Comparison of Auction Formats for Auctioning Wind Rights

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Abstract

The best sites for offshore wind farms on the US Outer Continental Shelf are scarce. To make the best use of this scarce resource, it is necessary to implement a fair and efficient mechanism to assign leases to companies that are most likely to develop off-shore wind energy projects. Coastal states, particularly along the eastern seaboard, are taking aggressive actions to spur the growth of an offshore wind sector in their states to help meet their renewable portfolio targets while nurturing the supporting on-shore infrastructure. This paper compares the various auction formats described in "Auction Design for Wind Rights" (Ausubel and Cramton 2011a), and the multiple factor considerations documented in "Multiple Factor Auction Design for Wind Rights" (Ausubel and Cramton 2011b). The paper describes in further detail four different clock auction designs for auctioning off these alternative energy leases and highlights considerations that should be factored into the auction rules.

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Contents

Terminology v
1 Summary 1
1.1 Introduction 1
1.2 Outline 2
2 Auction design alternatives for alternative energy leases (Summary of Paper 1) 2
2.1 Objectives of effective auction design 2
2.2 "Family of Auctions" 3
2.3 Three categories of auctions: Sealed Bid, SMRA, Clock Auctions 7
2.4 Clock Auction and Package Clock Auction 8
3 Multiple factor auction design (Summary of Paper 2) 9
3.1 Overview of Formats 9
3.1.1 Comparative hearing 9
3.1.2 Single-Phase MFA 9
3.1.3 Scoring Auction 10
3.1.4 Two-Phase MFA 10
3.1.5 Summary: The Two-phase MFA is the most appropriate MFA design 10
3.2 Selection Criteria 10
3.3 Two phase multiple factor auction and Clock Auctions (including Package Clock Auctions) 11
4 Comparison of Standard and MFA auction formats 12
4.1 Overview 12
4.2 Underlying reasons for including factors other than price in an auction design 12
4.3 Comparing alternatives against characteristics of good auction design 13
4.4 Factoring in competition constraints 15
5 Further discussion on various Clock Auction designs (including the Package Clock Auction) 15
5.1 Overview 15
5.2 Clock Auction for a Single Lot 16
5.3 Three Possible Clock Auction Designs for Multiple Lots 16
5.3.1 Approach I: Clock Auction considering bids from the final auction round. 16
5.3.2 Approach II: Clock Auction considering bids from all rounds 17
5.3.3 Approach III: Package Clock Auction 17
5.3.4 Comparison of Different Approaches 18
5.3.5 Scenario Illustrating Effect of Different Approaches 21
5.3.6 Determining winners for the three approaches 25
5.3.7 Summary of Results 28

5.3.8 Point-Based Activity Rule 28
5.3.9 Exit Bids 29
5.3.10 Revealed Preference Activity Rule 31
5.3.11 Winning Prices – First Price, Second Price, and Clearing Price 34
6 Considerations for Auction Rules 35
6.1 Pre-Auction rules and procedures 35
6.1.1 Lots to be offered 35
6.1.2 Prohibition of Collusion; compliance with Antitrust Laws 36
6.1.3 Notification of auction dates, requirements, seminars 36
6.1.4 Auction Bidder qualification 36
6.1.5 Information Policy (Pre-Auction) 37
6.2 Clock Auction rules and procedures 37
6.2.1 Distribution of auction system credentials (login/password, etc.) 37
6.2.2 Documentation & Training 37
6.2.3 Auction Structure 38
6.2.4 Communication with the Auctioneer 38
6.2.5 Submitting clock auction bids 38
6.2.6 Clock auction prices 38
6.2.7 Point-Based Activity Rule 39
6.2.8 Financial Limit 40
6.2.9 Contiguous lots rule 40
6.2.10 Revealed Preference Activity Rule – Clock Auction 40
6.2.11 Competition constraints 41
6.2.12 Bidding in exceptional circumstances 41
6.2.13 End of clock auction 41
6.2.14 Supplemental round (if Package Clock Auction) 41
6.2.15 Revealed Preference Activity Rule (Supplemental Round) 42
6.2.16 Determining Winners 43
6.2.17 Determining Winning Prices 44
6.2.18 Information Policy (during Auction) 44
6.3 Post Auction Rules & Procedures 45
6.3.1 Final Contract 45
6.3.2 Final payment/refunds 45
6.3.3 Information Policy (post-Auction) 45
6.3.4 Bidder defaults and secondary market lease trading 45

7 Summary 46
Appendix A: New Jersey 48
7.1 Determining the lots 48
7.2 Clock Auction including factors other than price 50
References 51

Terminology

The following terms are used throughout this document.

Term	Description
Activity percentage	A mechanism that is sometimes used with a Point-Based Activity Rule to give bidders some flexibility to switch between packages from round to round in a Clock Auction – without losing eligibility points. The activity percentage might start out at 80% and then be raised to 90% (or 100%) later in the auction. This is explained more fully in Section 5.3.8.
Activity rule	The rule that limits what bids a bidder can make in subsequent rounds of a multiple round auction based on the bidder's bids in earlier rounds. The activity rule is intended to avoid bid sniping. A bidder with large demands late in the auction must express large demands in the earlier rounds when prices are lower.
Assignment stage	A stage of the auction in which bidders who have won generic lots are assigned specific lots, either based on an additional round of bidding or another mechanism for allocation.
Bid amount	The value or values that the bidder specifies for its bid. This can be a price or a quantity depending on the auction format.
Bid shading	The strategy of bidding below your valuation, typically as a way to improve profits in first price auctions.
Bid sniping	The tendency to wait until the last possible opportunity to place a serious bid as in an eBay auction. Auctions often have activity rules in place to prevent bid sniping.
Bidder discount	A bidder-specific percentage discount that is applied after winners and gross payments are determined. A bidder's gross payment is reduced by the bidder discount.
Block	An approved subdivision of the Outer Continental Shelf (OCS) intended for leasing purposes. In the Atlantic, an OCS block is 4800 meters square containing 2304 hectares (5693.3 acres) or about 9 square statute miles.
Call for Information and Nominations (Call)	A *Federal Register* notice that BOEMRE publishes during its renewable energy leasing process. The publication of a Call indicates that (1) BOEMRE has determined competitive interest exists in an area based upon the results of an RFI, or (2) BOEMRE anticipates that there will be competitive interest in an area. The notice solicits nominations of competitive interest in developing a project in the area described, as well as comments from the public. Following the comment period described in the notice, BOEMRE may proceed with its competitive lease issuance process, its non-competitive lease issuance process, both, or neither, depending on the information received in response to the Call and whether an RFI for the area was published previously.
Cap	A competition constraint rule that would prohibit a single bidder from winning more than some percentage (e.g. 45%) of the available lease area. Caps often take prior

	holdings into account when determining how to apply the rules to a specific bidder.
Clearing Price	The price at which the demand for a lot (or set of lots) is no longer above its supply, and thus is the price when the lot (or set of lots) "clears." This is typical of ascending clock auctions. This clearing price may be less than the winner's bid price.
Clock auction	A multiple round auction in which in each round the auctioneer announces prices and the bidders respond with demands at the specified prices. Prices then increase on products with excess demand and the process repeats. Three common types of clock auctions are a Simultaneous Clock Auction, an Independent Clock Auction and a Clock Auction for a Single Lot.
Clock Price	A price for a lot in a round of a clock auction.
Collusion	Two or more bidders working together to manipulate the auction outcome.
Common value	Model of bidder values in which packages of items have similar values to all bidders. Typically, the bidders do not know the exact common value but rather have an estimate, in which case each bidder is said to face common value uncertainty.
Comparative hearing	Sometimes known as a "Beauty Contest." Winners are determined based on the attractiveness of each proposal.
Competition constraint	A rule designed to achieve social goals such as encouraging competition in a given area. Competition constraints may be implemented in a number of ways, such as setting caps.
Competitive lease	A lease that has been issued using BOEMRE's competitive lease issuance procedures. For more information, see BOEMRE's regulations at 30 CFR § 285.211 and 285.220-225.
Complementary goods	X and Y are complementary goods (opposite of substitute goods) if when the price of Y increases demand for X decreases. Complementary goods are typically purchased together and are more valuable together than they are apart (the sum is greater than the parts). The complementarity may be strong or weak. The value of a package of goods with strong complementarities is much higher if sold to one buyer as a package than the sum of values when broken up and sold to multiple buyers. The goods have weak complementarities if the value of the package is only slightly higher when sold together. The level of complementarity between goods is important in auction design.
Demand reduction	A bid for fewer lots at a given price (compared to the demand a price just above), either for an individual bidder or in aggregate.
Dynamic auction	Any auction format that involves multiple opportunities to bid and where some information about the bidding is revealed to the bidders during the course of the auction. An English auction is the most common form of dynamic auction.
Eligibility Points	A bidder's eligibility points define the upper limit of lots that the bidder can bid for (based on the sum of bidding points associated with the lots in its bid). In the first round, the number of eligibility points is set by the upfront deposit amount for the bidder. In subsequent rounds, the number of eligibility points is set by the bids

	placed by the bidder in the previous round (and the activity percentage for that round).
English auction	A format for auctioning a single item. Bidders submit successively higher bids for the item, until no bidder is willing to bid higher. The final bidder wins the item and pays the amount of his final bid.
Exit Bid	An offer to pay less than the sum of the clock prices for a package of lots in a given round. An exit bid allows a bidder to specify the highest price he is willing to bid for a package of lots instead of only having the "in or out" option of bidding at the clock price for the round. When exit bids are used, the system is better able to assign the lots to the bidder who values them the most, and as it reduces the chance of a tie.
Exposure	The risk of winning only some lots in a collection of complementary lots and thereby not reaping the complementarities. This occurs when bids are treated independently (such as in an SMRA auction) instead of being treated as a package.
Final Rule	BOEMRE's offshore renewable energy regulations, found at 30 CFR Part 285. The regulations can be downloaded from BOEMRE's web site at: http://www.boemre.gov/offshore/RenewableEnergy/PDF/FinalRenewableEnergyRule.pdf.
Final Sale Notice	A *Federal Register* notice published at least 30 days before the date of the sale describing the final terms and conditions that will be used in the sale. A list of items that will be included with the final sale notice can be found in BOEMRE's regulations at 30 CFR § 285.216.
First-price auction	An auction in which bidders specify the price they are willing to pay for an item, and if they win that item, they pay this price.
Gaming	Bidding in an auction in a way that does not truthfully represent the bidder's true value, but may increase the bidder's chances of a favorable outcome. A good auction design should minimize the possibility of gaming.
Generic lots	Lots that are sufficiently similar that they may be bid as one category and have one price. Bidders may then express a demand for the number of generic lots at a particular price.
Gross payment amount	The amount a winner pays, before the deduction of the bidder-specific discount.
Hold up	The strategy of a speculator insisting on getting something from a large bidder as quid pro quo for not pushing prices high on key lots desired by the large bidder.
Independent Clock Auction	A clock auction for many products in which each product closes independently. An activity rule requires that demands for each product cannot increase as prices rise. This format is suitable for settings where values are roughly additive—the value of the package is the sum of the values of its individual products (i.e. the lots are not complementary).
Indication of interest	An applicant's response to a Request for Interest sent to BOEMRE. The applicant must include items listed in 30 CFR § 285.213.

Information policy	The policy that determines the information that is revealed to bidders during the course of a dynamic auction. The information revealed might include bid-specific information such as the price of the bid and the identity of the bidder, or aggregate information such as the total number of bids made on a certain product (demand for that product).
Lease	A legal document that gives the lease holder a reservation with respect to other developers. Before a lessee may develop a tract, BOEMRE needs to approve a Site Assessment Plan and/or a Construction and Operations Plan.
Lease area	The tract that is leased. It is comprised of one or more lots.
Lot	A contiguous set of one or more blocks or sixteenth of blocks that is the basic product that a bidder places bids for.
Multiple factor auction	An auction in which the winning bidder is selected following consideration of (1) both monetary and non-monetary factors or (2) solely non-monetary factors.
Outer Continental Shelf (OCS)	All submerged lands lying seaward and outside of the area of lands beneath navigable waters, as defined in section 2 of the Submerged Lands Act (43 U.S.C. 1301), whose subsoil and seabed appertain to the United States and are subject to its jurisdiction and control.
Package auction	An auction that allows package bids.
Package bid	A package bid is a bid on a set of lots. In auctions that do not allow package bids, a bidder interested in a set of lots must submit multiple bids for each of the lots, which exposes the bidder to the possibility that only part of the package is won.
Package clock auction	A clock auction with an additional supplemental round. During the clock auction, bidders specify the packages they wish to purchase at various prices. After the clock auction ends, an additional round is held during which bidders may bid on new packages and improve their bids on packages from the clock auction.
Parking	A strategy in which bidders bid on lots they do not expect to win simply to maintain greater eligibility for later in the auction. This often occurs in an SMRA auction.
Payment amount	The amount a winning bidder pays for the lease. This is the gross payment amount less the bidder discount if any.
Point-Based Activity Rule	An activity rule based on eligibility points. Bidders initially qualify for eligibility points at the beginning of the auction; the number of eligibility points is adjusted based on the bidding history. Each lot is assigned a certain number of "bidding points," and a bidder cannot bid for package bids where the sum of the bidding points for these lots exceeds the bidder's eligibility points.
Power purchase agreement (PPA)	A legal contract between an electricity generator (provider) and a power purchaser (buyer). The contract will specify the duration and the terms of sale, including the pricing, quantities, and delivery requirements for the products to be provided such as energy, capacity, ancillary services, and renewable energy credits.
Price discovery	A feature of dynamic auctions in which information about bidder demands is

	reported to bidders, giving bidders the opportunity to adjust subsequent bids based on the information.
Pricing rule	The rule that determines the price paid by the bidder for each lot that it has won.
Prior holding	Product such as offshore wind leasing rights that a bidder already has that is related to what is being auctioned. Prior holdings are factored in when there are competition constraints.
Proposed Sale Notice	A *Federal Register* notice with a public comment period of 60 days describing the proposed terms and conditions to be used in the sale. A list of items that will be included with the proposed sale notice can be found in BOEMRE's regulations at 30 CFR § 285.216.
Proxy Bid	A mechanism by which a bidder may submit a bid ahead of time before the auction reaches a given price. The proxy bid is automatically entered into the system when certain conditions are met.
Request for Interest (RFI)	A *Federal Register* notice in which BOEMRE requests indications of interest and comments relevant to the leasing and potential development of a designated area. BOEMRE uses the information received in response to RFIs to determine whether there is competitive interest in obtaining a lease in the area described in the notice.
Reserve price	The minimum price at which the seller will sell an item.
Revealed Preference Activity Rule	A mechanism by which past bids affect what can be bid for in future rounds. A Revealed Preference Activity Rule can be incorporated into the clock rounds and, for package clock auctions, the supplemental round.
Scoring Auction	An auction where a score is calculated based on several factors including price and technical factors. The auction then clears based on the bidder with the highest score.
Sealed-bid auction	An auction in which bidders submit bids without receiving any information relating to the bids placed by other bidders.
Second-price auction	An auction in which the highest bid wins and the winner pays the second price. A useful interpretation of this auction is that the bidder pays the smallest price that enables the bidder to win. This encourages the bidder to bid its true value.
Second price	In a sealed-bid auction of individual lots, the second price is generally the highest price bid for a given lot by a bidder who did not win the lot. In an auction where a solver determines the winner based on the various combinations of package bids that were submitted, the second price is the smallest price the winner can pay such that no other bidder or combination of bidders would have a higher value from their bids. In essence, it is the lowest price the winner can pay such that no other set of bidders has offered more. Depending on the algorithm used, the second price for a combinatorial problem will vary. Common solutions include Vickrey prices and VCG-nearest prices.
Set-aside	A competition constraint rule that sets aside specific lots for bidders meeting certain criteria. A set-aside is sometimes used for new entrants in a market where

	new entry is desirable to increase competition. However, this is likely not an option for BOEMRE's auctions, due to the absence of any provision for it in BOEMRE's regulations.
Simultaneous ascending auction with package bids (SAAPB)	An SMRA with package bids. In each round each bidder places a bid for a package of lots. The system solves the combinatorial winner determination problem for that round, and determines provisional winner(s) for the lots based on the packages submitted. A bidder can only be a provisional winner for all of the lots in his package or none of the lots in his package; the bidder cannot be a provisional winner for some of the lots in the package bid.
Simultaneous clock auction	A clock auction similar in design to an SMRA. The key difference is that provisional winners are not determined at the end of each round, only the aggregate demands for each product. The auction ends when there is no excess demand for any product. In each round, the auctioneer announces prices and each bidder bids for the package of lots desired at the announced prices. Bids are package bids. An activity rule requires bidders to maintain a level of activity throughout the auction that is commensurate with their desired winnings.
Simultaneous multiple round auction (SMRA)	A format for auctioning multiple items, commonly used for auctioning spectrum licenses. The auction is a natural generalization of the English auction, especially useful when selling many related items. The items are auctioned simultaneously in a sequence of rounds. In each round, each bidder can submit bids on any of the items, raising the provisionally winning bid by at least the bid increment. The auction ends when no bidder is willing to bid higher on any item. An activity rule requires bidders to maintain a level of activity throughout the auction that is commensurate with their desired winnings. Note that this format suffers from the "exposure problem," as bidders often face significant withdrawal penalties if they attempt to withdraw from any lot in which they are the provisional winner because the combination of lots is not the package they desire.
Single-phase multiple factor auction	A multiple factor auction where qualification, technical details, and cost proposals are submitted in a single phase and all evaluated at once.
Sixteenth of a block	BOEMRE's renewable energy program uses the sixteenth of an OCS block as the smallest unit of leasing. Each sixteenth contains approximately 355.83 acres.
Solver	The software that determines the winners and winning prices. For clock auctions, the solver algorithm is quite simple. For combinatorial situations (such as package clock auctions), standard off-the-shelf optimization software is used to determine which combination of packages yields the best value, given the defined constraints.
Specific lot	Lots that are treated individually, each with its own characteristics, allowing the bidder to specify during the auction the particular lots desired. Specific lots are appropriate when each lot has unique characteristics that determine its value.
Spectrum auction	An auction for radio spectrum (bandwidth at particular frequencies in specified regions).
Substitute goods	X and Y are substitute goods (opposite of complementary goods) if when the price

	of Y increases demand for X increases.
Substitution	The act of shifting demands across products (lots) in response to price changes, increasing the demand of the product that has become relatively more attractive as a result of the price change.
Supplementary round Or Supplemental round	A special round that occurs at the end of the clock auction in a package clock auction. Bidders bid on new packages and improve their bids on packages from the clock auction.
Tacit collusion	Cooperative behavior among bidders whereby the bidders do not engage in any explicit communication and do not enter into any explicit agreement but they are still able to coordinate on a better joint outcome than would be attained by purely competitive bidders. Explicit collusion is usually banned by antitrust law but tacit collusion may be legal. See, for example, "The Economics of Tacit Collusion" (Ivaldi, Julien, Rey, Seabright and Tirole 2003).
Tract	The set of lots that a bidder is interested in.
Two-phase multiple factor auction	A multiple factor auction where qualification and technical details are submitted in an initial phase, and then the financial aspect is evaluated in a separate second auction step.
VCG-nearest price	Method of calculating second prices in a combinatorial optimization problem, as described in "The Quadratic Core-Selecting Payment Rule for Combinatorial Auctions" (Day and Cramton 2012). VCG is an abbreviation for Vickrey-Clarke-Groves.
Vickrey auction	An auction format for multiple identical items. Bidders simultaneously submit demand curves. Each bidder wins the quantity demanded at the clearing price, and pays the opportunity cost of its winnings (the valuations of those bidders that are prevented from winning). For a single-item auction, the Vickrey auction is a second-price auction. When the approach is applied to the auction of non-identical items, the Vickrey auction is often referred to as the generalized Vickrey auction or the Vickrey-Clarke-Groves mechanism.
Winner's curse	The insight that winning an item in an auction is bad news about the item's value, because winning implies that no other bidder was willing to bid as much for the item. Hence, it is likely that the winner's estimate of value is an overestimate. Since a bidder's bid is only relevant in the event that the bidder wins, the bidder should condition the bid on the negative information winning conveys about value. Bidders that fail to condition their bids on the bad news winning conveys suffer from the winner's curse in the sense that they often pay more for an item than it is worth.
Winner determination	The process of determining winners and winning prices using the solver.

1 Summary

This paper compares standard auction designs and multiple factor auction (MFA) designs for alternative energy leases on the US Outer Continental Shelf (OCS). It is the final paper in a three paper series, the first two being "Auction Design for Wind Rights" (Ausubel and Cramton 2011a) and "Multiple Factor Auction Design for Wind Rights" (Ausubel and Cramton 2011b). This paper summarizes the various auction designs introduced in the first paper, and highlights some inherent problems with some of these designs for the OCS environment. Next, the various approaches for an MFA design are discussed and compared. Because a clock auction design will support the large variation in OCS lease areas, we discuss four possible clock auction designs in greater detail – one for auctioning off a lease area that contains a single lot and three possible designs for auctioning off a lease area with multiple lots. If political and business concerns dictate it, factors other than price can be factored into any of the auction designs, preferably as a price discount. This paper also lists a number of considerations to include in the auction rules for the forthcoming OCS auctions.

1.1 Introduction

Wind energy is growing rapidly in importance as the world moves toward renewable energy sources. In the US, much of the developable wind energy, especially near major population centers, is located offshore. Even in waters less than 30 meters deep, the wind energy potential in New England and the Mid-Atlantic States is estimated to be 56 GW (Musial and Butterfield 2004). Potential wind farm sites differ substantially in value based on such factors as: average wind speed and variance, water depth, and proximity to population centers. Although there is an abundance of potential sites, the best sites are scarce.

The Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) is responsible for issuing leases for alternative energy such as wind rights through a competitive bidding process for sites where there is competing demand on the OCS, much as it does today for oil drilling rights. However, while the oil drilling rights are traditionally assigned using a sealed-bid auction, BOEMRE has much more flexibility in how it is to assign wind rights. This paper compares the standard auction designs identified in our first paper with the MFA solutions identified in our second paper, and provides guidance on what auction design may be best for this application and under what circumstances.

Our findings suggest that a clock auction design will work for all lease area configurations that BOEMRE may need to auction. A clock auction for a single lot can be used for simple situations where the lease area can only realistically support one tract. For more complicated scenarios, a simultaneous clock auction or a package clock auction may be most appropriate. A package clock auction design provides bidders the most flexibility in specifying alternative bids in an environment with strong complementarities. In each of the clock auction designs, bidders bid on packages of contiguous lots in a simple price discovery process. Bidders are never exposed to the possibility of winning only a portion of their desired lots. An activity rule and pricing rule encourage truthful bidding throughout the process, which supports an efficient outcome.

Multiple factor auctions are often viewed as unattractive, due to the subjective nature of deciding what factors deserve what discount. However, political and business conditions may necessitate using them. If deciding factors cannot be factored into a qualification step, then they can be incorporated into any of the clock designs as a bidder discount. When they are factored into the bidder discount, they indirectly affect the determination of winners by reducing the payment amount due, and thus enabling a bidder with a discount to bid more.

This paper includes a simple example of how winners are determined in a package auction; a list of considerations to factor into the auction rules, including considerations that are specific to clock auctions; and an example that summarizes how a package clock solution can be applied to the New Jersey lease area.

We are not aware of any direct conflicts with BOEMRE's regulations or statutory authority, and have endeavored to suggest formats and rules the bureau can use under its existing regulatory framework. However, subsequent determinations by BOEMRE could find that some of the formats or rules discussed in this paper may not be implemented as stated without changes or departures from the regulations.

1.2 Outline

The next section summarizes various auction designs described in our first paper, "Auction Design for Wind Rights" (Ausubel and Cramton 2011a), and discusses why certain auction designs are better suited for auctioning leases for alternative energy use on the OCS. Section 3 summarizes the types of multiple factor auctions described in our second paper, "Multiple Factor Auction Design for Wind Rights" (Ausubel and Cramton 2011b), and describes how multiple factor variables can be taken into account when determining the winning prices. The various auction design alternatives are then compared in Section 4. A number of clock auction designs are discussed in greater detail in Section 5; this section includes an example that illustrates how bids are selected when determining the winner(s) of an auction. Section 6 highlights a number of factors that should be taken into account for the auction rules for the clock auction, including point-based activity rules, revealed preference activity rules, and limitations on the number of supplemental bids. We conclude the paper with a brief appendix showing how an MFA solution can be applied to the OCS Offshore New Jersey, assuming conditions are such that factors other than price must be included in the decision as to who wins tracts in this lease area.

2 Auction design alternatives for alternative energy leases (Summary of Paper 1)

2.1 Objectives of effective auction design

Our first paper, "Auction Design for Wind Rights" (Ausubel and Cramton 2011a), examined alternative auction designs and provided guidance on the suitability of these auction designs for auctioning alternative energy leases on the Outer Continental Shelf. The primary objectives of such an auction are efficiency, competition, consistency, neutrality, revenues, simplicity, and transparency. In order to achieve these objectives, three main principles of effective auction design were highlighted early in the paper: allow for product substitution, encourage price discovery, and induce truthful bidding. This section summarizes this paper.

Product Substitution

One of the challenges of designing an auction for alternative energy leases is the fact that the geographic areas that are available for these leases vary greatly in size and configuration; some areas may support multiple leases and some areas may not. For some lease offerings (such as New Jersey), the bidders have different overlapping areas of interest. Thus, one of the fundamental tasks in designing an auction is to define the products that are being auctioned. We have adopted the term "lot" to define the product that is being sold, such that bidders can bid for one or more "lots" to create a viable tract that they could lease. For some lease areas (such as New Jersey), a lot would be a set of blocks (and sixteenth of blocks) that logically belong together, based on geographic reasons and/or upfront bidder input. For other lease areas where only one lease can realistically fit into the space, all of the blocks (and sixteenth

of blocks) would be combined into a single lot for purposes of the auction. For auctions where multiple lots are being auctioned, substitution can be achieved by adapting the tract configuration to maximize value as the auction progresses. Ideally, bidders would also be able to specify different combinations of lots that they would be willing to receive at the prices in effect at any point in time. That would allow bidders to specify that that they would be willing to receive a lease for area A at $100, or a lease for area B at $90, but not both. Finally, in some circumstances (such as deep sea areas) it might even be possible to use what is known as "generic lots," in which the lot is not for a specific block or set of blocks but can represent one of a number of different areas, all of which have similar properties. In this case, more than one of that type of lot would be available in the auction, and the bidder would be able to specify how many "generic lots" it wishes to receive.

Price Discovery

A second challenge for designing an alternative energy lease auction is the fact that this is a relatively new industry with the potential for competing approaches for using the same lease area. There are a large number of unknowns, all of which factor into the valuation decision for a particular tract. First, the technology is new and rapidly evolving. Second, the level of competition will be unknown, as substantial entry into and exit from the alternative energy sector will be present. Third, valuations of different lots will be highly dependent on the location and quality of the lots, as assessed by the possible bidders. Finally, there will be substantial political uncertainties and the bidders may be asymmetrically affected by the various regional and state factors, such as subsidies, and the bidders may possess asymmetric information about these factors. Some auction designs are more desirable than others in providing information to bidders as to how valuable the lease area is to others and to mitigate situations where bidders may overpay and be subject to what is known as the "winner's curse."

Truthful Bidding

Finally, a third challenge is to design an auction that encourages bidders to bid truthfully. Many auction designs used in the past have resulted in bidders winning products they did not want, bidding up the price on certain products only to withdraw (with limited penalties), or bidding up the price on certain products only to later default on payment. This either could be because they wanted to force a competitor to pay more, or could just be that they did not fully understand the implications of their bid. Other risks include demand reduction, in which large bidders bid for smaller quantities at low prices in order to keep prices low, and bid shading, in which bidders bid below their valuation to improve profitability. A good auction design leads to better efficiency and price discovery.

2.2 "Family of Auctions"

Based on these objectives, the first paper identified five different auction designs, a "family of auctions," that may be well-suited for the offshore wind leasing environment depending on the specifics of the lease area to be auctioned:

- Sealed-bid second-price auction
- Clock auction for a single item
- Clock auction for multiple generic units of a single item (followed by an assignment phase)
- Simultaneous clock auction
- Package Clock auction

The following figure and table illustrate that the choice of auction design depends on the number of lots, whether the lots are similar (generic) or dissimilar, and whether the lots have weak or strong complementarities. Figure 1 shows five different scenarios resulting from the design factors listed

assuming all of the lots in the OCS lease area are to be treated the same in the auction, but there also may be hybrid solutions if some of the lots should be treated differently (e.g. BOEMRE decides to auction a small area associated with a neighboring state at the same time a larger state area); Table 1 provides additional information about each of the scenarios, including a hypothetical situation for each of them.

Figure 1: Family of Auctions: Flowchart highlighting which Auction Format is most appropriate

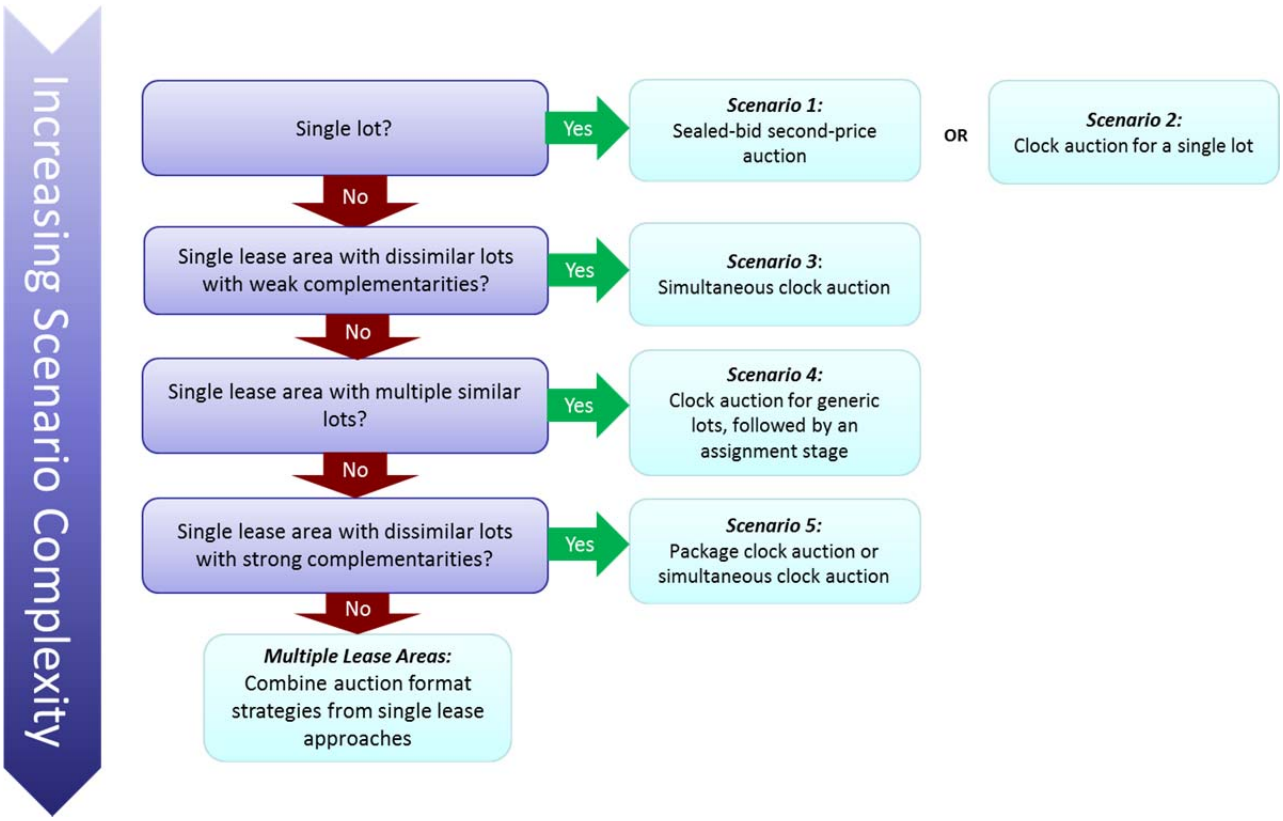

Table 1: Family of Auctions: Auction Scenarios, including Hypothetical Situations

Scenario	Hypothetical Situation	Scenario (Economic terms)	Suggested Auction Format
1	Suppose BOEMRE finds only one project may be supported by a given lease area and offers it a single lot, accordingly. Also, suppose that offshore wind leasing auctions have been running for a few years and the bidders have a good sense as to how much the lot will be worth. BOEMRE could auction a single lot using a sealed-bid second-price auction.	Single lease area, one lot	Sealed-bid second-price auction
2	Suppose BOEMRE finds only one project may be supported by a given lease area and offers it as a single lot, accordingly, but that there is considerable uncertainty about the lot's value. BOEMRE would auction it off as a single unit with one winner.	Single lease area, one lot	Clock auction of a single lot
3	Suppose BOEMRE is able to specify lots within a lease area ahead of time that are each capable of supporting a single offshore wind project. Most of the bidders only want one of the lease areas.	Single lease area for dissimilar lots; weak complementarities	Simultaneous clock auction
4	Suppose BOEMRE is able to identify zones within a lease area where the lots in each zone are of similar value to one another (generic lots).[1]	Single lease area for multiple similar contested lots	Clock auction for multiple generic lots, followed by an assignment stage
5	Suppose BOEMRE offers a larger lease area capable of supporting multiple projects in which the bidders are expected to have different, overlapping areas of interest, both in size and location, and widely varying valuations. The RFI packages for New Jersey illustrate this situation.	Single lease area for dissimilar lots; strong complementarities	Simultaneous clock auction or package clock auction. This allows bidders to aggregate different combinations of lots to form viable tracts. A lot could consist of a block, or a combination of blocks and/or sixteenth of blocks.

[1] It will be difficult for BOEMRE to pre-select generic lots, as bidders will have different valuations for these lots. Thus, this option may not be viable.

Scenario	Hypothetical Situation	Scenario (Economic terms)	Suggested Auction Format
Multiple lease areas	The scenario and preferred auction design will vary depending on the combination. One example: Suppose BOEMRE offers two distinct lease areas at the same time. One of the OCS lease areas is offshore a smaller state and is only capable of supporting a single small project, and the other lease area is offshore the adjoining state and is capable of supporting multiple projects. They are being offered at the same time, as some bidders have expressed an interest in having a large wind farm that spans the two areas.	Lease area 1: single lot. Lease area 2: dissimilar lots; strong complementarities	Simultaneous clock auction or package clock auction with custom auction rules specific to the situation. For example, the auction design might specify that each lease area is an independent “group” and eligibility points and MFA discounts are handled independently for each of the groups.

2.3 Three categories of auctions: Sealed Bid, SMRA, Clock Auctions

The paper then discussed auction design from a broader perspective, grouping the auction designs into three major categories: sealed-bid, simultaneous multiple round auctions (SMRA) including a variation with package bids, and clock auctions including package clock auctions. These auction designs were explained in depth, and the paper highlighted why certain designs were not well-suited for the alternative energy lease auctions.

The first type of auction addressed was the *sealed-bid auction*. In this auction, bidders submit bids for the items in a concealed fashion. This process can be as simple as submitting the bids in a sealed envelope (hence its name) or can be done via an online system. A sealed-bid auction can be for a single lot, many lots, or packages of lots. However, because bidders will have difficulty valuing the lots in the alternative energy lease auction and the fact the lots have strong complementarities in areas like New Jersey; this auction design should not be used for auctions in which there are multiple lots in the auction. With multiple lots, the valuation problem is sufficiently complex that a dynamic auction with good price discovery is desirable. Even in the case of a single lot auction, a sealed-bid auction may not be desirable. If bidders have difficulty valuing the lot, they will be unsure what bid to specify, as they will receive no information relating to the values of other bidders for the lot. This further exacerbates the issue of the "winner's curse," common to first-price auctions. Furthermore, there are probably not many situations where the lease area can be divided into a single lot. Therefore, for consistency, it makes sense to use the same auction design for the few circumstances where there is a single-lot scenario that is being used for the multiple-lot scenarios.

The second type of auction addressed was the *simultaneous multiple round auction (SMRA)*. This auction is a natural generalization of the English auction, and has been used for spectrum auctions in the late 1990s and early 2000s. An SMRA auction was used for auctioning many related items simultaneously. The items are auctioned simultaneously in a sequence of rounds. In each round, each bidder can submit bids on any of the items, raising the provisionally winning bid by at least the bid increment. The auction ends when no bidder is willing to bid higher on any item. An activity rule requires bidders to maintain a level of activity throughout the auction that is commensurate with their desired winnings. This auction design has a number of strengths, in that it has an effective and simple price discovery process, it allows arbitrage across substitutes, allows bidders to see the total price for all lots they are currently bidding for, and reduces winner's curse by revealing common value information during the auction. However, this style of auction has many weaknesses. It encourages large bidders to keep prices low through demand reduction. It also encourages tacit collusion, parking (bidders bidding on lots they do not expect to win simply to maintain a greater number of eligibility points for later in the auction), exposure (the risk of winning only some lots in a collection of complementary lots and thereby not reaping the complementarities), hold up (strategy of a speculator insisting on getting something from a large bidder as quid pro quo for not pushing prices high on key lots desired by the large bidder), limited substitution, and complex bidding strategies. Furthermore, due to the nature of its design, SMRA auctions are quite long, many of them taking several months of bidding to complete. To deal with the exposure problem, a variation of SMRA that allows package bids, a simultaneous ascending auction with package bids (SAAPB), has been studied in academic and lab settings, but has been found to have many shortcomings. The weaknesses of the SMRA often outweigh its strengths, and many SMRA auctions are being replaced with clock auctions over time.

The third type of auction addressed was the *clock auction*. This auction is a multiple round auction in which the auctioneer announces prices for a round and the bidders respond with their demands—which lots they would like to obtain at the specified prices for that round. Prices then increase on products with excess demand and the process repeats. The key difference between a clock

auction and an SMRA is that provisional winners are not determined at the end of each round, only the aggregate demand for each product. The auction ends when there is no excess demand for any product. There are many variations of clock auctions. The simplest variation is a *clock auction for a single item*. In a more complicated variation, *simultaneous clock auction*, bids are package bids. An activity rule requires bidders to maintain a level of activity throughout the auction that is commensurate with their desired winnings. Depending on the product design, a clock auction may be followed by an assignment phase, as would be the case, for example, for a *clock auction of multiple generic lots*.[2] In this situation, all winners of the generic lots would be required to bid for a package of specific lots based on the number of generic lots they have been awarded (with some constraints, such as lots need to be contiguous), and the lots would be allocated according to be the bids received.

The strengths of clock auctions include their openness, transparency, and fairness. Clock auctions have a strong tendency to put the lots in the hands of those who value them the most and they tend to identify competitive market prices. They are a fully dynamic auction, yet can be run from start to finish in short amount of time (often less than a day) and can accommodate limitations in internet access. Furthermore, the activity rule eliminates bid sniping, which is the tendency to wait until the last minute to place serious bids, as is the case with eBay. However, simultaneous clock auctions may lead to unsold lots, demand reduction, and the possibility of too few bids.

A variation of the clock auction, the *package clock auction*, provides all of the advantages of a simultaneous clock auction coupled with the ability to specify additional bids in a supplemental round to reduce the possibility of undersell (unsold lots). Thus, a package clock auction is conducted in two steps. The first step is a clock auction in which bidders specify the packages they wish to purchase at prices specified by the auctioneer; the second step is a supplementary round in which bidders can bid on additional packages as well as improve their bids on packages already placed in the clock auction, subject to a revealed preference activity rule. The auction system then examines all the bids from the clock auction and the supplementary round and finds the assignment of lots that maximizes total value. Payments are often set using a second price rule. The activity rule based on revealed preference motivates bidders to bid consistently throughout the auction process. The strengths of this auction include its elimination of exposure by allowing package bids; its minimization of gaming as a result of package bids, second pricing, and the revealed preference activity rule; it is readily customized to a variety of settings; and it accommodates settings with strong and varied complementarities among bidders, yet works well in simpler settings. Its main weakness is the level of complexity of implementation.

2.4 Clock Auction and Package Clock Auction

Based on the broader discussion of auction designs, the clock auction and the package clock auction stand out as the most appropriate auction designs for the alternative energy leases. The sealed bid auction is not well-suited for an auction with more than one lot, and it is not ideal to have a different auction solution for a single lot auction. An SMRA auction, including the SAAPB variation, has many weaknesses including the length of the auction, demand reduction, and the fact that bidders may end up bidding on (and winning) lots they do not want. A clock auction involving generic units is likely to be infeasible, as BOEMRE's auction team may encounter significant difficulties specifying generic lots given the variation in properties of the different blocks. A clock auction design for simple situations and a package clock auction design for more complicated situations would achieve the design objectives that

[2] Note that it will be difficult for BOEMRE to pre-select lots that they consider to be generic, as bidders are likely to have different valuations for these lots. Thus, this option may not be viable.

were highlighted in the first paper: allow for product substitution, encourage price discovery, and induce truthful bidding.

3 Multiple factor auction design (Summary of Paper 2)

3.1 Overview of Formats

Our second paper, "Multiple Factor Auction Design for Wind Rights" (Ausubel and Cramton 2011b), examines the design of a Multiple Factor Auction (MFA) within the context of off-shore wind energy. This includes a discussion of a variety of MFA formats and the strengths and weaknesses of each one. Special attention is given to the Single-phase MFA and the Two-phase MFA.

Multiple Factor Auctions are used whenever there are additional factors beyond monetary value that need to be allowed to interact with monetary value to determine the winners. These factors can include many different social objectives, such as a desire to favor small businesses or preliminary investments that improve the likelihood of a successful project.

There are four main designs that have been used historically in a government setting to implement multiple factor auctions: comparative hearings, single-phase multiple factor auction, scoring auctions, and two-phase multiple factor auctions. In the following paragraphs, each of these designs is briefly described, and the Two-Phase MFA is proposed as the most appropriate of the multiple factor designs for auctioning OCS wind rights.

3.1.1 Comparative hearing

In a competitive hearing, sometimes called a "beauty contest", winners are determined based on the attractiveness of each proposal to government regulators. There are many problems, however, with comparative hearings. Knowledge of the criterion for winner determination allows the participants to heavily game the system, making themselves seem attractive when they are in fact not. The process of selecting a winner can also be time consuming and expensive, and is vulnerable to litigation. The FCC comparative hearings for cell phone spectrum conducted over a decade from 1971 to 1982 are a prime example of the problems inherent in comparative hearings.

3.1.2 Single-Phase MFA

The single-phase multiple factor auction is the next format that was reviewed. This format is analogous to a Request for Proposal (RFP) process where providers of goods or services submit a sealed bid proposal in response to a procurement request. The proposal contains technical and commercial parts. The technical proposal is usually evaluated first to make sure minimum standards are met. Then, all proposals meeting these minimum technical requirements are evaluated and scored, with the bidder receiving the highest score being the winner. This evaluation can be an evaluation of the bids alone (i.e. the least expensive that meets the minimum requirements wins), or can be a combination of the bids and the technical factors (with an appropriate weighting for each), typically achieved by adjusting the bid price according to the technical factors and then comparing the adjusted bid prices. The problems with this method include the subjective nature of evaluation criteria and the blind financial sealed bid. This exposes bidders to greater risk (as the bidder does not know whether bidding slightly more would enable it to win), and to the winner's curse, and thus encourages bid shading (placing bids below actual valuation), and reduces auction efficiency.

3.1.3 Scoring Auction

In a scoring auction, each bidder is given a score based on the combination of their technical and financial bid. During the auction, the bidder has the opportunity to revise not only its financial bid, but also its technical bid. The contract is then awarded to the bidder who submits the bid with the highest score. This format allows for a "second score" equivalent to a second price. However, it requires objective scoring criteria and the ability for the government to fully and accurately establish the values for the criteria for all bidders. This can be difficult in practice where the government has limited information about the tradeoffs between scoring factors.

3.1.4 Two-Phase MFA

The two-phase multiple factor auction is the most compelling for the purposes of BOEMRE. In the two-phase approach, bidders are first evaluated based on a technical proposal (Phase 1). This technical proposal determines if the bidder is eligible for the products being awarded, and any bidding discounts. Then, all eligible bidders participate in an auction (Phase 2), preferably a clock auction or package clock auction, as discussed below. Bidders will know if they have a price discount after Phase 1 has concluded, and this will affect how high they bid in Phase 2. Other than the discounts that are factored into final payments, the auction is conducted the same manner as a price-only auction. The two-phase format has the advantages of considering multiple factors while also allowing all the benefits of clock auctions.

3.1.5 Summary: The Two-phase MFA is the most appropriate MFA design

Based on the factors outlined above, the two-phase multiple factor auction is the MFA design that is best-suited for auctioning alternative energy leases when there are additional factors beyond monetary value that need to be allowed to interact with monetary value to determine the winners. This approach then allows adoption of any of the clock auction designs in the second phase.

3.2 Selection Criteria

Crucial to the success of the MFA will be setting the technical criteria that will be used to give one applicant priority over another. Each criterion must be transparent, objective, simple and verifiable. We prefer the use of percentage bidder discounts rather than fixed dollar amounts for those bidders meeting the various criteria. Large discounts can have an adverse impact on competition and efficiency. In addition, to the extent that large discounts are available, bidders will have a strong incentive to invest substantial resources into qualifying for the largest possible discounts, instead of engaging in potentially more productive efforts such as assessing lot-specific factors and improving their technological capabilities for carrying out the project. Therefore, we suggest limiting total discounts, say, to at most 25% per bidder. The criteria and associated percentages are decisions that depend on political and business goals that are state-specific. BOEMRE will need to make these decisions. The following table provides samples of the types of factors that can be included.

Table 2: Example factors used in setting bidder discount

Potential factors*	Criteria	Percentage discount*
Currently a holder of an interim policy lease for federal waters?	Yes / No	3%
A certified winner of a competitive process for off-shore wind energy in an adjacent state?	Yes / No	5%
Implemented off-shore wind energy in adjacent state on time?	Yes / No	3%
Responded to state RFP for off-shore wind energy in an adjacent state?	Yes / No	2%
Has applicant constructed a meteorological tower?	Yes / No	5%
Has applicant conducted NEPA-related assessments?	Yes / No	3%
TOTAL		No more than 25%

** All of the factors and percentages listed in the table are hypothetical; they are included to illustrate the concept of how a bidder discount is set in an MFA environment.*

Many of these factors encapsulate preliminary investments that have already been made and which would contribute to the ultimate likelihood of project success. These investments give the bidder greater credibility with capital markets and contribute an advantage in the auction separate from any bidder discount. Since early investments by bidders are automatically recognized in the auction process and lead to a greater probability of winning (as these bidders will be able to bid higher as a result), it may not, in fact, be necessary to recognize them separately by assigning them with bidder discounts, and by doing so, the auction may be double counting these factors.

3.3 Two phase multiple factor auction and Clock Auctions (including Package Clock Auctions)

As stated above, we feel that a two phase multiple factor auction is the most suitable design for an MFA on the OCS. The description of the MFA factors that are eligible for a bidder discount would be defined in the documentation associated with Proposed Sale Notice (PSN) and the Final Sale Notice (FSN). During Phase 1, bidders would submit their qualification materials, including any documentation required to justify receiving discounts from the MFA design. The materials would be analyzed to determine the appropriate bid discount for each bidder. Bidders would be told what their discount is before Phase 2 begins so that they can factor these discounts into their bidding strategy for Phase 2. Bidders should not be told what other bidders received as a discount, as documented in the Information Policy section, Section 6.1.5.

The decision for what type of auction design to use for Phase 2 is the same decision that is used for what auction design to use in a price-only auction. Therefore, depending on the scenario, either a sealed bid auction or a type of clock auction would be appropriate, as outlined in Figure 1 and Table 1.

During Phase 2, bidders bid "full" prices before receiving any discount, as these are the prices that correspond to the auction prices in a given round. However, good auction software will also display the discounted prices on the screen. During the supplemental round, bidders will also bid "full" prices before receiving any discount, as these are the prices that will be compared to other bidders' bids.

The bidder discounts do not directly factor into who will 'win' and be awarded a lease. Rather, they factor into the final price paid. If the final price paid for a package of lots is comparatively lower

than other bidders based on the bidder discount, then that bidder should be willing to bid higher than the other bidders if their valuation of the lots is the same. If they are willing to bid higher, they will increase the chance of being awarded a lease. Thus, in the two-factor MFA design, the bidder discounts often influences who wins the lots and the price paid.

Note that the winner determination problem can proceed for the clock auction without any special knowledge of the multiple factor aspects. This MFA method minimizes the complexity of the clock auction by effectively isolating the MFA aspects to the calculation of final prices.

4 Comparison of Standard and MFA auction formats

4.1 Overview

The main disadvantage of a multiple factor auction design for alternative energy leases on the OCS, is that multiple factor auctions tend to be highly subjective and may not yield efficient outcomes. In an MFA design, someone must make the decision as to what factors to include and the weight given to each of these factors. Bidders then decide whether to adjust their project, upfront investment, and company structure to increase their chances of winning. An MFA design works better in a procurement environment where the buyer is requesting bids for a known commodity and can more easily compare bids based on dimensions such as features, quality, and delivery time. In comparison, generating alternative energy on the OCS is a new industry, and it is not clear which projects proposed by the bidders would be best suited for generating alternative energy on the OCS.

4.2 Underlying reasons for including factors other than price in an auction design

In order to compare standard auction formats to multiple factor format auctions, it is important to understand some of the underlying reasons for multiple factor auctions and discuss whether there are better approaches for addressing these needs. The following list highlights some of the reasons why MFA designs may have been considered for alternative energy leases on the OCS:

1. Preference for bidders with proven experience in developing alternative energy in offshore land tracts and/or proven experience in developing new technologies in a related field;
2. Preference for bidders with sound financial and technical backing;
3. Preference for bidders who have made a significant effort (due diligence) to study the conditions of the lease area;
4. Preference for bidders who have agreements in place for connecting the wind farm (or other alternative energy use) to the adjoining electricity grid;
5. Desire to nurture promising new technologies for alternative energy;
6. Desire to foster competition;
7. Desire to set up an environment where a small business may successfully compete with larger players for this limited resource; and
8. Preference for bidders that meet state-specific goals and interests.

To a large extent, much of the first four concerns can in large part be mitigated with a thorough qualification process. BOEMRE should publish minimum standards for any bidder who wishes to bid for leases on the OCS. These standards should include documentation showing their experience in developing alternative energy projects, their financial and technical backing, proof of due diligence in

studying the topology and wind, and any requisite agreements for connecting their alternative energy project to the electricity grid. In many ways, this is no different than a proposed land-based resource of electricity. It is important that only viable projects be proposed for the limited offshore area. If these concerns can be mitigated through a good qualification process, then there is no need to do this through an MFA process.

The fifth concern, desire to nurture promising new technologies for alternative energy, can be accomplished through use of an MFA process in which new technologies earn a discount. However, BOEMRE may have a higher rate of failure for alternative energy projects in this lease area, as new technology always brings a certain level of risk.

BOEMRE's desire to foster competition may be better served by setting competition constraints such as a maximum number of lots any bidder can win. For situations where there are already lease holders, prior holdings can be factored into the calculation.

The seventh concern, desire to set up an environment where a small business may successfully compete with larger players for this limited resource, can be solved with a good package clock design. Businesses of all sizes can submit bids for lots that meet their business needs. If a small business desires a smaller tract, it is quite possible that their smaller tract may be part of the winning solution, depending on the package bids submitted by the other bidders. We do not advocate bidder discounts for small businesses except as mandated by Congress and only if strict measures are employed so that the small businesses are not fronts for larger businesses. Otherwise large businesses will just establish small businesses to abuse this mechanism.

The politics underlying the last issue, preference for bidders that meet state-specific goals and interests, may necessitate an MFA design. As discussed in our second paper, "Multiple Factor Auction Design for Wind Rights" (Ausubel and Cramton 2011a), any criterion chosen to give bidders a discount must be transparent, objective, simple and verifiable. The discount should be applied as a bidder discount percentage rather than a fixed dollar amount, and we suggest that the total discount be limited, say, to no more than 25% per bidder. BOEMRE will need to make these decisions depending on the state-specific requirements.

4.3 Comparing alternatives against characteristics of good auction design

In order to compare the various MFA and price-only formats, we return to the seven principles of good auction design: efficiency, competition, neutrality, revenues, simplicity and transparency. The following table compares the relative properties of the various MFA and price-only formats for each of these principles for alternative energy leases on the OCS. In the table, the designs that are in the family of auctions are in bold black text, and those that do not appear to be appropriate for the OCS environment are in gray italic text. The Two-Phase MFA design does not rate as high as the price-only formats due to the subjective nature of the bidder discounts. Note that the Two-Phase MFA design is listed several times, as the second phase can be a Sealed-Bid Auction, a Clock Auction for a Single Lot, a Simultaneous Clock Auction or a Package Clock Auction, depending on the complexity of the OCS lease area.

Table 3: Comparison of Different Auction Designs

Format	Efficiency	Competition	Consistency	Neutrality	Revenues	Simplicity	Transparency
MFA Designs							
Comparative hearing	*Very Poor*	*Poor*	*Poor*	*Very Poor*	*Fair*	*Fair*	*Very Poor*
Scoring Auction	*Fair*	*Good*	*Fair*	*Fair*	*Good*	*Fair*	*Fair*
Single Phase MFA	*Fair*	*Good*	*Fair*	*Fair*	*Good*	*Fair*	*Fair*
Two-Phase MFA / Sealed Bid	**Poor**	**Good**	**Fair**	**Fair**	**Good**	**Fair**	**Poor**
Two-Phase MFA / Clock Auction for Single Lot	**Good to Excellent**	**Good**	**Fair**	**Fair**	**Good**	**Good**	**Good**
Two-Phase MFA / Simultaneous Clock Auction	**Fair to Good**	**Good**	**Fair**	**Fair**	**Good**	**Fair to Good**	**Good**
Two-Phase MFA / Package Clock Auction	**Good to Excellent**	**Good**	**Fair**	**Fair**	**Good**	**Fair**	**Fair**
Price – Only Designs							
Sealed Bid	**Poor**	**Good**	**Excellent**	**Good**	**Good**	**Fair**	**Poor**[3]
SMRA	*Fair*	*Good*	*Excellent*	*Good*	*Good*	*Fair*	*Good*
SAAPB	*Fair*	*Fair*	*Excellent*	*Good*	*Good*	*Poor*	*Good*
Independent Clock Auction	*Fair*	*Good*	*Excellent*	*Good*	*Good*	*Poor*[4]	*Good*
Clock Auction for a Single Lot	**Excellent**	**Excellent**	**Excellent**	**Excellent**	**Excellent**	**Excellent**	**Excellent**
Simultaneous Clock Auction	**Good**	**Good**	**Excellent**	**Good**	**Good**	**Good**	**Excellent**
Package Clock Auction	**Excellent**	**Excellent**	**Excellent**	**Good**	**Good to Excellent**	**Fair**	**Good**

[3] A sealed-bid auction may not be appropriate due to high uncertainty regarding prices.
[4] Due to strong complementarities between most lots, an independent clock auction is not appropriate for most circumstances.

4.4 Factoring in competition constraints

There are a number of ways that factors other than price can enter into the decision as to who is awarded a lease for alternative energy leases on the OCS.

First, all bidders must satisfy a minimum standard (technically, financially, and legally) in order to be qualified for a lease. This qualification step is independent of and precedes the auction process. Qualification, by its very nature, gives priority to certain criteria, and any applicant not meeting these criteria cannot win a lease.

Second, if it is desirable to have more than one winner of a given lease area (or overall in the OCS area), competition constraints such as setting a limit on the number of lots won or the number of acres won can easily be incorporated in a clock auction. For environments where there are already existing businesses, the competition constraints can take into consideration prior holdings.

Finally, if the above measures are not enough to incorporate all non-price factors, these additional factors can be incorporated into an MFA design. If an MFA design is used, we prefer a two-phase approach and use bidder discounts to give credit to bidders that meet certain factors.

All of these design options can factor into the clock auction approaches discussed in this paper. A qualification step would precede a clock auction and determine who can bid in the auction. For the MFA auction, the determination of the bidder discount would be Phase 1, and the clock auction, simultaneous clock auction or package clock auction would be Phase 2. The bidder discount would be applied at the end of Phase 2. Competition constraints would also limit which lots a bidder could bid for in the auction.[5]

5 Further discussion on various Clock Auction designs (including the Package Clock Auction)

5.1 Overview

One viable approach that can meet the needs of all scenarios is a clock auction. The clock auction format is a simple format that can be adjusted to handle more complicated economic settings as needed. By using a clock format for all lease areas, the auctioning of wind rights would be handled in a consistent fashion. We will discuss four different varieties of clock auction – one for a clock auction for a single lot and three possible alternatives of a clock auction for multiple lots.

[5] Theoretically, another way to give credit to bidders that have certain characteristics is to do a "set-aside" for proposals that meet certain criteria; only bidders having the desired characteristics can bid for the lots in this set-aside area. Set-asides are sometimes used in other auctions to foster competition in an area to encourage entry and additional competition. However, there is no provision in BOEMRE's regulations to set aside areas in its leasing process, so this is not a viable option in this case and is not listed as an option. In any event, set-asides seem problematic in this application. Determining which lots to set-aside and under what requirements seems highly subjective and therefore vulnerable to legal challenge. Note that The FCC has backed away from set-asides for small businesses due to the fact that participants were gaming the system and acting as fronts for larger companies.

5.2 Clock Auction for a Single Lot

In the rare instance when BOEMRE finds only one project may be supported by a given lease area, this area can be auctioned as a single lot using an ascending clock auction. This clock auction proceeds as a series of rounds, in which the price for the lot continues to rise if the aggregate demand for that lot exceeds one (1). Bidders would specify if they want to continue bidding for the lot at the highest price for that round. With a single lot, bidders are often allowed to specify an exit bid when they want to drop out of bidding. An exit bid allows a bidder to specify the highest price he is willing to bid for the lot instead of only having the "in or out" option of bidding at the highest price for the round. When exit bids are used, the system is better able to assign the lot to the bidder who values it the most, and it also reduces the chance of a tie. Ties should be rare if bidders are allowed to name their own exit price for this single lot, but if it occurs, the winner can be selected randomly from those tied at the winning price.

5.3 Three Possible Clock Auction Designs for Multiple Lots

In most circumstances, there will be multiple lots to auction at the same time in a given auction. A simultaneous clock auction is favored over an independent clock auction in this setting, since we can expect strong complementarities among lots. The simultaneous clock auction allows bidders to bid on packages of lots, and allows bidders to shift demand among lots, depending on the prices reached in the auction. In each round, a bidder would specify the package of lots he most prefers at the current prices.

One of the challenges of a simultaneous clock auction is to minimize undersell—the possibility of selling only a subset of what is available. This may happen when one or more bidders make large reductions in demands as prices increase. The more packages the auction system can consider when determining the winners, the less chance there is undersell in the auction. Increasing the number of packages a bidder can specify also helps bidders specify alternative packages that they are happy to win – perhaps with a different number of lots or a different price. But this added flexibility adds complexity to the bidding process.

The following sections highlight how the number of package bids affects who wins tracts and at what prices. Three alternative designs are discussed – starting with a relatively simple design and ending with a more complicated design – the package clock auction. All of these designs have advantages and disadvantages, which are discussed in greater detail in Section 5.3.4. Four concepts are discussed in greater detail: the point-based activity rule; exit bids (either during the clock auction or during a supplemental round of a package clock auction); the revealed preference activity rule (during a supplemental round of a package clock auction); and the determination of prices paid by the winners.

5.3.1 Approach I: Clock Auction considering bids from the final auction round.

The simplest approach to determine which package bids to include from a simultaneous clock auction is to only consider the bids placed in the final auction round. The auction proceeds in rounds. Each round, each lot in the auction is assigned a price. Bidders choose the package of lots they wish to bid on at the specified prices. Each round, the price on each lot is increased based on the demand, which is the number of bidders bidding on that lot. The price increases on all lots with demand greater than one. Each bidder then adjusts its bid based on the new prices. If the prices have become too high for a bidder, the bidder indicates that they no longer wish to bid and drops out of the auction. The process continues until no lot has a demand greater than one. At this point, the auction ends. For this scenario, the winning bidders are only those that are still bidding in the final round.

This approach is suitable for use only in extremely simple situations. For example, where there can only be a single winner. In more complex situations, this design may yield a large number of unsold lots and a relatively low value, as will be shown in Section 5.3.4 below.

5.3.2 Approach II: Clock Auction considering bids from all rounds

The next approach is a slight increase in complexity from Approach I. In this approach, all bids from previous rounds are considered in determining the winning bids, subject to the constraint that any bidder who was still bidding at the final clock auction prices will win at least the lots he was bidding for at those prices. This is detailed in the next two paragraphs.

The auction proceeds in exactly the same manner as Approach I: Bidding in this auction is identical to bidding in Approach I, and the only difference occurs in the determination of the winning bids. Rather than simply assigning lots to the bidders who remain in the auction in the final round, the entire set of package bids submitted by each bidder in the course of the auction is used in order to find the assignment that maximizes total value. The winning outcome is the collection of non-overlapping package bids, at most one per bidder, which maximizes the total value subject to the constraint listed below. This has the effect of reducing the number of lots that go unsold in Approach I above.

There are two constraints needed in determining the winning set of bidders. First, while the winning bids can potentially be chosen from any of the bids submitted at any point in the auction, each bidder may win at most one of their bids. Second, any bidder who bid for lots in the final round will be guaranteed to win at least those lots.[6] The winning set of bids is then determined as the set of bids that maximizes the total value of all the lots that are assigned, subject to these two constraints. This determination is performed by a "solver" (industry standard software, available off-the-shelf). All bids and the appropriate constraints are fed into the solver, and it returns the value maximizing solution.

5.3.3 Approach III: Package Clock Auction

The final approach is the package clock auction. This auction format is best suited for an auction with multiple lots and the potential for multiple winners, but it is more difficult to implement and does have added complexity for the bidders as described in Section 5.3.4.

Bidding in the package clock auction format proceeds identically to Approach I and Approach II above. However, after demand has fallen sufficiently to end the clock auction, there is an additional round called the supplemental round.

In the supplemental round, which is a single sealed-bid round, bidders are given the opportunity to increase their bids from the final round and to place additional bids. Each bid entered must satisfy a revealed preference activity rule. In the supplemental round, bidders can potentially enter a large number of bids, with each bid for a different package. All of the bids from the clock auction and the supplemental round are fed into the solver, just as they are in Approach II above.[7] The solver then

[6] If this constraint were not present, bidders who dropped out in earlier rounds would have an unfair advantage over bidders who continued to bid in the auction, as bidders who stayed in the auction would not otherwise have been able to express their value, which often would be higher than the prices in the final round of the auction. This constraint properly motivates bidders to stay in the auction and provides each bidder with a means to guarantee that the bidder will win its desired package.

[7] Observe that the Package Clock Auction (Approach III) does not impose the constraint that a bidder will necessarily win the lots on which it bid in the final clock round. This is because a bidder can express its true value for these packages during the supplemental round.

determines the combination of bids with the highest value and the set of winners. As a practical matter, each bidder is limited to a maximum number of bids, such as 500. This ensures that the number of bids is small enough for the solver to find the solution in a reasonable length of time.

The package clock auction enables bidders to more fully express their preferences for packages of lots. Larger bidders with potentially many usable configurations of lots can submit many package bids, while bidders with only a few usable configurations may not need to submit any supplemental bids at all. By having the largest set of bidder preferences to work with, the package clock auction typically will return the highest value and allocate the lots in the most efficient and fair way possible.

5.3.4 Comparison of Different Approaches

Each of the three approaches for a Clock Auction for multiple units described above has advantages and disadvantages. These differences are outlined in the table on the following page. BOEMRE will need to take these points into consideration when considering which approach to use for a given auction.

Table 4: Comparison of Three Auction Approaches

	Approach I (Consider bids from final round)	**Approach II** (Consider bids from all rounds, subject to constraints)	**Approach III** (Package Clock)
Number of bids that bidders can specify	One per round	One per round	One per round, then many bids in the supplemental round, capped at some maximum to guarantee that the winner determination problem can be solved in a reasonable length of time.
Flexibility of being able to define alternative packages of lots which are acceptable.	Limited to one package bid per round	Limited to one package bid per round	Flexible. Can easily define many distinct areas as being acceptable with different valuations.
Ability to specify exact value for package bid	The simplest implementation of Approach I does not allow for exit bids. In this implementation, the auction will end at the clock prices of a given round and bidders bidding for packages at that price will win the lots in those packages. However, the design can be enhanced so that bidders specify an exit bid for their most recent package when they drop out of the auction. This exit bid would only be considered if there was no demand for any lot in the final clock round and the exit bid was entered during this final clock round. The price of the exit bid is capped at the clock price of the round in which it was entered.	The simplest implementation of Approach II does not allow for exit bids. In this implementation, bidders who were bidding for lots at the clock prices of the final clock round will either win that package – or a superset package containing those lots. Other bidders may win packages they were bidding on in previous rounds, provided those packages do not contain any of the lots that had positive demand at the end of the final clock round. The design can be enhanced so that bidders may specify an exit bid for the package they were last bidding on when they switch to a different package or when they drop out of the auction. The price of an exit bid is capped at the clock prices of the round in which it is entered.	Flexible. Bidders determine exact values for all packages, subject to the revealed preference activity rule.
Activity Rules and Limits that Bidder could be constrained by	Point-Based Activity Rule Exit Bid Price Limit Contiguous Area	Point-Based Activity Rule Exit Bid Price Limit Contiguous Area	Point-Based Activity Rule Revealed Preference Activity Rule Contiguous Area

	Approach I (Consider bids from final round)	**Approach II** (Consider bids from all rounds, subject to constraints)	**Approach III** (Package Clock)
How winners are determined	In the simplest implementation, the winners are simply the bidders who entered a package bid at the clock prices in the final round. However, if no bidder bid for lots at the clock prices for the final round and if exit bids are part of the implementation, a solver would be used to determine which combination of bidders should win their package bids. Only bids in the final clock round including exit bids are considered. The winning bidders would be those whose combination of package bids give the highest value.	The solver determines the feasible combination of package bids that gives the highest total value subject to the constraints that a bidder wins at most one of its packages, and that a bidder bidding for lots in the final round wins at least the lots it bid for in the final round.	The solver determines the combination of package bids (from the clock auction plus the supplemental round) that gives the highest value. The bidders who were bidding for lots in the final Clock Auction round may or may not win these lots, depending on their bids in the supplemental round. All bidders are subject to the Revealed Preference Activity Rule.
How tie bids could be handled	If two or more package combinations of exit bids yield the same value, the winning combination is chosen randomly.	If two or more package combinations yield the same total value, the winning combination is chosen randomly.	If two or more package combinations yield the same total value, the winning combination is chosen randomly.
How prices are determined	Winning prices are simply the prices bid in the final clock round.	Winning prices are the highest price bid for a given package. Lower bids for the same package are ignored.	Second pricing is used to motivate truthful bids throughout the auction. The algorithms for determining second prices are more complicated than determining first prices, but can be solved using off-the-shelf software.
Potential for undersell	Most undersell of the three approaches	Degree of undersell depends on how much variation there is in packages submitted each round. Will likely be less undersell than Approach I.	Least undersell of the three approaches

5.3.5 Scenario Illustrating Effect of Different Approaches

This section presents an example scenario showing possible differences among three different methods of winner determination in an ascending simultaneous clock auction. First, the scenario is set up with a set of simplified products and bidders. Next, the different winner determination methods are discussed. Finally, the example scenario is followed through an auction, showing the results of each winner determination approach.

Products: There are a total of 12 individual lots, each one a unique product. For the purposes of this example, the lots can be labeled lot 1 through Lot 12. Each lot will be auctioned starting at a Price of $10. The lots are equally sized and occupy a 3x4 grid. For simplicity, the lots will be assumed to be similar other than their physical location.

Lots		
Lot 1	Lot 2	Lot 3
Lot 4	Lot 5	Lot 6
Lot 7	Lot 8	Lot 9
Lot 10	Lot 11	Lot 12

Bidders: There are four bidders. Each bidder has a different business plan for a different set of lots, as outlined in the table below. The bidders are named A, B, C, and D.

Table 5: Business Plans for each of the Bidders

<table>
<tr><th>Bidder</th><th>Business Plan</th></tr>
<tr><td>Bidder A</td><td>Bidder A plans to build a large Wind Farm, utilizing Lots 1 through 8 or Lots 4 through 11. The bidder can afford to pay up to $90 in either case.
<table>
<tr><th colspan="3">Plan A1</th></tr>
<tr><td>1</td><td>1</td><td>1</td></tr>
<tr><td>1</td><td>1</td><td>1</td></tr>
<tr><td>1</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">$90</td></tr>
</table>
<table>
<tr><th colspan="3">Plan A2</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>1</td><td>1</td><td>1</td></tr>
<tr><td>1</td><td>1</td><td>1</td></tr>
<tr><td>1</td><td>1</td><td></td></tr>
<tr><td colspan="3">$90</td></tr>
</table></td></tr>
<tr><td>Bidder B</td><td>Bidder B wants a set of 4 contiguous blocks arranged in a square. (Lots 5, 6, 8, and 9, for example). However, bidder B does not want Lot 1 in any of its packages. The bidder can afford to pay up to roughly $47 for the 4 lots. Some of the sets of 4 lots are worth slightly less, some slightly more. Bidder B also has a larger plan for 5 Lots (Plan B6), and can afford to pay up to $58 for this configuration.
<table>
<tr><th colspan="3">Plan B1</th></tr>
<tr><td></td><td>1</td><td>1</td></tr>
<tr><td></td><td>1</td><td>1</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">$46</td></tr>
</table>
<table>
<tr><th colspan="3">Plan B2</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>1</td><td>1</td><td></td></tr>
<tr><td>1</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">$47</td></tr>
</table>
<table>
<tr><th colspan="3">Plan B3</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td>1</td><td>1</td></tr>
<tr><td></td><td>1</td><td>1</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">$46</td></tr>
</table></td></tr>
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<table>
<tr><td></td><td>
<table><tr><th colspan="3">Plan B4</th></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr><tr><td>1</td><td>1</td><td></td></tr><tr><td>1</td><td>1</td><td></td></tr><tr><td colspan="3">$47</td></tr></table>
<table><tr><th colspan="3">Plan B5</th></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td>1</td><td>1</td></tr><tr><td></td><td>1</td><td>1</td></tr><tr><td colspan="3">$48</td></tr></table>
<table><tr><th colspan="3">Plan B6</th></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td>1</td><td>1</td></tr><tr><td>1</td><td>1</td><td>1</td></tr><tr><td colspan="3">$58</td></tr></table>
</td></tr>
<tr><td>Bidder C</td><td>Bidder C wants a set of 3 contiguous blocks arranged in a horizontal line. (So, Lots 1, 2, and 3 or Lots 7, 8, and 9, for example). The bidder can afford to pay up to roughly $33 for the 3 lots. Bidder C does not want Lots 10, 11, or 12.
<table><tr><th colspan="3">Plan C1</th></tr><tr><td>1</td><td>1</td><td>1</td></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr><tr><td colspan="3">$33</td></tr></table>
<table><tr><th colspan="3">Plan C2</th></tr><tr><td></td><td></td><td></td></tr><tr><td>1</td><td>1</td><td>1</td></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr><tr><td colspan="3">$32</td></tr></table>
<table><tr><th colspan="3">Plan C3</th></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr><tr><td>1</td><td>1</td><td>1</td></tr><tr><td></td><td></td><td></td></tr><tr><td colspan="3">$34</td></tr></table>
</td></tr>
<tr><td>Bidder D</td><td>Bidder D has 3 possible business plans. The bidder is willing to utilize any one of the plans but is not capable of using more than one of the plans at once. The bidder would like to pick the plan where they make the largest profit.
Plans:
Plan D1: Lots 1, 4, and 7. The bidder is willing to pay $32 for these blocks.
Plan D2: Lots 7, 10 and, 11. The bidder is willing to pay $34 for these blocks.
Plan D3: Lots 2, 3, and 5. The bidder is willing to pay $34 for these blocks.
<table><tr><th colspan="3">Plan D1</th></tr><tr><td>1</td><td></td><td></td></tr><tr><td>1</td><td></td><td></td></tr><tr><td>1</td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr><tr><td colspan="3">$32</td></tr></table>
<table><tr><th colspan="3">Plan D2</th></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr><tr><td>1</td><td></td><td></td></tr><tr><td>1</td><td>1</td><td></td></tr><tr><td colspan="3">$34</td></tr></table>
<table><tr><th colspan="3">Plan D3</th></tr><tr><td></td><td>1</td><td>1</td></tr><tr><td></td><td>1</td><td></td></tr><tr><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td></tr><tr><td colspan="3">$34</td></tr></table>
</td></tr>
</table>

Auction Format: The auction proceeds as a clock auction in rounds. Remember that in a clock auction, there are no provisional winners. After each round, the next round's prices and the excess demand are reported to all bidders for each lot. No additional information (such as the details of individual bids) is revealed. The auction continues until there is no excess demand for any lots in a round. At that point, winners are determined, or the supplemental round is held in the case of the package clock auction.

There are three approaches to determining the winners:

- ***Approach I (Clock Auction with Bids from final round considered)***: The simplest approach is to use only the bids from the final round of the auction to determine winners.
- ***Approach II (Clock Auction with all Bids considered)***: This approach is similar to Approach I except now all bids from all rounds of the auction are considered. A bidder may only win at most one of

their bids. A bidder who bids for lots in the final round is guaranteed to win a package with at least those lots. The winning set of bids maximizes total value subject to this constraint.

- ***Approach III (Package Clock Auction)***: The final approach is the package clock auction. After the clock auction is completed, bidders are allowed to submit additional bids in a supplemental round. The set of winning bids is then determined from the set of all bids submitted during the clock auction and during the additional supplemental round.

Example Auction: For simplicity we assume bidders will bid as high as their value for a given lot but not higher, and that exit bids are not possible. For Approach I and II, winning prices are as bid. For Approach III, we will use a second price methodology to determine winning prices. Other alternatives exist for determining these winning prices (See Section 6.2.17). With all these conditions in place, the example will proceed as follows:

Round 1

All lots have a starting price of $10.

Round 1 Prices for each Lot:

Prices in $		
10	10	10
10	10	10
10	10	10
10	10	10

Round 1 Bids:

Bidder A		
1	1	1
1	1	1
1	1	
$80		

Bidder B		
	1	1
1	1	1
$50		

Bidder C		
1	1	1
$30		

Bidder D		
	1	1
	1	
$30		

After the close of bidding in Round 1, the following total demand in each of the lots is reported to all bidders:

Round 1 Total Demand for each Lot:

Demand (# of Bidders)		
2	3	3
1	2	1
1	2	1
1	1	1

Round 2

Prices are increased based on excess demand. For simplicity, each lot will have its price increased by $1 for each point of excess demand. Excess demand is simply the total demand minus 1. Thus, the price will not increase on lots which have a demand of 0 or 1.

Round 2 Prices for each Lot:

Prices in $		
11	12	12
10	11	10
10	11	10
10	10	10

In response to the price increase on many of the lower numbered lots, bidders will switch to the cheaper, higher numbered lots.

Round 2 Bids:

Bidder A		
1	1	1
1	1	1
1	1	
$82		

Bidder B		
	1	1
1	1	1
$51		

Bidder C		
1	1	1
$31		

Bidder D		
1		
1	1	
$30		

This causes total demand to shift significantly from Round 1.

Round 2 Total Demand for each Lot:

Demand (# of Bidders)		
0	0	0
1	1	1
3	3	3
3	3	1

Round 3

Prices are again increased for lots with excess demand. At this point many of the lots have become too expensive for the bidders.

Round 3 Prices for each Lot:

Prices in $		
11	12	12
10	11	10
12	13	12
12	12	10

The bidders are now constrained in what they are able to bid for. Note that Bidder A dropped out, as Lots 4-11 cost $91 and Lots 1-8 cost $91, both of which exceed its budget of $90. Bidder D also dropped out, as the price for Lots 1,4, and 7 costs $33; Lots 7, 10 and 11 costs $36; and Lots 2, 3, and 5

cost $35, all of which exceed its budget. Finally, Bidder B can no longer afford its large package of 5 blocks.

Round 3 Bids:

Bidder A		
Drops out		

Bidder B		
	1	1
	1	1
$47		

Bidder C		
1	1	1
$31		

Bidder D		
Drops out		

The demand for each lot has now fallen to 1 or 0. Thus, the clock auction has concluded.

Round 3 Total Demand for each Lot:

Demand (# of Bidders)		
0	0	0
1	1	1
0	1	1
0	1	1

5.3.6 Determining winners for the three approaches

Approach I

In this simplest approach, the bidders who remained in the auction in the final round of the clock are winners.

Approach I Winners:

Demand (# of Bidders)		
-	-	-
C	C	C
	B	B
	B	B
Total Value = $78 Bidder B ($47) + Bidder C ($31)		
Unsold Lots: 5		

Approach II

In this approach, all Bids from all Rounds of the auction are considered and the set of bids with the highest value is selected. Bidders who bid for lots in the final round are guaranteed to win those Lots. In this example, Bidder B's Round 2 Bid for 51 can be used to slightly decrease undersell.

Approach II Winners:

Demand (# of Bidders)		
-	-	-
C	C	C
	B	B
B	B	B
Total Value = $82 Bidder B ($51) + Bidder C ($31)		
Unsold Lots: 4		

Approach III

In this approach, bidders are allowed to place additional supplemental bids (and sometimes increase their bids on existing packages) if their preferences have not yet been fully expressed in the clock auction. Given the business plans of the bidders, the bidders will each place bids for all available sets of lots that are feasible. The bids that can be placed are limited by the revealed preference activity rule. See 6.2.15 for more information on the revealed preference activity rule.

Bidder A's Bids in Supplemental Round:

Bid from Clock Auction (Updated Price)		
1	1	1
1	1	1
1	1	
$90		

Bid from Clock Auction (Updated Price)		
1	1	1
1	1	1
1	1	
$90		

Bidder B's Bids in Supplemental Round:

Extra bid		
	1	1
	1	1
$46		

Extra Bid		
1	1	
1	1	
$47		

Extra bid		
	1	1
	1	1
$46		

Extra bid		
1	1	
1	1	
$47		

Bid from Clock Auction (updated price)		
	1	1
	1	1
$48		

Bid from Clock Auction (Updated Price)		
	1	1
1	1	1
$58		

Bidder C's Bids in Supplemental Round:

Bid from Clock Auction (Updated Price)		
1	1	1
$33		

Bid from Clock Auction (updated price)		
1	1	1
$32		

Bid from Clock Auction (Updated Price)		
1	1	1
$34		

Bidder D's Bids in Supplemental Round:

Extra bid		
1		
1		
1		
$32		

Bid from Clock Auction (Updated Price)		
1		
1	1	
$34		

Bid from Clock Auction (Updated Price)		
	1	1
	1	
$34		

With all bids in place, the Winner Determination problem is solved and the most efficient set of bids is found. Note that the Total Value is $123 based on a $90 bid from Bidder A and a $33 bid from Bidder B. However, a package clock auction is often done as a second price auction. One approach for determining second prices is to calculate VCG-nearest prices, as described in "The Quadratic Core-Selecting Payment Rule for Combinatorial Auctions" (Day and Cramton 2012). Based on this calculation, Bidder A will pay $80 and Bidder D will pay $30.

Approach III Winners:

Demand (# of Bidders)		
C	C	C
A	A	A
A	A	A
A	A	
Total Value = $123 Bidder A (Bid $90) + Bidder C (Bid $33)		
Unsold Lots: 1		

Bidders who did not drop out may feel some uncertainty regarding whether they will ultimately be winners in the auction, as the supplemental round is essentially a sealed-bid round. This uncertainty is largely mitigated by the Revealed Preference Activity rule, as bids in the supplemental round are capped. For example, bidders who were still bidding at the prices in the final Clock Auction round can bid as much as they want for their final package bid; bidders who dropped out before the final Clock Auction round cannot do that. Bidders who were still bidding for lots at the final clock prices will win the lots in their final package bid that was entered in the clock auction (or more), with a high degree of likelihood, if they raise their final package bid by the amount of the unsold lots in the clock auction

(valued at the final clock prices). See Propositions 1 and 2 of "Spectrum Auction Design" (Cramton 2009).

5.3.7 Summary of Results

The above example auction is characteristic of the three possible approaches to the Winner Determination Problem. Approach I, using only the final clock auction bids, resulted in significant undersell, when a large bidder dropped out in the final round. Approach II, using the full set of clock auction bids, had less undersell and a more efficient outcome. This approach took into consideration the bidders who valued the most highly-desired lots, but note that it was limited to bids that were submitted during the clock auction: bidders were not able to define alternative areas that they would be willing to lease. Approach III, in which the bidders were allowed to fully express their preferences by adding additional bids in the supplemental round, provided the most efficient outcome. The bidders who were most willing to pay for lots were the ones who were awarded lots. In this way, Approach III can be said to be the most fair and efficient to all the parties involved: it gives all the bidders the best opportunity to express their preferences and win when their winning maximizes total value. The strengths of Approach III (e.g. bidders being able to express all of their preferences) must be balanced against its complexity (e.g. bidders being restricted by the revealed preference activity rule during the supplemental round, second prices, and the (albeit small) level of uncertainty associated with a sealed-bid supplemental round.

5.3.8 Point-Based Activity Rule

In order to ensure that the auction ends within a reasonable period of time and to encourage bidders to bid truthfully and not "bid snipe," clock auctions often include a point-based activity rule that limits bidding activity later in the auction based on bidding activity earlier in the auction. This rule encourages bidders to submit truthful bids in each round of the auction and provides a disincentive to conceal their preferences. Bidders are assigned an initial number of eligibility points that is based on their upfront deposit amount. Each lot is assigned a number of bidding points, most likely based on the number of acres in a given lot (or some other rough estimate of their relative value). In the first round of the auction, bidders are allowed to place bids on lots with bidding points which sum to less than or equal to their initial number of eligibility points. In subsequent rounds, bidders are restricted to placing bids on packages with a total number of bidding points that are less than or equal to their current number of eligibility points. If bidders bid for packages that contain fewer points than their eligibility points, the number of eligibility points for that bidder may be lower in the following round, depending on the activity percentage. An activity percentage is used to give bidders some flexibility to switch between packages from round to round without losing eligibility points. For example, the activity percentage may start at a lower percentage (e.g. 80%) and be raised at announced times during the auction (e.g. 80%, then 90%, then 100%). If the activity percentage is set to 80%, then a bidder only needs to place a bid for 80% of his eligibility points in order to maintain this number of eligibility points in the following round. This is the approach used for many spectrum auctions.

For the three round auction described above, each lot was assumed to be roughly the same size and had been assigned 1 bidding point. In this example, each of the four bidders (A-D) was assigned a maximum of 12 eligibility points in Round 1. Each of the four bidders placed a bid for a package of lots in Round 1.

Based on these Round 1 bids, the Round 2 bids would be limited by the current number of eligibility points for that bidder. The right-hand column of the following table illustrates the number of eligibility points each of these bidders has going into Round 2 if the activity percentage was 90% and if we round up. Notice that this precludes Bidder D from combining two of his packages into a big package

in Round 2, as that would add up to 6 points when he only bid for a package that adds up to no more than 4 bidding points. Since Bidder D is down to a maximum of 4 eligibility points going into Round 2, he can only bid for each of these packages separately. If the activity percentage is 100%, the limit is just the number of bidding points from the Round 1 Bid (as shown in the 4th column).

Bidder	Round	# of Bidding Points in Round 1 Bid	Limit: # of Eligibility Points for Round 2 (based on 100%)	Limit: # of Eligibility Points for Round 2 (based on 90%)
Bidder A	1	8	8	9
Bidder B	1	5	5	6
Bidder C	1	3	3	4
Bidder D	1	3	3	4

Section 6.2.7 contains a more complicated example where the number of bidding points per lot varies due to the size of each lot.

5.3.9 Exit Bids

An exit bid is a mechanism by which a bidder can specify the highest price he is willing to bid for a given package. This price must be less than the price that was announced for a given round. Exit bids help minimize undersell and help resolve ties.

Suppose the prices in a given round were such that all bidders dropped out. In this case, nothing would be sold. Some auction designs allow the last auction round to be re-run with smaller price increments. A better approach is to allow bidders to specify exit bids when they stop bidding on a given package. An exit bid for a given package would, by definition, add up to less than the sum of the clock prices for those lots.

The applicability of exit bids varies depending on the auction design. For Approach I, an exit bid would only be allowed when a bidder dropped out of the auction. In this case, the bidder would be asked to specify the highest price it would be willing to pay for the package. For Approach II, exit bids would be allowed on a given package if a bidder bid for a different package in the next round or if the bidder stopped bidding altogether. For Approach III, exit bids are entered in the supplemental round and may be for existing packages or new packages.

For Approach I, if all bidders dropped out of the auction in a given round due to prices getting too high, the exit bids from that round would be used to determine winners. A solver would be used to determine the solution with the highest total value.

An example of an exit bid for Approach I for Bidder D would be:

Exit Bid (entered in Round 3)		
1		
1	1	
$34		

For Approach II, exit bids allow bidders to more precisely specify the value of their package bids, as the clock prices may not be precise enough. This will help assign the lots to bidders who value them the most and will reduce the chance of a tie. The solver would determine the solution with the highest total value. If at least one bidder was still bidding when the clock auction closed, the exit bids from that round plus the exit bids from previous rounds would be used to determine winners, subject to the constraint that any bidder who was bidding for a package at the clock auction prices would necessarily win that package (or another larger package that contained those lots). The solver would determine the combination that maximizes total value.

An example of the exit bids for Approach II for Bidder D would be as follows. Both of these packages were valued at the same price, as can be seen by the initial valuations in the Business Plans table on page 21:

Exit Bid Entered in Round 2		
	1	1
	1	
$34		

Exit Bid Entered in Round 3		
1		
1	1	
$34		

For Approach III, bidders are given an opportunity to increase their bid for any packages they bid for, plus place bids for additional (new) packages. If a bidder dropped out during the auction, the bid for any existing package must be less than the sum of the lots' clock prices in the last round they were eligible to bid for this package (based on eligibility points).[8] Any additional package bid must be less than the sum of the lots' clock prices in the last round they were eligible to bid for this new package. If a bidder did not drop out of the auction, the bidder may also optionally increase the package bid for the final package they were bidding on. If they increase their final package price, this will increase the maximum price they can bid for other packages, subject to the limits defined in the revealed preference activity rule. The next section illustrates this concept in greater detail.

[8] This is different than the exit bid for Approaches I and II, for in these approaches, the exit bid for a round must be less than the sum of the lots' clock prices for that round.

5.3.10 Revealed Preference Activity Rule

For Approach III, an additional rule is needed to constrain bids in the supplemental round. Intuitively, bidders should not be allowed to place bids in the supplemental round for packages at prices where they have already chosen to drop out in the clock auction. For purposes of illustration, we will assume the activity percentage for the point-based activity rule is 100%.

An illustrative example of such a rule is provided in the United Kingdom Ofcom "Consultation on assessment of future mobile competition and proposals for the award of 800 MHz and 2.6 GHz spectrum and related issues," Annex 9 Sections 9.69 – 9.72:

> *Supplementary bid amounts for all packages other than the FPP are subject to a relative cap. The cap on a package A is set to:*
>
> *a) The amount of the highest bid (made in either a primary bid round or the supplementary bid round) for package B, where B is the package that the bidder bid for the last primary round in which the bidder was eligible to bid for package A; plus*
>
> b) *The price difference between the two packages (price of package A minus price of package B) at the round prices prevailing in the last round that the bidder was eligible to bid for package A.*

In this rule, the Final Primary Package (FPP) is the package that the bidder was bidding on in the final clock auction round. So, the FPP is not subject to a cap. The bidder may increase their bid on their FPP as much as they want. All other packages, however, are capped. Determination of these caps is best illustrated through examples.

The price and bid data in the following examples is displayed using the following format:

Lots		
Lot 1	Lot 2	Lot 3
Lot 4	Lot 5	Lot 6
Lot 7	Lot 8	Lot 9
Lot 10	Lot 11	Lot 12

Example of Revealed Preference in Supplemental Round for Bidder C

Prices										
Round 1				Round 2				Round 3		
10	10	10		11	12	12		11	12	12
10	10	10		10	11	10		10	11	10
10	10	10		10	11	10		12	14	12
10	10	10		10	10	10		12	12	10

Bidder C Clock Bids										
Round 1				Round 2				Round 3		
1	1	1								
								1	1	1
				1	1	1				
$30				$31				$31		

Bidder C Supplemental Bids										
Package 1				Package 2				Package 3		
1	1	1								
				1	1	1				
								1	1	1
$33				$32				$34		

The bid for the FPP will determine the caps for all other packages, so we look at Package 2 first:

Package 2: Since Package 2 is Bidder C's Final Primary Package (the package they bid on in the final Round of the Clock Auction), Bidder C has no cap for Package 2.

Package 1: To compute the cap on Package 1's price, we must sum the two parts (a) and (b) above. In Round 3, Bidder C bid on Package 2, but was eligible to bid on Package 1. So, part (a) is Bidder C's Supplemental Package bid of $32. The price of Package 1 in Round 3 is $35, while the price of Package 2 in Round 3 is $31. Therefore, the cap for Package 1 is the sum of the (a) and (b) parts, or $32 + ($35 - $31) = **$36**. Note that this cap is dependent upon Bidder C placing the $32 bid for Package 2 in the Supplemental Round.

Package 3: In Round 3, Bidder C was eligible to bid on Package 3. So, part (a) is Bidder C's Supplemental Package Bid of $32. The price of Package 3 in Round 3 is $37, while the price of Package 2 in Round 3 is $31. Therefore, the cap on Package 3 is $32 + ($37 - $31) = **$38**. Again, this depends on Bidder C placing the $32 Bid for Package 2 in the supplemental Round.

Example of Revealed Preference in Supplemental Round for Bidder D

Prices										
Round 1				Round 2				Round 3		
10	10	10		11	12	12		11	12	12
10	10	10		10	11	10		10	11	10
10	10	10		10	11	10		12	14	12
10	10	10		10	10	10		12	12	10

Bidder D Clock Bids										
Round 1				Round 2				Round 3		
	1	1								
	1									
				1						
				1	1					
$30				$30				$0		

Bidder D Supplemental Bids										
Package 1				Package 2				Package 3		
1									1	1
1									1	
1				1						
				1	1					
$32				$34				$34		

Package 1: Bidder D was last eligible to bid on package 1 in Round 3. Part (a) is $0, the package bid that bidder places for the empty package in Round 3. Part (b) is the price of package 1 in Round 3, $33, minus the price of the empty package in Round 3, $0. So, the cap for package 1 is $0 + ($33 - $0) = **$33**.

Package 2: Bidder D dropped out with package 2 in Round 2 with a bid of $30. However, they were last eligible to bid on package 2 in Round 3. Part (a) is $0, the package bid that Bidder D placed for the empty package in Round 3. Part (b) is the price of package 2 in Round 3, $36, minus the price of the empty package in Round 3, $0. So, the cap for package 2 is $0 + ($36 - $0) = **$36**.

Package 3: Bidder D was last eligible to bid on Package 3 in Round 3. Part (a) is thus again $0. Part (b) is the price of package 3 in Round 3, $35, minus the price of the empty package, $0. So, the cap for package 3 is $0 + ($35 - $0) = **$35**.[9]

[9] One issue that is notable from the above examples is that for a given package, bidders are able to bid up to and including the price of that package in the round that they dropped out. This can be slightly confusing. For example, in Round 3, Bidder D chose not to bid for package 3 at a price of $35. They dropped out instead. Nonetheless, their cap for package 3 in the supplemental Round is in fact $35, allowing them a second chance to bid for package 3 at the price for that package in Round 3.

A simple way to fix this is to decrease all of the computed bid cap amounts by $1. This would cause Bidder D's package 3 cap to be $34, or one dollar less than the price of Package 3 in Round 3. Note that in a real auction with large prices and the ability to specify prices to one dollar precision, a difference of one dollar would be too small to cause any real issues. It is only in the example where the prices are small that it appears to be a more serious problem.

Section 6.2.15 contains a more complicated example that highlights a revealed preference activity rule when the lots are worth different amounts of bidding points. The example focuses on a situation where the bidder wants to place an additional bid for a package that they were eligible to bid for in a previous round.

5.3.11 Winning Prices – First Price, Second Price, and Clearing Price

There are three types of winning prices for OCS auctions, depending on the auction format:

- In a "first price" auction, a winner of a lot pays what it bid for that lot, i.e. it is "pay as bid."
- In a "second price" auction for individual lots, a winner of a lot pays the price bid for that lot by a bidder who did not win the lot (the "runner up"). In a "second price" auction where a solver determines the winner based on the various combinations of package bids that were submitted, the second price is the smallest price that the winner can pay such that no other bidder or combination of bidders would have a higher value from their bids. Academic research has shown that bidders are more likely to bid their true values if they end up paying a "second price." See Vickrey (1961) and Ausubel and Milgrom (2002), for example.
- In a clock auction, the "clearing price" is the price at which the demand for the lot is less than or equal to its supply.

The determination of winning prices for the auction formats described in this section varies depending on the alternative and on the use of exit bids.

- For a clock auction of a single lot, the winning price is the "clearing price."
- For Approach I, the winning price(s) are the "clearing prices" of the lots in the clock auction unless all bidders drop out in the final round and exit bids are part of the auction design. In that case, the winning price(s) will be exit bid(s), a "first price" solution.
- For Approach II, the winning prices vary depending on which package bids are selected by the solver. If the solver chooses a package bid that the bidder was bidding for at the clock prices in the final clock round, then that winning price is a "clearing price" for that package. Otherwise, the winning price is either the highest clock price that a bidder entered for that package (if exit bids are not used) or the exit bid price for that package (if exit bids are used). In either case, these latter bids correspond to a "first price" solution.
- For Approach III, the Package Clock auction design, the winning prices are normally calculated using "second prices." The rationale for doing this is that bidders would typically only agree to submit their true value if they are assured that they would be required to only pay a price that is based on the competitive bids of the other bidders. Common "second price" solutions for a combinatorial solver include Vickrey prices and VCG-nearest prices.

In all cases, the winning prices are reduced by any multiple factor discounts if such factors exist for a particular auction.

6 Considerations for Auction Rules

6.1 Pre-Auction rules and procedures

6.1.1 Lots to be offered

Defining the lots to be offered in the auction is an important aspect of pre-auction planning. The auction procedures can be less complicated if lease areas are predefined by the government. However, aggregating lease areas can be difficult for the government in situations where bidders have unique business plans and where there are multiple technology options for building out wind farms that require more or less lease space. Modern auction methodologies allow regulators to use smaller geographic areas ("lots") that bidders can combine to create unique packages that meet their business needs. The government should try to aggregate lease areas where it makes business sense to minimize the number of lots in an auction wherever possible. These proposed lots should be included in the Call as well as the PSN and FSN to allow bidders to provide their feedback on the lots to be offered in the auction. For example, in Maryland there may only be enough space for a single viable wind farm. In that circumstance it makes sense to aggregate the blocks and sixteenth of blocks into a single auction lot. We would also suggest that sixteenth of blocks be aggregated with neighboring blocks to simplify the auction interface for bidders and the winner determination problem for the Government. Our second paper, "Multiple Factor Auction Design for Wind Rights" (Ausubel and Cramton 2011b), provided a few simple rules that could be used to do this aggregation:

- For partial blocks, group the partial blocks with one of its neighbors, preferably a full-block. Many of the blocks for New Jersey only contain 1 or 3 sixteenth of blocks, and these can easily be combined with a full block next to it. These blocks may otherwise go unsold, as they cannot easily be used by others.
- For blocks that do not have any contiguous blocks on three of its four sides, group it with its neighboring block. Otherwise, this block may go unsold.
- In special cases, such as contiguous deep water lots with very similar properties, group these blocks together, if possible, as generic lots with assignment of specific lots to winners being performed after the auction.
- Finally, based on the RFI responses, look for groupings that all potential bidders consider to be part of a set. For example, if in all responses, bidders have either selected to include blocks X and Y in their nominations or exclude blocks X and Y from their nomination – i.e. no bidder has chosen X and not Y, nor Y and not X – then both X and Y could be grouped together. However, it should be noted that as such RFI responses are non-binding, such nominations may not reflect the bidders' true interests. Furthermore, there may be other bidders who did not respond to the RFI which want lots grouped together differently than those indicated by the RFI responses.

In addition to defining the lots to be included in the auction, BOEMRE must specify the rights, responsibilities and restrictions of each lot in the auction. These rules might include such things as lease duration, build-out deadlines, known lease stipulations, and required protections of neighboring areas. BOEMRE would also need to identify any competition constraints in the auction that would limit the amount of the available lease area that any one bidder could win in the auction.

6.1.2 Prohibition of Collusion; compliance with Antitrust Laws

Auction competition and efficient lease assignment are compromised when bidders collude before, during or after an auction. Collusion can take many forms in a multiple round auction process and sellers must be diligent in defining and enforcing anti-collusion rules. In the Proposed Sale Notice (PSN) and Final Sale Notice (FSN), BOEMRE would specify rules to prohibit collusion during the auction process. The rules must clearly specify the entities that are subject to the rules, when the rules are effective, and what is considered prohibited communications. Entities that intend to bid as a group should be required to disclose any and all such bidding agreements and arrangements. Bidders should be required to certify that they understand the anti-collusion rules, will abide by them, and will report any prohibited communications that they become aware of. They should make BOEMRE aware of any existing arrangements, and any companies that are linked (or have such an arrangement) would be required to bid as a single bidder. Enforcement of the rules may include forfeiture of bidders' upfront payment deposits, additional fines, removal from the auction process, and/or black listed for future auctions. Bidders should also be reminded that they are required to comply with all applicable antitrust laws.

6.1.3 Notification of auction dates, requirements, seminars

In the Proposed Sale Notice and Final Sale Notice, BOEMRE would specify the pre-auction dates and deadlines, logistical information regarding the auction seminar and registration procedures, and general auction application and financial requirements. The FSN would identify the lots that will be offered and the auction format that will be used. If an MFA design is to be used, the FSN must clearly identify the factors that will be considered when calculating the bidder discount. The FSN may also include bidder warnings to conduct due diligence prior to participating in a lease auction and/or warnings regarding the speculative nature of wind farm operations. Finally, the FSN should provide an internet address where information about the auction and copies of auction-related documentation can be found, including the auction schedule.

6.1.4 Auction Bidder qualification

The PSN and FSN should specify the auction bidder qualification requirements and application filing procedures. The bidder qualification requirements may dictate that certain technical, financial, and legal standards be met. The documentation required to meet these standards must be clearly articulated. If a bidder is not qualified, they will not be eligible for a lease.

Generally, government auction procedures require bidders to submit an auction application and financial deposit prior to becoming a registered bidder.[10] The financial deposit requirements (both before the auction and after the auction) must be clearly articulated.

The auction application normally requires potential bidders to disclose their ownership structure, contact information and various auction certifications that they are qualified to bid and will be bound by the auction rules. The application must be signed by an authorized individual of the company. Requiring bidders to disclose detailed ownership information as part of their auction application can be

[10] In FCC auctions, bidders are allowed to "cure" defective applications, as long as they meet the application or financial deposit deadline. The FCC sends out "cure" letters to bidders who are required to resubmit their application. Public Notices are released to identify applicants who are qualified, incomplete, and disqualified. Applicants that do not cure their application by the resubmission deadline are disqualified. A final "qualified bidder" Public Notice is issued that identifies the qualified and disqualified applicants.

important to enforce anti-collusion rules, to score bidders in multiple factor auction procedures, and to enforce competition constraints.

Bidder contact information is collected during the application process, and is used by the auctioneer to send out bidder credentials. Having bidders self-certify that they are qualified to bid and will abide by the auction rules coupled with a significant auction bidding deposit have worked well in high-stakes government auctions to ensure that only serious bidders participate in the auction process.

If a multiple factor auction design will be used, the scoring criteria must be clearly articulated. The documentation requirements for these criteria must be included in the Proposed Sale Notice.

The application standards should be articulated. For example, will bidders be permitted to resubmit their application if it is found to be defective or will they be held to a "letter perfect" standard. If a bidder misses the application or financial deposit deadline, will they be disqualified? How will bidders be notified of their bidder status?

6.1.5 Information Policy (Pre-Auction)

Auction applications are generally publically available. In some cases confidential business information is redacted if the application requires, for example, financial information to be disclosed. In some cases, the amount of the upfront payments or financial limits is withheld until after the auction because disclosure of such information could be detrimental to the competitiveness of the auction. In general, all information is made public after the auction. It is particularly important to release the identities of the bidders and their ownership structure before the auction starts, so that bidders know exactly who is participating in the auction so that they can abide by the anti-collusion rules.

6.2 Clock Auction rules and procedures

The following section describes the clock auction process that would be followed by all bidders that have been qualified for the auction.

6.2.1 Distribution of auction system credentials (login/password, etc.)

Bidders nominate bidding representatives either in the auction application process or once the bidder has been qualified. Generally the bidder is permitted to nominate up to three individuals who are permitted to login to the auction system and place bids on behalf of the bidding entity and the auctioneer distributes the login credentials to each of these individuals in advance of the auction. If additional security is required, security software and/or hardware can be distributed to bidding representatives in addition to the login credentials.

6.2.2 Documentation & Training

Prior to the auction, a User Guide is distributed to qualified bidders explaining the bidding process, the bidding system interface, the IT requirements for accessing the system, the system login procedures, and file structure of any files that can be downloaded or uploaded (e.g. supplemental bids for a package clock auction). This document contains all of the necessary information for bidders to use the auction system and includes frequently asked questions and contact information for a bidder help desk. A few days before the auction, the auctioneer conducts a mock auction that allows bidders to practice logging into the system and placing bids. The mock auction normally runs for a number of rounds and allows bidders to become familiar with the bidding and round results processes. This is also an opportunity for bidders to test their back up procedures in the event that their internet access is interrupted or if they have a problem with their primary computer. Some bidders may want to develop

their own tools to analyze round results, and for package clock auctions, to generate supplemental bids. The mock auction allows bidders to test these tools.

6.2.3 Auction Structure

As stated in Section 5, the clock auction consists of a series of discrete rounds. The auctioneer sets a round schedule for the first day or two of the auction. The round schedule often contains bidding rounds that are generally 30 minutes to one hour in length and include 15 – 30 minute recesses between rounds. Once the round opens, bidders are permitted to submit their bids. When the round closes, the auctioneer processes the round results and sets the next round prices. The demand information and new prices are made available to the bidders through the auction system. Bidders can download round results files and analyze the bidding activity. The next round opens and the process repeats until a round ends and there is no excess demand on any of the lots in the auction.

In a package clock auction, there is a supplemental round following the clock auction during which bidders are permitted to make additional bids in a single round that they were not able to express in the clock auction rounds.[11] As stated in Section 5 above, this supplemental round can be important to reduce the number of lots that may be unallocated at the end of the auction. All bids placed during the supplemental round are subject to the revealed preference activity rule described in Section 6.2.15.

6.2.4 Communication with the Auctioneer

Bidders have a variety of options during the auction to communicate with the Auctioneer. There is a dedicated help desk for each auction where bidders can call and ask questions or get help using the auction system. These calls are normally logged and recorded. The Auctioneer communicates with the bidders through the announcement and messaging facilities of the auction system. Announcements are sent by the Auctioneer to communicate to all bidders. Messages can be sent to and from specific bidders. All announcements and messages are recorded in the system audit log.

6.2.5 Submitting clock auction bids

Once the round opens, bidders are permitted to submit bids. The auction system should not accept any bids that are in conflict with point-based activity rules, financial limits, revealed preference activity rules, and competition constraints. The bidder should be able to modify their bids at any point during the round until the round closes.

6.2.6 Clock auction prices

Each of the auction lots is assigned an opening price in the auction, and if required, a reserve price, as defined in the Final Sale Notice. The reserve price is the minimum price that the auctioneer is allowed to sell the lot for. Generally in government auctions, the reserve price is published and is often the same as the opening price.

Once bidding begins, if there is excess demand, the price increases in the next round. The amount of the increase is called a bid increment and the new price is often referred to as the minimum acceptable price. Generally, the price increment is zero when there is no excess demand and is increasing in the level of excess demand -- but the choice of price increment depends on the desired duration of the auction and the relationship between the starting price and the expected clearing price.

[11] If all products sold in the last round of the primary clock phase and there was no undersell, a supplemental round does not need to take place. The Auction Rules should specify whether or not the supplemental round occurs in this situation.

The following table provides an illustrative example of default increment percentages:

Table 6: Illustrative Default Increment Percentages for Clock Auction

Excess Demand	Default Increment
0	0%
1	4%
2	8%
3	12%
4	16%
Greater than or equal to 5	20%

The incrementing rules are often published in advance to bidders, but the auction rules normally provide flexibility that the percentages can be adjusted if market conditions warrant such changes. The percentage increases will obviously impact the number of rounds in the auction.

6.2.7 Point-Based Activity Rule

In order to ensure that the auction ends within a reasonable period of time and to encourage bidders to bid truthfully and not "bid snipe," clock auctions often include a point-based activity rule that limit bidding activity later in the auction based on bidding activity earlier in the auction. This rule effectively forces bidders to submit relevant bids in each round of the auction and provides a strong disincentive to concealing their preferences. The exact rules depend on the level of anticipated competition for a particular lease area, the desired length of the auction, and the extent of substitutability among different lots.

Section 5.3.8 discussed the point-based activity rule in detail and provided a simple example. This section provides a more realistic example where the number of points varies by lot, as the lot sizes may vary. Table 7 shows the bids for a single bidder for each of six lots (Lot A – Lot F) for each of five auction rounds. Prices in bold and shaded in yellow represent lots that the bidder is bidding for, while lots that are italics (not shaded in yellow) are not within the package bid. Note that prices for the lots are increasing each round if there is excess demand, and so the bidder is adjusting his bids accordingly:

Table 7: Bids during clock auction – eligibility point example

Round #	Lot A Price (200 Bidding Points)	Lot B Price (250 Bidding Points)	Lot C Price (150 Bidding Points)	Lot D Price (50 Bidding Points)	Lot E Price (60 Bidding Points)	Lot F Price (40 Bidding Points)	Sum of Bidding Points for lots bid ("Aggregate Bidding Points")	Price Bid
1	**50**	**50**	**50**	**50**	**50**	**50**	750	300
2	**90**	**100**	**80**	**80**	**90**	**90**	750	530
3	**100**	**100**	**90**	**90**	*100*	*90*	650	380
4	**130**	**140**	**140**	**140**	**130**	*130*	710	680
5	**130**	**140**	**150**	**140**	*130*	*130*	650	560

Table 8 shows the bidder's eligibility points for each round. The number of eligibility points is determined based on the current activity percentage (e.g. 80%, 90%, 100%) and what the bidder bid in the previous round. Notice that the "Eligibility Points" for the next round reduces as the auction

progresses due to the bidder reducing his demand and due to the change in pre-defined activity percentage. These changes reduce the bidder's options as to what he can bid for in subsequent rounds, and thus minimizes prevents bid sniping.

Table 8: Eligibility Points Example

Round #	"Activity Percentage" for the round set by Auctioneer	"Eligibility Points" for the bidder	Maximum "Aggregate Bidding Points" the bidder can bid for	Minimum "Aggregate Bidding Points" the bidder must bid for or lose "Eligibility Points" in the next round (based on Activity %)	Aggregate Bidding Points of bid shown in Table 6	"Eligibility Points" for Next Round as a result of the bid placed
1	80%	800[12]	800	640	750	800
2	90%	800	800	720	750	800
3	90%	800	800	720	650	722
4	100%	722	722	722	710	710
5	100%	710	710	710	650	650
. . .						

6.2.8 Financial Limit

Bidders can also be limited in terms of the total financial bid that they submit in the auction. In some auctions, the bidders' upfront deposit is used to calculate an upper bound on the amount that he can bid in the auction, often known as a financial limit. However, for most auctions, it is more common to use the upfront deposit to set a bidder's eligibility points (and thus limit the quantity it can bid for) rather than providing a financial constraint.

6.2.9 Contiguous lots rule

In order to prevent a bidder from holding a lot or two hostage ("hold up") during the auction, which it has no intention of using, it is important that BOEMRE establish rules that require a bidder to bid for contiguous lots. Otherwise, a bidder can bid for a single lot in the middle of someone else's lease area just to increase the clock prices for that package bid for their competitor.

BOEMRE must balance the needs of bidders who genuinely want two areas in the auction that are not contiguous (perhaps to combine with areas that they already have rights to) with the desire to prevent one bidder from holding up another bidder.

6.2.10 Revealed Preference Activity Rule – Clock Auction

Some clock auctions include a "revealed preference activity rule" to encourage bidders to bid their true preferences during the clock auction rounds. The rule requires bidders when changing packages to shift toward packages that have become relatively less expensive. For package clock

[12] Eligibility Points for Round 1 are set based on upfront deposit amount.

auctions, the "revealed preference activity rule" is often applied during the supplemental round. See Section 6.2.15 for a discussion on the revealed preference activity rule.

6.2.11 Competition constraints

BOEMRE may want to achieve social goals such as encouraging competition in a given lease area. In this case, the government may want to implement a lease area cap that would prohibit a single bidder from winning more than some percentage (e.g. 45%) of the available lease area. Although this constraint does add another dimension to the determination of the winners, it is different than the MFA factors discussed in Section 3. With an MFA, bidders either receive a discount in what they pay for a lease or receive a better score in determining who is awarded a lease. With a bidding cap, all bidders are limited in what they can bid for.

In some government auctions where there are existing players and new entrants bidding for scarce resources (as is the case for FCC spectrum auctions), the competition caps can be bidder-specific; that is, each bidder has a different cap such that their overall holdings after the auction would be below a specified percentage (e.g. 45%). This issue is probably not a concern for the initial auctions for renewable energy leases, but may be an issue for later auctions.

Any lease area caps must be implemented carefully and corporate structures must be scrutinized to ensure that existing companies are not bypassing the constraints by setting up "new entrants" to bid on their behalf.

6.2.12 Bidding in exceptional circumstances

Bidders are responsible for ensuring that they have back up mechanisms in place in the event that they are unable to submit their bids via their standard Internet connection before the round closes (such as having an alternative computer or internet connection). The backup mechanism is often tested during the mock auction. In the event of an exceptional Internet service outage, power failure, or other technical or human failure that prevents a bidder from entering a bid in the electronic auction system, bidders may be allowed to phone or fax their bid to the auctioneer at BOEMRE's discretion. Strict procedures will be followed to ensure the request is authentic, complete, has been received on time, and is logged.

In some clock auction implementations, each bidder is allowed one round extension. If a bidder fails to submit a bid during the round, the auction round is automatically extended for 10 to 15 minutes in order for the bidder to submit its bid and continue to participate in the auction. Under no circumstances should bidders be allowed to rejoin an auction in a later round after failing to bid in a round, as that gives that bidder an unfair advantage over other bidders (and is in breach of the activity rule).

6.2.13 End of clock auction

The clock auction ends when there is no excess demand in the round on any of the lots in the auction.

6.2.14 Supplemental round (if Package Clock Auction)

In a package clock auction, bidders are given an opportunity to submit additional bids that they were unable to express in the clock phase of the auction. This takes place during a supplemental round. All bidders who placed at least one bid during the clock phase may participate in the supplemental round. Bidders may adjust their package bids and/or submit additional packages during this

supplemental round, subject to financial limits, competition constraints, and a constraint known as a "revealed preference activity rule."

The auction rules normally include a limitation on the number of package bids that can be submitted in the supplemental round. The limitation is based on practical factors such as how long it will take to solve the winner determination problem. For BOEMRE, it is reasonable to assume that bidders can submit up to, say, 500 package bids in the supplemental round of the auction, but the exact number should be finalized at a later date after analysis is done regarding the expected number of bidders and lots for a particular lease area.

6.2.15 Revealed Preference Activity Rule (Supplemental Round)

It is important to include a revealed preference activity rule for the supplemental round in a package clock auction to prevent bid sniping during the supplemental round. "System and Method for a Dynamic Auction with Package Bidding" (Ausubel and Milgrom 2001), and "The Clock-Proxy Auction: a Practical Combinatorial Auction Design" (Ausubel, Cramton and Milgrom 2006) document how a revealed preference activity rule works. The details of the revealed preference activity rule for an alternative energy lease auction should be defined in the FSN.

Section 5.3.10 describes how a revealed preference activity rule could be applied to the sample auction described earlier in Section 5.3. The revealed preference activity rule used in that example is based on the rules used by Ofcom for its auction of 800 MHz and 2.6 GHz spectrum. A slightly more complicated example is documented below. This example describes a situation where a bidder wants to place a package bid for more lots than he was bidding for at the end of the clock phase. In this example, the number of bidding points varies by lot. This example is also based on the Ofcom rules, and is provided for illustrative purposes only.

Suppose a bidder is bidding in an auction that has 6 lots. In this example, the number of bidding points for each product equals the acreage of that lot. The activity percentage is 100%; if bidders bid for fewer bidding points, their eligibility will go down the next round. Suppose the clock auction lasted 5 rounds. The price of the lots for each of the 5 rounds is listed in the following table. Prices in bold and shaded in yellow represent lots that the bidder is bidding for, while lots that are in italics (not shaded in yellow) are not within the package bid.

Table 9: Prices of lots for each clock auction round – Revealed Preference Activity Rule example

Round #	Lot 1 Price (35 Bidding Points)	Lot 2 (50 Bidding Points)	Lot 3 (55 Bidding Points)	Lot 4 (50 Bidding Points)	Lot 5 (80 Bidding Points)	Lot 6 (60 Bidding Points)	Sum of Bidding Points for lots bid ("Aggregate Bidding Points")	Price Bid
1	**50**	**50**	**50**	**50**	**50**	*50*	270	250
2	*90*	*100*	**80**	**80**	**90**	*90*	185	250
3	*100*	*100*	**90**	**90**	**100**	*90*	185	280
4	*130*	*140*	**140**	*140*	**130**	*130*	135	270
5	*130*	*140*	**150**	*140*	**130**	*130*	135	280

Thus, the bidder has placed bids for the following packages:

- Round 1: 1, 2, 3, 4, 5 (Bid price: $250)
- Round 2: 3, 4, 5 (Bid price: $250)

- Round 3: 3, 4, 5 (Bid price: $280)
- Round 4: 3, 5 (Bid price: $270)
- Round 5: 3, 5 (Bid Price: $280)

Suppose the bidder wants to place an additional bid for lots (2,3,4,5) in the supplemental round. This supplemental bid must abide by certain constraints. In this illustrative example, the constraints can be summarized as follows, and are applied iteratively from the smallest packages to the largest packages:

- Any bidder who dropped out of the auction at a given point is allowed to increase his final package up to and including the price of the round in which they dropped out, subject to financial limits. This allows them to more accurately specify how much they are willing to pay for their final package.[13]
- Any bidder who bid a positive quantity for a package of lots during the final clock round may raise his bid for that final package, subject to financial limits.
- Any bidder is allowed to raise his bid for a previous package (Package A), subject to financial limits and subject to a relative cap based on the package the bidder did bid for (Package B) in the last round in which the bidder was *eligible to bid for* Package A (based on eligibility points).
- Any bidder is allowed additional package bids based on constraints. A new package bid (Package C), can be added subject to financial limits, competition constraints, and subject to a relative cap that is based on the package the bidder did bid for (Package D) in the last round in which the bidder was *eligible to bid for* Package C (based on eligibility points). This allows bidders to specify alternative packages that they are willing to receive.

So, for this example, package (2,3,4,5) requires 235 eligibility points. The last round the bidder could have bid for this package based on eligibility points was Round 2. Note that during Round 2 of the clock auction, the bidder chose to bid for package (3,4,5). The revealed preference activity rule price cap for package (2,3,4,5) is $380, calculated as follows:

- The highest amount the bidder bid for package (3,4,5) in any round: $280
- Plus the difference in price for package (2,3,4,5) and (3,4,5) in the last round that the bidder could have bid for package (2,3,4,5) – Round 2. $100+$80+$80+$90 - ($80+$80+$90) = $100

Therefore, the bidder can place a bid for lots (2,3,4,5) in the supplemental round up to a price of $380 ($280 + $100).

6.2.16 Determining Winners

Which bidder wins a particular lot depends on a number of factors: which bids are counted and the specifics of those bids, as detailed in Section 5. For a *clock auction of a single lot*, the bidder who bid the most for that lot is the winner. For a *simultaneous clock auction in which only bids from the final round are considered* (Approach I), the winners will be those who are bidding for lots in the final round[14].

[13] Another alternative is to give bidders the option to specify "drop-out" prices for their final package in the last clock round in which they want to bid.

[14] If no bidders are bidding for lots at the final clock prices and an exit bid strategy is in place, then the solver will determine the winners from the exit bids in the final round based on the set of package bids that maximize value.

For a *simultaneous clock auction with all bids considered (Approach II)*, winner determination will be the set of package bids that maximize value, subject to the constraint that a bidder bidding for lots in the final clock round wins at least those lots. For a *package clock auction* (Approach III), all bids from the clock auction and the supplemental round are considered by the solver and the winners are the set of package bids that maximize value. In all designs, the solver will assign at most one package to each bidder and will assign each lot only once. There are a number of ways to resolve ties if more than one set of bids result in the same value. In practice, ties are resolved randomly or by applying tie breaking constraints such as maximizing lots sold, or maximizing number of winners. See Section 5.3.9.

6.2.17 Determining Winning Prices

The determination of winning prices varies depending on the type of auction and the specific auction rules. The winning price may be a "first price," "second price" or a "clearing price," depending on the auction rules. See Section 5.3.11 for a description of the winning prices for the clock auction formats proposed in that section. In all cases, the winning prices are reduced by any multiple factor discounts if such factors exist for a particular auction.

6.2.18 Information Policy (during Auction)

As noted earlier, it is important to release the identities of the bidders and their ownership structure before the auction bidding so that bidders know exactly who is participating in the auction so that they can abide by the anti-collusion rules. The bidder list for the auction should be made available after qualification. If a two-phase MFA design is used, bidders should also be told their bidder discount prior to the clock auction phase (Phase 2), as this will influence their bidding decisions. They should not, however, be told the bidder discounts of the other bidders, as this may inadvertently reveal private information such as contracts with PPAs.

Prior to the clock auction, each bidder should have the following information:

- the up-to-date auction schedule;
- a list of the lots available for auction and the associated bidding points;
- the initial eligibility points for their company;
- the financial limits, if any, for their company; and
- any competition constraints associated with their company (caps, maximum percentage they can bid for).

The following information should be available to all bidders after each clock round is processed:

- the aggregate demand for each round;
- whether the clock auction will continue for another round; and
- their eligibility points for the next round.

The following information should be available to all bidders after the next round's prices are announced:

- The minimum number of activity points they need to bid for in order to stay in the auction another round; and
- The price of all lots for that coming round.

Although this information is made available to bidders on the auction website, summary information should be made available to the general public on a different website for security reasons. This keeps the internet traffic to the production website to a minimum.

In most clock auctions, only the aggregate demands—and not the individual bids or the identities of the associated bidders—are reported to participants. In early simultaneous multiple round auctions, the FCC and other spectrum regulators adopted full transparency policies where the bid amount and bidder identity were published after each round of the auction. Recently, regulators have modified their policies and procedures to limit the amount of information that is made available to bidders during the auction bidding process. In full transparency auction settings, bidders could easily park their eligibility on lots that they had no chance of winning and could engage in anti-competitive bidding behavior retaliating against their competitors. In most recent auctions, the auctioneer discloses only the aggregate demand on each lot and does not disclose the identities of the bidders.

6.3 Post Auction Rules & Procedures

6.3.1 Final Contract

Once the auction winners and final prices are determined, the bidders are usually required to take additional steps to obtain their lease. In many auctions, the bidding rules contain a contract that the bidder must execute after the auction. Note that BOEMRE has a legal responsibility to provide the Department of Justice (DOJ) at least 30 days following the auction in which to conduct an antitrust review of the sale; this responsibility must be met before it can issue the leases.

6.3.2 Final payment/refunds

Upfront deposits are either applied to the winning bidders' final prices or are returned to unsuccessful bidders. Winning bidders must pay the balance of their winning bid and file the required financial assurance within 10 business days of receiving the lease copies from BOEMRE.

6.3.3 Information Policy (post-Auction)

Once the winners are announced, many government auctioneers disclose all bidding information publically including the package definitions, bid prices, and the identities of the bidders. Winning bidders generally do not want regulators to disclose their final bids since they normally represent their true value for the packages and could be considered confidential business information. The advantage of full disclosure is that interested parties can replicate the results of the auction. If bidding information is withheld after the auction, it is important to have an independent auditor validate the auction results so that losing bidders are assured that the process was conducted fairly and in full compliance with the stated auction rules.

6.3.4 Bidder defaults and secondary market lease trading

If a winning bidder does not deposit its final payment, the bidder is in default; its upfront deposit is forfeited, the lease area remains unallocated and can be re-auctioned at a later date.

If a winning bidder who holds a lease decides to sell its lease, regulators must determine whether the lease transfer is permissible based on the lease rules (including competition constraint

objectives) and must also decide whether a winner in a multiple factor auction should be required to reimburse the government for its discount if the lessee would not qualify for the original discount. [15]

7 Summary

As discussed in our first paper, "Auction Design for Wind Rights" (Ausubel and Cramton 2011a), Albert Einstein's advice that we should "make things as simple as possible, but not simpler" is an important principle of market design. This design principle is adhered to in this paper, where we discuss various auction designs that can be used to award leases for alternative energy leases on the US Outer Continental Shelf (OCS).

Our first paper analyzed a number of standard auction formats and concluded that a "family of auctions" would best serve BOEMRE's needs for auctioning off leases for alternative energy uses (such as wind farms) on the OCS. Further analysis indicated that one of the alternatives, auctioning generic lots, was not feasible due to the difficulty in defining these generic lots. In addition, a sealed-bid auction design was problematic due to the lack of price discovery. We noted that a clock auction design supports the various types of scenarios that BOEMRE is likely to encounter for off-shore wind rights. A clock auction for a single lot can be used when the lease area can only support a single winner. A simultaneous clock auction or a package clock can be used for more complicated scenarios. If preliminary analysis indicates that only one lease (such as a wind farm) can fit in the lease area for Maryland, then Maryland would be an example of when to use a clock auction for a single lot. If, instead, preliminary analysis indicates that two or more leases can fit in Maryland, then a simultaneous clock auction format is probably appropriate. For New Jersey, we know that there are many bidders interested in different tracts within the lease area. Thus, New Jersey is a good example of when a simultaneous clock auction or a package clock auction should be considered.

Our second paper analyzed a number of multiple factor auction (MFA) designs and concluded that a two-phase auction design would best serve BOEMRE's needs if factors other than price needed to be counted in determining who wins a lease. These factors could enter into the equation directly (by being part of a score to compare to other bids) or indirectly (by discounting the price the bidder would pay). All MFA auctions are subjective in nature, as someone needs to decide what factors would give one bidder relative priority over another bidder, and how these factors interact with price. Most of these decisions are political in nature and outside the scope of this paper. Ideally, these deciding factors should be part of a qualification process (technical, financial, and legal). If deciding factors cannot be factored into a qualification step, then they can be incorporated into the auction design as a bidder discount. When they are factored into the bidder discount, then they indirectly affect the determination of winners through the price paid.

In this paper, we compared the auction formats on a number of dimensions of good auction design: efficiency, competition, neutrality, revenues, simplicity and transparency. We also discussed the implications if a competition constraint was factored into the auction design, and how this would work with a clock auction. If a clock auction is used as the underlying mechanism, the bidding interface is simple and consistent, and the auction design provides much-needed price discovery.

[15] The Federal Communications Commission instituted unjust enrichment provisions in its rules that require auction winners within three years of the auction to pay back the amount of the discount if the license is transferred to a party that is not eligible for the discount.

We provided a simple example for how winners are determined in the various clock auctions, commented on a number of considerations for the auction rules, including points-based activity rules and revealed preference activity rules. We conclude this paper with a brief appendix showing how an MFA solution can be applied to the area off of New Jersey, assuming that factors other than price must be included in the decision as to who wins tracts in this lease area.

Clock auctions have been used successfully for over 10 years around the world to auction commodities such as spectrum, electricity, and natural gas. Package Clock auctions have been successfully used in recent years to solve more complicated auction problems for telecommunications spectrum. These auctions have used commercial auction software to facilitate bidding and enforce the auction rules. A similar strategy can be employed by BOEMRE to meet its needs for an auction of alternative energy leases on the Outer Continental Shelf.

Appendix A: New Jersey

The area off the shore of New Jersey is one of the highest demand areas, and thus it is one of the most likely contenders for an auction. Indeed, there were 11 responses to the New Jersey Call. Based on the responses, there are clearly multiple feasible lease areas with strong and varied complementarities across the product space. Due to these factors, the New Jersey area should be divided into a number of lots to be auctioned.

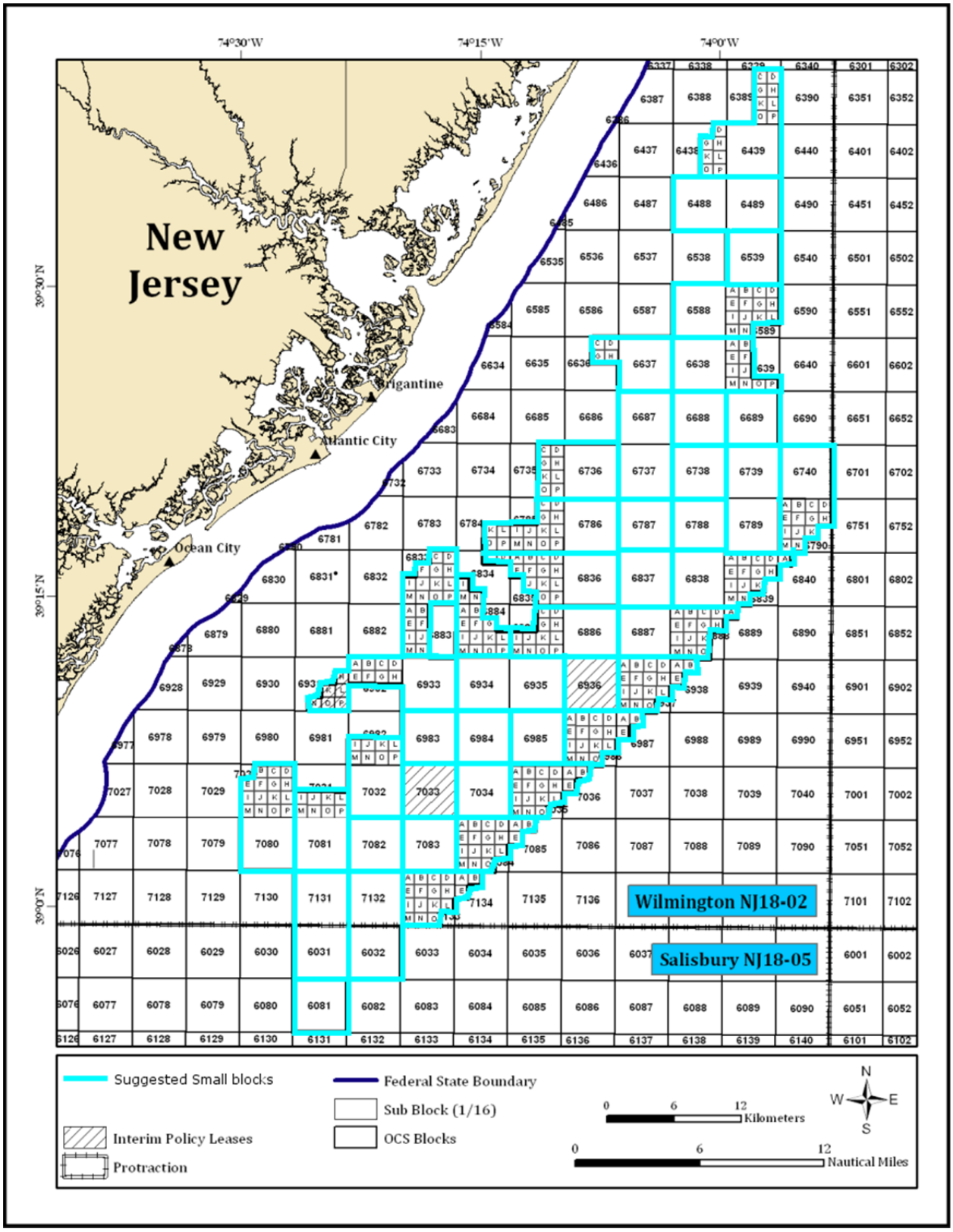
The New Jersey area could be done with a simultaneous clock auction or a package clock auction. A package clock auction would give more flexibility to bidders in specifying lease areas that meet their needs. The responses to the RFI show that at least one bidder would be happy to receive one of three very different lease areas. The package clock auction is specifically designed to allow the bidder to express a rich set of alternatives.

7.1 Determining the lots

New Jersey, like other lease areas, contains a number of blocks, some of which contain 16 sixteenth of blocks, and some of which are partial blocks. Using the criteria for grouping blocks and sixteenth of blocks into lots, as described in Section 6.1.1, we have produced an illustrative set of groupings that reduce the total number of lots available to 44, shown in Figure 2: Example of lots for New Jersey.

There are many advantages in grouping neighboring blocks. First, the complexity of solving the winner determination problem is reduced. With 44 total lots, 11 bidders, and a reasonable cap on the total number of package bids per bidder (such as 500), there should be no difficulty solving the winner determination problem quickly on modern hardware. More importantly, however, is that the complexity of bidding is reduced as well. Reducing the number of lots means that bidders will need to create fewer packages; this makes the auction results easier to understand and more fair to unsophisticated bidders.

Figure 2: Example of lots for New Jersey



7.2 Clock Auction including factors other than price

Based on the number of lots and the likelihood for multiple winners, a good approach for the New Jersey auction is to use a price-only clock auction, either a simultaneous clock auction or a package clock auction. A package clock auction will give bidders the most flexibility in specifying alternative lease areas. However, if political and business conditions in New Jersey are such that factors other than price need to be part of the decision of who wins leases, then a two-phase multiple factor auction design can be used. Phase 1 of the MFA would determine the bidder discount. Phase 2 would be a package clock auction. Bidder discounts would be applied after the second-price auction problem is solved.

In Phase 1 of the auction, bidders will submit their qualification information and BOEMRE will evaluate all the candidates. Bidders who did not meet certain qualification standards would be disqualified and not allowed to participate in the auction. Any bidder discounts can be determined at this time. It is important that any bidder discounts that are used are modest in nature.

Phase 2 of the auction could be conducted as a package clock auction. In each clock round, the bidders will place a bid for a package of lots, subject to point-based activity rule constraints, revealed preference activity rule constraints, financial constraints and competition constraints. In the supplemental phase, additional package bids may be placed, subject to these same constraints. After the supplemental round, the winner determination problem is solved, winners are identified, and winning prices (second prices) are determined. If the winner has a bidder discount, this discount is then applied to this winning price.

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