Electricity Demand Response—One LMP Size Does Not Fit All

By Steven A. Glazer*

In March 2011, the Federal Energy Regulatory Commission ("FERC" or "Commission") endorsed and standardized demand response ("DR") as a recognized form of energy supply for the nation's electric power grid. DR is the practice among electric utilities of paying electricity consumers to cut consumption during times of high demand. Since the start of DR programs in the nation's electric markets, various industries have contributed resources to the program that have yielded positive results. Its future success, however, depends a great deal on the impact that DR has on the home markets of these industries, which to date has been a little-studied question.

DR became an electric industry practice as a result of FERC's Order No. 745 ("Order") and subsequent clarifying orders, all entitled *Demand Response Compensation in Organized Wholesale Energy Markets*.[1] In those orders, FERC recognized the efforts of several Regional Transmission Organizations ("RTO") to pay electricity consumers to reduce their energy usage during peak hours instead of dispatching high-cost electricity during those times. FERC theorized that these "negawatts" of foregone electricity consumption were no different from megawatts of active electricity generation for the purpose of satisfying peak demand and therefore merited compensation on an equal footing with generation.[2] Accordingly, the Order mandated payments to demand-responders for electricity forbearance during peak hours at a rate equal to the same locational marginal price ("LMP") per kilowatt that generators were entitled to earn for their kilowatt generation during those hours.[3]

Since the issuance of the Order, DR has met with considerable success. PJM Interconnection, L.L.C. ("PJM"),[4] the RTO for utilities serving the Mid-Atlantic region and several Midwestern states, implemented the Order in its region in April 2012, and the results of its efforts to elicit DR improved.[5] Economic DR is a term used in the industry to differentiate DR during periods of high demand from Emergency DR, which is the type of DR that emerges during power outages. PJM reported that "Aggregate Economic DR performance has significantly improved after the implementation of [the Order] market rules."[6] PJM also reported that

> The vast majority (86%) of all Economic DR activity in the energy market from April to October 2012 has come from a small number of very large customers (greater than 10MW) . . . . Customers greater than 5MW delivered almost all (97%) of the energy delivered by Economic DR resources following the implementation of Order No. 745 rules.[7]

Eighty-six percent of all megawatt-hours ("MWh") delivered by Economic DR in the post-Order era came from industrial and manufacturing facilities (67%) and large schools such as university campuses (19%).[8]

However, there have been problems. One problem is how to measure DR, which typically requires the demand-

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1. Demand Response Compensation in Organized Wholesale Energy Markets, Order No. 745, 134 FERC ¶ 61,187 (2011), 76 Fed. Reg. 16,658 (Mar. 24, 2011), *reh'g denied and clarif. denied in part and granted in part*, Order No. 745-A, 137 FERC ¶ 61,215 (2011), *reh'g denied*, Order No. 745-B, 138 FERC ¶ 61,148 (2012) [hereinafter Order No. 745], *rev'd sub nom.* Electric Power Supply Ass'n v. FERC, 753 F.3d 216 (D.C. Cir. 2014) (reh'g en banc pending).
2. *Id.*
3. A "locational marginal price," or LMP, is essentially the price per megawatt that is paid by a transmission system to a generator who delivers energy to a location, or "node" on the transmission system, or that is charged to an energy recipient, or "load," at that node during a given hour of electricity service. LMPs vary by location of the node (hence, "locational") depending on the degree of congestion on the transmission lines that serve that node. The price level is set at the price of the last, least costly megawatt that is dispatched to that node (hence, "marginal") at that hour. *See* Order No. 745, 134 FERC ¶ 61,187 at 2 n.5, 53 (2011); Sacramento Mun. Util. Dist. v. FERC, 616 F.3d 520, 524 (D.C. Cir. 2010).
4. PJM runs the RTO for electricity transmission in all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and the District of Columbia. *About PJM*, PJM, http://pjm.com/about-pjm/who-we-are.aspx (last visited Mar. 19, 2014).
5. PJM, 2012 Economic Demand Response Performance Report 2 (Mar. 25, 2013), *available at* http://www.pjm.com/~/media/markets-ops/dsr/economic-dr-performance-report-analysis-of-activity-after-implementation-of-745.ashx.
6. *Id.*
7. *Id.* at 10.
8. *Id.* at 12.

responder to reduce its electricity use from a baseline of normal operations during the peak hour in which a negawatt payment is earned. The establishment of a demand-responder's baseline is difficult and susceptible to manipulation, as reported in recent FERC enforcement cases involving certain paper manufacturers in Maine.[9] In these cases, New England's RTO, ISO New England Inc. ("ISO-NE"),[10] is alleged to have paid for purported DR that the paper manufacturers simulated by inflating their baseline operating levels.[11]

Another problem is in the lack of information on DR's cost to the economy. DR requires negawatt suppliers, which normally manufacture goods and services in other industries, to cut back production in those arenas in order to help electric producers meet the demands of the electricity market, a market in which they do not usually participate other than as consumers. There has been scant study of the impact of DR on non-electric supply, demand, and prices. This uncertainty may call into question whether DR, although useful to the electricity industry, is equally beneficial to the economy as a whole.

This Article offers an approach for addressing these problems. As an alternative to the manner in which DR is currently measured, DR pricing should take the microeconomics of a demand-responder's home product market into account. This Article will examine the effects of DR on the demand-responder's home market supply. It is not an exhaustive analysis, and the electric power industry must do much further study on the problems raised here. This Article is instead intended to encourage new ideas and avenues for future research.

I. The Development of Order No. 745: The FERC Proceedings

On March 18, 2010, FERC initiated the rulemaking proceeding that sought to spur more DR on the nation's electric grid.[12] In its Notice of Proposed Rulemaking ("NOPR"), FERC stated that the essential justification for paying for DR was that "[i]n balancing supply and demand, a one megawatt reduction in demand is equivalent to a one megawatt increase in energy for purposes of meeting load requirements and maintaining a reliable electric system."[13] By implementing DR, an RTO "is able to avoid dispatching suppliers with higher bids, be they generation or DR, by accepting a lower bid to either reduce consumption or increase generation."[14]

FERC observed that "active participation by customers in organized wholesale energy markets through demand reductions helps to increase competition in those markets."[15] Despite its efforts to lower barriers for and offer compensation to participants in DR, FERC found that such resources had so far played only "a small role" in the wholesale electricity supply markets.[16] Until this time, FERC had been pursuing a system-by-system approach to introducing DR initiatives in the various regional RTOs.[17] By March 2010, however, it was finding that "some existing, inadequate compensation structures ha[d] hindered the development and use of demand response."[18]

At the conclusion of the rulemaking proceeding, which generated an intense amount of interest, on March 15, 2011, FERC issued the Order, its Final Rule on *Demand Response Compensation in Organized Wholesale Energy Markets*.[19] FERC determined in the Order that when a demand-responder can help balance supply and demand as an alternative to more expensive generation and when the dispatch of that demand-responder's resources produces a net benefit to the system, "that DR resource must be compensated for the service it provides to the energy market at the market price for energy, referred to as the locational marginal price (LMP)."[20]

Before issuing the Order, FERC noted that the regional grids had been trying different approaches to compensating DR.[21] PJM was paying demand-responders the LMP set in the electric supply markets for each hour of each day but was subtracting from the payment the generation and transmission portions of the retail electric rate.[22] ISO-NE and New York Independent System Operator, Inc. ("NYISO")[23] were paying LMP when prices were above certain threshold levels.[24] Midwest Independent Transmission System Operator, Inc. ("Midwest ISO")[25] was paying LMP for DR in the real-time energy market whenever the demand-responder purchased the foregone power in the day-ahead market for energy and ancillary services (that is, the forward market for electricity to be supplied the following day).[26] California Independent System Operator Corp. ("CAISO")[27] was

9. *Overview*, ISO New England, http://www.iso-ne.com/aboutiso/co_profile/overview/ (last visited Jan. 21, 2014).
10. ISO-NE runs the RTO for electricity transmission in New England, *i.e.*, the states of Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont. *Id.*
11. *See* Lincoln Paper and Tissue LLC, 144 FERC ¶ 61,162 (2013) (assessing civil penalty); Rumford Paper Co., 142 FERC ¶ 61,218 (2013) (approving stipulation and consent agreement); Competitive Energy Services, LLC, 144 FERC ¶ 61,163 (2013) (assessing civil penalty); Richard Silkman, 144 FERC ¶ 61,164 (2013) (assessing civil penalty) [hereinafter, collectively, *Paper Cases*].
12. Demand Response Compensation in Organized Wholesale Energy Markets, 130 FERC ¶ 61,213 (2010), 75 Fed. Reg. 15,362 (Mar. 29, 2010).
13. *Id.* at 15,366.
14. *Id.*
15. *Id.* at 15,363.
16. *Id.* at 15,365.
17. *Id.* at 15,364.
18. *Id.* at 15,365.
19. Order No. 745, 76 Fed. Reg. 61,658 (Mar. 24, 2011).
20. *Id.* at 61,659.
21. Demand Response Compensation in Organized Wholesale Energy Markets, 75 Fed. Reg. at 15,365.
22. *Id.*
23. NYISO runs the ISO for electricity transmission in the state of New York. *Electric Power Markets: New York (NYISO)*, Fed. Energy Reg. Commission, http://www.ferc.gov/market-oversight/mkt-electric/new-york.asp.
24. Demand Response Compensation in Organized Wholesale Energy Markets, 75 Fed. Reg. at 15,364–65.
25. Midwest ISO runs the RTO for electricity transmission in all or portions of the states of Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Montana, North Dakota, Ohio, South Dakota and Wisconsin. *Electric Power Markets: Midwest (MISO)*, Fed. Energy Reg. Commission, http://www.ferc.gov/market-oversight/mkt-electric/midwest.asp#geo (last visited Mar. 20, 2014).
26. Demand Response Compensation in Organized Wholesale Energy Markets, 75 Fed. Reg. at 15,365.
27. CAISO runs the RTO for electricity transmission in the state of California. *Electric Power Markets: California (CAISO)*, Fed. Energy Reg. Commission,

paying LMP to qualifying resources providing day-ahead and real-time energy and non-spinning reserves.[28] Southwest Power Pool, Inc. ("SPP")[29] had no DR program at all.[30]

FERC became convinced that potential demand-responders would not participate unless there were "stable competitive pricing structures," and that "demand response quite simply will not occur without adequate compensation."[31] Toward this goal, the Commission in the NOPR proposed a new rule that every RTO that solicited DR offers to pay the demand-responders the market price for every kilowatt-hour that they reduce their electricity consumption.[32] The market price is the full LMP set in the day-ahead or real-time energy market on the day and at the hour that the demand-responder bids a reduction into the market.[33]

The Commission was not of one mind upon issuing the NOPR. At that time, the Commission was made up of four sitting members and one vacant seat. One of the two sitting Commissioners, Philip D. Moeller,[34] issued a partial concurrence and dissent.[35] Commissioner Moeller agreed with the other Commissioners that "the benefits that demand response resources can bring to the energy markets are proven and significant," but with regard to the payment of full LMP at all hours to demand-responders, cautioned that "to propose a standard payment could have unintentional effects on both demand response participation and the efficient operation of the organized markets over the longer term."[36] In particular, as Commissioner Moeller pointed out, pricing DR at the wholesale level leaves out participation by retail customers (that is, homeowners and small-scale business users) whose prices do not vary by time of day. The approach being adopted by the Commission, Moeller noted further, "may also lead to a situation where residential ratepayers could be subsidizing other classes of service while unable to participate themselves in demand response programs."[37]

The NOPR generated an avalanche of comments and considerable industry media interest.[38] All of the RTOs offered their views.[39] Celebrated economists weighed in on the various sides of the issue.[40] A plethora of advocacy groups expressed their views.[41] Individual citizens and state public service commissions offered thoughts.[42]

The intense interest prompted FERC to issue a supplemental notice of proposed rulemaking ("Supplemental NOPR") on August 2, 2010, setting a series of technical conferences on details of various proposals offered by the comments.[43] At the outset of the Supplemental NOPR process, the Commission determined that full LMP must be paid for DR at all hours.[44] The Commission put three remaining questions to participants: (1) whether demand-responders should be paid LMP only for reductions during hours when such reductions meet a net benefits test, whereby "the incremental payment for demand response equals the incremental benefit of the reduction in load"; (2) what requirements, if any, should apply to the method of determining net benefits upon adopting a net benefits test; and (3) in connection with funding the payment of LMP to demand responders, "what, if any, requirements should apply to how the costs of demand response are allocated" among energy consumers.[45]

In the final rule, FERC returned to its original idea of requiring full LMP payment to demand-responders.[46] FERC further required demand-responders to meet two conditions for such payment: (1) they must have the capability to "displace a generation resource in a manner that serves the RTO . . . in balancing supply and demand" and (2) the LMP payment "must be cost-effective, as determined by the net benefits test" that was further outlined in the Order.[47] According to the final rule, the net benefits test would be passed if "reductions in LMP from implementing demand response results in a reduction in the total amount consumers pay for resources that is greater than the money spent acquiring those demand response resources at LMP."[48]

II. The Economic Foundation for Demand Response

A. *Demand Response Payments Are Not "Something for Nothing"*

One objection to DR would be that if an electric customer curtails its use, it does not have to pay for that energy. If it is then paid the LMP of the energy it saves, then it seems to be in fact collecting twice that amount. It would appear that demand-responders are paid something for nothing—essentially, a bounty for not buying electricity. This problem bedeviled the public debate on DR both before and after the Order came out.

http://www.ferc.gov/market-oversight/mkt-electric/california.asp (last visited Mar. 20, 2014).

28. Demand Response Compensation in Organized Wholesale Energy Markets, 75 Fed. Reg. at 15,365.
29. SPP runs the RTO for electricity transmission in all or portions of the states of Arkansas, Kansas, Louisiana, Mississippi, Missouri, Nebraska, New Mexico, Oklahoma and Texas. *Electric Power Markets: Southern Power Pool (SPP)*, Fed. Energy Reg. Commission, http://www.ferc.gov/market-oversight/mkt-electric/spp.asp (last visited Mar. 20, 2014).
30. Demand Response Compensation in Organized Wholesale Energy Markets, 75 Fed. Reg. at 15,365.
31. *Id.*
32. *Id.*
33. *Id.*
34. *About FERC—Commissioner Philip D. Moeller*, Fed. Energy Reg. Commission (Dec. 5, 2013), http://www.ferc.gov/about/com-mem/moeller.asp.
35. Demand Response Compensation in Organized Wholesale Energy Markets, 75 Fed. Reg. at 15,369–71 (Moeller, Comm'r, concurring in part and dissenting in part).
36. *Id.* at 15,369–70.
37. *Id.* at 15,370–71.
38. *See* Order No. 745, 76 Fed. Reg. 16,658, 16,678 (Mar. 24, 2011).
39. *Id.*
40. *Id.*
41. *Id.*
42. Demand Response Compensation in Organized Wholesale Energy Markets, 132 FERC ¶ 61,094, 75 Fed. Reg. 47,499, 47,500 (proposed Aug. 6, 2010) (to be codified 18 C.F.R. pt. 35) (Supplemental NOPR).
43. *Id.* at 47,502.
44. Transcript of Sept. 13, 2010 Technical Conference at 6:7-9, FERC Docket No. RM10-17-000 (2010).
45. Demand Response Compensation in Organized Wholesale Energy Markets, 75 Fed. Reg. at 47,499.
46. Order No. 745, 76 Fed. Reg. 16,658 (Mar. 24, 2011).
47. *Id.* at 16,666.
48. *Id.*

From an economist's perspective, however, this notion does not stand up to scrutiny. DR is, in essence, a form of rationing. Rationing is a concept that Americans today are fortunately unfamiliar with. During World War II, citizens could only consume an allotted share of certain goods needed for the war effort, like gasoline.[49] To enforce this order, the federal government issued monthly ration books containing stamps for buying gasoline.[50] Once an individual's allotment of stamps was exhausted, one was not entitled to buy more gasoline until the next ration book came out.

Markets abhor a vacuum, however, and the vacuum created by unmet demand under a rationing regime did not last, even in wartime. One who was out of stamps could turn to the black market and purchase stamps from someone else.[51] The seller, for a price, would forego her own ration of gasoline. The black market price was higher than the official price of gas because the seller would only offer the stamp for a price that equaled her opportunity cost; that is, the value to her of what she *could otherwise do with the gas*, not the value deemed to be the official price of the gas.[52] If, for instance, she could have used the gas to drive a truck and make a profit, she would sell the stamp for the value of the lost profit that she would have made at that occupation, not for the officially-posted price at the gas station. She would not care how much that official price was because she would not be buying the gas anyway. So for the black market stamp seller, the value of the sold stamp was not a double-recovery of the official gas price; it was only compensation for the opportunity cost of her foregoing the gas altogether.

The reality of black market activity in response to gas rationing during wartime is also true of contemporary DR in the electricity market. A demand-responder is like the ration stamp seller, only operating legally: entitled to buy electricity, but willing to forego that entitlement in return for a payment that compensates him for giving up the profit he would otherwise earn in his home market. Stated more legalistically, the payment represents "liquidated damages" to the demand-responder for the "failure" of the electric grid to meet the demand-responder's full energy needs during the cutback period. The cost of the foregone electricity, which he does not incur, does not matter to him in this respect because he never incurs it. Like the rationing black market, these liquidated damages do not represent a double recovery of the price of foregone electricity because the price of electricity does not even factor into consideration.

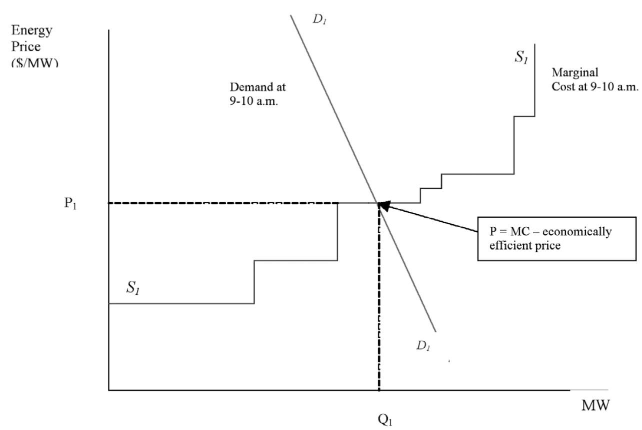
Seen this way, DR is not a payment of something for nothing, but is rather compensation to a manufacturer for a lost opportunity to use foregone electricity to make something to sell for a profit in its home market. This view is critical in the creation of an accurate model of the full effects of DR, both in the electricity market and in the home market of the demand responder.

B. *The Electricity Market Model*

Paying LMP for DR allows grid dispatchers to lower the price of electricity from peak generation LMP to the lower LMP of an earlier non-peak hour. The demand-responder is rewarded with the payment of the LMP that prevailed during that previous hour, saving consumers money during the peak.

This phenomenon can be represented by a diagrammatic model that is well-known to students of microeconomic theory. The model can be constructed for a competitive real-time electric energy market in an RTO with an electric transmission system managed by an Independent System Operator ("ISO"). During any particular hour of the day, e.g. 9:00 A.M. to 10:00 A.M., the demand for electric capacity in megawatts is balanced by the ISO precisely with the supply from various competing electric generating sources in the RTO, starting with the lowest marginal cost generator up to the highest marginal cost generator. Diagram 1 illustrates this model:

Diagram 1



The origin of Diagram 1 can be found in the works of Prof. William W. Hogan of Harvard University's Kennedy School of Government. *See, e.g.*, William Hogan, A Competitive Electricity Market Model 18 (Harvard Elec. Pol'y Group, Oct. 9, 1993) (Draft), *available at* http://www.hks.harvard.edu/fs/whogan/transvis.pdf. In developing the economic model that became the progenitor of today's standard electric market design for Regional Transmission Organizations, Professor Hogan described a representative "short-run electricity market" as a step-increasing supply curve facing a relatively inelastic demand curve that moved outward as demand increased over the hours of the day.

The demand for electric capacity during the hour in question is represented in Diagram 1 by line D_1, sloping downward from left to right, showing that consumer demand declines as the price of electricity rises. The supply capacity is represented by line S_1, rising from left to right to represent the marginal cost of adding progressively more expensive generating units as capacity needs increase during the hour in question, up to a finite megawatt capacity comprising the uppermost limit of the RTO's available supply.

D_1 and S_1 intersect at the point where supply and demand are in balance during this hour. Generators are willing to

49. *See, e.g.,* U.S. Office of Price Admin., Rationing in World War II 1 (1946).
50. *Id.* at 8.
51. *Rationing: A Necessary but Hated Sacrifice*, Life on the Home Front, http://arcweb.sos.state.or.us/pages/exhibits/ww2/services/ration.htm (last visited Mar. 20, 2014). *See also* John W. Jeffries, World War II and the American Home Front: Part One 27 (Nat'l Park Serv. 2004).
52. *See id.*

supply, and consumers are willing to use, an electric capacity of Q_1 megawatts for a price of P_1 dollars per megawatt during the hour of 9:00 A.M. to 10:00 A.M. This price is the LMP for this particular hour in the electric market. In theory, the point of intersection is the economically efficient price for and quantity of electricity for this market at this hour.

C. The Commercial Consumer Model

Now assume that there is a large industrial customer, M, among the consumers of electricity in this RTO. M is a manufacturer of widgets in a perfectly competitive market for that product, in which it has no market power to influence widget prices by altering its supply to that market. Under classical microeconomic theory, M faces the market realities depicted in Diagram 2:

Diagram 2

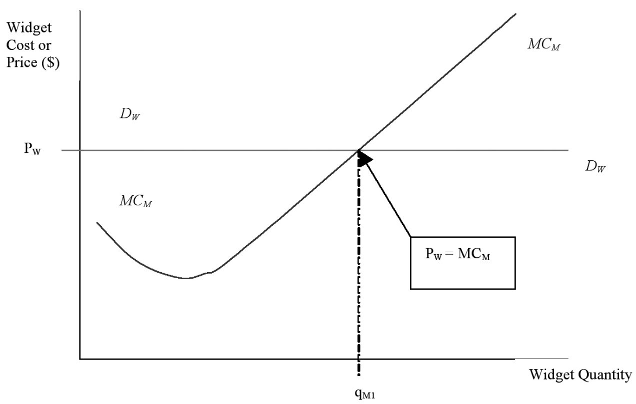


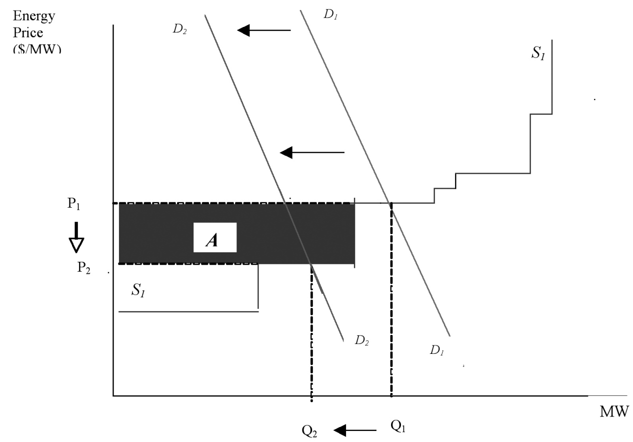
Diagram 2 is derived from the classic supply curve of a firm in a competitive industry that endeavors to produce up to the point where its marginal cost equals the market price of the good, a price the firm has no power to influence upwardly or downwardly. A detailed discussion of this concept can be found in the textbook of PAUL A. SAMUELSON & WILLIAM D. NORDHAUS, ECONOMICS 475–80 (McGraw-Hill Book Co., 12th ed. 1985).

In this market, horizontal line D_W represents the demand for widgets in the widget market, which is so perfectly competitive that consumers alone name the price, P_W, and they will not purchase widgets at any other price. Curve MC_M represents M's marginal cost curve for making widgets, which typically slopes downward initially as M benefits from economies of scale at lower production levels, but starts sloping upward as higher production entails ever higher capital and variable costs. At the point where M's marginal cost intersects with the demand price P_W, M will be willing to manufacture exactly q_{M1} widgets.

D. A Demand-Response Scenario

M's local ISO initiates a voluntary DR program. The ISO enlists M in the effort because of its large share of the ISO's overall electricity demand. Assume that the ISO offers M no compensation for cutting back demand during certain peak hours. Prior to the 9:00 A.M. to 10:00 A.M. hour of peak demand, the ISO asks M to reduce its electricity demand during that hour and M complies, changing electric market conditions at that time as shown in Diagram 3:

Diagram 3



The author derived Diagram 3 independently from Diagram 1, and a similar diagram was used to describe a different aspect of demand response during FERC's rulemaking deliberations by members of the Market Surveillance Committee of the California ISO. JAMES BUSHNELL, SCOTT M. HARVEY, BENJAMIN F. HOBBS & STEVEN STOFT, OPINION ON ECONOMIC ISSUES RAISED BY FERC ORDER 745, "DEMAND RESPONSE COMPENSATION IN ORGANIZED WHOLESALE ENERGY MARKETS" 18 (June 6, 2011) (this report was lodged with FERC in Docket Number RM10-17-000 on June 17, 2011 (FERC eLibrary Submittal No. 20110617-5158)).

The DR is a success as far as the ISO is concerned. The demand for the ISO's supply of electricity has been reduced from Q_1 to Q_2, safely within its capacity constraint. All electricity consumers benefit as well, because the marginal cost at which demand intersects supply is lower, cutting back the price per megawatt from P_1 to P_2. However, generating utilities make less money because demand and price are down, represented by shaded rectangle ***A*** of lost net revenue. This reduced profitability is problematic because they have a lower surplus above cost with which to recoup their original capital investments in higher-end generating units at the upper right-hand end of S_1. Nevertheless, the generators are still able to stay in business.

Our widget manufacturer M, however, is not better off in the widget world. The impact on M's widget market position is shown in Diagram 4. M has to cut back widget production from q_{M1} to q_{M2} in order to meet its DR commitment.

Diagram 4

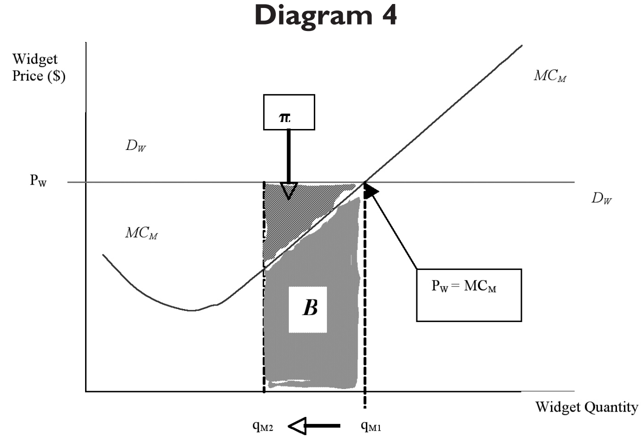


Diagram 4 is further manipulations of the preceding diagrams.

It avoids the cost of that additional production, including the cost of electricity used in such production, which is represented by area *B* below the marginal cost line and between quantities q_{M1} to q_{M2}. M is still able to receive price P_W for every widget that it makes, but it could have made *more* widgets for a greater profit if it had used the electricity. M's lost profit is represented by the shaded area π between the price and marginal cost lines and the intercepts of quantities q_{M1} and q_{M2}. Further, M at this point is operating at a level in the widget market that is economically inefficient because its marginal cost no longer equals the market price. As a result, our noble manufacturer must operate at a loss as a result of its DR in the electric market. As a result, M will choose not to be a demand-responder for long.

The only way to induce M to be a demand-responder is to compensate it for sacrificing profits in the widget market. FERC has recognized this fact: "For users that derive more than $1,000 per MWh of value from consuming energy," FERC said, "their cost of providing demand response exceeds $1,000 per MWh, since they give up in excess of $1,000 per MWh of value by reducing energy usage. Such users would generally be unwilling to reduce their energy usage at compensation levels below $1,000 per MWh."[53]

This sacrificed value, however, is *not* the manufacturer's avoided cost of production (including avoided electricity cost), as the foregoing diagram shows, because avoiding cost *B* makes M no richer and no poorer. Remember, when M is using electricity, M is making a widget and making a profit. That also means that M is covering the cost of electricity. It doesn't matter how much profit is made on a widget; that M makes any profit at all is what matters. Thus, only the *lost profit*, π, represents a real sacrifice to M, because that *would* have made M richer than it was before. This is the reason why DR is not a double payment for reducing electric consumption (that is, both avoided cost *and* LMP for every megawatt-hour foregone) as it is sometimes portrayed. Rather, the avoided costs disappear with the reduced electric consumption. Any payment to demand-responder M compensates only for the *profit* that it fails to earn by producing fewer products in its home market.

The money to buy M out of the electricity market during this critical hour, when LMP threatens to go exceedingly high as overall demand peaks, ultimately comes from the other participants in the market—generators, transmitters, distributors and consumers—because they are the ones who benefit from M's cutback. In a sense, they are the ones who are "liable" to the demand-responder for paying its liquidated damages for lost profits in the form of LMP payments. Exactly who the particular payers of such compensation should be is an issue that is not reached here.

Compensating demand-responders for the benefit of the electric market exacts a corresponding cost on the widget market. M experiences a loss of economic efficiency in the widget market as a result of its underutilization of potential energy resources.[54] This interplay between the electric market and the widget market makes it possible to model mathematically how much compensation is needed to draw a demand-responder out of its native field.

E. *The Trade Off Between the Electric Market and the Home Market*

Suppose the ISO adopts a DR compensation plan to pay demand-responders full LMP at all hours, just as FERC has ordered. Specifically, the plan pays demand-responders the full LMP posted at the beginning of that hour ("*ex ante* LMP") for every negawatt of DR offered. The shifts that take place in the electric market during the hour of 9:00 A.M. to 10:00 A.M. from an anticipated LMP of P_X and load of Q_1, to a post-DR LMP of P_P and load of Q_2, are illustrated in Diagram 5.

Diagram 5

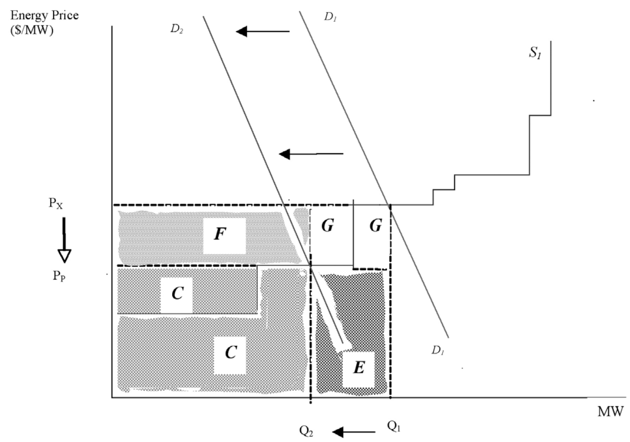


Diagram 5 is a further manipulation of the preceding diagrams.

Area *C* represents the total revenue that market participants must pay to generators for supplying electricity capacity up to the point where supply curve S_1 intersects post-DR demand curve D_2. Area *E* represents the total revenue that market participants must pay demand-responder M for exiting the electricity market for that hour that results in the demand cutback from D_1 to D_2. Area *F* represents the savings that non-demand-responding market participants enjoy as a result of M's DR; without it, they would have to pay generators $P_X \cdot Q_1$ for full-scale demand at level D_1. Area *G* represents the extra revenue that generators would have earned from supplying M with peak power generation, but instead lose as a result of relying on M's DR.

Since part of the savings from DR, as shown above, is considered by generators to be lost potential revenues, those generators will naturally oppose this scheme. That is not only because it cuts into their profits. It is also because those rev-

53. PJM Interconnection, L.L.C., 139 FERC ¶ 61,057, at 47 (2012).

54. *See* Order 745-A, 137 FERC ¶ 61,215 at 37, 56 (2011) (explaining that the Illinois Commerce Commission, in its comments to the Commission upon rehearing of Order 745, argued this point but it was rejected by the Commission).

enues would otherwise have gone toward a return on their investment in fixed and capital costs, particularly for building highly-profitable peak-load generating plants and associated transmission systems. If DR programs succeed, inevitably generators will be forced to reduce generation capacity in the long run.

On the other side of the DR equation is the reaction of potential demand-responders like M to the lure of *ex ante* LMP revenue for every megawatt foregone. The mathematics of this reaction can be found in the Appendix at the end of this article. It is sufficient to say that the math shows that a demand-responder will react to an offer of LMP revenue for its DR according to the following relationship:

$$P_P > ½ \bullet P_W \bullet K$$

This formula ("DR Formula") determines, on the basis of the product price in M's home market (P_W) and the ratio of products per kilowatt-hour that M can manufacture (K), the amount that the *ex ante* LMP (P_P) must exceed in order to induce M to offer a DR in the electric market that drops M's electricity demand from Q_1 to Q_2.

Suppose that M is asked to reduce electricity consumption during the hour in question when M's production is making five widgets per kilowatt-hour consumed.[55] Assume that the wholesale price of a widget in M's home market (P_W) is $2.00. Therefore, under the DR Formula, in order to induce M to exit the electricity market for the hour in question, the *ex ante* LMP must be:

$$P_P > ½ \bullet (\$ 2.00/\text{widget}) \bullet (5 \text{ widgets/kWh})$$

Completing the calculation:

$$P_P > \$ 5.00/\text{kWh}$$

In other words, the *ex ante* LMP immediately preceding the peak hour in question must equal or exceed $5.00 in order to induce M to cut its own widget production in order to save electricity.

Peak-hour LMPs in the PJM market in 2009 reached a high of approximately $200 per MWh[56] or $0.20 per kWh. Assuming that this is the highest level that the *ex ante* LMP would reach in this fictional ISO energy market during the hour in question, M would not be likely to cut its production in order to offer a DR. M will not accept a mere $0.20 per kWh reimbursement when it needs at least $5.00 per kWh to recover its lost widget profit.

Suppose that M were an automobile manufacturer in a perfectly competitive automobile market. Say that each car requires 2,000 kWh of electric energy to manufacture. Therefore, K equals 0.0005 cars per kWh consumed (that is, the inverse of 2000 kWh/car = 1/2000 of a car per KWh = 0.0005 car/KWh). Assume that the cost of the manufacturer's cars to the car dealer is $25,000. To induce M to exit the electricity market at a particular hour, the *ex ante* LMP at that hour must be:

$$P_P > ½ \bullet (\$25{,}000/\text{car}) \bullet (0.0005 \text{ cars/kWh}) = \$6.25/\text{kWh}$$

Again, at the $0.20 per kWh LMP rate available from the ISO, M will not offer a DR as an automobile manufacturer any more than as a widget manufacturer.

The DR Formula can also be used to determine the likely reaction of a demand-responder that is able to cut back electricity consumption with little or no reduction in production in its home market. For example, some stores might be able to turn off lights and lower air-conditioning temperatures without diminishing their sales revenues during the peak hour in question. As a consequence, the production rate per kilowatt-hour, K, for such entities is zero. Therefore, to induce the store or college to be a demand-responder:

$$P_P > 0$$

In other words, an entity that experiences no cutback in productivity at all as a result of reducing electricity consumption will offer a demand-response at *any* LMP rate, no matter how small. These outcomes tell us a great deal about the type of electricity consumers that are the most likely to be demand-responders on a regular basis.

The derivatives of the DR Formula say a few things about the sensitivities of DR to price and productivity changes. The derivative dP_P/dP_W is equal to ½K, a positive number, and the derivative dP_P/dK is equal to ½P_W, also a positive number. This means that as widget prices rise, *ex ante* LMP payments must also rise in order to induce a DR from M. It also means that as M becomes more energy efficient (*i.e.*, M changes its production technique to make more widgets per kilowatt-hour than it is now making), *ex ante* LMP will also have to rise to continue inducing a DR from M. On the other hand, the more energy-intensive the manufacture of a product is, such as the car manufacturer mentioned above who makes only a fraction of a car per kilowatt-hour used, *ex ante* LMP needed to induce a DR declines. Therefore, as inflation pushes prices upward or as industrial energy efficiency improves, DR will become more and more expensive for RTOs to acquire even though it may already be too expensive to induce at current LMP levels. While DR would likely be offered in regions where energy-intensive industry is concentrated, it would come about only if LMPs become much higher than we have seen to date. By contrast, businesses that can cut back electricity usage with no effect on production, such as big box stores, are likely to offer DR readily at any LMP level.

The DR Formula determines how much must be paid to M for its DR cutback in order to make up for M's lost profit. That lost profit, however, also represents something else: the product market's loss of economic efficiency because M is making fewer widgets than the market wants to buy. In other words, paying for DR rewards electricity market participants at the expense of the customers in the demand-responder's

55. It must be borne in mind that K, being a marginal rate, may differ depending on the time of the workday and the level of M's usual production level during that time of day. This variance is not critical for the purposes of this analysis, which is limited to M's demand response within a given hour of production.

56. Monitoring Analytics, LLC, 2010 Quarterly State of the Market Report for PJM: January Through June 28 figs. 2-15 (2010), *available at* http://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2010/2010q2-som-pjm.pdf.

home market, who may experience shortages in the supply of the home good.

The preceding discussions do not address the effects of M's ability to exercise market power, which are relevant for areas of the country served by regulated vertically-integrated utilities.[57] If M can, it would want to increase its profits by restricting supply and raising prices above the level of perfect competition.[58] To induce M's DR in the electric market, M must be reimbursed for its foregone monopoly profits, less what M can recover by raising prices to its customers. The outcome is even more inefficiency in an already inefficient home market.

The DR Formula marks the break-even point at which a demand-responder in a particular home market, faced with a particular LMP level, will or will not offer a cutback in its energy consumption in order to equilibrate the electricity market. As LMP is a quantity that is determined by economic and technological factors in the electricity market rather than in the demand-responder's home market, that quantity may at times be significantly higher than the break-even point of a particular demand-responder, but may at the same time be too small to induce any DR at all from others in other markets. In other words, DR based on LMP payments is not a "one size fits all" proposition.

III. The Formula as a Tool for Demand-Response Measurement

Viewing DR in terms of its economic impact on the home market of the demand-responder indicates more than simply who will offer DR and how their offer is affected by economic changes. It also provides information on how much DR a particular offeror is likely to generate. This feature has important implications for assuring compliance with the DR rules.

As the *Paper Cases* explain, the prevailing method of setting a baseline for a demand-responder's electricity use during its normal operations consists of determining the average hourly load of the DR resource, rounded to the nearest kilowatt-hour, for each of the twenty-four hours in a day.[59] The level of its actual production of goods in its home market is not a factor in this evaluation. When a new demand-responder resource is introduced to the grid, its baseline is calculated for each hour in a day based on meter data from the initial five business days after the resource has been approved and hourly meter data has been recorded.[60] This calculation does not take into account the demand-responder's actual production of home market goods.

As a result, manipulation of this benchmark is a simple task, especially where the demand-responder possesses its own sources of on-site electric generating capability, known as "behind-the-meter generation," like in the *Paper Cases*. A demand-responder would run its plant during the five-day test period without using on-site generators that it normally uses to power the plant. It would purchase the metered electricity needed for normal operation during that period from the utility instead. This trick would establish a higher metered baseline for the plant than is normally the case when on-site generators run. Once the test period was completed, the plant would turn the on-site generators back on. It would then offer DR to the grid for production below the inflated baseline and get paid for that response, all the while drawing its usual electric amount from the utility and maintaining normal plant production throughout the peak period.[61]

Instead of setting a demand-responder's baseline in this way, using the DR Formula improves reliability by establishing better baseline metrics. The DR Formula does not differentiate between the use of behind-the-meter generation or utility generation that is used by the producer for normal operations. Instead, it relies on two verifiable independent variables: (1) the price of the demand-responder's home market product, and (2) the rate of the demand-responder's production of its goods per kilowatt-hour. Data for these variables should be available from a demand-responder's own historical records of production and electricity use.[62] The rate of goods production per kilowatt-hour is a marginal rate at normal production levels, which may vary when the market for the home good is depressed or booming. The use of fairly recent historical data for production and electricity use would probably suffice to capture the appropriate marginal rate at the then-prevailing level of demand. Although this procedure may be somewhat more costly to carry out, it is likely to be more reliable than relying exclusively on electric meter data, because the production level of the demand-responder in its home market is observed and measured as part of the DR evaluation.

When DR is needed during peak hours, the RTO would use the DR Formula by calling for demand-response offers only from those whom the RTO determines would benefit from the then-existing *ex ante* LMP level; that is, demand-responders for whom the DR Formula is true at that time. All other demand-response offers would be rejected by the RTO as uneconomical. This requirement might have the

57. A "vertically integrated" entity is one in which the entire chain of production, transmission and distribution is controlled by the same or overlapping ownership. *See*, *e.g.*, Cablevision Sys. Corp. v. F.C.C., 597 F.3d 1306, 1308 (D.C. Cir. 2010) ("Cable programmers began to develop programs for sale or license to cable operators. These two halves of the cable industry often had—and still have—overlapping ownership, with cable operators having ownership interests in cable programmers, and vice versa. Such companies constitute 'vertically integrated' entities.").
58. *See* Paul A. Samuelson & William D. Nordhaus, Economics 514-16 (McGraw-Hill Book Co., 12th ed. 1985).
59. Richard Silkman, 144 FERC ¶ 61,164, at 11 (2013).
60. *Id.*
61. *Id.* at 15.
62. If the measure of the rate of a demand-responder's production of its goods per kilowatt-hour is based upon electricity measured at the meter, then the presence or absence of behind-the-meter generation would influence an accurate reading of "*K*," potentially skewing the results just as it does to existing baseline measurement techniques. However, the objective here is to obtain a cost-effective cutback in the demand-responder's *home market good*, not just a cutback in electricity use. "*K*" is strictly a factor of home market good production and electricity consumed to produce it, which means that if it is measured at the meter, it is best measured with behind-the-meter generation turned off rather than turned on. This aspect eliminates behind-the-meter generation as a tool for manipulation.

effect of reducing the number of eligible demand-responders, but is offset by the benefit of squeezing out the manipulators. It is likely that a plurality of demand-responders would come from entities whose home market production is not appreciably affected by cutting electric consumption, like the big box store in the earlier example.

IV. Conclusion

In sum, DR calls upon the resources of other product markets in order to supply the needs of the electric power market. It is equivalent to peak generation without the need for capital investment in generating resources. The absence of capital investment does not mean that it is cost-free. DR is paid for by inducing inefficiencies in the other product markets. It is preferable to balance the need for DR in the electric market with the inducement of inefficiencies in those other product markets in order to achieve relative economic efficiency overall. This objective is achievable, and readily measurable, by using the DR Formula devised in this Article to gauge when DR should occur. This analysis will assist the electric industry in better utilizing DR resources for the good of the economy as a whole.

Appendix

Computation of the Demand-Responder's Reaction to LMP

This Section focuses on the microeconomic picture of widget-maker M's DR as previously seen in Diagram 4 of the article, reproduced here as Diagram A:

Diagram A

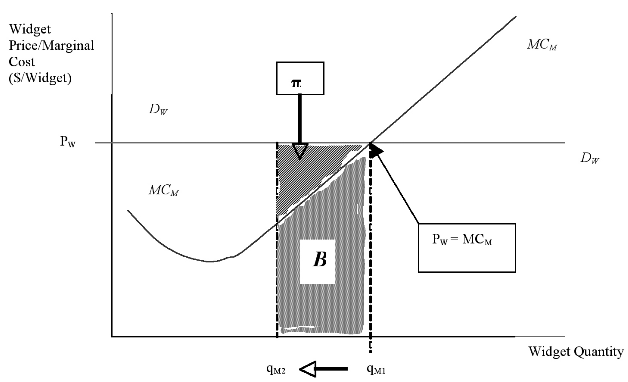


Diagram A is a further manipulation of the preceding diagrams.

Although marginal cost curve MC_M is nonlinear overall, it is safe to assume for the purpose of simplifying the analysis that over the short interval between widget quantities q_{M1} and q_{M2} it is linear with slope k and a y-intercept at zero on the widget price-cost axis. We can assume, then, that for $q_{M2} \leq q \leq q_{M1}$,

$$MC_M = kq \quad [1]$$

where k is the factor that determines M's marginal cost, MC_M, at a given production level of q widgets.

In accordance with the economic theory of perfectly competitive markets that M's marginal cost equals the market price P_W at the point where production and demand is at q_{M1}, we can substitute P_W for MC_M and insert q_{M1} into equation [1] such that:

$$P_W = kq_{M1} \quad [2]$$

and, therefore, that:

$$k = \frac{P_W}{q_{M1}} \quad [3]$$

Now assume that the quantity of widgets (q) that M produces is related to the quantity of electricity (Q) that M consumes such that M consumes more electricity to make more widgets and less electricity to make fewer widgets. Thus, the relationship of widget production to electricity consumption over a short interval is represented by a line with a constant slope K, such that:

$$q = f(Q) = K \bullet Q$$

where $K \geq 0$.

Hence, at widget production levels q_{M1} and q_{M2}, we have the following expressions of M's use of the electricity supply available in the market:

$$q_{M1} = K \bullet Q_1 \quad [4]$$

$$q_{M2} = K \bullet Q_2 \quad [5]$$

When M reduces its production level down to q_{M2} widgets, it has met its demand-response contribution in full. Since it is only the foregone production resulting from that DR that we are concerned about, not the amount of the reduced level that it reaches, we can treat M's electricity consumption and widget production at the reduced level to be the equivalent of zero kilowatts and zero widgets. Therefore:

$$Q_2 = 0 \quad [6]$$

and:

$$q_{M2} = K \bullet Q_2 = K \bullet 0 = 0 \quad [7]$$

The total revenue that M foregoes by cutting back production of widgets from q_{M1} to q_{M2} is equal to the area $P_W \bullet (q_{M1} - q_{M2})$. This area equals the sum of area π and area B that are depicted in Diagram A:

$$P_W \bullet (q_{M1} - q_{M2}) = \pi + B \quad [8]$$

Area B can be represented as the integral of curve MC_M from q_{M2} to q_{M1}. Hence, equation [8] can be rearranged to represent π as follows:

$$\pi = P_W \bullet (q_{M1} - q_{M2}) - \int_{qM2}^{qM1} kq \, dq \quad [9]$$

Solving the integral, we have:

$$\pi = P_W \bullet (q_{M1} - q_{M2}) - \frac{k}{2} \bullet (q_{M1}^{\ 2} - q_{M2}^{\ 2}) \ [10]$$

Factoring the difference in squares on the right results in:

$$\pi = P_W \bullet (q_{M1} - q_{M2}) - \frac{k}{2} \bullet (q_{M1} + q_{M2}) \bullet (q_{M1} - q_{M2})$$

subsequently resulting in:

$$\pi = [P_W - \frac{k}{2} \bullet (q_{M1} + q_{M2})] \bullet (q_{M1} - q_{M2})$$

Substituting $\frac{P_W}{q_{M1}}$ (for k, we get:

$$\pi = [P_W - \frac{P_W}{2q_{M1}} (q_{M1} + q_{M2})] \bullet (q_{M1} - q_{M2}) \ [11]$$

The factor in brackets on the right side of equation [11] can be rearranged to:

$$\pi = \frac{P_W}{2} \bullet (1 - \frac{q_{M2}}{q_{M1}}) \bullet (q_{M1} - q_{M2}) \ [12]$$

We now focus the electric market as previously seen in Diagram 5 of the article, but stripped-down as shown here in Diagram B:

Diagram B

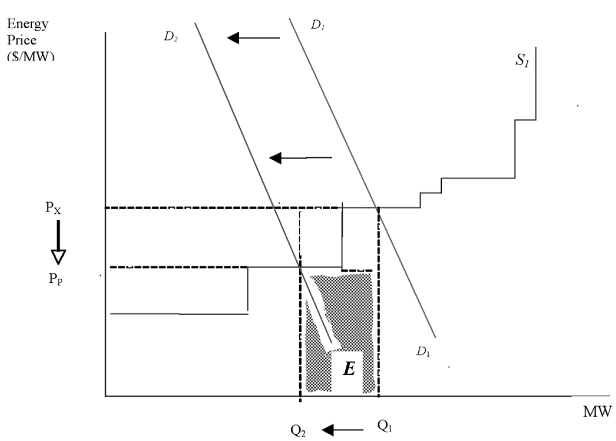


Diagram B is a further manipulation of the preceding diagrams.

In order for a DR to be worthwhile to M, π must be less than the revenue represented by area *E* in Diagram B, equal to $P_P \cdot (Q_1 - Q_2)$, which represents what electric market participants must pay demand-responder M at the *ex ante* LMP rate P_P in order to induce M to exit that market. In mathematical terms:

$$E > \pi$$

Consequently:

$$P_P \bullet (Q_1 - Q_2) > \frac{P_W}{2} \bullet (1 - \frac{q_{M2}}{q_{M1}}) \bullet (q_{M1} - q_{M2}) \ [13]$$

Shifting factors around results in:

$$P_P > \frac{P_W \bullet (1 - \frac{q_{M2}}{q_{M1}}) \bullet (q_{M1} - q_{M2})}{2 \bullet (Q_1 - Q_2)} \ [14]$$

Finally, substituting $K \bullet Q_1$ for q_{M1} and the zero values of q_{M2} and Q_2, equation [14] becomes:

$$P_P > \frac{P_W \bullet (1 - 0) \bullet (K \bullet Q_1 - 0)}{2 \bullet (Q_1 - Q_2)}$$

Which, upon simplification, becomes:

$$P_P > ½ \bullet P_W \bullet K \ [15]$$

Equation [15] determines, on the basis of the price and energy factors that M faces in its home market, the amount that the *ex ante* LMP (P_P) must exceed in order for M to offer a DR in the electric market that drops M's electricity demand from Q_1 to Q_2.