California Independent System Operator Corporation

California ISO

Willing seller market design for congestion revenue rights

October 23, 2024

Department of Market Monitoring

Summary

Congestion revenue rights (CRRs) sold in the ISO's auction are equivalent to forward price swaps. Payments in the auction are exchanged for a future payment (or charge) based on day-ahead market prices. This forward contract allows auction participants to hedge financial exposure to—or speculate on—differences in day-ahead prices between two locations. While CRRs are intended to be used as hedges by entities engaging in forward energy contracting, most CRRs are purchased by purely financial entities that do not use CRRs for such hedging.

Unlike most other forward contract markets, the current CRR auction allows participants to take positions without a willing counterparty offering to take the opposite position. Market participants buy CRRs in the auction without a counterbalancing trade with a willing seller. The ISO essentially offers to sell CRRs at a $0 offer price. CRRs sold by the ISO are purely financial instruments that obligate the ISO's transmission ratepayers to pay entities that are purchasing these CRRs the difference in day-ahead market prices between two locations.

Since the beginning of the ISO's nodal market in 2009, revenues collected from sales of CRRs in the ISO's auction have consistently been significantly lower than the payouts made for CRRs clearing the ISO's auction. From 2012 to 2018, CRRs sold by the ISO to non-load serving entities in the CRR auction resulted in losses to transmission ratepayers averaging $114 million per year. Over this period, revenues from sales of congestion revenue rights to non-load serving entities have averaged about 48 percent of the congestion revenues paid out for buyers of these financial rights. Rather than being funded by auction revenues, this revenue loss is funded out of day-ahead congestion rents, which would otherwise be refunded to transmission ratepayers who pay the full cost of the transmission system.

In response to these systematic losses, the ISO instituted significant changes to the congestion revenue rights auction in 2019. While these changes reduced losses from the congestion revenue rights auction, the losses continue to be significant. From 2019 to 2023, losses from the auction have averaged about $62 million per year, with CRR auction revenues equaling only 67 percent of congestion rents paid out to buyers of these CRRs.

Since 2017, DMM has recommended that the ISO develop a CRR market design based on willing sellers that would not expose transmission ratepayers to these losses. This paper proposes a new market design for congestion revenue rights that is based on sales of congestion revenue rights by willing sellers. Under this market design, the ISO would serve as a central clearinghouse for trading based on bids submitted by entities willing to buy or sell congestion revenue rights contracts (price swaps). This new design provides an efficient centralized market for price swaps between willing counterparties, who bear the full cost and risk of these price swaps.

This paper includes analysis of this willing seller market design using bids submitted to the ISO's congestion revenue rights auction in 2017-2018. This analysis shows that under this proposed design, significant volumes of congestion revenue rights could be sold by financial entities, as well by load serving entities selling a portion of their allocated congestion revenue rights which are not needed to hedge their actual energy procurement. These results show that the willing seller design is workable, and can provide an effective and efficient alternative to the current auction design. This approach eliminates losses from the current auction, and allows all congestion rents to be returned to transmission ratepayers.

DMM is releasing this report in advance of a new Congestion Revenue Rights Enhancements Initiative that the ISO has scheduled to begin with a meeting in November.

1 Background

Locational marginal pricing

Under the standard market design of all major centrally cleared electricity markets in the U.S., locational marginal prices (LMPs) reflect the different value of energy at each location or node on the network. Locational marginal prices include three components: the system marginal price, losses, and the cost of transmission congestion.

Congestion occurs when constraints in the transmission system are binding, i.e., are being fully utilized and are limiting the flow of lower cost energy to other parts of the grid. When congestion occurs, it causes differences in nodal LMP prices, which represent the congestion charge for moving energy between nodes on the grid. Since transmission constrains power flowing from generation to load, load will pay more for energy than is paid to generation when transmission constraints are binding. This surplus in revenue collected by the ISO is referred to as *congestion surplus* or *congestion rent*. These congestion rents are the spot market payments to the transmission system.

Allocating congestion rents back to transmission ratepayers

The ISO collects the annualized fixed and variable costs of the transmission system—plus a regulated rate of return for transmission assets—through the transmission access charge (TAC). This charge is collected from load serving entities and exports on a $/MWh basis. In return for paying the costs and rate of return to the entities building the transmission system, these transmission ratepayers receive the value of the transmission system, including its use and any revenues it may generate.

Since congestion rent results from the use of the transmission system, the market is designed to allocate this congestion rent back to the transmission ratepayers that pay for the cost of the system. This is consistent with the concept that those paying the full cost of an asset should receive the full revenues from the asset. In addition, because transmission ratepayers are also the buyers of energy, their allocation of the congestion rent also hedges their costs of procuring energy.

The ISO market is designed to reallocate this congestion rent back to entities that pay for the cost of the transmission in two ways:

- First, load serving entities receive congestion revenue rights though an allocation process based on their projected load and expected usage of the transmission system.
- Second, any congestion rent that remains after payment of allocated congestion revenue rights is re-allocated directly back to load serving entities and exporters based on their *pro rata* load share.

If the ISO did not allocate congestion revenue rights to load serving entities, or auction off additional congestion revenue rights after this allocation, all congestion rents would be allocated back to load serving entities and exporters that pay for the cost of the transmission system through these two mechanisms.

In addition to being a means of distributing a portion of congestion rent back to transmission ratepayers, allocated congestion revenue rights can also provide a means for transmission ratepayers to better align the rent they receive with their market positions, to better hedge their costs of buying energy.

Congestion revenue rights auction

The congestion revenue rights auction provides a market in which load serving entities (LSEs) can voluntarily sell back CRRs received in the allocation process, or purchase any additional CRRs they might want to procure as a hedge against congestion costs. However, in addition to auctioning CRRs voluntarily bid by LSEs after the allocation process, the ISO also auctions off additional CRRs—up to the quantity of modeled physical transmission—that are financially backed from congestion rents that would otherwise be refunded back to LSEs and exporters, based on their pro rata share of load and exports.

Although the ISO auctions CRRs up to the limit of physical transmission availability, CRRs do not reflect a physical transmission right. Congestion revenue rights sold in the ISO's auction are purely financial instruments that obligate the ISO's transmission ratepayers to pay entities that are purchasing these CRRs the difference in day-ahead market prices between two locations. These CRRs are equivalent to a forward price swap. Payments in the auction are exchanged for future payments (or charges) based on day-ahead market prices. This forward contract allows auction participants to hedge financial exposure to—or speculate on—uncertain day-ahead price differences between two locations.

Unlike most other forward contract markets, the CRR auction allows participants to take positions without a counterparty offering to take the opposite position. Market participants can buy CRRs in the auction without trading with a willing seller. The ISO essentially offers to sell these CRRs at a $0 offer price. By default, the ISO's transmission ratepayers are the counterparty to contracts bought from the CRR auction without being an explicit willing seller.

Congestion revenue rights auction results

The ISO has acknowledged that "over the long-term, congestion revenue rights prices should reflect the value of the hedge provided against day-ahead market congestion charges, and consequently should generate auction revenues that are more or less commensurate with the payments congestion revenue rights receive from the day-ahead market … [But that] the ISO's congestion revenue rights auction has not been efficient because auction revenues have been much less than congestion revenue right payments, rather than producing prices reflecting congestion revenue rights' value as hedges."[1]

Thus, in theory, over time the auction revenues received by transmission ratepayers from sales of CRRs by the ISO should be approximately equal to the expected value of the CRR payments made out of congestion rents. Moreover, to the extent CRRs are actually purchased as hedges—as intended by the ISO—the hedging value of these instruments could even drive auction prices above the expected value of CRR payments.

In practice, however, payouts to entities purchasing these congestion revenue rights have consistently and systematically exceeded these auction revenues by a significant amount every year since the auction began in 2009. This represents a profit to entities purchasing rights in the auction, but represents a significant revenue loss to transmission ratepayers each year.

[1] *Decision on congestion revenue rights auction efficiency proposal*, Management memo to ISO Board of Governors, March 14, 2018, pp 3-4: https://www.caiso.com/documents/decision_congestionrevenuerightsauctionefficiencyproposal-memo-mar2018.pdf

As shown in Figure 1-1 and Figure 1-2, from 2012 to 2018:

- CRRs sold by the ISO to non-load serving entities in the CRR auction resulted in losses to transmission ratepayers averaging $114 million per year (Figure 1-1).
- Over this period, revenues from sales of congestion revenue rights to non-load serving entities have averaged about 48 percent of the congestion revenues paid out for buyers of these financial rights (Figure 1-2).

In response to these systematic losses from congestion revenue rights auction sales, the California ISO instituted significant changes to the congestion revenue rights auction starting in the 2019 settlement year.[2] While these changes reduced losses from the congestion revenue rights auction, the losses continue to be significant:

- Ratepayer losses from the auction have averaged $62 million from 2019-23 (Figure 1-1).
- Revenues from sales of congestion revenue rights to non-load serving entities have averaged about 67 percent of the congestion revenues paid out to buyers of these financial rights from 2019 to 2023 (Figure 1-2).

Most of these losses have consistently stemmed from profits made by purely financial entities and marketers, rather than from entities buying congestion revenue rights as financial hedges. In 2023:

- Financial entities received about $43 million in profits, or about 73 percent of total losses by transmission ratepayers.
- Marketers received profits of about $11 million, or about 19 percent of these losses.
- Physical generation entities received about $2 million in profits from auctioned rights.

Through the first half of 2024, transmission ratepayers lost about $67 million from the sales of CRRs in the ISO's auction. As in prior years, most of these losses continue to stem from profits made by purely financial entities and marketers, rather than from entities buying congestion revenue rights as financial hedges.

Analysis by DMM suggests that most of the reduction in auction losses since 2019 have resulted from a settlement rule that limits congestion revenue right payments to not exceed congestion rents actually collected from the underlying transmission constraints settlement. This settlement rule is effectuated through the *deficit offset charge*, which is described in more detail below.

[2] These changes are summarized on page 8 of this report.

Figure 1-1 Auction revenues and CRR payments to non-load serving entities

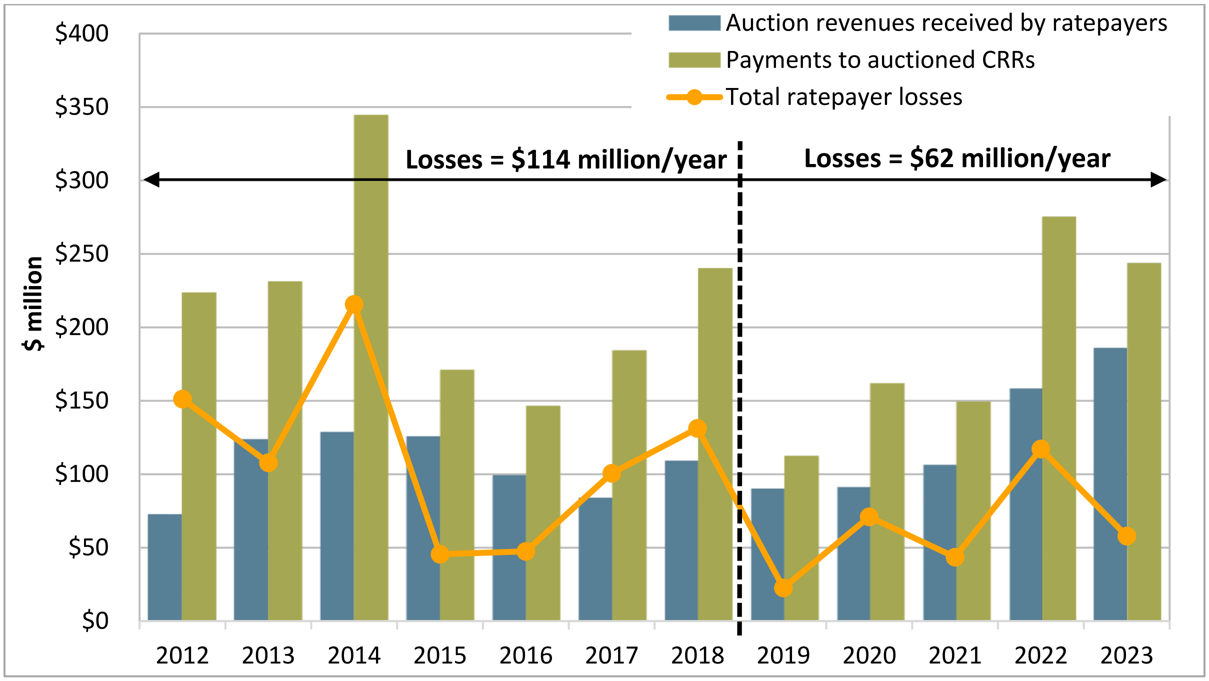
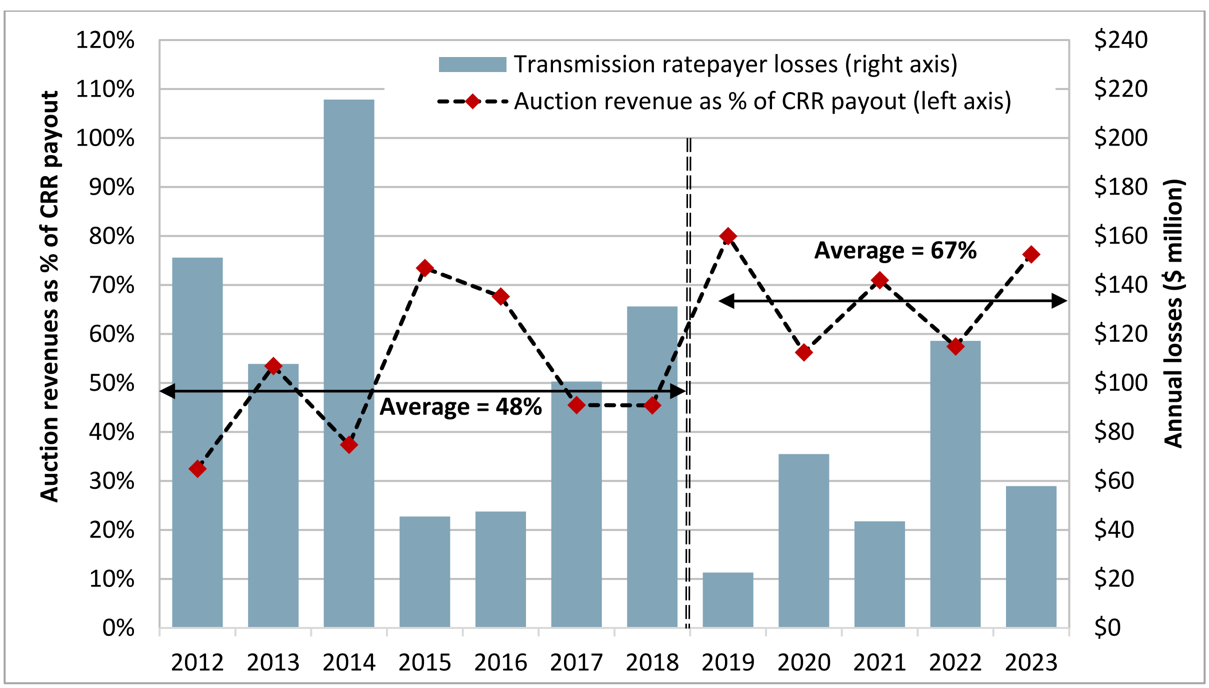


Figure 1-2 Auction revenues as percent of CRR payments to non-load serving entities



Auction changes in 2019

In response to these systematic losses from congestion revenue rights auction sales, the California ISO instituted significant changes to the congestion revenue rights auction starting in the 2019 settlement year. These changes include the following:

- Track 0 – Increasing the number of constraints enforced by default in the congestion revenue right models, identifying potential enforcement of "nomogram" constraints in the day-ahead market to include in the congestion revenue right models, and other process improvements.
- Track 1A – Limiting allowable source and sink pairs to "delivery path" combinations, and adding requirements for reporting planned transmission outages prior to the auction.[3]
- Track 1B – Limiting congestion revenue right payments to not exceed congestion rents actually collected from the underlying transmission constraints.[4] This settlement rule is effectuated through the *deficit offset charge*, which is described in more detail below.

In addition, beginning in 2019, the ISO decreased the percentage of expected transmission capacity modeled in the annual allocation and auction processes by reducing the global de-rate factor from 75 percent to 65 percent. The global de-rate factor takes the transmission ratings estimated by the ISO for use in the congestion revenue rights processes and reduces them all down by this factor.[5]

Deficit offset charges

Changes implemented in 2019 included a new settlement rule that congestion revenue right payments based on congestion rents actually collected from the underlying transmission constraints. This settlement rule is effectuated through the *deficit offset charge*. A general description of this rule is as follows:

- For each hour of the day-ahead market, the congestion revenues collected from each binding constraint are summed up on a constraint-by-constraint level.[6]
- For each hour of the day-ahead market, the CRR payments that result from each binding constraint are summed up on a constraint-by-constraint level.[7]
- If the congestion revenues collected from any binding constraint in the day-ahead market are insufficient to cover the CRR payments that result from that constraint, then CRR payments for

[3] California ISO, *Congestion Revenue Rights Auction Efficiency Track 1A Draft Final Proposal Addendum*, March 8, 2018: https://www.caiso.com/documents/draftfinalproposaladdendum-congestionrevenuerightsauctionefficiency-track1.pdf

[4] California ISO, *Congestion Revenue Rights Auction Efficiency Track 1B Draft Final Proposal Second Addendum*, June 11, 2018: http://www.caiso.com/InitiativeDocuments/DraftFinalProposalSecondAddendum-CongestionRevenueRightsAuctionEfficiencyTrack1B.pdf

[5] For example, if the ISO estimated that a transmission element should have a rating of 100 MW for a quarter, the de-rate factor would reduce that to 75 MW prior to the 2019 change, or 65 MW after the change. The ISO continued to auction congestion revenue rights in the monthly auctions based on the same monthly global de-rate factor as in prior years.

[6] This calculation is performed by multiplying the shadow price for each constraint by the MW scheduled to flow on that constraint during that hour in the day-ahead market.

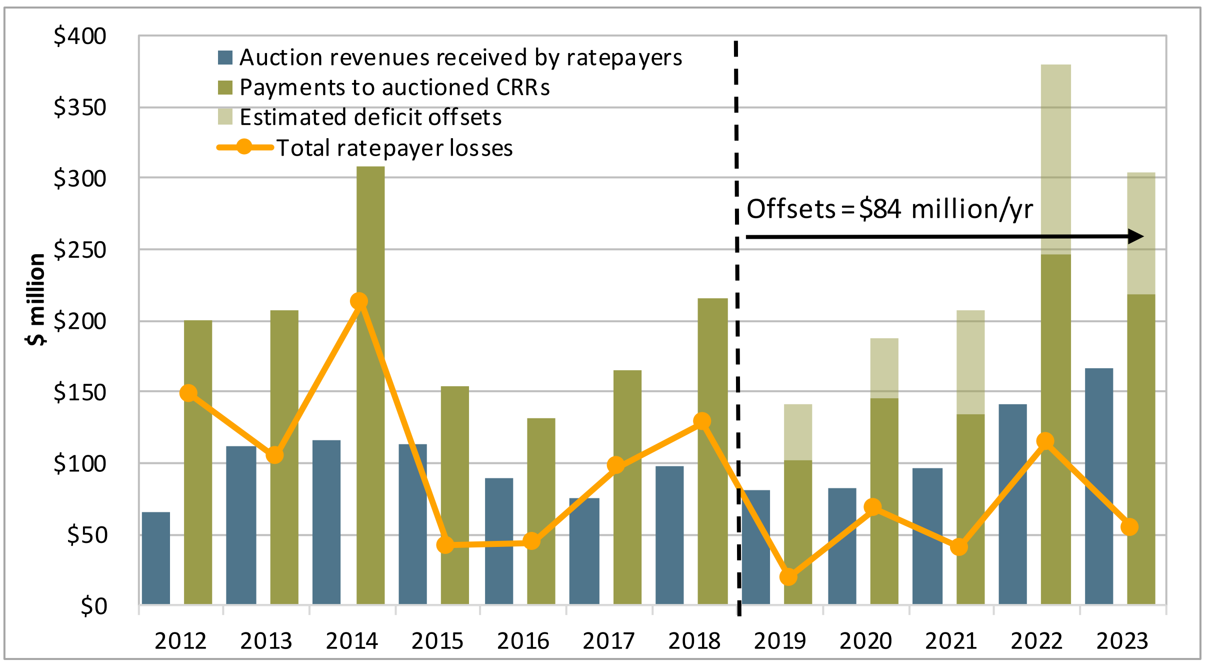
[7] This calculation is performed by determining the impact of congestion on each constraint on the price at all nodes that are the source or sink of CRRs. The price impact is then combined with the volume of CRRs settled at each source or sink node to calculate the total cost impact of each congested constraint on total CRR payments for each hour.

each participant are reduced *pro rata* so that these CRR payments equal the congestion rent collected.

- Reductions in CRR payments are effected through a *deficit offset charge*, which is applied separately from the nominal CRR payments made based on the price differences at the source and sink of each CRR.
- On a monthly basis, the surpluses from constraints in hours having surpluses are used to reduce the deficit offsets paid by congestion revenue rights holders in hours with deficits over the month on that same constraint.

Analysis by DMM suggests that the deficit offset charges implemented under Track 1B changes have accounted for most of the $52 million reduction in auction losses since 2019. As shown by the light green bars in Figure 1-3, DMM estimates that deficit offset charges applied to CRRs sold in the auction have averaged about $84 million per year from 2019 to 2023.[8] Thus, the deficit offsets of $84 million per year appear to account for most or all of the $52 million per year drop in auction losses that has occurred since the various different changes were implemented in 2019.[9]

Figure 1-3 Impact of deficit offset charges on losses from auction



[8] With the implementation of this new settlement rule, it is not possible to calculate precisely how much of the ratepayer losses are from the ISO sales versus sales of CRRs by load serving entity trades. This is because it is not possible to directly tie the offsets actually paid by congestion revenue rights purchasers to the sales of specific congestion revenue rights. DMM has created a simplified estimate of these offsets by estimating the notional revenue that would have been paid to the sold rights, had they been kept, and applying the average ratio of deficit offsets to notional revenues.

[9] $114 million - $62 million = $52 million

While deficit offsets have resulted in lower total losses since 2019, these offsets have also had a significant impact in terms of reducing the actual net payment for CRRs below the notional payment received based on the price difference at the source and sink node.

- As shown in Figure 1-3, deficit offset charges for CRRs purchased by non-LSEs in the auction have totaled about 31 percent of the notional CRR payments made based on nodal price differences.
- DMM estimates that deficit offset charges for CRRs acquired by LSEs in the auction process have totaled about 25 percent of the notional CRR payments for allocated CRRs.[10]

These relatively high deficit offset charges have two potentially detrimental market impacts:

- Entities offering to purchase or sell CRRs in the auction must factor their expectation of these deficit offset charges into their bid prices in the auction.
- For LSEs and any other entities that actually use CRRs as hedges, these offset charges prevent CRRs from providing a full hedge against price differences between the source and sink of each CRR.

[10] This is estimated from Q2 2020 through Q4 2023.

2 Willing seller market design

Background

Beginning in 2016, DMM has been recommending that the CRR auction design should be changed so that these forward contract obligations are only established between willing counterparties.[11]

In a 2017 whitepaper, DMM identified numerous ways in which the CRR auction differs from a competitive market and other forward financial markets. These differences create opportunities for purely financial entities to purchase CRRs at prices systematically lower than CRR payments that transmission ratepayers are obligated to pay the auction participants.[12]

In another 2017 whitepaper, DMM discussed various alternatives to the auction based sales of energy swaps between willing sellers and buyers, which are not backed financially by transmission ratepayers through the congestion surplus.[13]

The ISO and its Market Surveillance Committee (MSC) have argued that even if auction revenues from CRRs are consistently much lower than CRR payments, auctioned CRRs provide hedges to suppliers that might result in lower energy procurement costs that might outweigh losses from sales of these CRRs for load serving entities. However, no analysis has been done by the ISO or MSC to assess any such potential indirect benefits to ratepayers.

During the 2018 stakeholder process, the concept of developing a CRR market based on “willing buyers and willing sellers” was proposed by DMM and some load serving entities. One way for implementing this approach, proposed by Southern California Edison (SCE), was as follows:

- The ISO would first allocate all CRRs that are feasible given projected transmission capacity to load serving entities based on their CRR nominations.
- The ISO would then utilize the CRR model to conduct a market by clearing only bids to buy and sell CRRs by willing counterparties. To implement this, the ISO would set the limits on additional transmission sold in the auction to a net value of zero. Thus, CRR bids would only clear to the extent that bids from one or more other parties created an equal and opposite counter-flow.

Under this approach, which became referred to as the SCE Proposal, load serving entities could still utilize the auction to essentially sell back any CRRs they were allocated and/or buy additional CRRs. Any party wishing to purchase or sell CRRs—either to hedge a physical risk or to speculate on value—would be able to do so in the auction. All CRRs offered in this market would be cleared against CRRs from other willing buyers and sellers, so that these CRRs would not require any payment out of the congestion rents that are otherwise refunded to transmission ratepayers or from direct uplifts funded by transmission ratepayers.

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[11] *Shortcomings in the congestion revenue right auction design*, DMM whitepaper, November 28, 2016: http://www.caiso.com/Documents/DMM-WhitePaper-Shortcomings-CongestionRevenueRightAuctionDesign.pdf.

[12] *Problems in the performance and design of the congestion revenue right auction,* DMM whitepaper, November 27, 2017: http://www.caiso.com/Documents/DMMWhitePaper-Problems_Performance_Design_CongestionRevenueRightAuction-Nov27_2017.pdf

[13] *Market alternatives to the congestion revenue rights auction,* DMM whitepaper, November 27, 2017: http://www.caiso.com/Documents/DMMWhitePaper-Market_Alternatives_CongestionRevenueRightsAuction-Nov27_2017.pdf

In 2018, the ISO's Market Surveillance Committee (MSC) stated that:

> The DMM/SCE design would very likely be effective in preventing financial market participants from acquiring CRRs at a discount to the expected payout. However, it would also prevent physical market participants from acquiring CRRs at a discount or a premium to the expected payout. In other words, while the proposal would effectively eliminate the purchase of speculative CRRs in the auction, it does so at a cost of sharply reducing access to ISO-backed hedging CRRs.[14, 15]

The MSC concluded that:

> At this time, we do not support the DMM/SCE proposal. In particular, it would be counter to the open access principles that motivated the creation of congestion revenue rights as a hedge in the first place; replacement hedges would likely be available only at a much higher price for market participants who do not participate in the free allocation stage of CRR allocation; and caution should be the rule when considering market changes that would profoundly affect the availability and cost of transmission hedging services. If the Track 1 and 2 changes prove to be ineffectual in reducing CRR auction losses, then the DMM/SCE proposal is one alternative that could be considered.[16]

As summarized in the prior section, the Track 1A and 1B (referred to as Track 1 and 2 above) changes implemented in 2019 have clearly proven to be ineffectual in reducing CRR auction losses. To the extent losses have been reduced, analysis by DMM indicates this is attributable—mostly or entirely—to high deficit offset charges made under Track 1B changes. However, these high deficit offset charges (which have averaged over 30 percent of nominal CRR payouts) have significantly reduced the hedging value of CRRs for any entities that actually utilize these as a hedge.

Proposed market design based on willing counterparties

DMM has collaborated with researchers at Stanford University to further develop and assess an alternative CRR market design based on willing counterparties. Attachment 1 provides a written summary by researchers at Stanford University of the theoretical foundation and the detailed mathematical formulation of this proposed market design.[17]

This proposed design—based on a purely financial network market design—is consistent with other financial derivatives markets, such as a futures contract that settles financially against a future spot price. The financial network auction only clears a point-to-point CRR if there is a set of counterparties that willingly take the other side of this CRR obligation at the clearing prices of all point-to-point financial network CRRs. Implementing this feature of all existing financial forward contracts ensures that any CRRs sold in the financial network auction no longer use day-ahead market congestion revenues or

[14] *Opinion on Congestion Revenue Rights Auction Efficiency*, Market Surveillance Committee of the California ISO, March 15, 2018, pp 9-10: https://www.caiso.com/documents/mscdraftopiniononcongestionrevenuerightsauctionefficiency-mar15_2018.pdf

[15] DMM has noted that the term "ISO-backed hedges" in the MSC opinion refers to CRRs that are sold by the ISO (at a $0 bid price), but which are actually backed financially by congestion rents otherwise refunded to transmission ratepayers.

[16] *Opinion on Congestion Revenue Rights Auction Efficiency*, Market Surveillance Committee of the California ISO, March 15, 2018, pp 22-23: https://www.caiso.com/documents/mscdraftopiniononcongestionrevenuerightsauctionefficiency-mar15_2018.pdf

[17] *Financial Network Congestion Revenue Rights*, Frank A. Wolak, Stanford University, Prepared for the CAISO Department of Market Monitoring, July 7, 2024 (included as Attachment 1).

other uplifts to transmission ratepayer to fund CRR payouts. Instead, any CRR position purchased is fully funded by other CRR positions purchased in auction.

The alternative CRR market design being proposed is functionally almost equivalent to the willing buyer/willing seller approach (or SCE Proposal) supported by DMM and other entities in 2018. The proposal put forward in 2018 would use the existing CRR auction model, but would constrain limits so that flows in the CRR network model could not exceed levels resulting only from allocated CRRs. This approach was suggested as a practical option for implementing the key feature of this approach: that all CRRs sold in the auction (after the allocation process) would be fully backed financially by a willing seller, rather than being backed by day-ahead congestion rents. With this proposed approach, the ISO does not intervene in the auction by essentially offering to sell CRRs backed by congestion rents at a $0 bid price.

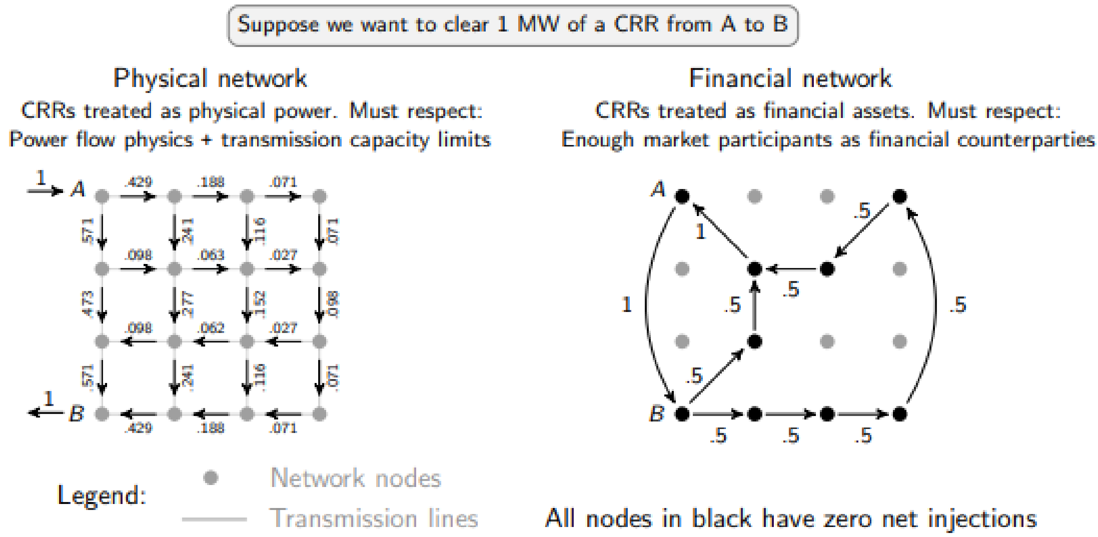
As described in Attachment 1, Stanford researchers have developed an approach based on the type of financial model used in other financial markets with a central clearing house. With this approach, the ISO serves as a central clearing house that facilitates trading by multiple counterparties, but does not have any financial exposure from this trading. This ensures that no congestion rents are needed to fund CRR payments for CRRs clearing this financial market. DMM believes this purely financial model framework is much simpler to implement and will be much less subject to the type of modeling errors that occur with the current CRR transmission modeling.

The difference in how CRR contracts are treated in the physical network model used in the current CRR auction, compared to the financial network model being proposed, is illustrated in Figure 2-1.

- As shown on the left side of Figure 2-1, under the current CRR auction, CRR contracts are modeled under physical network constraints. The CRR contract is treated as if it represents a physical injection of power at the source and a physical withdrawal of power at the sink. The distribution of flows along transmission lines is entirely driven by the physics of power flow.
- As shown on the right side of Figure 2-1, under the proposed financial model, all transmission lines are ignored, and only the locations (nodes) matter. This figure shows an example of how a 1 MW CRR from A to B could be issued under financial transmission constraints. For this to happen, the quantity supplied and the quantity demanded at nodes A and B must be the same. A bilateral transaction is not necessary (despite being sufficient). All that is needed is a chain of transactions that function as a counterparty to this CRR, as illustrated with the particular chain represented in the picture.

Attachment 1 also provides detailed mathematical formations showing the difference in these two models. Section 3 of this paper summarizes results of analysis of the willing seller market design performed by researchers from Stanford University.

Figure 2-1 Physical network vs financial approach for CRR market



Source: Based on *Financial Network Congestion Revenue Rights* (Attachment 1)

With the financial market being proposed, the current CRR model can still be used in the process for allocating CRRs to load serving entities and exporters. This model requires that allocated CRRs be simultaneously feasible under the physical network model that is assumed to exist in the annual and monthly allocation processes. Transmission limitations would continue to be imposed in this process to ensure that congestion rents collected in the day-ahead market are generally sufficient to fully fund all CRRs allocated in this process. Entities that are allocated CRRs in this process can continue to sell (or buy) additional CRRs as willing counterparties in the subsequent financial CRR market.

3 Analysis of willing seller design

This section summarizes results of analysis based on the willing seller market design performed by researchers from Stanford University using the mathematical formulation summarized in Section 2 and Attachment 1.

Methodology

For this analysis, the proposed financial market is solved using bids to buy and sell CRRs that were submitted by market participants for the 2017 and 2018 CRR auctions. No modifications were made to these bids and no additional bids were added. These bids include those submitted by LSEs that are the equivalent of "selling back" CRRs allocated in the auction, as well as bids to buy and sell CRRs submitted by all other participants.

These actual bids were cleared using the financial network under the willing seller design. Results from clearing the bids under the willing seller design are then compared to results of the actual CRR auction using a variety of metrics, including quantities and profitability of CRRs clearing the auction. The profitability of CRRs clearing with the willing seller design is calculated using prices and quantities from this willing seller auction, combined with actual day-ahead energy prices for the source and sinks of each CRR.

If the willing seller design had been used in the 2017 and 2018 auctions, participants might have submitted different bids knowing that the auction would clear using a financial network without the ISO selling CRRs on behalf of ratepayers. Different bids would have led to different results than using the actual 2017-2018 bids used in this analysis.

This 2017-2018 time period is used in this analysis because several of the changes beginning in 2019 would cause bids submitted by participants to be significantly different than bids that would be submitted under the willing seller design DMM proposes, as described below:

- **The allowable source and sink pairs for CRR bids were limited to "delivery path" combinations** beginning in 2019. These limitations significantly restrict participants to willingly sell CRRs to a counterparty. These limitations would not be needed under the willing seller design.

- **The deficit offset charges implemented in 2019 have totaled about 31 percent of the nominal CRR payments** (i.e., the difference in price at the CRR source and sink). These charges significantly reduce the net payment for many CRRs, and would therefore have a significant impact on the expected value of CRR payouts and bid prices reflecting participants' expected payouts from CRRs. No deficit offset charges would be needed under the willing seller design since all CRRs under this design have a counterparty that assumes all financial responsibility.

- **The percentage of expected transmission capacity made available in the annual allocation and auction model was reduced from 75 percent to 65 percent**. Under the willing seller market design, the amount of transmission made available in the allocation process could be increased back to 75 percent or even higher. Since more CRRs could be allocated to LSEs, more CRRs might then be offered by LSEs under the willing seller design than have been offered by since 2019.

All of these three changes were implemented in 2019 to reduce losses under the current auction design, but would not be needed under the willing seller market design. Thus, the 2017-2018 data used in this study represent the most recent period in which bids submitted by participants can be feasible and more representative of bids that would be submitted under the willing seller market design.

Results of this analysis are shown for four different types of participants:

- Financial entities that only participate in CRRs and virtual bidding.
- Marketers that schedule some energy in the ISO markets, and may also participate in the ISO's purely financial markets (CRRs and virtual bidding).
- Generators that schedule generation units located within the ISO system.
- Load serving entities.

In theory, all bids submitted in the annual and monthly auctions should be based on the expected value of future payments for each CRR. In some cases, bids submitted in the monthly auctions could be affected by the amount of CRRs procured in the annual auction. Because of this potential issue, results of this analysis are also provided for CRRs purchased in the annual and monthly auctions separately.

Willing seller auction results

This section provides combined results for all of the annual and monthly auctions in the 2017 to 2018 time period for different types of market participants. Figure 3-1 compares the total volume of CRRs that cleared the actual auctions with the volumes that cleared under the willing seller market design based on actual bids submitted.

- For **financial entities**, about 41 percent of the volume of MWs that cleared the CRR auction cleared under the willing seller market design.
- For **marketers**, about 38 percent of the CRR volumes clearing the 2017-2018 auctions cleared under the willing seller market design.
- For **generators**, about 53 percent of the CRR volumes clearing the auctions over this two year period cleared under the willing seller market design.
- For **load serving entities**, about 83 percent of the CRR volumes clearing the auctions cleared under the willing seller market design.

Figure 3-2 compares the net profits from CRRs that cleared under these two different market designs. As shown in Figure 3-1 and Figure 3-2:

- **Financial entities** had $163 million in net profits from CRRs purchased in 2017-2018, and would have received $27 million in net profits during this period from bids clearing under the willing seller design.
- **Marketers** had $37 million in net profits from CRRs purchased in the two year study period, and would have lost $17 million from their CRR bids under the willing seller design.
- **Generators** had $27 million in net profits from CRRs in the study period, and would have received $3 million in net profits under the willing seller design.
- **Load serving entities** lost about $17 million from their sales in the CRR auction during these years, and would have lost about $13 million under the willing seller design.

Figure 3-1 Total cleared CRR contract volumes (TWh)

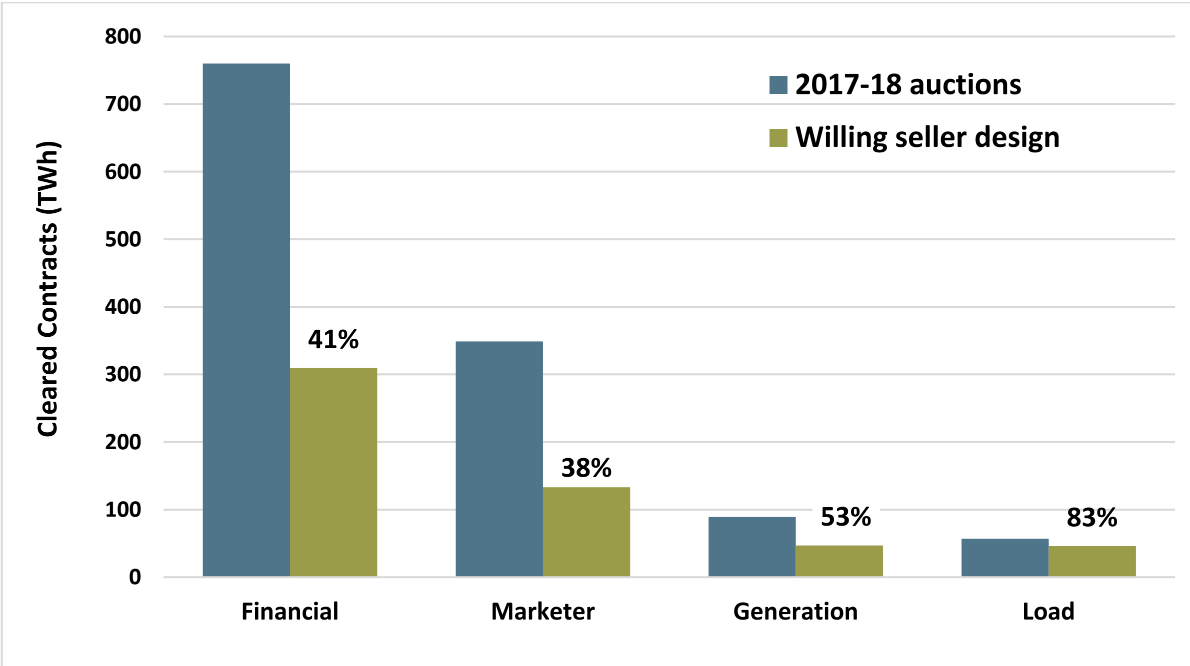
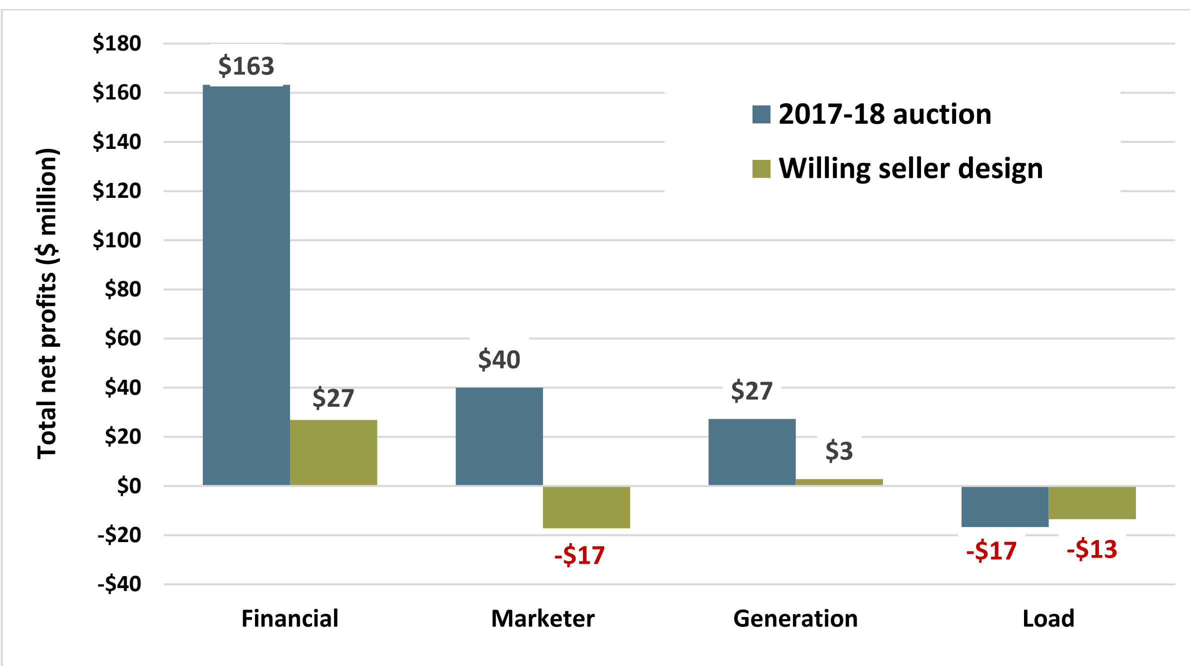


Figure 3-2 Total profits for cleared CRR contracts (millions)



As shown in Figure 3-2, all of the three groups of non-LSEs purchasing CRRs in 2017-2018 made tens of millions of dollars in profit from these CRRs, with total profits of $227 million. Under the willing seller approach, LSEs would lose about $12 million, but the sum of the net profits and losses for all four categories of market participants equals $0.

Under the current auction design, auction revenues and day-ahead market payments among auction participants do not net to zero. The net auction revenues are payments to CRRs sold by the ISO and backed by transmission ratepayers. The net CRR payments (shown by the blue bars in Figure 3-2) are payments from transmission ratepayers to the auctioned CRRs. The difference between the net auction revenues and net payments are the losses for transmission ratepayers. With the willing seller design, the auction revenues net to $0 and the CRR payments also net to $0, so that the sum of profits among all auction participants nets to $0.

Figure 3-3 further highlights this important difference between the current auction design compared to the willing seller approach.

- The dark blue and green bars in Figure 3-3 show gross payments to auction participants from the auction and CRR payouts under the current auction design, and the willing seller design, respectively.
- The light blue and green bars show gross payments received by auction participants from the auction and CRR payouts under these two different auction designs.
- As shown in the blue bars on the left side of Figure 3-3, net payments into the 2017-2018 auctions totaled $164 million in positive auction revenues. Payouts for these CRRs totaled $378 million dollars, representing a net payment out of $214 million from total congestion rents collected in the day-ahead market.[18]
- As shown in the green bars on the right side of Figure 3-3, under the willing seller design, initial payments in the auction net to $0 and subsequent payments for these CRRs based on congestion also net to $0.

Negative values for auction payments in Figure 3-3 represent the sum of all negatively priced CRRs clearing the market. Participants get paid for these negatively priced CRRs, but must then pay when congestion occurs from the sink to the source of these CRRs in the day-ahead market. These negatively priced CRRs are referred to as *counterflow* CRRs, since the negative price indicates a market expectation that the prevalent direction of congestion charges will be from the sink to the source. These counterflow CRRs allow an equal amount of additional CRRs in the opposite direction to clear the auction.

Figure 3-4 shows the same data as in Figure 3-3, but provides a breakdown of these data by participant group.

[18] $164 million in net auction revenues + $378 million in net payments to CRR holders from congestion rents = $214 million reduction in congestion rent that is refunded to transmission ratepayers.

Figure 3-3 Total auction and CRR payments (all participants)

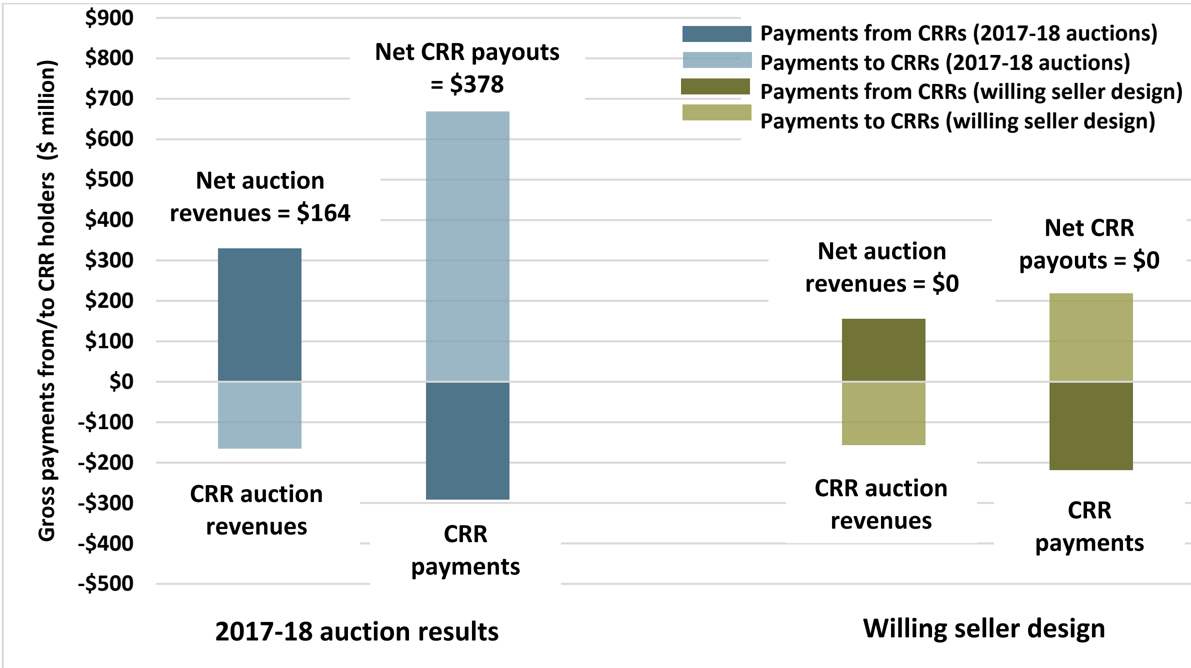
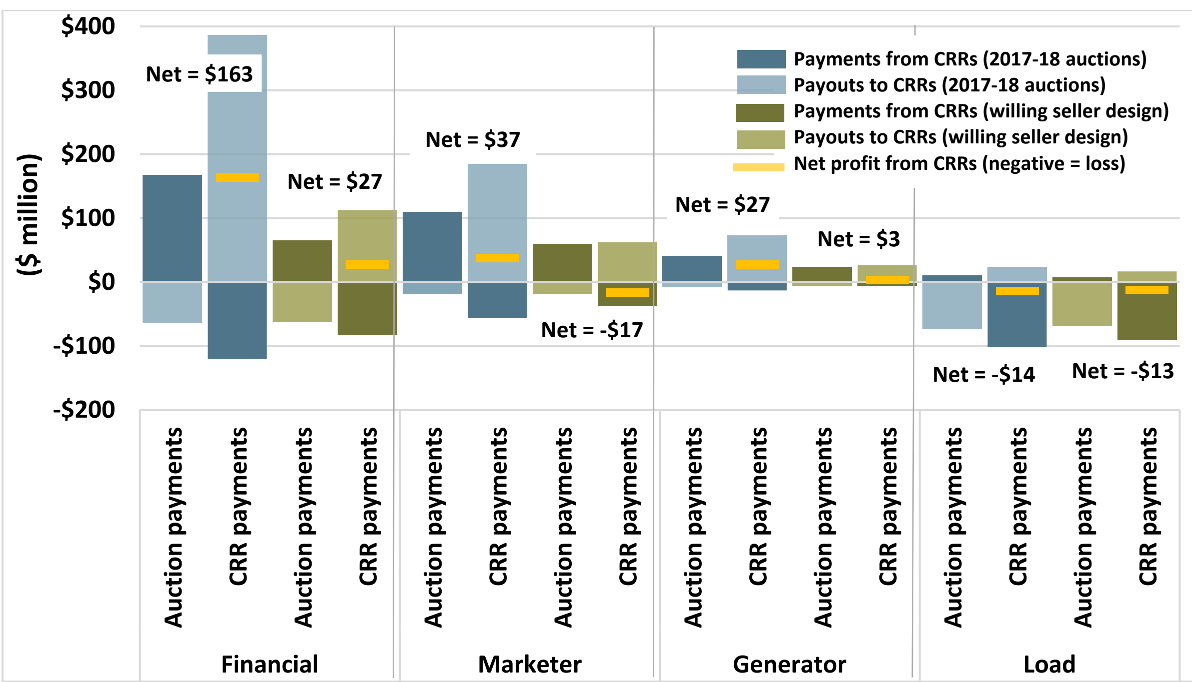


Figure 3-4 Auction revenues and CRR payments by participant type



Negatively priced CRRs represent CRRs being sold to other counterparties that are purchasing these CRRs either based on financial speculation or as hedges for actual energy contracting.

- A significant portion of these counterflow CRRs represent resales of CRRs acquired by LSEs in the allocation process.[19]
- This analysis also shows that a significant portion of these counterflow CRRs represent bids by financial entities that expect the price they receive in the auction to exceed the CRR congestion charges that they will be obligated to pay back over the term of the CRR.
- Some of these counterflow CRRs may also represent CRRs purchased by non-LSEs in the seasonal auction (for three month periods) that are being re-sold for individual months in the monthly auctions.

In this analysis, we compare results of the willing seller design to the 2017-18 auction results using two measures of the financial volume of negatively priced CRRs: (1) the total auction payments made for negatively priced CRRs, and (2) the payments subsequently collected by the ISO from sellers of these negatively priced CRRs. Table 3-1 and Table 3-2 compare negatively priced CRRs clearing under both these auction designs, using these two different measures of the financial volume of negatively priced CRRs.

Table 3-1 Auction revenues from negatively priced CRRs

	Auction Revenues		% of 2017-18	Share of auction revenue	
	2017-2018	Willing Seller	clearing willing	2017-2018	Willing Seller
Financial	-$65	-$62	97%	39%	40%
Marketer	-$19	-$18	98%	11%	12%
Generator	-$8	-$7	81%	5%	4%
Load	-$74	-$68	92%	45%	44%
Total	-$165	-$156	94%	100%	100%

Table 3-2 CRR payments made for negatively priced CRRs

	Day-Ahead Payouts		% of 2017-18	Share of day-ahead payouts	
	2017-2018	Willing Seller	clearing willing	2017-2018	Willing Seller
Financial	-$120	-$83	69%	41%	38%
Marketer	-$57	-$37	66%	19%	17%
Generator	-$13	-$7	52%	5%	3%
Load	-$101	-$90	90%	35%	41%
Total	-$291	-$218	75%	100%	100%

[19] Prior to 2019, in order to re-sell allocated CRRs, LSEs needed to submit bids to sell CRRs in the opposite direction of the allocated CRRs. Since LSEs choose allocated CRRs from sources to sinks in the direction of potential congestion, LSEs needed to sell CRRs in the opposite (counterflow) direction in order to “sell back” these allocated CRRs.

As shown in these tables and Figure 3-3:

- The total auction payments for negatively priced CRRs clearing under the willing seller design would have been about $156 million—or about 94 percent of the $165 million of negatively priced CRRs clearing the 2017-18 auctions.

- The total CRR payments made by sellers of negatively priced CRRs clearing under the willing seller design would have been about $217 million—or about 75 percent of the $291 million of negatively priced CRRs clearing the 2017-18 auctions.

As shown in Table 3-1 and Figure 3-4, load serving entities and financial entities accounted for most negatively priced CRRs clearing the 2017-18 auctions and under the willing seller design.

- Load serving entities accounted for about 45 percent of auction costs and about 35 percent of CRR payments associated with negatively priced CRRs clearing the 2017-18 auctions.

- Under the willing seller design, LSEs accounted for about 44 percent of auction costs and about 41 percent of CRR payments associated with negatively priced CRRs.

- Financial entities accounted for about 39 percent of auction costs and about 41 percent of CRR payments associated with negatively priced CRRs clearing the 2017-18 auctions.

- Under the willing seller design, financial entities accounted for about 40 percent of auction costs and about 38 percent of CRR payments associated with negatively priced CRRs.

These results indicate that a significant volume of counterflow CRRs offered for sale by LSEs and non-LSEs would clear under the willing seller design. These results are contrary to the expectation or prediction of the ISO, MSC, and most CRR market participants during the 2017-18 stakeholder process that culminated in the CRR market changes made in 2019.

CRR participant portfolios

Figure 3-5 provides a graphical summary of net auction payments by individual participants for CRRs that would be sold or purchased under the willing seller design (y-axis), compared to the net payments (or charges) for these CRRs based on congestion in the day-ahead market (x-axis). As shown by the annotation included in Figure 3-5, this figure can be used to illustrate several different types of CRR auction participants.

- The bold vertical line (intersecting the y-axis at the midpoint of 0) divides CRR participant portfolios that resulted in net negative auction payments (to the left) from CRR portfolios that resulted in net positive auction payments (to the right). Thus, portfolios on the left half of this figure represent entities that were net sellers of CRRs, while those on the right half represent entities that were net buyers of CRRs.

- The bold horizontal line (intersecting the x-axis at the midpoint of 0) divides entities that received positive net CRR payouts (on the upper half) from entities with negative CRR payouts (on the lower half). Thus, points on the upper half of this figure represent entities that received CRR payments, while the lower half represent entities that on balance were charged for congestion associated with their CRRs.

- The upward diagonal dashed line separates CRR portfolios that were profitable (above the diagonal line) from portfolios that were unprofitable (below the diagonal line).
- Most CRR portfolios lie fairly close to this horizontal line, and are either in the lower left quadrant (net sellers of CRRs that paid CRR congestion charges) or in the upper right quadrant (net buyers of CRRs that received CRR payouts).

Figure 3-6 through Figure 3-9 provide these same graphical summaries of results under the willing seller design for individual participants in each participant group separately. Comments on results for each of these groups are provided below each of these figures.

Figure 3-5 Willing seller auctions results (2017-2018 data)
Net auction payments and CRR payouts by participant

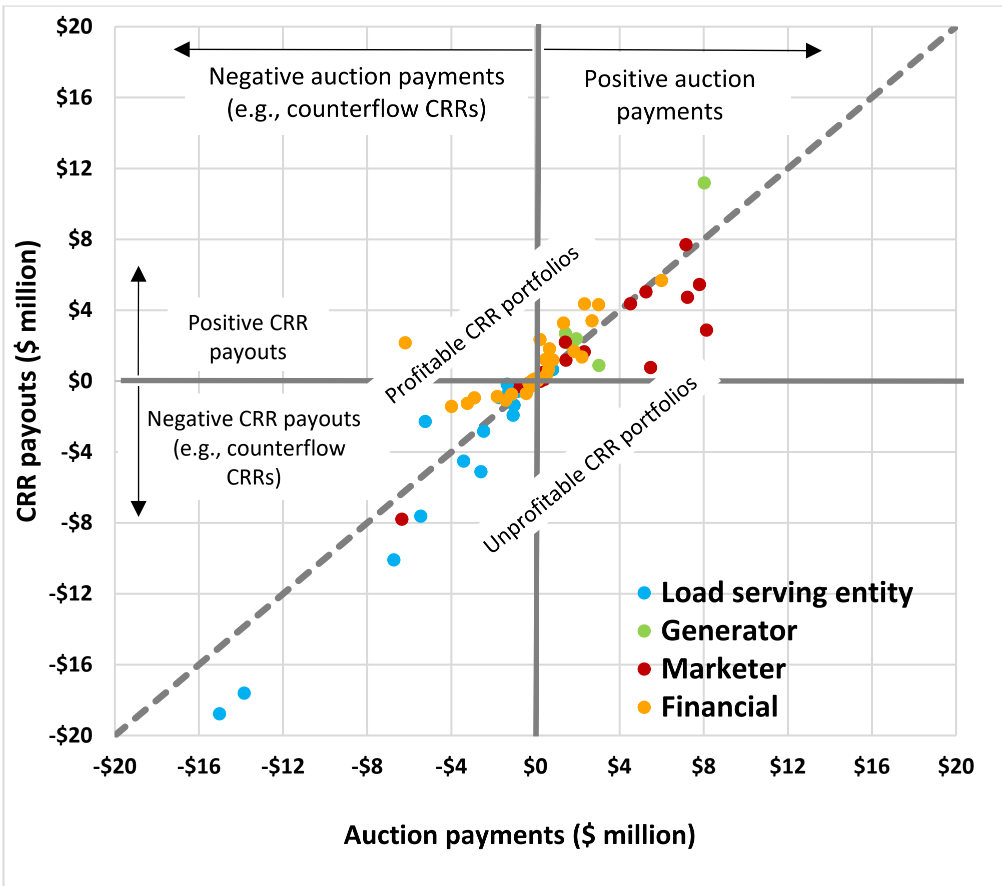
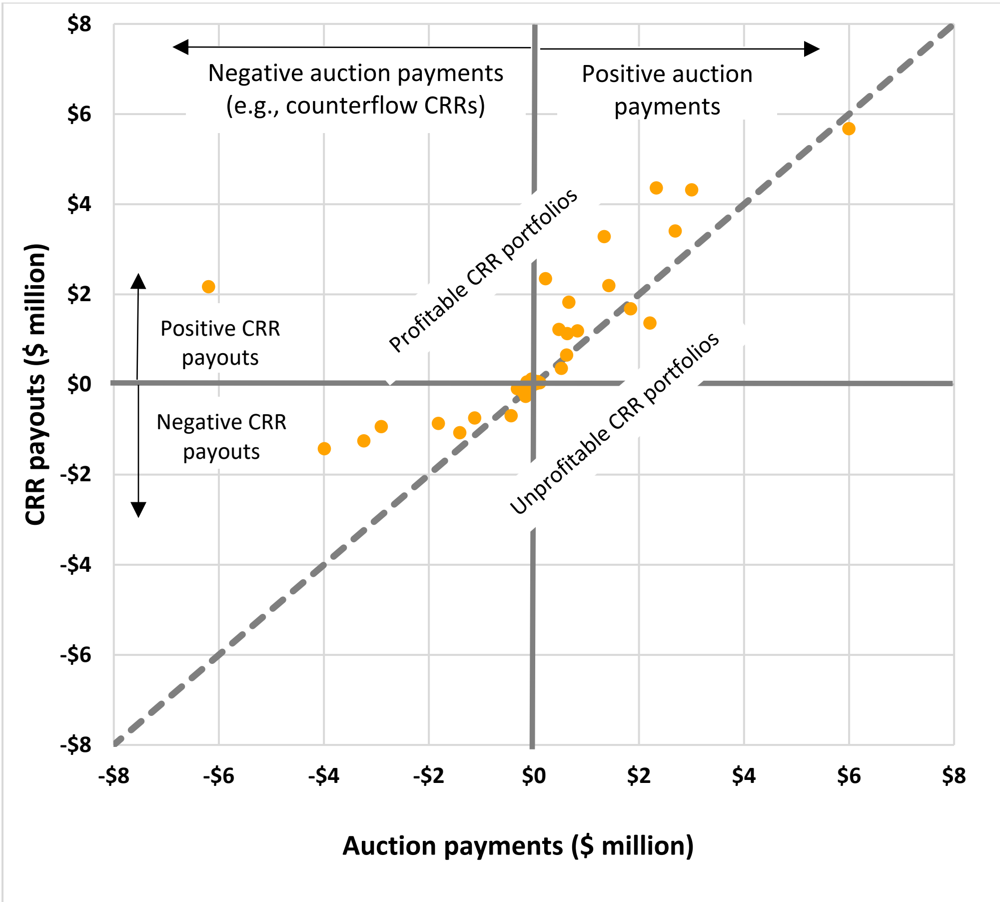
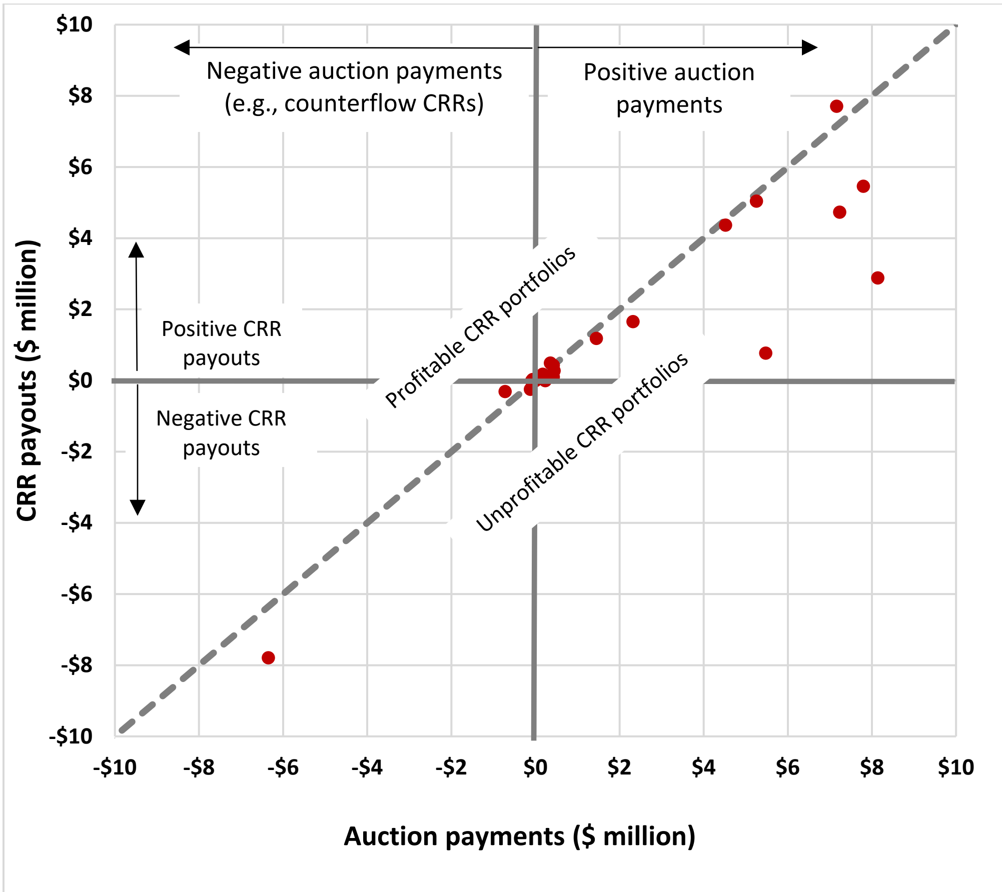


Figure 3-6 Willing seller auctions results - Financial entities
Net auction payments and CRR payouts by participant



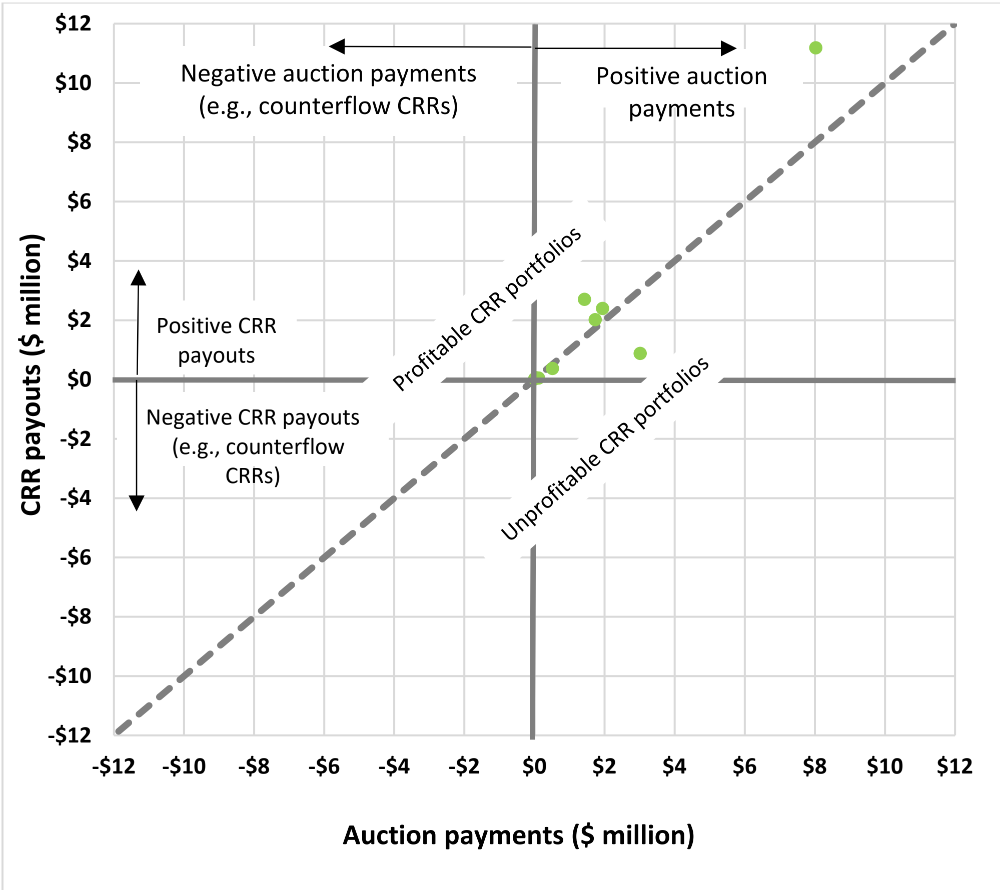
- Financial entities are all above or just below the dashed vertical line, indicating that CRRs would continue to be profitable for these entities under the willing seller design.
- A majority of financial entities are net buyers of CRRs (upper right quadrant), with most of these CRR portfolios being profitable (above or near the dashed line).
- A significant portion of these entities can be characterized as net sellers of CRRs (lower left quadrant), with most of these CRR portfolios being profitable (above or near the dashed line).

Figure 3-7 Willing seller auctions results - Energy marketers/traders
Net auction payments and CRR payouts by participant



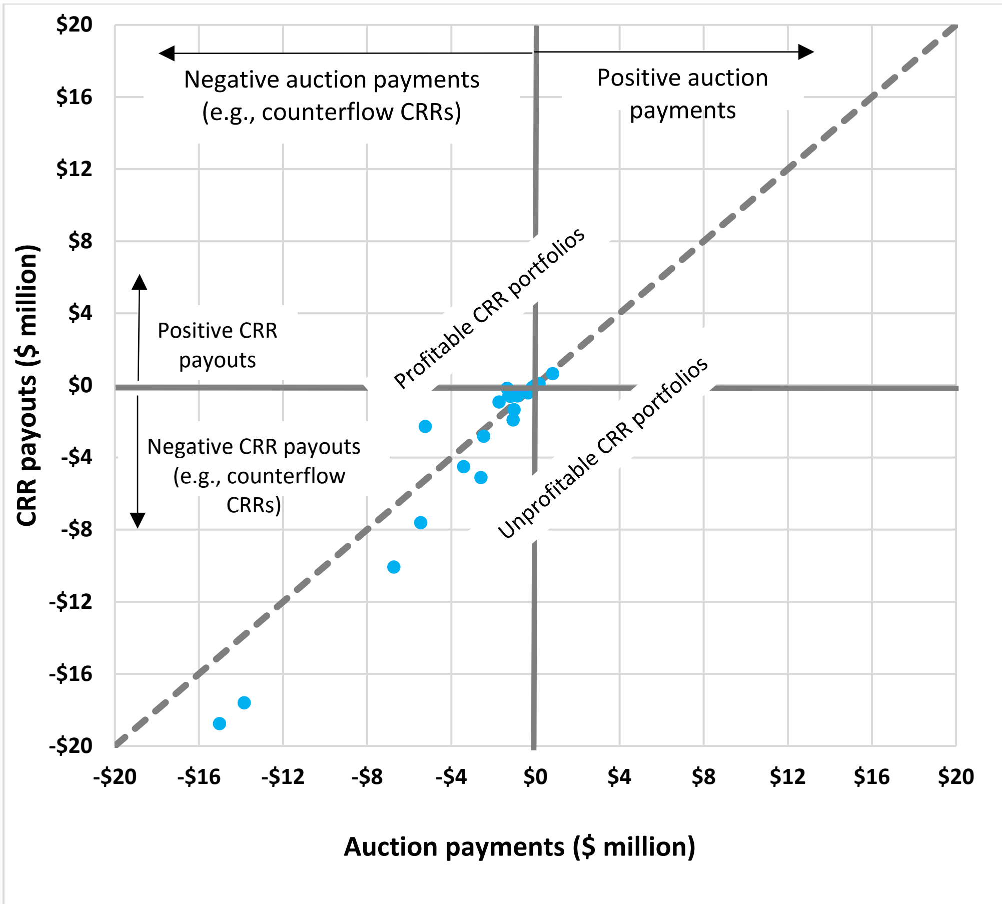
- Most entities classified as energy marketers are net buyers of CRRs, with just one being a major seller (or buyer of negatively priced CRRs).
- Most of these entities have portfolios falling near or below the dashed horizontal line, indicating that they about broke even or incurred net losses on their CRR portfolios. None of these entities had a highly profitable portfolio of CRRs.
- These results suggest that some of these CRRs clearing under the willing seller design may be purchased by these entities as a form of hedging energy trading and marketing activities.
- Many of the most profitable CRRs purchased by these entities in the 2017-18 auctions would not clear under the willing seller design, as this group garnered a net profit of $37 million in the 2017-18 auctions, but had a net loss of $17 million under the willing seller design.

Figure 3-8 Willing seller auctions results - Generators
Net auction payments and CRR payouts by participant



- Results show that generators would continue to be net buyers of CRRs under the willing seller design, and would continue to account for a relatively small portion of CRR purchases.
- Most generators have portfolios under the willing seller design that fall near the dashed horizontal line, indicating that most of these CRR portfolios would not be highly profitable or unprofitable.
- These results suggest that some of these CRRs clearing under the willing seller design may be purchased by these entities as a form of hedging.

Figure 3-9 Willing seller auctions results - Load serving entities
Net auction payments and CRR payouts by participant



- Almost all load serving entities would continue to be net sellers of allocated CRRs, with sales of CRRs under the willing seller design being just slightly lower than CRR sales in the 2017-18 auction.
- Most load serving entities sold CRRs for less in the auction than the payouts for these CRRs, and therefore appear in the lower left quadrant of this chart, below the dashed horizontal line.
- Overall, revenues from CRRs sold by LSEs in the willing seller auction would be about 84 percent of CRR payouts for these CRRs.
- Losses from sales of CRRs by LSEs totaled about $17 million in the 2017-18 auctions, compared to about $13 million under the willing seller design.

Comparison of seasonal and monthly results

The ISO holds auctions annually for CRRs covering four different seasonal (three month) periods, and then holds auctions in advance of each month for CRRs covering each month individually. Since there may be some relationship between results of the seasonal auction and bids in the monthly auction, this section provides key metrics of the analysis separately for the seasonal and monthly auctions in the 2017 to 2018 time period.

- Figure 3-10 compares the total volume of CRRs that cleared the seasonal and monthly auctions with the volumes that would have cleared the willing seller market design based on actual bids submitted.
- Figure 3-11 compares the net profits from CRRs clearing the seasonal and monthly auctions under these two different market designs.
- Figure 3-12 and Figure 3-13 provide a more detailed breakdown of auction payments and payouts for seasonal and monthly auctions under these two market designs.

These results show that there are no significant differences in these metrics for the seasonal vs. monthly auctions. In addition, this analysis shows that the CRRs clearing in the seasonal auctions under the willing seller approach is lower than CRRs that cleared in the actual seasonal auction.

Figure 3-10 Total cleared CRR contract volumes (seasonal vs. monthly)

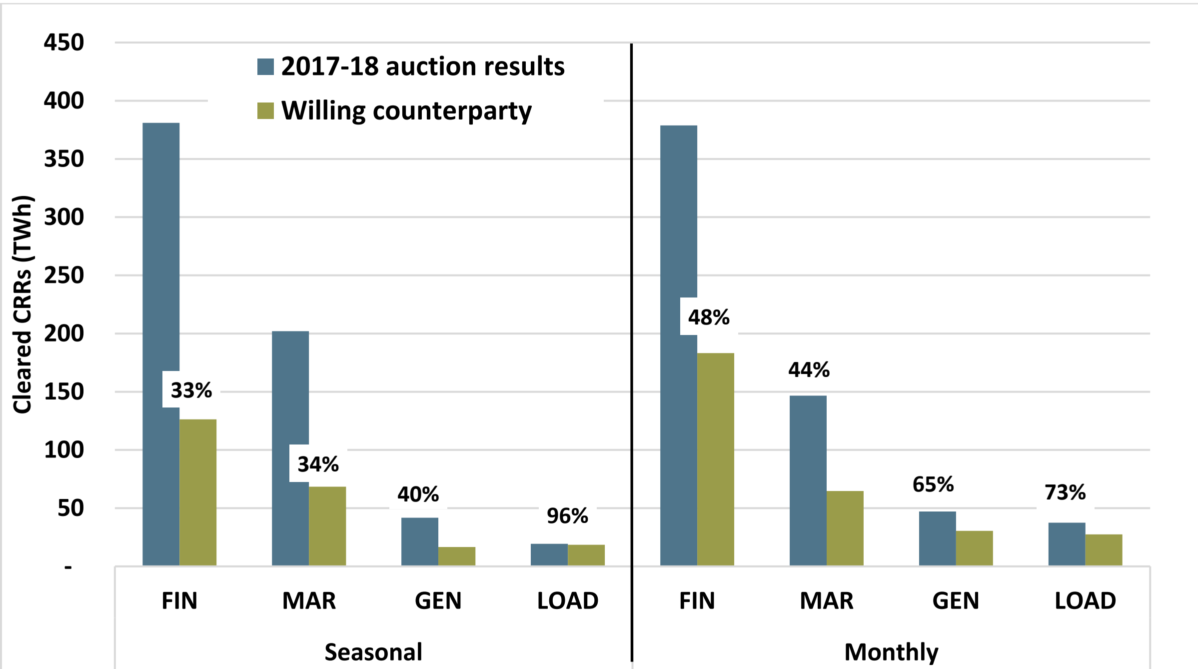


Figure 3-11 Total profits for cleared CRR contracts (seasonal vs. monthly)

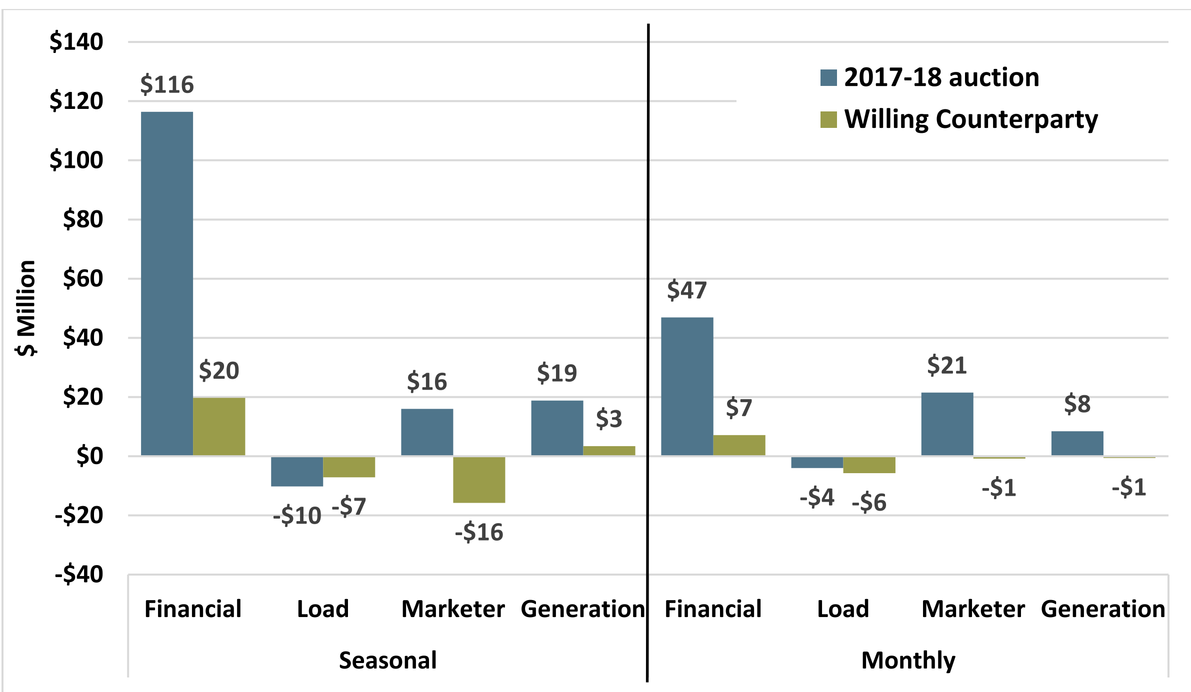


Figure 3-12 Seasonal and monthly payments and profits (actual auction)

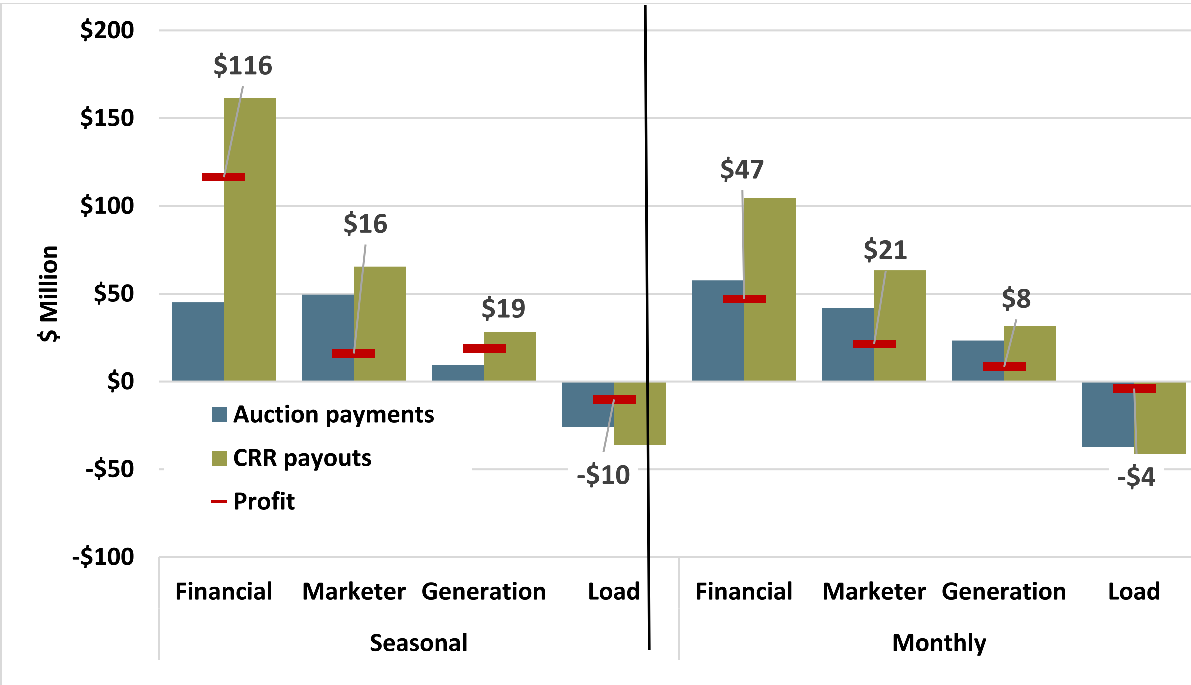
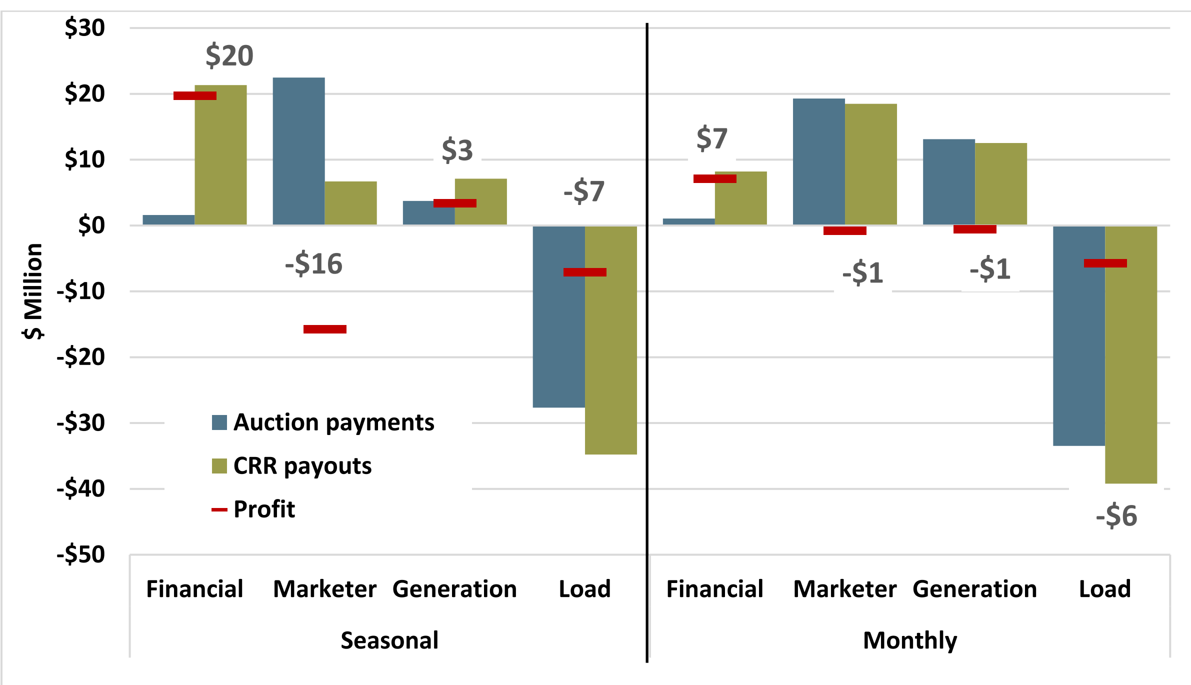


Figure 3-13 Seasonal and monthly payments and profits (willing seller)



4 Current congestion revenue rights market

Analysis in this report shows that a significant volume of CRRs were voluntarily sold by LSEs and non-LSEs in the 2017-18 auctions, and that a significant portion of these CRRs would also clear under the willing seller market design. Changes made to the CRR auction in 2019 placed significant limitations on CRR bidding locations and payments, such that DMM cannot extend our analysis of the willing seller approach using data from 2019 to present. While these 2019 changes clearly reduced the losses for transmission ratepayers, these restrictions would not be needed under the willing seller design and would be eliminated under the willing seller market design.

Since 2019, the share of load served by the state's two largest investor owned utilities (IOUs) has dropped, while the share of load served by numerous smaller community choice aggregators (CCAs) has increased significantly. In this section, we provide several metrics that we believe can be used to assess how CRR market conditions in the 2017-18 period used in this analysis, compare to CRR market conditions during the more recent 2022-23 period.

Table 4-1 compares the financial volume of negatively priced CRRs clearing the ISO's auction in 2017-18 to the volume of negatively priced CRRs clearing in 2022-23.[20] Results are provided for LSEs and non-LSEs.

As in the prior section of this report, results in Table 4-1 include two different ways of quantifying the financial volume of negatively priced CRRs: (1) the sum of auction payments to entities for negatively priced CRRs, and (2) the payments based on day-ahead prices that are subsequently received from entities holding these negatively priced CRRs.

Since total congestion charges in the day-ahead market were more than twice as high in 2022-23 than in 2017-18, the financial volume of negatively priced CRRs clearing in these two periods is also presented in Table 4-1 as a percentage of total day-ahead congestion charges (or rents) in these different two-year periods.

CRR payments and congestion rents for 2022-23 shown in Table 4-1 are notional values, before application of deficit offset charges, since we cannot estimate these charges for individual CRRs. However, DMM estimates that total deficit offset charges have been about 25 percent of notional CRR payouts for LSEs and about 30 percent for non-LSEs.

[20] The data needed to calculate negatively priced CRRs clearing the auction is now archived by the ISO for only the prior three years. Therefore, we cannot perform this analysis for the 2019-21 period.

Table 4-1 Negatively priced CRR auction revenue and payments*

	Negatively priced CRRs		% of total congestion rent	
	Auction revenue	CRR payments	Auction revenue	CRR payments
2017-2018 (Total day-ahead market congestion rent = $986 million)				
LSEs	$74	$101	7%	10%
Non-LSEs	$92	$190	9%	19%
Total	$165	$291	17%	30%
2022-2023 (Total day-ahead market congestion rent = $1.932 million)				
LSEs	$172	$242	9%	13%
Non-LSEs	$104	$65	5%	3%
Total	$276	$308	14%	16%

* 2022-2023 estimated CRR payments are notional before deficit offset charges.

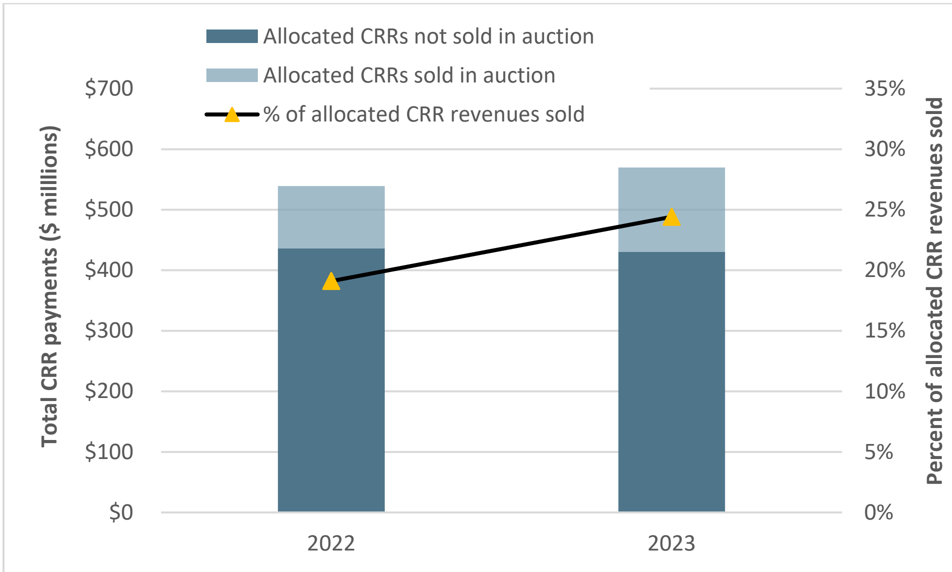
As shown in Table 4-1:

- Auction revenues from negatively priced CRRs clearing in 2017-18 totaled about $165 million, compared to $276 million in 2022-23. These auction revenues totaled about 17 percent of total day-ahead congestion charges in 2017-18 and about 14 percent in 2022-23.
- Payments received from negatively priced CRRs clearing in 2017-18 totaled about $291 million, compared to $308 million in 2022-23. These payments totaled about 30 percent of total day-ahead congestion charges in 2017-18 and about 16 percent in 2022-23.
- The financial volume of negatively priced CRRs sold by LSEs was higher in 2022-23 by both these measures. Auction revenues for negatively priced CRRs sold by LSEs totaled about 7 percent of congestion rents in 2017-18 and about 9 percent in 2022-23. CRR payments for these CRRs totaled about 10 percent of congestion rents in 2017-18 and about 13 percent in 2022-23.
- The financial volume of negatively priced CRRs sold by non-LSEs was lower in 2022-23 by both these measures. Auction revenues for negatively priced CRRs sold by LSEs totaled about 9 percent of congestion rents in 2017-18 and about 5 percent in 2022-23. CRR payments for these CRRs totaled about 19 percent of congestion rents in 2017-18 and about 3 percent in 2022-23.

Figure 4-1 shows the portion of allocated CRRs sold by LSEs in 2022 and 2023. For this figure, we use the payouts for CRRs allocated to LSEs and CRRs sold by LSEs in the auction to measure the financial volume of these CRRs. As shown in Figure 4-1, LSEs sold about $242 million in CRRs in the 2022-23 auctions, or about 22 percent of CRRs received by LSEs in the allocations process.

Since the ISO does not retain information on allocated CRRs for the 2017-2018 period, DMM cannot calculate the percentage of allocated CRRs sold by LSEs in the 2017-2018 auctions. However, as shown in Figure 4-1, CRR payments associated with negatively priced CRRs sold by LSEs in the 2017-18 auctions totaled $101 million (or about 10 percent of total day-ahead market congestion revenues), compared to about $242 million (or about 13 percent of congestion rent) in the 2022-23 auctions.

Figure 4-1 Portion of allocated CRRs sold by LSEs (2022-23)



Overall, DMM believes these results provide strong evidence that a significant volume of counterflow CRRs would continue to be offered in the CRR market by LSEs and non-LSEs under a willing seller design. This expectation is also consistent with CPUC rulings on acquisition and sales of allocated CRRs by LSEs. DMM understands that the CPUC encourages LSEs to acquire CRRs in the allocation process to hedge their actual expected grid usage, but also expects LSEs to seek to sell any allocated CRRs that are not reasonably related to their actual grid use.[21]

Given the current allocation process and state regulatory framework, we would expect LSEs to continue to be sellers of a significant volume of allocated CRRs under the willing seller design. However, beyond selling a portion of their allocated CRRs, we would not expect LSEs to willingly offer additional CRRs under the willing seller design.

The ISO's Market Surveillance Committee (MSC) has contended that load serving entities are "natural counterparties [sellers]" of CRRs, since the congestion rents they receive provide an "opposite revenue stream" to payments that must be made by sellers of CRRs.[22] Some financial entities have also argued that CRRs sold by the ISO reduce risk for LSEs by replacing a variable revenue stream of congestion rents with a less variable auction payment.

Both these arguments are flawed for two reasons, as illustrated in Figure 4-2.

- First, as shown in Figure 4-2, the annual auction revenues from CRRs purchased by non-LSEs (bottom green line) has always been significantly *lower* than the payments made to these CRRs out of congestion rents (middle solid blue line). Thus, while the auction revenues may be less variable from year to year, these revenues are always *less than* the congestion rents that LSEs

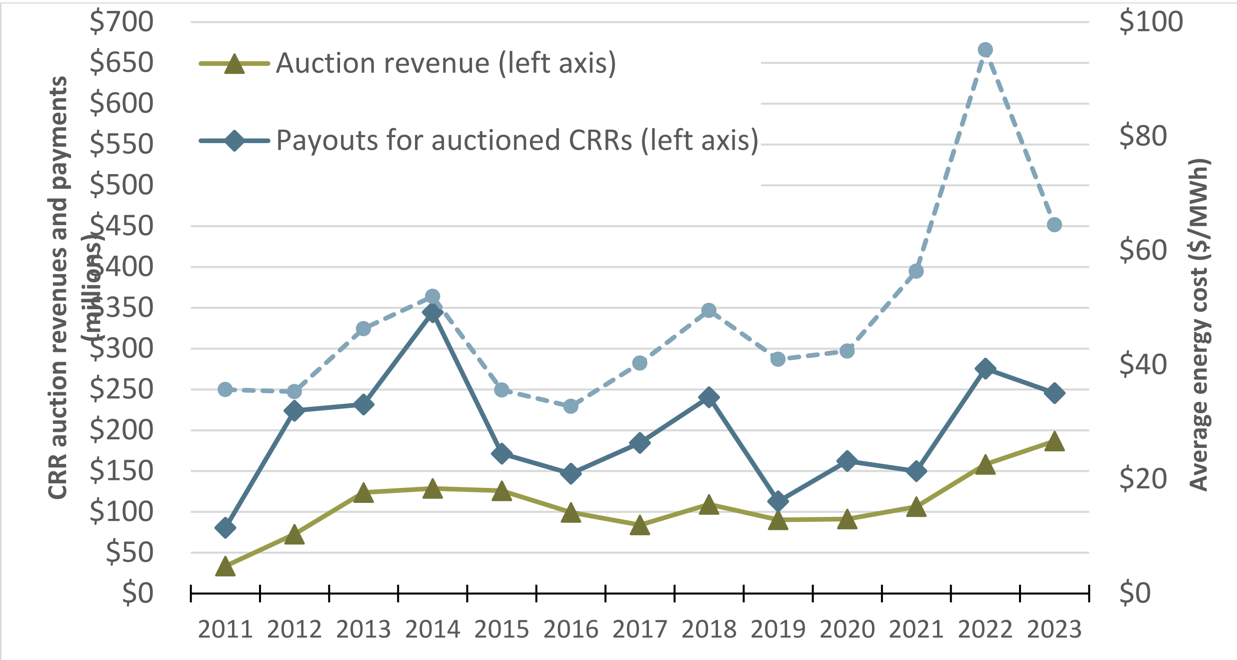
[21] https://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_RESOLUTION/76251.PDF

[22] The MSC's 2018 opinion asserts that "The ISO, or indirectly the ratepayers who are residual claimants to congestion revenues, are therefore in a unique position to provide CRRs to market participants. They are the natural counter-parties since they have the opposite revenue stream." *Opinion on Congestion Revenue Rights Auction Efficiency*, p 4. (op sit.)

lose from the sale of these CRRs. Thus, losses from sales of CRRs by the ISO do not decrease risk for LSEs by any measure of financial risk.

- Second, payments made out of congestion rents for CRRs sold in the auction (middle solid blue line) are highly correlated with year-to-year changes in LSEs' total energy costs (upper dotted blue line). However, there is only a slight correlation between auction revenues (bottom green line) and LSEs' total energy costs. Thus, sales of CRRs in the auction by the ISO actually reduces the hedge that congestion rents naturally provide against changes in LSEs' total energy costs.

Figure 4-2 Correlation of annual CRR auction revenues, payments, and energy costs



Thus, while we would expect LSEs to continue to be sellers of a significant volume of allocated CRRs under the willing seller design, we would not expect LSEs to willingly offer to sell additional CRRs under this design.

Attachment 1

Financial Network Congestion Revenue Rights

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Technical Appendix prepared for the Department of Market Monitoring
California Independent System Operator (CAISO)

October 22, 2024

1 Introduction

This document describes the details of a financial network design for congestion revenue rights (CRRs) that eliminates the potential for *underfunding* that has persistently plagued CRRs that use realized congestion revenues from "spot" market outcomes to fund CRRs. This financial network CRR auction only clears a point-to-point CRR if there is a set of counterparties that willingly take the other side of this CRR obligation at the clearing prices of all point-to-point financial network CRRs.

The willing counterparties requirement for all point-to-point financial network CRRs purchased reduces the likelihood of systematic *underpricing* of point-to-point CRRs sold in the financial network auction, because the willing counterparties requirement applies to all non-zero quantities of point-to-point CRRs cleared in the financial network auction.

This financial network design for point-to-point CRRs is consistent with other financial derivatives markets, such as a commodities futures contract that settles financially against the "spot" price on the settlement date of the contract. The buyer of a cash-settled forward contract for a commodity at a future "settlement" date requires a collection of willing counterparties to take the other side of this financial contract.

The following example of a cash-settled futures contract for oil illustrates this point. The buyer of 4,000 barrels of oil for a future date and location at \$60 per barrel in a forward contract must find a collection of willing sellers of this quantity of oil for this future settlement date and location at \$60 per barrel. Four sellers, each of which is willing to sell 1,000 barrels of oil for \$60 per barrel for this future settlement date and location, can serve as the counterparties to 4,000 barrels forward market purchase.

If the spot price of oil at the settlement location on the settlement date is \$50 per barrel, the buyer of the forward contract must pay the sellers of the forward contract the difference between the contract price, \$60 per barrel, and the spot price, \$50 per barrel, times the 4,000 barrels sold. In this example, each of the four sellers of the forward contract would receive \$10,000 = 1,000 barrels × \$10/barrel. Both the buyer and the four sellers of the forward contract have a guaranteed price of \$60 per barrel for the number of barrels they bought (4,000 barrels) or sold (1,000 barrels for each seller) in forward contracts, regardless of the spot price on the settlement day at the settlement location. The forward market operator has no financial exposure to any forward market transaction. It is only responsible for ensuring that all parties to this transactions are able to meet their financial obligations on the settlement date, which in this example is the \$40,000 payment by the buyer of the contract that the market operator uses to make the four payments of \$10,000 to each of the willing counterparties to the forward contract.

The financial network CRR auction mechanism implies that all point-to-point CRRs sold are firm in the financial commitments that no longer use realized spot market congestion revenues to fund CRR payouts. Instead, any financial network auction CRR position purchased is fully funded by other CRR positions purchased in auction.[1]

The most straightforward design for a financial network CRR market is *bilateral* transactions for each source-to-sink CRR product as described above for the fixed-price forward contract for 4,000 barrels of oil. Specifically, for a 10 megawatt (MW) CRR from node A to node B to clear in the financial network CRR auction at a price of \$500 per MW,

[1] Note that point-to-point financial network CRRs, like the current physical network CRRs, can be purchased at both a positive and negative price.

a 10 MW CRR from node B to node A must clear in the auction at −\$500 per MW.[2]

The financial network CRR auction design does not require only bilateral transactions (even though they are allowed to occur in the auction). Rather, buyers of all point-to-point products will be matched indirectly by enforcing the market clearing condition that net ”injections” at each network pricing location[3] are equal to zero. For a sale from location A to location B to take place, there must be sufficient CRRs sinking at A and sourcing at B at the prevailing clearing prices so that net injections at nodes A, B and all other pricing locations are zero.

These point-to-point CRRs are called *financial network* CRRs because the configuration of transmission network is irrelevant to the MW quantities of point-to-point financial network CRRs that can purchased in this auction. Only the identity of individual pricing locations and the willingness of market participants to bid for financial CRRs between these locations are needed to clear the financial network CRR auction.

Because locational marginal pricing (LMP) wholesale electricity markets typically have thousands of pricing locations, there is a large number of point-to-point CRR bids in the financial auction that could be used to provide a counterparty to any point-to-point CRR that clears in the auction. More specifically, if there are a thousand pricing locations in a transmission network, there are close to a million point-to-point CRRs that could potentially be used to construct the collection of counterparties for any point-to-point *financial network* CRR cleared in the auction.

Mathematically, the financial network CRR auction is implemented based on an optimization problem where the ISO chooses the quantity of CRR contracts purchased by each market participant so as to maximize the as-bid valuations subject to nodal balance constraints. The objective function of financial network CRR auction is the same as the current

[2] In this example, the the buyer of the 10 MW CRR from node A to node B would have a willingness-to-pay of a least \$500 per MW for this CRR and the buyer of the 10 MW CRR from node B to node A would least have a willingness-to-pay of at least -\$500 per MW. Any payments received from owning the 10 MW financial network CRR from node A to node B would be paid by the buyer of the 10 MW financial network CRR from node B to node A.

[3] In this document, “pricing location” includes both individual pricing nodes and aggregated pricing nodes such as Load Aggregation Points and Trading Hubs.

auction market design, but physical transmission constraints and shift factors between pricing nodes and transmission lines are replaced with the financial network constraints that the net injections at each pricing location is equal to zero.

Because the payouts of financial network CRRs are *not* funded by realized spot market congestion revenues during the term of the CRR, the California ISO would need to decide what to do with spot market congestion revenues if it decides to adopt financial network CRRs. There are a variety of possible uses for the realized spot market congestion revenues. They could be refunded to load serving entities and exporters or used to reduce the transmission access charge. How realized spot market congestion revenues are allocated to individual market participants is also likely to impact the willingness-to-pay of market participants for individual financial network CRRs. Analyzing the impact of different ways to allocate the realized spot market congestion revenues to different market participants on their willingness-to-pay for different financial network CRRs is beyond the scope of this document. Consequently, it is important to emphasize that CRR auction participants are likely to change their point-to-point CRR bids under a financial network CRR auction, depending on how realized congestion revenues from spot market outcomes are allocated to individual market participants.

2 Current Physical Network CRRs

Display (1) characterizes the optimization problem solved by the system operator to clear a CRR auction under the current physical simultaneous feasibility test (SFT). The variable, $x_{ij}^{k,s}$, corresponds to the CRR quantity (in MW) awarded from location i (source) to location j (sink) along the segment s of the bid curve k. Let $S_{ij,k}$ denotes the total number of segments in the bid curve k for the CRR from location i to location j. Bid prices and quantities are denoted by $b_{ij}^{k,s}$ and $q_{ij}^{k,s}$, respectively.

The implied power flows along transmission branches by net injections of awarded CRRs at each location must respect lower and upper transmission branch limits, LB_ℓ and UB_ℓ, respectively. These implied power flows are computed using the standard linear approximation based on shift factors. We use the notation $\mathrm{SF}^{\mathrm{AUC}}_{\ell i,r}$ to represent the shift factor of node i with respect to the transmission branch ℓ in the network model used in the CRR auction (AUC) with reference node r. Shift factors (SFs) allow power flows over transmission branches to be expressed as a linear function of *net* injections at each node (where a negative net injection at a node represents a net withdrawal at that node).[4]

$$\max_{x_{ij}^{k,s}} \sum_{k=1}^{K} \sum_{i=1}^{I} \sum_{j\neq i} \sum_{s=1}^{S_{ij,k}-1} \int_0^{x_{ij}^{k,s}} v_{ij}^{k,s}(z)\, dz$$

s.t.

(i) As-bid valuations:

$$v_{ij}^{k,s}(z) = \begin{cases} b_{ij}^{k,s} + \left(\dfrac{b_{ij}^{k,s+1} - b_{ij}^{k,s}}{q_{ij}^{k,s+1} - q_{ij}^{k,s}}\right) \cdot z & \text{if } q_{ij}^{k,s+1} > q_{ij}^{k,s} \\ b_{ij}^{k,s} & \text{if } q_{ij}^{k,s+1} = q_{ij}^{k,s} \end{cases} \qquad \forall k, i \neq j, s < S_{ij,k} \tag{1}$$

(ii) Bounds on quantity increment per bid curve segment:

$$0 \leq x_{ij}^{k,s} \leq q_{ij}^{k,s+1} - q_{ij}^{k,s} \qquad \forall k, i \neq j, s < S_{ij,k}$$

(iii) Physical transmission capacity limits:

$$\mathrm{LB}_\ell \leq \textstyle\sum_{i=1}^{I} \mathrm{SF}^{\mathrm{AUC}}_{\ell i,r} \cdot x_i \leq \mathrm{UB}_\ell \qquad \forall \ell$$

where $x_i = \sum_{k=1}^{K} \left(\sum_{j\neq i} \sum_{s=1}^{S_{ij,k}-1} x_{ij}^{k,s} - \sum_{n\neq i} \sum_{s=1}^{S_{ni,k}-1} x_{ni}^{k,s} \right)$ is the net injection at node i.

It is important to emphasize that satisfying the SFT test on a prospective basis for physical network CRRs does not guarantee that the California ISO will recover sufficient congestion revenues from operating spot market to meet its physical network CRR payout obligations for the dutration of the CRR. This result holds because the physical transmission

[4] A network G with N nodes and L transmission lines contains $N \times L$ shift factors. The shift factor $\mathrm{SF}^{G}_{\ell n,r} \in [-1, 1]$ of node $n \in \{1, \ldots, N\}$ on transmission branch $\ell \in \{1, \ldots, L\}$ in the network G corresponds to the fraction of power that flows over branch ℓ when one unit of power is injected at node n and withdrawn at the reference node $r \in \{1, \ldots, N\}$. The choice of the reference node is a simple normalization because power flows between nodes due to their voltage differences. Negative values of $\mathrm{SF}^{G}_{\ell n,r}$ mean that power is flowing along branch ℓ opposite to its (arbitrary) reference direction.

network model assumed for the CRR auction is not the same as the physical transmission network models used to operate the spot market each day during the duration (month or quarter of year and peak or off-peak hours of day) of the CRRs.[5]

3 Financial network model

Display (2) characterizes the optimization problem solved by the market operator to clear a CRR auction under a financial network model. The only difference between the formulations in Display (1) and Display (2) is constraint (iii). In a physical network model (Display (1)), there is one constraint per transmission element (typically transmission lines and transformers). In a financial network model (Display (2)), there is one constraint per node (location) and total injections and total withdrawals must be the same at each pricing location. It is important to emphasize that for the same set of CRR bid curves, the set of feasible CRR allocations in a financial network is always a proper subset of the set of feasible allocations in a physical network. However, market participants are unlikely to submit the same bid curves to a financial network CRR auction as they would submit to the current physical network auction. In addition, as noted earlier, depending on how realized congestion revenues from the spot market are allocated to market participants, the bid curves submitted by participants in the financial network CRR auction could be significantly different from those submitted to the physical network CRR auction and different quantities of point-to-point CRRs are likely to clear under the two CRR auction designs.

[5] A network model with significantly less transfer capacities could be employed in the CRR auction to make this outcome less likely, but would result in fewer MWs of CRRs sold and potential persistent over-funding of SFT CRR obligations.

$$\max_{x_{ij}^{k,s}} \sum_{k=1}^{K} \sum_{i=1}^{I} \sum_{j \neq i} \sum_{s=1}^{S_{ij,k}-1} \int_0^{x_{ij}^{k,s}} v_{ij}^{k,s}(z)\, dz$$

s.t.

(i) As-bid valuations:

$$v_{ij}^{k,s}(z) = \begin{cases} b_{ij}^{k,s} + \left(\dfrac{b_{ij}^{k,s+1} - b_{ij}^{k,s}}{q_{ij}^{k,s+1} - q_{ij}^{k,s}} \right) \cdot z & \text{if } q_{ij}^{k,s+1} > q_{ij}^{k,s} \\ b_{ij}^{k,s} & \text{if } q_{ij}^{k,s+1} = q_{ij}^{k,s} \end{cases} \qquad \forall k, i \neq j, s < S_{ij,k} \tag{2}$$

(ii) Bounds on quantity increment per bid curve segment:

$$0 \leq x_{ij}^{k,s} \leq q_{ij}^{k,s+1} - q_{ij}^{k,s} \qquad \forall k, i \neq j, s < S_{ij,k}$$

(iii) Financial network limits:

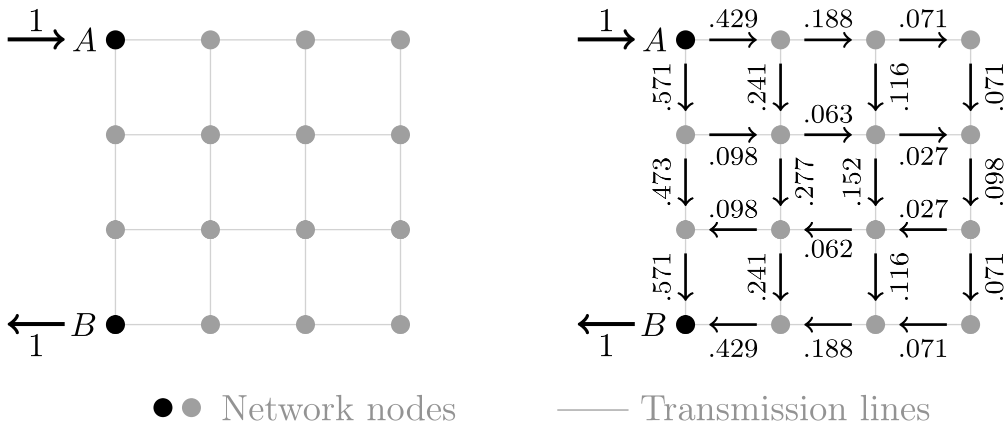
$$x_i = 0 \qquad \forall i$$

where $x_i = \sum_{k=1}^{K} \left(\sum_{j \neq i} \sum_{s=1}^{S_{ij,k}-1} x_{ij}^{k,s} - \sum_{n \neq i} \sum_{s=1}^{S_{ni,k}-1} x_{ni}^{k,s} \right)$ is the net injection at node i.

Figures 1 and 2 show an example of how CRR contracts are modelled under the current physical network model and financial network model. The underlying physical transmission network used to operate spot market during the duration of the both types CRRs is the same. Assume we want to clear 1 MW of a CRR from node A (source) to node B (sink).

Under the current market design based on a physical SFT, each CRR is treated as simultaneous injection (generation) of power at the source location (node A) and a withdrawal (consumption) of power at the sink location (node B). Assuming all transmission lines have the same physical characteristics, the injection at A with withdrawal at B of 1 MW imply the flows depicted in the right panel in Figure 1. These flows are entirely determined by physics. The physical SFT requires that implied flows respect the capacity limits of all transmission lines. The net injection at node A is 1 MW, whereas the net injection at node B is -1 MW.

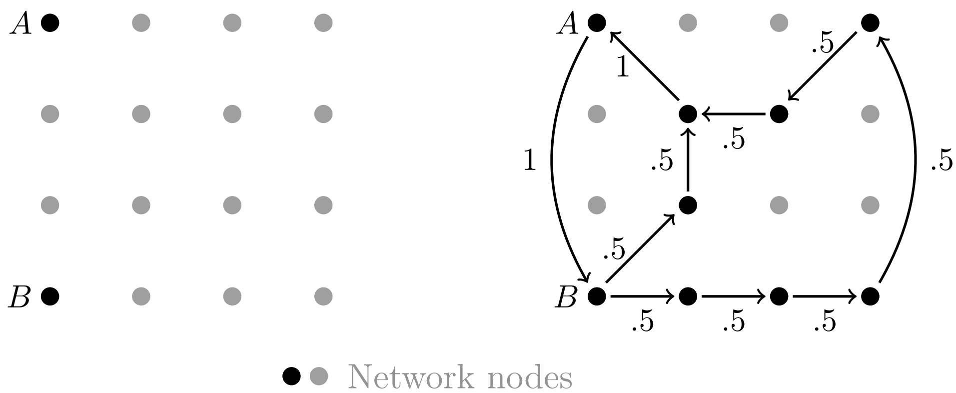
Figure 1: Example of CRR modelling under physical network constraints



Notes: The figure shows an example of how CRR contracts are modelled under physical network constraints. The CRR contract is treated as if it represented a physical injection of power at the source and a physical withdrawal of power at the sink. The distribution of flows along transmission lines is entirely driven by the physics of power flow. All transmission line between locations are assumed to have the same physical properties.

Figure 2 shows an example of our financial network model for the same underlying power grid. The first aspect to notice is that all transmission lines (and their physical properties) are ignored. Only the locations (nodes) matter in our financial network model. The panel on the right displays an example of how a 1 MW CRR from A to B could be issued under financial transmission constraints. For this to happen, the quantity supplied and the quantity demanded at nodes A and B must be the same. A bilateral 1 MW transaction from B to A is not necessary (despite being sufficient). All that is needed is a chain of transactions that function as a counterparty to this 1 MW CRR as illustrated with the particular chain represented in the picture. Note that, in contrast to Figure 1, nodes A and B and all other nodes have zero net injections.

FIGURE 2: Example of CRR modelling under financial network constraints



Notes: The figure shows an example of how CRR contracts are modelled under financial network constraints (the MWs demanded equals MWs supplied at each location). The CRR contract is treated a purely financial asset. The implied point-to-point "flows" between the network nodes is driven by the willingness to buy and sell at these locations by market participants. In the figure, we illustrate a potential chain of transactions (among multiple others) that would allow a 1 MW CRR to be cleared from node A to node B.

An important property the financial network CRR auction is that the ISO assumes no financial exposure to the realized spot market for energy as shown in Theorem 1 shown below. Intuitively, the result follows from the fact that net injections at all locations are zero by design of auction. At each location the ISO has the same CRR volume sourcing and sinking, so that CRR payments are just financial transfers between market participants as shown in the earlier example of a forward contract for 4,000 barrels of oil.

Theorem 1. *Under the financial network model, the ISO has zero uncovered financial exposure to the spot market.*

Proof. Consider a financial network with $N \in \mathbb{N}$ nodes and a financially feasible CRR allocation $\{q_{ij} \in \mathbb{R}_+ \mid 1 \leq i, j \leq N, i \neq j\}$. By design all network nodes $n \in \{1, \ldots, N\}$ have zero net injection x_n where

$$x_n := \sum_{\substack{i=1 \\ i \neq n}}^{N} q_{in} - \sum_{\substack{j=1 \\ j \neq n}}^{N} q_{nj}$$

is the difference between the total quantity injected and the total quantity withdrawn at node n. Define $q_{nn} := 0\ \forall n$. Then the ISO's exposure to the spot market is given by

$$\begin{aligned}\sum_{i=1}^{N}\sum_{j=1}^{N} q_{ij}\cdot(p_j-p_i) &= \sum_i\sum_j q_{ij}\cdot p_j - \sum_i\sum_j q_{ij}\cdot p_i \\ &= \sum_j p_j\cdot\sum_i q_{ij} - \sum_i p_i\cdot\sum_j q_{ij} \\ &= \sum_j p_j\cdot\sum_i q_{ij} - \sum_i p_i\cdot\sum_j q_{ji} \\ &= 0\end{aligned} \tag{3}$$

where in moving from the second to the third line we used the fact that $\sum_j q_{ji} = \sum_j q_{ij}$ for all i because the net injection at node i is zero for the financial network CRR auction solution. ■

This property restores the hedging value of CRRs because payments to all MWs of financial network CRRs purchases are fully-funded by the other market participants who voluntarily took counterparty positions in the CRR auction at the prevailing auction prices of CRRs. The ISO will still need to manage counterparty credit risk to ensure that no CRR holder defaults on its CRR obligations, but this is a role the ISO already performs in requiring credit postings for participants in all ISO markets.

4 Conclusion

The financial network auction design for point-to-point CRRs auction produces point-to-point CRRs that are consistent with the design all financially settled forward contracts. The financial network CRR auctions would be operated by the ISO with open access to any interested market participant, similar to financially financially settled forward contracts. Consequently, under the financial network model, CRR payouts are fully funded by a combination of other CRR contracts and all CRR prices are determined by the bids of market participants for these financial network CRRs. The role of the market operator in the model is to function as a standard central counterparty clearing house, with financial positions exactly balanced and zero net payment obligations.

The financial network CRR design leaves the congestion revenues from realized spot market operation for the duration of the CRR untouched. There are a variety of ways to allocate the realized congestion revenues, but as mentioned earlier, different allocation mechanisms will likely lead to different bid curves and market outcomes in the financial network CRR auction.

Congestion Revenues from Spot Market Operation

Consider a network G of N nodes, L transmission constraints, and $N \cdot L$ shift factors $\{\mathrm{SF}^r_{n\ell G} \mid n \in \mathbb{N}, 1 \leq n \leq N, \ell \in \mathbb{N}, 1 \leq \ell \leq L\}$ with respect to an arbitrary reference node r. Let $\{Q_n\}_{n=1}^N$ be the set of *net* nodal power injections implied by the optimal dispatch. $Q_n < 0$ ($Q_n > 0$) means that node n is a net consumer (producer, respectively) of electricity. Let MCC_{rn} be the MCC component of the LMP at node n when the reference node is r. Then the congestion revenue collected by the ISO is:

$$\text{Congestion revenue} := \sum_{n=1}^{N} -Q_n \cdot \mathrm{MCC}_{rn}. \tag{4}$$

Equation (4) reflects the fact that locations that are net consumers of electricity ($Q_n < 0$) must pay the marginal cost of congestion (MCC) to the ISO, whereas locations that are net producers ($Q_n > 0$) are paid the MCC. Multiplying the net injection by -1 captures the ISO's perspective of this monetary transfer. Only the MCC component of the LMP is relevant for congestion revenues because the SMEC does not vary across the system. In addition, only net injections matter because consumption and production at the same node are settled at the same LMP.

5 Postscript on Financial Trading

Two points relevant to the current discussion are worth emphasizing about the determinants of volume of financial versus physical trading in commodities using the example of the global oil market. A key determinant of the volume of futures contracts traded is the extent of disagreement among market participants about the future spot price of the commodity.

If the future spot price is known with certainty to all market participants, there would be little reason for parties purchase a futures contract that clears against this spot price. The party that buys this contract has the option to purchase the commodity at the settlement date at this spot price and seller of this contract has the option sell the commodity at the settlement date at this spot price and both parties have common knowledge of the value of this future spot price. Under these conditions, there would be little financial rationale for either party to engage in this futures contract transaction.

If the future spot price is extremely uncertain, there may be a futures contract price at which both the buyer and seller are willing to engage in a trade. Suppose the buyer and seller of contract have private information about the availability of the commodity at the settlement date and location. The buyer's private information is about the availability of the commodity is more pessimistic than that of the seller of the contract. This disagreement about the future spot price of the commodity among sophisticated players is a major determinant of the volume of future trading in a commodity.

For a futures contract to continue to have non-zero volume traded, this disagreement over the future spot price cannot persistently favor one side of the futures contract or else there will no longer be any willing counterparties for this contract. For example, if buyers of a futures contract persistently make money, this necessarily means that sellers of these contracts persistently lose money. The willing counterparty requirement for the sale or purchase of a futures contract ensures that there is not persistent underpricing of a futures contract.

Uncertainty about the future spot price of oil is well documented empirically. Besides political tensions in major oil producing regions of the world, the scalability of shale oil extraction technology outside of the United States, and the speed that economies can transition away from oil in the transportation sector are likely drivers of the uncertainty in the future spot price of oil. Figure 3 plots the daily volume traded in the two major benchmark oil futures contracts for the West Texas Intermediate (WTI) location in Cushing, Oklahoma and the Brent location in the North Sea on the Chicago Mercantile Exchange (CME) and the Intercontinental Exchange (ICE) versus the physical volume of oil consumed globally, currently slightly more than 100 million barrels per day. The daily volume traded in the forward market is currently more than at least twenty times that amount.

Rapid increase in the volume of financial trading in oil on the CME and ICE over the past decade is consistent with the logic that the extent of disagreement among sophisticated financial participants over the future spot price of oil has increased over this same time period. As shown in the earlier example of the futures contract for oil, the buyer of the futures contract for oil at $50 per barrel willingly agreed to buy at this price and the four sellers of willingly agreed to sell at this same price. A likely explanation for this outcome is the many factors that determine the future spot price oil that can lead to disagreement among buyers and sellers of these futures contracts.

Similar logic applies to locational differences in hourly prices in a locational marginal pricing (LMP) electricity market. There is an increasing number of factors that determine the future values of these locational spot price differences over the duration of a CRR. In fact, it is difficult to imagine a commodity that is subject to so much locational price volatility at such a high frequency, particularly in regions with significant intermittent renewable generation resources.

The requirement of willing counterparties for any financial network CRRs ensures that any point-to-point CCR that persistently clears in financial network CRR auctions is unlikely to be persistently underpriced, because any payment to the CCR holder must come from the willing counterparties to this CRR.

FIGURE 3: Physical Volume versus Financial Volume of Oil Traded

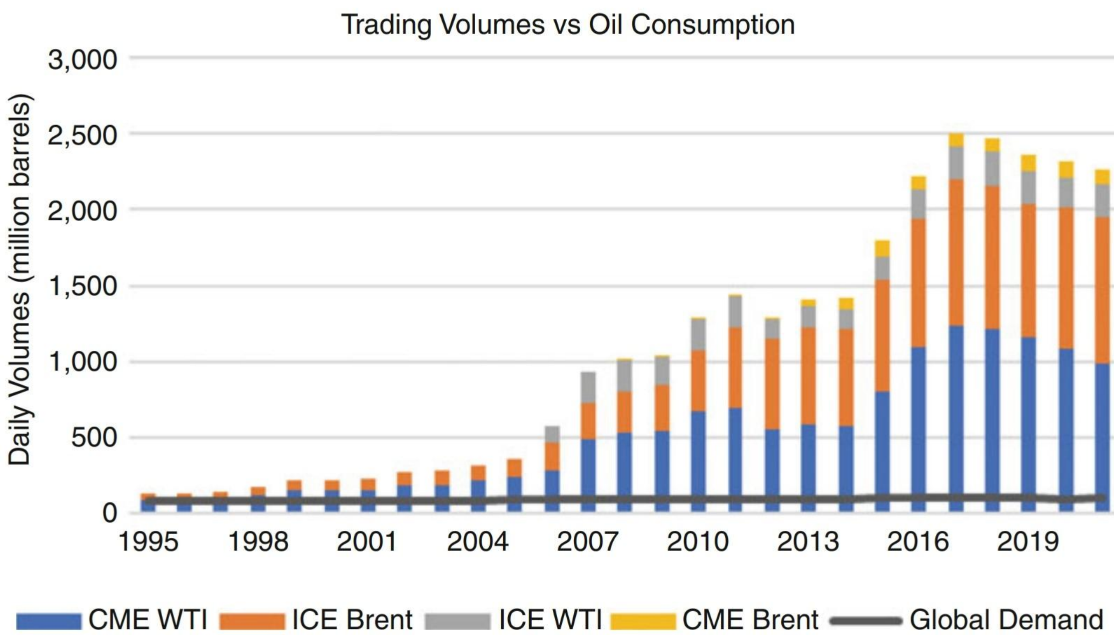


Fig. 1.1 Daily trading volume of two benchmark oil futures contracts, WTI and Brent, is at least twenty times larger than daily global oil consumption. Source: CME, ICE, EIA

Source: Bouchouev, Ilia (2023) *Virtual Barrels: Quantitative Trading in the Oil Market*, Springer Texts in Business and Economics, page 4.