## Western Climate Initiative cap-and-trade model: documentation

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Mason Inman (minman@nearzero.org) is the project manager and technical lead for the development of this model. View the [model code](https://github.com/nearzero/WCI-cap-and-trade) on Github.

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# Overview of model

Near Zero's open-source model of the Western Climate Initiative 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.

Given an input scenario, the model calculates market outcomes by applying the actual market rules laid out in the regulations of WCI jurisdictions. 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 emissions at least 40% from 1990 levels.

The model runs through 2030, and it incorporates post-2020 market design changes that the California Air Resources Board (ARB) is preparing as part of the AB 398 implementation process. It also reflects the effects of Ontario’s planned withdrawal from the program.

## Supply of emissions instruments

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

* sales of allowances at auction
* free allocation of allowances directly to emitters
* supply of offset credits

In addition, the model represents allowances held in Reserve accounts that are only available for sale at prices much higher than current market prices. After 2020, the model also represents sales of additional instruments at the price ceiling. The model allows sales of Reserve allowances and ceiling instruments if needed for compliance, given the user’s specified emissions projection.

The model assumes that Reserve and/or price ceiling accounts will not be accessed until the private bank of emissions instruments is exhausted. In reality, such accounts could be accessed while a private bank still exists, depending on future market prices and the choices of market participants.

## Demand for emissions instruments

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

## Supply-demand balance

For calculating 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

Then, user settings specify projections for each category, beyond the historical data.

How many emissions instruments enter private accounts, and thus are able to be used to satisfy compliance obligations, depends heavily on the results of quarterly auctions of allowances. Our model lets the user specify a scenario for auction outcomes, to see the effects 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 two key metrics for oversupply on an annual basis: (1) **private bank**: how many emissions instruments are held in private accounts beyond outstanding compliance obligations to date and (2) **unused instruments**: how many instruments remain unused beyond outstanding compliance obligations, which could have been used to date (the instruments banked in private accounts plus those allowances that had been offered at auction but remain unsold in government accounts).

Given a particular emissions scenario, the model calculates when the bank of excess emissions instruments would be used up, and the quantities of Reserve allowances that would have to be sold to allow emitters to remain in compliance with the program.

## Uses of the model

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

* What was the likely size of the oversupply at the end of 2017?
* How much of the oversupply at the end of 2017 was already banked in private accounts?
* What would be the supply-demand balance over time through 2020 or 2030, given a particular emissions pathway?
* How much would the supply-demand balance be affected by some auctions not selling out?
* In what scenarios might Reserve allowances be sold and used?
* In what scenarios might allowances available at the price ceiling be exhausted, and sales of “price ceiling units” begin?

## Post-2020 market design changes

The California Air Resources Board (ARB) has proposed a set of market design changes (ARB 2018b) as directed by AB 398, the bill that extended the cap-and-trade program in California through 2030. The model includes the proposed market design changes, most of which would take effect after 2020.

The proposed changes do not make any significant changes to the market design to address concerns about oversupply. In the future, the model could also be used to evaluate potential market design changes.

## List of assumptions

There are a wide variety of 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.

The documentation [Appendix](#_ql60xqqb4ba7) lists the assumptions that are hard-coded into the model. Each assumption has a link to the section of the documentation that provides more detail and context.

# Summary of model details

## 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 (industrial, etc.).
* Allowances consigned to auction by emitters (a portion of consignment is optional).

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

* emissions pathways
* offsets supply
* auction outcomes (i.e., whether some auctions do not sell out)

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).

## Auction scenarios

The model allows users to specify particular auction outcomes for the current and advance auctions. The user specifies 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 same percentage 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, this would reduce the supply in the short run that is available for use for compliance. Allowances unsold in current auctions can be offered again at later current auctions, under certain conditions. But in CA, unsold allowances can also be removed from the normal auction supply if they remain unsold for more than 24 months, thus affecting the normal auction supply over the long-term (Inman et al. 2018).

## Emissions scenarios

The model allows users to specify scenarios for covered emissions in CA and QC separately, using either percentage annual changes over specific time spans, or by specifying a custom emissions trajectory.

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

## Offsets supply

The model makes a default projection of additions to the supply of offsets, based on historical data and on ARB’s assumptions about future offset use through 2030 in its justification for its 2018 market design proposals (ARB 2018c).

Assumption: The model makes a projection of offset supplies that assumes they are 75% of the limit of what can be used.

## Post-2020 market design changes

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

### Post-2020 Reserve and price ceiling

The table below summarizes ARB’s proposed distribution of allowances across the two post-2020 Reserve tiers and the price ceiling. Prior to 2020, ARB has proposed to divide one third of the current Reserve allowances across the three pre-2021 Reserve tiers, holding the remaining two thirds outside of the Reserve to ensure compliance with AB 398 requirements.

|  |  |  |
| --- | --- | --- |
| **Tier** | **Post-2020 Reserve** | **Notes** |
| Reserve Tier 1 | 40.6 M + 26.2 M  = 66.8 M | 1/3 of Reserve at end of 2017 plus half of 52.4M from post-2020 caps. |
| Reserve Tier 2 | 40.6 M + 26.2 M + 22.7 M  = 89.5 M | Same as Tier 1 plus additional 22.7M from post-2020 caps. |
| Price Ceiling | 40.6 M + 39 M  = 79.6 M | 1/3 of Reserve at end of 2017 plus pre-2021 unsold allowances. |

Allowances in the Reserve at the end of 2017 were all those initially put into the Reserve from budget years 2013-2020, minus any that were removed. For CA, none were removed by the end of 2017; for QC, ~800,000 were removed.

Allowances remaining in the Reserve at the end of 2020 will be transferred to the post-2021 price ceiling account; this includes any unsold allowances transferred to the Reserve during 2018-2020.

The current CA regulations allocate ~52.4M allowances from the post-2020 budget years to their Reserve, and current QC regulations allocate ~19.9M to their Reserve, for a total of ~72.3M in both. ARB has suggested moving an additional ~22.7M from California’s 2021-2030 caps to its Reserve, moving an equal amount (~2.27M) from each annual budget.

Assumption: The model assumes that QC will *not* make similar changes to its post-2020 regulations, and thus will not assign additional allowances to its Reserve.

The model currently does not explicitly represent particular tiers, or distinguish reserve sales at the tiers from reserve sales at the ceiling price (including the unlimited “price ceiling units”). A future version of the model may include these tiers, and Reserve sales at particular prices.

### Treatment of unsold allowances

Through 2020, ARB has proposed that allowances that remain unsold for more than 24 months would be divided equally among the three Reserve tiers (and would then be transferred to the price ceiling post-2020).

From 2021 on, allowances that remain unsold for more than 24 months would be divided equally across the two new reserve tiers post-2020.

### EIM retirements from annual budgets (rather than from unsold allowances)

As its default, the model has no retirements for EIM outstanding emissions. However, the model has the ability to simulate these retirements, and incorporates the mechanisms ARB has proposed, as follows:

* For EIM retirements in 2018 for 2017 emissions: Any EIM retirements for 2017 emissions will come from unsold current allowances, as stipulated in current regulations.
* Starting in 2019, for EIM retirements for 2018 and 2019Q1 emissions: EIM retirements will come from the annual allowance budget two years after the current budget, thereby reducing the amount that would become available as state-owned allowances in current auctions.
* Starting in 2020 for 2019Q2 emissions and beyond: EIM Purchasers will have a compliance obligation, based on the ratio of the EIM Purchaser’s EIM purchases (MWh) to total EIM purchases serving CA load.

### Retirements to account for bankruptcies

Starting in 2019, allowances will be retired to account for outstanding compliance obligations due to bankruptcy, from the budget two years after the current budget year.

ARB’s April 2018 “Post-2020 Caps” report assumed: “Approximately 5 million allowances to be retired in response to a recent bankruptcy” (ARB, 2018a).

Assumption: Assume one-off bankruptcy retirement of 5M allowances, matching ARB assumption; assume it will occur in 2019, using vintage 2021 allowances. Assume retirements for future bankruptcies will be zero (but this can be modified if new data comes in).

### Industrial assistance factors

ARB has proposed raising the “assistance factors” used in calculating industrial allocations. Through 2017, the assistance factors were 100% for all industries. In the current regulations (Oct. 2017), these assistance factors were 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. ARB has proposed raising the assistance factors for 2018-2020 to 100%, and applying these changes retroactively, as needed, to provide more allocations for those years.

The model implements ARB’s proposed increase in assistance factors as follows:

* The model calculates the difference between ARB’s projection for allocations under the current regulations, and ARB’s projection for allocations with 100% assistance factors.

* Assumption: The model assumes that these changes will be implemented in time for the 2020 industrial allocation (to be distributed in late 2019) to use the 100% assistance factor.

* Assumption: The model also assumes that 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.

## Ontario’s effect on supplies

Ontario began participating in the WCI cap-and-trade auctions in 2018Q1, and withdrew from the market after the 2018Q2 auction, participating in only two auctions. During the time of linkage, Ontario-based entities were also able to purchase allowances from California and Quebec on the secondary market. After Ontario withdrew from WCI auctions, regulators in CA and QC instituted a freeze on instrument trades with Ontario entities, at which point transfers to or from ON entities were no longer possible.

After the end of 2018Q2, regulators released a Compliance Instrument Report that excluded instruments held by Ontario entities. Comparison to the 2018Q1 report showed a net flow of allowances out of ON of ~13.2 million (Mastrandrea et al. 2018).

Assumption: In calculating metrics for CA-QC (the banking metric and balance metric), the model includes this net flow from ON entities to CA-QC entities of 13.2 million instruments, which are added to the privately held supply in 2018.

We note that ARB’s 2018 regulatory proposal incorporates a mechanism by which this net flow could be addressed by retirement of allowances, to ensure environmental integrity of the program. The model will be updated if this mechanism is adopted and utilized.

# Full model documentation

## Allowance pools

### Annual allowance budgets (caps)

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

* CA 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.
* QC cap quantities:
  + For 2013-2020, from Quebec 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 Quebec 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.

### Allowance Price Containment Reserve (Reserve) allowances

#### CA 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 regs § 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 regs § 95871(a) and Table 8-2 (2021-2030).
* Rules for reserve sales stated in § 95913.

#### QC Reserve

* Quantities stated in Quebec 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&pointInTime=20180119>
* Rules for Reserve sales stated in Division IV.

### Voluntary Renewable Electricity Reserve allowances (CA only)

* Portion of annual caps set aside for this reserve are established in regs § 95870(c): 0.5% of cap for 2013-2014, 0.25% of cap for 2015-2020
* There are no Voluntary Renewable Electricity Reserve Account allowances allocated from budget years after 2020.

### Advance auction quantities

#### CA 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).
* CA 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 2012Q4.
* 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."

#### QC 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.”
* QC 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 2013Q4.

### Direct allocations

#### CA allocations (fixed)

##### Electrical Distribution Utility Sector Allocation

* For 2013-2020: § 95870(d)(1), with details specified in regs § 95892(a)(1) & § 95892(a)(2)
* For 2021-2030: § 95871(c)(1)
* 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.)

##### 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.
* 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.

##### 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.

#### CA 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. As of this writing, historical values for these allocation were known through 2018, so the model uses a projection for “industrial and other” allocations published by ARB (ARB 2018b).

##### 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 2018 allocation report 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.”

##### Allocation to University Covered Entities and Public Service Facilities

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

##### 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.

##### Allocation for Waste-to-Energy Facilities

* Annual allocation report had allocations for "waste-to-energy" in 2015-2018, each for emissions from two years prior (as stated on the first page of allocations reports). (See § 95852(k): "Limited Exemption of Emissions for Waste-to-Energy Facilities").
* In its 2018 proposed regulatory changes, ARB has proposed additional allocations for 2020-2023, as specified in § 95891(f) and § 95871(i).

##### 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"
* 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.

##### 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 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)).

##### Projection of “industrial and other” allocations 2019-2030

* Assumption: The model uses ARB’s projection for “industrial and other” allocations, as published in slides for a workshop (“[Amendments to Cap-and-Trade Regulation Workshop](https://www.arb.ca.gov/cc/capandtrade/meetings/20180302/ct_workshop_3-1-18.pdf),” slide 9, March 2, 2018), 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).

#### QC allocations (variable)

In QC, allocations are based on “the total quantity of reference units produced or used,” and as such are not predetermined (from Quebec [Environment Quality Act (chapter Q-2), r. 46.1](http://legisquebec.gouv.qc.ca/en/ShowDoc/cr/Q-2,%20r.%2046.1), sections 39-44). 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.

QC reports the cumulative amount allocated for 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. The true-up quantities can be calculated from the cumulative reports.

There was no clear trend in the QC allocation data 2013-2018. Nonetheless, the model assumes the allocations will decrease in the future (see below).

Assumption: The model assumes that Quebec’s allocations will scale down in line with the annual caps, so that projected final allocations decrease from ~17.9 MMTCO2e in 2018 to ~13.4 MMTCO2e in 2030.

## 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 (currently extending through the Q3 2018 auction). In the user interface settings, the first year that can be set to have unsold allowances is in 2019.

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).

### Initial conditions for simulation

Drawing on historical data on the state of the cap-and-trade market, as determined by a “hindcast” run of the model beginning in 2012Q4, 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 sold out, which determines whether state-owned unsold allowances can be reintroduced to auction.

Assumption: The model assumes that 2018Q4 current and advance auctions sell out.

The model accepts as inputs auction results for auctions held in 2019 and beyond, as specified by the user. The user specified percentage that goes unsold is applied to both current and advance auctions held in the stated year(s).

### Preparatory steps

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

* Prior to the Q1 auction, any allowances unsold in advance auctions three years prior are redesignated to the current auction, and any allowances retired to account for bankruptcies are moved to the retirement account.
* Prior to the Q4 auction, any allowances retired to account for EIM Outstanding Emissions (hereafter “EIM retirements”) are moved to the retirement account. (For more on EIM retirements, see [details above](#_v5w15jdektbv).)

### Processing auctions

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

#### Processing advance auctions

##### 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.

##### 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.

##### 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 redesignated 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 redesignation to current auctions. (This rule for redesignation of unsold allowances from advance auctions to later *current* auctions is implemented in the model.)
  + Note: For CA, when allowances go unsold in advance auctions, there is a rule for redesignating 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 redesignated for sale.
  + QC 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.”

#### Processing current auctions

##### Calculates available allowances

* First, 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. These allowances are 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 redesignated 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.

* + - 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. If some historical data is available (as is currently the case for 2018), 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, redesignates 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 in a prior current auction can be redesignated (aka “reintroduced”) 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 reintroduction, the quantity that can be reintroduced for each jurisdiction is 25% of that jurisdiction’s allowances newly made available for that auction, prior to redesignation of state-owned allowances unsold in prior current auctions. (These redesignations of state-owned allowances that went unsold at a prior current auction are also known as “reintroduced” allowances.)

##### 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.

##### Processes quarterly auctions

* Assigns sales to particular sets of allowances, based on the order of sales specified in regulations (for CA, § 95911(f)(1)). Based on QC regulations and historical record, QC appears to use the same order of sales as CA. The order of sales in the regulations, and implemented in the model, is:
  + 1. Consignment allowances (for CA only); no distinction between redesignated and newly available
  + 2. Reintroduced state-owned allowances
  + 3. State-owned allowances available at current auction for the first time (which includes any allowances unsold in advance auctions that were redesignated to current auction)
* When current auctions do not sell out, unsold allowances are retained for possible redesignation in later current auctions.
* Model removes CA allowances from unsold stock if they have remained unsold for more than 24 months.
* In Q4 of applicable years, prior to Q4 auction, processes retirements for EIM Outstanding Emissions.
* 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).

## Emissions scenarios

The model allows users to specify scenarios for the emissions pathway for covered emissions in CA and QC 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 ARB's 2017 Scoping Plan scenario for California 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 (ARB 2017). This is also similar to Energy Innovation’s “Oversupply Grows” report (Busch 2018), extended to 2030, which assumes a decline of 1.9% per year.

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

## Banking and balance metrics

The model calculates the total supply and demand for emissions instruments each year, and from this calculates metrics for oversupply (or overallocation) in the cap-and-trade program.

### Total supply

The total private supply of emissions 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 that had not yet been described in the documentation are marked by asterisks, and these categories are described below.

In addition to the instruments privately held above, there are also publicly held allowances that are not yet sold or distributed.

#### Offsets supply

A percentage of each regulated entities' 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 Quebec, 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 Q3 2018, based on the Q3 2018 compliance instrument report. Through 2018Q3, 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 ARB’s assumption for future offset supply in the period 2021-2030 (ARB 2018a; ARB 2018c). Thus we set the default projection for offset supply for all projection years to be 75% of the limit for each jurisdiction, for each relevant time period. Users can specify a higher or lower supply using the available settings.

Assumption: The model makes a projection of offset supply that assumes it is 75% of the allowable limit for offset use.

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.

#### 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.

#### Early Action allowances

Quebec issued ~2.0 million “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.

#### Reserve allowances distributed to private accounts

In 2016Q3, 826,677 allowances were moved out of the Reserve (of CA and/or QC), and into private accounts. We do not know why these allowances were moved into private accounts, but since they were moved into private accounts, we presume they can be used to satisfy compliance obligations, and so the model counts them toward the private supply of allowances.

### Total demand

The total demand for emissions instruments in a given year is the covered emissions that occur in that year.

The demand is different from the compliance obligations due in any given year, because there is always a lag between when emissions occur and when compliance obligations are due. For details on compliance obligations, see the section below, “[Instrument retirements](#_6mhmdvqhs90e).”

### Banking metric

We calculate a banking metric that is the private supply minus the demand. For this, we count only the private supply of allowances that have vintages up to the present year in the model. So for calculating the bank of instruments in 2020, the model counts only the private supply of vintages up to 2020, and does not count allowances of later vintages sold in advance auctions.

For each year, annual additions to the bank are supply minus demand for that year. The cumulative banking metric is a cumulative sum of additions (or subtractions) from the bank.

### Balance metric

The balance metric counts both the private supply and public supply of emissions instruments, up to a given vintage, toward the supply. It is the equivalent of the banking metric plus the publicly held allowances that are not yet sold or distributed, of vintages up to the present year in the model.

## Instrument retirements

### 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 in the current regulations (Oct. 2017) is 8%. AB 398 requires a change to California’s offset limits, lowering them to 4% in 2021-2025 and 6% for 2026-2030. In Quebec’s current regulations, offset limits are 8% for all years through 2030.

Assumption: By default the model assumes particular rates of offset use that are below the limits required by current regulations (Oct. 2017) of 8% of emissions, and in AB 398 (4% for 2021-2025, and 6% for 2026-2030). The model assumes that offset use for CA and QC collectively will be, as a percentage of their covered emissions:

* for 2018-2020: 5.0%
* for 2021-2025: 3.0%
* for 2026-2030: 4.5%

Through the end of 2018Q3, offsets sold to date were ~6% of emissions to date, given the default assumption that covered emissions decreased 2% per year after 2016. So the model assumes that offset use 2018-2020 will be about the same as that rate of offset use, rounding it off to 5%. This rate is applied to CA and QC emissions as a whole.

For 2021-2030, the offset use rates are the same as ARB’s assumed offset use for CA entities (ARB 2018a; ARB 2018c).

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.)

### 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 banking metric is calculated based on the total supply of instruments in private accounts.

## Reserve sales (including price ceiling sales)

Assumption: If there are not enough instruments available for compliance in the private bank, then the model assumes that sales from the Reserves (and price ceiling accounts, if necessary) will begin after the private bank of emissions instruments is completely exhausted.

Assumption: The model assumes that the CA and QC Reserves can be treated as a whole, for purposes of calculating when they will be accessed and how quickly the allowances will be sold.

Under CA’s current regulations (Oct. 2017), only CA entities are eligible to buy allowances from CA’s Reserve, and similarly only QC entities are eligible to buy allowances from QC’s Reserve.

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.

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.

Evaluating the likelihood of a particular emissions trajectory continuing, even if it requires purchases of large quantities of high-priced Reserve allowances, is beyond the scope of this model.

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# Appendix: Model assumptions

Below is a list of the assumptions that are hard-coded into this version of the model (that is, cannot be modified by the user). Each assumption has a link to the section of the documentation that provides more detail and context.

The model assumes:

* When the user inputs a custom projection for covered emissions for California and Quebec combined, the model assumes that the split between California and Quebec is proportional to each jurisdiction’s caps over the projection period (85% California and 15% Quebec). [[link](#klg82y3rh4qj)]
* The model makes a projection of offset supply that assumes it is 75% of the limit of what can be used, given projected emissions. Overview: [[link](#lpqcd4cste5a)]
* The model assumes that QC will *not* assign additional allowances to its Reserve from post-2020 budgets, beyond what is already committed. [[link](#kix.17z84oh70loj)]
* Assume one-off bankruptcy retirement of 5M allowances. [[link](#bjtwrnsh739)]
* Changes to assistance factors will be implemented in time for the 2020 industrial allocation (to be distributed in late 2019) to use the 100% assistance factor. [[link](#bjc97n5sndvi)]
* Retroactive increases in allocations for years 2018 and 2019 will be through the true-ups to be issued in late 2019 and late 2020. [[link](#a9547iy0z72s)]
* A net flow from ON entities to CA-QC entities of 13.2 million instruments, which are credited toward the supply in 2018. [[link](#98ag62wt3t01)]
* Use of ARB’s projection for “industrial and other” allocations. [[link](#hslb757sf89c)]
* Quebec’s allocations will scale down in line with the annual caps, so that projected final allocations decrease from ~17.9 MMTCO2e in 2018 to ~13.4 MMTCO2e in 2030. [[link](#e1y4uz1urai8)]
* The model assumes that 2018Q4 current and advance auctions sell out. [[link](#aen6z6qutk5v)]
* Allowances consigned to be sold in a given year are assumed to be split equally across the four quarterly auctions—or, if some historical data is available for part of a year (from auction results and/or auction notices), then the remaining allowances consigned are assumed to be split equally across the remaining auctions. [[link](#s1xoqqvphg2z)]
* The model makes a projection of offset supply that assumes it is 75% of the limit of what can be used, given projected emissions. Details: [[link](#b158quknu2c9)]
* Sales from the Reserves for each jurisdiction will begin after the private bank of emissions instruments is completely exhausted. [[link](#g1bgy0j8dhva)]
* The CA and QC Reserves can be treated as a whole, for purposes of calculating when they will be accessed and how quickly the allowances will be sold. [[link](#frdubx9u56m3)]

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