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**Managing Uncertainty in Carbon Offsets:
Insights from California’s Standardized Approach**

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Abstract

Carbon offsets allow greenhouse gas emitters regulated under an emissions cap to comply by paying others outside of the capped sectors to reduce emissions. The first major carbon offset program, the United Nations' Clean Development Mechanism (CDM), has been criticized for generating a large number of credits from projects that do not actually reduce emissions. Following the controversial CDM experience, California pioneered a second-generation compliance offset program that shifts the focus of quality control from assessments of individual projects to the development of offset protocols, which define eligibility criteria and methods for estimating emissions reductions for categories of projects. We assess how well California's protocol-centered approach mitigates the risk of over-crediting greenhouse gas reductions. This analysis is relevant because the offset program could make up the full effect of the state's cap-and-trade program through 2020, and half of its effect through 2030. We review the development of two of California's offset protocols—Mine Methane Capture and Rice Cultivation—and examine the regulator's treatment of three sources of uncertainty in emission reduction estimates that led to large-scale over-crediting under the CDM: determining additionality, estimating the counterfactual baseline scenario, and avoiding perverse incentives that inadvertently increase emissions.

We find that while the risk of over-crediting can be reduced through careful analysis, conservative design decisions, and ongoing monitoring of protocol outcomes, even best practices result in significant uncertainty in quantifying true emission reductions. Rather than eliminate the risk of over-crediting, California's approach shifts risk from project-level to protocol-level quality assessments. To the extent that carbon pricing policies include large offset programs, as is the case in California, government priorities and methodological choices drive program outcomes, contrary to the common perception that carbon pricing policies mainly delegate decision-making to private actors. Ultimately, relying on carbon offsets to lower compliance costs risks lessening total emission reductions and increases uncertainty in whether an emissions target has been met. As a result, offsets can be understood as a way for regulated emitters to invest in an incentive program that achieves difficult-to-estimate emission reductions rather than as quantifiable and verifiable reductions equivalent to reductions under a cap. Substantial ongoing regulatory oversight is needed to contain uncertainty and avoid over-crediting.

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Executive Summary

Carbon offsets allow greenhouse gas emitters covered under an emissions cap to comply by paying others outside of the capped sectors to reduce emissions. By expanding the range of activities that can be counted towards compliance with an emissions cap, carbon offsets lower compliance costs. This flexibility has important downsides, however, as carbon offset programs are technically complex and their credited emission reductions inherently uncertain.

The first major carbon offset program, the United Nation’s Clean Development Mechanism (CDM), is understood to have generated a large proportion of its credits from projects that did not actually reduce emissions and thereby enabled countries to claim greater emission reductions than they actually achieved. By allowing a wide range of project types to participate and focusing quality control on assessments of each proposed project individually, the CDM made it easy for project developers to game the rules and claim exaggerated quantities of credits. Importantly, project-level assessments failed to filter out “non-additional” projects—projects that would have been implemented regardless of the offset program.

Following criticism of the CDM experience, the California Air Resources Board (ARB) pioneered a second-generation compliance offset program that shifts the focus of offset quality evaluation, including additionality, from the project level to the protocol (or project-type) level. This offset program structure, commonly called a “standardized approach,” defines project eligibility criteria, project baselines, and methods for estimating emissions reductions more prescriptively at the protocol level. All projects that meet the protocol’s eligibility standards are considered additional and are allowed to generate offset credits pursuant to the protocol’s methodologies.

Here, we examine how well ARB’s standardized approach to carbon offset protocol design mitigates the risk of over-crediting. We focus on three interrelated sources of uncertainty in estimating emissions reductions: (1) determining additionality, (2) estimating emissions reduced relative to a counterfactual baseline scenario, and (3) avoiding perverse incentives that inadvertently increase emissions. This analysis has important implications for the effectiveness of California’s cap-and-trade policy due to the large size of its offset program. If capped emitters use the maximum offsets allowed, offset use would exceed ARB’s estimate of the total effect the cap-and-trade program is expected to have on emissions through 2020, and would equal over half of the same effect from 2021 through 2030.

Our analysis is rooted in our experiences from 2013 through 2015 as a team of researchers participating in the technical working groups established by ARB to support the development of two new offset protocols, the Mine Methane Capture and Rice Cultivation protocols. We also draw on discussions with researchers and practitioners as well as our own quantitative assessments. We use examples from these two protocols to illustrate each source of uncertainty and explore the types of analysis and protocol design decisions that could be used to reduce or avoid over-crediting under California’s standardized approach.

Our work shows that ARB can reduce the risk of over-crediting with reforms to its current offset protocol design and review processes. We highlight two of these reforms here.

First, ARB should conduct an explicit and quantitative analysis of the balance of over-crediting and under-crediting expected from participating projects when developing its offset protocols; ARB should also quantify actual outcomes when updating those protocols. Protocol-level eligibility criteria enable all qualifying projects to participate and earn offset credits, including those that are non-additional but satisfy the requisite criteria. To avoid over-crediting, offset protocols should be structured so that over-crediting resulting from the participation of non-additional projects is explicitly counterbalanced by systematic under-crediting from the use of conservative methods to estimate emissions reductions and/or discount factors on the quantity of offset credits generated. Ideally, protocol development and review would involve four explicit estimates: (1) expected business-as-usual trends that lead to non-additional but eligible projects, (2) the expected influence of the protocol on truly additional project development, (3) under-crediting of truly additional projects from conservative emissions estimation methods, and (4) a discount factor designed to counterbalance any remaining over-crediting. Assumptions about business-as-usual and additional project development should be reassessed periodically, enabling regulators to dynamically modify project type exclusions, emission estimation methods, and discount factors. Consistent with current practices, regulators could use this approach to demonstrate the legal requirement of additionality by showing that the total number of credits generated by projects under a protocol is unlikely to exceed the total reduction in emissions actually achieved by the protocol across its full portfolio of projects. While these assessments involve substantial uncertainty and subjective expert judgment, performing them would explicitly improve transparency, accountability, and policy effectiveness.

Second, ARB should assess, monitor, and take precautions to avoid the creation of perverse incentives that increase emissions. For example, profits created by California's Mine Methane Capture Protocol could enable coal mine owners to keep coal mines operating longer than they otherwise would, or create incentives to flare methane that they would otherwise capture for productive use as fuel. Offsets can also increase pressure on governments not to regulate emissions because any reductions that are legally required cannot be sold as offsets. Statements made by staff of the U.S. Bureau of Land Management suggest that the Mine Methane Capture Protocol may have influenced federal decisions not to regulate methane emissions from coal mines on federally-owned lands during the Obama Administration. A "do no harm" approach would carefully assess and monitor these potential effects and exclude project types with the potential for significant perverse incentives. Fundamentally, however, perverse incentives are difficult to avoid.

While the risks of over-crediting and perverse incentives can be reduced through careful analysis, conservative design decisions, and periodic review of protocol outcomes, uncertainty and risk are inherent to carbon offsets. This is because offsets pay for reductions rather than charge for emissions. Quantifying emission *reductions* involves estimating the difference between observed emissions and those projected in an unobservable, and therefore uncertain, counterfactual scenario that describes what would have happened without the offset program, including the effect of non-additional projects that are allowed to participate under the protocol's eligibility criteria. Instead of internalizing an externality (as is done by charging polluters for their emissions), income created by *paying* for reductions can create a range of perverse incentives, including improving the profitability

of high-emitting activities, inducing a shift in activity rather than a net reduction in emissions, and creating a disincentive for governments to regulate emissions.

Our work also highlights an important gap between the perception and practical function of carbon pricing policies that include large offset programs. Carbon pricing policies, such as cap-and-trade or carbon taxes, are often promoted as market-oriented solutions that allow the free market to identify the least-cost compliance portfolio with minimal direction from government. In turn, offsets are typically justified as an essential mechanism for containing compliance costs while simultaneously extending market-based incentives beyond the carbon pricing policy's borders. Due to the need to manage uncertainty in emissions reduced, however, the practical operation of offset programs rests on a complex set of protocol standards and rules developed by program regulators. The choices regulators make about what project types are allowed to participate and how emissions reductions are calculated drive outcomes in the offset market. Therefore, to the extent that offsets are used to deliver a substantial share of emissions limits, program outcomes will be heavily determined by government priorities and quality judgments, rather than primarily by decision-making that has been delegated to private actors.

Instead of describing offsets as a market-based compliance strategy like cap-and-trade, it may be more useful to think of offsets as a government-intermediated incentive program that regulated emitters pay into in lieu of directly reducing their own emissions. Like most programs that create financial incentives for technology deployment, the effect on emissions is difficult to assess because of uncertainty in how much the technology would have been deployed without the incentive, uncertainty in the emissions associated with that counterfactual scenario, and uncertainty about the effects of the incentives outside of project boundaries. Just as with any other technology support program, program outcomes are largely determined by government decisions about which types of activities receive support and the methods used to estimate program effects. As a result, we suggest that the emission reductions credited under offset protocols are fundamentally different from reductions under carbon pricing policies in terms of the ability to quantify and verify emission reductions and the role of government in decision-making.

Our observations also indicate a critical governance challenge facing carbon pricing policies that rely on offsets. In order to address uncertainty and contain the risk of over-crediting, offset program regulators must invest in substantial, ongoing, and often under-appreciated regulatory oversight. Yet to date, governance of environmental integrity concerns in the California offsets program is focused on the initial development of protocol rules, rather than their ongoing oversight and reform. Formalizing the analytical framework and processes used to manage offsets integrity could provide opportunities for evidence-based improvement.

Rather than eliminating the risk of over-crediting, California's standardized approach to offset program design shifts that risk from project-level assessments to protocol-level design decisions. Careful interdisciplinary analysis and conservative protocol design decisions are needed to contain the risk of over-crediting; to sustain this objective, policymakers must also invest sufficient resources in program oversight. Nevertheless, even the most careful and conservative program design and oversight process will result in significant uncertainty in true emission reductions. Offsets allow

regulated emitters to emit more than program cap levels, in exchange for a corresponding but less certain amount of reductions outside of the cap. Thus, where carbon offsets play a significant role in the total reductions expected under a cap-and-trade program (as they do in California), they increase uncertainty in—and risk lessening—the true emission reductions achieved by a cap-and-trade program.

1. Introduction

Carbon offsets allow greenhouse gas emitters regulated under a cap-and-trade program to pay for emission reductions outside of the capped sectors in lieu of reducing their own emissions or acquiring allowances from other regulated parties. Offsets have been widely used in cap-and-trade programs to lower compliance costs and support reductions in regions and sectors outside of capped sectors (ARB 2010, Bushnell 2012). During the first commitment period of the Kyoto Protocol (2008-2012), for example, the European Union Emissions Trading Scheme used offset credits equal to 11% of covered emissions (Ellerman, Marcantonini, & Zaklan 2014, 2015). In the first eight years of California's carbon market, regulated parties can submit offsets for up to 8% of their total emissions, or about 79% of the total reductions the California Air Resources Board (ARB) expects from the state's capped sectors (Haya 2013).

Although carbon offsets are widely used in cap-and-trade programs, they have also been controversial. Empirical studies of the Kyoto Protocol's offset program, the Clean Development Mechanism (CDM), find that many CDM projects received credits far in excess of the actual reductions they achieved. These studies point to three principal sources of over-crediting. First, the CDM credited large numbers of "non-additional" projects—projects that were happening on their own, independent of the income from offset credits (Aldy & Stavins 2012, Cames et al. 2016, Haya 2009, He & Morse 2013, Wara 2008). This occurred, in part, because of difficulty evaluating project developers' individual claims that they would not have moved forward with their proposed offset projects without the offset program (Haya 2010). Second, project developers need to estimate emission reductions against an unobservable, and therefore uncertain, counterfactual scenario of what would have happened in the absence of the offset program. Project developers have a financial incentive to exaggerate emissions estimated in the counterfactual scenario in order to claim greater reductions and generate more credits (Lazarus & Chandler 2011). Third, offset programs can inadvertently create "perverse" financial incentives that increase emissions. For example, due to the extremely high global warming potential of hydrofluorocarbons (HFCs) as greenhouse gases, profits generated by offset sales from HFC destruction projects were large enough to create an incentive for refrigerant producers to increase production and reduce production efficiency in order to generate more HFC by-product that could be destroyed to generate more offset credits (Schneider & Kollmuss 2015, Wara 2008). Carbon offsets can also create an incentive for governments to delay enactment of policies requiring reductions from sectors profiting from offset credits, since reductions are no longer eligible for offset revenue once they are required by law. For example, Latin American governments considered weakening laws in the early years of the CDM to increase CDM eligibility for certain projects (Figueres 2006).

These three potential sources of over-crediting—crediting non-additional projects, uncertainty in the counterfactual baseline scenario, and perverse incentives—create significant challenges for climate regulators. Proposed solutions have included the exclusion of project types that risk generating large quantities of false credits (Cames et al. 2016, Erickson, Lazarus, & Spalding-Fecher 2014, Thamo & Pannell 2015); discount factors or conservative baselines to reduce credits awarded to off-

set projects to counterbalance over-crediting from non-additional projects (Bento, Kanbur, & Leard 2016); program-, policy-, or sector-scale offset crediting (Lewis 2010, van Benthem & Kerr 2013); and standardized protocol-level evaluations that define quality criteria by project-type (Government of Italy 2014, UNFCCC 2014).

Following the controversial experience with the CDM's project-level additionality evaluations, California pioneered a compliance offset program design that concentrates evaluation at the protocol-level, commonly called a "standardized approach" to carbon offset program design. This approach was first implemented by the Climate Action Reserve, a state-chartered voluntary¹ offset developer; in parallel, several CDM methodologies were modified to include a standardized approach to additionality testing (Hayashi & Michaelowa 2013). Under a standardized approach, offset protocols specify project eligibility criteria. Every project meeting these criteria is deemed to fulfill the additionality requirement and is allowed to generate credits according to the protocol's standardized methodology for calculating baseline emissions and net emission reductions. This approach differs from previous offset programs, which test additionality for each proposed project and allow more flexibility for project developers to customize baseline and emissions reduction methods. In contrast, the standardized approach manages offset credit quality for the portfolio of offset projects as a whole, rather than for every participating project individually.

The standardized approach is expected to lower costs for participating project developers (Hayashi & Michaelowa 2013, Spalding-Fecher & Michaelowa 2013) and offer greater ability to avoid non-additional crediting (Haya 2010). If protocol-level eligibility criteria are too lenient, however, a standardized approach could still lead to large-scale over-crediting (Bushnell 2011, Cames et al. 2016, Hayashi & Michaelowa 2013, Spalding-Fecher & Michaelowa 2013) while potentially prohibiting truly-additional projects from participating (Schneider et al. 2012).

In this paper, we explore how California's standardized approach to carbon offsets addresses the risk of over-crediting, focusing on the three principal sources of over-crediting observed under the CDM: (1) non-additional crediting, (2) inflated baseline emissions, and (3) perverse incentives. We use examples from the development of two California offset protocols—Mine Methane Capture (MMC) and Rice Cultivation—to illustrate each of these risks and explore strategies for mitigating them during the protocol design and implementation phases. Our analysis is rooted in our experiences during 2013 through 2015 as a team of researchers participating in the technical working groups established by California to support the development of these two protocols (see Haya, Strong, Grubert, & Cullenward 2016). We also draw on discussions with researchers and practitioners as well as our own quantitative assessments. The goals of this analysis are to examine how effectively California's standardized approach to offsets prevents the risk of over-crediting, how the protocol design and review process could be improved, and what California's experience tells us about the risks and opportunities of carbon offset programs in general. Our results have important impli-

¹ The *compliance offset market* generates offset credits that can be used towards meeting a legally enforced obligation; the *voluntary offset market* generates offset credits for any other use, such as by cities, universities, companies, and individuals wishing to lower their carbon footprint.

cations for climate policy design, especially as more jurisdictions and international bodies consider implementing offset programs.

2. Background

a. California's cap-and-trade program

California's climate laws, known as AB 32 and SB 32, require the state to reduce its greenhouse gas (GHG) emissions to 1990 levels by 2020 and to 40% below 1990 levels by 2030. ARB was tasked with developing policy to achieve the state's GHG targets and eventually adopted a suite of policies that include direct regulatory instruments and an economy-wide cap-and-trade program (Wara 2014).

The cap-and-trade program covers approximately 75% of the state's greenhouse gas emissions (ARB 2018a, 2018c)—about 450 large emitters in the state's highest emitting sectors: electricity, industrial, transportation fuels, and natural gas (ARB 2015b). Covered emitters must submit compliance instruments (allowances and offsets) equal to their reported greenhouse gas emissions. So far, ARB has relied on cap-and-trade as a “backstop” policy, while traditional regulations are doing most of the work needed to meet California's 2020 target (ARB 2014a, Bang, Victor, & Andresen 2017). Cap-and-trade has likely played only a modest role in driving emissions reductions due to the oversupply of compliance instruments on the market (Legislative Analyst's Office 2017). Going forward, however, ARB expects cap-and-trade to deliver approximately 38% of the cumulative emission reductions projected to be necessary over the period 2021 through 2030, and fully 47% of the annual reductions needed to achieve the state's 2030 climate target (ARB 2017: Figure 7).

b. California's offset program

ARB's cap-and-trade regulations limit the use of offsets to 8% of each regulated emitter's total emissions each year through 2020.² Thus, if all emitters fully exploit this limit, their total emissions would increase to approximately 8% above the cap, with offsets crediting reductions in sectors outside the cap in an amount that is equal to that increase. In the market's post-2020 period, the offsets limit will be reduced to 4% of capped emissions from 2021-25 and then increase back up to 6% from 2026-30. In addition, beginning in 2021, credits worth no more than half of the offsets limit may originate from projects that do not generate “direct environmental benefits” to California air or water quality.³ Companies submitted offset credits equal to 4.4% of their emissions in the market's first compliance period (2013-14) (ARB 2015a) and 6.4% of their emissions in the second (2015-17) (ARB 2018b). Many regulated companies would prefer to increase their use of offsets because off-

² California Code of Regulations, title 17, § 95854.

³ California Health & Safety Code § 38562(c)(2)(E) (as modified by AB 398).

sets are expected to be less expensive than reductions under the cap (Borenstein, Bushnell, Wolak, & Zaragoza-Watkins 2018).

Although the offset limits might seem small compared to total emissions, they constitute a large share of the reductions required under cap-and-trade. ARB forecasted that cumulative reductions required in capped sectors through 2020 will be approximately 10% of those sectors' business-as-usual emissions (Haya 2013). The 8% offsets limit therefore represents approximately 80% of the mitigation required in capped sectors through 2020. From 2021 through 2030, the lower offset limits are equivalent to 20% of total mitigation required in capped sectors, and over half of the projected effect of cap-and-trade program itself (Haya 2018). As a result, the environmental effectiveness of the cap-and-trade program will likely turn on the quality of the carbon offsets program.

Each California offset protocol defines a specific set of activities eligible to generate offset credits and includes detailed methodologies for estimating the emissions reduced (and therefore credits generated) by each participating project. California's first four offset protocols were largely based on protocols developed for the voluntary market by the Climate Action Reserve (CAR): U.S. Forest, Livestock, Ozone Depleting Substances (ODS), and Urban Forest. In 2013, ARB started developing two more offset protocols: MMC and Rice Cultivation. Like the four original protocols, both were largely based on voluntary, pre-existing CAR protocols; however, the final MMC and Rice Cultivation protocols were developed through a multi-year stakeholder process that involved technical working groups in which the authors participated (Haya et al. 2016). We briefly summarize these two protocols before discussing the challenges of estimating their effect on emissions.

i. Mine Methane Capture (MMC) Projects Protocol

Many coal deposits contain methane, a potent greenhouse gas. When coal is mined, methane can be released into the atmosphere. The MMC Protocol credits the destruction of methane that would otherwise have been released into the atmosphere from coal mines. Creditable methods of methane destruction are (1) flaring from drainage wells, which tend to have high methane concentrations; (2) methane capture from drainage wells for use, including through pipeline injection, use in vehicles, and on-site electricity generation; and (3) oxidizing methane from ventilation systems, which tend to have low methane concentrations. Each method converts methane into carbon dioxide, lowering the climate impact because methane is a far more potent atmospheric greenhouse gas than carbon dioxide. Eligible mines include active underground and surface coal mines, abandoned underground coal mines, and trona mines⁴ in the United States. ARB adopted the MMC Protocol in April 2014. As of July 2019, MMC projects had generated 6.1 million offset credits, each representing the equivalent of one metric ton of carbon dioxide (tCO₂e) reduced (ARB 2019).

⁴ Trona is a form of sodium carbonate (used as soda ash) that is mined in the United States.

ii. Rice Cultivation Projects Protocol

Rice cultivation is an important source of anthropogenic methane and nitrous oxide emissions. Rice is grown in flooded fields where anaerobic decomposition of organic material in saturated conditions produces methane and anaerobic denitrification produces nitrous oxide. The Rice Cultivation Protocol credits reduced methane emissions resulting from shorter flooding periods achieved by (1) seeding fields under dry, rather than wet, conditions; (2) draining fields earlier in the fall; or (3) drying fields periodically during the summer cultivation period. The protocol uses the DeNitrification-DeComposition (DNDC) process-based biogeochemical model (University of New Hampshire 2012) to estimate net carbon dioxide, nitrous oxide, and methane emissions from changing rice cultivation practices in the United States, based on field-specific crop management, fertilizer, field management, and weather parameters. ARB adopted the Rice Cultivation Protocol in June 2015. As of July 2019, no projects had earned credits under the Rice Cultivation protocol (ARB 2019).

3. Challenge 1: Additionality

Because an offset credit allows its holder to emit one extra ton above a cap-and-trade program's cap in exchange for one ton reduced or sequestered outside of the capped sectors, the offset project must cause (and not merely be coincident with) emission reductions. California's climate law, AB 32, codifies this additionality standard by requiring that reductions from market-based compliance mechanisms be "in addition to ... any other greenhouse gas emission reduction that otherwise would occur."⁵

Additionality can be assessed at the project or protocol level. The CDM generally requires individual project developers to demonstrate that each proposed project is additional. In contrast, protocol-based additionality standards do not require each individual project to be additional. Under this paradigm, a regulator can address the risk of over-crediting from the participation of non-additional projects by assessing the entire pool of credits expected to be generated by a protocol. So long as the total number of credits awarded to non-additional projects is counterbalanced by conservative⁶ accounting methods that reduce the estimated emission reductions and thereby reduce the overall number of credits awarded, the protocol-level additionality standard is satisfied.

ARB has chosen to operationalize its protocol-level additionality requirement with a "common practice" assessment. Under this approach, a project type is considered additional if it is not common practice, a determination that is based on "staff's best estimate of the percent of the technology or mitigation in use" for the relevant sector (ARB 2013a: 7-8). Here we analyze ARB's application of its common practice assessment to one project type—methane capture at abandoned coal mines.

⁵ California Health & Safety Code § 38562(d)(2).

⁶ " 'Conservative' means, in the context of offsets, utilizing project baseline assumptions, emission factors, and methodologies that are more likely than not to understate net GHG reductions or GHG removal enhancements for an offset project to address uncertainties affecting the calculation or measurement of GHG reductions or GHG removal enhancements." California Code of Regulations, title 17, § 95802.

a. Methane capture at abandoned coal mines

The MMC Protocol illustrates how different interpretations of the common practice test can significantly alter the additionality determination. During the MMC Protocol development process, ARB's initial definition of common practice shifted from a broad assessment that risked generating large quantities of credits from non-additional methane capture to a more refined evaluation in the final protocol that substantially reduced the risk of non-additional crediting. As discussed below, however, an additional step is needed to avoid over-crediting.

After ceasing operation, gassy underground coal mines continue to emit methane (U.S. EPA 2008). At the time of MMC Protocol development, 38 (6%) of the approximately 645 abandoned gassy underground mines in the United States engaged in methane capture, mostly for injection into natural gas pipelines (Ruby Canyon Engineering 2013). An early draft of the protocol concluded: "from the population of ... abandoned underground mines in the United States, few currently capture and destroy mine methane" and therefore "abandoned underground mine methane recovery activities are deemed additional" (ARB 2013b: 7). This initial approach to evaluating common practice risked generating a large proportion of credits from non-additional activities for three reasons.

First, ARB initially focused its common practice assessment on the number of mines, rather than the quantity of emissions. The difference matters because methane concentrations vary substantially across mines. Even though only 6% of abandoned mines captured methane in 2011, these projects captured approximately 33% of total methane released from abandoned mines in the United States (U.S. EPA 2013b).

Second, methane capture is financially or technologically infeasible at most of the 645 abandoned mines in the United States. One study found that additional methane capture is feasible at only 67 abandoned mines in the United States (Ruby Canyon Engineering 2013). Based on this study, abandoned mines already captured approximately one-half of total feasibly captured methane emissions. Thus, if ARB assessed common practice based on how much of the *feasible* methane capture was already occurring, it would have determined that abandoned mine methane capture is already common practice.

Third, an aggregated, sector-wide assessment may fail to identify sub-categories of projects that are common. For example, all mines abandoned between 1993 and 2012 that captured methane when they were active continued to capture methane after abandonment (Collings 2013, U.S. EPA 2016b). If past rates of coal mine abandonment and abandoned mine methane capture development continue—and all abandoned mines are eligible to generate credits—business-as-usual methane capture could generate credits equal to 44-54% of total feasible new methane capture potential at the current pool of abandoned mines (see Supplemental Materials, Table SM-2). Thus, the quantity of non-additional credits generated from abandoned mines would likely exceed—possibly by a large amount—the total credits generated from truly additional abandoned mine methane projects.

In its final protocol, ARB modified its common practice analysis to explicitly exclude abandoned mines that captured methane when they were active on the grounds that methane capture at this particular sub-category of mines is already common practice. ARB's decision to assess a common

practice at a higher resolution avoided a significant risk of non-additional crediting. However, one more assessment is needed to contain the risk of over-crediting.

During the period 1993 to 2012, new abandoned mine methane capture systems were built at 30 abandoned coal mines that, if built today, would meet the eligibility requirements of the MMC Protocol. Half of these mines' annual reductions are from projects that participated in a voluntary carbon offset program; the other half were from projects that received no such incentive payments. The projects that were built without the voluntary offsets incentives and those that received offsets but would have been built anyway are "business-as-usual" projects. While it is not possible to know with certainty the rates of project development going forward without the protocol's financial incentive, if rates over the past twenty years continue unchanged, business-as-usual abandoned mine methane capture projects could generate a quantity of non-additional credits equal to 8 to 16% of total feasible methane capture from eligible abandoned mines (see Supplemental Materials, Table SM-2).

To contain this particular risk of over-crediting, ARB could first conduct a market analysis to assess the likely business-as-usual deployment of mine methane capture systems going forward. ARB could then reduce the number of credits expected to be generated from the total portfolio of abandoned mine methane capture systems by the amount of anticipated non-additional crediting that is eligible under its MMC Protocol. This could be done using conservative methods to estimate emissions reduced by projects participating under the protocol, or by applying an explicit discount factor to all credit generation. While these options risk weakening the effectiveness of the protocols in incentivizing emissions reductions (van Benthem & Kerr 2013), if carried out well, they should also reduce the quantity of over-crediting. If total under-crediting from the discounting of additional credits equals total over-crediting from participating non-additional projects, then the credits generated would equal the net impact of the protocol on emissions and all credits could be considered additional. This example illustrates the challenge of assessing additionality for any project type already being implemented without the added incentive from a carbon offset program.

4. Challenge 2: Estimating Baseline Emissions

Establishing additionality is one aspect of a broader challenge—estimating baseline emissions that would occur in the absence of an offset project. Project emissions can be observed and independently validated, but the baseline scenario never occurs and therefore cannot be observed. As a result, baseline emission projections are uncertain.

a. Scientific uncertainty in the baseline: methane release from abandoned mines

Estimating baseline emissions in the MMC Protocol is difficult because methane capture devices can extract more methane than would have escaped to the atmosphere in the absence of the device (ARB 2013b). Because these extra emissions would not occur in the absence of MMC projects, the total methane captured by offset projects cannot be used as a baseline. Instead, the protocol estimates baseline emissions from abandoned mines using a hyperbolic emission rate decline curve

model (U.S. EPA 2016c). This model projects a rate of decline in emissions based on empirical data from U.S. coal mines reflecting characteristics such as the geologic formation, mine gassiness, and whether a mine has been sealed. Project developers can input either default coefficients or measured site-specific values.

For projects at mines that never drained methane when active and use default parameter values, ARB discounts the number of credits awarded by 20% to account for possible discrepancies between the default and the actual project-specific baseline. ARB's decision to apply a discount factor addresses a known uncertainty, but the specific discount factor—20%—reflects the agency's subjective expert judgment, based on stakeholder feedback. When methodological issues cannot be addressed empirically and instead require subjective judgment calls, uncertainty in the true emission reductions achieved under the protocol increases.

b. Technological and behavioral uncertainty in the baseline: rice farmer practice

The Rice Cultivation Protocol defines baseline cultivation practices—such as when fields are drained or how much fertilizer was applied—in two ways, depending on the location of the project. Both methods make important assumptions about farmers' cultivation choices. For projects in the Mid-South of the United States, baseline emissions are projected using the widely-used DD50 rice management model developed to aid farmers in cultivation decisions (University of Arkansas 2018). For projects in California, however, baseline emissions are defined based on what each farmer reports about past cultivation practices, rather than model projections.

Both approaches to baseline setting are uncertain and vulnerable to over-crediting. Modeled common farmer practice in the Mid-South does not necessarily predict any single farmer's practice. For example, farmers who were already draining fields earlier than the DD50 model recommends can earn credit for early drainage without changing their practices. Similarly, in California, simple averages of a specific farmer's past cultivation practice are not necessarily good predictors of future practice because cultivation decisions reflect each season's specific conditions. It is also common for farmers to experiment with new practices to reduce risk, improve yield, lower costs, respond to market prices, or achieve other goals like water conservation. Furthermore, it can be difficult for third party auditors to verify past farmer practice.

In light of these challenges, ARB decided to test alternative methods that third-party verifiers can use to verify baseline emissions at different project sites to explore their feasibility and effectiveness. As of this writing, however, no projects have been credited under this protocol and the experience with verification remains unknown.

5. Challenge 3: Perverse Incentives

Financial incentives created by an offset protocol can also inadvertently increase emissions, for example by increasing the profits of high-emitting activities, creating disincentives to enact legally

binding climate regulations, and inducing business-as-usual mitigation projects to shift their activities to earn offset credits.

a. Increasing profits: from coal mining

The U.S. coal industry has been in decline in recent years (U.S. EIA 2016, 2019b). In a shrinking market for coal production, increased profits from offset credit sales might extend the lives of otherwise uncompetitive coal mines.

To assess the scale of this risk, we analyzed potential profits from implementing mine methane capture projects at the eight active underground coal mines in the United States that EPA identified as having methane drainage wells that vented the majority of drainage methane to the atmosphere and that did not already have pipeline injection systems (U.S. EPA 2016b). These coal mines are prime candidates for mine methane capture systems because of their large and high-concentration methane releases (U.S. EPA 2013a), and because capture is more economically favorable when mines are active.

We used EPA's Coal Mine Methane Project Cash Flow Model version 3.0 (U.S. EPA 2016a), 2012 data for coal production (Fiscor 2013), coal sales prices (U.S. EIA 2013), and methane releases (U.S. EPA 2016b) for each of the eight mines (see Supplemental Materials, Table SM-3).⁷ Our analysis indicates that ARB's MMC Protocol could increase coal mining profits by as much as 17% if offset credits sell at \$10 per tCO₂e (lower than prevailing allowance prices in California), with a production-weighted average increase in mining profits of 3% across the eight mines analyzed. At \$50 per tCO₂e—a price for carbon credits that is not imminent but is plausible in coming years (Borenstein, Bushnell, & Wolak 2017)—mine profits could more than double at some mines, with a production-weighted average increase of 23% across the eight mines analyzed.

b. Increasing profits: inducing a switch from corn to rice production

By providing an additional source of revenue to rice farmers, the Rice Cultivation Protocol could shift the relative profitability of rice in comparison to other crops, leading to crop switching with emissions impacts. In areas of the Mid-South of the United States, farmers commonly shift between rice and corn production (Jekanowski & Vocke 2013). However, rice production is about four times more emissions-intensive than corn production in those areas (Nalley, Popp, & Fortin 2011). Corresponding changes in Arkansas crop prices and acreage since 2005 indicate that shifts between rice and corn in Arkansas are correlated with changes in relative crop prices (data from USDA 2013a, USDA 2013b). Assuming historical elasticities between prices and acreage, offset profits of \$10 per

⁷ ARB assessed the impacts on coal mining revenues of two ventilation air methane (VAM) projects at underground mines and one methane capture project at a surface mine and found that the offset revenues were too small to affect coal mining decisions (ARB 2014b). ARB did not publish a similar assessment of a project that flares drainage methane at an active underground mine, the project type analyzed here.

tCO₂e could induce a shift of 1 to 2% of corn acreage to rice production. If only a fraction of this crop switching were to occur, the emissions benefits of the protocol would be weakened by 9 to 41% (see Supplemental Materials). The potential emission increases associated with such offset-induced crop switching are material enough to warrant monitoring if offset prices increase and Rice Cultivation Protocol projects start to be implemented. This example highlights the potential for carbon offsets to affect emissions by changing the relative profitability of competing products.

c. Weakening or delaying climate regulation

Carbon offsets can also exert perverse effects on the political economy of climate policy development. By definition, any emission reductions that are required by law are non-additional and therefore ineligible to earn offset credits. As a result, carbon offset revenues create an added incentive for those benefiting from offset projects to advocate against the development of legally binding regulations that apply to their activities.

These concerns have manifested in California's carbon offset regime, which may have affected federal climate policy decisions during the Obama Administration. In April 2014, the Bureau of Land Management (BLM) issued an Advance Notice of Proposed Rulemaking (ANPRM) on reducing emissions of waste methane from active underground mines on federal lands (Bureau of Land Management 2014). The ANPRM contemplated various options, including mandating or creating incentives for capture. However, mandatory regulations would preclude affected mines from earning offset credits through California's MMC Protocol. BLM issued a final rule limiting methane emissions from oil and gas operations on federal lands effective January 2017 (Bureau of Land Management 2016) without mention of methane from coal mines.

Preliminary evidence suggests, though does not conclusively establish, that incentives from California's MMC Protocol may have contributed to BLM's decision not to require methane capture at coal mines on federal lands. At the 2014 U.S. Coal Mine Methane conference held by the U.S. Environmental Protection Agency in Pittsburgh, Pennsylvania, BLM representatives stated during their presentation that BLM was taking California's MMC Protocol into account in deciding whether and how to regulate or incentivize the capture of waste methane from active underground coal mines on federal lands (Leverette & LaSage 2014). The representatives further indicated to conference participants that BLM intended to support California's offset program. It is not possible to know what BLM action (and by extension, methane mitigation activity) would have occurred in the absence of California's offset program. Nevertheless, it is notable that the BLM subsequently opted to regulate methane emissions from oil and gas operations but not from coal mines, and that the BLM representative conveyed that the California protocol was part of the federal agency's deliberations. We believe this example illustrates the potential for carbon offset programs to delay or weaken legally binding climate regulations.

d. Creating incentives for only some activities that reduce emissions

To avoid over-crediting, offset protocols generally exclude project types likely to result in non-additional crediting. While necessary, such exclusions can lead to unintended effects. For example, the MMC Protocol excludes projects at active underground mines that capture methane for injection into the natural gas pipeline network because ARB determined that projects of this type are common practice and therefore non-additional. Since pipeline injection is ineligible under California's offset program, but flaring remains eligible at qualifying drainage wells, mine operators face a choice. If they sell captured methane into the natural gas pipeline network, they receive the market value of methane's use as a fuel. Alternatively, mine operators could choose to flare the captured methane, which would be eligible for carbon offset credits.

Figure 1 illustrates the relative revenues from pipeline injection versus flaring for different combinations of carbon and natural gas prices. Since capital costs are often lower for flaring than for pipeline injection (Somers, Burklin, McClutchey, & Cote 2013) and are not taken into account in Figure 1, flaring methane instead of capturing it for beneficial use may be preferable under a wider range of conditions. Given current and likely future carbon market prices (Borenstein et al. 2017), flaring captured methane for carbon credits is likely to be much more valuable than the productive use of that methane—even under relatively high natural gas prices that occurred prior to the expansion of unconventional hydrocarbon resource production in the United States.

The MMC Protocol excludes projects that flare methane from wells that captured and injected methane into pipelines within the previous year. Because protocol eligibility criteria are determined for each drainage well, however, this restriction does not affect the incentives for operators of new wells or mines, or of wells for which pipeline injection ceased for at least one year. Operators of these wells who may have chosen to sell methane into a pipeline in the absence of the protocol may now have a financial incentive to flare this methane instead to earn carbon credits. In these cases, the protocol would not only result in non-additional crediting, but would also have the added impact of flaring methane that would otherwise have been put to productive use as a fuel.

6. Discussion and Conclusions

Drawing on examples from the development of two offset protocols, we examine how California's standardized approach to carbon offset program design addresses three interrelated challenges: assessing project additionality, estimating baseline emissions, and avoiding perverse incentives that increase emissions.

By concentrating decisions about project eligibility and emission reduction estimates in the protocol development process, California's standardized approach reduces some of the governance challenges associated with project-by-project assessments used by first generation offset programs. In particular, the standardized approach offers the ability to address additionality and avoid over-crediting for the portfolio of carbon offset projects as a whole using project type exclusions, conservative methods for estimating emissions reductions, and discount factors. Protocol-level additionality determinations and methods for estimating emissions reductions also lessen transaction

costs for project developers by reducing the need for expensive and complicated project-level analysis. Finally, California’s protocol-scale approach facilitates public stakeholder participation in program decisions (Haya et al. 2016).

However, California’s approach does not resolve the significant uncertainty surrounding emission reductions credited to carbon offsets. Assessments of additionality, counterfactual baseline scenarios, and the effects of perverse incentives are inherently uncertain. Using detailed examples from the Mine Methane Capture and Rice Cultivation protocols, we describe a range of ways that uncertainty manifests in California’s offset program. Ultimately, the risk of over-crediting can be reduced, but not eliminated, with careful analysis, conservative design decisions, and ongoing monitoring of program outcomes.

a. Recommendations for improvement

ARB could reduce the risk of over-crediting with three reforms to its offset protocol design and review processes.

First, ARB should improve the way it applies its “common practice” assessment to address additionality. As discussed in the context of the MMC protocol, non-additional crediting can be reduced by focusing the assessment on emissions, rather than projects; on feasible projects, rather than all possible projects of a certain type; and on project type sub-categories individually to filter out those with high over-crediting risks.

Second, ARB should conduct and periodically review an explicit, quantitative analysis of the expected portfolio-level balance of over-crediting and under-crediting. Protocol-level eligibility criteria enable all qualifying projects to participate and earn offset credits, including those that are non-additional but satisfy the requisite criteria. To avoid over-crediting, regulators could deliberately choose to under-credit calculated reductions from each participating project such that the credits awarded to projects under the protocol reflect the best estimate of net reductions achieved by the protocol across all projects, while being cognizant that this approach could make some truly additional projects uneconomic. Ideally, protocol development would involve four estimates: (1) expected business-as-usual trends that lead to non-additional but eligible projects (non-additional credits), (2) expected additional projects (additional credits), (3) under-crediting from conservative protocol methods, and (4) explicit discount factors designed to counterbalance any remaining over-crediting. Additionality would be preserved at the protocol level if total credits generated by a protocol do not exceed conservative estimates of the effect of the offset protocol on emissions. Assumptions about business-as-usual and additional project development should be reassessed periodically, enabling the regulator to dynamically modify project type exclusions, emission estimation methods, and discount factors. While these *ex ante* and *ex post* assessments involve substantial uncertainty and subjective expert judgment, performing these assessments would explicitly improve transparency, accountability, and policy effectiveness.

Third, ARB should assess, monitor, and take precautions to avoid the risk of creating perverse incentives that increase emissions. For example, profits created by California’s Mine Methane Cap-

ture Protocol could create incentives for coal mine owners to keep mines operating longer than they otherwise would, or to flare methane that they would otherwise capture for productive use as fuel. Experience with the Mine Methane Capture Protocol suggests that it may have influenced federal decisions not to regulate methane emissions from coal mines on federally-owned lands during the Obama Administration. A “do no harm” approach would carefully assess and monitor these potential effects, excluding project types with the potential for significant perverse incentives. Fundamentally, however, perverse incentives are difficult to avoid.

b. Implications for governance

Even with best practice protocol design and updating, carbon offsets’ emission reductions are inherently uncertain because offsets pay for reductions, rather than charge for emissions. Estimating emission *reductions* requires a regulator to quantify the emissions of an unknowable counterfactual scenario, as well as estimate the proportion of eligible offset projects that will be non-additional. *Paying* for reductions can create a range of perverse incentives, such as by improving the profitability of high-emitting activities, inducing a shift in activity rather than net reduction in emissions, and creating a disincentive for governments to regulate emissions.

Whether conducted explicitly or implicitly, uncertainty management in carbon offset programs illustrates a critical disconnect between the perception and practical function of cap-and-trade programs that feature large offset programs. Cap-and-trade programs are often promoted as market-oriented solutions that allow the free market to identify the least-cost compliance portfolio with minimal direction from government (e.g. Washington Post Editorial Board 2016). In turn, offsets are often seen as an essential mechanism for containing compliance costs and voluntarily extending carbon price incentives to sectors not covered by cap-and-trade. Yet the practical operation of offset programs rests on a complex set of government-determined protocol standards needed to manage uncertainty in reductions achieved. The choices regulators make about what project types to target with protocols and how to calculate reductions under those protocols drive outcomes in the market. Therefore, to the extent that offsets are used to deliver a substantial share of emission reductions (as is the case in California), program outcomes will be strongly influenced by government priorities and quality judgments, rather than primarily determined by private actors’ decisions.

Instead of thinking of offset credits as equivalent to reductions under an emissions cap, it may be more useful to think of offsets as a government-intermediated incentive program in which regulated emitters invest in lieu of directly complying with emission limits. Like most programs that create financial incentives for behavior change, the effect on emissions is difficult to assess because of uncertainty in how much the change in practice would have occurred regardless of the new incentive, uncertainty in the emissions associated with the counterfactual scenario, and uncertainty about the effects of its incentives outside of project boundaries. Just as with any other government incentive program, outcomes are largely determined by government decisions about which types of activities receive support and the methods used to estimate program effects. As a result, we suggest that the emission reductions credited under offset protocols are fundamentally different from reductions

measured under carbon pricing policies, both in terms of the ability to quantify and verify emission reductions and the role of government in decision-making.

Public comments at ARB offset workshops indicate that stakeholders hold profoundly different views of the offset program's purpose. Some emphasize the role offsets play in helping California meet its target for reducing emissions. Others view offsets primarily as a much-needed source of funding for activities that reduce emissions and increase co-benefits in uncapped sectors. Offsets are often portrayed as win-win, delivering both benefits at once (Anderson, Field, & Mach 2017). Our experience with protocol development, detailed here, shows that decisions about program size and stringency involve trade-offs between these goals. An offset program that prioritizes the environmental integrity of the cap-and-trade program needs to carefully target project types that are not already being implemented on their own and for which emissions reduction estimates are relatively certain. Such a program could miss many promising opportunities to reduce emissions in the sectors eligible for offset credits. For example, some of the most promising opportunities can be excluded because they have a high risk of being non-additional, such as pipeline injection at underground coal mines under the Mine Methane Capture Protocol. As another example, strict monitoring requirements for rice cultivation projects give greater confidence in credited reductions, but also diminish offsets' financial incentives, especially for smaller projects. In turn, high compliance costs may explain the lack of any participation in the Rice Cultivation Protocol so far. These tradeoffs illustrate another fundamental tension in the use of offsets as a form of climate policy.

Our observations also indicate a critical governance challenge facing carbon pricing policies that rely on offsets. In order to address uncertainty and contain the risk of over-crediting, offset program regulators must invest in substantial, ongoing, and often under-appreciated regulatory oversight. Yet to date, governance of environmental integrity concerns in the California offsets program is focused on the initial development of protocol rules, rather than their ongoing oversight and reform. Formalizing the analytical framework and processes used to manage offsets integrity could provide opportunities for evidence-based improvement.

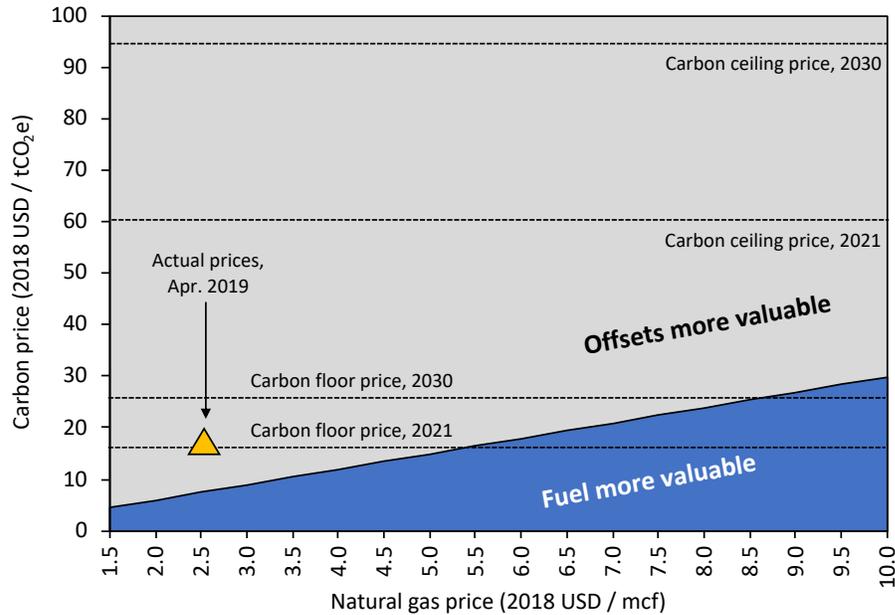
Rather than eliminate the risk of over-crediting, California's standardized approach to offset program design shifts risk from project-level assessments to protocol-level design decisions. Careful interdisciplinary analysis and conservative protocol design decisions are needed to contain the risk of over-crediting; policymakers must also invest sufficient resources in ongoing program oversight. Nevertheless, even the most careful and conservative program design and oversight process will result in significant uncertainty in true emission reductions. Offsets allow regulated entities to emit more than the program cap levels, in exchange for a corresponding but less certain amount of reductions outside of the cap. Thus, where carbon offsets play a significant role in the total reductions expected under a cap-and-trade program—as they do in California—they risk lessening total emission reductions achieved by the cap-and-trade program and increase uncertainty in whether the emissions target has been achieved.

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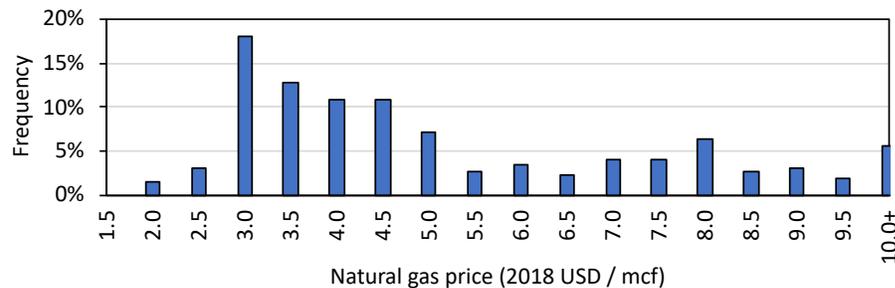
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Figure 1. Income from flaring methane for offset credits versus sale of natural gas

(a) Breakeven analysis for methane, offsets value vs. fuel value



(b) Histogram of monthly natural gas prices, U.S. Henry Hub (1997-2019)



Natural gas captured at drainage wells can be sold for fuel, or, if eligible for the MMC Protocol, flared to generate carbon offset credits. Panel (a) shows the market conditions under which flaring will be more valuable (top area) and under which fuel sales will be more valuable (bottom area). Dashed lines indicate California’s minimum carbon price floor in 2021 and 2030, as well as the maximum price ceiling in 2021 and 2030. Panel (b) shows a histogram of monthly natural gas prices from 1997-2019, which have generally ranged from \$3-8/thousand cubic feet (mcf), with recent prices in the \$2-4/mcf range (U.S. EIA 2019a). If carbon prices remain near program minimums, then flaring methane to sell offset credits will generate higher revenues than selling methane as fuel, unless natural gas prices reach historically high levels. At carbon prices a few dollars above the minimum carbon price, drainage wells will generally profit more from offset sales, no matter the price of natural gas. This analysis indicates that mine owners face a perverse incentive: it is more profitable under a wide range of scenarios to flare methane captured from drainage wells, even if it would be economic to capture the methane for productive, private use.

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