Nodal Value-Based Pricing of Demand Response in Wholesale Markets

***Abstract*—Economic demand response is used in wholesale energy markets during peak hours to lower locational marginal prices. This resource is typically offered in energy markets as there is no demand response market at present. In other words, there are no wholesale purchasers of demand response, only wholesale purchasers of energy. Since energy buyers (consumers) are considered the beneficiaries of market price reductions caused by demand response, the cost of compensating demand response resources is allocated to energy buyers. This cost allocation is generally implemented through an LMP adjustment. In this paper, we present an alternative method for compensating demand response. Here, load serving entities purchase wholesale demand response in order to increase their margins. Although the effect of demand response will ultimately be reflected in the energy market, the price of demand response offered to customers is based on the value of load reductions to the load serving entities that wish to purchase demand response. Because of this nuance, the proposed pricing method avoids many of the concerns that have been brought up in the recent case before the Supreme Court: FERC vs. EPSA, which challenges, in part, the appropriateness of paying demand response LMP. In particular, the risk of over-paying demand response is eliminated as is the need to allocate the cost of demand response compensation to buyers in the energy market.**

***Index Terms*—Demand response, FERC Order 745, Value-based pricing**

I. Introduction

THE controversy surrounding the price of economic demand response in wholesale markets has recently reached unprecedented heights. Although it is widely accepted that there are economic benefits to price responsive loads, whether and how these resources should be compensated at the wholesale level is, at present, a contentiously debated legal issue. The primary questions at hand (and major points of contention) are twofold: First, is demand response by definition a retail level resource the price of which is subject to States and only States regulation or is there a legally justified role for federally regulated demand response prices in wholesale markets as well? Second, if there is a role for demand response in wholesale markets, how can these resources be priced in a way that does not encroach upon State authority over retail sales, and is fair to wholesale market participants? These questions have been argued in court since 2011, when FERC issued Order 745 requiring wholesale energy markets to pay economic demand response resources the full locational marginal price – a move many felt was not the federal agency's to make [1]. Several alternatives to full LMP payments have been proposed, including, the "LMP-G", or LMP less the generation portion of the DR provider's electricity retail rate as well as "LMP-G&T", or LMP less generation and transmission portion of the DR provider's retail rate [2] [3]. In this paper, we propose a value-based pricing methodology that avoids much of the controversy surrounding the above two questions by creating a new market product for which there are actually buyers, and setting prices based on the value to said buyers. In this manner, both wholesale and retail DR programs co-exist without conflict.

Despite this recent jurisdictional battle, demand response has a long and arguably successful history, both at the retail and wholesale level. For decades, vertically integrated utilities implemented various forms of retail level demand response programs, usually, through interruptible rates offered to large customers [4]. Such programs allowed the utilities to avoid costly upgrades due to infrequent peaks. However, restructuring of vertically integrated utilities during the late 1990's separated generation from the transmission and distribution components of the utility and oversaw the creation of wholesale markets to facilitate the sale of energy from independent power producers. This changed the traditional utility business model, stripping it of any major financial incentive to implement peak energy saving measures at best, and placing the utility at odds with demand response and energy efficiency efforts at worst. However, it should be noted that a number of states are addressing this financial disincentive mainly through revenue decoupling [5].

At the same time, as wholesale markets developed, demand response was eventually incorporated into wholesale energy markets. From the early 2000's to 2011, independent system operators (ISOs) offered various prices to wholesale demand response resources, the most common being full locational marginal price (LMP) and locational marginal price less the generation portion of the demand response resource's retail rate (LMP-G) [3] [6]. And in 2011, the Federal Energy Regulatory Commission (FERC) issued Order 745, mandating full LMP payments for economic demand response in wholesale energy markets when said resources meet the requirement of cost effectiveness (net-benefits test) [7]. This Order was highly contested, with one FERC commissioner dissenting and EPSA (Electric Power Supply Association), a group representing generators, ultimately filing suit against FERC. In May 2014, a lower DC district court overturned the FERC Order, ruling that a) FERC did not have jurisdiction to regulate demand response as it is a retail product and thus subject to States regulation, and b) that even if FERC had jurisdiction, the price (LMP) was arbitrary and capricious [8]. FERC immediately appealed and in May of 2015, the Supreme Court of the United States agreed to rehear the case.

Perhaps on the surface, it appears that this legal conflict rests in the fact that States-regulation of electricity prices predates the creation of federal energy regulatory entities (i.e. FERC and its predecessor FPA), which were created solely to fill what was discovered to be a regulatory gap that inevitably arose during interstate transactions [9] [10]. However, it is the authors' assertion that the root of the problem lies in the fact that DR is currently sold in energy markets. Because of the link between wholesale energy prices and energy demand, independent system operators (ISOs) have for the past decade incorporated economic demand response into existing wholesale energy markets, allowing these resources to compete on an equal footing as generators and often times to be paid the same price as generators. And this in and of itself creates several problems:

1) Lack of DR revenue: FERC has coined this missing money problem, "the billing unit effect." When DR is sold in an energy market, revenue is only collected for energy and nobody actively buys DR. This effect requires buyers in the energy market to be charged for DR through cost allocation (i.e. adjustments to the LMP) [7].

2) DR priced at generator prices (LMP) effectively states that reduction is equal to production. This is not a reasonable statement. Even if load reduction balances supply and demand just as generation increase would, the value of reduction vs. production differs among the different market participants. This fact leads to the third problem.

3) Economic efficiency of DR is currently measured through the "net benefit test". This test ensures that the avoided market cost gained through DR (benefit) is greater than or equal to the cost to compensate DR (cost). Thus, the benefit of DR in energy markets is currently measured from the point of view of energy buyers' cost rather than from the view of maximum welfare. In other words, maximum welfare is not the same as lowest cost and should not be treated as such.

The contribution of this paper is the development of a demand response pricing model that a) creates a potential incentive for LSE's to support demand response, b) creates a means for States and FERC to co-optimize DR both at the wholesale and retail level, c) allows the nodal value of load reductions to be reflected in DR prices, and d) prevents uneconomic quantities of demand response. Furthermore, as the proposed methodology calls for demand response to be separated from the energy market, we also present an analysis of social welfare gains and losses given demand response participation. We conclude with a discussion of the impact that the four possible Supreme Court rulings in FERC v. EPSA might have on this methodology.

II. Proposed DR Pricing Methodology

The proposed DR pricing methodology is based on the premise that demand response is not an energy resource. As such, demand reductions should not be offered in wholesale energy markets. Instead, these resources would be offered as a new, "wholesale demand response product". This new wholesale product is defined as an option to purchase electricity and would be offered to load serving entities as a means of managing their wholesale expenses. In other words, the intended beneficiary of the demand response product would be load serving entities themselves, and not load serving entities on behalf of their customers.

A. Defining Value of Demand Response

In [11], the authors proposed a market mechanism for pricing demand response proportionally to the benefits it provides to its buyers. This benefit comes in the form of increased gross margin for LSEs. The gross margin is the difference between the retail and wholesale prices multiplied by the volume of energy sold. This margin (illustrated in Figure 1) is maximized at an optimal load L^*. While wholesale prices vary with demand, retail prices are usually fixed. Because of this, at peak loads, the LSE experiences declining margins and it is during these peak hours that there is a potential for the LSE to purchase DR as load reductions will increase gross margins. This is only economic if the cost of purchasing DR is less than the LSE's economic gain due to DR.

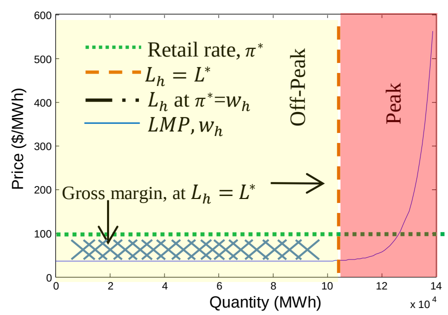

Figure 1. Illustration of gross margin at L^*.

B. Market Design

Figure 2 shows a high level schematic of the proposed wholesale demand response market. Here, demand response acts as a "demand side resource" and not as an energy resource. This is an important distinction as it requires the creation of a new type of "supply curve" to price demand response as well as a new type of demand curve to define the market equilibrium price for DR.

This new "supply curve for DR" is analogous to the generation supply curve in the energy market. In Figure 2, we observe that in the energy market, LSEs bid loads into the energy market. Generators submit offers based on, presumably, their marginal costs. From this information, the independent system operator (ISO) establishes a supply curve and sets the day-ahead market prices. In the proposed demand response market, demand response providers offer DR via aggregators or their LSEs, who are also the ultimate buyers of DR. An LSE's demand for DR will be a function of day-ahead energy market prices (or the generation supply curve) and its retail rates. Therefore, LSEs register their retail rates, DR providers submit their DR offers, and from this information, the ISO is able to generate a market price for DR that maximizes the LSEs' gross margins. In this way, the two markets are linked, but generate unique prices.

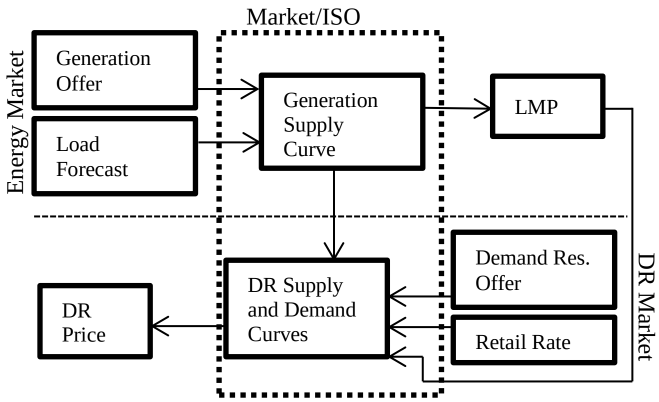

Figure 2. Proposed process to determine demand response price

C. Supply and Demand Curves

In competitive markets, a product's price is determined by the intersection of supply and demand curves. The supply curve represents the marginal cost of producing the next unit of the product. The demand curve represents the cost at which a customer is able and willing to purchase a given quantity of the product. Thus market equilibrium occurs when the marginal cost of production equals the marginal revenue from purchases. Keeping in line with these definitions, when the aforementioned product is demand response, then the "demand curve" represents the maximum price at which a load serving entity is willing to buy demand response. And the "supply curve" represents the marginal cost of demand response.

1) Demand Curve for DR

Since load serving entities would purchase demand response to reduce their expenses, then they would be willing to pay a price for demand response that is less than or equal to the benefit that they derive from demand response. In this case, that benefit of demand response is an increase in gross margin (i.e. the difference between gross margin with and without DR). Then, the maximum price that a rational load serving entity would be willing to pay at any given hour is the change in gross margin due to DR divided by the amount of DR needed to produce said change in gross margin. This price V_h^d, is given in Equation (1).

$$V_h^d = \frac{\left(\pi^* - \lambda^d_{h,L_h^d - D_h^d}\right)\left(L_h^d - D_h^d\right) - \left(\pi^* - \lambda^d_{h,L_h^d}\right)L_h^d}{D_h^d}, \quad \left(\frac{\$}{NWh}\right) \quad (1)$$

where,

$$\pi^* = \sum_n \frac{L_{h,n}^d}{L_h^d} * \pi_n \;, \quad \left(\frac{\$}{NWh}\right) \quad (2)$$

Here, π^* is weighted average retail rate defined in Equation (2), $\lambda^d_{h,L_h^d - D_h^d}$ is the wholesale price on day d, at hour, h, when the net system load is $L_h^d - D_h^d$ and λ^d_{h,L_h^d} is the wholesale price on day d, at hour h, when the system load is L_h^d. Thus, L_h^d is the baseline load and D_h^d is the demand response cleared in the market.

It is important to note, that different LSEs could have different retail rates, and the potential economic value of a unit of DR would be different for each LSE – perhaps economic to some and not to so others. This method makes use of a single representative retail rate. Thus, it is the role of the ISO to select a rate "π^*" that best represents all of the DR buyers. In Equation (3), we approximate that rate as the load weighted retail rates of the load serving entities buying in the DR market, where π_n is the retail rate of the n^{th}LSE, and $L_{h,n}^d$ is the local load of the n^{th} LSE.

2) Supply Curve for DR

As in the energy market, demand response suppliers in this new market can bid their marginal costs. These bids represent the value that DR providers place on relinquishing an option to use electricity. For the purpose of our analysis in this paper, we generate this curve based on the definition of demand response market products: Since we define these products as "options to purchase energy", then the market value of that option can be represented by the marginal cost of the demand response provider opting to exercise its right to consume electricity. This means that starting from a baseline load, L_h^d, the marginal cost S_h^d, of demand response D_h^d, can be approximated as the energy market price when total demand is $L_h^d + D_h^d$. Thus, in Equation (3), f is ideally the supply curve based on DR price/quantity bids, but for the purpose of this paper, it is the generation supply curve.

$$S_h^d = f\left(L_h^d + D_h^d\right), \quad \left(\frac{\$}{NWh}\right) \quad (3)$$

D. Interpretation of Supply and Demand Curves under Order 745

For comparison, current demand response compensation is based on benefits from retail customer's point of view. In that case, customers have a demand for DR up until the point when the cost of DR, (LMP multiplied times DR), is greater than the benefit (the change in LMP multiplied times load). This effectively defines a demand curve for DR as Equation (4).

$$V_{h,FERC}^d = \frac{\left(\lambda^d_{h,L_h^d - D_h^d} - \lambda^d_{h,L_h^d}\right) * \left(L_h^d - D_h^d\right)}{\left(D_h^d\right)}, \quad \left(\frac{\$}{NWh}\right) \quad (4)$$

Since the FERC Order also sets the price of DR at full LMP, then this effectively defines a supply curve of DR at full LMP.

However, since LMP reduces with increasing DR, the DR supply curve has a negative slope and is given in Equation (5). In Equation (6), f is the generation supply curve.

$$S_{h,FERC}^{d} = f\left(L_h^d - D_h^d\right), \quad \left(\frac{\$}{NWh}\right) \tag{5}$$

An alternative interpretation of the supply curve is based on the net benefits test under Order 745, which determines the minimum price μ, at which DR can bid (and be paid). This threshold is the price on the generation supply curve where the price elasticity is equal to -1 [7]. Since any DR bid in the energy market less than LMP is guaranteed LMP, most DR providers simply bid this price. Thus, in this alternative interpretation, the supply curve is a horizontal line of magnitude μ. In this paper, we analyze the welfare benefits using this alternative interpretation of the effective supply curve under Order 745.

III. Market Equilibrium and Welfare Analysis

In a sufficiently competitive market, price is determined by market equilibrium, or the intersection of supply and demand curves. The price and quantity of a commodity sold at this equilibrium maximizes social surplus. And at any other quantity and price, there are deadweight losses. Thus using this welfare analysis for either of the supply and demand curves defined in Section II.C and Section II.D, producer surplus, consumer surplus and social surplus are defined in Equations (6) - (8), respectively.

$$P_h^d = \int_0^{D_h^d} S_h^d\left(D_h^d\right) - S_h^d(D), \qquad (\$) \tag{6}$$

$$C_h^d = \int_0^{D_h^d} V_h^d(D) - S_h^d\left(D_h^d\right), \qquad (\$) \tag{7}$$

$$W_h^d = P_h^d + C_h^d, \qquad (\$) \tag{8}$$

Deadweight losses are given by Equation (9), where lowercase w_h^d is the total loss of social welfare and D^* is the quantity of DR at the intersection of supply and demand curves.

$$w_h^d = \int_{D_h^d}^{D^*} V_h^d(D) - S_h^d(D), \qquad (\$) \tag{9}$$

A. Alternative Market Equilibrium and Welfare Analysis

Economic demand response has no utility beyond reducing energy costs. An energy buyer's surplus continuously increases to market equilibrium because energy can be used. DR, however, cannot be used and it therefore is not in the DR buyer's interest to continue purchasing DR until the cost of DR equals the benefit of DR to the buyer (at that point, the buyer has neither gained nor lost). This means that consumer surplus in the demand response market cannot be accurately represented by the equations above. We therefore modify the consumer surplus as Equation (10).

$$C_h^d = \left(V_h^d - S_h^d\left(D_h^d\right)\right) * D_h^d, \quad (\$) \tag{10}$$

Furthermore, because economic gains from DR come at a cost, maximum social welfare no longer occurs at the intersection of supply and demand curves; rather, it occurs when the *potential* economic gain of DR equals the cost to procure it. This new equilibrium D^{**}, is described in Equation (11) and is illustrated in **Figure X**. Here, $Area_1$ is the potential financial gain from DR and $Area_2$ is the cost to procure those financial gains.

$$Area_1\left(D_h^d\right) = Area_2\left(D_h^d\right), \quad if \;\; D_h^d = D^{**} \tag{11}$$

$$Area_1 = \int_{D_h^d}^{D^*} V_h^d(D) - S_h^d(D), \qquad (\$) \tag{12}$$

$$Area_2 = \int_0^{D_h^d} V_h^d(D) - V_h^d\left(D_h^d\right), \qquad (\$) \tag{13}$$

Note that $Area_1$ in the alternative welfare analysis is equivalent to deadweight loss in the traditional welfare analysis in Equation (9). In the alternative method, deadweight loss is the difference between $Area_1$ and $Area_2$ in Equation (14). The interpretation of (14) is that if w_h^d is positive, then there remains *economic* (cost-effective) DR that could be bought.

$$w_h^d = Area_1 - Area_2, \qquad (\$) \tag{14}$$

IV. Case Study

We tested the proposed DR pricing method using a network represented by the 6-bus system in Figure 3. For this initial study, no transmission constraints are considered and there is a single market price for at each node. (Concurrent work includes congestion and losses).

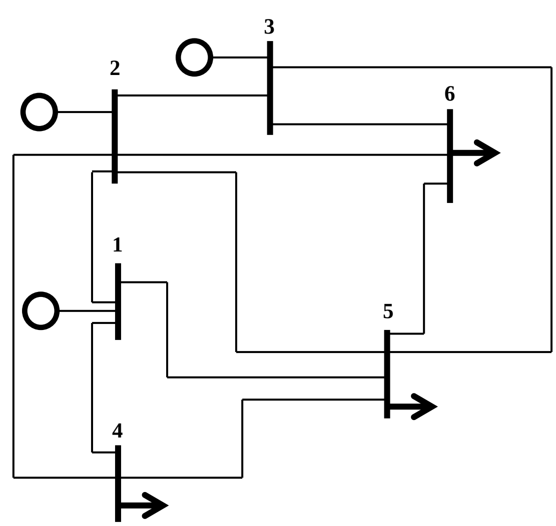

Figure 3. Test Network

The network has three generators and three load serving entities, each with different parameters (Table 1and Table 2). The generation supply curve is determined from the cost curves of the three generators. Keeping with convention established with Order 745, this generation supply curve is then approximated by a smooth curve [7], in this case, a third order polynomial.

Table 1. Load Serving Entity Rate and Load Parameters

	Bus (#)	*Flat Retail Rate ($/MWh)*	*Peak Retail Load (MWh)*
LSE 1	4	13.7	150
LSE 2	5	15.7	143
LSE 3	6	18.7	130

Table 2. Generator Cost and Output Parameters

	Bus (#)	*Cost Curve Coefficients* $\left[\frac{\$}{MW^2}, \frac{\$}{MW}\right]$	P_{min} *(MW)*	P_{max} *(MW)*
Gen. 1	1	[0.0040, 8.5]	50	100
Gen. 2	2	[0.0050, 9.0]	37.5	250
Gen. 3	3	[0.0700, 9.5]	45	180

The following analyses were performed for both the proposed method as well as the Order 745:

a. DR supply and demand curves (including alternative welfare analysis)

b. Comparison of DR market evaluated with traditional welfare analysis and the alternative welfare analysis

c. Comparison of welfare at market equilibrium point and point of maximum social surplus.

V. Results

Since each of the LSEs has a different retail rate (illustrated in Figure 4a), they each maximize their gross margins at a different "optimal demand" (illustrated in Figure 4b). Thus, it is the role of the wholesale market to pool DR resources and identify a system-wide optimal load that maximizes the sum of all LSE gross margin increases when they purchase wholesale DR. Given the three retail rates π_i, $(i = 1 \dots 3)$ and using Equation 2, the optimal rate is ($15.2/MWh).

For the proposed method, the supply and demand curves are given in Figure 5a. Here, the supply curve is based on the incremental increases in gross margin as the demand response increases from 0 to 60% of the peak. The market equilibrium is at 20% peak reduction and has a price of $33/NWh, however social surplus is not maximized at this equilibrium. Figure 5b illustrates the change in welfare with increasing penetration of DR. Consumer surplus increases until peaking at 10% peak load reduction. Producer surplus is continuously increasing. Social surplus is maximized at 13% peak reduction providing a value of $1455 (which corresponds to a price of $27/NWh). Again, in this case, the "consumers" are the load serving entities, not their retail customers.

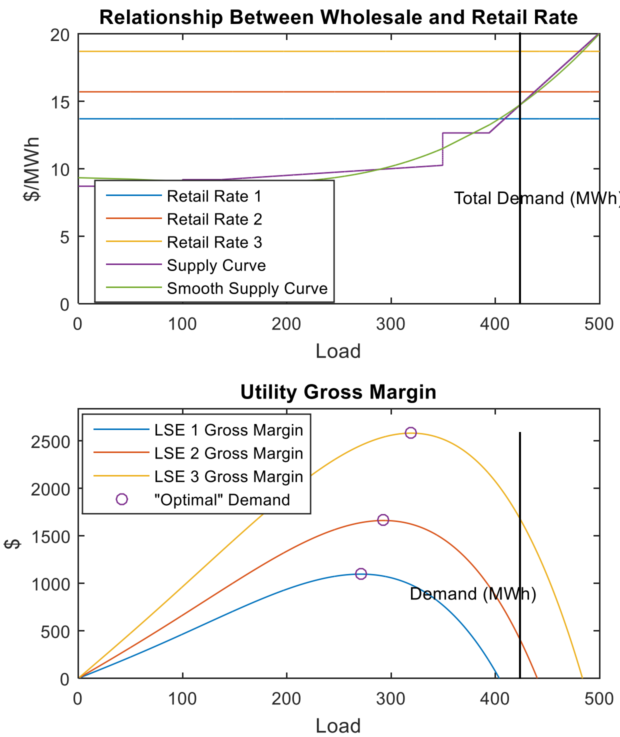

Figure 4. a) LSE retail rates. b) Gross margin as a function of total demand

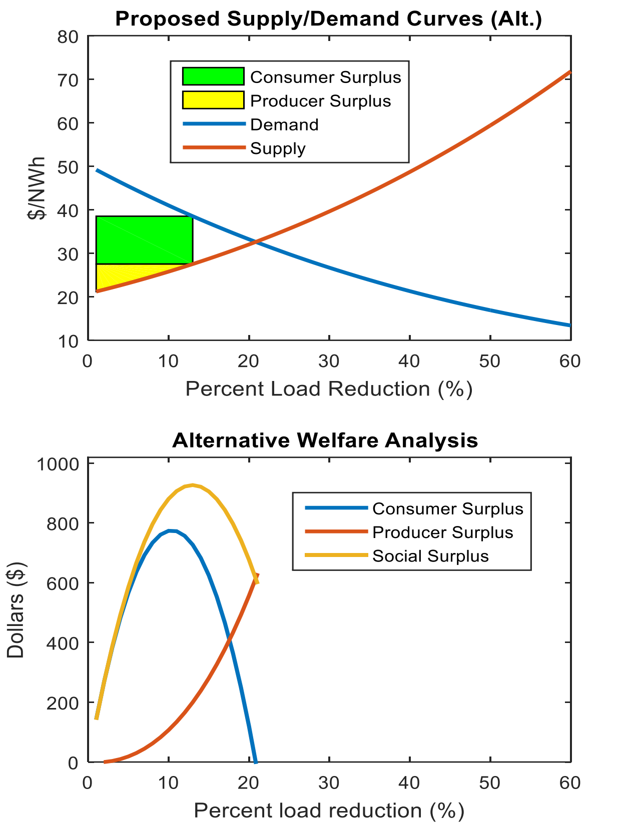

Figure 5. a) Proposed supply and demand curves. b) Welfare analysis

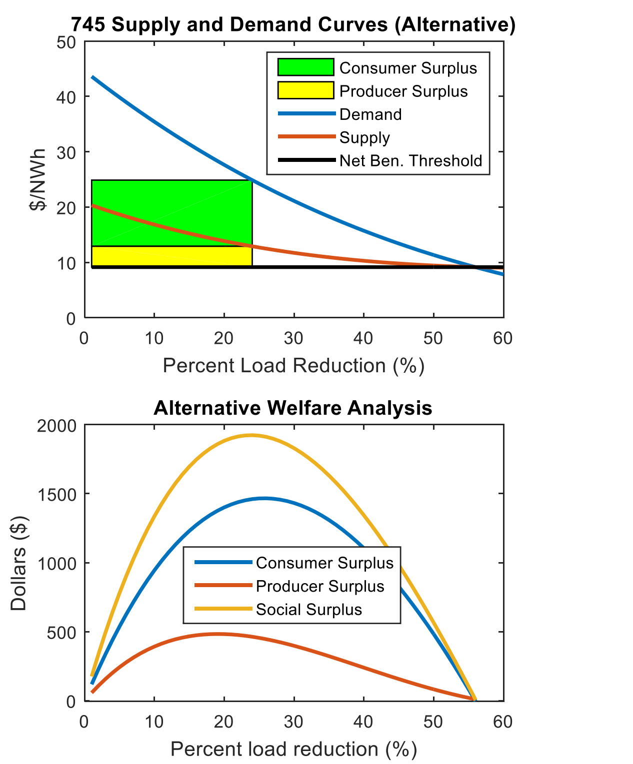

Figure 6. a)Supply and demand under Order 745. b) Welfare analysis

Figure 6a presents the supply and demand curves for DR under the current Order 745 pricing method. Here, the demand curve for DR is the value of DR to retail customers and the supply curve for DR is the LMP. However, for the welfare analysis, we assume that the marginal cost of DR is the threshold price, μ (Otherwise, the negative slope of the supply curve would result in a negative producer surplus). Based on the smooth generation supply curve in Figure 4a, this threshold price is $\mu = \$9.2/NWh$. Figure 6b illustrates the welfare analysis. Because of the decreasing slope of the market price (LMP), the producer surplus does not increase for all load reductions. Rather, the producer surplus peaks at 19% load reduction with a surplus of $476, while the consumer surplus peaks at 26% load reduction. The threshold price is reached at 56% peak load reduction. At this point, the producer surplus, consumer surplus and therefore social surplus are all zero. Here we note that under the 745 method, "consumers" are retail customers (not the LSEs themselves).

The most notable difference between Figure 6a and Figure 5a is that the market equilibrium in the 745 case occurs at a much higher quantity of DR and much lower price. This means that during peak periods, the proposed method places a higher value and therefore higher price on DR. However, since we assume that the cost of DR is an increasing function, the quantity at equilibrium will be lower than in the 745 case (which has a decreasing supply curve for DR). As for social surplus, there are two important points on Figures 5b and 6b: The quantity of DR at market equilibrium, and the quantity of DR at maximum social surplus. Ideally, these two points should be one and the same, but in the case of demand response, this is not the case. That is because, while the supply curve represents the maximum price the LSE is able and willing to pay for DR, it also represents the only value of DR to the LSE (i.e. there is no utility beyond cost reductions). So at market equilibrium, the DR buyer actually gives up all benefit *of* DR to pay *for* DR. Thus, the proposed case results in a maximum social surplus of $926 at 13% load reduction and the Order 745 case results in a maximum social surplus of $1924 at 26% load reduction.

Table 3 summarized the results in Figures 5 and 6 at the market equilibrium points and maximum social surplus points. In comparing the proposed DR market pricing method with the current Order 745 method we find that the proposed method has both its market equilibrium point and maximum social surplus point at lower quantities of DR than in the FERC 745 method. In terms of absolute value, the Order 745 method results in a higher social surplus when DR is limited to maximizing social surplus. This is because the decreasing price of DR allows for larger quantities of DR. At the market equilibrium however, the proposed method provides a higher social surplus. This is because the increasing value of DR allows DR to enjoy a surplus even if the consumers do not. In other words, at market equilibrium, the social surplus is entirely producer surplus.

Table 3. Welfare Comparison

Market Equilibrium Point			
	Unit	*Proposed Method*	*Order 745 Method*
Equilibrium Price	($/NWh)	32.7	9.14
Equilibrium Quantity	(NWh),	106 (21% of load)	285 (56% of load)
Consumer Surplus	($)	0	0
Producer Surplus	($)	601	0
Social Surplus	($)	601	0
Maximum Social Surplus Point			
	Unit	*Proposed Method*	*Order 745 Method*
Max SS Price	($/NWh)	27.5	12.9
Max SS Quantity	(NWh)	66 (13% of load)	122 (24% of load)
Consumer Surplus	($)	726	1461
Producer Surplus	($)	200	463
Social Surplus	($)	926	1924

Finally, Table 4 shows the distribution of costs and benefits for the various market participants.

	Benefits	***Costs***
	Gross Margin Increase	*Payments in DR Market*
LSE 1	$1,325	$947
LSE 2	$851	$608
LSE 3	$368	$263
	DR Market Revenue	
DR Providers	$1,819	---

VI. Conclusion

The fate of economic demand response in wholesale markets currently rests in the hands of the impending Supreme Court decision. Given the historic success of demand response at both wholesale and retail levels, it is very likely that the Supreme Court will rule that DR can participate in FERC regulated programs. However, there are in fact four potential endings to this case and the applicability of the proposed method differs in each scenario:

1. The court rules that FERC has no jurisdiction <u>*and*</u> even if it did, LMP is arbitrary and capricious.
2. The court rules that FERC has no jurisdiction <u>*but*</u>, LMP is not arbitrary or capricious. (This is an unlikely scenario, because if FERC is found not to have jurisdiction, then the price question is moot.)
3. The court rules that FERC has jurisdiction, <u>*but*</u> that LMP is arbitrary and capricious:
4. The court rules that FERC has jurisdiction <u>*and*</u> that LMP pricing is not arbitrary or capricious.

In scenario 1 and 2, the proposed method could potentially still be a suitable alternative to LMP pricing of DR as it gets around the issue of "consumers" being retail customers. In fact, in the proposed method, the consumers would be wholesale participants and without doubt subject to FERC regulation. States may still view this as encroachment on State authority. However, where there is no jurisdictional friction, the proposed method provides a potential for States to maximize locational value of DR through the wholesale market.

Scenario 3 provides the greatest potential for the proposed method as FERC would find that in order to continue its much desired wholesale DR program, it would need to establish a different price and ensure that it is neither arbitrary nor capricious.

In the case of scenario 4, FERC will most likely choose not to look further into pricing methodologies for DR and Order 745 will continue to be enforced. However, even if DR continues to be paid full LMP, FERC has shown much flexibility in the net benefits test and at the very least would benefit by redefining the price threshold of DR from the market equilibrium point to the maximum social surplus point as described in this paper. Furthermore, as demand response becomes used for more specialized services, such as targeted emission reductions or variable generation integration, there would be great potential for the proposed DR market to facilitate these new transactions.

This work on value based pricing of wholesale DR represents preliminary results in a network without congestion. Current work extends this method to allow the nodal value of load reductions during congestion to be reflected in DR market prices.

References

[1] *Brief for the Respondends on Writs of Certiorari to the United States Court of Appeals for the District of Columbia Circuit, FERC v EPSA*, 2015.

[2] G. Heffner and F. A. Sullivan, "A Critical Examination of ISO-Sponsored Demand Response Programs," Center for the Advancement of Energy Markets (CAEM) and Distributed Energy Financial Group (DEFG), 2005.

[3] PJM Interconnection, "2012 Economic Demand Response Performance

Report," PJM, 2013.

[4] *Brief of Southern Company Services Inc., As Amicus Curiae supporting Respondends, FERC v EPSA,* 2015.

[5] The Regulatory Assistance Project (RAP), "Revenue Regulation and Decoupling," 2011.

[6] D. J. Lawrence and B. F. Neenan, "The status of demand response in New York," in *IEEE PES General Meeting*, 2003.

[7] Federal Energy Regulatory Commission (FERC), "Order No. 745: Demand Response Compensation in Organized Wholesale Markets," 15 March 2011. [Online]. Available: www.ferc.gov/EventCalendar/Files/20110315105757-RM10-17-000.pdf. [Accessed 2014].

[8] District of Columbia Circuit, United States Court of Appeals, 23 May 2014. [Online]. Available: www.cadc.uscourts.gov/internet/opinions.nsf/DE531DBFA7DE1ABE85257CE1004F4C53/$FILE/11-1486-1494281.PDF. [Accessed 2014].

[9] Energy Information Administration (EIA), "The Changing Structure of the Electric Power Industry: An Update," 1996.

[10] *Public Utilities Commission v. Attleboro Steam Co., US Supreme Court, 273 U.S. 83,* 1927.

[11] A. Negash and D. S. Kirschen, "Optimizing demand response price and quantity in wholesale markets," in *IEEE Power and Energy Society General Meeting*, 2014.