WCI-RULES cap-and-trade model documentation

Model version 1.1; documentation last updated 2019-09-09

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View the model code and input files here:

- https://github.com/nearzero/WCI-cap-and-trade (Github)
- https://doi.org/10.17605/OSF.IO/S7HQ3 (Open Science Framework)

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1. Model overview

WCI-RULES, an open-source model of the Western Climate Initiative (WCI) cap-and-trade program, is intended to help project, analyze, and track market outcomes. It allows users to explore the future market supply-and-demand balance through 2030, based on actual market rules and users' assumptions about (1) future emissions that are covered by the program, (2) the supply of carbon offset credits, and (3) quarterly auction outcomes. Our goal is to provide a neutral accounting tool that allows stakeholders to explore a wide range of scenarios and their implications.

The model's full name, WCI Regulations and Uncertainties for Lowering Emissions across Scenarios, refers to the model's detailed representation of the regulations governing the WCI program and the uncertainties that can be explored through user-specified scenarios.

Given an input scenario, the model calculates market outcomes by applying the actual market rules laid out in the regulations of WCI jurisdictions (Cal. Code Regs., 2019; Québec, 2019). For example, the model can show when the market may shift from its present state of oversupply to a state of undersupply, and how the current Private Bank of excess allowances may grow or shrink over time. Ultimately, the model supports evaluation of the extent to which cap-and-trade may contribute to meeting California's 2030 climate goal of cutting economy-wide emissions at least 40% from the 1990 level.

The model runs through 2030. It incorporates post-2020 market design changes that the California Air Resources Board (CARB) adopted in December 2018 and that came into effect in April 2019 (Cal. Code Regs., 2019) as part of the AB 398 implementation process. It also reflects the effects of Ontario's linkage and subsequent withdrawal from the program in 2018, including the July 2019 adjustments made by California and Québec to account for Ontario's departure.

1.1. Supply of compliance instruments

The model makes a detailed characterization of the supply of compliance instruments in various pools that are set out in each participating WCI jurisdiction's regulations. The model simulates three main categories of supplies:

- Sales of allowances at auction
- Free allocation of allowances directly to emitters
- Offset credits

In addition, the model represents allowances held in government-controlled Reserve accounts that are only available for sale at prices much higher than historical market prices as of this writing (in September 2019). After 2020, the model also represents sales of additional instruments at the Price Ceiling, known as Price Ceiling Units. The model calculates sales of Reserve allowances and Price Ceiling Units if needed for compliance, based on the user-specified scenario.

The model assumes that sales of Reserve allowances will not begin until the Private Bank of compliance instruments is exhausted. (For details on the model's calculation of the Private Bank metric, see Section 3.4.2.) In reality, such accounts could be accessed while a Private Bank still exists, depending on future market prices and the choices of market participants.

1.2. Demand for compliance instruments

The model lets the user specify emissions pathways—that is, scenarios for demand for compliance instruments. The user can specify an annual percentage change over the whole simulation period or can specify alternative emission trajectories.

1.3. Supply-demand metrics

To calculate metrics that characterize the supply-demand balance, the model draws on the latest historical data available in the following categories:

- Covered emissions: from annual compliance reports
- Auction results: from quarterly auction results
- Offset supply: from quarterly Compliance Instrument Reports

For each category, users specify projections beyond the historical data.

Quarterly allowance auctions are the primary way in which allowances are distributed to private entities, thus the auctions strongly influence how many allowances enter private accounts, and thus are available to be used to satisfy compliance obligations. The model lets the user specify a scenario for auction outcomes. Auction parameters can be adjusted to analyze the effect of some auctions failing to sell out (e.g., simulating a period of low auction sales similar to that which occurred in 2016-2017).

The model then calculates six annual metrics, representing the state of the market at the end of each calendar year:

- Private Supply
- Private Bank
- Government Holding Accounts
- Reserve Sales
- Price Ceiling Unit Sales
- Reserve Accounts.

The model also calculates six Compliance Period metrics, which are approximations of the state of the market immediately following the compliance events in which all remaining obligations for a given compliance period are due (e.g., immediately after the November 1, 2018, compliance event, at which all remaining obligations incurred in 2015-2017 were due).

The Compliance Period metrics are:

- Private Allowances

- Private Offsets
- Private Bank
- Government Allowances
- Government Offsets
- Reserve Accounts.

1.4. Uses of the model

The model can address questions regarding the supply-demand balance in the WCI cap-and-trade market, such as:

- How will the supply-demand balance evolve through 2030 for a given emissions scenario?
- How much would the supply-demand balance be affected by some future auctions not selling all of the available allowances?
- In what scenarios might Reserve allowances be sold?
- In what scenarios might Reserve allowances be exhausted, and sales of Price Ceiling Units begin?

1.5. Post-2020 market design changes

In December 2018, CARB adopted a set of market design changes as directed by AB 398, the bill that extended the cap-and-trade program in California through 2030. The new regulations came into effect in April 2019 (Cal. Code Regs., 2019). WCI-RULES version 1.1 reflects these market design changes.

In the future, the model could incorporate any further regulatory updates and also be used to evaluate potential market design changes.

1.6. List of assumptions

Users specify projections for the primary factors affecting future supply and demand in the WCI program. However, there are various secondary assumptions built into the model that are necessary for making projections without requiring users to input an onerous number of parameters, but that have only minor effects on the results. Each assumption is marked in the documentation with "**Assumption:**".

2. Summary of model details

2.1. Allowance pools

The model tracks all emissions allowances, grouped into categories.

The allowance pools explicitly specified **in the regulations** include:

- The annual allowance budget (or cap)
- Allowances set aside in Reserves
- Allowances set aside for advance auctions
- Fixed allowance allocations each year (electricity, natural gas, wholesale water)

Other allowance pools are described in the regulations, but are not predetermined, so the model draws on **additional data** published each year for these allowance pools:

- Allowances directly allocated to emitters in amounts that vary from year-to-year (principally industrial sector allocations).
- Allowances consigned to auction by emitters (some consignment is required by law, but some entities may choose to consign more than the minimum required).

The model is also driven by **user-specified projections**, including:

- Emissions pathways
- Offsets supply
- Auction outcomes

Once those inputs are set, the model simulates quarterly auctions through the end of 2030. The model applies market rules specified in the regulations regarding how many allowances will be made available (including unsold allowances that are reintroduced in later auctions), and how many allowances will sell from each category (in auctions that do not sell out).

2.2. Emissions scenarios

The model allows users to specify scenarios for covered emissions in California and Québec separately, using either percentage annual changes over specific time spans, or by specifying a custom emissions trajectory. The default projection is for emissions in both jurisdictions to decrease 2% per year from the latest historical data for covered emissions. (As of this writing in September 2019, the latest covered emissions data is for 2017.)

> ***Assumption:*** *When the user inputs a custom projection for covered emissions for California and Québec combined, the model assumes that the split between California and Québec is proportional to each jurisdiction's caps over the projection period (85% California and 15% Québec).*

2.3. Auction scenarios

The model allows users to specify particular auction outcomes for the current and advance auctions. The default auction projection is that all future auctions will sell out, both current auctions and advance auctions.

Alternatively, the user can specify particular years in which the auctions do not sell out, and the percentage of allowances that go unsold in each auction in those years, between 0% and 100%. The percentage unsold is applied in each quarter in the specified years and is applied to both current and advance auctions.

Based on the user-specified auction results, the model calculates the quantities of allowances that sell from particular pools, based on the order of sales as specified in the regulations (e.g., for California, consignment allowances sell before state-owned allowances).

Unsold allowances are retained in the Auction Holding Account and are redesignated to later auctions based on the rules stipulated in the regulations.

If some current auctions don't sell out, then the near-term supply of allowances decreases. Under certain conditions, allowances that go unsold in current auctions can be offered for sale at subsequent current auctions, where they can be purchased by market participants. In California, unsold allowances are removed from the current auction supply if they remain unsold for more than 24 months. They are transferred instead to reserve accounts, available at particular price tiers specified in regulations, and thus any such transfers affect the long-term supply of allowances and the prices at which they become available to market participants (Inman et al., 2018).

2.4. Offsets supply

The model makes a default projection concerning additions to the supply of offsets, specifically that each year's supply of offsets is equal to 75% of the limit that applies to offsets use in the same year, in each jurisdiction. For example, both California and Québec limit offsets use to 8% of emissions in the period 2018-2020; accordingly, WCI-RULES uses a default assumption that the offsets supply for 2019 is equal to 6% of WCI-wide 2019 emissions. This assumption is directly comparable to CARB's own assumptions about future offset use through 2030 (CARB, 2018a). This default projection can be changed in the user interface.

2.5. Post-2020 market design changes

CARB implemented a set of market design changes (CARB, 2018b) as directed by AB 398, the bill that extended the cap-and-trade program in California through 2030. The model includes these market design changes, most of which take effect after 2020, as follows.

2.5.1. Post-2020 Reserve and Price Ceiling

In 2019, CARB took one-third of the Reserve allowances from budget years 2013-2020 and divided this third across the three pre-2021 Reserve tiers; the remaining two-thirds of Reserve allowances were retained in the Reserve Account, but are not available for sale until 2021. Reserve accounts also include ~37 M California state-owned allowances that remained unsold for 24 months and were subsequently transferred to the Reserve in 2018 and 2019. California's April 2019 regulations assign ~75.1 M allowances from the 2021-2030 budgets to California's Reserve (compared with 52.4 M allowances under the October 2017 regulations).

For the post-2020 period, all Reserve allowances will be made available for sale, divided roughly equally between three levels—two intermediate price tiers and the Price Ceiling. (In addition, if California's Reserve is exhausted, California will make unlimited quantities of Price Ceiling Units available for sale at the ceiling price, although only for California-based compliance entities.)

There have been no WCI Reserve sales to date (as of September 2019). Given recent allowance prices and the fact that the next major compliance event is not until November 2021, it is very unlikely that there would be any Reserve sales before the end of 2020.

In the model, it is possible to simulate Reserve sales prior to the end of 2020 in extreme scenarios for emissions (e.g., increase of > 10% per year), or with a sharp increase in emissions in conjunction with a collapse of auction sales. However, we consider such scenarios extremely unlikely. Even if such a scenario were to occur, larger quantities of Reserve allowances, and unlimited quantities of Price Ceiling Units would become available in 2021, prior to the major compliance event on November 1, 2021, in which all remaining compliance obligations for the period 2018-2020 must be satisfied.

> ***Assumption:*** *The model assumes the post-2020 regulatory framework applies to any projected sales of Reserve allowances and Price Ceiling Units.*

Currently, the model does not explicitly represent particular price tiers, nor distinguish Reserve sales at the price tiers from Reserve sales at the ceiling price; however, the model does distinguish Reserve allowance sales from Price Ceiling Unit sales (shown in the model output file, which can be saved from the user interface). The magnitude of sales in a given scenario can be compared with the allowances available at each price tier and the Price Ceiling to infer which allowance pools would be accessed.

2.5.2. Treatment of unsold allowances

Through 2020, California state-owned allowances that remain unsold for more than 24 months are transferred to the Reserve and divided equally among the three existing Reserve tiers. In 2021, any unsold allowances that had been transferred into the Reserve by that time would then be transferred to the Price Ceiling. There were ~37 M allowances unsold during 2016-2017 that hit the 24-month limit and were transferred to Reserves.

Following the 2019 Q2 auction, all California state-owned allowances that previously went unsold at current auctions have either been sold, transferred to Reserve, or retired to compensate for EIM Outstanding Emissions. Even if there are auctions that do not sell out in 2019 or 2020, no further unsold state-owned allowances can hit the 24-month limit before the end of 2020. This means any future unsold California state-owned allowances would be governed by the post-2020 regulatory framework, which requires any unsold allowances transferred into the Reserve to be divided equally between two post-2020 price tiers.

2.5.3. EIM retirements from annual budgets

The model includes historical retirements for Energy Imbalance Market (EIM) Outstanding Emissions, with retirements beginning in 2018 for emissions incurred from 2016 forward.

Prior to the April 2019 AB 398 regulations, California's program was operating under the October 2017 version of the cap-and-trade regulations. Under these regulations, CARB retired allowances in 2018 for EIM Outstanding Emissions incurred in 2016 and 2017. Specifically, CARB retired allowances from the pool of unsold allowances following the 2016-17 auction collapse. The Compliance Instrument Report (CARB, 2019) for 2018 Q3 indicated that CARB retired allowances in 2018 to account for 517,460 tCO_2e in 2016 and 664,0046 tCO_2e in 2017.

Under California's April 2019 regulatory amendments (Cal. Code Regs., 2019), allowances retired to compensate for subsequent EIM Outstanding Emissions will instead be retired from annual budgets of specified vintages, per § 95852(l)(1) and § 95892(a)(3):

- Incurred 2018: Will be retired in 2019, from state-owned allowances of vintage 2022.
- Incurred 2019Q1: will be retired in 2020, from state-owned allowances of vintage 2023.
- Incurred 2019Q2-Q4: will be retired in 2020Q3, from electricity allocations of vintage 2021.
- Incurred 2020: retired in 2021Q3, from electricity allocations of vintage 2022.
- Incurred 2021 through 2028: from electricity allocations, following same pattern as for EIM Outstanding Emissions incurred in 2020 (from vintages 2 years after the year in which the EIM Outstanding Emissions were incurred, with the retirement occurring 1 year after the emissions were incurred).
- Incurred in 2029 or 2030: no retirement unless cap-and-trade program is extended beyond 2030.

Assumption: *The model assumes that the annual quantity of future EIM Outstanding Emissions will be the same as the historical average to date. This assumption can be modified as new data become available.*

2.5.4. Retirements to account for bankruptcies

Starting in 2019, CARB will retire allowances to account for outstanding compliance obligations due to bankruptcy, "from the allowance budget two years after the current allowance budget year that is not already allocated to entities" (§ 95911(h)(1)).

As of mid-2019, the only historical bankruptcy that led to outstanding compliance obligations was for La Paloma Generating Company, LLC., which, in Compliance Period 2 (2015-2017) had unfulfilled obligations of 3,767,027 tCO_2e. To compensate for the unfulfilled obligation, CARB retired an equal number of government-owned vintage 2022 allowances on June 27, 2019 (see the 2019 Q2 Compliance Instrument Report).

> ***Assumption:*** *The model assumes that there will be no future bankruptcies leading to unfulfilled obligations, and therefore no further retirements to compensate for bankruptcy. This assumption can be modified as new data become available.*

2.5.5. Industrial assistance factors

California's October 2017 regulations calculated industrial allocations for 2018-2020 using "assistance factors" set at 75% for sub-categories of industries rated to have medium risk of leakage, and at 50% for sub-categories of industries rated to have low risk of leakage.

California's April 2019 regulations raise the assistance factors for 2018-2020 allocations to 100%, applying these changes retroactively to the 2018 and 2019 allocations. Therefore, revisions for 2018 and 2019 allocations, to be distributed from vintage 2020 and 2022 allowances, will include quantities to retroactively raise the total allocations for 2018 and 2019 to the level required by the 100% assistance factor.

The model implements CARB's increase in assistance factors as follows:

- The model calculates the difference between CARB's projection for allocations under the October 2017 regulations, and CARB's projection for allocations with 100% assistance factors.
- Retroactive increases in allocations for years 2018 and 2019 will be through the true-ups to be issued in late 2019 and late 2020. The 2018 true-up will come from the 2020 budget, and 2019 will come from the 2021 budget.
- The 2020 industrial allocation (to be distributed in late 2019) uses the 100% assistance factor.

2.6. Ontario's effect on supplies

Ontario linked with the WCI program effective January 1, 2018, and began participating in WCI cap-and-trade auctions beginning in 2018 Q1. Ontario subsequently withdrew from the market after the 2018 Q2 auction. Beyond purchasing allowances at quarterly auctions, Ontario-based entities were also able to purchase allowances from California and Québec on the secondary market. After Ontario withdrew from WCI auctions, regulators in California and Québec

instituted a freeze on instrument trades with Ontario entities, at which point transfers to or from Ontario entities were no longer possible.

The official Compliance Instrument Report indicates that Ontario's exit led to a net transfer of ~13.2 million allowances into the WCI program. Despite incomplete public reporting data, the net flow can be attributed to particular vintages of allowances (Mastrandrea et al., 2018). The model uses these attributions in its calculations of WCI allowance supplies.

Thus, the model reflects that 13.2 million instruments were added to the privately held supply in 2018. For some vintages of allowances, the net flow was negative (i.e., that there was a flow from California and Québec entities to Ontario entities), but the net flow across all vintages was positive (i.e., that the overall flow was from Ontario entities to California and Québec entities).

In 2019, regulators retired allowances to compensate for the net flow of allowances from Ontario. The Compliance Instrument Report (CIR) (CARB, 2019) for 2019 Q2 stated: "On June 27, 2019, California retired an equal amount of vintages 2021 through 2030 for a total of 11,340,792 allowances. Québec retired 1,846,175 vintage 2017 allowances from the Auction Account on July 10, 2019." (Note that Québec's retirements occurred after July 5, 2019, the date at which a snapshot of the state of the market was taken for the CIR, so those retirements are not reflected in the 2019 Q2 CIR.) WCI-RULES retires allowances from government holding accounts following regulators' description above.

> ***Assumption:*** *We infer that the allowances retired by California regulators came the government's Allocation Holding Accounts, since that is the only account holding sufficient numbers of allowances of all of the specified vintages. We infer that Québec's retirements were taken from vintage 2017 allowances that remained unsold after the auction collapse of 2016-2017, and were held in the government's Auction Holding Account, because there was no other pool of remaining government-held vintage 2017 allowances.*

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3. Full model documentation

3.1. Allowance pools

3.1.1. Annual allowance budgets (caps)

The quantity of allowances in each annual budget (or cap) is specified in the regulations for each jurisdiction.

- California cap quantities:
    - From § 95841. Annual Allowance Budgets for Calendar Years 2013-2050:
    - Table 6-1: 2013-2020 California GHG Allowance Budgets
    - Table 6-2: 2021-2031 California GHG Allowance Budgets

    - For broad cap (including transportation fuels), caps decrease from 394.5 MMTCO2e in 2015 to 200.5 MMTCO2e in 2030.
- Québec cap quantities:
    - For 2013-2020, from Québec Environment Quality Act (chapter Q-2), r. 15.2: http://legisquebec.gouv.qc.ca/en/ShowDoc/cr/Q-2,%20r.%2015.2
    - For 2021-2030, from Québec Environment Quality Act (chapter Q-2), r. 15.3: http://legisquebec.gouv.qc.ca/en/ShowDoc/cr/Q-2,%20r.%2015.3
    - For broad cap (including transportation fuels), caps decrease from 65.30 MMTCO2e in 2015 to 44.14 MMTCO2e in 2030.

3.1.2. Allowance Price Containment Reserve (Reserve) allowances

3.1.2.1. California Reserve

The quantity of allowances added to the Reserve accounts from each year's cap is specified in the regulations for each jurisdiction.

- Fractions of cap for 2013-2020 specified in § 95870(a):
    - One percent of the allowances from budget years 2013-2014;
    - Four percent of the allowances from budget years 2015-2017; and
    - Seven percent of the allowances from budget years 2018-2020.
- Quantities for 2021-2031 budget years specified in § 95871(a) and Table 8-2.
- Rules for Reserve sales stated in § 95913.

3.1.2.2. Québec Reserve

- Quantities stated in Québec Environment Quality Act (chapter Q-2), r. 46.1, s. 38: http://legisquebec.gouv.qc.ca/en/showversion/cr/Q-2,%20r.%2046.1?code=se:38 (in force date 2012-09-01).
- Rules for Reserve sales stated in Q-2 r. 46.1, s. 58: http://legisquebec.gouv.qc.ca/en/showversion/cr/Q-2,%20r.%2046.1?code=se:58 (in force date 2017-11-29)

3.1.3. Voluntary Renewable Electricity allowances (California only)

- Portion of annual caps set aside for this account are established in § 95870(c): 0.5% of cap for 2013-2014, 0.25% of cap for 2015-2020.
- There are no Voluntary Renewable Electricity allowances allocated from budget years after 2020.
- Once VRE allowances are set aside in the VRE account, these allowances are effectively removed from the cap-and-trade program.

3.1.4. Advance auction quantities

3.1.4.1. California advance auctions

- Portion of annual caps set aside to be made available at advance auction are established in § 95870(b) & § 95871(b): for all years 2015-2031, 10% of cap.
- Allowances are offered in advance auctions held 3 years prior to their vintage, in equal quarterly amounts, as specified in § 95910(c)(2).
- California advance auctions began in 2012 with vintage 2015 allowances. This year was an anomaly, with the full quantity of advance allowances offered in a single auction held in 2012 Q4.
- These allowances are transferred in blocks into the Auction Holding Account. For budget years 2013-2020: "Upon creation of the Auction Holding Account, the Executive Officer shall transfer 10 percent of the allowances from budget years 2015-2020 to the Auction Holding Account." For budget years 2021-2030, upon creation of the allowances for those budget years: "The Executive Officer shall transfer 10 percent of the allowances from budget years 2021 and beyond to the Auction Holding Account."

3.1.4.2. Québec advance auctions

- Quantities are not specified in regulations, but are described in guidance documents. The WCI annual auction notice for 2018 states: “Advance Auction Allowances Offered for Sale: The Advance Auction budget represents 10 percent of the allowances from each of the jurisdiction’s allowance budgets that are created for the year three years subsequent to the current calendar year.”
- Québec advance auctions began in 2013 with vintage 2016 allowances. This year was an anomaly, with the full quantity of advance allowances offered in a single auction held in 2013 Q4.

3.1.5. Direct allocations

3.1.5.1. California allocations (fixed)

3.1.5.1.1. Electrical Distribution Utility Sector Allocation

- For 2013-2020: § 95870(d)(1), with details specified in § 95892(a)(1) and § 95892(a)(2). Details for each utility are in https://www.arb.ca.gov/cc/capandtrade/allowanceallocation/edu-ng-allowancedistribution/electricity-allocation.xlsx.
- For 2021-2030: § 95871(c)(1). Details determined by § 95892(a), with allocation quantities explicitly stated in § 95892 Table 9-4. For 2021-2030, utilities not identified as IOU or POU, so model identifies them based on categorization in period 2013-2020.
- This allocation decreases from ~95.8M in 2013 to ~61.5M in 2030.

- The allocation is specified for each entity (each electricity distribution utility), and they are categorized into two groups:
    - Investor Owned Utilities (IOUs), which must consign all their allocated allowances to auction
    - Publicly Owned Utilities (POUs) and Electrical Cooperatives, which are not required to consign any of their allocated allowances to auction, but which can optionally consign any quantity up to the full allocation. (In the model, cooperatives are grouped together with POUs, and referred to as POUs throughout.)

3.1.5.1.2. Natural Gas Supplier Sector

- This allocation began in 2015 (at which time compliance obligations for natural gas suppliers also began).
- For 2015-2020, § 95870(h); method described in § 95893(a)
    - Beginning in 2015, this allocation is:
        - allowances = [emissions in 2011] * [annual adjustment factor for natural gas]
    - The annual adjustment factor for natural gas is the same as the “cap adjustment factor.”
    - The emissions in 2011 are not stated in the regulations, but it can be inferred from the quantities allocated in this category. Emissions in 2011 = (reported allocations for year X) / (cap adjustment factor for year X). Inferred to be 48,047,669 metric tons. The method was confirmed to be accurate; calculated values for allocations 2015-2018 are either exactly the same as what was allocated, or are within 1 allowance.
- For 2021 and beyond, § 95871(g); method is "pursuant to sections § 95893(b) and § 95831(a)(6)".
- This allocation decreases from ~45.4M in 2015 to ~23.7M in 2030.

3.1.5.1.3. Allocation to Public Wholesale Water Agencies

- For 2013-2020: Specified by § 95870(d)(2), with details in § 95895(a) and § 95895 Table 9-7: "Allocation to Each Public Wholesale Water Agency" [2015-2020].
- For 2021 and beyond: Specified by § 95871(c)(2), with details in § 95895(b).
- This allocation decreases from ~0.18M in 2013 to ~0.02M in 2030.

3.1.5.2. California allocations (variable)

The variable allocations are determined based on rules in the regulations, but the quantities allocated depend on levels of economic activity or energy use, so are not predetermined.

The “other” category consists of Public Wholesale Water Agencies (quantities established in regulations; see above), University Covered Entities and Public Service Facilities, Legacy

Contract Generators (included with Industrial, from 2018 allocation onward), Production of Qualified Thermal Output, Waste-to-Energy Facilities, LNG suppliers.

3.1.5.2.1. Industrial allocation

- Rules for calculating for 2013-2020: § 95870(e)
- Rules for calculating for 2021 and beyond: § 95871(d)
- More details on this allocation are in § 95891, “Allocation for Industry Assistance”
- Note: The allocation reports for 2018 and later stated the combined allocation for “Industrial Allocation and Legacy Contract Allocation.” In 2017, the Legacy Contract Allocation was ~0.4M, so it was likely responsible for < 1% of the combined category “Industrial Allocation and Legacy Contract Allocation” in 2018 and later years.
- On industry assistance factors: In 2018 and 2019, assistance factors followed October 2017 regulations (Table 8-1); sub-sectors with "low" leakage risk were assigned an industry assistance factor of 50%, and sub-sectors with "medium" leakage risk were assigned an industry assistance factor of 75%. In April 2019 regulations, CARB raised assistance factors for all sub-sectors to 100%, including making retroactive allocations for 2018 and 2019. Therefore, there will be larger-than-usual true-ups in 2020 and 2021 for retroactively increasing the assistance factors for the allocations for emissions in 2018 and 2019.

3.1.5.2.2. Allocation to University Covered Entities and Public Service Facilities

- 2013-2020: § 95870(f)
- 2021 and beyond: § 95871(e)

3.1.5.2.3. Allocation to Legacy Contract Generators

- 2013-2020: § 95870(g)
- 2021 and beyond: § 95871(f)
- Starting from 2018, this allocation was reported in combination with the industrial allocation, and likely contributed < 1% of the total combined allocation.
- Thus, the model does not make a projection for the Allocation to Legacy Contract Generators separate from the Industrial Allocation.

3.1.5.2.4. Allocation for Waste-to-Energy Facilities

- Annual allocation report had allocations for waste-to-energy in 2015-2019, each for emissions from two years prior (as stated on the first page of allocations reports). Related: § 95852(k), "Limited Exemption of Emissions for Waste-to-Energy Facilities."
- California’s April 2019 regulations (Cal. Code Regs., 2019) include waste-to-energy allocations for 2020 and later years, as specified in § 95871(i) and § 95891(f)(1)-(2).

3.1.5.2.5. Allocation for Production of Qualified Thermal Output

- Full name in annual allocation reports: "Allocation to Facilities with Limited Exemption of Emissions from the Production of Qualified Thermal Output." Related: § 95852(j) "Limited Exemption of Emissions from the Production of Qualified Thermal Output."
- This was a limited-time allocation. The annual allocation reports stated allocations for "qualified thermal output" of vintage 2015 (for 2013 emissions) and vintage 2016 allowances (for 2014 emissions), as stated on the first page of allocations reports. No allocation was reported after 2016.
- From 2015 to 2029, these facilities' emissions are not counted as covered emissions, and thus they do not incur compliance obligations and do not receive further allocations.
- Per section 95851(c), these facilities will have a compliance obligation starting in the first year for which natural gas suppliers are required to consign 100 percent of allocated allowances to auction, so they will have a compliance obligation starting in 2030. However, our understanding is that these facilities will not be awarded an allocation in 2030 and beyond.

3.1.5.2.6. Allocation for LNG suppliers

- Full name in annual allocation reports: Allocation to "Suppliers of Liquefied Natural Gas and Compressed Natural Gas"
- This category had an allocation only in 2018, for emissions with compliance obligations in second compliance period (2015-2017). This category is given a limited exemption for emissions in years from 2018 onward (see § 95852(l)(1), "Limited Exemption for Emissions from LNG Suppliers").
- Allocation in 2018 was ~0.05 MMTCO2e, so the average allocation per year 2015-2017 was ~0.017 MMTCO2e.
- Note that regulations specify that there could be a true-up of the allocation for emissions incurred 2015-2017; this allocation true-up would be taken from vintage 2019 (§ 95852(l)(1)). However, no such true-up was reported in California's vintage 2019 allocations report (CARB, 2018c).

3.1.5.2.7. Projection of "industrial and other" allocations 2019-2030

- ***Assumption:*** *The model uses CARB's projection for "industrial and other" allocations, as published in slides for a workshop (CARB, 2018d), which combines all allocations except the electricity allocation and natural gas allocation. The "other" category includes the allocations listed above (University Covered Entities and Public Service Facilities, Legacy Contract Generators, Waste-to-Energy Facilities, Production of Qualified Thermal Output, LNG suppliers). The model uses this projection only for future years, beyond the historical data available.*
- In addition to the allocations intended for each year, the model calculates true-up quantities for the 2018 and 2019 allocations, which are distributed in 2020 and 2021, to retroactively raise the industrial assistance factors for all industries to 100%.

3.1.5.3. Québec allocations (variable)

In Québec, allocations are based on "the total quantity of reference units produced or used," and as such are not predetermined, following Québec's regulations, sections 39-44 (Québec, 2019). The allocations are awarded initially as 75% of the estimated total allocation for a particular year, and then a true-up for the remaining 25% is awarded in the subsequent year, with additional true-ups as needed if updated data indicates the full allocations were not correct.

Québec reports the cumulative amount allocated for emissions incurred in each year, starting with the initial 75% estimate and continuing through any subsequent true-up quantities (including negative true-ups), but does not explicitly state the true-up quantities awarded in each distribution of allowances. The true-up quantities that occurred at particular times can be calculated from the cumulative reports.

Prior to 2019, Québec issued separate reports for the cumulative allocations for emissions incurred in each year. These individual reports have been removed from the MELCC website; we have archived those older reports in the WCI-RULES repository on OSF (Inman, 2019). In January 2019, MELCC issued allocation data in a new format, in a single report with cumulative values to date for allocations for emissions incurred in each year, available at http://environnement.gouv.qc.ca/changements/carbone/ventes-encheres/allocation-gratuite/Qte-unites-versees-2013-2020.pdf.

Québec's allocations were relatively flat over 2013-2019, varying between ~17.8 M and ~18.9 M allowances per year. Nonetheless, the model assumes the allocations will decrease in the future (see below).

> ***Assumption:*** *The model assumes that Québec's allocations will scale down from the latest historical value in line with the annual caps.*

Shown below in Figure 1 are the historical and projected values of the allocations for California & Québec, given historical data through 2019. California allocations increase in 2020 and 2021 due to large true-ups to retroactively raise the assistance factors for 2018 and 2019 allocations to 100%.

For projected allocations, the model calculates a total allocation for emissions incurred in each year, consisting of allowances with vintages equal to that year. The model distributes 75% of each year's allocation as the initial distribution at the start of that year (in keeping with historical practice). The model sets aside the remaining 25% of the allocation to distribute as a true-up in September of the following year (also in keeping with historical practice).

WCI-RULES uses Compliance Instrument Report data for Reserve allowance distributions and Reserve sales from the data input file to determine any distribution of Reserve allowances that were not from Reserve sales. As of 2019Q2, no WCI Reserve sales had occurred, but ~1.3 M Reserve allowances had been distributed to private entities.

***Assumption**: The model assumes that Reserve allowance distributions not from Reserve sales were part of Québec allocation true-ups, credited to the prior year's allocation.*

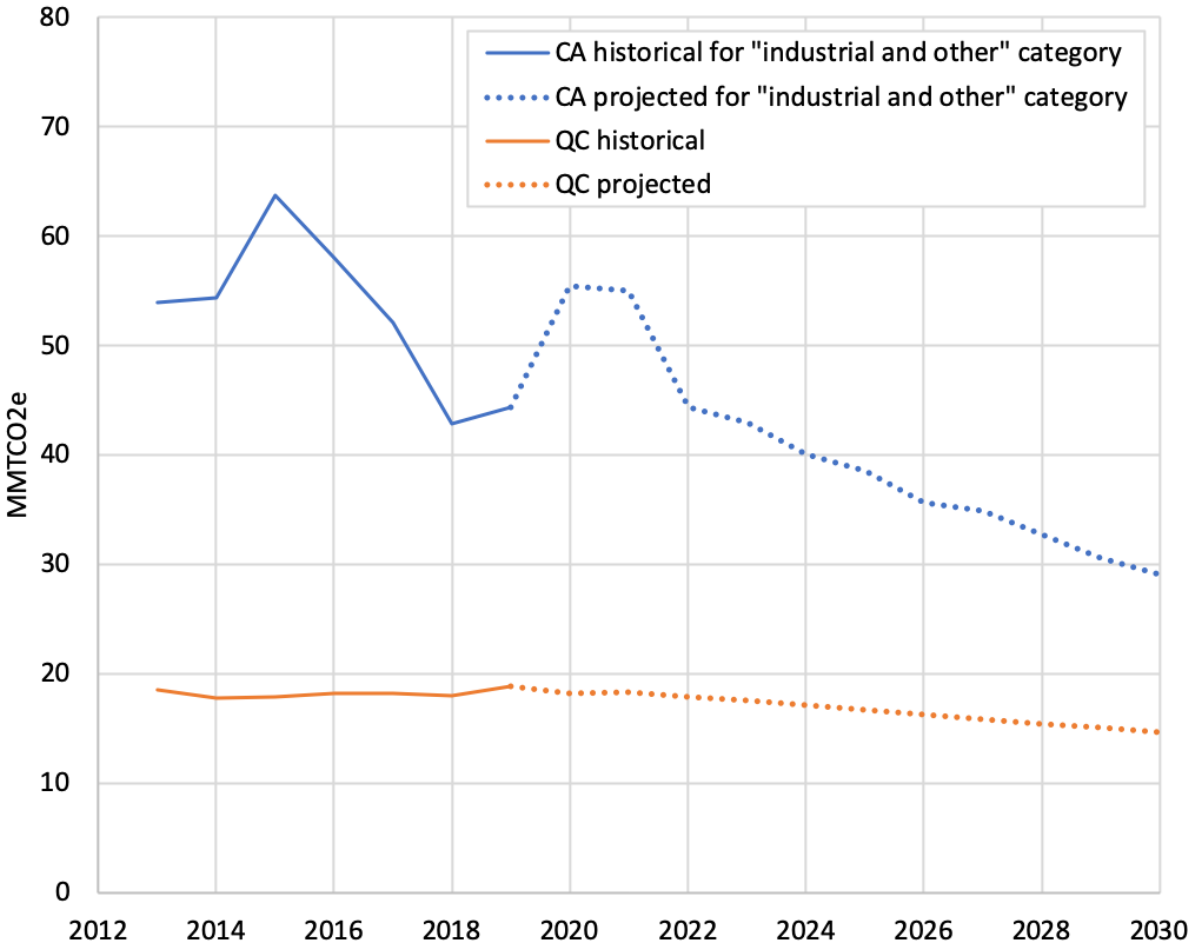

Figure 1. WCI-RULES projections for allowances freely allocated, given historical data through 2019. For California (CA), allocations shown are for CARB's "industrial and other" category of allocations; it is all allocations other than those to electricity distribution utilities and natural gas distribution utilities. For Québec (QC), total allocations are shown.

3.2. Emissions scenarios

The model allows users to specify scenarios for the trajectories for covered emissions in California and Québec separately.

By default, the model uses a projection in which covered emissions decrease 2% per year, starting from emissions in 2016 (the latest year with official reporting data). Users can specify higher or lower emissions scenarios using the available settings. The default scenario follows CARB's 2017 Scoping Plan scenario for California "covered sector" emissions, which includes the effects of prescriptive policy measures (e.g., the Renewables Portfolio Standard for electricity), but does not incorporate effects of the cap-and-trade program (CARB, 2017). This

default rate of change in covered emissions is also similar to Energy Innovation's "Oversupply Grows" report (Busch, 2018), which assumes a decline of 1.9% per year through 2020.

To choose an alternative emissions pathway, the user can specify an annual percentage change over the whole simulation period or specify more detailed trajectories for different year ranges. The user can also specify a custom emissions trajectory.

For historical data, there can be differences between the data in each year for covered emissions and data for compliance obligations incurred, for the following reasons:

- Historical covered emissions data may be revised by regulators, without a change in the related compliance obligations. For California, the latest version of the covered emissions data, as well as archives of prior versions, are available at: https://ww2.arb.ca.gov/mrr-data.
- There can be permanently unfulfilled obligations, such that some compliance obligations associated with emissions will never be satisfied. The only significant instance so far was due to the bankruptcy of La Paloma Generating Company, LLC., in which 3,767,027 tCO_2e worth of compliance obligations were discharged in bankruptcy court and therefore will go permanently unfulfilled; in 2019, CARB retired that same quantity of allowances to compensate.

The model's output file reports both the covered emissions (using the version of the data from regulators specified in the model's data input file, in the sheet "emissions & obligations") and the compliance obligations incurred (excluding those permanently unsatisfied).

Note that compliance obligations are not always the same as covered emissions. This can be because:

- The latest data for historical covered emissions may have been revised since the initial issuance of the data, but the compliance obligations incurred may not have been revised.
- There may be permanently unfulfilled obligations, such as due to bankruptcy, that mean the remaining obligations are lower than covered emissions.

3.3. Simulation of quarterly auctions

The model begins its simulation of each scenario at the end of the historical data as specified in the model's input file. The model processes each quarter individually, including quarterly auctions and steps that occur before and after particular auctions (i.e., steps that occur each year before the Q1 auction).

3.3.1. Initial conditions for simulation

Drawing on historical data on the state of the cap-and-trade market and a "hindcast" run of the model beginning in 2012 Q4, the model determines the initial conditions for a new run:

- Allowances unsold, from both advance auctions and current auctions.

- The number of auctions in a row that have sold out, which determines whether state-owned unsold allowances can be reintroduced to auction.

The model's default projection is that all future auctions will sell out, including both current and advance auctions.

The user can specify alternative scenarios for future auction results (later than the latest historical auction data in the model's input file). The user-specified percentage that goes unsold is applied to both current and advance auctions held in the stated year(s).

3.3.2. Preparatory steps

Each year the model does preparatory steps prior to particular auctions:

- **Unsold allowances from advance auctions**: Prior to the Q1 auctions, any allowances unsold in advance auctions three years prior are re-designated to the current auction, and any allowances retired to account for bankruptcies are moved to the retirement account. These allowances are retained within government Auction Holding Accounts, but within the model their metadata is updated to re-designate them to current auctions.
- **Retirements for EIM Outstanding Emissions**: Under the October 2017 regulations, there was an historical retirement for EIM Outstanding Emissions that occurred at the end of 2018 Q3. The April 2019 regulations require retirements for EIM Outstanding Emissions to occur each year prior to the November 1 compliance events. For projection years, the model assumes these retirements occur annually at the start of Q4; any allowances retired to account for EIM Outstanding Emissions (hereafter "EIM retirements") are moved from government holding accounts to the retirement account. (To replicate historical data, the retirement for EIM Outstanding Emissions that occurred in 2018 is forced to occur in Q3.) For more on EIM retirements, see details in Section 2.5.3.
- **Retirements for bankruptcy**: The regulations do not require retirements for bankruptcy to occur at a particular time. There was an historical retirement on June 27, 2019. For projection years, the model assumes any bankruptcy retirements will occur annually at the start of Q4, prior to the Q4 auctions; any allowances retired to account for bankruptcies are moved from government holding accounts into the retirement account.

3.3.3. Processing auctions

For each quarterly auction, the model goes through the following steps for advance auctions and current auctions.

3.3.3.1. Processing advance auctions

3.3.3.1.1. Calculates available allowances

- Quantity available in advance auctions each year is 10% of each jurisdiction's budget for that year.
- Amount available in each quarterly auction is one-quarter of the annual total.

3.3.3.1.2. Calculates allowances sold

- By default, the model assumes all future auctions—following the latest historical auction data in the model's input sheet—will sell out.
- The user can specify different auction outcomes by choosing the percentage that goes unsold in particular years (i.e., 50% unsold in 2024 and 2025). The unsold percentage applies to both current auctions and advance auctions held in the specified years.
- The percentages sold are applied to each of the jurisdictions.

3.3.3.1.3. Processes quarterly auctions

- Processes advance auctions for each jurisdiction, assigning sales to particular allowances, and moving those allowances out of the available stock, recording quantities sold.
- Under certain conditions, unsold advance allowances may be re-designated to a later advance auction in that same year. This can occur in a particular year only if the first quarterly auction does not sell out, and then the next two do sell out.
- Any unsold allowances from advance auctions that remain at the end of the calendar year are retained for re-designation to current auctions. (This rule for re-designation of unsold allowances from advance auctions to later *current* auctions is implemented in the model.)
    - Note: For California, when allowances go unsold in advance auctions, there is a rule for re-designating these for sale in advance auctions again during the same calendar year. This can only occur if some allowances go unsold in the first quarter of the year, and then the next two auctions sell out; then in the fourth quarter, some of the unsold allowances can be re-designated for sale.
    - Québec does not have a similar rule in their current regulations (Jan. 2018). The regulations state: "Emission units of the vintage of a year subsequent to the year of the auction are put up for sale again when their vintage becomes the vintage of the current year."

3.3.3.2. Processing current auctions

3.3.3.2.1. Calculates available allowances

- First, the model calculates quarterly quantities of allowances to be made available in current auctions for the first time. Quarterly allowances are made up of three sets:
    - State-owned allowances available for the first time in current auctions. In each quarterly auction, one-quarter of the annual total is made available. The total number of such allowances is calculated as the remainder of the annual budget, after removing:
        - Reserves
        - Allowances set aside for advance auctions
        - Allocated allowances
    - State-owned allowances available in advance auctions that remained unsold at the end of the calendar year. (In Q1 each year, prior to Q1 auction, the advance unsold are re-designated to current auction.)
    - Consignment allowances. Newly available consigned allowances for each year are the minimum required to be consigned by the regulations, plus any additional that entities choose to consign. The model makes a default projection for optional consignment 2019-2030. The model then calculates quarterly quantities to be made available for each year.
    - Consigned allowances for each quarter are moved from the private Limited Use Holding Account to the government Auction Holding Account at least 75 days prior to the auction (per § 95910(d)(4)), therefore the transfer occurs in the quarter prior to the quarter in which the consigned allowances will be available at auction.
        - ***Assumption:*** *If no historical data is available for part of a given year, then the model assumes that the quarterly values will each be one-quarter of the annual. For the latest year with historical auction data, if data are available for only part of the year, then the model calculates the remaining quantity to be consigned in future auctions and assumes that it will be equally divided between the remaining auctions.*
- Second, the model re-designates any eligible allowances that went unsold in earlier current auctions.
    - For consignment allowances, any unsold are redesignated to the following auction.
    - For state-owned allowances, allowances unsold in a prior current auction can be re-designated (sometimes referred to as being “re-introduced”) at a later current auction, after two current auctions in a row have sold at above the floor price. When state-owned unsold allowances are eligible for re-introduction, the quantity that can be re-introduced for each jurisdiction is 25% of that jurisdiction’s allowances newly made available for that auction, prior to re-designation of state-owned allowances unsold in prior current auctions. (State-owned allowances that

went unsold at a prior current auction and are then re-designated to auction are also known as “reintroduced” allowances.)

3.3.3.2.2. Calculates allowances sold (based on user parameters)

- By default, the model assumes all future auctions—following the latest historical auction data in the model’s input sheet—will sell out.
- The user can specify different auction outcomes by choosing the percentage that goes unsold in particular years (i.e., 50% unsold in 2024 and 2025). The unsold percentage applies to both current auctions and advance auctions held in the specified years.
- The percentages sold are applied to each of the jurisdictions.

3.3.3.2.3. Processes quarterly auctions

- Assigns sales to particular sets of allowances, based on the order of sales specified in regulations (for California, § 95911(f)(1)). Based on Québec regulations and historical record, Québec appears to use the same order of sales as California. The order of sales in the regulations, and implemented in the model, is:
    1. Consignment allowances (for California only); no distinction between re-designated and newly available allowances (§ 95911(f)(1)(A)-(B))
    2. Re-introduced state-owned allowances (§ 95911(f)(1)(D))
    3. State-owned allowances available at current auction for the first time (which includes any allowances unsold in advance auctions that were re-designated to current auction) (§ 95911(f)(1)(E))
- When current auctions do not sell out, unsold allowances are retained for possible re-designation in later current auctions.
- Model removes California allowances from unsold stock if they have remained unsold for more than 24 months.
- Model updates conditions for reintroduction of unsold state-owned allowances, to serve as input to the next auction.
- Model records allowances available, sold, and unsold in each auction. These are distinguished by jurisdiction, seller, vintage, date sold (if any), initial unsold date (if any), latest unsold date (if any).

3.4. Annual metrics for supply and banking

The model calculates the total supply and demand for compliance instruments each year, and from this calculates annual metrics for oversupply (or overallocation) in the cap-and-trade program. In summary, the annual metrics are:

(1) **Private Supply** (annual additions): The quantity of compliance instruments that are transferred into private accounts in each year, through allowances sold at auction, free allocations of allowances, and offsets sold.

(2) **Private Bank** (cumulative): The quantity of compliance instruments that are held in private accounts beyond outstanding compliance obligations to date, following methods published previously (Cullenward et al., 2019).
(3) **Government Holding Accounts** (cumulative): The quantity of compliance instruments held in government holding accounts, following methods published previously (Cullenward et al., 2019).
(4) **Reserve Sales** (cumulative): Sales of Reserve allowances from the Allowance Price Containment Reserves, as needed for regulated entities to have enough instruments to satisfy their compliance obligations.
(5) **Price Ceiling Unit Sales** (cumulative): Sales of Price Ceiling Units, a distinct type of compliance instrument that California will make available from 2021 onward in unlimited quantities.
(6) Reserve Accounts (cumulative)**:** The quantity of compliance instruments held in government Reserve accounts (also known as Allowance Price Containment Reserve accounts), following methods published previously (Cullenward et al., 2019).

3.4.1. Private supply

The total private supply of compliance instruments that are privately held at any time, or were previously privately held, is made up of:

- Allowances allocated freely to emitters
- Allowances sold at auction
- Offsets supply*
- Allowances or offsets retired*
- Early Action allowances*
- Reserve allowances distributed to private accounts*

The categories listed above with asterisks have not yet been described in the documentation and are described below. Those without asterisks are described above.

In addition to the instruments privately held above, there are also publicly held allowances that are not yet sold or distributed (see Section 3.4.3, Government Holding Accounts).

3.4.1.1. Offsets supply

A percentage of each regulated entity's compliance obligation can be satisfied by offsets, representing emission reductions outside the cap-and-trade program that offset emissions from covered sources. For California, the limits on offset usage are 8% through 2020, 4% (2021-2025), and 6% (2026-2030). For Québec, the limit is 8% for all years. Limits on offset usage are applied for each multi-year compliance period.

The model incorporates actual offset supply through 2018 Q3, based on the 2018 Q3 Compliance Instrument Report. Through 2018 Q3, historical offset sales were ~6% of covered emissions (contingent on the default emissions projection, with emissions decreasing 2% per

year in 2017 and 2018). This is 75% of the offset usage limit in the program to date, and matches CARB's assumption for future offset supply in the period 2021-2030 (CARB, 2018a, 2018e).

> ***Assumption:*** *The model's default projection for offset supply for all projection years is set at 75% of the limit for each jurisdiction, for each relevant time period. Users can specify a higher or lower supply using the available settings.*

Like allowances, offsets can also be banked for future use. Thus, we include offsets in our banking calculations, which implicitly assumes that the number held in private accounts does not exceed the cumulative limits imposed on their future use. There are no regulatory limits that apply to the number of offset credits a private entity can hold at any given point in time.

3.4.1.2. Allowances or offsets retired

Those instruments that have already been retired for compliance or other purposes are counted by the model towards the private supply.

3.4.1.3. Early Action allowances

Québec issued ~2.0 M "Early Action" allowances (also called "Early Action credits") to private entities. These are additional emissions allowances, beyond those in the annual budgets. No more Early Action allowances will be issued. The model counts those issued toward the private supply.

3.4.1.4. Reserve allowances distributed to private accounts

As of 2019 Q2, a total of ~1.3 M allowances had been moved out of the Reserves (of California and/or Québec), and into private accounts—most of which were subsequently surrendered to satisfy compliance obligations and placed in retirement accounts.

> ***Assumption:*** *The model assumes that these allowances were distributed by Québec as part of allocation true-ups, following section 42 of the Québec regulations (Québec, 2019). Other than Reserve sales, which have not occurred as of this writing (September 2019), allocation under the Québec regulations is the only mechanism we are aware of for distributing reserve allowances to private entities. The model counts these allowances toward the private supply of allowances.*

3.4.2. Annual Private Bank metric

For years with full data on the supply side (available once all quarterly auctions are complete), we calculate the Private Bank metric using the model results and following a previously published method (Cullenward et al., 2019). That method calculates a Private Bank metric at the end of each year equal to the private supply minus the outstanding emissions obligations.

We count the following sets of instruments toward the supply in private accounts (General Account and Compliance Account):

- Vintaged allowances with vintages up to the year of the metric. For example, in calculating the Private Bank of compliance instruments in 2018, vintaged allowances of vintages up to 2018 count toward the metric, but later vintages do not.
- All non-vintaged allowances, which consist of Early Action Allowances (Québec only) and Reserve allowances. As of 2019 Q2 there have not yet been any Reserve sales, but Québec has distributed ~1.3 M Reserve allowances to private entities as part of its free allocations, so some Reserve allowances have entered circulation, and have been surrendered to satisfy compliance obligations.
- All offsets held in private accounts.

The model calculates the instruments remaining in private accounts after retirements for satisfying compliance obligations.

The outstanding emissions obligations are based on the total emissions obligations incurred, minus instruments surrendered for compliance, and minus any permanently unfulfilled obligations (e.g., ~3.7 M of obligations unfulfilled due to the La Paloma bankruptcy).

Because this method only counts vintaged allowances up to a particular vintage (equal to the year of the metric), the metric is affected by "borrowing" of future vintages for compliance purposes. For example, in the November 1, 2018 compliance event, compliance entities surrendered ~0.7 M allowances of vintage 2018 and ~0.6 M allowances of vintage 2019. Generally, these vintages of allowances could not be used for compliance at this time, but under the cap-and-trade regulations there are exceptions to the rule. Thus, we refer to such surrenders of allowances with vintages higher than what can normally be surrendered in a particular year as "borrowing." When compliance entities engage in borrowing, this causes the banking metric to be higher than it would otherwise be, because more allowances of current vintage or earlier remain in private accounts than if borrowing had not occurred; the increase is equal to the sum of the borrowed allowances (e.g., the 2018 Private Bank metric is ~1.3 M higher due to the borrowing described above).

For years based on projections for the supply side and emissions side, the Private Bank metric is calculated as the private supply minus covered emissions. That is, the Private Bank calculation implicitly assumes that all emissions obligations will be satisfied on time and that surrenders for compliance obligations will not involve borrowing.

The model may have different values for metrics in 2018 than have been published previously (Cullenward et al., 2019), due to differing assumptions about covered emissions in 2018. The primary reason is due to differences in projections for covered emissions in 2018. The aforementioned paper used a central projection for 2018 covered emissions that assumed the annual percentage rate of change from 2017 to 2018 would be the same as from 2016 to 2017 (–0.4%), resulting in a central projection of 2018 covered emissions of ~379 $MMtCO_2e$. In contrast, the WCI-RULES default, as of this writing, uses an annual percentage change of –

2.0%, resulting in a projection for 2018 covered emissions of ~373 $MMtCO_2e$, a value ~6 $MMtCO_2e$ lower than in the aforementioned paper, leading to an annual Private Bank metric that is ~6 M higher. (If the user selects a different covered emissions projection, then the projection for 2018 will differ from the value described above for the WCI-RULES default case.)

3.4.3. Government Holding Accounts

The Government Holding Accounts metric tracks the quantity of compliance instruments held in government holding accounts (Allocation Holding Accounts, Auction Holding Accounts, and Offset Issuance Accounts), following methods published previously (Cullenward et al., 2019). Allowances in this category include those that went unsold at auction, as well as some Québec allowances retained for later allocation true-ups. Small quantities of offsets in government holding accounts count toward this metric; these are offsets issued by regulators but not yet transferred to private accounts.

3.4.4. Reserve Sales

When a scenario leads to a shortfall of instruments available through normal supplies—instruments acquired through allocations, auctions, and offset sales—then the model simulates sales of Reserve allowances from the Allowance Price Containment Reserves, as needed for regulated entities to have enough instruments to satisfy their compliance obligations. Reserve sales are simulated to occur in the year in which the shortfall occurs.

As of 2019 Q2, there had not yet been any Reserve sales in WCI. If some Reserve sales do occur, the model factors these into the supply-demand calculations. If no Reserve sales occur historically by the time the modeled Private Bank has been exhausted, then the model calculates Reserve sales required.

Although regulations allow Reserve sales to occur quarterly, in WCI-RULES Reserve sales are assumed to occur only once per year, at the end of each year, in order to balance the supply and demand for each year.

3.4.5. Price Ceiling Unit Sales

If the Reserves are exhausted, the model simulates sales of Price Ceiling Units, a distinct type of compliance instrument that California will make available from 2021 onward as needed, in unlimited quantities. As the name implies, Price Ceiling Units are offered for sale at California's Price Ceiling in a given year; the Price Ceiling rises over time from 2021 to 2030.

3.4.6. Reserve Accounts

The quantity of compliance instruments held in government Reserve accounts (also known as Allowance Price Containment Reserve accounts). These are predominantly allowances set aside as Reserves by regulation, but also include: (a) California state-owned allowances that went unsold at auction and remained unsold for 24 months, at which point they were removed

from the normal supply and transferred to Reserves, and (b) other vintaged allowances added to Reserve accounts, apparently as part of negative true-ups for Québec allocations, in which private entities transferred allowances to the government.

3.5. Compliance Period metrics for supply and banking

The model also calculates several Compliance Period metrics, which are approximations of the state of the market immediately following the compliance events in which all remaining obligations for a given compliance period are due (e.g., immediately after the November 1, 2018 compliance event, at which all remaining obligations incurred in 2015-2017 were due). The Compliance Period metrics are:

(1) **Private Allowances** (cumulative): The quantity of allowances that are remaining in private accounts after the compliance event, following methods published previously (Cullenward et al., 2019).
(2) **Private Offsets** (cumulative): The quantity of emissions allowances that are remaining in private accounts after the compliance event, following methods published previously (Cullenward et al., 2019).
(3) **Private Bank** (cumulative): The sum of the Private Allowances metric and Private Offsets metric; this is the Compliance Period equivalent of the annual Private Bank metric.
(4) **Government Allowances** (cumulative): The quantity of allowances that are remaining in government holding accounts (Allocation Holding Accounts and Auction Holding Accounts) after the compliance event, following methods published previously (Cullenward et al., 2019).
(5) **Government Offsets** (cumulative): The quantity of offsets that are remaining in government holding accounts (Offset Issuance Accounts) after the compliance event, following methods published previously (Cullenward et al., 2019).
(6) **Reserve Accounts** (cumulative): The quantity of allowances remaining in Reserve accounts after the compliance event. Since Reserve sales are assumed to occur at the end of each year, then the Compliance Period metric Reserve Accounts corresponding to a particular compliance event is the same as the annual metric Reserve Accounts in the year prior to that compliance event. (For example, for the 2027-2029 compliance period, with all obligations due by the November 1, 2030 compliance event, the Compliance Period metric Reserve Accounts is the same as the annual metric Reserve Accounts for 2029.)

The Compliance Period metrics are calculated following methods previously published (Cullenward et al., 2019). These metrics are not shown in the WCI-RULES interface but are included in the output file that can be downloaded from the user interface.

3.6. Instrument retirements

3.6.1. Limits on offset usage (or surrender)

Since the quantity of offsets that each entity can use is limited by regulations to a certain percentage of their covered emissions, the model calculates a limit on offset use. For California, the limit on offset use for emissions obligations incurred through 2020 is 8%; then 4% for emissions obligations incurred 2021 through 2025, and 6% for emissions obligations incurred 2026 through 2030. In Québec's current regulations, offset limits are 8% for emissions obligations incurred in all years through 2030.

For projections through 2030, the offset use rates are the same as CARB's assumed offset use for California entities (CARB, 2018a, 2018e), which are 75% of the maximum that can be used in each year and for each jurisdiction.

Note that these assumptions about offset use are separate from assumptions for offset supply, discussed above. If cumulative offset use is less than cumulative offset supply, then surplus offsets are banked.

The model calculates the maximum possible offset use, given the limits stated above and the offset supply over time. If the user's settings for offset supply would lead to excess offsets, beyond what could be used by the end of 2030, then the model gives the user a warning. (This warning is also saved in the output file that can be downloaded from the user interface.)

3.6.2. Surrender of instruments

To comply with regulations, emitters must surrender sufficient instruments to satisfy their obligations, and can use offsets up to the limits stated above. The model is agnostic about what share of offsets emitters may submit in the future for compliance. The Private Bank metric is calculated based on the total supply of instruments in private accounts.

3.7. Sales of Reserves and Price Ceiling Units

Under California's regulations, only California entities are eligible to buy allowances from California's Reserve (§ 95913(b)). We are not aware of a similar rule that only Québec entities are eligible to buy allowances from Québec's Reserve; requirements for entities to purchase Reserve allowances are in section 59 of the Québec cap-and-trade regulations (Québec, 2019).

If entities in one jurisdiction ran short of allowances, they might purchase allowances from another jurisdiction if there were another linked jurisdiction with a surplus of allowances. Thus, trade of allowances between jurisdictions might delay the onset of Reserve sales, compared with what might occur if each jurisdiction were independent. In WCI-RULES, the WCI-wide supply-demand balance is used to calculate Reserve sales, without distinguishing between Reserves of different jurisdictions.

Assumption: *If there are not enough compliance instruments available in the Private Bank to satisfy compliance obligations, then the model assumes that sales from Reserves will begin after the Private Bank of compliance instruments is completely exhausted, sufficient to balance WCI-wide supply and demand. The model assumes that when the Reserves are exhausted, sales of Price Ceiling Units will occur as needed to balance WCI-wide supply and demand. The model assumes that all WCI jurisdictions' Reserves can be treated as an aggregated whole for the purposes of calculating when they will be accessed and how quickly they will be sold.*

If one jurisdiction did begin Reserve sales, it is likely that prices (at auction and on the secondary market) would rise at least to the price at which Reserve allowances are sold (if prices had not already reached that level prior to the start of Reserve sales). Likewise, if allowances at the first Reserve tier were exhausted for both jurisdictions, prices would likely rise sufficiently to access the second Reserve tier, and so on, accessing additional Reserve and Price Ceiling allowances as needed for compliance.

The model does not evaluate the likelihood of a particular emissions trajectory occurring, nor any feedback between emissions and market prices implied by a scenario in Price Ceiling Units are accessed to comply with emission limits.

4. How to run WCI-RULES

4.1. Preparation to run WCI-RULES

To run WCI-RULES on your computer, you must have Python 3 (preferably 3.7 or higher) and the Python libraries Pandas, Bokeh, Jupyter and their dependencies (including Numpy), and a few extensions for importing Excel files and creating interactive components of the user interface.

We recommend installing the software within a virtual environment using Conda, https://docs.conda.io/projects/conda/en/latest/index.html.

(Steps below will be slightly different if using a different type of virtual environment.)

Create a conda environment and then activate it. All but one of the required packages can be installed using <conda install -c conda-forge PACKAGENAME==VERSION>, e.g., <conda install -c conda-forge pandas==0.25>. These required packages and versions are:

- Python version 3.7
- Pandas version 0.25
- Bokeh version 1.3
- Numpy version 1.16
- xlrd version 1.2

- openpyxl version 2.6
- Jupyter version 1.0
- ipywidgets version 7.5
- Jupyter Notebook Extensions version 0.5

The packages above can be installed all together in a new conda environment with the following command: <conda install -c conda-forge python==3.7 pandas==0.25 bokeh==1.3 numpy==1.16 jupyter==1.0 ipywidgets==7.5 xlrd==1.2 openpyxl==2.6 jupyter_contrib_nbextensions==0.5>.

Attempting to run WCI-RULES using different versions than the packages listed above may lead to errors or unexpected behavior. The Pandas package, in particular, may have changes to its API that are not backwards compatible, so it is strongly encouraged to use the package versions listed above.

4.2. Running the model

- Download the set of files in the repository (from Github or OSF).
- Open Jupyter notebook with the command <jupyter notebook>; Jupyter notebook should open in the user's default web browser.
- In Jupyter Notebook, open the interface file, <WCI-RULES_model_interface.ipynb>. The interface file will access the other files, such as the model code <WCI-RULES_model.py> and the data input files. As long as the model files are retained in the folder as downloaded from the repository, the interface should find them automatically.
- The interface should appear and automatically begin initialization steps.
- After the initialization is complete, the model will show results for the default scenario, called the PATHWAYS Scenario. For more information about the default scenario, see (Inman et al., 2019).
- To run a different scenario, specify different settings for covered emissions, auction outcomes, and/or offset sales, then click the button "Run supply-demand balance."
- To save summary results for any scenario, click the button "Save results & settings (csv)"

4.3. Model updating

WCI-RULES can be updated to reflect more recent data, by inputting additional data into the file <WCI-RULES_data_input_file.xlsx>, available on the model's Github repository and in the model's OSF repository (Inman, 2019). In the data input file, sheets with tabs colored green are updatable by the user. Within those sheets, cells that should be updated are unlocked and therefore can be changed; other cells are locked.

(If the user wants to modify other cells, they can unlock the sheets; no password is required. However, this should not be necessary to update the model.)

Near Zero plans to update the data input file regularly (e.g., quarterly) so that the model will be kept up to date. However, if there is newer data available and the model has not yet been updated, then users who install and run the model themselves can update the data input sheet to reflect the latest data.

4.3.1. Data sources

The sheet “data sources” includes references for all the data sets used in the data input file.

4.3.1.1. Emissions and obligations

The sheet “emissions & obligations” includes data on California covered emissions and compliance obligations (which can sometimes differ from covered emissions), as well as data on Québec covered emissions (which historically have been exactly the same as compliance obligations). Data on covered emissions are normally released in early November of each year, with data for the prior year. Annual compliance reports, which include quantities of compliance obligations incurred, are normally released in mid-to-late December of each year, with data for the prior year.

4.3.1.2. Annual compliance reports

The sheet “annual compliance reports” contains data that regulators issue annually (for California) or every three years (for Québec). The data in this sheet records quantities of instruments surrendered to satisfy compliance obligations. Allowances are separated by vintage or other non-vintage status (Reserve allowances or Early Action Allowances), and offsets are reported separately from allowances. Annual compliance reports are normally released in mid-to-late December of each year, with data for the prior year.

4.3.1.3. Annual auction notices

The sheet “annual auction notices” contains data on the number of allowances consigned to auction for each year, which utilities must decide upon prior to that year. The data on consigned quantities is normally reported in the text of the report, rather than in a table. Annual auction notices are usually released in early December each year, with data for the following year.

4.3.1.4. Quarterly auction results

The sheet “quarterly auctions” report data on the allowances auctioned, separated into sets by:

- Auction date
- Jurisdiction (California or Québec)
- Instrument category (state-owned or consignment)
- Vintage

Then there is data for each set of allowances on the quantity of allowances available for auction (the column “Available”), and how many of those available sold (the column “Sold”).

The user can input new data on sets of allowances, including the auction date, other metadata, and the quantities available and sold.

Auctions are held in mid-February, mid-May, mid-August, and mid-November, and the results are available about one week after the date of the auction.

4.3.1.5. California allocations

The sheet “California allocations” contains data on the various categories of allocations listed in California’s annual allocation reports that are not pre-determined by regulations.

Note that this sheet does not include the allocations that are pre-determined by regulations; those allocations are listed in sheets that cannot be updated by the user (electricity distribution utility allocations, in the sheets “California elec alloc 2013-2020” and “California elec alloc 2021-2030”) or are calculated within the model (for natural gas distribution utility allocations).

4.3.1.6. Québec allocations

The sheet “Québec allocations” states cumulative quantities of allowances allocated for each year’s allocation, in the column “quantity to date.” The column “quantity on date for true-ups” automatically calculates the quantities distributed in each event shown.

4.3.1.7. Energy Imbalance Market (EIM) and bankruptcies

The sheet “EIM & bankruptcy” contains data on historical quantities of allowances retired to compensate for Energy Imbalance Market (EIM) outstanding emissions and for unfulfilled obligations due to bankruptcy. Both types of retirements are for California only.

California rules regarding retirements for EIM Outstanding Emissions are in § 95852(l), and for bankruptcy in § 95911(h). Data on retirements for EIM Outstanding Emissions and bankruptcies have been reported in the quarterly Compliance Instrument Reports.

4.3.1.8. Reserve & PCU sales

The sheet “Reserve & PCU sales” states the quantities of allowances sold from Reserves and/or Price Ceiling Units, separating categories of Reserve allowances (e.g., California pre-2021 first tier Reserves). The sheet automatically calculates quarterly subtotals for all California and all Québec Reserve sales, as well as WCI-wide Reserve sales. If no Reserve sales have occurred for a given quarter, then in the sheet “Reserve sales,” values of 0 can be entered in all columns.

4.3.1.9. Compliance Instrument Report (CIR) file

The model also uses quarterly CIRs to determine the following data:

- Offset sales
- Distributions of Reserve allowances

4.3.1.10. Schedule of data updates:

To summarize the information above, data related to a given year are released on the following schedule:

- Year prior, early December: Annual auction data announcement
- Year prior, early December: California allocation data
- Same year, January: Québec allocation data
- Same year, late February: Q1 auction results
- Same year, early April: Q1 Compliance Instrument Report
- Same year, late May: Q2 auction results
- Same year, early July: Q2 Compliance Instrument Report
- Same year, late August: Q3 auction results
- Same year, early October: Q3 Compliance Instrument Report
- Same year, late November: Q4 auction results
- Following year, early January: Q4 Compliance Instrument Report
- Following year, early November: Data on covered emissions
- Following year, mid-to-late December: Annual compliance reports

Since WCI has not yet held Reserve sales, it is not clear when such sales, if they occur, would be reported. As set by California's cap-and-trade regulations, California may hold four quarterly Reserve sales: Q1 around late March-early April, Q2 in late June, Q3 in mid-August, and Q4 in late December. The exact dates are listed in Appendix C of the cap-and-trade regulations (Cal. Code Regs., 2019).

5. References

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