Design of the Alberta Capacity Market

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12 September 2018
Initial Filing

I was asked by the Alberta Utilities Commission to review and comment on the proposed design of the Alberta Capacity Market. This filing presents my initial views.

I am an independent witness, residing at 6418 Dahlonega Rd, Bethesda MD 20816, USA. I have substantial expertise in the design of capacity markets and electricity market design more broadly. I have advised governments and system operators on the design of capacity markets in North America, South America, and Europe. My CV is attached (Schedule A). Research papers and filings are available on my website: www.cramton.umd.edu.

I was instructed by the Alberta Utilities Commission to review the proposed design of the Alberta Capacity Market as presented on the Alberta Electric System Operator website. I focused on the consolidated proposal and the consolidated rationale that are available on this site. I also drew on my experience in capacity market design in other regions and my knowledge of the Alberta electricity market. I comment broadly on most elements of the proposed design. My specific Statement of Work with the Commission is contained in Schedule A to document number 23757 X0008 (or exhibit 8 in proceeding # 23757).

I acknowledge that I have a duty to provide opinion evidence to the Commission that is fair, objective and non-partisan.

I have made no factual assumptions in preparing this report. The body of my report refers to the references relied upon. My experience in the study and design of capacity markets is detailed in my CV.

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Summary

I review and comment on the proposed design of the Alberta Capacity Market as presented on the Alberta Electric System Operator website. I draw on my experience in designing capacity markets in many regions. A well-designed capacity market can support the goal of reliable electricity at least cost. The market coordinates investment to ensure resource adequacy, consistent with the reliability requirement.

To be successful, the capacity market must have certain features. Capacity must be procured well in advance, so that new entry can compete before costs are sunk. The capacity product must be defined as the ability to provide energy and reserves during periods of reliability risk. Strong performance incentives are needed to motivate capacity suppliers to meet supply obligations. The design should be technology neutral and be as simple as possible.

The proposal and rationale for the Alberta market are comprehensive, covering all critical aspects of the market. Only some details are left for subsequent development. Overall, I found the design choices to be consistent with best practice recognizing the Alberta setting. I found no serious flaws in the proposed design. Key parameters of the market, such as the demand curve and performance incentives were chosen with care. The auction format is sound. The mitigation of market power is effectively addressed.

Performance incentives are addressed in an interesting hybrid way. Suppliers are motivated to be available during the 250 tightest hours and to deliver energy and reserves during hours of reserve shortage. Including availability in tight hours extends the incentives to a larger number of hours and thereby reduces performance risk. Performance incentives during shortage hours are weaker but still strong. The approach appears sound.

Neither the capacity market nor the energy market provide locational price signals. This can work provided transmission constraints rarely bind. If constraints do bind frequently, then locational pricing will ultimately be needed—at least in the energy market.

Based on my review, I am optimistic that the proposed design will work well in Alberta.

Contents

Contents 3
Introduction 4
Challenges and essential features of capacity markets 4
Key elements of the Alberta market design 6
Eligibility 6
Delisting 7
Capacity value 7
Demand curve 7
Base auction 8
Rebalancing auctions 9
Monitoring and mitigation 9
Supply obligations and performance incentives 9
Robustness of the proposed design to future market developments 11
Conclusion 11
References 11

Introduction

I was asked by the Alberta Utilities Commission to review and comment on the proposed design of the Alberta Capacity Market. This paper presents my initial views. It is based primarily on my study of the Alberta electricity market and the final proposal and rationale for the market as appears on the Alberta Electric System Operator (AESO) website. I draw on my experience in designing capacity markets in North America, South America, and Europe, as well as my experience in electricity market design more broadly.

A well-designed capacity market can facilitate the overall market goal of reliable electricity at least cost. The market coordinates investment in resources to ensure resource adequacy. The market also restores any missing money from the energy and reserve markets (Newbery 2016). Revenues in spot markets may be insufficient to ensure resource adequacy because of operator actions or market rules, such as market power mitigation, that may result in too-low spot prices, especially in times of scarcity. The parameters of the market, such as the demand curve, are tuned to express the desired level of reliability in Alberta.

I begin with my general views on capacity markets, both challenges and essential features. Then I discuss the key elements of the proposed Alberta design and whether the design choices of each element are consistent with best practice, recognizing other elements of the Alberta electricity market.

Challenges and essential features of capacity markets

The main challenge of capacity markets today is largely the same as it always has been: to provide investment incentives for generation resources to reliably meet demand at least cost. To achieve this goal, the capacity market must be built within a sound market framework that provides: (1) a predictable and stable regulatory setting, and (2) effective market rules that support the efficient medium and short-term operation of existing resources. Embedded within a sound framework, a capacity market can unfold its complementary benefits of coordinated efficient investment, reduced investment risk, and improved operation during periods of scarcity.

However, to be successful, the capacity market must have certain key features that support the goal of promoting efficient investment (Cramton et al. 2013).

First, capacity should be procured several years in advance to enable new entry to participate and investments to be made. Spot capacity markets are unable to determine a reliable capacity price that properly motivates long-term investments. In contrast, a forward capacity market allows projects to compete before the investments are sunk, and thereby be reflected in the capacity price. To further improve pricing, a downward sloping demand curve should be used that reflects the incremental value of additional capacity.

Second, the capacity product should be defined clearly and simply in a way that is consistent with the market's objective: *capacity is the ability to supply energy and reserves during a reserve shortage*. This definition of capacity makes clear that capacity is a reliability product. Resources are rewarded based on their ability to reduce shortages during scarcity conditions.

Third, strong performance incentives should come from supply obligations during shortages. Each supplier is obligated to provide its proportionate share of demand (load plus reserves) during reserve shortages. Deviations from obligations are priced at a high shortage price. Thus, each supplier is highly motivated to supply energy and reserves during scarcity events. Those that provide more than their share are rewarded; those that provide less than their share are penalized.

Early capacity markets in the US and elsewhere suffered from performance incentives that were too weak. This is not surprising. It is natural for suppliers to argue for weak performance incentives. Doing so reduces performance risk and makes the capacity product seemingly more attractive. However, it also degrades the product and undermines the reliability objective by favoring unreliable resources.

Pleas to weaken performance incentives are often listened to given that a key motivation of the capacity market is to reduce investor risk, which it does by substituting a constant capacity payment for highly uncertain scarcity rents. However, strong performance incentives are critical to the market. Performance risk must be borne by someone and this risk is best held by the party best apt to manage it: the capacity resource.

There are many investments that a resource owner can make to mitigate performance risk, such as firm fuel supply and improved maintenance. A well-maintained resource together with a firm fuel supply provides a physical hedge for performance risk. Intermittent resources face greater performance risk, but this appropriately recognizes the contribution of the resource to reliability.

The weakening of performance incentives often comes from including a myriad of exceptions to a firm obligation. Resources identify their chief vulnerability and then lobby for an exception. For example, slow resources that are rarely on lobby for advanced notice of scarcity events so they have time to ramp up; resources behind a transmission constraint lobby for an exception in the event transmission prevents delivery. The rule of “no exceptions” is the best here. Such a rule simplifies the market and properly rewards a resource for its contribution to reliability.

The need for stronger performance incentives is especially great looking forward. Tomorrow’s market will have an increasing share of intermittent resources, such as wind and solar, and a greater dependence on gas during scarcity conditions. The reliability of the system may be increasingly vulnerable to disruptions in the gas supply. Investments in dual-fuel technologies and improved gas delivery can improve reliability, but weak performance incentives discourage these investments.

Strong performance incentives bring an important additional benefit. By putting suppliers in a roughly balanced position during times of scarcity, they make the spot market work better. Suppliers are motivated to supply as much as possible, rather than to withhold supply to achieve a high price. In addition, load is fully hedged from the high scarcity prices. This protection makes it easier to establish high scarcity prices. The high prices properly motivate behavior, yet only a small quantity is transacted at the high prices, so the amount of money changing hands is limited.

One challenge of capacity markets is complexity. Too often the market rules grow complex with specific needs, requirements, and exceptions. A successful market manages this complexity with a simple underlying structure, the key component of which is the simple product definition above: the ability to

supply energy or reserves during reserve shortages. Of course, the capacity market must recognize operational constraints, such as the limits of the transmission grid, but the market should permit substitution wherever it is possible. For example, absent transmission constraints, capacity prices should not differ by location.

Another form of substitution is generation technology. To the extent possible, capacity markets should be technology neutral. All resources, regardless of technology, should compete to supply capacity on an equal basis. Of course, "equal basis" recognizes the different contributions each resource makes to the reliability objective.

The system operator rates each resource based on its expected performance in supplying energy and reserves when the market is tight. The rating determines the amount of capacity that the resource can offer to the market. A new gas turbine may be rated at 94% of nameplate capacity, whereas a wind resource may be rated at 30% of nameplate. Demand response is also rated based on its expected contribution to reliability. Resource ratings are revised based on experience so that they do reflect the long-run expected performance during reserve shortages. In general, resource ratings depend on the composition of resources in the market. For example, if the quantity of wind resources increased substantially, the shortage event is more apt to be caused by a lack of wind, and therefore the ratings of wind resources would be reduced.

A technology neutral capacity market is both simpler and more efficient than alternatives that attempt to specify specific technological needs and thereby limit substitution. Maximizing substitution across technologies has the additional benefit that the capacity market is less fragmented. This promotes competition.

Key elements of the Alberta market design

I now consider the main elements of the proposed market design and evaluate whether they are best-suited to the Alberta market.

Eligibility

Existing resources are automatically eligible to participate in the capacity market. An exception is proposed for resources that are part of the Renewable Electricity Program. These resources are compensated separately. It is best to remove them from both supply and demand, so they do not adversely distort the outcome.

New resources are eligible provided they are credible. A financial guarantee is required to ensure credibility. As milestones are met, the size of the guarantee falls. This makes sense.

The proposed approach recognizes the importance of making sure that new resources are credible yet does not create entry barriers by imposing excessively high financial guarantees on new resources. A delicate balance is achieved.

Delisting

The capacity market should encourage efficient new entry and at the same time encourage retirement of non-economic resources. Retirements are apt to be especially important as the resource mix changes and plants age. Resources wanting to delist either permanently or temporarily apply to the AESO. Temporary delists can only occur in the second balancing auction and the owner must offer the net avoidable costs into the second rebalancing auction. This is intended to prevent a supplier from exercising market power through a temporary delist.

Retirements are permanent and as such are much less apt to be intended to impact the price in a single capacity auction. For this reason, retirement offers are not mitigated.

I find the treatment of delisting resources to be consistent with best practice.

Capacity value

Capacity values are set for each resource based on UCAP for the 250 tightest hours in each year over a five-year period. Owners can adjust UCAP within a limited range. Limiting the range is important to ensure resource adequacy. Otherwise, if performance incentives are too weak, suppliers would be motivated to inflate capacity values.

One exception in the UCAP calculation is to exclude transmission system constraints. This is consistent with Alberta's single-price energy market. The market operates well when transmission constraints rarely bind. However, this approach requires a robust and responsive transmission grid. Should transmission constraints become significant, then Alberta will need to consider an energy market with locational prices.

The downside of the Alberta approach is that neither the energy nor the capacity market sends price signals to motivate the efficient location of resources. Ignoring locational price signals has proven to be problematic in other markets. Nonetheless, it is a huge simplification of the market and it may succeed if transmission is able to expand to relieve all important constraints. This may become increasingly difficult with the expansion of wind and solar. If energy and capacity are more valuable at specific locations, then the prices should reflect this.

UCAP is calculated with availability factors for resources that follow energy market dispatches. For intermittent resources—wind, solar, run-of-river hydro—a capacity factor methodology is used. The methodology for calculating UCAP is sound.

Demand curve

The administrative demand curve is a critical element of the market. It determines the quantity of capacity resources that are purchased as a function of price. In this way, it represents the reliability standard. The more that is purchased, the greater the reliability. The reliability standard in Alberta is for at most 0.0011% of unserved energy.

The proposed design has a downward-sloping, convex demand curve. It is determined from several parameters. The minimum quantity is defined by the reliability standard of 0.0011% unserved energy. This is the quantity demanded at the price cap. The price cap is the maximum of 1.75 net-CONE or .5 gross-

CONE. CONE is the cost of new entry estimated from a reference unit. Net-CONE subtracts the estimated energy and ancillary service profits from gross-CONE. There is an inflection point at .875 net-CONE at 7% above the minimum quantity. The foot is at 18% above the minimum quantity at a price of zero. The demand curve is the two line-segments connecting these three points, plus the horizontal line from zero to the minimum quantity at the price cap.

The downward-sloping demand curve recognizes that additional resources beyond the minimum have value but at a reduced rate. The downward-sloping curve gives a better representation of the marginal value of resources. It also reduces price volatility, improves price formation, and reduces incentives to exercise market power.

The proposed demand curve is consistent with best practice.

Base auction

Aside from a transition period in the first few years, the base auction is conducted three years ahead. This is long enough forward that new entry can effectively compete in the auction. This is important for price formation.

The product has a one-year obligation. Some capacity markets allow new entry to lock in a price and obligation for multiple years to reduce investment risk for new entry. However, given that the capacity price is only a fraction of resource revenues and the multi-year lock-in is still short relative to the life of the asset, I suspect that the risk reduction is not too significant. The advantage of a one-year obligation is that it is the same for all resources. Further it means that the capacity payments will more closely reflect year-by-year changes in market fundamentals.

A sealed-bid uniform-price auction is proposed. Some markets use a descending-clock auction, rather than a sealed-bid auction. The descending-clock auction elicits demands in a sequence of rounds, allowing some price and outcome discovery to occur during the auction. This can be helpful for some market participants in deciding how to bid. However, it can create stronger incentives to exercise market power. Experience in markets using the descending-clock auction suggests that little is lost with a sealed-bid auction in this setting (Harbord and Pagnozzi 2014). The single-round auction also simplifies auction implementation.

One important complication in the auction design is that resource blocks often come in discrete lumps. An inflexible block is either in or out for all its capacity. By contrast, flexible blocks can be rationed at any level. The presence of inflexible blocks means that it may not be possible to set the quantity at the exact point where the aggregate supply curve crosses the demand curve. The auction must specify both who wins and the capacity price in this case. Addressing this lumpiness issue is especially important in a smaller market like Alberta.

Consistent with best practice, the proposed clearing algorithm selects resources to maximize social surplus, the area between the demand and supply curves. When the marginal block is flexible or the intersection of supply and demand occurs at a vertical part of the supply curve, the algorithm picks the

point where supply and demand cross. In cases where an inflexible block is accepted at the margin and extends beyond the demand curve, the price is set at the offer of the marginal block.

This same approach for clearing and pricing is used in the Alberta energy market. It is best practice.

Rebalancing auctions

The rebalancing auctions allow participants to adjust supply in response to new information. The system operator may also update the demand curve, but not its shape, for example in response to higher growth than expected. Rebalancing auctions are conducted 18 and 3 months before the obligation starts. The number and timing of the auctions seems right. The rebalancing auctions should be few to concentrate liquidity.

The rebalancing auctions use the same auction format and methodology as the base auction. This is the best approach. It is expected that most capacity will transact in the base auction. The rebalancing auctions nonetheless play an important role in letting participants adjust to new information about supply and demand.

Monitoring and mitigation

The proposal includes consumer protections to mitigate the potential exercise of market power. The protections are like what we see in other markets. There is a must-offer obligation. All non-delisted resources must submit offers. An ex ante market power screen—the ability to profitably increase price by 10% or more—then determines whether the offers are subject to mitigation. Firms that fail the screen must offer at or below .8 net-CONE, unless they demonstrate higher net going forward costs. Mitigation only applies to existing capacity in the base auction. There is no mitigation in the rebalancing auctions.

The approach appears to be a good one. It is a simple method of identifying firms that may have an incentive to increase price through economic withholding. Mitigating price to .8 net-CONE is a reasonable compromise between over-mitigation and higher prices from market power.

One feature that discourages economic withholding is the possibility that the withholding will lead to new entry. In this case, the withholding supplier must trade-off the one-year higher price vs. the introduction of new capacity that will promote competition in many future years. This is one reason competition in capacity markets typically has been strong.

The exercise of buyer market power by those with a net-short position was considered; however, no participants were identified with enough net-short positions to benefit from significant exercise of market power.

Supply obligations and performance incentives

Supplier obligations and performance incentives play a critical role in the market. Indeed, poorly specified obligations and too-weak performance incentives were a source of failure of early capacity markets.

Supplier obligations begin with meeting development milestones. If progress toward development milestones is significantly delayed, the supplier will need to purchase replacement capacity in a

rebalancing auction. Existing capacity with obligations greater than its UCAP also must purchase replacement capacity in the second rebalancing auction.

Capacity assets are evaluated during the obligation period based on availability during tight conditions and delivery during shortage conditions. Payment adjustments then are made for over or under performance. These payment adjustments provide the performance incentive. The incentive is split with 40% coming from availability and 60% coming from delivery. The delivery assessment is given higher weight, since these are the hours when the system is at greatest risk. The payment adjustment is tied to the asset's full capacity revenues. The approach is technology neutral.

Availability is assessed in the 250 tightest hours of the obligation year. Focusing on the 250 tightest hours motivates availability when the system is at risk, yet it is not so focused to exclude a specific season.

The unavailability payment rate is a $/MWh value equal to 40% of 1.3 times the weighted average asset-specific capacity revenue per MW across all auctions in the obligation year divided by 250. 40% is the weight put on availability. 1.3 scales up adjustments from 1 so that resources would lose by taking on the obligation and then not being available.

Over-availability is rewarded with positive adjustments. These are funded 100% from the unavailability payments. In this way, the payment adjustment is a symmetric price incentive, positive for over-performance and negative for under-performance.

Delivery is assessed during EEA events. These are shortage events in which all available capacity is required to meet load plus reserves. Delivery performance is actual performance minus obligation volume, measured in MWh. The obligation volume is capacity times the balancing ratio—the energy and reserves produced by capacity resources during the event divided by total committed capacity. Multiplying by the balancing ratio makes the obligation follow load. During low-load periods the obligation is proportionally lower.

The non-delivery payment rate is a $/MWh value equal to 60% of 1.3 times the weighted average asset-specific capacity revenue per MW across all auctions in the obligation year divided by the maximum of 20 and the expected EEA hours. Given that we are dividing by a small number of hours, the non-delivery payment rate is a large number.

Over-delivery, like over-availability, is rewarded with positive adjustments. Over-delivery payments are made at the non-delivery payment rate. Any residual funds are applied to reduce total capacity charges to consumers.

To reduce risk, payment adjustments are capped. Over-availability and over-delivery payment adjustments are capped at 100% of the of the asset's annual obligation revenue. Monthly non-delivery payment adjustments are capped at 300% of the monthly obligation revenue. Annual non-delivery and unavailability adjustments are capped at 130% of the annual obligation revenue. Suppliers also have the option of ex ante substitution of assets or ex post volume reallocation to reduce non-delivery adjustments.

Together, these payment adjustments provide a strong performance incentive to be available in tight hours and to deliver energy or reserves during shortage events. The only excuse for non-performance is

being constrained down due to transmission constraints. This exception is consistent with the market philosophy that transmission constraints rarely bind and therefore providing locational incentives is not important. The caps on payment adjustments also damage incentives when the caps are reached. However, I suspect it would unusual for a participant to bump into these caps.

Robustness of the proposed design to future market developments

A good capacity market design is durable. It can withstand anticipated changes to the market in the years ahead. Some of these changes arise from technology and economic changes, such as the shift in the resource mix toward more intermittent resources and more demand response. Others arise from changes to market rules. Alberta currently has a relatively simple electricity market design. This simple structure appears to work well now, but changes to the market rules are inevitable as the market evolves.

My judgment is that the proposed design is robust to most future changes. The technology neutral design handles renewables and demand response well. The design is built on sound principles of capacity market design.

One area of potential concern are transmission constraints. If the grid becomes congested on a routine basis, then the single-price market may no longer work. Locational price signals would first be required in the energy market. Ultimately, they may be required in the capacity market too. However, introducing locational pricing would greatly complicate both the energy market and the capacity market. Perhaps a better solution for Alberta is to continue to invest in ample transmission capacity so that constraints rarely bind.

Conclusion

The proposed design of the Alberta Capacity Market is sound. I have reviewed each of the key features of the market. The proposal is comprehensive. Many judgments are needed in selecting features and setting parameters of the market. I have been unable to discover any serious flaws. The judgments appear to be well-motivated and consistent with the long-term objective of reliable electricity at least cost. I am optimistic that the proposed design will work well in Alberta.

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12 September 2018

Peter Cramton is Professor of Economics at the University of Cologne and the University of Maryland. Since 1983, he has conducted research on auction theory and practice. This research appears in leading economics journals. The focus is the design of auction-based markets. Applications include communications, electricity, and financial markets. On the practical side, he is an independent director on the board of the Electric Reliability Council of Texas and an advisor and chief economist to several companies. Since 1993, he has advised 13 governments and 41 bidders in spectrum auctions. He is a co-inventor of the spectrum auction design used in Canada, Australia, and many European countries to auction spectrum. Since 2001, he has played a lead role in the design and implementation of electricity and gas auctions in North America, South America, and Europe. He has advised on the design of carbon auctions in Europe, Australia, and the United States, including conducting the world's first greenhouse-gas auction held in the UK in 2002. He has led the development of innovative auctions in new applications, such as auctions for airport slots, wind rights, diamonds, medical equipment, and Internet top-level domains. He received his B.S. in Engineering from Cornell University in 1980 and his Ph.D. in Business from Stanford University in 1984.

Academic Positions

Professor of Economics—Department of Economics, University of Cologne, January 2018 to present.

Professor of Economics—Department of Economics, University of Maryland, August 1996 to present, Emeritus since July 2018. *Affiliate*, Agriculture and Resource Economics, 2008 to present.

Research Affiliate—Reinhard Selten Institute, January 2017 to present.

International Faculty—Department of Economics, University of Cologne, July 2015 to December 2017.

Part-time Professor of Economics—Department of Economics, European University Institute, September 2015 to August 2017.

Associate Professor of Economics—Department of Economics, University of Maryland, August 1993 to June 1996.

National Fellow—Hoover Institution, Stanford University, September 1992 to August 1993.

Associate Professor of Economics and Management—Yale School of Management, Yale University, July 1988 to August 1993.

Assistant Professor of Decision Theory—Yale School of Management, Yale University, July 1984 to June 1988.

Education

Stanford University, Doctor of Philosophy, June 1984, Graduate School of Business.
Dissertation: *The Role of Time and Information in Bargaining*.

Cornell University, Bachelor of Science with distinction, May 1980, School of Operations Research and Industrial Engineering. Graduated first in class.

Recent Courses

Market Design. Doctoral and advanced masters course on market design.

Advanced Microeconomics. Doctoral course in game theory with emphasis on auctions and market design.

Methods and Tools of Economic Analysis. Undergraduate introduction to the mathematical tools used in economics.

Game Theory. Undergraduate introduction to modern game theory.

Market Design. An advanced undergraduate course on auction and market design.

Research Interests

Market design, auction theory and practice, bargaining theory, industrial organization, experimental economics, contract theory, game theory, decision theory, labor economics, information economics, and law and economics.

Honors

Winner of the Utah Winter Finance Conference Best Paper Award, 2015.

Winner of the AQR Insight Award for most insightful unpublished paper in finance, 2014.

Distinguished Service Award, American Association for Homecare, 2012.

Resident Scholar, Rockefeller Foundation, Villa Serbelloni, Bellagio, Italy, Spring 2007.

Departmental Undergraduate Teaching Award, Spring 1996 (2), Spring 1997 and Spring 2002.

Departmental Graduate Teaching Award, Fall 1994, Fall 1998, and Fall 2007.

Hoover National Fellow, Hoover Institution, Stanford University, 1992-93.

Winner of the *1984 Leonard J. Savage Thesis Award* for an outstanding dissertation in Bayesian Economics.

American Assembly of Collegiate Schools of Business Doctoral Fellowship, 1983-84.

National Association of Purchasing Management Scholarship, 1983-84.

Dean's Award for Service to Stanford University, 1983-84.

Two-time recipient of *Stanford Merit Fellowship*, 1981-83.

Elected by the Operations Research faculty as outstanding senior, 1980.

Affiliations

Econometric Society, American Economic Association, Society for Economic Analysis, and Society for the Promotion of Economic Theory.

Research on Auction and Market Design

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- Video of opening remarks (33 minutes) [Transcript of entire event, Presentation, pptx with animation]
    - Peter Cramton, Professor of Economics, University of Maryland
- Video of panelists (42 minutes)
    - Tom Milam, Member, Program Advisory and Oversight Committee (PAOC), Former COO, AmMed Direct
    - Barbara Rogers, PAOC Member and President/CEO National Emphysema/COPD Association
    - Paul Gabos, Chief Financial Officer, Lincare, Round One Re-Bid Winner
    - Robert Brandt, Owner, City Medical Services, Round One Re-Bid Winner
    - Nancy Johnson, 24-year Congresswoman (R-CT)
    - Sue Myrick, Congresswoman (R-NC)

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Medicare Auction Conference, Inn & Conference Center, University of Maryland, 1 April 2011. [HomeCare 11 Apr, InsideHealthPolicy 4 Apr]

- Video of opening remarks (30 minutes) [Transcript]
    - Peter Cramton, Professor of Economics, *University of Maryland* [Presentation]
    - Jonathan Blum, Deputy Administrator, *Centers for Medicare & Medicaid Services*
- Video of a proposed auction approach for Round 2 (40 minutes), Peter Cramton [Presentation, Transcript]
- Video of auction demonstration, Larry Ausubel and Peter Cramton, *University of Maryland* [Presentation, Transcript]
- Video of first panel: Sustainability, market structure, and beneficiary choice (43 minutes) [Transcript]
    - Moderated by Lance Leggitt, Chair, Federal Health Policy, *Baker Donelson*
    - Zachary Schiffman, President, *United States Medical Supply*
    - Nancy Lutz, Program Director, Economics, *National Science Foundation*
    - Joel Marx, Chairman, *Medical Service Company*
    - Amy Law, Vice President Government and Healthcare Strategy, *KCI, Inc.*
    - Paul Gabos, Chief Financial Officer, *Lincare*
- Video of second panel: Product design and ensuring performance [Transcript]
    - Moderated by Thomas Milam, Member of *Program Advisory and Oversight Committee (PAOC)*
    - Cara Bachenheimer, Senior Vice President Government Relations, *Invacare Corporation*
    - Michael Iskra, Chief Operating Officer, *Simplex Healthcare*

    - Scott Lloyd, Co-founder and President, *Extrakare LLC*
    - Mike Pfister, Executive Vice President, Government Relations, *The SCOOTER Store*
    - John Shirvinsky, Executive Director, *Pennsylvania Association of Medical Suppliers*
- Video of final panel: What have we learned? (59 minutes) [Transcript]
    - Tom Bradley, Chief, Medicare Cost Estimates, *Congressional Budget Office*
    - Walt Gorski, Vice President, Government Affairs, *American Association for Homecare*
    - Nancy Johnson, 24-year Congresswoman (R-CT), Senior Public Policy Advisor, *Baker Donelson*
    - Thomas Kruse, President and CEO, *Hoveround Corporation*
    - Evan Kwerel, Senior Economic Advisor, *Federal Communications Commission*
    - Wayne Sale, Chairman, NAIMES, and President and CEO, *Health First*
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1. Request for Bid Instructions (Round 1 Rebid), which defines the median pricing rule and other auction rules.
2. Federal Register, which presents the final rule and a discussion of its rationale.
3. Katzman and McGeary (2008), the study of the earlier trials showing the bid skewing and other problems.
4. Request for Bids Bidding Form to see what a bid looks like.
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6. Quality Standards to see the limited information on quality standards and performance obligations.

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Letter from Representative Tiberi to Secretary Sebelius (HHS) and Administrator Berwick (CMS), 27 October 2010.
Letter from Senator Casey to Administrator Berwick (CMS), 22 October 2010.
Letter from Senator Voinovich to Administrator Berwick (CMS), 18 October 2010.
Letter from Representatives Braley and Myrick to Administrator Berwick (CMS), 24 November 2010.

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Chairman Altmire, Investigations and Oversight Subcommittee, Small Business Committee, U.S. House of

Representatives.
Ranking Member Barton, U.S. House of Representatives Committee on Energy and Commerce.
Chairman Baucus, U.S. Senate Committee on Finance.
Ranking Member Camp, U.S. House of Representatives Committee on Ways and Means.
Chairman Conrad, U.S. Senate Committee on Budget.
Ranking Member Grassley, U.S. Senate Committee on Finance.
Representative Hall, U.S. House of Representatives.
Ranking Member Herger, U.S. House of Representatives Ways and Means Subcommittee on Health.
Chairman Levin, U.S. House of Representatives Ways and Means Committee.
Chairman Pallone, U.S. House of Representatives Committee on Energy and Commerce, Subcommittee on Health.
Chairman Rockefeller, U.S. Senate Committee on Finance, Health Care Subcommittee.
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"Shrewd Bargaining on the Moral Frontier: Toward a Theory of Morality in Practice," (with J. Gregory Dees) *Business Ethics Quarterly*, 1, 135-167, 1991.

"Sequential Bargaining Mechanisms," in *Game-Theoretic Models of Bargaining*, Alvin Roth (ed.), Cambridge University Press, Chapter 8, 149–179, 1985.

"Bargaining with Incomplete Information: An Infinite-Horizon Model with Two-Sided Uncertainty," *Review of Economic Studies*, 51, 579–593, 1984.

Other Research

"Ratifiable Mechanisms: Learning from Disagreement," (with Thomas R. Palfrey) *Games and Economic Behavior*, 10, 255–283, 1995.

"Relational Investing and Agency Theory," (with Ian Ayres) *Cardozo Law Review*, 15, 1033–1066, 1994.

"Cartel Enforcement with Uncertainty About Costs," (with Thomas R. Palfrey) *International Economic Review*, 31, 17–47, 1990. Reprinted in Stephen W. Salant and Margaret C. Levenstein (eds.), *Cartels*, Volume 1, Cheltenham, UK: Edward Elgar, 2005.

"Nonrandom Mixing Models of HIV Transmission," (with Edward Kaplan, and A. David Paltiel) in *Mathematical and Statistical Approaches to AIDS Epidemiology*, edited by Carlos Castillo-Chávez, *Lecture Notes in Biomathematics Series*, Springer-Verlag, 218–239, 1989.

Research Grants

"Testbed Experiments for CRP Auction Design," US Department of Agriculture, September 2013 to September 2018, $191,000.

"Design and Experimental Testing of Land Use Mechanisms: Auctions and Coexistence," US Department of Agriculture, June 2015 to September 2017, $52,000.

"Common Value Auctions with Liquidity Needs," National Science Foundation, September 2009 to August 2013, $400,000.

"Dynamic Matching Mechanisms," National Science Foundation, August 2005 to July 2008, $264,188.

"Slot Auctions for U.S. Airports," Federal Aviation Administration, Department of Transportation, September 2004 to August 2005, $309,729.

"Rapid Response Electronic Markets for Time-Sensitive Goods," National Science Foundation, July 2002 to June 2005, $2,000,000.

"Multiple-Item Auctions," National Science Foundation, July 2001 to June 2004, $313,872.

"Auctions for Multiple Items," National Science Foundation, April 1998 to March 2001, $318,175.

"Auctions and Infrastructure Conference," National Science Foundation, April 1998 to March 1999, $25,000.

"Auctions and Infrastructure," World Bank, March-June 1998, $25,000.

"Applying Strategic Bargaining Models to Union Contract Negotiations," National Science Foundation, April 1995 to March 1998, $143,637.

"Applying Strategic Bargaining Models to Union Contract Negotiations," National Science Foundation, April 1992 to March 1994, $177,760.

"Strikes and Delays in Wage Bargaining: Theory and Data," National Science Foundation, April 1990 to March 1992, $153,407.

"Gaming Exercises in Negotiation and Dispute Resolution," National Institute of Dispute Resolution, July to August 1988, $6,000.

"The Role of Time and Information in Bargaining," National Science Foundation, July 1986 to June 1988, $40,000.

"Public Sector Cases on Negotiation," Mellon Foundation, July to August 1985, $12,000.

Editorial and Public Service

Panelist, National Science Foundation, Enhanced Access to Radio Spectrum, 2012-2013.

Journal of Industrial Economics, Associate Editor, 1998-2007.

Member, RTO Futures (a working group of economists, executives, and government leaders to address critical issues in electricity restructuring), 2000-2007.

Panelist, National Science Foundation, Economics, 1999-2002.

Panelist, National Science Foundation, Electricity Power System Efficiency and Security, 2002.

Program Committee Chair, *North American Econometric Society Summer Meetings*, June 21-24, 2001.

Panelist, National Science Foundation, Knowledge and Distributed Intelligence, 1998.

Referee for

American Economic Review, American Political Science Review, Cambridge University Press, Econometrica, Economic Inquiry, Economic J, Economic Letters, Economic Theory, Energy J, Games & Economic Behavior, Group Decision & Negotiation, International Economic Review, International J of Game Theory, J of Business, J of Business & Economic Statistics, J of Conflict Resolution, J of Economic Theory, J of Economic Surveys, J of Economics & Management Strategy, J of Industrial Economics, J of Labor Economics, J of Law and Economics, J of Law, Economics & Organization, J of Political Economy, J of Public Economics, J of Regulatory Economics, Labour Economics, Management Science, Mathematical Social Sciences, Marketing Science, MIT Press, National Institute for Dispute Resolution, National Science Foundation, Omega, Operations Research, OPSEARCH, Quarterly J of Economics, Rand J of Economics, Research in Experimental Economics, Review of Economic Studies, Scandinavian J of Economics, Science, Social Choice & Welfare, Southern Economic J.

Recent Post-Docs (Initial Placement)

Darrell Hoy, April 2014-June 2017 (Tremor Technologies)
David Malec, June 2013-June 2018 (Tremor Technologies)

Recent PhD Committees Chaired (Initial Placement)

Hector Lopez, July 2015 (Rivada Networks)
Pacharasut Sujarittanonta, July 2010 (Morgan State University)
Nathaniel Higgins, December 2009 (USDA Economic Research Service)
Matias Herrera Dappe, May 2009 (Bates White)
Andrew Stocking, August 2009 (Congressional Budget Office)
Dipan Ghosh, May 2008 (CRA International)
Martin Ranger, May 2005 (Indiana University)
Jeffrey Lien, August 2001 (US Department of Justice)
Allan Ingraham, May 2001 (Criterion Auctions)
Jesse Schwartz, August 1999 (Vanderbilt University)
Laurent Martin, July 1999 (University of Washington)

Entrepreneurship

Founder, Cramton Associates, a consultancy providing expert advice in high-stakes auction markets. 1993 to present.

Chief Economist, Rivada Networks, a company developing open access wireless markets. 2015 to present.

Director, Arpent, a company developing markets for road use. 2015 to present.

Director and Chief Economist, Tremor Technologies, a company developing a smart market for reinsurance. 2017 to present.

Chair, Market Design Inc. (with Lawrence Ausubel, R. Preston McAfee, Paul Milgrom, Alvin Roth, and Robert Wilson), a consulting firm that works with governments and companies in designing and implementing state-of-the-art auction and matching methods, 1995 to 2016 (President since 1999, Chair since 2003). Major projects:

- Design auction market for rough diamonds.
- Design auction and suggest market reforms for British Columbia timber market.
- Design and implement virtual power plant auctions in France and Belgium.
- Design and implement auction to sell gas capacity in Germany and France.
- Design and implement U.K. auction to procure greenhouse gas emission reductions.
- Design and implement of spectrum auctions in U.S., Canada, Mexico, Australia, and the U.K.
- Design and implement electricity auctions in North America and South America.
- Design auctions to divest electricity generation plants and power purchase agreements in U.S. and Canada.

Founder, Criterion Auctions, a consulting firm that provides auction support services to governments and companies in high-stake auctions. December 2000 to June 2007.

Chair and Founder, Spectrum Exchange (with Lawrence Ausubel, Paul Milgrom, and Market Design Inc.), a firm to create value for the public by promoting the efficient exchange of spectrum. 1999 to 2009.

Expert Reports, Affidavits, and Testimony

"Design of the Reverse Auction in the Broadcast Incentive Auction" (with Hector Lopez, David Malec and Pacharasut Sujarittanonta), Working Paper, University of Maryland, 12 March 2015; Appendix. Filed by EOBC at the FCC.

"Bidding and Prices in the AWS-3 Auction" (with Pacharasut Sujarittanonta), Working Paper, University of Maryland, May 2015. Filed by the Competitive Carriers Association.

ISO New England, Docket Nos. ER14-1050-000, -001, Federal Energy Regulatory Commission, "Prepared Testimony of Peter Cramton on Behalf of ISO New England," January 2014. Comments on ISO New England's proposed Pay For Performance reforms to the Forward Capacity Market.

ISO New England, Docket Nos. ER14-1050-000, -001, Federal Energy Regulatory Commission, "Supplemental Prepared Testimony of Peter Cramton on Behalf of ISO New England," February 2014. Comments on NEPOOL's critique of ISO New England's proposed Pay For Performance reforms to the Forward Capacity Market.

"The Revenue Impact of Competition Policy in the FCC Incentive Auction," December 2013. Comments on the revenue impact of spectrum-aggregation limits in the FCC's incentive auction. On behalf of T-Mobile USA.

"The Rationale for Spectrum Limits and Their Impact on Auction Outcomes," August 2013. Argues that well-crafted spectrum aggregation limits can increase competition both in the market for mobile broadband services and in the spectrum auctions in which they apply. On behalf of T-Mobile USA.

ISO New England and New England Power Pool, Docket No. ER12, Federal Energy Regulatory Commission, "Testimony of Peter Cramton," April 2012. Examines the New England regulation market and proposes an alternative market design. For ISO New England.

Verizon Wireless spectrum transaction with SpectrumCo and Cox, Federal Communications Commission, WT Docket No. 12-4, "Supplemental Declaration of Peter Cramton." March 2012. Supplemental declaration on the FCC's spectrum screen used to evaluate spectrum transactions. On behalf of T-Mobile US.

Verizon Wireless spectrum transaction with SpectrumCo and Cox, Federal Communications Commission, WT Docket No. 12-4, "Declaration of Peter Cramton." February 2012. Declaration on the FCC's spectrum screen used to evaluate spectrum transactions. On behalf of T-Mobile US.

"700 MHz Device Flexibility Promotes Competition," July 2010. Argues that the carrier-specific band plans proposed by AT&T and Verizon Wireless for the 700 MHz paired spectrum will undermine competition. On behalf of the Rural Cellular Association.

"Foreword to Ross Baldick's 'Single Clearing Price in Electricity Markets'," Compete Coalition, www.competecoalition.com, February 2009. Argues that consumers and suppliers are better off with the clearing-price auction in electricity markets.

"Report on Key Design Elements of Auctions Under Australia's Carbon Pollution Reduction Scheme," Tradeslot Report to Australian Department of Climate Change, 26 October 2008.

DC Energy, LLC v. HQ Energy Services (US) Inc., Docket No. EL07-67-000, Federal Energy Regulatory Commission, "Affidavit of Peter Cramton." August 2007. Affidavit arguing that HQ manipulated the NYISO TCC and day-ahead energy markets. On behalf of DC Energy, LLC.

The People of the State of Illinois, et al., Docket No. EL07-47-000, Federal Energy Regulatory Commission, "Affidavit of Peter Cramton." June 2007. Affidavit arguing that the Illinois auction for energy for small customers was a competitive auction. On behalf of J. Aron & Company and Morgan Stanley Capital Group Inc.

Australia National Emissions Trading Taskforce, "Possible Design for a Greenhouse Gas Emissions Trading System," August 2007.

700 MHz Auction, Federal Communications Commission, "Why Large Licenses are Best for the 700 MHz Spectrum Auction." April 2007. On behalf of Verizon Wireless.

New York Independent System Operator, Docket No. ER07-360-000, Federal Energy Regulatory Commission, "Affidavit of Peter Cramton." February 2007. Affidavit identifying manipulation of New York's capacity market by KeySpan and the need for market monitoring and mitigation. On behalf of Consolidated Edison Company of New York.

United States vs. Mario Gabelli. Expert report showing the damages caused by Gabelli's false claims in FCC spectrum auctions. The case was settled in June 2006. Gabelli paid $130 million in damages. On behalf of the United States.

Devon Power LLC, et al., Docket No. ER03-563-030, Federal Energy Regulatory Commission, "Affidavit of Peter Cramton," March 2006. Affidavit in support of the settlement agreement defining the New England Forward Capacity Market. For ISO New England.

AWS Auction, Federal Communications Commission, "Declaration of Peter Cramton." February 2006. Declaration on various auction rules for the AWS auction. On behalf of T-Mobile US.

AWS Auction, Federal Communications Commission, "Reply Declaration of Peter Cramton." February 2006. Reply declaration on various auction rules for the AWS auction. On behalf of T-Mobile US.

AWS Auction, Federal Communications Commission, "Ex Parte of Peter Cramton." March 2006. Ex parte communication on various auction rules for the AWS auction. On behalf of T-Mobile US.

MDI retained as Auction Manager for virtual divestiture of 2,600 MW of nuclear energy as part of the proposed merger between Exelon and PSEG. August 2005.

US-Canada Softwood Lumber Trade Dispute, "Competitive Auction Markets in British Columbia" (with Susan Athey). December 2005. White Paper, Market Design Inc. On behalf of British Columbia Ministry of Forests.

US-Canada Softwood Lumber Trade Dispute, "Comments on DOC Notice of Preliminary Results of Countervailing Duty Review" (with Susan Athey). July 2005. White Paper, Market Design Inc. On behalf of British Columbia Ministry of Forests.

US-Canada Softwood Lumber Trade Dispute, "Competitive Auction Markets in British Columbia" (with Susan Athey). February 2004. White Paper, Market Design Inc. On behalf of British Columbia Ministry of Forests.

US-Canada Softwood Lumber Trade Dispute, "Upset Pricing in Auction Markets: An Overview" (with Susan Athey and Allan Ingraham). March 2003. White Paper, Market Design Inc. On behalf of British Columbia Ministry of Forests.

US-Canada Softwood Lumber Trade Dispute, "An Analysis of Auction Volume and Market Competition for the Coastal Forest Regions in British Columbia" (with Susan Athey and Allan Ingraham). September 2002. White Paper, Market Design Inc. On behalf of British Columbia Ministry of Forests.

US-Canada Softwood Lumber Trade Dispute, "Reserve Prices, Stumpage Fees, and Efficiency" (with Susan Athey and Allan Ingraham). September 2002. White Paper, Market Design Inc. On behalf of British Columbia Ministry of Forests.

US-Canada Softwood Lumber Trade Dispute, "Auction-Based Timber Pricing and Complementary Market Reforms in British Columbia" (with Susan Athey and Allan Ingraham). March 2002. White Paper, Market Design Inc. On behalf of British Columbia Ministry of Forests.

US-Canada Softwood Lumber Trade Dispute, "Setting the Upset Price in British Columbia Timber Auctions" (with Susan Athey and Allan Ingraham). September 2002. White Paper, Market Design Inc. On behalf of British Columbia Ministry of Forests.

US-Canada Softwood Lumber Trade Dispute, "Auctioning Timber to Maximize Revenues in British Columbia" (with Susan Athey and Allan Ingraham). June 2002. White Paper, Market Design Inc. On behalf of British Columbia Ministry of Forests.

US-Canada Softwood Lumber Trade Dispute, "A Comparison of Equation-Based and Parity Pricing of Stumpage Fees for British Columbia Timber Under Long-Term Tenures" (with Susan Athey and Allan Ingraham). April 2002. White Paper, Market Design Inc. On behalf of British Columbia Ministry of Forests.

US-Canada Softwood Lumber Trade Dispute, "Testing for Anti-Competitive Bidding in Auction Markets" (with Susan Athey and Allan Ingraham). March 2002. White Paper, Market Design Inc. On behalf of British Columbia Ministry of Forests.

New England Power Pool, Federal Energy Regulatory Commission, "Review of the Proposed Reserve Markets in New England," (with Hung-po Chao and Robert Wilson) Market Design Inc., January 2005.

U.S. Department of Defense, Services, "Criterion Auctions, December 2003.

Expert Report of Peter Cramton, *D. Lamar Deloach, et al. v. Philip Morris, Inc., et al.*, Civil Action No. 00-CV-1253, United States District Court, Middle District of North Carolina. October 2003. For R.J. Reynolds. Concluded that R.J. Reynolds did not collude in U.S. tobacco auctions during the class period.

Supplier Behavior in California Energy Crisis, Federal Energy Regulatory Commission, Docket Nos. EL00-95-075 and EL00-98-063, "Competitive Bidding Behavior in Uniform-Price Auction Markets," March 2003. For Duke Energy.

Supplier Behavior in California Energy Crisis, Federal Energy Regulatory Commission, Docket Nos. EL00-95-075 and EL00-98-063, "Rebuttal Addendum: Assessment of Submissions of the California Parties," March 2003. For Duke Energy.

U.S. Department of Transportation, Docket Nos. FAA–2001–9852, FAA–2001–9854, "Comments on Alternative Policy Options for Managing Capacity and Mitigating Congestion and Delay at LaGuardia Airport," June 2002. Recommending auctions to manage congestion at LaGuardia.

Verizon Wireless Petition for Permanent Forbearance from CMRS Number Portability, Federal Communications Commission, WT Docket No. 01-184,"Declaration of Peter Cramton," February 2002. Comments in support of wireless number portability. For Leap Wireless.

ISO New England, Docket No. ER02, Federal Energy Regulatory Commission, "Affidavit of Peter Cramton," February 2002. Comments on proposed changes to how the energy clearing price is calculated. For ISO New England.

2000 Biennial Regulatory Review Spectrum Aggregation Limits For Commercial Mobile Radio Services, WT Docket No. 01-14, Federal Communications Commission, "Ex Parte Declaration of Peter Cramton," October 2001. Further comments on the CMRS spectrum cap. For Leap Wireless.

ISO New England, Docket No. EL00-62-015, Federal Energy Regulatory Commission, "Affidavit of Peter Cramton," June 2001. Comment on modifications to installed capability market. For ISO New England.

2000 Biennial Regulatory Review Spectrum Aggregation Limits For Commercial Mobile Radio Services, WT Docket No. 01-14, Federal Communications Commission, "Declaration of Peter Cramton," April 2001. Comments on the CMRS spectrum cap. For Leap Wireless.

C and F Block Broadband PCS Auction, Federal Communications Commission, "Declaration of Peter Cramton," March 2001. Comments on the impact of fronts in the C and F Block Broadband PCS auction.

"Lessons Learned from the UK 3G Spectrum Auction," May 2001. An export report on the UK 3G Spectrum Auction. For UK National Audit Office.

"Market Effectiveness Assessment," (with Jeffrey Lien) May 2001. An expert report assessing the effectiveness of the electricity restructuring plan in Ontario. For TransCanada.

First Millennium Communications, Inc. and Barbara Laurence vs. Entravision Communications Company, No. 1420009074, "Expert Report of Peter Cramton," May 2001. Comment on the value of clearing rights for broadcast television stations 59 to 69. For First Millennium Communications and Barbara Laurence.

Pacific Communications vs. American Wireless, Superior Court of Fulton County, Georgia, No. 2000CV20099, "Reply Declaration of Peter Cramton," April 2001. Further comments on the impact of a delayed sale of spectrum license by Pacific Communication. For American Wireless.

Pacific Communications vs. American Wireless, Superior Court of Fulton County, Georgia, No. 2000CV20099, "Expert Affidavit of Peter Cramton," February 2001. Comments on the impact of a delayed sale of spectrum license by Pacific Communication. For American Wireless.

"Lessons from the United States Spectrum Auctions," Prepared Testimony of Peter Cramton before the United States Senate Budget Committee, February 2000.

New England Power Pool, Docket No. EL00-83-000, Federal Energy Regulatory Commission, "Affidavit of Peter Cramton," July 2000. Comment on deficiency charge in installed capability market. For ISO New England.

NSTAR Services Company vs. New England Power Pool, Docket No. EL00-83-000, Federal Energy Regulatory Commission, "Affidavit of Peter Cramton," June 2000. Further comments on energy price cap as a response to design flaws. For ISO New England.

NSTAR Services Company vs. New England Power Pool, Docket No. EL00-83-000, Federal Energy Regulatory Commission, "Affidavit of Peter Cramton," June 2000. Comments on energy price cap as a response to design flaws. For ISO New England.

New England Power Pool, Docket No. EL00-62-000; ER00-2052-000, Federal Energy Regulatory Commission, "Affidavit of Peter Cramton," May 2000. Comments on installed capability market. For ISO New England.

New England Power Pool, Docket No. ER00-2016-000, Federal Energy Regulatory Commission, "Affidavit of Peter Cramton," April 2000. Comments on one-part vs. three-part bidding in energy market. For ISO New England.

New England Power Pool, Docket No. ER99-4536-000, Federal Energy Regulatory Commission, "Affidavit of Peter Cramton," October 1999. Summary of review of reserves and operable capability markets. For ISO New England.

New England Power Pool, Docket No. OA97-237-000, Federal Energy Regulatory Commission, "Affidavit of Peter Cramton," October 1998. Reply to comments on review of rules. For ISO New England.

New England Power Pool, Docket No. OA97-237-000, Federal Energy Regulatory Commission, "A Review of ISO New England's Proposed Market Rules,"(with Robert Wilson), September 1998. For ISO New England.

Best Digital vs. U.S. West, American Arbitration Association, Denver Office, No. 77 181 00204 97, "Expert Report of Peter C. Cramton," September 1998. Determine the value of spectrum licenses won by Best Digital in the C-block Broadband PCS auction. For Best Digital.

NextWave vs. Antigone and Devco, Petition to Deny License Proceedings, Federal Communications Commission, "Statement on the Effect of NextWave's Participation in the C-block Auction on Antigone and Devco," March 1997. For Antigone and Devco.

NextWave vs. Antigone and Devco, Petition to Deny License Proceedings, Federal Communications Commission, "Reply Statement on the Effect of NextWave's Participation in the C-block Auction on Antigone and Devco," April 1997. For Antigone and Devco.

Personal

Born on 12 November 1957

Married to Catherine Durnell Cramton