November 15, 2007

Dear RGGI Board,

ISO New England Inc. ("ISO-NE") and the New York Independent System Operator are pleased to comment on the RGGI market design, as described in the Final Report, "Auction Design for Selling CO_2 Emission Allowances Under the Regional Greenhouse Gas Initiative," October 26, 2007 (hereafter "Final Report"). ISO-NE is the private, non-profit entity that serves as the regional transmission organization ("RTO") for New England. ISO-NE operates the New England bulk power system and administers New England's organized wholesale electricity market pursuant to the ISO New England Transmission, Markets and Services Tariff and the Transmission Operating Agreement with the New England Participating Transmission Owners.

The New York Independent System Operator, Inc. ("NYISO") is the not-for-profit corporation responsible for operating New York's bulk electricity grid, providing non-discriminatory access to transmission service and administering wholesale markets for electricity and transmission products in New York.

To help in our assessment and understanding of the design issues of this critical market, we asked Professor Peter Cramton of the University of Maryland, a well known and well regarded expert in auction design, to comment on the market design. . In addition to Professor Cramton's widely-cited academic research on auction design, he has applied this research to design high-stake auction markets in many countries and industries, including markets for electricity and emission allowances. Professor Cramton's comments are included as an attachment to this letter.

We have studied the RGGI market, including the Model Rule, the Phase 1 Report, and the Final Report. We have also met with Professor Cramton and others to discuss the RGGI market design. We outline our consensus view, which is consistent with the Professor Cramton's comments on the RGGI market design.

We agree with many of the recommendations of the Final Report, but believe that some require modification or extension to best achieve the RGGI objectives. We briefly summarize our views here, although we urge the RGGI Board and other policy makers to examine Professor Cramton's paper for a detailed analysis and explanation.

Most significantly, we recommend an ascending clock auction for each quarterly auction rather than the sealed bid auction recommended in the Final Report. The ascending clock auction is simple for bidders and has an excellent record of practical success.

The ascending clock auction is similar to the recommended uniform-price auction, but it has important advantages. The main advantage is better price discovery. Bidders can learn from the bidding process and condition their bids on this information. In the RGGI context, it is proposed that two products, spot and forward, be auctioned in each quarter. The clock auction would allow the bidders to substitute between these close substitutes in a single auction. Thus, any price difference is a reflection of the different market values for the two products.

The problem with two separate sealed-bid auctions, as proposed in the Final Report, is that the resulting prices may be inconsistent with bidder preferences. Because of banking, the spot product is always worth as least as much to the bidder as the forward product. However, when separate sealed-bid auctions are conducted, the clearing price for spot may be less than the forward price. This can occur because the auctions are independent: bidders are not able to express that they always prefer the spot product if its price is lower than the forward product. With a clock auction this substitution can be easily accomplished.

The Final Report recommends the sealed-bid design for two reasons: concern about potential collusion, and the absence of significant price discovery benefits of the clock in the experiments. Our view is that both the sealed-bid and clock formats have similar risks of collusion in the RGGI context, and therefore, the benefits of better price discovery that should favor the clock format. We note that the clock format tested in the Final Report was unusual in that it did not provide bidders with information on excess demand during the auction—absence of this information would frustrate price discovery. Moreover, intraround bids or exit bids were not included, which would reduce both efficiency and revenues.

We recommend that a low reserve price be set, especially in the early auctions, when price uncertainty is greatest. Professor Cramton describes a simple method of setting the reserve price based on the history of clearing prices. In addition, we recommend that some supply response be included for prices close to the reserve price to provide greater price stability. Finally, it is desirable to allow other parties in addition to the RGGI states to offer supply in the quarterly auctions.

In the event that some allowances go unsold, we recommend that the surplus be sold in future quarterly auctions according to a specific formula. Relative to an actively managed contingency reserve, a specific formula reduces political risk. Professor Cramton describes one simple method.

The ISOs appreciate having this opportunity to comment on the RGGI market design. We have learned over the years the enormous benefit of good market design. Please let us know if we can be of further assistance.

Yours truly,

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Comments on the RGGI Market Design[1]

Peter Cramton[2]

15 November 2007

1 Summary

The Regional Greenhouse Gas Initiative (RGGI) is a cap and trade program to limit the total CO_2 emissions from electricity sources in the ten member states on the East Coast from Maryland to Maine, excluding Pennsylvania. Each RGGI state has an allocation of emission allowances for each three-year compliance period. Sources must purchase these allowances in a sequence of auctions, such that on the compliance date, two months after the end of the compliance period, the source holds sufficient allowances to cover its emissions over the compliance period. The first compliance period is 2009 to 2011. This paper comments on the market design, and especially the auction design, as described in the 26 October 2007 Final Report (hereafter "Final Report").[3]

The primary purpose of the RGGI market is to achieve an environmental goal—lower CO_2 emissions—at minimum cost. This is accomplished by assigning allowances to sources in an efficient auction, putting allowances in the hands of those who value them the most. RGGI also has many secondary objectives, such as transparency, neutrality, risk minimization, liquidity, simplicity, and consistency. In this context, auction design should emphasize efficiency, not revenue maximization, although to be sure, substantial revenues will result from an efficient auction.

The Final Report makes sixteen recommendations on the RGGI market design. As shown in Table 1, I agree with most of the recommendations, but some require enhancement to best achieve the RGGI objectives. Fortunately, all of the enhancements are easily accomplished.

[1] This paper was supported by ISO New England and New York ISO. I thank ISO-NE and NYISO staff for helpful comments. The views are my own.

[2] Peter Cramton is Professor of Economics at the University of Maryland and Chairman of Market Design Inc. Over the last 20 years, he has published research on auction theory and practice in the leading peer-reviewed economics journals. During the last 12 years, he has applied this research in the design and implementation of auction markets worldwide. He has led the design and implementation of dozens of high-stake auctions in the energy and telecommunication industries. He has advised over 30 companies on bidding strategy in energy and telecommunication auctions. In 2002, he advised the UK on the design and implementation of the first greenhouse gas auction. Since 1997, he has advised ISO New England on electricity market design, including the development of its forward capacity auction. In 2006-7, he led the design of Colombia's firm energy market and its forward energy market. He received his B.S. in Engineering from Cornell University and his Ph.D. in Business from Stanford University.

[3] "Auction Design for Selling CO_2 Emission Allowances Under the Regional Greenhouse Gas Initiative," by Charles Holt, William Shobe, Dallas Burtraw, Karen Palmer, and Jacob Goeree. I have also reviewed the RGGI Model Rule, the Phase 1 Report of 25 May 2007 (hereafter "Phase 1 Report"), and all the comments on the Phase 1 Report posted on www.rggi.org as of 15 November 2007.

Table 1. Recommendations of Final Report and proposed enhancements

	Recommendation	
	Final Report	**Proposed enhancement**
1	Uniform price	same
2	Sealed-bid	Ascending clock with proxy bid
3	Separate auctions for each vintage	Each vintage is separate product
4	Quarterly auctions	same
5	Forward sales up to four years ahead	same
6	Reserve price, publicly disclosed	Supply curve, publicly disclosed, including aggregate of supply offers from participants
7	Unsold allowances either sold in next aucion or held in a contingency reserve account for late sale	Unsold allowances added to supply curve of future auctions according to specific market rule
8	Lot size of 1,000 tons	same
9	Auctions open to anyone with financial qualification; quantity cap of 33% in each auction	same
10	Bids are binding contracts; quantity limited by financial guarantee	same
11	Joint and uniform auction for allowances from all RGGI states	same
12	Market monitoring should take advantage of existing activities of federal and state agencies, as well as other interested parties	same
13	RGGI should require that authorized account representatives disclose the "beneficial ownership" of any allowance holdings	same
14	Information for public disclosure includes the clearing price, identities of the winners, quantities won by each winner	In addition, the aggregate demand is disclosed for prices below the clearing price
15	Statement of Intent should be agreed to by participants	same
16	Performance of the auction should be evaluated on an onging basis	same

In contrast with the Final Report, I recommend an ascending clock auction for each quarterly auction instead of the uniform-price auction. The ascending clock auction is a simple auction process that has been used for many years to auction electricity, gas, emission allowances, radio spectrum, as well as other products. It is a dynamic version of the uniform-price auction (or clearing-price auction), which is the most common sealed-bid method to auction divisible goods, like allowances.

The primary disadvantage of the uniform-price auction in this setting is the potential to have prices for the two vintages (spot and forward) that do not reflect the bidders preferences. Given that each bidder must submit its demand curve in advance, the bidder must guess at what the demand by the other bidders would be for these two products. A wrong guess can lead to wrong prices.

Consider the case of a bidder that needs 800 allowances. Suppose that either the spot or forward vintages would satisfy the need, since the bidder's need is in the forward compliance period and allowances can be banked. Should the bidder bid for 800 forward allowances or 800 spot allowances, or split its bid between the two? To answer the question, the bidder has to speculate about what the other bidders are going to do, since that is what will determine the clearing price in the two separate auctions. Often the bidder will make the wrong guess and buy some forward allowances, when the spot allowances are less expensive. With the clock approach the bidder is able to buy all its quantity at the less expensive vintage, consistent with the bidder's preferences.

An ascending clock auction is a simple and powerful dynamic auction that inherently addresses this shortcoming of the uniform-price auction. In each round, the auctioneer announces a price and the excess demand at the prior price. Each bidder then indicates the quantity it desires to buy at that price. In subsequent rounds, the price increases, and each bidder again expresses the quantity it desires to buy at the new price. This process is repeated until there is no excess demand. Each bidder is awarded the quantity it bids at the clearing price. The format is readily generalized to handle multiple vintages and multiple sellers.

The chief advantage of this approach is price discovery: bidders can learn about the demand of other bidders from the bidding process and condition their bids on this information. This is especially useful when there are multiple products, as is the case here where both the spot and forward products are sold at the same time. The clock auction allows bidders to substitute freely between spot and forward products, so that any price separation is a reflection of the difference in value of the two products.

The enhanced price formation improves auction efficiency. To improve price discovery, the auction includes a simple activity rule: as prices rise, a bidder can only maintain or decrease its quantity. This prevents bidders from bid sniping—waiting until the last instant before bidding seriously.

Some bidders, especially small bidders, may prefer to bid just once, rather than in a series of rounds. This is accomplished with a proxy bid. A proxy bid lets a bidder submit its complete demand curve in one step in the initial round, just as it would in a sealed-bid uniform-price auction. Alternatively, the bidder can take advantage of price discovery, and bid in a series of rounds. It is the bidder’s choice.

The clock auction can be conducted in a single day (about eight rounds) or even half a day (about four rounds). The pace of the auction is readily managed through the bid increment policy. Larger bid increments are made possible without any efficiency loss through a common technique of intraround bids or exit bids, which effectively makes the discrete clock continuous.

The Final Report recommendation of a sealed-bid uniform-price auction was based on two factors: a concern with collusion in the clock auction and the fact that the clock auction did not appear to outperform the sealed-bid auction in the experiments. This conclusion is unfounded. First, as I discuss later, collusion is unlikely to be a problem in this context. Second, the price discovery benefits of the clock auction were not seen in the experiments, because the experiments used a non-standard clock format that did not include the price discovery features essential to obtaining the benefits of a clock auction. To facilitate price discovery, clock auctions make public the excess demand at the conclusion of each round, and use either intraround bids or exit bids to improve revenues and efficiency. The clock format in the experiments included neither of these techniques, which have proven to be highly effective in practice.

Importantly, the clock auction is easily extended to allow the auctioning of two products, spot and forward. The examination of this case is important, since it highlights an advantage of the clock approach and a flaw with using two separate sealed-bid auctions, as proposed in the Final Report. With a clock auction bidders can substitute freely between the two close substitutes. This guarantees that any price difference between the two products reflects the preferences of the bidders.

The Final Report recommends the use of a reserve price, and I concur. In addition, I recommend an administrative supply curve that determines the quantity sold at various prices. For clearing prices above a low level (the typical case), the target quantity is sold. For low prices, the supply increases linearly to the target level as prices rise. The supply curve is flat at the reserve price, which is set at a low level based on the history of clearing prices. This supply curve is intended to address insufficient competition or inadequate demand in a particular auction. As a result, it stabilizes the clearing price in unusual situations and mitigates demand-side market power where one large bidder can purchase a large number of allowances for a low price when there is limited competition. However, it is not intended as a device to increase auction revenues. The starting price of the clock auction is the reserve price.

I recommend that supply come not only from the RGGI states, but from market participants that have a surplus of allowances. These participants submit individual supply curves one week before the auction. The auction supply curve then is the sum of the administrative supply curve and the individual supply curves. This approach allows sources to rebalance positions in a liquid and transparent auction each quarter, similar to what is done with SO_2 allowances.

Market monitoring is important in addressing various collusive or manipulative strategies. To be effective, monitors need the information that might suggest a problem. For this reason, market participants should disclose the "beneficial ownership" of any allowance holdings. While the market monitoring units at ISO-NE, NYISO, and PJM could be helpful in advising RGGI, Inc. and state entities as they plan for monitoring the RGGI carbon allowance market, the market monitoring function itself needs to be separate from the market monitoring units of the ISOs.

The auction design described here is largely consistent with the Final Report. I have provided many details that are not addressed in the Final Report, such as how to set the reserve price and what to do with unsold allowances. My hope is that these remarks will be helpful in the further development of RGGI—a program that is especially important in that it will serve as a model for other jurisdictions.

In what follows, I discuss the purpose of the market, the product design, the auction design, and finally the transition to the steady state. Throughout I compare my recommendations with those of the Final Report. I conclude this paper with my reaction to the comments of others.

2 Purpose of the market

The first step in any market design is understanding the objective of the market. Many objectives must be considered in the design of the RGGI market. These can be grouped into seven interrelated categories: efficient price formation, transparency, neutrality, risk management, liquidity, simplicity, and consistency.

- *Efficient price formation*. The market should produce reliable price signals based on market fundamentals. It should encourage the least-cost attainment of the environmental goal by putting allowances in the hands of those that value them the most.
- *Transparency*. The market should be highly transparent. It should be clear how the pricing and assignment was done, and why one bid was accepted and another rejected. The auction should result in prompt regulatory review and approval, and encourage regulatory certainty.
- *Neutrality*. All participants should be treated equally.
- *Risk management*. The market should minimize risks for market participants, yet be responsive to long-run market fundamentals. The market should shield participants from short-term transient events, and address counterparty risk.

- *Liquidity*. The market should promote a transparent secondary market, including a liquid market for allowances in the current and next compliance period.
- *Simplicity*. The market should be simple for participants, for the market operator, and for the regulator.
- *Consistency*. The market should be consistent with the other key elements of the electricity markets in the RGGI states. It also should be consistent with, or improve upon, the best-practice in related markets.

Fortunately, these objectives are largely complementary with one another. Hence, it is possible to design the market to satisfy all of these objectives.

The Final Report included one objective not listed above: revenue maximization. Although it makes economic sense for allowances to be purchased as an incentive for actions to reduce emissions, the issue with what to do with the revenue is a policy debate for the states to decide. In any event, revenue maximization should not be an auction objective on par with the first seven objectives identified above.

3 Product design

The second, and perhaps the most important, step of market design is defining *what* is being traded. This is the product design.

Under RGGI, the product is an allowance for one ton of CO_2 emissions from a source in a RGGI state during the vintage year or any year thereafter. An annual product is needed, since the compliance period, which typically is three years, may be extended by one year in the event of sustained high prices. This means that with the exception of the first three years, 2009-2011, it is not certain which compliance period a particular vintage applies to. Since banking is allowed, at any particular time allowance prices P_Y for vintage Y satisfy

$$P_{2009} = P_{2010} = P_{2011} \geq P_{2012} \geq P_{2013} \geq \ldots$$

The equalities follow, since it is certain that 2009-2011 allowances will all be in the first compliance period. The inequalities follow from banking, which makes earlier vintages superior—they can be used in the same compliance periods as any later vintage, and possibly more.

Within three months of the end of the compliance period, each source must hold allowances that cover the source's CO_2 emissions during the entire compliance period. If a source has surplus allowances, these allowances may be banked to cover emissions in a later compliance period. The advantage of this structure is that it gives sources a great deal of flexibility in acquiring their allowances over time. This should reduce the cost to comply as well as the market risk and help assure system reliability by enabling generators the flexibility in acquiring allowances.

Since CO_2 is a long-term global pollutant, the allowance should be defined for as large a market as possible—all the RGGI states.

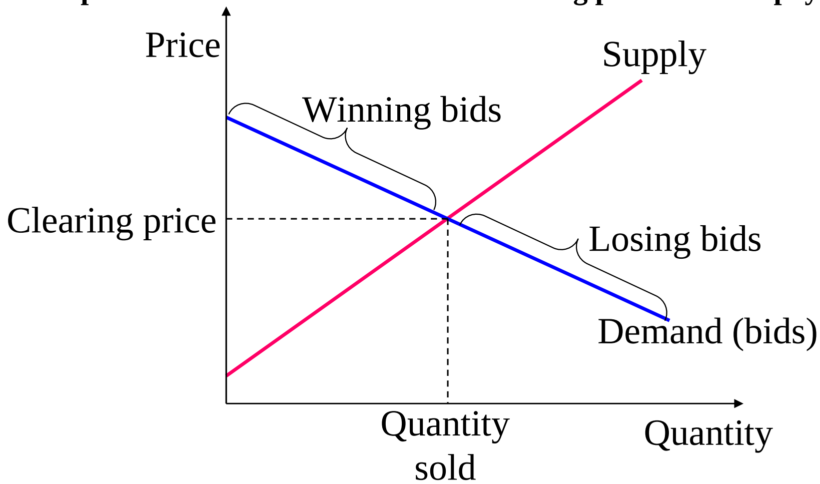
4 Auction design

The third step of market design is establishing how the product will be traded. In the case of RGGI, this is the auction design.

The most important element of the auction design is improving price formation and auction simplicity by holding a single sequence of auctions for all the RGGI states, rather than separate auctions for each state. Since the product is the same for each RGGI state, and perfectly substitutable across states, there is no reason to separate auctions by state. Not surprisingly all commenters supported a single sequence of auctions for all states.

As mentioned, I recommend an ascending clock auction for all the RGGI auctions. This is a simple auction process that has been used for many years worldwide for electricity, gas, emission allowances, radio spectrum, and other products. The approach is essentially a dynamic version of the sealed-bid uniform-price auction (sometimes called a clearing-price auction or single-price auction), which is the most common method of auctioning a divisible good. Figure 1 displays how the uniform-price auction works. Each bidder simultaneously submits its individual demand curve. The auctioneer aggregates all the demand bids and crosses it with supply to determine the clearing price. All bids above the clearing price win and are awarded quantity at the clearing price.[4]

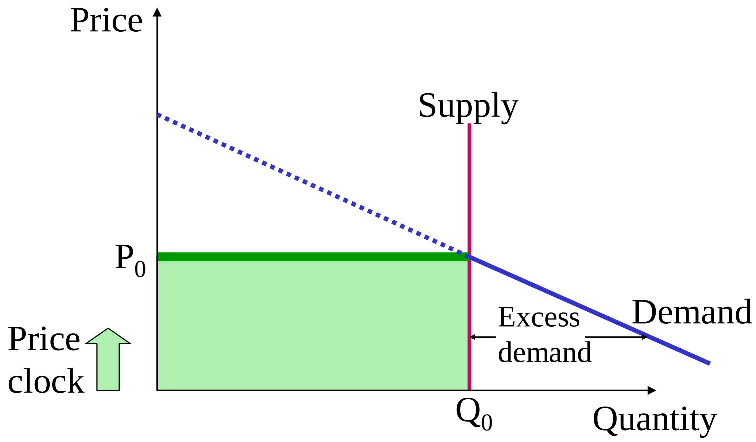
Figure 1. Uniform-price auction: all bids above the clearing price win and pay the clearing price



The ascending clock auction is an especially simple and powerful dynamic implementation of the uniform-price auction. In each round, the auctioneer announces a price and the excess demand at the prior price. Each bidder then indicates the quantity it desires to buy at the current price. In subsequent rounds, the price increases, and each bidder again expresses the quantity it wishes to buy at the new price. This process is repeated until there is no excess demand. Figure 2 depicts a clock auction, in this case with a vertical supply curve. The price rises until there is no excess demand; the bidders are then awarded the quantity they are bidding for at the clearing price P_0. The format is readily generalized to handle multiple vintages and multiple sellers, which I describe below.

[4] Other pricing rules, such as pay-as-bid pricing are possible; however, there is substantial theoretical, empirical, and experimental evidence that uniform-pricing should be preferred in this context. See, for example, Kahn et al. (2001).

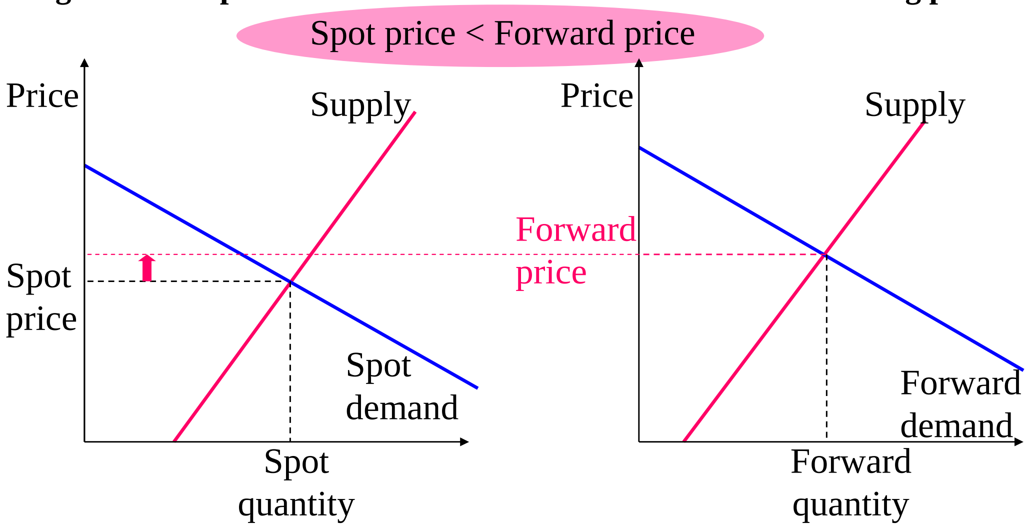
Figure 2. Ascending clock auction: the price rises until there is no excess demand



The motivation for using a dynamic auction, rather than a sealed bid auction, is explained in detail in Cramton (1998) and Ausubel and Cramton (2004). In brief, the approach allows price discovery: bidders can learn from the bidding process and condition their bids on this information. This is especially useful when there are multiple products, as is the case here where both spot and forward products are offered in the same quarter. The clock auction allows bidders to freely substitute across spot and forward products, as I describe in detail later. As a result, market prices are achieved that are consistent with the bidders' preferences. Any price difference between spot and forward reflects the extra value to bidders of the spot product's greater flexibility of use.

In contrast, if the two highly-substitutable products are sold in two independent uniform-price auctions, as proposed in the Final Report, the outcome could easily be inconsistent with efficient prices. That is, the price of the superior spot product may be less than the price of the inferior forward product, even though all bidders value the spot product at least as highly. This price reversal, shown in Figure 3, can occur because a bidder is unable to express its substitution preferences between the two products with the independent sealed-bid format. Had the investigators of the Final Report conducted an experiment in which two substitutable products were simultaneously sold, this flaw in their proposal would have been identified. The potential for price reversal is mitigated somewhat if the sealed-bid auctions are done in sequence, but a much better solution is to allow the bidders to express substitution preferences during an ascending auction, as I describe in detail later.

Figure 3. Independent sealed-bid auctions can result in the wrong prices



One of the major insights of auction design over the last fifteen years is the importance of dynamic auction processes when auctioning two or more substitutable products. Simultaneous clock auctions have become the standard approach in such cases. The clock format includes all the benefits of a sealed-bid uniform-price auction, but in addition allows rich substitution possibilities across products.

Clock auctions also tend to be viewed as more transparent and open than sealed-bid auctions and so, at the end of the day, the participants are likely to be more satisfied with an ascending clock auction than a sealed-bid auction.[5]

Although clock auctions are relatively new, they have already been applied successfully in high-stakes auctions in many countries and sectors, including the environmental sector. Applications have included electricity auctions in France, Belgium, the Netherlands, Brazil, Colombia, and the US, and gas auctions in Germany, France, Denmark, Hungary, and Austria. The UK Emissions Trading Scheme Auction in 2002 used a clock auction for greenhouse gas emission reduction incentives, and the Clear Skies Bill in the US proposes a clock auction for SO_2, NO_x, and mercury emission allowances. Most RGGI market participants will already be familiar with the clock auctions as a result of major auctions that use that format in New Jersey (the NJ BGS auctions) and New England (the Forward Capacity Auction).

The only potential downside of a clock auction compared with a sealed-bid auction is the clock auction takes time to run, which entails some cost for both the market operator and the bidders. This should not be a concern here, since the clock auction can easily be completed in a

[5] The term "ascending clock auction," is used here whereas the Phase 1 Report uses the terms "English clock auction" or "English clock auction with shootout round." Ascending is more descriptive than English. The price clock ascends. Although "English auction" is commonly used for the oral-outcry auction (think Sotheby's), even there the English are given too much credit, since the approach was used for many centuries before England even existed. The "English clock auction with shootout round" is best thought of as a particular implementation of the ascending clock auction describe below. The term "shootout" is misleading, since it suggests that the bidders can upset the results of the clock process in a final "shootout." In fact, the bidders are tightly constrained by an activity rule, so the "shootout" is much less dramatic than suggested. Another good reason for not using the "shootout" term in experiments is that because "shootout" is such a dramatic term it could affect experimental results through framing.

single day (about eight rounds of bidding) or even a half-day (about four rounds). Moreover, to the extent that there are smaller bidders who do not wish to take advantage of the dynamic process, these bidders can submit all their bids at one time if that is what they prefer. This is called a proxy bid. A further simplification is to either allow or require bidders that are below a particular size to bid as "non-competitive" bidders. These bidders simply submit a quantity (or budget), and are awarded that quantity at the clearing price. This is commonly done in Treasury auctions to simplify the bidding for small bidders.

I now address several other elements of the auction design: the auction schedule, the supply curve and starting price, the auction mechanics, and the secondary market.

4.1 Auction schedule

The timing and frequency of the auctions can play an important role in price formation and risk management. The Final Report recommends quarterly auctions. This makes sense. Quarterly auctions allow a source to purchase allowances gradually throughout the compliance period. In addition it is recommended that the sale of each vintage be split 50-50 between spot and forward sale. 50% should be sold in four quarterly auctions during the vintage year, and 50% in the four prior years. The forward auctions allow a source to purchase allowances on a schedule that is more consistent with the source's forward energy sales, which should reduce supplier risk. Forward auctions are also helpful for price formation, sending an early price signal one or more years in advance of the compliance period.

Figure 4. Recommended auction schedule

Auction date		Vintage							
Year	Qtr	09	10	11	12	13	14	15	16
2008	Aug	1/4	1/6	1/6					
	Nov	1/4	1/6		1/8	Steady State:			
2009	Feb	1/8	1/6			4 forward + 4 spot			
	May	1/8		1/6		each vintage			
	Aug	1/8			1/8				
	Nov	1/8				1/8			
2010	Feb		1/8	1/6					
	May		1/8		1/8				
	Aug		1/8			1/8			
	Nov		1/8				1/8		
2011	Feb			1/8	1/8				
	May			1/8		1/8			
	Aug			1/8			1/8		
	Nov			1/8				1/8	
2012	Feb				1/8	1/8			
	May				1/8		1/8		
	Aug				1/8			1/8	
	Nov				1/8				1/8

	Share
Spot	50%
Forward	50%
1 year ahead	1/8
2 years ahead	1/8
3 years ahead	1/8
4 years ahead	1/8

Figure 4 shows a recommended schedule, which is a slight variation of the schedule in the Final Report. The difference is in the early years. In particular, the schedule above recognizes that it would be difficult or impossible to schedule auctions in advance of third-quarter 2008. Thus, only two auctions would be conducted in 2008 (August and November) with the forward sale necessarily compressed for the 2009-2011 compliance period. Beginning with vintage 2012, the sale would follow the steady state, with four forward and four spot auctions, each assigning one-eighth of the total vintage. A similar schedule of forward and spot auctions has been proposed for Australia (see Australia National Emissions Trading Taskforce 2007).

The first auction in August 2008 can take advantage of the fact that the 2009, 2010, and 2011 vintages are perfect substitutes, since all three vintages can be used in the first and any later compliance period. The three vintages are auctioned with a single clock and bidders express demands for all three years combined. Each winner receives a blend of 2009, 2010, and 2011 in the exact proportion to the quantity of each that is sold. In this way, the auction enforces the perfect-substitute constraint that $P_{2009} = P_{2010} = P_{2011}$.

Similarly, the second auction in November 2008 would treat the 2009 and 2010 vintages as perfect substitutes. In addition, this auction would include the close but not perfect substitute of the 2012 vintage. Thus, this auction would be conducted as a two-product auction, as discussed below.

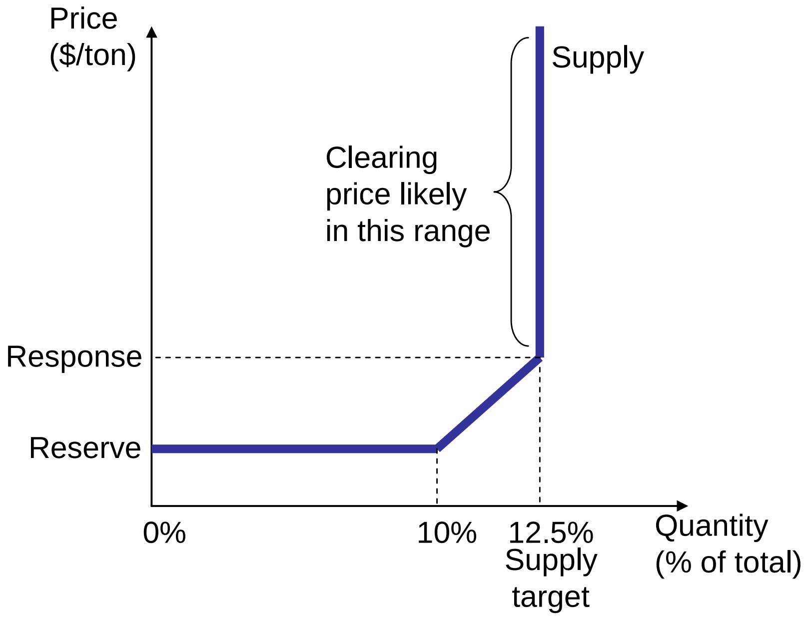
Ideally, the timing of the forward auctions would correspond at least roughly with the pattern of forward energy sales. Participants then would be able to lock in carbon prices at the same time as forward energy prices. Although the schedule does not precisely match the pattern of forward energy trades, it should provide enough price information and liquidity to facilitate effective hedging strategies.

4.2 Supply curve and starting price

The supply curve determines the quantity that is sold at various prices. The Final Report recommends a supply curve that is horizontal at the reserve price and then vertical at the supply target. I show a slight variation in Figure 5, which includes some supply response at prices below the "response price."[6] For prices above the response price, the full supply target (12.5%) is sold; at the reserve price only 80% of the supply target is sold; for prices from the reserve price to the response price, the quantity sold increases linearly from 10% to 12.5% as the price rises.

[6] Supply response (sell more at higher prices) is the analog of demand response (buy less at higher prices). Demand response is helpful in mitigating seller market power; supply response is helpful in mitigating buyer market power.

Figure 5. Administrative supply curve addresses insufficient competition

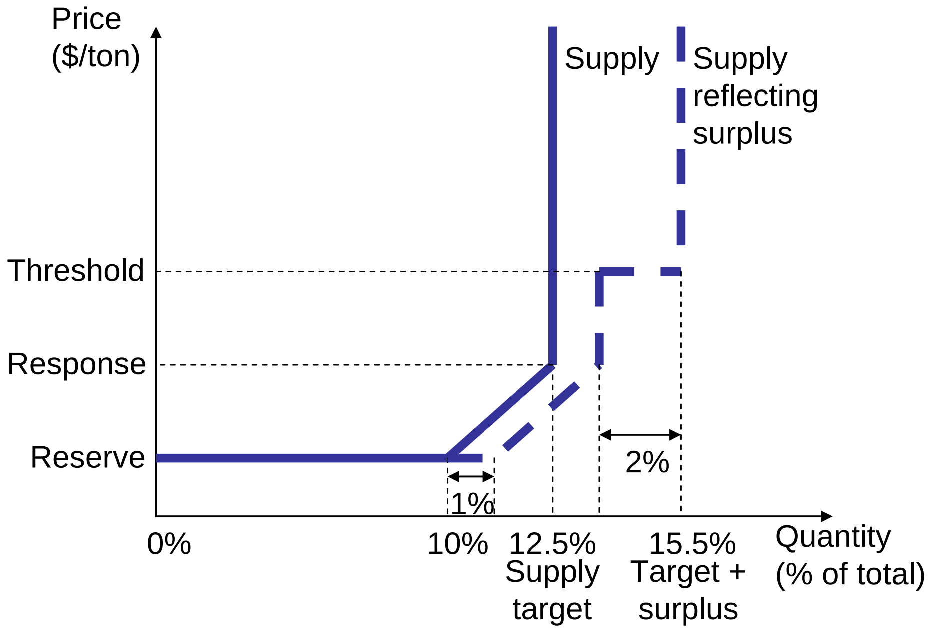


The supply curve does two important things: 1) it stabilizes prices across auctions by preventing the price from falling below the reserve price, and 2) it addresses the possibility of insufficient competition or inadequate demand in any particular auction by shifting some of the sale to later auctions in either case. By construction, *it is likely that the targeted quantity is sold in each quarterly auction*. In the event that the target is not sold, the shortfall is carried over to subsequent auctions. This approach is both simple and effective.

Unsold allowances should be sold in future auctions according to a specific schedule, rather than put in an actively managed contingency reserve account. The reason is that the management of such an account could be highly political. Rather than reduce market uncertainty as intended, the contingency reserve may increase uncertainty by introducing political risk.

A sensible deterministic rule is easy to construct. For example, unsold spot allowances could be carried forward to subsequent quarterly auctions with an upper limit of 1% of the total vintage per auction, unless the price is above the stage one threshold price, in which case all spot allowances are offered at the stage one threshold price. Figure 6 depicts this rule in the event of a 3% surplus. One-third (1% of the total vintage) is added to the supply at the reserve price, and then the remaining two-thirds (2% of the total vintage) appears in the supply for prices at or above the stage one threshold price. Any surplus allowances are bundled with the spot product, since the products are perfect substitutes. Similarly, the sale of surplus forward allowances can be split among the remaining forward sales for the same vintage or included in the vintage's spot auctions, if allowances went unsold in the last forward auction for the vintage.

Figure 6. Supply curve including a 3% surplus of spot allowances from the prior auction



I propose setting the reserve price based on the history of prior auctions. Here is one simple approach.

- Let p_t be the clearing price at time t.
- Let h_1 be an estimate of the clearing price in the first auction.
- Let h_{t+1} be the history summary at time t+1, where $h_{t+1} = (h_t + p_t)/2$.
- Let d_t be the reserve discount factor in year t, where $d_t = .05(1 + t)$ for t = 1,…,8, and d_t = 50% otherwise.
- Let R_t be the reserve price at time t, where $R_t = d_t\, h_t$.

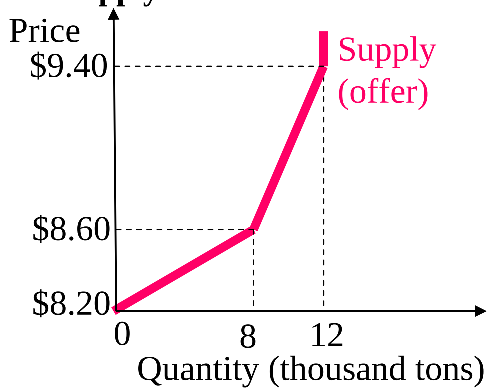
Thus, the reserve price in an auction is a discount from the weighted average of historical clearing prices, where the discount factor is 1/10 in the first auction and then increases 5% each quarter until it reaches 1/2.

With this approach the reserve price serves its important role of stabilizing prices, yet is responsive to market forces. If for some reason the reserve price is initially set too high, the reserve price in future quarters will quickly fall, and the clearing price will be determined on the vertical portion of the administrative supply curve: the target quantity will be purchased and the demand bids will determine the price, not the supply curve. The reason is that the reserve price in the future is never more than 50% of weighted history of auction prices; thus, the reserve price falls exponentially, when the reserve price is binding.

The Final Report does not consider the possibility that market participants would be able to participate in the auction as sellers. This should be allowed, as it is in the US SO_2 auctions. Any market participant holding allowances at the time of the auction can offer these allowances by submitting a supply curve one week before the auction. Individual supply curves should be piecewise linear and strictly upward sloping, as shown in Figure 7. Such a curve is specified with a sequence of price-quantity pairs, where as the prices rise, the quantities strictly increase. This approach gives the participants ample flexibility in expressing preferences and facilitates auction clearing.

Figure 7. Individual supply curve

Price ($/ton)	Quantity (tons)
$8.20	0
$8.60	8,000
$9.40	12,000



The auction supply curve, which is announced one week in advance of the auction, is simply the sum of the administrative supply curves from each state and the individual supply curves from each participant. Although it is possible for each state to have its own administrative supply curve, simplicity suggests that each adopt the same curve. The inclusion of sellers other than the RGGI states is also desirable. It does not complicate the clock auction and allows participants to sell surplus allowances in a liquid and transparent auction. The auction supply curve is piecewise linear and strictly upward sloping at all prices above the reserve, since each of these properties is inherited from the individual curves.

The supply curve is simply a generalization of the reserve price that is used in nearly all auctions. The supply response helps address market power on the demand side. Supply-side market power is addressed by requiring that supply curves be submitted and published in aggregate form before the auction starts.[7]

For the ascending clock auction to work as intended, it is important for the starting price to be set sufficiently low that it creates significant excess demand. Setting too low a starting price causes little harm. It is competition among the bidders that determines the clearing price. The low starting price will quickly be bid up, unless there is insufficient competition, which is unlikely in this context. In contrast, setting too high a starting price can damage the auction.

I recommend that the starting price be set at the reserve price—the lowest price on the supply curve.

4.3 Auction mechanics

The clock auction is done in discrete rounds. There is one price "clock" indicating the price per ton for allowances for a particular vintage (or compliance period in the case of the initial auction). How the auction is extended to handle multiple products (spot and forward) is discussed below, but it is useful to first describe the mechanics for a single product.

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[7] Announced reserves are commonplace, especially in government auctions, and are recommended here. Secret reserves tend only to be used in private auctions where revenue maximization is a primary goal or where collusion is a particular concern as a result of limited competition (timber and oil leases).

In each round, the auctioneer announces: 1) the excess demand at the end of the prior round, 2) the start of round price, and 3) the end of round price. Excess demand is reported in all clock auctions in practice to promote price discovery. In contrast, the clock auctions discussed in the Final Report omitted this important piece of information, which may explain why the clock experiments did not appear to have better price discovery.

Since this is an auction to sell allowances, the clock ascends, so the start of round price is below the end of round price. Each bidder submits an aggregate demand curve at all prices between the start of round price and the end of round price. The auctioneer determines and reports the excess demand at the end of round price. So long as there is excess demand, the price increases. The price increment is determined by best-practice methods, essentially in relation to the extent of excess demand. If there is no excess demand, the auction ends and the clearing price is determined.

4.3.1 Activity rule

An activity rule in a dynamic auction is intended to enhance price discovery by motivating each bidder to bid throughout the auction in a manner that is consistent with the bidder's true interests. To the extent that bids better reflect each bidder's true preferences, the process reveals more market-based information, improving price formation. This allows bidders to focus their decision-making attention on more realistic prices. This focus improves bidder decision making, especially with respect to costly information acquisition. Bidder participation costs are reduced and efficiency is improved if the bidder's evaluation is guided by a price process that better reflects true market preferences.

The need for an activity rule in a dynamic auction is seen in the tendency of sophisticated bidders in eBay auctions to bid snipe. Bid sniping is waiting until the last minute before submitting a bid. There are numerous reasons for this common behavior, but one of the most frequent is a desire to prevent other bidders from responding to your bid. If all bidders bid snipe, then the dynamic auction becomes a sealed-bid auction and the benefits of price discovery are lost.

Fortunately, there is a simple and general activity rule, based on one of the basic principles of economics: revealed preference. Whenever a consumer selects one package over another, the consumer is effectively saying, "At these prices, I prefer this package." The economist then infers this preference from the consumer's choice. This is revealed preference: the consumer reveals something about her preferences through her choices.

We can apply the same revealed preference approach in a clock auction. In each round of the auction, the bidder is given a price and is asked to select the quantity it desires. The bidder is effectively saying, "At these prices, I prefer this quantity." The activity rule requires the bidder to bid consistently with this revealed preference throughout the auction. In the context of the RGGI auction, the activity rule is especially simple.

Activity rule: *A bidder can only maintain or reduce quantity as prices rise. That is, the bidder must bid a (weakly) downward-sloping demand curve throughout the auction.*

4.3.2 Intraround bids

An important feature in the clock auction is what is known as intraround bids: the ability to express a demand curve for all prices between the start of round price and the end of round price.

This feature allows better expression of bidder preferences without requiring too many rounds. This improves auction efficiency and lets the auctioneer better manage the pace of the auction. A further advantage is that the incidence of ties are reduced, making it likely that only a single bidder will be rationed at the clearing price. Allowing intraround bids or exit bids is a straightforward and general way of achieving the benefits of what the Phase 1 Report called a "shootout round."[8]

Figure 8. Individual demand bid for a round

Price ($/ton)	Quantity (tons)
$8.70	12,000
$9.40	9,000

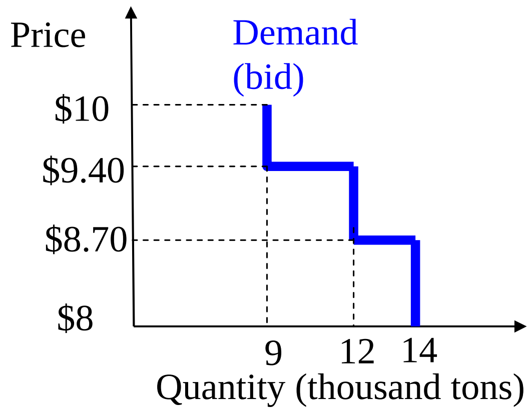

Figure 8 shows a tabular and graphical version of a bid in a round. In this round, the start of round price is $8 and the end of round price is $10. The bidder simply needs to state at which price, if any, it wishes to reduce its quantity from its start of round quantity of 14,000 tons. In this case, the bidder makes two reductions: the first at $8.70 to 12,000 and the second at $9.40 to 9,000. The resulting demand curve in this case has two steps.

The advantage of this approach is easily seen when one considers what would happen in a clock auction without intraround bids; that is, when a bidder only expresses its desired quantity at the end of round price. This is shown in Figure 9. The result typically is overshoot. In Round 5, there is significant excess demand, but at the end of round 6 there is significant excess supply. The discrete clock process overshot the clearing price.

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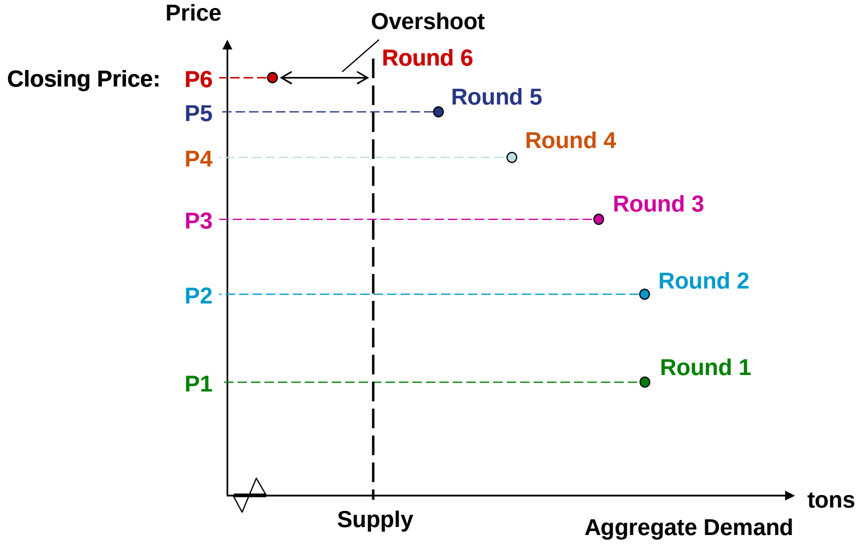
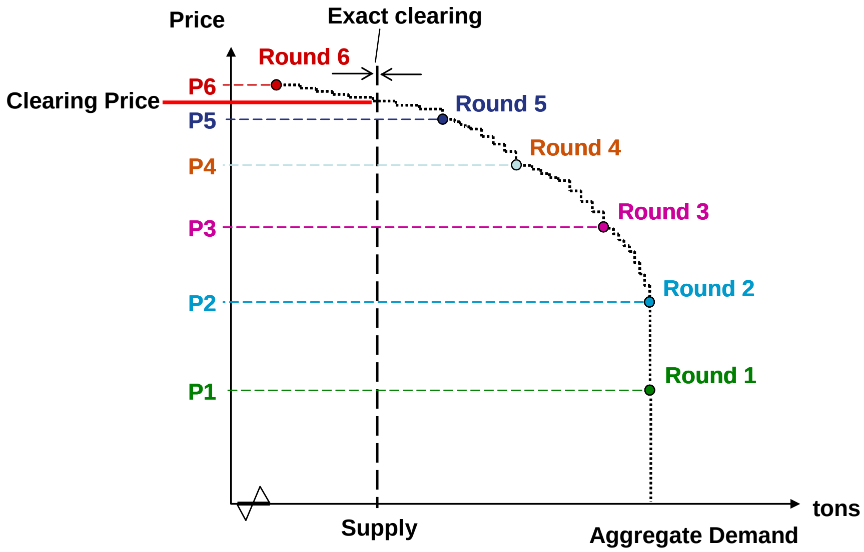
[8] An exit bid is an intraround bid in which only a single quantity reduction and associated price is allowed each round. Exit bids are used in the NJ BGS auction; intraround bids are used in New England's forward capacity auction and most other clock auctions in practice.

Figure 9. A clock auction without intraround bids overshoots the clearing price



The problem of overshoot is readily avoided by allowing intraround bids. This makes the aggregate demand curve much smoother and better reflects the bidders' true demands, as shown in Figure 10. As a result, auction efficiency is improved. Importantly, since the prices of reduction are specified by the bidder, rather than the auctioneer, they represent true points of indifference, and can be treated as such. The approach results in a unique clearing price and exact clearing.

Figure 10. A clock auction with intraround bids avoids overshoot and improves efficiency



An alternative implementation of intraround bidding, called ex post intraround bidding, is to allow the clock auction to run without intraround bids until there is no excess demand at the end of round price (round 6 in the figure above). Then at the conclusion of round 6, the auctioneer informs the bidders that there is no excess demand at the round 6 price and asks for intraround bids for all prices between the round 5 price and the round 6 price. The intraround bids must still be consistent with the activity rule. This approach is nearly equivalent to the "English clock with a final shootout round," as discussed in the Phase 1 Report, except it uses uniform-pricing, rather than pay-as-bid pricing in the final round.

There are two differences between standard intraround bidding and ex post intraround bidding: 1) the ex post version economizes on the amount of "intraround" bid information that is collected—it is only collected in the final round, and 2) the bidder has some extra information when it places its intraround bids in the final round; namely, it knows that this is the final round and can condition its bids on this information.

The distinction between the two versions of intraround bidding is subtle. Based on theory and experience, I believe that the standard approach is apt to perform better on both efficiency and revenue grounds in settings like this one in which there is a strong common value element.[9] The reason is that in the ex post approach when the auctioneer informs the bidders that there is no longer excess demand, this is bad news about the market value of allowances. As a result bidders rationally revise downward their estimates of value, resulting in a group of bidders reducing quantity at the minimum price. Thus, there is a greater likelihood of the auction clearing at the minimum price with many ties at this price. Both revenues and efficiency have been reduced in this case. In contrast, in a private value setting, whether a bidder revises its bids upward or downward will depend on the bidder's beliefs about the bids of others.

Since the RGGI setting is one with strong common value elements as a result of a liquid resale market, I recommend the standard intraround bidding approach. It should be emphasized that the experiments discussed in the Final Report relied on a version of the clock auction that is nonstandard and much inferior with respect to the important element of price discovery. Moreover, the experimental setting only included private value environments and therefore was ill-suited to identify the benefits of improved price discovery even if the standard clock auction was used. A more relevant setting is one with strong common value elements. In such settings the clock auction has been found to perform quite well (see, for example, Ausubel and Cramton 2002).

All high-stake clock auctions of which I am aware, with the exception of the Virginia NOx auction, have used standard intraround bidding. In practice, bidders find it easy to use and like the flexibility it gives them in expressing preferences and the higher efficiency it yields. Both standard and ex post versions are much preferable to a clock auction without intraround bidding.

The Final Report provides little explanation for its chosen clock implementation. Indeed there is only this single sentence which provides any explanation: "The experience with the Virginia NOx auction and in other settings that we have reviewed suggests that it is best not to reveal the total number of allowances requested in each round" (p. 19). Missing from the discussion was the substantial experience with clock auctions, which have been used to auction tens of billions of dollars in assets in many countries. All have revealed excess demand after each round. The investigators concern is apparently with demand reduction, but this phenomenon is present in the uniform-price auction as well. Although it is true that some simultaneous ascending auctions have been vulnerable to tacit collusion (see, for example, Cramton and

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[9] A common value setting is one in which the bidders have the same value for the good, but that value is uncertain, and each bidder has a different estimate of the true value. A private value setting is one in which each bidder knows its own value, and the bidder's value does not depend on the value of others. Most real auctions have both common and private value elements. In RGGI, the common value element is especially strong, because of a liquid market for resale in subsequent quarterly auctions or secondary markets.

Schwartz 2002), these auctions were characterized by 1) weak competition, 2) many products, and 3) the ability to engage in retaliatory bidding strategies. None of these elements is expected in the RGGI context. Most importantly, retaliatory bidding is not possible, since only aggregate bid information is provide, rather than individual bids.

4.3.3 Auction clearing rule

The auction ends when there is no excess demand. The clock ticks up while there remains excess demand. Thus, the auction will conclude when excess demand is zero or negative at the end of round price. The auctioneer then backs up the demand curve to determine the clearing price, where demand and supply balance.

In the RGGI auction, it is desirable to facilitate clearing by rationing bids at the clearing price if necessary. In the typical case, clearing is reached (demand and supply balance) when a single bidder reduces quantity at a particular price. For example, a bidder might drop from 20,000 to 15,000 at $10/ton, and clearing occurs (S = D) at 17,000. The bidder wins 17,000 tons, not either 20,000 or 15,000. Indeed, the bidder's bid is interpreted as "at $10/ton, I am happy with any quantity between 15,000 and 20,000 tons." The bidder buys 20,000 if the price is below $10/ton and buys 15,000 if the price is above $10/ton. Only when the bidder's reduction is at the clearing price can the quantity purchased fall between the two quantities bid.

In the unlikely event that there are multiple bidders on the margin (multiple bidders reduce quantity at the clearing price), then proportionate rationing is used.[10] Each receives its proportionate share. Thus, if one bidder dropped from 20,000 to 15,000 at $10/ton and a second bidder dropped from 40,000 to 30,000 at the same price, and if a total quantity of 51,000 is needed from these two bidders for the market to clear, then the two bidders are bidding between 60,000 and 45,000 at $10/ton, and the first bidder wins 15,000 + 2,000 = 17,000 and the second wins 30,000 + 4,000 = 34,000. The second gets twice as much of the rationed quantity, since its reduction is twice as large at the clearing price. Alternatively, as is recommended in the Final Report, the orders can be filled in random bidder order. Such a rule has some competitive benefits under pay-as-bid pricing, but has almost no benefit under uniform pricing. The reason is that in pay-as-bid pricing, colluding bidders need to coordinate on price, whereas, under uniform-pricing, colluding bidders can coordinate on quantity. Proportionate rationing, as described here, is used in almost all uniform-price and clock auctions conducted in practice.

In auctions with lumpy investments and without good secondary opportunities for purchase or sale, then rationing is not used. An example is the bid of a new resource in a forward capacity auction, as in New England's Forward Capacity Auction. Here, however, the going-forward investments are not lumpy, and there are ample secondary opportunities for trading. Thus, rationing bids at the clearing price is appropriate.

4.3.4 Proxy bids

Even with the auction conducted in a single day with just a handful of rounds, a small bidder may prefer to submit a single demand curve to be used throughout the auction, rather than participate explicitly in each round. This is handled as a *proxy bid*. The bidder has the option of

[10] Multiple reductions at the same price are unlikely because of the use of intraround bids: the price of reduction is selected by the bidder from a fine price grid (cents per ton), not by the auctioneer. This is an important advantage of intraround bidding.

simply entering its demands at the beginning of the auction, just as in the uniform-price auction, or the bidder may submit bids iteratively as the auction progresses. Indeed, with proxy bids allowed, the ascending clock auction dominates the uniform-price auction for bidders. The bidders can treat the auction as a uniform-price auction or they can take advantage of price discovery if they find that valuable.

4.3.5 Information policy

The information policy determines who knows what in the auction. I recommend that the supply curve and the starting price be announced before the auction. At the end of every round, the auctioneer reports: 1) the excess demand at the end of the prior round, 2) the start of round price, and 3) the end of round price. This is an anonymous auction in the sense that no individual demand bids are reported. Reporting of individual bids during the clock auction is undesirable, since it would introduce the possibility of retaliatory bidding, as a means to develop and enforce tacit collusion.

4.3.6 Handling two products, spot and forward

The examples and figures above are all based on a single product, as would occur in each spot auction if only allowances for the current vintage are sold. However, the Final Report recommends that both spot and forward allowances be auctioned at the same time. It is a simple matter to extend the approach to include two products, both spot and forward. The approach described here has been adopted for Colombia's forward energy auction, see Cramton (2007).

The first point to make is that the two products—spot and forward allowances—are excellent substitutes. The spot product is a superior good, since as a result of banking, it can be used in either the current or any future compliance period; whereas, the forward vintage may be in a later compliance period. Thus, we know that the spot price must be at least as great as the forward price. If participants expect allowance prices to increase faster than the rate of interest, then the spot price will approximately equal the forward price; otherwise, the spot price will be above the forward price.

Because of the close relationship between the two products, it makes sense to auction both products simultaneously, and moreover allow the bidders to freely substitute between the spot and forward products. This is done by basing the activity rule on the bidder's aggregate demand across both products: as prices rise, the bidder can only maintain or decrease its aggregate quantity (spot plus forward). The auction still has a single price clock, indicating the spot price. Bidders specify an aggregate demand as well as how the aggregate demand is split between the spot and forward products as a function of the price spread between the two products.

Figure 11 gives a sample bid with two products, spot and forward. The first part of the bid expresses the bidder's aggregate demand (both spot and forward) as a function of the spot price, for all prices from the start of round price to the end of round price. The bidder's offer at the start of round price is carried forward from the prior round. The end of round price is specified by the auctioneer. The bidder simply has to express the prices at which it desires to reduce its quantity. In the example below, the bidder indicates that at a spot price of $7.30, it desires to reduce its quantity from 14,000 to 12,000, and then at a price of $7.80, it desires to further reduce its quantity from 12,000 to 10,000. Most clock auctions limit the number of steps that can be specified to five per round; this constraint almost never binds in practice.

Figure 11. Sample bid

Carried forward from end of prior round
Set by auctioneer at end of prior round
Bidder's bid in round

Bidder activity	Spot price ($/ton)	Total quantity (tons)
Start of round prices and quantities	$7.00	14,000
Reduces total demand to 12,000	$7.30	12,000
Reduces total demand to 10,000	$7.80	10,000
End of round prices and quanties	$8.00	10,000

Substitution between spot and forward product

	All spot	All forward
Price spread ($/ton)	$0.90	$1.00

The second part of the bid, shown in the lower box of Figure 11, is where the bidder expresses its substitution preferences between spot and forward products. In this example, the bidder is stating:

1. whenever the price spread—the difference between the spot price and the forward price— is less than $0.90, the bidder wants all its quantity to be spot;
2. whenever the price spread is greater than $1.00, the bidder wants all its quantity to be forward; and
3. whenever the price spread falls between $0.90 and $1.00, the bidder wants a linear mix of spot and forward product, according to the formula:

$$\text{spot quantity} = \text{total quantity} \times (1.00 - \text{spread}) / (1.00 - 0.90),$$

where spread = spot price – forward price.

This approach gives the bidder great flexibility in expressing its substitution preferences. For example, if the two products are perfect substitutes, then the bidder would give a single number for "all spot" and "all forward," reflecting the bidder's value difference between the spot product and the forward product. Then the bidder's demand would be either all spot or all forward depending on whether the price spread is below or above the number bid. Alternatively, the bidder can slow the substitution across products by submitting a lower number for "all spot." Then the bidder's mix of spot and forward product shifts gradually to forward as the price spread increases.

Figure 12. The price spread is calculated to balance excess demand across products

	$/ton	D/S ratio		Spot	Forward
Spread	1.37	120.0%	Price	$8.00	$6.63
			Total market	800	800
			Share auctioned	12.5%	12.5%
Supply	200		Amount auctioned	100	100
		Bid		120.0%	120.0%
		All	All	Demand	
Bidder	Demand	spot	forward	Spot	Forward
A	19	$1.71	$2.20	19	0
B	19	$1.50	$2.00	19	0
C	14	$1.42	$1.80	14	0
D	48	$1.36	$1.60	47	1
E	29	$1.23	$1.50	14	15
F	38	$1.20	$1.40	6	32
G	10	$1.11	$1.11	0	10
H	24	$0.95	$1.20	0	24
I	29	$0.94	$1.10	0	29
J	10	$0.90	$1.00	0	10
Demand	240			120	120

Figure 12 shows how the price spread at the end of round price is calculated to balance excess demand across the two products. In the example, the end of round spot price is $8.00. The question is, "What is the price spread that results in the same ratio of demand over supply for both products?" In this case, given the aggregate demand of all the bidders, it turns out that a price spread of $1.37/ton results in a demand over supply ratio of 120% for both the spot and forward products. Given the strictly upward-sloping supply curves for both products, the weakly downward-sloping total demand curves for each bidder, and the linear substitution across products for each bidder, there will always be a unique price spread that balances the demand over supply ratio for each product. As the price rises and bidders make reductions in quantities, we eventually will reach the point where demand equals supply for each product. The motivation for calculating the price spread in this way is that it provides the best predictor for the price spread at the ultimate clearing price. The price spread is reported at the end of each round.

For those auctions in which the spot and forward products are surely in the same compliance period, the two products are perfect substitutes with a price spread of zero. In this case, the bidding can be simplified to omit the price spread portion of the bid: ($0, $0) is assumed for all bidders. A winning bidder receives a mixture of the two vintages with proportions determined by the supplied quantities of each product.

4.3.7 Internet auction

The auction should be conducted over the Internet using a standard web browser and industry-standard security. This approach reduces implementation costs, but more importantly reduces participation costs for bidders.

4.4 Secondary market

To allow sources to rebalance positions, it makes sense to encourage a robust secondary market. Any party can buy and sell allowances in the secondary market subject to disclosure rules. In some settings, it is helpful for the market maker to maintain an organized secondary market, such as when the secondary market is apt to be too thin or specialized for an informal secondary market to appear. In the case of RGGI, it is likely that a robust secondary market will appear, based on continuous trading in a bid-ask market. The secondary market is well-supported by the efficient pricing in the quarterly auctions. Buyers and sellers should be happy to trade in a secondary market with reduced price uncertainty, and therefore a smaller bid-ask spread.

5 Transition

A final step of market design is establishing the transition from the current state to the steady-state market. Often this involves early years with a different auction schedule or different quantities until the steady-state is reached. In this case, the transition may be especially easy. The only thing that requires modification is the auction schedule through the February 2010 auction. In particular, a more compressed auction schedule for the forward products is required, recognizing the fact that regulatory review and legislative action will make an auction before August 2008 difficult. I recommend that only two quarterly auctions be held in 2008 (August and November).

With prompt attention to auction design approval, development, testing, and implementation, the auction should not be a constraint in this schedule. The design is straightforward. If, as can be expected from press reports, many of the RGGI states will be ready to participate in the first regional auction in third-quarter 2008. The first auction should be held at that time. I strongly recommend that a deadline be set in second-quarter 2008 for RGGI states to announce participation in the first auction. States that are unable to commit until after the deadline could include their allowances in subsequent regional auctions. Although a third-quarter 2008 start compresses the forward sales into a shorter time period, the late start in the initial year has two important advantages: it allows more RGGI states to participate in the first auction, and it allows additional planning and study to occur before the first auction, which should improve price formation.

Some (Edison Electric Institute and Independent Power Producers of New York) have argued that even if 100% auctioning is adopted, it makes sense to phase it in over a period of time, beginning with 25%. The justification given is that a more gradual approach will be less risky. I disagree. There is nothing risky about 100% auctioning, and indeed, 100% auctioning likely reduces, rather than causes, some of the most common problems, such as hoarding and illiquidity. Plus this dual approach to allocating allowances requires the maintenance of two programs: 1) the auction program, and 2) another more costly program to determine how the non-auction allowances are allocated among sources. This substantially increases transaction costs for participants, as well as management costs for the governing agency.

6 Collusion, manipulation, and market monitoring

With a good auction design, there are many reasons to expect that the RGGI market should work well. Nonetheless, effective market monitoring is important to identify problems that may arise and to correct those problems before significant damage is done. The two most common problems that can be anticipated are collusion and manipulation. I discuss each. My discussion is preliminary as I have not completed an analysis of the market structure—the market share and portfolio of generating assets of the major market participants.

6.1 Collusion

Collusion seems unlikely in this setting for several reasons. The market is only moderately concentrated. There are many market participants, each of different size and with a variety of generating portfolios and mix of fuel types. All the large participants are large companies, fully aware of the dangers of collusion. Most importantly, collusion is illegal. Violations can result in substantial fines (triple damages), loss of job, and potentially jail time. Bidding strategies in these large companies typically are determined by a bidding team that includes many people, including legal counsel and officers of the company. Many people within multiple large companies would need to coordinate bidding strategies in clear violation of the law. I find this implausible.

Moreover, since only a small fraction of allowances are sold in any particular auction, collusion in any particular auction is readily undermined by the expanded purchases of non-colluding buyers who find the low price attractive.

Finally, the product is homogenous within vintage with rich substitution possibilities across vintages. There are no locational constraints and few timing constraints that might limit competition at a particular time and place.

Collusion is much more apt to occur in auctions in which the same cohesive group participates regularly in auctions with weak competition, and where the individuals engaged in the collusive activity receive large personal rewards.

The Final Report's discussion of collusion is insufficient as a basis for the design conclusions it spawns.

The report speculates about the greater possibility of collusion in dynamic auctions as a deciding factor in recommending a sealed-bid uniform-price auction over a clock auction. Although it is true that some dynamic auctions are vulnerable to collusion, a well-designed clock auction is specifically designed to mitigate collusion. This is done by enhancing substitution possibilities and by limiting information release to the aggregate information that is most relevant for price discovery.

The experimental sessions specifically targeted to examine collusion found no compelling evidence of greater collusion risk with the clock format. Indeed, the clock format achieved higher revenues in the loose-cap case intended to magnify the possibility of collusion. The other collusion-enhancing case was allowing the bidders to communicate freely in a chat room, but only the sealed-bid formats were tested in this setting. Even so, the environment of six students able to freely communicate about bidding strategy, absent any antitrust laws, may not have realistically tested collusion in the RGGI setting.

6.2 Manipulation

Manipulation of the market by a single market participant may be a much more likely problem than collusion. Whereas collusion often is enhanced by bidder similarities, individual manipulations tend to be strongest in the presence of large differences among the bidders. In the context of RGGI, the primary concern is large market participants that have an unbalanced portfolio of fuel types. For example, the coal-only supplier or the nuclear-only supplier present particular challenges. The coal-based supplier has a strong incentive to keep the carbon price low, since the supplier is only partially compensated for its outlay in allowances. In particular, the electricity price reflects the carbon cost of the fuel type on the margin in the spot electricity market. If gas is often the marginal fuel, then the coal-based supplier only recoups about one-half of its carbon outlay. In contrast, a nuclear-based supplier has no carbon outlays and so benefits from a high carbon price, since the electricity price increases based on the carbon cost of the marginal fuel type. The marginal fuel typically is gas on peak and in shoulder hours, and sometimes coal in off-peak hours.

Two factors mitigate these problems. First, many large suppliers have a more balanced portfolio of generating units. Suppliers acquire resources with risk in mind. Holding an unbalanced portfolio is risky for suppliers. Second, while a supplier may be able to generate a short-term gain by either limiting or expanding its allowance purchase in one auction, that gain is offset in a later auction when the supplier is forced to take the reverse action to once again balance its position.

There are still a few instances of potential concern.

One would be an instance where the supplier is aware that the positive impact is short-lived, but nonetheless is beneficial. For example, suppose a supplier is spinning off its nuclear assets. Such a supplier may benefit from expanding its purchase of allowances in the auctions leading up to its nuclear sale, since the value of the nuclear assets increases with the expected future carbon price. The buyer of the nuclear assets may wrongly assume that the recent high carbon price is an indicator of high carbon prices in the future, and thereby overpay for the nuclear assets.

6.3 Market monitoring

Market monitoring is important in addressing various collusive or manipulative strategies. For monitoring to be affective the monitors need the information that might suggest a problem. For this reason, I concur with the Final Report recommendation that market participants disclose the "beneficial ownership" of any allowance holdings. This allows monitors to look for imbalanced positions, which is often the clearest sign of potential manipulation.

The market monitoring function for the carbon allowance market needs to be separate from the market monitoring units of ISO-NE and NYISO. Nonetheless, the market monitoring units at ISO-NE, NYISO, and PJM could be helpful in advising RGGI, Inc. and state entities as they plan for monitoring the RGGI carbon allowance market. The expertise of Northeast ISOs in the analysis of behavior in electricity markets should be drawn upon in developing a carbon allowance-specific monitoring effort.

7 Reaction to the comments of others to the Phase 1 Report

This section provides comments to the main comments of others.

100% auctioning is unprecedented and risky.

Public policy makers need to decide whether 100% auctioning of carbon allowances is appropriate. However, government bonds, spectrum licenses, and oil rights are all auctioned, and 100% auctioning may reduce the chief risks of hoarding and illiquidity. An open and transparent auction minimizes the risk from hoarding and maximizes liquidity.

The Phase 1 Report relies too heavily on experiments with students. Pilots with actual market participants are desirable.

Most of the results of the experiments with students have strong empirical support from actual auctions with real participants. There is also strong support that bidding behavior of financially motivated students is largely consistent with that of experienced traders.

Conducting experiments with actual market participants is not possible, since the incentives of at least some participants would be distorted by their desire to influence the auction design in a particular direction. However, it does make sense to conduct a mock auction with the actual bidders in advance of the first real auction. This is standard practice in high-stake auctions. Indeed, at least one month before the first auction, a bidder training session should be held, followed by a mock auction approximately one week before the first auction. The mock auction gives the bidders an opportunity to see exactly how the auction system works and confirm that there are no technical difficulties.

Revenue maximization should not be the goal.

Agreed. Efficiency should be the primary goal: putting the allowances in the hands of those who value them the most, and thereby minimize the cost of achieving the environmental goal.

The auction should not have a reserve price.

The auction should not have a high reserve price. High reserve prices are generally intended to increase auction revenues, and as I state above, that should not be a primary goal.

The reserve price is important in avoiding a surplus of allowances, which may occur as a result of initial caps being set too high and declining too slowly.

A modest reserve price is desirable, especially in the early auctions when price uncertainty is greatest. The purpose of such a reserve is not to increase auction revenues, but rather to address the possibility of either insufficient competition or inadequate demand in a particular auction for one reason or another. A modest reserve stabilizes the price in such circumstances and also mitigates certain manipulation strategies.

As a result of a competitive market for allowances and the ability to bank allowances for future compliance periods, my expectation is that the auction price will exceed the reserve price in all but unusual circumstances.

The auction should not be open to anyone, but should be limited to sources covered by RGGI.

Financial participants generally play an important and useful role in markets by improving liquidity and price formation. Although a legitimate reason for limiting participation to RGGI sources may be a concern of manipulation by outsiders, it is extremely unlikely that the manipulation would be profitable in a regional auction. Profitable manipulation strategies are more apt to come from large RGGI sources (i.e., those with market power), rather than from outsiders.

Manipulation is much better addressed through good market design and effective monitoring and enforcement, rather than exclusion of participants.

Forward sale of allowances is important to manage risk.

To best manage risk and improve price discovery, it makes sense to auction some portion of allowances in advance of the vintage. The sale of allowances should roughly conform to the sale of energy. This allows the allowance cost to be included in forward energy contracts without any price risk.

There are significant incentives for hoarding; thus, hoarding should be a main concern in the design. It will be important to simulate the impact of hoarding.

Although hoarding is a possibility, there are not significant incentives for hoarding in the design proposed here. Hoarding is an exercise of market power. Market power chiefly is a concern with large suppliers who are able to take large positions and impact prices.

First consider a large RGGI source. The incentive of the source works in the opposite direction. Rather than buying more than it needs, pushing the allowance price up, the supplier's profit incentive is to buy less in order to keep the allowance price low. (See Ausubel and Cramton 2002.)

Second consider a large non-RGGI source that desires to import into a RGGI state. This supplier might benefit from a high allowance price, but only if it is able to capture the congestion rent on the import path, say because it holds all the financial transmission rights (FTRs) or it is the only supplier with access to the path. However, given the large size of RGGI and the limited quantity of electricity that can be imported on any such path, it appears unlikely that the large supplier could impact the RGGI price sufficiently to make the exercise of market power profitable.

Third consider a large supplier within RGGI that has a fleet dominated by low-CO_2 emitting resources, such as nuclear and renewables. Such a supplier also benefits from a high allowance price, since it increases its profit margin. This case is more problematic than the importer case, since the supplier's sale into the RGGI market is unconstrained by transmission limits. However, it is still the case that the supplier would need a large and fuel-unbalanced portfolio in order to make hording profitable. Fortunately, hoarding in this case is easily observed and mitigated in a transparent auction.

It should also be noted that this problem of hoarding is not something that is limited to CO_2 allowances. Hoarding is an issue for all inputs to production. Indeed, the hoarding problem likely is greater for other inputs. RGGI is a deep market. Hoarding is much more effective in a thin input market, such as allowances for local pollutants, generation sites in load pockets, FTRs in load pockets, and gas contracts where gas transmission constraints are apt to bind. Cornering the market for CO_2 allowances is even more foolhardy than the famous attempt by the Hunt brothers in 1980 to corner the silver market. Deep markets are not easily cornered. Moreover, RGGI is a deep regulated market that will be closely watched by market monitors.

Rather than apportioning the quantity equally across the auctions, the quantity should be apportioned according to the load in the period.

This would make sense if forward energy contracts were not important, but they are important. Nonetheless the idea that allowance sales should track energy sales is a good one. Given the anticipated liquidity of the market, it is not necessary that the tracking fit perfectly, but a rough tracking with the major tendencies of forward sale is desirable.

An all-states regional auction is important to promote liquidity and minimize transaction costs.

Absolutely. On this point there is complete consensus. Ideally, there will be one product, one set of market rules, and a single sequence of auctions, covering all RGGI states. Such an ideal plan is readily accomplished with continued coordination of the RGGI states.

The secondary market should be transparent, with sales and purchases posted.

Transparency typically is desirable in markets. It improves price formation. In the case of CO_2 allowances where there may be concerns about hoarding, transparency is especially desirable. Transparency through a central registry is readily accomplished at nearly zero cost.

The initial auction should occur as soon as possible, ideally in first-quarter 2008.

Although the first auction should occur early, there are important benefits to delaying the first auction to third-quarter 2008. The extra time can be productively used for additional planning and coordination among the RGGI states. It will enable as large a set of RGGI states to participate in the first auction.

The ISOs should help monitor the auctions and market.

The market monitoring function for the carbon allowance market needs to be separate from the market monitoring units of ISO-NE and NYISO. Nonetheless, the market monitoring units at ISO-NE, NYISO, and PJM could be helpful in advising RGGI, Inc. and state entities as they plan for monitoring the RGGI carbon allowance market. The expertise of Northeast ISOs in the analysis of behavior in electricity markets should be drawn upon in developing a carbon allowance-specific monitoring effort.

8 Conclusion

RGGI may well prove to be a model program to limit greenhouse gas. The proposed approach as specified in the RGGI Model Rule and further developed in the Final Report will satisfy the goals of the program, especially if the further refinements discussed above are adopted. In particular:

- *Efficient price formation*. The proposed market will produce reliable price signals, especially if the recommended clock format is adopted, which greatly enhances substitution between spot and forward products. Most importantly, it will achieve the environmental target at least cost through the efficient auctioning and trade of emission allowances.
- *Transparency*. The proposed market is highly transparent. The auction results in clear pricing and assignment. Each bidder knows why it won or lost. Prompt regulatory review and approval is readily accomplished.
- *Neutrality*. All participants are treated equally.
- *Risk management*. Each market participant has great flexibility in timing its allowance purchase. This flexibility enables participants to minimize risk. Through this timing, exposure from short-term transient events is reduced. Counterparty risk is largely eliminated through the centralized auction.
- *Liquidity*. Market liquidity is promoted through the quarterly auctions of a single standardized product. Excellent price formation in the primary auctions should support a

liquid secondary market, but in any event the quarterly auctions provide ample liquidity for participants to purchase what they need.

- *Simplicity*. The market and auction are simple. There is plenty of experience with the recommended approach. The auction approach is not only simple, but well studied and understood in theory, in the lab, and in practice.
- *Consistency*. The market, especially the timing of auctions, is consistent with the other key elements of the electricity markets in the RGGI states. The recommended ascending clock auction is consistent with, or improves upon, the best-practice in other markets.

References

Australia National Emissions Trading Taskforce (2007), "Possible Design for a Greenhouse Gas Emissions Trading System," Research Report.

Ausubel, Lawrence M. and Peter Cramton (2002), "Demand Reduction and Inefficiency in Multi-Unit Auctions," University of Maryland Working Paper 9607, revised July 2002.

Ausubel, Lawrence M. and Peter Cramton (2004), "Auctioning Many Divisible Goods," *Journal of the European Economic Association*, 2, 480-493, April-May.

Cramton, Peter (1998), "Ascending Auctions," *European Economic Review*, 42, 745-756.

Cramton, Peter (2007), "Colombia's Forward Energy Market," Working Paper, University of Maryland.

Cramton, Peter and Jesse Schwartz (2002), "Collusive Bidding in the FCC Spectrum Auctions," *Contributions to Economic Analysis & Policy*, 1:1, www.bepress.com/bejeap/contributions/vol1/iss1/art11.

Holt, Charles, William Shobe, Dallas Burtraw, Karen Palmer, and Jacob Goeree (2007), "Auction Design for Selling CO2 Emission Allowances under the Regional Greenhouse Gas Initiative," Final Report.

Holt, Charles, William Shobe, Dallas Burtraw, Karen Palmer, and Jacob Goeree (2007), "Auction Design for Selling CO2 Emission Allowances under the Regional Greenhouse Gas Initiative," Phase 1 Research Report.

Kahn, Alfred E. , Peter Cramton, Robert H. Porter, and Richard D. Tabors (2001), "Uniform Pricing or Pay-as-Bid Pricing: A Dilemma for California and Beyond," *Electricity Journal*, 70-79, July.