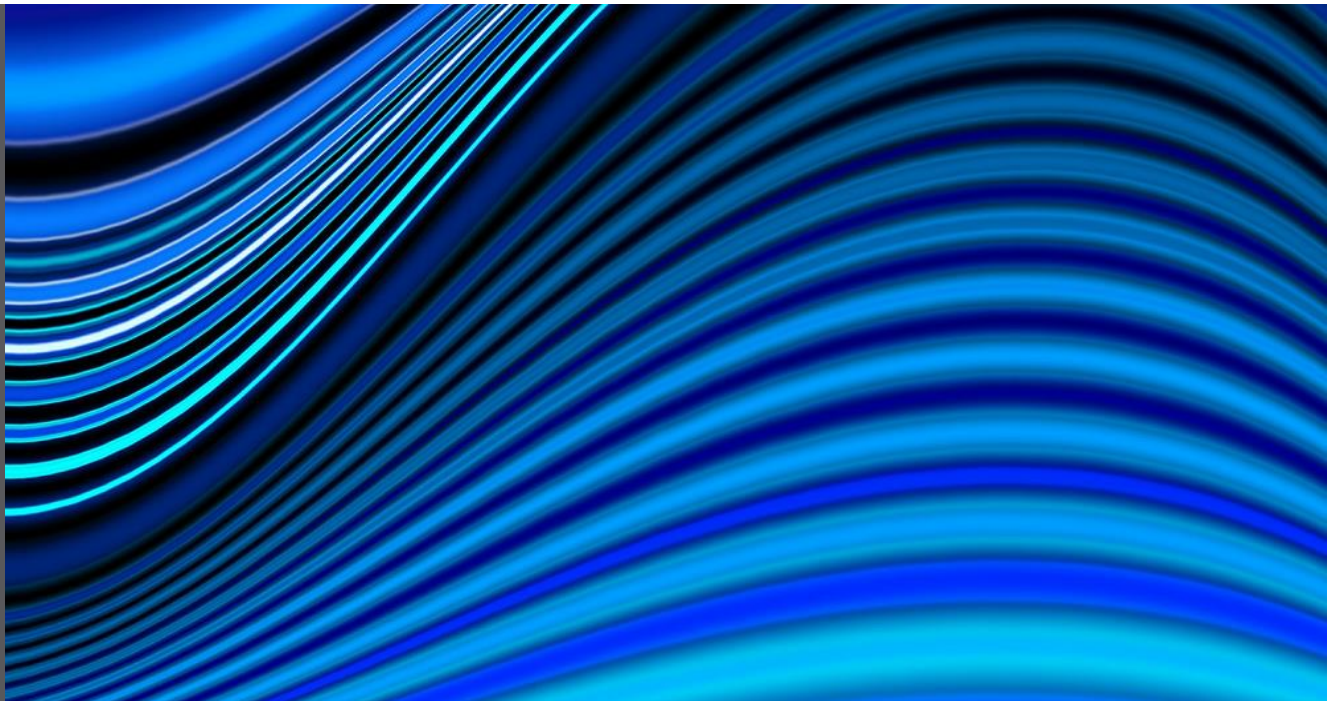

CHARTING CALIFORNIA'S CARBON COURSE:

WHY AND HOW THE STATE SHOULD SET A 2030 TARGET OF 40% BELOW THE 1990 LEVEL OF CARBON EMISSIONS

March 2015

By Chris Busch, Director of Research

ENERGY INNOVATION
POLICY & TECHNOLOGY LLC

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Energy Innovation: Policy and Technology LLC
98 Battery Street, Suite 202
San Francisco, CA 94111

www.energyinnovation.org

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DEFINITIONS OF TERMS AND ABBREVIATIONS

TERM	DEFINITION
Allowance	A permit to emit 1 ton of CO_2e.
Allowance Price Containment Reserve (The Reserve)	A reserve of allowances taken from the cap-and-trade allowance budget across all compliance periods that are made available for cost containment at the start of the cap-and-trade program.
AB 32	Assembly Bill 32, California's Global Warming Solutions Act, sets a 2020 statewide emissions limit at the 1990 emissions level (431 MMT of CO_2e).
Auction Reserve Price	The minimum price at which allowances will be sold at auction.
Banking or banked allowances	Allowances that are retained for use in a future compliance period instead of being submitted to cover emissions during a given compliance period.
The cap	The number of allowances left for distribution after allowances are taken out for deposit in The Reserve.
Capped emissions	Emissions directly covered by the cap-and-trade program.
California Air Resources Board (CARB)	Agency with authority to implement regulations to achieve California's air quality goals and emissions reductions targets.
Complementary policies	A term that has often been used in the AB 32 dialogue referring to all AB 32 policies other than the cap-and-trade program.
CO_2e	Carbon dioxide equivalent: the global warming impact of a greenhouse gas as measured by the mass of carbon dioxide that would create that same impact over a given time period (most commonly 100 years).
Compliance period	The two- or three-year time period for compliance under the cap-and-trade program. By the end of the compliance period, all entities covered by the program must submit allowances and offsets to account for their emissions.
MMT	Million Metric Tons.
Offsets	Emissions reductions from projects in sectors of the economy not covered by the cap-and-trade program, which are available for purchase by regulated entities. A limited quantity of these can substitute for allowances.
Reserve Sale	Quarterly sale of allowances of the three Tiers of the Reserve. Open only to entities covered under the program.
Tier	The allowances set aside for the Reserve initially are divided into three equal size allotments of allowances, each called a Tier (Tier 1, Tier 2, and Tier 3).
Uncapped emissions	Emissions not covered by the cap-and-trade program. These include entire sectors, such as agriculture and waste, which can receive offset credits under the cap-and-trade program, but allowances are not required to cover their emissions. There are also emissions in capped sectors that are not covered by the cap-and-trade program due to entities not meeting threshold requirements or monitoring challenges (as in methane).

EXECUTIVE SUMMARY

The accumulation of greenhouse gases (GHGs) in the atmosphere, due mainly to the burning of fossil fuels for energy, is one of humanity's most pressing problems. Climate-related damages are being felt earlier and more severely than scientists had predicted just a few years ago (Houser et al. 2014). By 2050, we must transition to a much greater reliance on zero-carbon energy sources to avoid dangerous climate change (California Council on Science and Technology 2011; Williams et al. 2012; Sustainable Development Solutions Network 2014).

This transition must accelerate rapidly over the next several years. Fortunately, a number of clean technologies, such as solar power, are taking off and demonstrating the type of explosive, nonlinear growth that will be required. In 2014, even as the global economy grew at 3%, global GHG emissions from energy use did not rise (IEA 2015). And in a growing number of places, such as California, emissions are falling in tandem with healthy economic growth. The pace of emissions reductions must ramp up significantly in these first-movers, and do so in a way that inspires others to follow. The decoupling of environmental gains and economic growth must intensify. California Governor Jerry Brown has set his sights on exactly this task, saying in his recent inaugural speech: "Taking significant amounts of carbon out of our economy without harming its vibrancy is exactly the sort of challenge at which California excels. This is exciting, it is bold, and it is absolutely necessary if we are to have any chance of stopping potentially catastrophic changes to our climate system," (Brown 2015).

California has already made great strides. From a peak of 493 million metric tons of carbon-dioxide equivalent (MMT of CO_2e) in 2004, emissions fell to 459 MMT in 2012 (the most recent data). California's Assembly Bill 32 (AB 32) sets a 2020 target for statewide GHG emissions: a return to the 1990 level of emissions. The state is well on track to meeting this goal. Governor Jerry Brown has called for a new 2030 target and has recently offered other goals in the areas of renewable electricity, petroleum consumption, and the energy efficiency of existing buildings. The state has set a 2050 target: an 80% reduction in emissions relative to the 1990 level of emissions.[1] One fundamental decision left is what statewide target should be set between 2020 and 2050, with much of the debate centering on 2030.

This paper argues that the State of California should:

1. Set a target of 40% below the 1990 level of emissions.
2. Continue the current approach that the California Air Resources Board (CARB) has developed to put the state on course to reach its 2020 target, which combines an almost economy-wide cap-and-trade program on top of a large set of sector-specific policies.
3. Extend the cost containment mechanisms in the current cap-and-trade program, with minor modifications, and set a linear glide path from 2020-2030 to a reduction in capped emissions consistent with the recommended target.

This paper recommends a 2030 statewide carbon target of 40% below 1990 emissions. This is a strong target that will get the state halfway to the 2050 target in one-third of the time. The plan outlined here builds in flexibility mechanisms should the task prove more difficult and expensive than it looks today.

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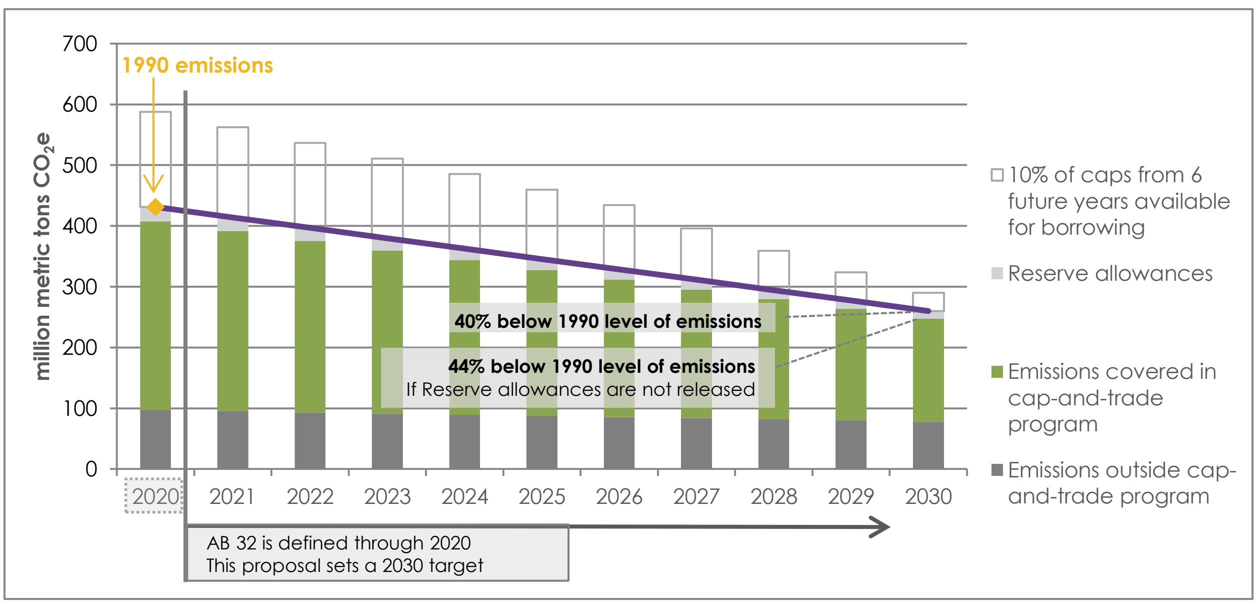
[1] The 2050 target of 80% below 1990 is reflected in Executive Order S-3-05 and Governor Brown's Executive Order B-16-2012.

However, Energy Innovation argues that the opposite is likely to be true. Historically, the total costs of compliance with environmental regulation typically turn out to be lower than expected (Morgenstern 2014). If prices do stay low under California's cap-and-trade program, the proposed approach will also automatically tighten the cap. It does so by carving out, from the initial cap level, a pool of allowances that are only released if allowance prices rise to certain price thresholds.

California should extend the current approach it is using to meet the AB 32 target for 2020, which uses a broad cap-and-trade program as a nearly economy-wide ceiling on GHG emissions. The cap-and-trade program covers 85% of the state's GHG emissions today. Extending the program through 2030 will provide greater certainty for investors. The cap-and-trade program also provides substantial cost containment. While there is an undeniable need to set future policy, in no small part to give businesses and other economic actors confidence about the future rules of the market, there is also no way around the inherent uncertainty about the maximum level of cost-effective reductions when we look years out into the future. The approach recommended in this paper manages this uncertainty by setting a stringent target that will be achieved if allowance prices remain below a threshold. If costs turn out to be unexpectedly high, the cap would be relaxed to lessen the emissions reduction effort.

Figure ES-1 shows how the proposed cap-and-trade program puts the state on a path to the recommended target in 2030. Cap-and-trade drives down emissions by requiring those covered by the program to obtain "allowances." Allowances are permits to emit GHGs. (Offsets are an alternative compliance option that is discussed in the body of the report.) The cap in any given year is equal to the total number of allowances made available. The proposed design contains costs by setting aside allowances from the initial cap levels (for 2021 and into future years) at the outset of the program extension.[2] If allowance prices rise to pre-determined levels, CARB will make these "Reserve" allowances available at auction. Should this initial set-aside ever be depleted, then allowances from future years can be accessed through a borrowing mechanism.

Figure ES-1 – Charting a course for 40% below 1990 emissions levels by 2030



[2] This is the same cost containment approach as the current cap-and-trade program, which extends through 2020.

Figure ES-1 shows that if prices stay low and allowances from the Reserve are never tapped, statewide emissions would fall 44% below the 1990 level of emissions. If allowance prices rise high enough, released Reserve allowances would allow higher emissions. Despite this potential for annual variation, cumulative emissions would still have a fixed limit equal to the sum of all the annual caps over the life of the extended program.

The proposed target of 40% below the 1990 level of emissions is ambitious, but two recently completed analyses show it is achievable almost entirely with technology that is commercially available today. Greenblatt (2015) uses a policy-driven model with detailed technology and energy features to map a pathway to a reduction in 2030 of 41% below 1990 emissions. The technical consulting group Energy and Environmental Economics (E3) (Mahone et al. 2015) use an even more fine-grained representation of energy technologies to map emissions pathways that lead to reductions of 25-36% below the 1990 level by 2030. Examining the E3 analysis, we expect that further analysis will reveal additional technically feasible and cost-effective reductions in land-based carbon reduction, energy savings due to water efficiency, and lower transportation emissions from better urban design. As such, after accounting for these additional emissions reduction opportunities, we believe the E3 analysis indicates that a 40% reduction below the 1990 level of emissions is achievable.

E3's recent work also provides reason for optimism about the economic impact of a strong 2030 carbon target. The research analyzes the costs of technology upgrades and the associated energy savings required to achieve their emissions reduction pathways. They find small net costs (defined as costs minus energy savings) under their main assumptions and small net benefits under some scenarios. Additionally, our assessment of the literature is that there are likely to be substantial co-benefits—such as local and regional clean air benefits, quality-of-life benefits from better urban design, and more robust technology innovation—from such clean energy solutions, which are not factored into the economic impact analysis.

There are no guarantees when talking about 2030. Today, however, this much is clear: The world needs California's continued leadership. Now is the time for boldness and vision. Fortunately, California policymakers are up to the task, and the people of California continue to be overwhelmingly supportive of efforts to demonstrate the benefits of moving from the early to middle stages of the clean energy transition. California has taken on the challenge of demonstrating decarbonized prosperity. The time is now to set a strong 2030 target on the way to 2050. Forty percent below the 1990 level of emissions is ambitious, but looks to be achievable. By extending the cost containment mechanisms crafted by CARB in the existing program, the recommendations set forth here combine stringency and flexibility.

1. INTRODUCTION: THE CHALLENGE DEFINED

The accumulation of GHGs in the atmosphere, due mainly to the burning of fossil fuels for energy, is one of humanity's most pressing problem. Climate-related damages are being felt, earlier and more severely than scientists had predicted just years ago (Houser et al. 2014). By 2050, we must transition to much greater reliance on zero-carbon energy sources if dangerous climate change is to be avoided (California Council on Science and Technology 2011; Williams et al. 2012; Sustainable Development Solutions Network 2014).

This transition must accelerate rapidly over the next several years. Fortunately, a number of clean technologies, such as solar power, are taking off and demonstrating the type of explosive nonlinear growth that will be required. In 2014, even as the global economy grew at 3%, global GHG emissions from energy use did not rise (IEA 2015). And in a growing number of places, such as California, emissions are falling in tandem with healthy economic growth. The pace of emissions reductions must ramp up significantly in these first-movers, and do so in a way that inspires others to follow. The decoupling of environmental improvement and economic growth must intensify. California Governor Jerry Brown has set his sights on exactly this task, saying in his recent inaugural speech: "Taking significant amounts of carbon out of our economy without harming its vibrancy is exactly the sort of challenge at which California excels. This is exciting, it is bold, and it is absolutely necessary if we are to have any chance of stopping potentially catastrophic changes to our climate system."

California has already made great strides. From a peak of 493 MMT of CO_2e in 2004, emissions fell to 459 MMT in 2012, the most current data available. AB 32 sets a 2020 target for statewide GHG emissions: a return to the 1990 level of emissions. The state is well on track to meeting this goal. Governor Jerry Brown has called for a new 2030 target and has recently offered other goals in the areas of renewable electricity, petroleum consumption, and the energy efficiency of existing buildings. The state has set a 2050 target: an 80% reduction in emissions relative to 1990 levels.[3] One fundamental decision left is what statewide target should be set between 2020 and 2050, with much of the debate centering on 2030.

1.1 OVERVIEW

The next section of the paper provides background on the AB 32 program in general and the cap-and-trade program in particular. Section 3 presents our recommendations. Section 4 discusses the evidence and reasoning that underpin these recommendations. Section 5 outlines some of the limitations of the current analysis, and suggests next steps for research. The conclusion is followed by two appendices. Appendix 1 provides more detail on the proposed extension of the cap-and-trade program. Appendix 2 provides additional discussion of trends and forecasts of emissions not covered under the state's cap-and-trade program.

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[3] The 2050 target of 80% below 1990 is reflected in Executive Order S-3-05 and Governor Brown's Executive Order B-16-2012.

2. BACKGROUND: THE CURRENT PROGRAM

Two aspects of the current program deserve some explication: (1) the overall approach to achieving the 2020 emissions level required by AB 32; and (2) the particulars of how cost-containment is integrated into the structure of the cap-and-trade program.

2.1. A PACKAGE OF POLICIES WITH CAP-AND-TRADE AS CAPSTONE

CARB's approach to meeting the AB 32 target combines a cap-and-trade program with a broad array of sector-specific policies. The cap-and-trade program provides a nearly economy-wide ceiling on GHG emissions. It covers 85% of the state's GHG emissions today. However, the majority of emissions reductions are expected to come from sector-specific policies. These include policies such as the Renewable Portfolio Standard (increasing the share of renewable energy in the state's electricity mix), the low-carbon fuel standard (decreasing the carbon intensity of the state's transportation fuel mix), new building and appliance energy efficiency standards, and the 21 actions laid out in the Scoping Plan (CARB 2008, Table 2, page 17).

2.2. COST CONTAINMENT IN THE CURRENT CAP-AND-TRADE PROGRAM

Cap-and-trade programs require those entities covered by the program to obtain permits (allowances in the parlance of cap-and-trade) or offsets (discussed further below) in an amount equal to their emissions. These permits to emit are called allowances in cap-and-trade terminology. Each allowance entitles its holder to emit 1 metric ton of CO_2e. Regulators have the choice of auctioning allowances or distributing them freely to emitters. California is doing both, but it mostly auctions them, and the percentage of auctioned allowances is increasing over time. Allowances are tradable. As such, cap-and-trade limits the total emissions from the regulated entities, but does not prescribe who must reduce or how these reductions must be attained. This flexibility allows the prioritization of the lowest-cost reductions to achieve the cap.

California's cap-and-trade program includes several different design features that act to smooth prices, working to ensure that allowance prices are neither too low (and therefore not providing a meaningful incentive to reduce emissions) nor too high (and therefore requiring emissions reductions that are very expensive). These price-smoothing features include: (1) the Auction Reserve Price; (2) linkage to other programs; (3) multi-year compliance periods; (4) banking of allowances; (5) offsets; and (6) the allowance price containment reserve. The last of these is the strongest cost-containment mechanism, and it is the focus of this paper.

Auction Reserve Price

One of the main real-world lessons from cap-and-trade program implementation is that there are real risks that the initial cap level will be set so high as to not require any emissions reductions. This happened in southern California's program to control NOx emissions. As a result, the price of an allowance was zero at the outset and persisted as such for the first years of the program, though the program went on to achieve meaningful emissions reductions over time. One way to reduce the negative impacts of a cap that is set too high is to set a price floor at auction. Allowances will only be made available for sale at or above a minimum price, which is called the Auction Reserve Price in California. The Auction Reserve Price started at $10 per ton of CO_2e in 2012 and rises 5% plus inflation each year. If demand for allowances in an auction is too low to sell all allowances at a price above the Auction Reserve

Price, some allowances will go unsold, lowering the total number of allowances in the system and thus further constraining emissions.

Linkage

California has formally linked its system with the cap-and-trade program in the Canadian province of Quebec. Allowances are freely usable and exchangeable across programs. All else equal, building a larger market will reduce price volatility. The state is actively working to link its cap-and-trade program with other jurisdictions. This outward expansion is valuable and should be encouraged to smooth allowance prices, to lower overall compliance costs, and to encourage other jurisdictions to cap their own emissions.

Multi-year compliance periods

California has adopted three-year compliance periods that can help smooth price variations that might otherwise occur due to periodic shocks, such as weather or macroeconomic fluctuations. For example, in years without much rain, hydropower is less available, which increases the carbon intensity of electricity generation. This effect has been observed in the recent drought. With longer compliance periods, there is more time to adjust, which in effect offers another type of cost containment. A countervailing force is the need to have a periodic tune-up to provide an impetus for capped entities to avoid procrastination and to ensure emission limits are respected. CARB chose three-year compliance periods to balance these goals.

Banking

Banking of allowances achieves a similar goal as a multi-year compliance period, but allows even greater flexibility: A regulated entity can save up unused allowances for future compliance periods. California allows unlimited banking of allowances.

Offsets

Offsets are emissions reductions from projects outside the reach of a cap-and-trade program. Offsets may come from projects undertaken in sectors of the economy not covered by the cap-and-trade program, or from projects in jurisdictions the cap does not cover. Entities regulated under cap-and-trade can purchase these quantified emissions reductions and use them as a substitute for allowances. Offsets can account for up to 8% of emissions under the current program.

The Allowance Price Containment Reserve (the Reserve)

The Reserve is a pool of allowances carved out of the total number of allowances available through 2020. At the start of the program, the Reserve was divided into three equal parts ("tiers," as in Tier 1, Tier 2, and Tier 3). These allowances are sold at quarterly Reserve Sales where California entities that are covered by the cap-and-trade program can purchase allowances at pre-established prices, which differ by tier. These tier prices started at \$40, \$45, and \$50 per allowance in 2013, and rise by 5% annually plus inflation. CARB refers to these as the Tier 1 Price, the Tier 2 Price, and the Tier 3 Price. Allowances in the Reserve are placed directly into an entity's compliance account, which means they cannot be traded to other entities but can be used for compliance.

The Reserve was established with 122 million allowances, all of which remain in the Reserve since no entities have participated in a Reserve Sale. This quantity of allowances is the sum of 1% of allowances from the first compliance period, 4% from the second compliance period, and 7% from the third compliance period. The full Reserve represents 4.9% of all the allowances under the cap through 2020.

In 2014, CARB approved an additional cost containment measure to ensure that the Reserve always contains sufficient allowances to keep prices at or below the Tier 3 Price. This new cost-containment feature, which does not have a name (probably an advantage, given all the terminology already involved), allows access to up to 10% of allowances allocated for future years, should the Reserve be depleted.

We call it forward borrowing, describing what it does. It works like this: If, at the Reserve Sale immediately preceding November 1, there is more demand for allowances at the highest tier price than there are allowances, 10% of the allowances from the year 2020 (i.e., the most distant budget year) are made available to be sold through the Reserve Sale at the highest price tier. If demand exceeds the supply initially set aside for the Reserve and 10% of 2020 vintage allowances, then 10% of the allowances from the year 2019 are made available at the highest price tier of the Reserve. This new measure made an additional 206 million allowances eligible for sale at the highest price tier of the Reserve Sale immediately preceding the 2014 compliance obligation on November 1, 2015. The timing of this sale is such that entities will know their reported emissions (and thus the number of allowances and offsets needed) and be able to purchase allowances at the Reserve Sale to use for compliance on November 1.

Figure 1 illustrates the annual caps, the Reserve, and the 10% of allowances available to borrow from future years if the Reserve needs to be replenished.

Figure 1 – Current cap-and-trade program structure to 2020

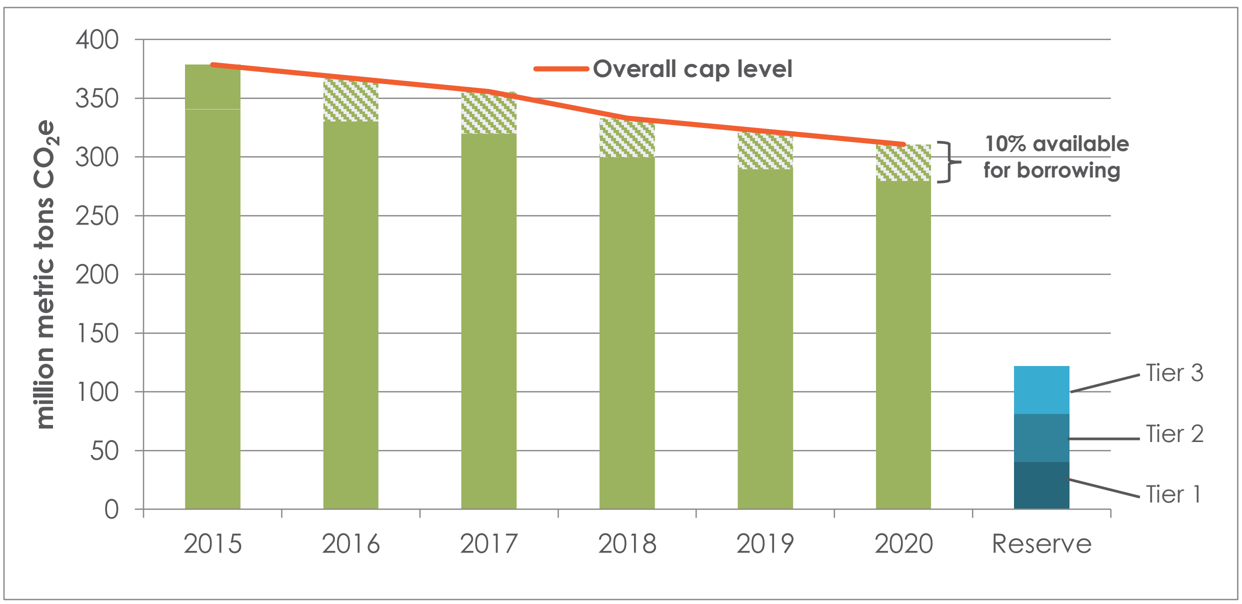


Figure 1 shows the allowances (at right in blue) that are carved out of the initial cap levels and placed in the Reserve. Thee three equal size parts of the Reserve, the three Tiers available at increasing prices, are illustrated with different shades of blue. The graph also shows, with a cross-hatched pattern, the 10% of future years' caps that are available to augment the Reserve if the initial allotment of allowances is ever fully demanded (i.e., if the Reserve sells out). The discontinuity, or nonlinear drop, between 2017 and 2018 is due to the way that allowances were set aside for the Reserve from the initial cap levels. There are 4% of allowances carved out of the 2015-2017 time period and 7% over 2018-2020.

3. RECOMMENDATIONS

Our recommendations, moving from broader to more specific, are that the State of California should:

1. Set a target of 40% below the 1990 level of emissions.
2. Continue the current approach that CARB has developed to put the state on course to meet its 2020 target, which combines an almost economy-wide cap-and-trade program on top of a large set of sector-specific policies.
3. Extend the cost-containment mechanisms in the current cap-and-trade program, and set a linear glide path to a reduction in capped emissions consistent with the 40% reduction target.

The rest of this section is largely devoted to outlining in specific terms an extension of CARB's current program in order to accomplish a statewide emissions reduction of 40% below 1990 by 2030. However, the proposal must also take into account emissions outside of the cap-and-trade program. This topic is addressed after the proposed cap-and-trade structure is presented.

3.1. STRUCTURING CAP-AND-TRADE POST 2020

Energy Innovation recommends that the current structure of cap-and-trade be carried forward in the post-2020 period. That structure includes:

- Annual caps that decline linearly between 2020 and 2030
- Three-year compliance periods
- Unlimited banking of allowances
- A price floor, called an Auction Reserve Price
- A three-tiered reserve system to guard against high prices
- The continuation of an approach that allows borrowing from future years' allowances in the event that demand exceeds the supply of allowances initially place in the Reserve. This feature which was added to the program in 2014

One modest variation relates to the initial size of the Reserve. In the current program, the Reserve equals 4.9% as a weighted average of caps over 2013-2020, the percentage of allowances carved out from initial cap levels for the Reserve increases over time, and 7% of the allowances from the third compliance period are set aside for the Reserve. Our proposal is to size the reserve equal to 7% of the extended cap-and-trade program.

Another design choice worth emphasizing concerns the approach to future borrowing, which would be allowed in the unlikely event that the initial allocation of allowances to the Reserve becomes depleted. We recommend that borrowing up to six years forward on a rolling basis be allowed.

To the extent that allowances that were initially placed in the Reserve remain there at the end of 2020, this paper recommends that they should be retired. Banked allowances should continue to be viable for compliance in the newly defined compliance periods.

Figure 2 illustrates Energy Innovation's recommendation for the shape of cap-and-trade post-2020 in order to achieve the semi-flexible target of a 40% reduction below 1990 levels required by 2030.

Figure 2 – Proposed Cap-and-Trade Structure Through 2030

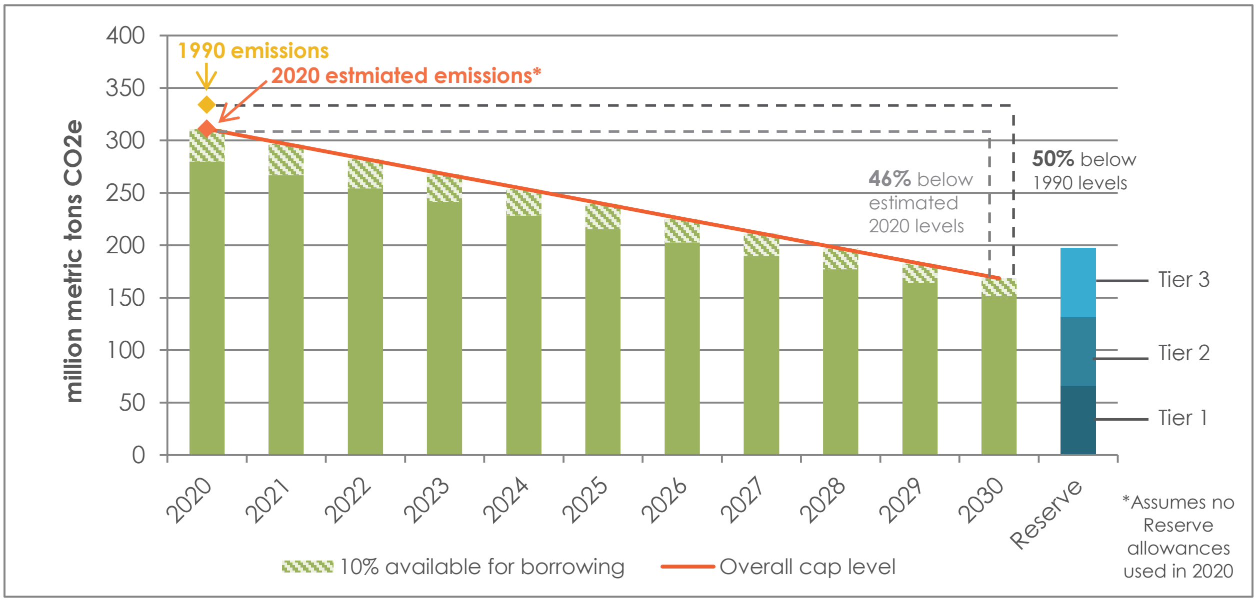


Figure 2 shows in blue at right the 7% of allowances set aside for the Reserve from the initial cap levels. The different shades of blue correspond to the three tiers. The cross-hatched area under the overall cap level shows the 10% of allowances that would be available for borrowing to fill the Reserve if the initial set aside is ever depleted.

The reductions in emissions covered under the cap-and-trade program can be framed in relation to the 1990 emissions level allowable under the cap (334 MMT of CO_2e) and the expected 2020 level of emissions. Another variation relates to whether or not allowances are released from the reserve. Table 1 captures these variations.

Table 1 – Reductions under the cap-and-trade program in 2030

	Reduction below 1990 emissions	Reductions below expected 2020 emissions
Cap level before allowances are taken out for Reserve	46%	42%
Cap level after allowances are taken out for Reserve	50%	46%

The use of three-year compliance periods introduces some nuance to the mapping of cap-and-trade to the statewide 2030 target. Continuing the use of three-year compliance periods would make 2030 the first year of a compliance period that would extend until the end of 2032. Allowances demonstrating compliance with the "2030 target" would actually be surrendered in concert with those for 2031 and 2032 targets at the end of 2032. For the sake of simplicity, and given the focus on the 2030 target, the graphs above only show the structure of cap-and-trade through 2030. Table A1 in Appendix 1 gives results through 2032, and includes the numerical values of the proposed cap and Reserve Tier levels.

If Figure 3 below were only to extend to 2030, readers might wonder why potential future borrowing has not dropped to zero by 2030. Thus, to avoid that source of confusion, Figure 3 extends all the way to 2032.

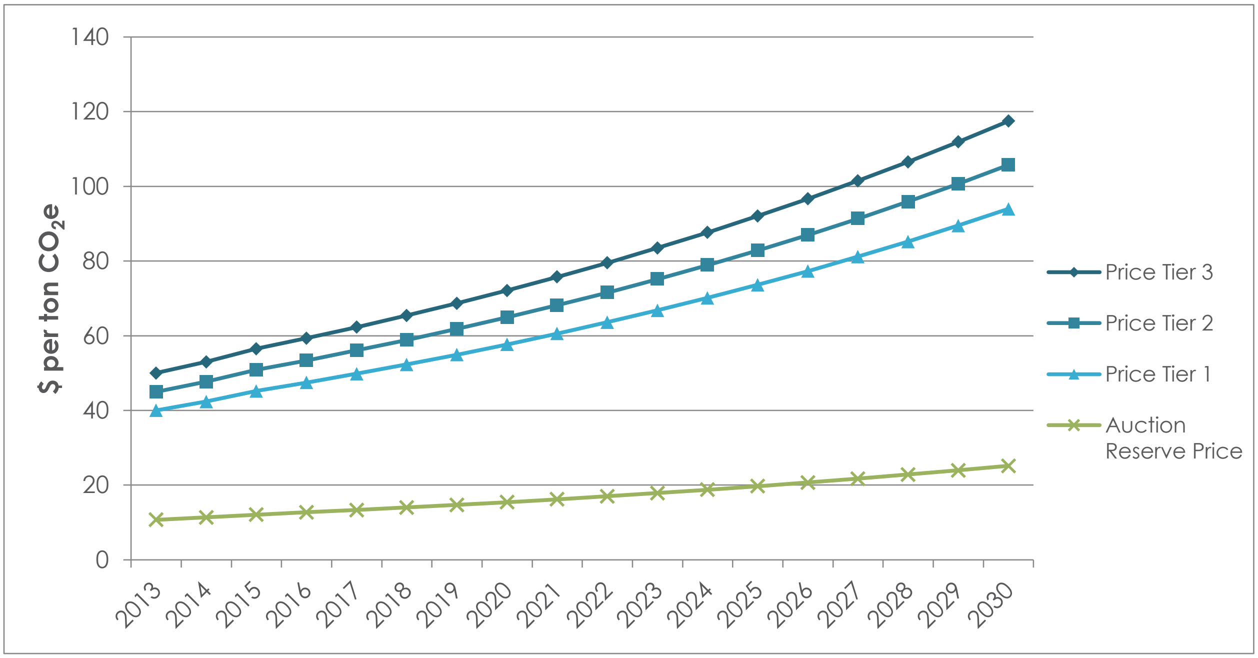
Figure 3 – Maximum Possible Reserve Availability Over Time

Figure 3 illustrates that the proposed extension of the program will offer significant flexibility. It displays in blue the amount of allowances carved out of the initial cap levels for placement in the Reserve. The new information displayed is the amount available in each year for borrowing in the event that the Reserve allowances sell out. This maximum level of borrowing equals the sum of 10% of six years into the future. The sharper drop off in the availability of these starting in 2028 reflects our reticence to make an assumption about how the program will be structured post-2032. We would recommend the program be defined further into the future prior to 2028. This would increase the availability of allowances for borrowing in 2028 and thereafter. However, we have not integrated such an assumption in Figure 3.

We propose extrapolating the current definitions of the Auction Reserve Price and prices for tiers of the Reserve in the post-2020 cap. Figure 4 shows the prices for these triggers for each tier and the cap-and-trade program's price floor (Auction Reserve Price as referred to in CARB's regulatory definitions). The Auction Reserve Price is the minimum price at which allowances are to be sold at auction. This started at $10 per ton of CO_2e in 2013 and increases at 5% plus inflation annually. Tier prices per ton of CO_2e start at $40 for Tier 1, $45 for Tier 2, and $50 for Tier 3, and also increase 5% annually.

Figure 4 shows that by 2030, the prices for the three Tiers range from $93 to $116 per ton of CO_2e and the Auction Reserve Price reaches just over $25 per ton of CO_2e. These dollar values do not incorporate future inflation. Thus, in effect, prices are in 2015 dollars.

Figure 4 – Prices for Auction Reserve Price (current program and proposed extension)



At an annual growth rate of 2%, the gross state product would reach $3.1 trillion in 2030. Even at the highest tier price, the total value of allowances under the cap in 2030 does not exceed 1% of the overall economy. Importantly, due to auctioning of allowances, if prices were to increase to this level, CARB would collect an amount of revenue for public interest use that is roughly equal to these compliance costs.

3.2. ACCOUNTING FOR UNCAPPED EMISSIONS IN THE CAP-SETTING PROCESS

Having established this recommended cap-and-trade structure, we turn to the question of emissions that fall outside of the program. The cap-and-trade proposal developed here is based on some simplified assumptions about these uncapped emissions. California must make progress on these uncapped emissions for the state's 2050 target to be achievable.

In order to set the annual caps to achieve the desired economy-wide reductions, we must consider uncapped emissions. Uncapped emissions are those not directly covered under the cap-and-trade program. These include entire sectors of the California economy, principally agriculture, forestry, and waste. Even in sectors covered by cap-and-trade, there are some emissions that remain uncapped, such as methane emissions from the oil and gas sector. Over time, CARB should increasingly bring uncapped emissions under the cap-and-trade program as advances in sensors, other monitoring equipment, and analytical techniques continue to improve and allow for their inclusion. However, absent a clear indication of how the scope of the cap-and-trade program will expand, this analytical framework assumes that the scope remains the same.

We estimate that uncapped sources will represent 22.5% of aggregate emissions in 2020. This is more than the 15% share they currently represent. This value is reached as follows: CARB set the level of the cap in 2020 at 334 MMT of CO_2e. AB 32 sets a target of 431 MMT of emissions in 2020. These values imply that CARB expects emissions outside of the cap-and-trade program to be no more than 97 MMT, or 22.5% of the total statewide inventory, in 2020. In reality, capped emissions are expected to be well below 334 MMT, as discussed later. However, CARB cannot count on this, but rather should drive down emissions in uncapped sectors in a way that allows for the possibility that capped emissions rise to the level of the cap in 2020.

Given that there are more policy instruments targeting capped sectors, it makes sense to expect that these emissions will fall more quickly. This expectation is also consistent with the assumption in our analytical framework that uncapped emissions rise from 15% of the statewide inventory today to 22% in 2020.

Though uncapped emissions are arguably more challenging for policymakers to address, meeting the 2050 cap will not be possible without significant improvements in these sectors. Policymakers know this and are targeting these emissions through a number of measures. The *First Update to the Scoping Plan* (pages 96-98) identifies next steps for agriculture (five action items); waste management (six action items); natural and working lands (six action items); and short-lived climate pollutants (seven action items). Additionally, the scope of cap-and trade should broaden to cover more sources over the period being considered. For these reasons, our analytical framework assumes that emissions outside of the cap-and-trade program will decline, even if not as quickly as within capped sectors.

More analysis will be needed to understand trends in uncapped emissions and the likely impact of planned policies. For this paper, we assume that post-2020 emissions not under the cap-and-trade program fall at half the rate of those in capped sectors. As a result, by 2030, reductions in uncapped sectors produce 11% of the overall reductions required in 2030 (half of the 22% of their overall emissions in 2020). This implies that the annual rate of uncapped emissions falls by 19 MMT of CO_2e from 2020-2030, dropping total uncapped emissions from 97 MMT to 78 MMT. We further assume that these reductions grow at a constant rate of 1.9 MMT per year over the time period.

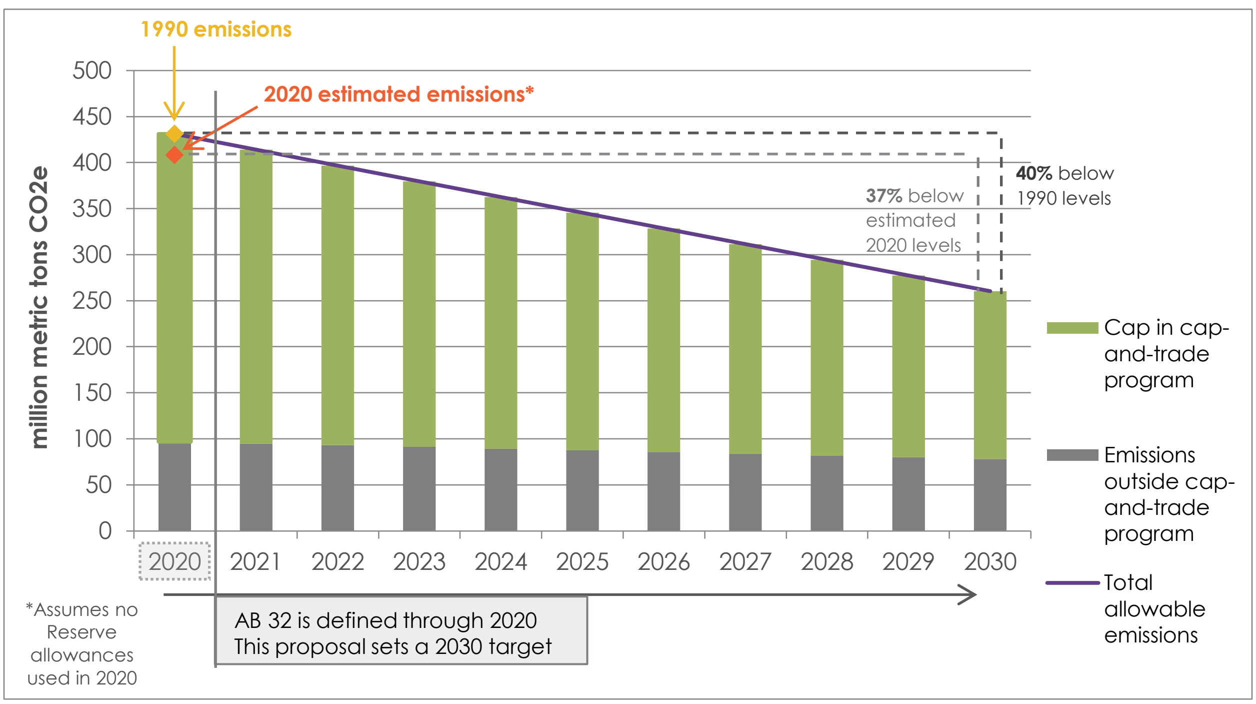
Table 2 presents the summary statistics for the recommended cap-and-trade structure under these assumptions about uncapped emissions.

Table 2 - Summary stats describing the proposed emission path to 2030

	MMT
Big picture	
1990 level of emissions	431
40% reduction compared to 1990 level	172
2030 emissions limit of 40% below 1990	259
Cap-and-trade specific parameters	
Initial cap level in 2030 (before allowances are set aside for the Reserve)	181
Allowances taken from initial 2030 cap and placed into the Reserve	13
2030 cap level after allowances are set aside for the Reserve	168
Focus on annual reductions	
Annual linear reductions – capped plus uncapped emissions	17
Annual reductions within emissions covered by cap-and-trade	15
Annual reduction in uncapped emissions	2

Figure 5 illustrates the pathways for both capped and uncapped emissions, given the aforementioned assumptions about uncapped emissions. In this graph, to better illustrate dynamics in capped and uncapped emissions, we leave aside the complications of the 7% of allowances recommended for the Reserve and the 10% available for borrowing. The graph also does not show year-to-year fluctuations possible due to flexibility mechanisms.

Figure 5 – Proposed Emissions Pathway to 2030



The recommendations developed here aim for a 40% reduction below the 1990 level of emissions. Figure 5 illustrates the economy-wide dynamics of the proposal, and the slight difference between the level of 2020 emissions reductions required under AB 32, a return to the 1990 level, and the level expected for 2020. The expectation is that the Reserve will not need to be accessed through 2020, meaning that expected 2020 emissions will be slightly below the 1990 level. The rationale for this is discussed in the next section.

Figure 6 brings together the perspectives shown in Figure 2 (showing cost compliance mechanisms under cap) and Figure 5 (showing the interplay of emissions under and outside of the cap-and-trade program).

Figure 6 – The pathway to 40% below 1990 emissions showing flexibility mechanisms within cap-and-trade

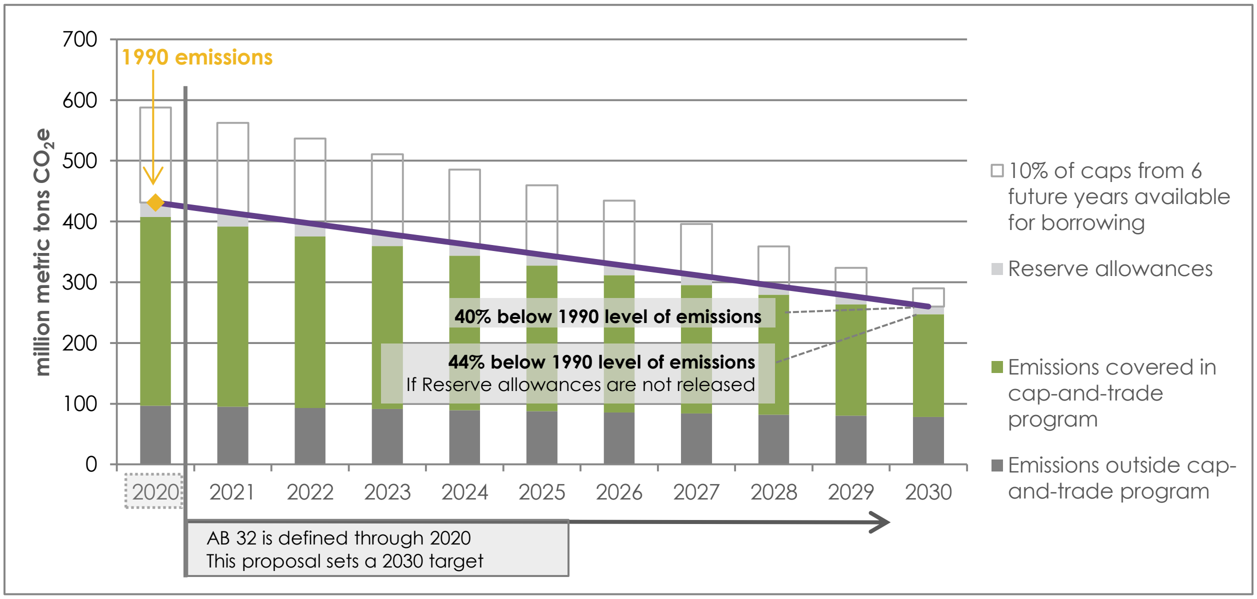


Figure 6 shows that if prices stay low and allowances from the Reserve are never tapped, statewide emissions would fall 44% below the 1990 level of emissions. If allowance prices rise high enough, released Reserve allowances would allow for higher emissions. Despite this potential for annual variation, cumulative emissions would still have a fixed limit equal to the sum of all the annual caps over the life of the extended program.

4. RATIONALE FOR OUR RECOMMENDATIONS

Moving from the more specific (cap-and-trade design) to more general (statewide cap-setting), this section explains the reasoning that underlies these recommendations.

4.1. ARGUMENT FOR THE PROPOSED CAP-AND-TRADE STRUCTURE

The current approach to cost containment under cap-and-trade should be extended because it strikes a smart balance between short-term flexibility and the imperative of staying within carbon budgets over the long run. The goals of emissions quantity and allowance price certainty are always in tension, to some extent (Weitzman 1974). While cap-and-trade offers year-to-year flexibility, CARB has structured the program to ensure that cumulative emissions are capped. Cumulative emissions drive climate change,[4] after all, so it makes sense to offer short-term flexibility within the context of a long-term fixed budget.

We chose a linear rate for tons reduced over time. This extends the approach California has used in its program design to date, and provides an incentive for steady progress toward the 2030 target. The level of the proposed 2030 cap under cap-and-trade is ambitious, but it combines stringency and flexibility. If allowance prices remain low and the Reserve remains untapped, the cap would be automatically tightened. If allowance prices are higher than expected, there is significant room for the cap to adjust using allowances in the Reserve.

We are recommending that 7% of annual allowances be placed in the Reserve. This is the same percentage used in the third compliance period (2018-2020). CARB steadily increased the reserve allocation through the first few compliance periods, but we feel 7% is an appropriate steady-state value.

We are not recommending unlimited forward borrowing, but instead recommend borrowing six years forward on a rolling basis. Unlimited borrowing would allow too large a deviation from the desired emissions pathway. If unlimited borrowing were allowed in 2017, that would make over 500 MMT in allowances available when borrowing post-2020 and allowances initially put into the Reserve are taken into account.

We suggest that any allowances remaining in the Reserve at the end of 2020 be retired. The initial cap levels were set before the full impact of the 2008 economic downturn was understood, and we would argue that the initial cap levels were set too high. Retiring allowances still remaining in the Reserve at the end of 2020 is a step toward correcting this. The post-2020 program will continue to allow more than adequate flexibility starting in 2021 under the newly defined structure.

Banked allowances should continue to be viable for compliance in the newly defined compliance periods, as these are allowances that entities have acquired or retained specifically to guard against potential high costs in the future—exactly the behavior that flexibility mechanisms are set up to encourage. Banking also has the effect of encouraging early emissions reductions because those under the cap do not face a "use it or lose it" situation. Perhaps most importantly, prohibiting the use of banked allowances post-2020 would create an incentive to use them prior to their expiration date.

4.2. ARGUMENT FOR CAP-AND-TRADE AS A BACKSTOP FOR SECTORAL POLICIES

A good amount of consideration and debate has surrounded the balance of cap-and-trade and other policies in the California climate policy debate. This paper does not attempt to solve the analytical puzzle of optimizing the balance of policy instruments across California's portfolio of climate and energy policies. We argue for a continuation of the current approach of having a portfolio of policies, with cap-and-trade spanning nearly the entire economy as an emissions ceiling on top of a foundation of sector policies.

We briefly offer some of the arguments for inclusion of a cap-and-trade program. It clearly makes sense to put a price on GHG emissions. Doing so ends the unpriced carbon pollution externality (economic terminology for a cost or benefit imposed on society due to economic activity, but not reflected in the prices driving profit-making decisions). Moreover, cap-and-trade and other economic incentive programs have stood up particularly well to economists' cost-benefit analyses. One lesson from the research is that

[4] The IPCC's (2013) ratification of the notion of a global carbon budget, building on earlier work by Harvey et al. (2013) and others, makes it clear that this is the best way to frame the challenge.

the flexibility of market incentives contributes to the cost-effectiveness of such policy instruments (Morgenstern 2014).

Turning to California-specific arguments, the state's cap-and-trade program is running smoothly. It is also providing revenue for public investment that will help to smooth the transition to a low-carbon economy. The revenue is efficient, per economic theory, in that it prices an otherwise unpriced external cost. More details about the program's performance can be found below.

While this paper argues for the value of using the cap-and-trade program as a capstone of a 2030 package of policies, sector-specific policies should continue to be the foundation for California's statewide carbon reduction efforts. Complementary policies are still needed to overcome market failures that are not best solved by a price on carbon emissions. Additionally, complementary policies can provide greater investment certainty and drive innovation. For example, the Renewable Portfolio Standard provides a clear investment signal to project developers, while vehicle tailpipe standards push manufacturers to improve car and truck efficiency. Cap-and-trade itself does not guarantee any particular type of innovation, and the price signal is relatively weak, especially when compared to the revenue signal of a power purchase agreement signed due to renewable electricity standards (Taylor 2012).

4.3. ARGUMENT FOR THE 2030 TARGET OF 40% BELOW 1990

We start with the argument in brief, and then offer details and citations point-by-point.

1. Adopting a 2030 target of 40% below 1990 emissions levels will maintain California's global climate leadership.
2. Two recent and authoritative studies of global emissions pathways that are downscaled to national commitments suggest that a 2030 target of this magnitude in California is required if the world is to avoid dangerous climate change.
3. Reducing GHG emissions mostly involves a transition away from the combustion of fossil fuels, which delivers important local air quality benefits. Studies have shown that the transition to cleaner fuels will likely need to exceed those modeled here to meet federal air quality standards.
4. A stronger climate target will bolster California's already established and rapidly growing clean technology industries. These companies, and the jobs they offer, have been growing quickly in California, and there's no evidence of any net macroeconomic downside.
5. Two recent studies indicate that an emissions reduction of 40% below 1990 levels is technically feasible and one finds low net costs in comparison to the overall size of the economy.
6. Finally, this strong target seems warranted as costs have, so far, been on the low side of expectations. The program is performing well.
7. Forecasts of program performance through 2020 are also favorable.
8. Our analysis shows that by 2020 entities under cap-and-trade are likely to have banked significant quantities of allowances that they can use to help meet future targets.

These points are now discussed in greater detail.

1. Maintaining California's leadership

In light of pledges made by the European Union (EU) and by the Obama administration for the United States as a whole, a reduction target of this magnitude is needed to maintain California's leadership.

Examples of other specific commitments:

- The EU has set a 2030 goal of 40% below 1990 emissions levels.
- Within the EU, Germany is arguably California's peer in the sense of viewing itself as a climate champion. Germany has adopted a 2030 goal of 55% below 1990 levels, and it is targeting 40% below 1990 by 2020 (Appunn 2015).
- The United States has set a goal of 26-28% below 2005 for the year 2025. The approach recommended here would achieve reductions of 33% below 2005 for the year 2025 if the Reserve is not used. If the Reserve is used at the average annual rate of 7%, the reduction below 2025 equals 30%.

2. The scientific imperative

Recent research has indicated that reductions of a magnitude similar to 40% below 1990 levels by 2030 are needed for the United States as a whole to contain climate-related damages.

- The International Energy Agency (2014) estimates that U.S. reductions of 37% below 1990 levels and 47% below 2005 levels in 2030 are needed as part of a global effort to offer a 50-50 chance of avoiding global average temperature increases of 2 degrees Celsius.
- A study by the Netherlands Environmental Assessment Agency (2012), which was used to set the EU Target for 2030, also provides a global analysis at the national level. This work apportioned emissions reduction efforts according to the Gross Domestic Product of different countries in order to give the world a 67% chance of staying below the 2 degree Celsius threshold. Under these conditions, in 2030, U.S. emissions must fall 37% below 1990 levels.
- It's imperative to think about our 2050 trajectory as we set a 2030 target. Recent work (Sustainable Development Solutions Network 2014) finds that U.S. emissions need to fall by an order of magnitude as part of a global effort to stay within 2 degrees Celsius of warming. Moreover, comments on this national level goal conclude that "it is technically feasible for the U.S. to reduce CO_2e emissions from fossil fuel combustion to less than 750 MMT CO_2 in 2050, which is 85% below 1990 levels and an order of magnitude decrease in per capita emissions compared to 2010," (p. 202).

This implies that the 2050 goal California has set, 80% below 1990 emissions, does not exceed California's share of the global effort. Rather, this is the minimum California should aim for. In 2010, U.S. energy-related emissions were approximately 18 metric tons (Mt) of CO_2 per person. Given the order of magnitude remark in the quote above, this implies that we need to shift to a nationwide emissions level of 1.8 Mt in CO_2e per person by 2050. In California, 2010 emissions were 12 Mt per person, implying a shift to 1.2 Mt per person in 2050 – even less than the 2050 goal. If California needs to only get to the implied national average in the Sustainable Development Solutions Network study, 1.8 Mt of CO_2e per person, the 2050 goal only barely surpasses this at 1.7 Mt per person.

3. Helping to achieve air quality goals

The reductions needed to get to the proposed 2030 carbon target will help meet local air quality goals and vice versa. There is some evidence that even more ambitious reductions in the use of fossil fuels will likely be required to meet the state's federally mandated local and regional air quality goals. Greenblatt (2013) shows that reductions in NO_x emissions will need to be approximately 90% below the 2010 level by 2032 in order to achieve the federal standard. Even Greenblatt's most aggressive scenario (S3), which achieves GHG reductions of 51% below 1990 levels in 2030, yields reductions in NO_x of roughly 80% below 2010 levels by 2032, less than those needed to sufficiently lower smog levels. The investments made to achieve the GHG reductions required by a 40% below 1990 by 2030 target will have multiple payoffs. Efforts to manage GHG emissions and improve local air quality are reinforcing, making each effort more affordable and compelling than they would be in isolation.

4. *Existing analyses indicates technical feasibility and suggest moderate costs*

The recommended target of 40% below the 1990 level by 2030 target is ambitious, but evidence shows it is feasible with technology available today or on the cusp of commercialization. Two recently completed analyses deserve mention. Greenblatt (2015) uses a policy-driven model with detailed technology and energy features to map pathways to a reduction of 41% below the 1990 emissions level in 2030. The technical consulting group Energy and Environmental Economics (E3) (Mahone et al. 2015) used an even more fine-grained representation of energy technologies to map technological approaches to emissions pathways that lead to reductions of 25-36% below 1990. We find these levels of technologically feasible reductions to support a goal such as 40% because E3 does not estimate carbon reductions from some sources, including land-based carbon reductions and energy savings due to water conservation.

E3's work also provides reason for optimism about the economic impact of the recommendations put forth here. Their research analyzes the costs of technology upgrades and the associated energy savings. The study estimates small net costs of attaining those targets (or even small net benefits under some scenarios, such as their highest gasoline price scenario, which considers the effect of a $4.75 per gallon price for gasoline in 2030).

Despite the inherent limitations of such economy-wide studies, it is important for policymakers to keep in mind the full range of expected co-benefits. These studies do not capture all costs either, but we would assert that the missed benefits are larger. The full range of benefits will include local and regional clean air benefits, the quality-of-life benefits of better urban design, and more robust technology innovation, which lowers the cost of clean technology and spawns vibrant new industries and companies that are making the products the world increasingly wants to buy. These economic opportunities are described next.

5. *Supporting clean tech innovation*

Given California's many clean tech jobs and industries, plus the potential for even greater innovation, the state should look at climate action as an economic opportunity. More ambitious targets will help drive technological progress, a process called induced innovation. As explained by Stanford economist Larry Goulder, "by stimulating additional technological change, climate policy can reduce the costs of meeting a given target for reductions in GHG emissions or concentrations. The presence of Induced Technological Change justifies more extensive reductions in greenhouse gases than would otherwise be called for" (Goulder 2004, p. iii).

By supporting energy technology innovation, California will be putting companies in a position for strong growth. Across a range of markets, cleaner technologies that are more efficient or less polluting are the fastest growing segments. In electricity generation, for example, 90% of new investment in U.S.

electricity generation capacity was for solar and wind power in January 2015 (Shahan 2015). For all of 2014, wind and solar accounted for 55% of new investment in U.S. electricity generation capacity (Ibid.).

Green jobs in California have been growing very quickly. Some 57,000 people are employed in the solar power industry in California today and 10,000 more are expected to be added in 2015 (The Solar Foundation 2014). Tesla Motors is now the largest auto sector employer in the state, with 8,000 workers in California (Olsen and Hochschild 2015). Tesla is also pushing the electric vehicle industry forward on cost and performance, hinting at a profound transformation in mobility.

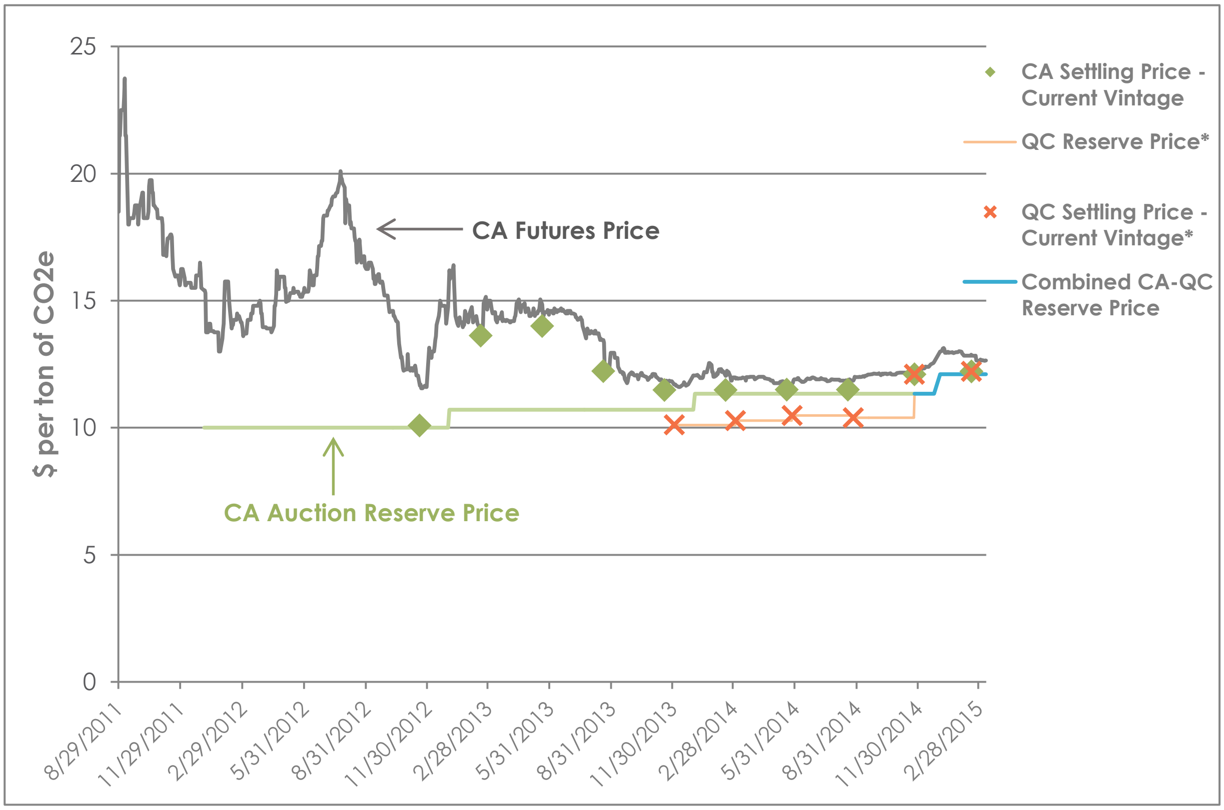
A larger review of the bright spots in California's green economy is beyond the scope of this paper, but it is clear California's economy is one that thrives on innovation. The biotech and IT industries are other examples. Critics say focusing on green jobs misses the big picture, but California has been outperforming the national economy for years. There is no compelling evidence that California's climate and energy policies are leading to net negative macroeconomic effects.

To the contrary, the state's overall business climate is strong. Since 2011, "the 63 publicly traded California companies in the Standard & Poor's 500 produced the best total return among the five states with the largest populations. California companies in the S&P 500 delivered returns of 134%; the closest big-state challenger was Florida, whose S&P companies had an 82% return," (Winkler 2015). In the year 2014, California created 27% more jobs than Texas, and the momentum is likely to continue as the state has set records in share of venture capital funding, exports, tourism, and tech industry growth (Levy 2015).

6. *Strong early program performance*

Since the first cap-and-trade auction was held in November 14, 2014, allowance prices have remained relatively stable and much lower than industry-funded forecasts offered before the program. Low prices in early years of the program are one indicator that compliance costs are coming in on the low side of expectations so far. This is a positive sign. Though one cannot place too much weight on the implications for future prices, given that the amount of emissions reductions demanded has been modest thus far. Figure 7 shows prices at auction in California and Quebec, and also shows futures contract prices for California allowances.

Figure 7 - California (CA) and Quebec (QC) Allowance Price History



(Source: Energy Innovation graphic with futures data from the Intercontinental Commodity Exchange, accessed 12 March 2015; CA market data from CARB. Canadian data from the government of Quebec.)

Figure 7 illustrates that the price for allowances has closely tracked the Auction Reserve Price (i.e., price floor) for the last six of the quarterly auctions. Demand has always been strong enough for current vintage allowances to sell out in California. For much of 2013, the price hovered around $15, and the price has dropped to only slightly higher than the price floor in 2014. On December 3, 2014, California held its first joint auction with Quebec. The auction sold out all available allowances from both the 2014 and 2017 vintages that were available for purchase. The 2014 allowances settled at a price of $12.10 per ton of CO_2e as compared to the floor price of $11.34. The 2017 allowances, which cannot be used until that year, sold for $11.86 per ton of CO_2e. The February 2015 joint auction with Quebec also sold out both current and future vintage allowances, with prices settling at $12.21 for 2015 allowances, just above the $12.10 Auction Reserve Price.

Figure 7 also shows that demand was expected to be stronger in the early stages of the program. After the first auction, the next three auctions produced prices significantly above the Auction Reserve Price. The fact that demand was expected to be stronger is evident in allowance futures prices, which are also shown. Allowance futures trading began in 2011, with allowances going for more than $20 each per ton of CO_2e.

CARB also offers allowances of a vintage three years forward. These allowances are not usable in the current compliance period, but only in future ones (note the difference from allowances in the Reserve, which can be used in any year). To avoid complicating the graph, Figure 6 does not track future price vintages. In every case, prices for future vintage allowances have also been very close to the Auction

Reserve Price, which is the same for both current vintage allowances and advance auctions of future vintages. The largest divergence of the settling price for a future vintage allowance from the Auction Reserve Price was in the November 2014 auction. In that case, the future vintage price was $0.52 above the price floor. The entire supply of future vintage allowances has sold out at five of the ten auctions held so far.

7. *Favorable forecasts of cap-and-trade performance to 2020*

The most recent forecasting work comes from Borenstein et al. (2015, 2014). Using inventory data from 1990-2011, the study provides a probabilistic look at future economic impacts due to the cap-and-trade program. They conclude the most likely outcome is that allowance prices are to remain low to 2020. The authors write, "Our empirical assessment of the potential demand for, and supply of, emissions allowances, as well as the offsets that augment this supply, suggests that the most likely 2020 market price will be very close to the auction reserve price floor" (Borenstein et al. 2015, p. 4). In fact, they find a 69% chance that prices will be near the floor (Auction Reserve Price) and a 6% chance the price will rise above the Tier 3 price.

Borenstein et al. (2015, Figure 6, p. 26) forecast the expected level of emissions covered by the cap through 2020 (call these broad-scope emissions, reflecting the expansion of the cap in 2015 to include coverage of transportation fuels). The center of the range of possible values in their forecast is approximately 400 MMT of CO_2e. The latest facility-level data from CARB (2014c) shows broad-scope emissions to be 348 MMT.

We understand the differences to be due to several factors.

1. Differences in emissions from imported electricity. Borenstein et al. used ARB's 2020 Emissions Forecast (ARB 2010), which forecasts about 54 MMT from imported electricity. However, the 2013 mandatory reporting data estimate emissions from imported electricity at 41 MMT (2014c). So, this difference is the source of 13 MMT of the overall difference of about 50 MMT. Keep in mind that the Borenstein et al. work is a forecast of business-as-usual emissions without the cap-and-trade program, so this can be framed as additional abatement that had not been forecasted by CARB.
2. Different treatment of emissions related to transportation and natural gas-distribution emissions. To some extent, this is due to the threshold requirements. Emissions from facilities that emit below the coverage threshold and that are also not indirectly covered in other ways. For example, some natural gas used at small industrial facilities would not be counted as an industrial source, but would be captured under the compliance obligation of a fuel distributor. There are some emissions that are included in sector emissions, but are not covered by cap-and-trade, such as methane leakage from local natural gas distribution, which is estimated at over 1 MMT in the 2013 data.
3. Differences in forecast and actual macroeconomic fundamentals. For example, economic growth may have been faster than had been forecasted.
4. More GHG emissions reductions than expected from capped sources and sector-based policies, for example anti-sprawl measures that have helped to reduce the amount of driving (in combination with other structural changes and shifting preferences) that resulted in less demand of gasoline and diesel fuels.

David Roland-Holst of U.C. Berkeley has been one of the most consistently engaged researchers analyzing these topics (e.g., Roland-Holst 2006). His work has correctly forecasted the current low prices, and his 2020 price forecasts have consistently been in the low 20s. In recent work (2010), Roland-Holst's most likely 2020 estimate is $21 per ton of CO_2e, with a possible range of $18-$43 per ton.

8. *Availability of banked allowances in future years*

We conducted a rough analysis to estimate that allowances banked through the end of current program (by the end of 2020) could be in the range of 80-120 MMT of CO_2e. Early banking makes future targets more easily achievable.

Our estimate of the expected amount of banking is based on three inputs.

1. *An assumption that emissions are flat from 2013 onward:* The latest facility-level information from CARB's 2013 mandatory reporting data (CARB 2014c) finds that the emissions corresponding to the scope of the cap in 2015 amounted to 348 MMT for the year. We choose this level in an effort to avoid overestimation of banking. It is reasonable to expect declining emissions from 2014-2017 because of increasing requirements in the realms of renewable electricity supply, transportation fuel supply, building energy standards, vehicle efficiency standards, and a plethora of other policy initiatives that will be increasing in stringency over the time period. Also, spending of auction revenue from cap-and-trade on projects to reduce GHG emissions will be increasing. For these reasons, it seems cautious to assume that statewide emissions will remain flat through 2017. Economic and population growth are factors that would tend to push emissions upward.
2. *Offset uptake starts slow, but picks up:* As of March of 2015, about 17 MMT[5] in offsets had been cleared for compliance use in California. At the end of 2014, covered emitters had acquired and placed in holding accounts 10.7 MMT in offsets. In the compliance event that took place in the fourth quarter of 2014, offsets accounted for 3.9% of compliance.[6] To factor in some of the uncertainty around offsets use, we estimated lower and higher offsets use scenarios. In the lower use scenario, we assume that offsets account for 3% of compliance in this compliance period and 4% of compliance in the next. In the higher offset use scenario, we assume a growth to 15 MMT in 2015 and an increase at a rate of 5 MMT annually thereafter, until the fully allowed amount of offsets is used in 2018 and thereafter. If more offsets are used than the amount assumed here, that would mean that fewer allowances would need to be used for a given amount of emissions, thus increasing the potential for banking.
3. *The known cap levels in the cap-and-trade program as defined in existing regulation*.

Table 3 brings these three inputs together.

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[5] CARB "Offsets Credits Issued," dated March 11, 2015 and accessed March 20, 2015.

[6] This information is available in spreadsheet form from CARB's website. However, we cannot directly link to the spreadsheet and it is not especially easy to find. Navigate to the cap and trade information page, then click on "publically available market information," which will reveal an option to click on a "compliance instrument report.")

Table 3 - A simple analysis of the potential for banking allowances through 2020

	2015	2016	2017	2018	2019	2020	Total
Cap	379	367	356	333	322	311	
Use of offsets (lower scenario)	15	15	15	18	18	18	
Use of offsets (higher scenario)	15	20	25	29	28	27	
Estimate of emissions under cap	348	348	348	348	348	348	
Expected banking is the difference between allowable emissions (cap + offsets) and estimated emissions							
Banking – low estimate	46	34	23	3	-8	-19	**79**
Banking – high estimate	46	39	33	14	2	-10	**123**

Under these assumptions, banked allowances would amount to roughly 80-120 MMT by the end of 2020.

4.4. A DEEPER LOOK AT THE E3 ANALYSIS

E3's recent research is arguably the most important study on the topic of choosing a 2030 target, given its integration of energy, emissions, and economic factors, and since it was commissioned by state policymakers. This section discusses the work in greater depth.

In 2030, E3's central scenario yields a 31% reduction below the 1990 level in statewide GHG emissions, with cost estimates ranging from a net saving of $4 billion to a net cost of $11 billion (all values in current dollars). At the midpoint, annual costs amount to $2 billion in total, or about $50 per household in 2030 (values in current dollars). Framed differently, $2 billion would amount to 0.07% of the overall size of the economy in 2030, assuming an average of 2% annual growth going forward. At 2% growth, the $2.2 trillion economy of 2013 expands to $3.1 trillion in 2030. Variations in these cost numbers can be scaled linearly, so $4 billion in 2030 costs would equal 0.14%, and so forth.

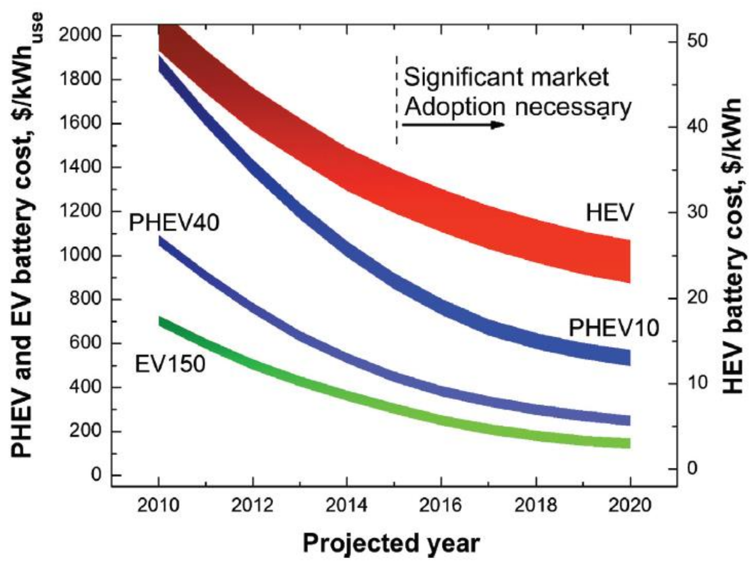
The E3 results suggest that reductions on the order of those recommended here can be accomplished at moderate cost. We come to this interpretation for two reasons: (1) cost declines in clean technology are likely to occur faster than their study assumes, and (2) reductions beyond those included in their study will likely be available.

On the cost side, E3 has been conservative in anticipating cost improvements. Some caution is called for in setting middle-of-the-road expectations. Moreover, our understanding is that the research involved significant consultations with working groups across state agencies, and outside experts and stakeholders. Such an involved process necessarily makes it challenging to keep up with the rapidly falling cost of renewable energy. The case of solar power from photovoltaic (PV) panels on residential rooftops provides an example. The residential PV capital costs estimates used by E3 for 2050 are higher than actual national capital costs as reported by GTM/SEIA (2015) for Q4 2014. E3 pegs the cost of residential PV 2015 at $5.26 per watt (W), with the expectation that it will drop to $3.79/W in 2050. GTM/SEIA estimate the capital cost of residential rooftop solar for Q4 2014 at $3.48/W, however, this is a national figure. To round out the comparison, it makes sense to consider that costs are somewhat higher in California. The most recent data show that costs for solar PV are about 12.6% higher in California (E3

2014, Table 35). Taking this into account, and the fact that California is more than half of the market, we adjust GTM/SEIA's Q4 2014 number upward by 6.3%. This would imply a Q4 2014 cost in California of $3.70, which is lower than the price forecast for 2050 in the E3 study.

The cost of battery electric vehicles is another case where we are more optimistic. Inspection of E3's graphical presentation of advanced vehicle cost assumptions (Mahone et al. 2015, p.79) shows a roughly 15% decline by 2030.[7] E3 does test a low price for cleaner technologies scenario. The low-price scenario only allows for an additional 5% decline in battery electric vehicle prices. Our reading of the current trends and industry forecasts suggests that this underestimates the likely pace of improvement.

Figure 8 - Vehicle battery cost reduction forecast due to Gallagher and Nelson (2014)



Batteries are the most important, albeit not the only, reason for the current cost differential between electric drive vehicles and internal combustion engine vehicles (National Research Council 2013). Gallagher and Nelson forecast strong improvements, writing, "the cost of batteries for HEV, PHEV, and EV[8] applications will decrease significantly over the coming years. A steep drop in these costs is already being witnessed," (2014, p. 124). They assemble the best current forecasts as shown in Figure 8.

Impressive gains are being made across the battery industry. A Brattle study finds that "Most importantly, several battery storage manufacturers have indicated that their costs will decrease substantially over the next few years. Public reports now forecast cost declines from the current $700-$3,000/kWh of installed electricity storage in 2014, to less than half of that over the next three years. Some analysts' projections and vendor quotes point to even more significant cost reductions, forecasting that installed costs of battery systems will drop to approximately $350/kWh by 2020," (Chang et al. 2014, p. 1).

Strong cost declines are being seen across applications (meaning the above forecasts for stationary storage has applicability to vehicles), as seen in a recent Citi Research report, which also forecasts significant near-term improvements in automotive battery costs, as shown in Figure 9 below.

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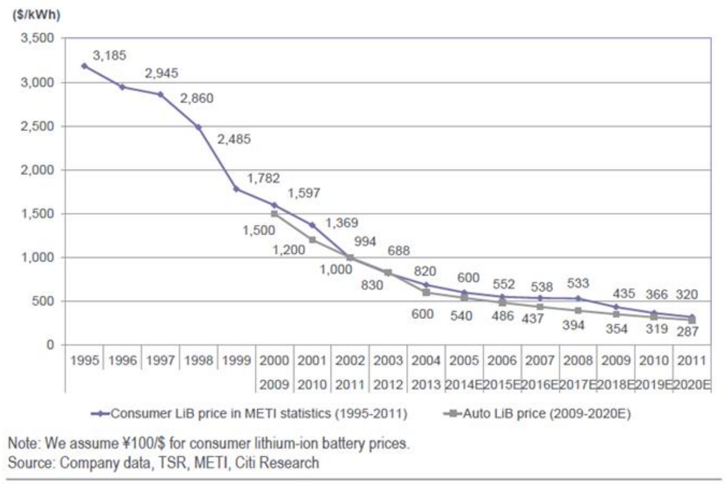
[7] E3's preliminary report does not provide numerical results for this assumption, but they have recently released a large set of data related to their work, which will provide a useful input to further policy analysis for months and perhaps years to come.

[8] HEV is the abbreviation for hybrid electric vehicle, PHEV is the abbreviation for plug-in hybrid, and EV is the abbreviation for battery electric vehicle.

Figure 9 - Historical Price Declines in Consumer and Automotive Lithium-Ion Batteries (Citi 2015)



Some of the areas where additional greenhouse gas reductions may exist beyond those quantified by E3 include: (1) land-based measures, (2) water efficiency, and (3) steps to reduce vehicle miles traveled.

Including land-based emissions reduction measures was outside the scope of E3's study. Land-based emissions reductions would include forestry protection and management, improved land practices, and protecting carbon sinks by limiting sprawl. There are questions about the impermanence of these land-based mitigation measures, but these seem manageable with a portfolio risk management approach (meaning as long as a collection of measures and projects are included with enough redundancy, a reasonable degree of certainty can be ascribed to the promised reductions). E3 did model reductions in demand for water and for car travel (i.e., vehicle-miles traveled), but our sense is that the assumptions are conservative and that more may be possible. Water efficiency measures would save energy because nearly one-fifth of the state's electricity use is for water transport.

Emissions reductions from reduced vehicle-miles traveled are attractive because this is an opportunity to help households lower their gasoline bills while improving mobility, quality of life, and access to goods and services without having to be dependent on a car. Nearby access is, to some extent, a preferred alternative to having to travel by car to satisfy demands for goods and services. The increasing consumer demand for housing that is close to city centers and near transit is evident in work by Nelson (2012), who estimates that in 2035, given current trends, the demand for transit station-accessible housing in California will exceed the supply by 4 million units, while there will be an oversupply of conventional suburban homes. Whereas car travel was something of a luxury good for baby boomers, for many millennials, car dependency is a lifestyle sacrifice they would rather not make.

5. NEXT STEPS FOR RESEARCH

In this section, we highlight some of the limitations of this work, and suggest some next steps for research. Much more evaluation of uncertainties is needed, especially an understanding of interactions among flexibility design features. When does flexibility become too large? This paper has only begun to highlight how flexibility mechanisms could interact, from banking to the Reserve to forward borrowing of up to 10% of future allowances.

This paper has relied on a simplistic approach to forecasting how emissions not subject to the cap-and-trade program will evolve over time. Much more work is needed to understand the baseline trends and emissions reduction opportunities in uncapped emissions.

E3's work provides a strong, bottom-up technological evaluation to build on. More work should be done to explore the 2030 supply curve for GHG emissions reductions and the economic effects their capture will entail. We would like to see the representation of policy-induced innovation, for example.

Policymakers are looking for more guidance from modelers on how to optimize across a suite of energy and climate policies, including how to strike the right balance between the emissions reduction efforts carried by cap-and-trade versus sector-specific policies. The modeling community is working to better represent the relevant dynamics. The challenge is to build an endogenous interaction of policy effects within a modeling framework. Computable general equilibrium models allow for the exploration of pricing policy instruments, but other policies must be represented via exogenous inputs. This effort should build on the collaborative modeling experiment that was held at CARB (Busch 2010) and the recent California Climate Policy Modeling dialogues at U.C. Davis (first dialogue summarized by Morrison et al., 2014). Now that we are starting to accumulate some years of experience with AB 32 policies, more *ex post* econometric analysis is needed. This empirical work can start to answer some of the questions raised in Section 4.2 about the optimal balance between cap-and-trade and sector-specific policies in a package of policies to achieve 2030.

In the argument for 40%, we make the case that local and regional clean air benefits from climate mitigation measures will be large and should be taken into account. We stand by the need to better factor in the public health benefits of climate policy mitigation. But there is a larger need to have more integrated, systematic policy formulation to address air quality challenges, from global to regional to local. It makes sense to have integrated policy decision-making where optimization questions are intermingled. Climate policy affects energy use, which affects air quality broadly, as long as fossil fuel combustion remains an important energy source. In light of this, we stand by the need to consider the value of co-benefits in deciding the right level of the emissions cap, and whether or not the allowance price is correctly reflecting the marginal social cost. What might be preferable would be a system of statewide, regional, local, and even neighborhood-level pricing schemes. Rapid improvements in air quality monitoring technology and its falling costs will allow for collection of more localized, spatially differentiated data on co-benefits and externality costs. In turn, this will allow for more precise targeting of pricing and other policy interventions at different scales.

6. CONCLUSION

Our proposed target of 40% below the 1990 emissions level by 2030 is an ambitious but achievable goal. At that pace, California would be halfway to the 2050 goal in one-third of the time. The proposal joins stringency and flexibility: If the goal proves easy to achieve, allowance prices will stay low, and some allowances will remain unused in the reserve. Under such circumstances, statewide reductions would be 44% below 1990 by 2030 (taking our treatment of uncapped emissions as a given). On the other hand, if allowance prices turn out to be higher, there are a significant numbers of allowances for sale at increasing prices to provide cost containment within the context of a cumulative cap. We believe the proposal detailed here sets the right course, and while the details remain subject to discussion and adjustment, we are confident that this is the right path for the state. We are optimistic, as California is poised to renew and deepen its commitment to proving that the low-carbon economy is a quality upgrade. As we provide the demonstration project for decarbonized prosperity, people in China, India, Mexico, and many other places are watching.

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[9] Professor Bushnell presented a 95% confidence interval range for the price of gasoline per gallon in 2030, citing modeling done by Professor Frank Wolak of Stanford University. The range was approximately $2.5-$8 per gallon in current dollars by inspection of the graph shown. We have requested the precise numerical values but have not yet received them. The work is unpublished but the results from the same model through 2020 are used in Borenstein et al. 2015).

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[10] We were not able to find separate confirmation of the figure of 8,000 Tesla workers in California, apart from this Op-Ed. A piece in Bloomberg Business (Ohnsman 2014) from mid-2014 put the figure at 6,000 with 500 jobs to be added in the following year.

APPENDIX 1. DETAILS ON CAP-AND-TRADE STRUCTURE

The cap-and-trade program's three-year compliance program means that 2030 would be the first year of a three-year compliance period. To avoid complicating the discussion, and in light of the policy dialogue's focus and our presentation of results on the 2030 timeframe, graphs in the body of the report only extend through 2030. For completeness, this appendix gives the details through 2032.

We start with a numerical description of the program to 2032. Table A1 shows the cap levels remaining after 7% of allowances have been set aside for the Reserve. The cap is shown in two parts, the 10% available for borrowing and the remaining 90%.

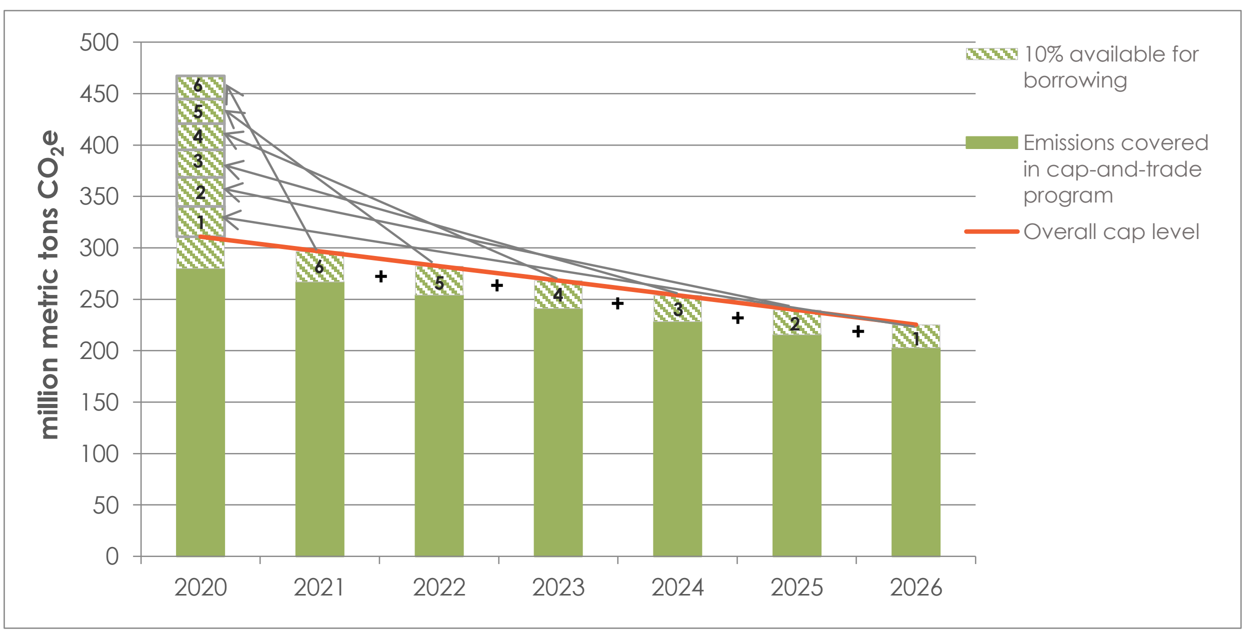
Table A1 - Numerical values of the proposed cap levels

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Cap (less 10%)	297	282	268	254	240	225	211	197	183	168	154	140
10% of cap	30	28	27	25	24	23	21	20	18	17	15	14

In addition to these annual caps, the proposed design sets aside allowances 197.1 MMT in allowances for the Reserve. This sum is divided into three equal sized Tiers, each containing 65.7 MMT in allowances.

Figure A1 provides a visual explanation of how CARB might access additional allowances to fill the Reserve through the forward borrowing mechanism if demand for allowances exceeds the amount initially placed in the Reserve. If the initial allocation to the Reserve is depleted, then CARB will make available up to 10% of the allowances from the annual caps from six subsequent years starting with the most distant year. For example, in Figure A1, if 2020 is the current year, then 2026 would be the first year accessed. If 10% of allowances from 2026 were not enough to satisfy demand, then up to 10% of allowances from 2025 would be accessed, and so forth. CARB would adjust downward future cap years to account for this borrowing.

Figure A1 – Diagram of forward borrowing in proposed cap-and-trade program



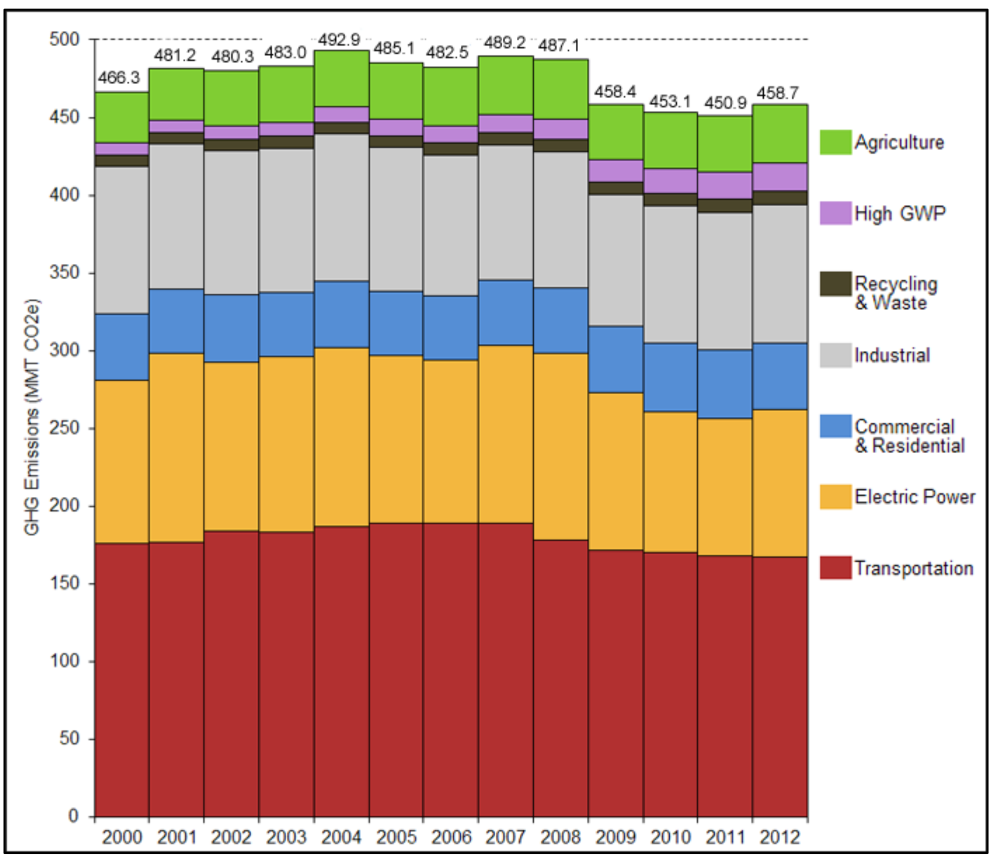
APPENDIX 2. DISCUSSION OF APPROACH TO UNCAPPED SOURCES

This Appendix discusses how our analytical framework establishes the proportion of uncapped emissions and their expected trends. This is a necessary assumption to extend the scenario analysis beyond capped sectors. We have assumed that these emissions fall at a slower rate than energy sectors. There are technical and political hurdles to regulating these sources. Yet, they must be part of the solution. Advances in monitoring technologies should offer new opportunities to fold these sectors in to the cap-and-trade program. Thus, it seems reasonable to assume progress (emissions reductions) in these sectors, even if the expected pace is slower than in the energy sectors.

Agriculture is the single largest sector not under the cap, as shown in Figure A3. Waste and recycling as well as high Global Warming Potential gases are also not directly subject to the cap. High Global Warming Potential gases include methane and fluorinated gases: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). On an equal-mass basis, these are more potent drivers of climate change than the more prevalent emissions of carbon dioxide, which is the single largest contributor to global warming.

One recent study found forestry was a source of emissions over 2000-2008 (Battles 2014) and the topic is now receiving renewed study.

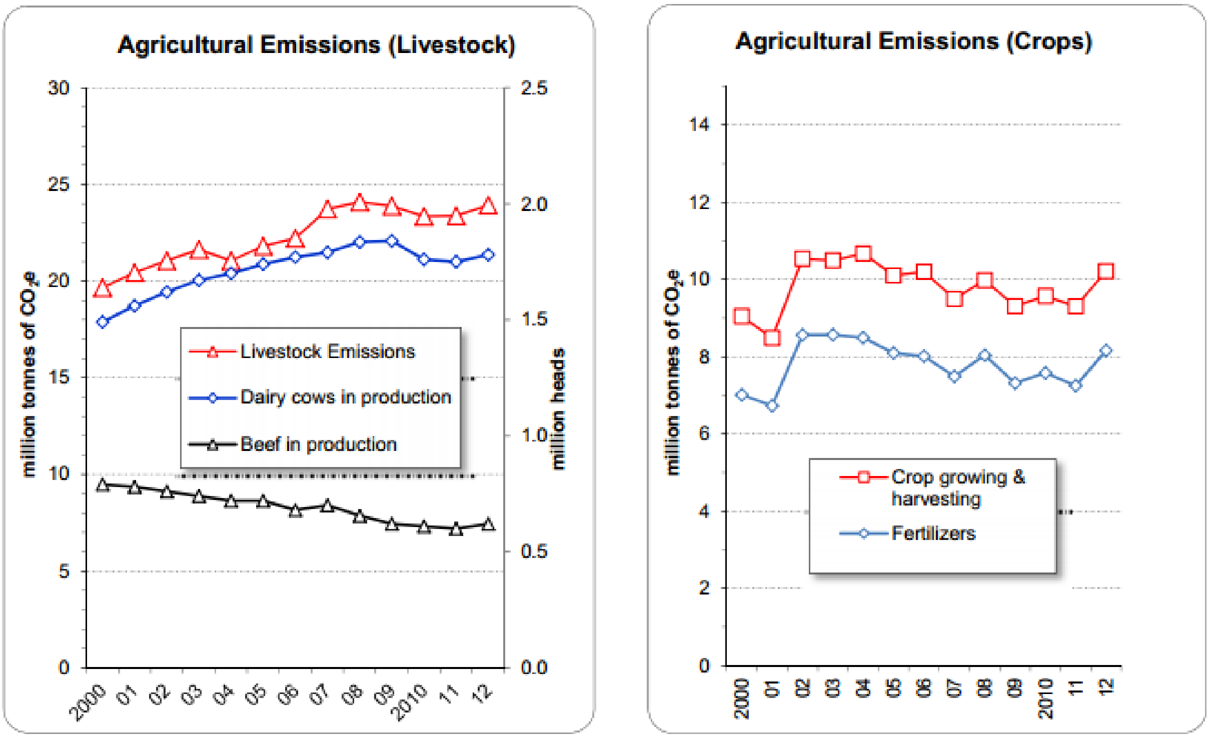
Figure A2 - Agriculture is the largest source of uncapped emissions



Source: California Air Resources Board. 2014. Greenhouse Gas Inventory

Turning to the agricultural data, emissions have been flat for crops, and were trending upward for livestock until 2008, when they leveled off.

Figure A3 - Agricultural sector emissions have been rising (livestock) or flat (crops)

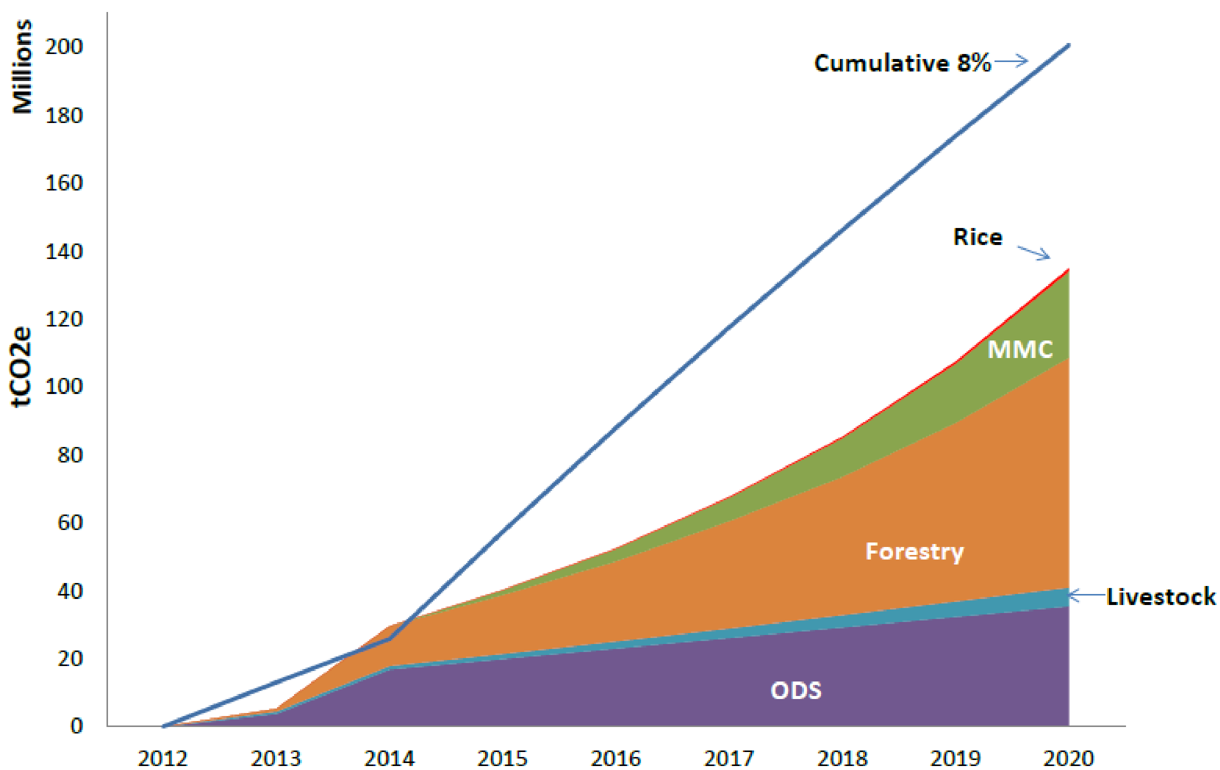


Source: California Air Resources Board. 2014. Greenhouse Gas Inventory

The inclusion of the installation of dairy methane digesters as a recommended voluntary strategy has not led to significant adoption. CARB has developed offset protocols that are expected to drive emissions reductions in the agricultural sector, and in discussing the lack of greater progress to date, suggests that stronger incentives or even mandated standards are on the table: "As new information becomes available, ARB will work with stakeholders to determine whether and how the program should become mandatory and/or more strongly incentivized" (p. 57). This statement is emblematic of CARB's commitment to driving down emissions across all sources.

While offsets are just one possible driver of emissions from uncapped sectors, they could be an important force in reducing emissions. ICF International has estimated the following supply of offsets, across all types of offsets through 2020, shown in Figure A3. Not all of these reductions will occur in California, though most will.

Figure A4 - Forecasted offset supply to the California carbon market



- MMC: Mine Methane Capture
- ODS: Ozone Depleting Substance

Source: [Saraf 2013]