of outstanding allowances will be needed, and emitters will need to purchase about 76 percent of allowances offered at auction in order to comply with the cap-and-trade regulation. Continued variability from auction to auction hammers home that our forward looking results present average long-run trends. Indeed, in light of the somewhat greater oversupply in the current compliance period as compared to our analysis of compliance periods two and three together (i.e. to 2020), it is entirely possible that demand could remain weak in the immediately upcoming auctions.

The California-Quebec program remains the best-designed carbon market in the world and the cap-and-trade program is doing the job it was created to do in the AB 32 Scoping Plan. It was intended as a supportive policy to sweep up emission reductions not accomplished through other policies, thereby providing a boost for lower carbon economic activity along with an economy-wide quantitative backstop ensuring the portfolio of climate policies delivers. Even if the cap-and-trade policy drives fewer reductions below business-as-usual than were forecasted at the time of program design, this is because business-as-usual emissions have been lower.

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[22] California Energy Commission. 2016. Tracking Progress, Renewable Energy. http://www.energy.ca.gov/renewables/tracking_progress/documents/renewable.pdf

[23] Reshuffling refers to the rearrangement of who is claiming credit and responsibility for which plants and emissions without changing the generation or use of these plants.

California is on track to surpass its 2020 emission reduction target, is building up expertise and institutions, and compliance rates are high. It has fostered international carbon market cooperation through the existing Quebec linkage and pending Ontario linkage, and is poised to spread even further. Meanwhile, California has the strongest major economy in the Western Hemisphere. The program is doing the job it was intended to do in the 2020 Scoping Plan.

At the same time, there is potential for constructive reform. It is neither an indictment of past market design choices, nor a big surprise the cap levels that made sense for the 2020 Scoping Plan would change when reconsidered as part of the 2030 Scoping Plan. With some incremental changes, the program can drive more reductions sooner to help put the state on the path to the aggressive 2030 target while also providing the more stable revenue that policymakers want.

# APPENDIX

## DESCRIPTIVE STATISTICS ON SCENARIOS

For the numerically inclined, Table A1 presents the numbers behind Figure 6.

| | High demand scenario | Low demand scenario | | | | |
|---|---|---|---|---|---|---|
| Total emissions 2015-2020 | 2,388 | 2,272 | | | High demand scenario | Low demand scenario |
| Demand after figuring in 4% offsets | 2,293 | 2,181 | | offsets at 4% of emissions | 96 | 91 |
| Demand after accounting for current allowance holdings | 1,377 | 1,265 | | Current allowance holdings | 916 | 916 |
| Demand after accounting for retired allowance in CP2 | 1,254 | 1,143 | | Allowances retired for use in second compliance period | 129 | 129 |

*Source: Author's calculations. See open-access spreadsheet for more details.*

## NOTES ON DATA SOURCES FOR FIGURES AND TABLES

*Figure ES-1 and Figure 2. Emissions and cap levels in the California-Quebec linked program.*

There are two sources of data for this graphic.

1. Mandatory reporting data on emissions for covered sources for 2013-2015 from:
    a. The California Air Resource Board: https://www.arb.ca.gov/cc/reporting/ghg-rep/reported-data/ghg-reports.htm
    b. The Quebec Ministry of Sustainable Development, Environment, Wildlife and Parks: http://www.mddelcc.gouv.qc.ca/changements/carbone/ventes-encheres/liste-etablissements-visesRSPEDE.pdf
2. Cap levels for 2013-2020 from
    a. The California Air Resource Board, Volume III, Appendix E, Proposed Regulation to Implement Cap-and-Trade Regulation: https://www.arb.ca.gov/regact/2010/capandtrade10/capv3appe.pdf
    b. Quebec's Cap-and-Trade Program for Greenhouse Gas Emissions: Technical Overview: http://www.mddelcc.gouv.qc.ca/changements/carbone/documents-spede/technical-overview.pdf

*Figure 1. Bid-to-cover ratios and volumes sold at joint California-Quebec auctions.*

The most recent results as well as archived auction results for all California auctions and all joint auctions can be found here: https://www.arb.ca.gov/cc/capandtrade/auction/auction.htm

*Figure 3. Historical data and high and low demand scenarios developed for this analysis.*

This figure combines mandatory reporting data with the emissions scenarios developed in this report.

*Table 1. Disposition of allowances for compliance through 2020.*

This table draws on the most recent quarterly compliance instrument report, at the time of publication, January 6th, 2017:
https://www.arb.ca.gov/cc/capandtrade/complianceinstrumentreport.xlsx.

*Figure 4. California allowance distribution over time.*

This graphic draws on the State Auction Budget Spreadsheet:
https://www.arb.ca.gov/cc/capandtrade/stateauction.htm

*Table 2. Free allocation under California Program in recent years.*

This table uses data from the two most recent reports on free allocation:

https://www.arb.ca.gov/cc/capandtrade/allowanceallocation/v2016allocation.pdf

https://www.arb.ca.gov/cc/capandtrade/allowanceallocation/v2015allocation.pdf

## WHY OVERSUPPLY IS A NECESSARY CONDITION FOR UNDERSUBCRIBED AUCTIONS

Using economic theory and real world examples, this section shows that oversupply is a necessary condition for allowance prices to be at a minimum boundary condition, i.e. to settle at an auction price floor or to fall to zero. The theory focuses on a simple, one-period model and ignores intertemporal complications. Banking certainly creates the potential for positive prices even when there is oversupply, as proven by California's first compliance period and the EU ETS second phase.

Figure A1 illustrates a "regular" market outcome under a cap-and-trade policy. A regular outcome is defined as one that is not at an extreme, i.e. not at a boundary condition, such as a price of zero or at a price floor.

Figure A1 has emissions along the horizontal axis. The price of carbon is along the vertical axis. A sloping line is the expected demand curve reflecting the cost of abatement for covered emitters, who will balance allowance purchases and emission reductions. Emission reductions are made internally up to the point where it becomes comparatively cheaper to buy allowances. The supply of allowances under cap-and-trade, without any price collaring, is a vertical line, reflecting its perfect inelasticity.

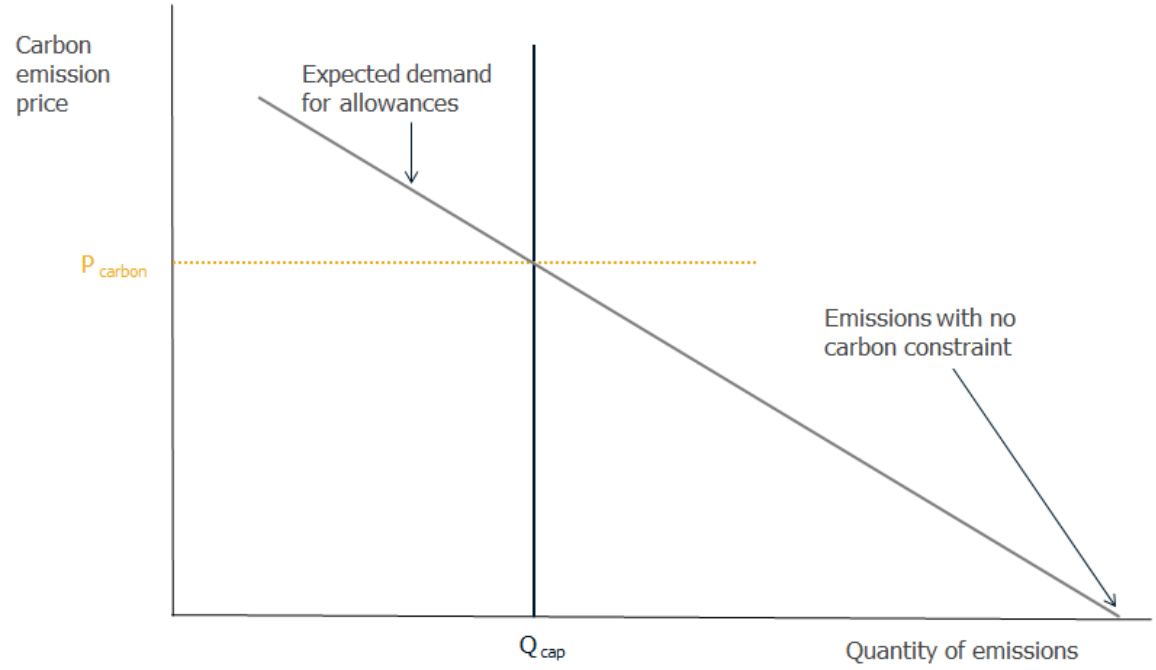


*Figure A1. Graphing a "regular" market outcome, i.e. an equilibrium not at a boundary*

Figure A1 shows this "regular" market producing a price and quantity outcome of $P_{carbon}$ at $Q_{cap}$. It shows that imposing short-term scarcity, if the cap is truly binding, will ensure the price remains above zero or the floor, if there is a price floor. If banking is allowed, this would only add to current demand as banking opens up intertemporal speculation activities. To activists,

this may sound nefarious, but to many economists this is a valuable price smoothing investment service.

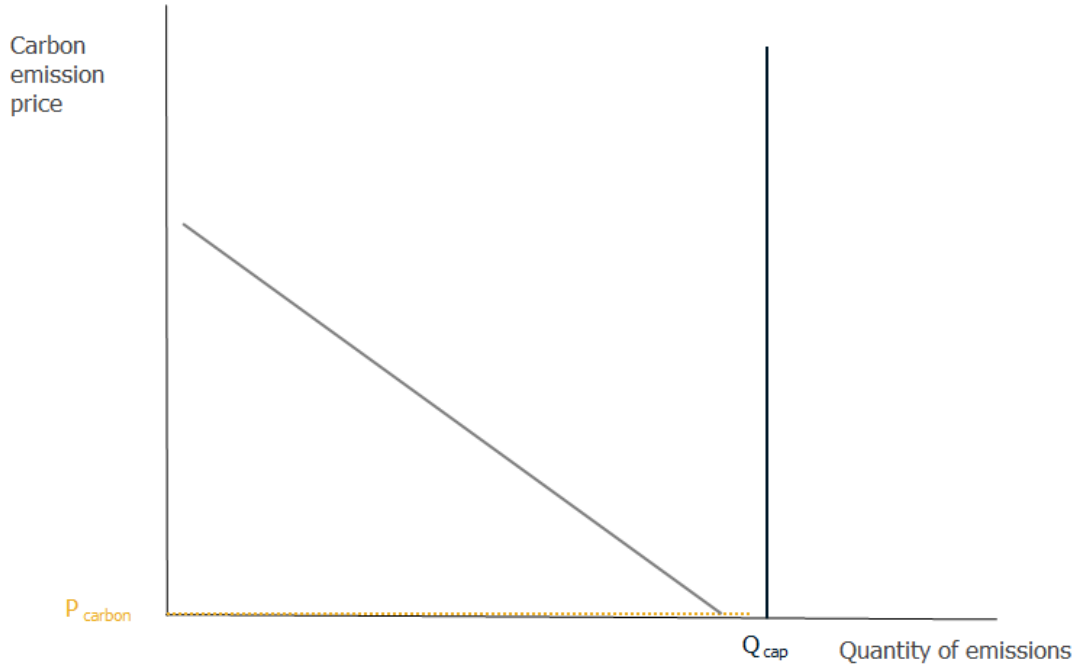


*Figure A2. An oversupplied market with no banking*

Figure A2 shows how price can be driven to zero, though we not aware of instances when this has happened when there is banking.

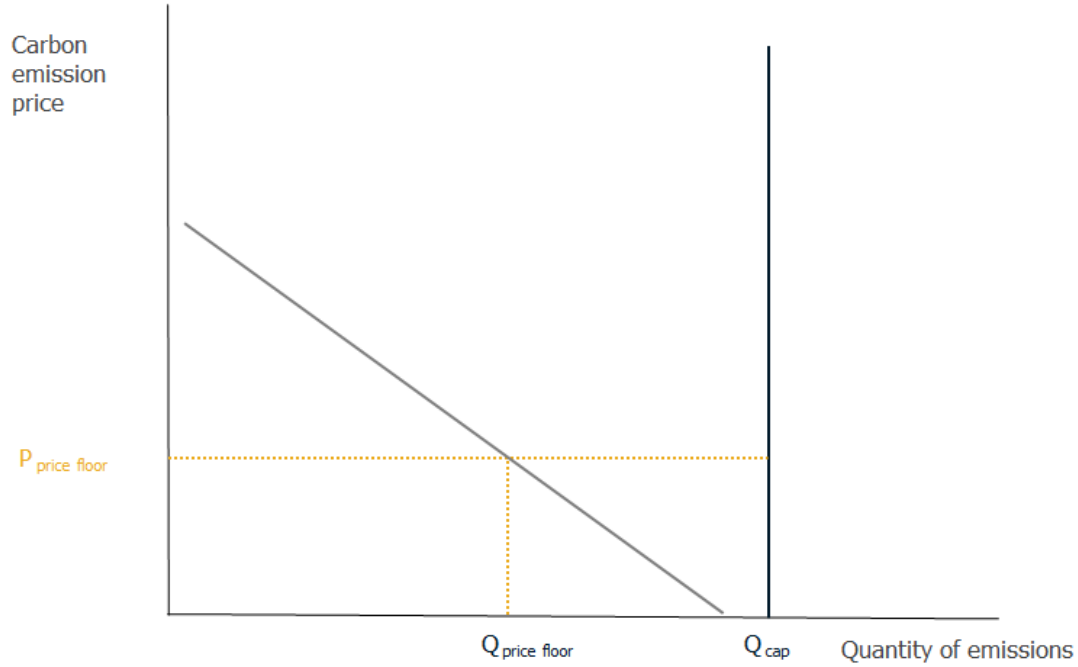


*Figure A3. An oversupplied market with a price floor*

Figure A3 illustrates a supply-demand balance that would lead to prices at a price floor and how this leads to some allowances, equal to $Q_{price\ floor}$ minus $Q_{cap}$, going unsold.

Next are some empirical cases, starting with the EU ETS. It is widely recognized that the EU ETS was over-allocated in its first compliance period, 2005-2007, and this combined with banking to drive the carbon price to zero.


*Figure A4. Allowance price trends in the EU ETS (Sources: main,* Sandbag *and inset,* Sandbag*)*

Even with very large oversupply with banking and prospects for steeper caps in the future, prices need not approach zero, as demonstrated in the EU ETS. Two gigatons of carbon allowances were banked in the second phase of the EU ETS (2009-2012). The extent of that system's oversupply is demonstrated in Figure A5, which shows the accumulation of banked allowances over time. Despite this large degree of oversupply, the EU ETS allowance price stayed well above zero.

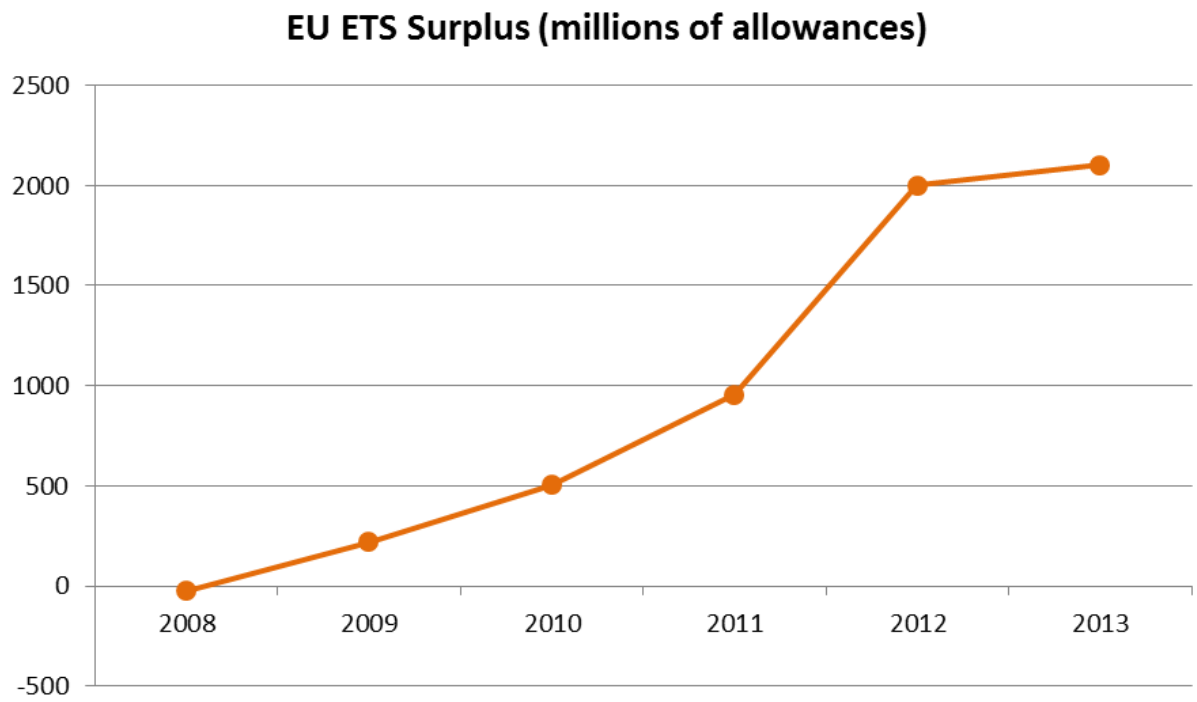


*Figure A5. Accumulated bank over time in EU ETS (Source: Environmental Europe)* [30]

The early history of the RECLAIM (Regional Clean Air Incentives Market) program, a cap-and-trade program for nitrous oxide (NOx) and sulfur oxide (SOx) emissions in Southern California, offers another historical example of oversupply driving the price of a tradable emission permit down to zero. Figure A6 illustrates the supply-demand imbalance (RTC credit standards for RECLAIM Trading Credit).

[30] http://environmentaleurope.ideasoneurope.eu/2014/06/26/eu-stakeholders-divided-over-reforming-the-eu-emissions-trading-system/

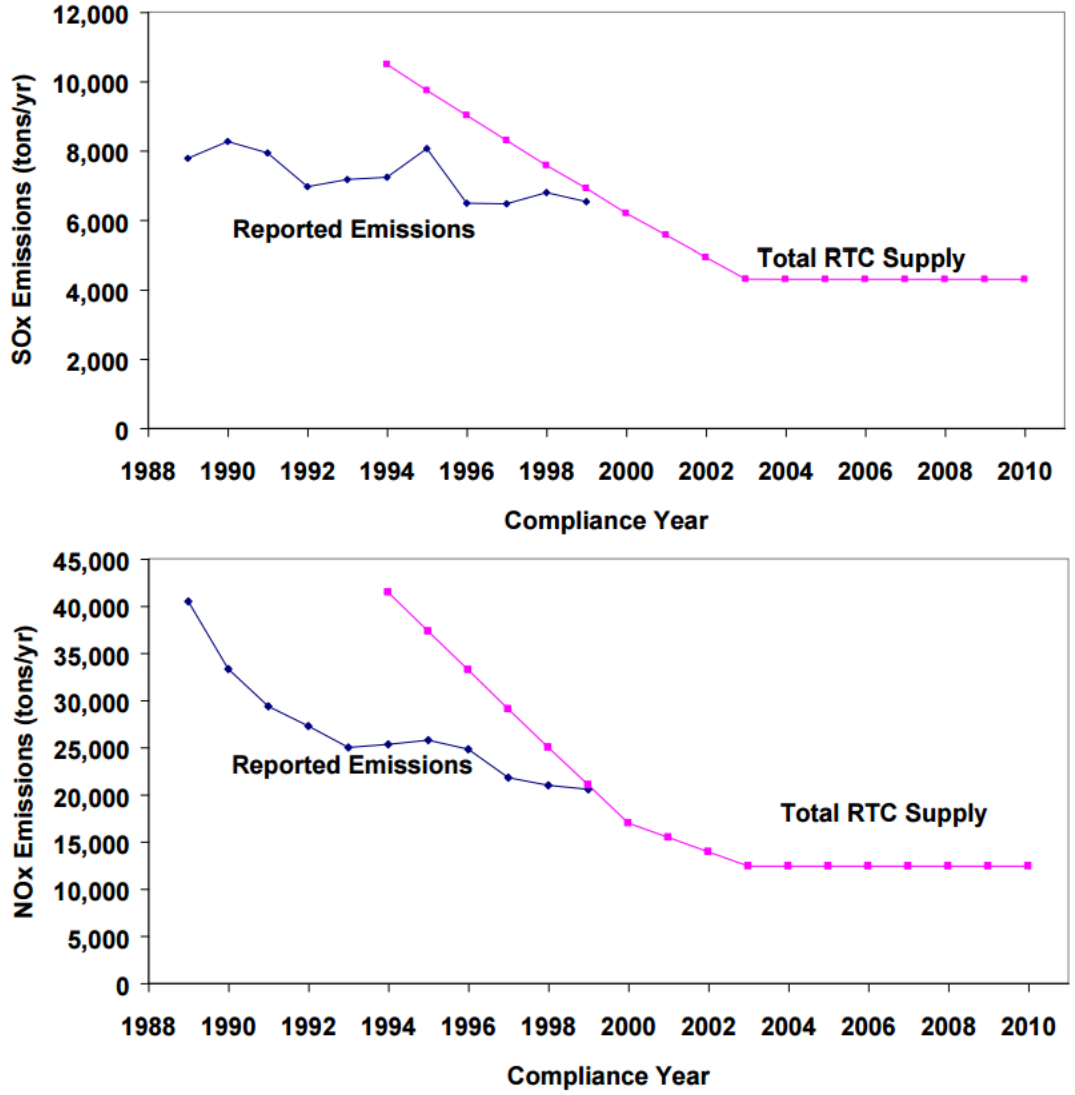


*Figure A6. Emissions below supply in early years of RECLAIM program. Accumulated Emission* (Source: Southern California Air Quality Management District)[31]

Oversupply combined with the lack of banking provisions meant that the RTC price remained stuck at zero in the first years of the program. It was only in 1999 and 2000 when the cap started to force reductions below business-as-usual when non-zero prices began to emerge, as Figure A7 shows.

[31] *http://www.aqmd.gov/docs/default-source/reclaim/white-paper-on-stabilization-of-nox-reclaim-prices.pdf*

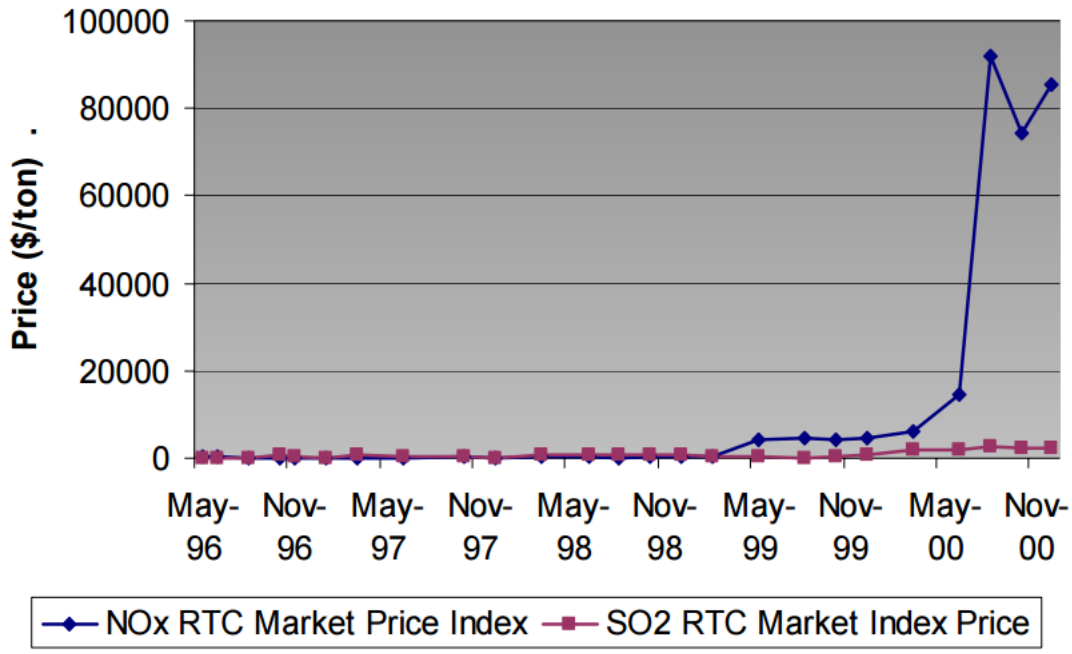


*Figure A7. Permit prices at zero under RECLAIM until 1999 (Source: Dallas Burtraw, slide 30)*