Economic Evaluation of Alternative Demand Response Compensation Options

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Samuel Newell and Kamen Madjarov

The Brattle Group

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TABLE OF CONTENTS

1. STUDY BACKGROUND, OBJECTIVES, SCOPE, AND APPROACH

In 2008, *The Brattle Group* was retained by ISO New England (ISO-NE) to provide research and analytical services to support stakeholder discussions concerning the participation of demand response (DR) resources in wholesale energy markets. The result of those discussions was the development of five alternative approaches to DR compensation. The same five DR compensation approaches were presented to the Federal Energy Regulatory Commission (Commission) in response to the March 18, 2010 Notice of Proposed Rulemaking regarding Demand Response Compensation in Organized Wholesale Energy Markets. On August 2, 2010, the Commission issued a Supplemental Notice of Proposed Rulemaking and Notice of Technical Conference (Supplemental NOPR) in which parties were asked to comment on whether the Commission should adopt a "net benefits test" for determining when to compensate demand response providers. In response to the Supplemental NOPR, ISO-NE asked *The Brattle Group* to complete a study evaluating alternative DR compensation approaches and to prepare this report.

The objective of this study was to compare how several alternative approaches to compensating DR in the wholesale energy market would affect economic efficiency, both in the short term and the long term. The DR compensation approaches evaluated were:

- Base Case: all consumers are on fixed retail rates with no opportunities to earn wholesale market payments for load reductions. All other cases are compared to this.
- Option 1 "LMP-RR": all consumers are on fixed retail rates, but those providing load reductions are paid the locational marginal price (LMP) less the avoidable retail generation rate (RR);
- Option 2 "RTP": all consumers are on dynamic rates equal to the real-time LMP (*i.e.*, real-time pricing or "RTP");[1]
- Option 3 "Full LMP in High-Priced Hours": all consumers are on fixed retail rates, but those providing load reductions are paid the full LMP in the subset of high-priced hours that correspond to ISO-NE's present Day-Ahead Load Response Program hours (*i.e.*, the 5-10% of hours with the highest LMPs);
- Option 4 "Full LMP When Price Savings > DR Payment": all consumers are on fixed retail rates, but those providing load reductions are paid the full LMP in the subset hours when energy procurements savings due to DR-induced LMP reductions exceed the cost of funding DR payments; and
- Option 5 "Full LMP in All Hours": all consumers are on fixed retail rates, but those providing load reductions are paid the full LMP in every hour.

[1] This option could be achieved either through dynamic retail rates, or through wholesale demand response where the customer has to buy a baseline quantity for every hour, then settles positive and negative deviations from the baseline at the real-time LMP.

Each option was evaluated on the standard measure of economic efficiency from welfare economics: the combined benefit to consumers and producers relative to the Base Case. The benefit to consumers is the value consumers receive in excess of the amount paid (*i.e.*, the "consumer surplus"). The benefit to producers is the amount of revenue producers receive in excess of the cost of production (*i.e.*, the "producer surplus"). Together, consumer and producer benefits convey the total economic value society achieves in excess of production costs (*i.e.*, the total "economic surplus"). Markets are considered efficient when they maximize net benefits by enabling all transactions where marginal benefits exceed marginal costs and not consummating those where marginal benefits are less than marginal costs.

The net benefit of each DR compensation option was analyzed with a model developed by the *Brattle* team based on standard welfare economics as described above. The modeling approach consisted of the following major elements:

- First, hourly linear supply and demand curves were constructed from historical market data and assumed elasticities of demand.

- Second, the supply and demand equations were solved simultaneously to determine the hourly clearing quantity and price. The clearing quantity occurs where consumers receive marginal benefits equal to the effective price they face for load reductions, which is based on the combined effect of the retail rate paid (or avoided) by consumers and the incentive payment for reductions in energy consumption, both of which vary with each DR compensation option. Estimating retail rates resulting from each DR compensation option is an important part of the analysis, given that retail rates must reflect wholesale market prices on an annual average basis and charges to retail customers for funding DR payments. The LMP is determined by the marginal cost of generation on the supply curve at the clearing quantity.

- Third, the short-term economic efficiency of each option was compared to the Base Case by calculating the change in economic surplus. The change in economic surplus was calculated as the sum of the change in consumer surplus (including DR payments) and producer surplus based on the relevant areas between the supply and demand curves.

- Finally, long-term economic effects were also estimated based on the assumption that, in a competitive market, generation suppliers would bid into the capacity market their going-forward costs not covered by energy margins. That is, capacity prices would adjust in response to changes in energy prices.

The numerical results of this analysis depend on the assumptions and methodological choices. The assumptions and methodological choices are reasonable but do not provide an expected value of future market conditions and demand response impacts. The results are an order-of-magnitude indicator of the relative efficiency of the various approaches to demand response compensation, and are not precise point estimates or forecasts.

2. METHODOLOGY

2.1 COMPONENTS OF THE ANALYTICAL MODEL

Each of the DR compensation options was evaluated using consistent assumptions over the course of 8,760 hours in a year. The evaluation methodology consisted of six components:

1. Construct linear supply and demand curves for use in analyzing all approaches to DR compensation.

2. Determine when DR compensation would be available under each option.

3. Identify wholesale market clearing quantities and prices, given price signals corresponding to each type of DR compensation and/or retail rate.

4. Iterate the annual retail rate until it is consistent with LMPs and DR payments in each case.

5. Quantify the effects on short-term economic surplus and distributional impacts relative to fixed rates.

6. Quantify the long-term net benefits including capacity market adjustments.

2.1.1 Construct linear supply and demand curves

Actual demand curves are impossible to observe directly given the disconnection between the retail prices paid by consumers and wholesale LMPs, but are probably non-linear. Actual supply curves are observable given the supply offers submitted by market participants to ISO-NE; however, these supply curves are discontinuous and non-linear. Including such discontinuities and non-linearities in the methodology would make the analysis excessively complicated and computationally intensive. Hence, continuous and linear supply and demand curves were constructed for the purpose of this analysis.[2]

In order to rely on publicly-available data, the study was limited to the years of 2007, 2008, or 2009. We chose to present 2007, although 2008 and 2009 are very similar, since all three years have a similarly mild load profile. Other periods, such as August 2006, have had more volatile prices, but hourly real-time bid data was not publically available. There are ways to estimate the bid curve from the price and load data, but that would have required a different approach and would have taken more time.

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[2] Linear approximations are reasonably accurate close to the data point around which the approximation is made and become less accurate farther from the data point. In this analysis, load fluctuations are small relative to the overall level of demand, suggesting that linear approximation is a reasonable approach.

Demand Curves

The demand curve reflects the marginal benefit consumers derive from each level of consumption, with all uses ranked in decreasing order of value. It indicates the amount customers, in aggregate, would consume at any given price. For a given price, consuming any more would bring less marginal value than the price paid; consuming less would imply foregone activities whose value exceeds the price paid. The price may or may not reflect the marginal *cost* of production, as addressed in detail in this study, but it is the signal that determines customers' consumption decisions. Therefore, it is necessary to have an expression for the demand curve in order to analyze how customers respond to various price signals.

Unfortunately, the only point on the hourly demand curve that can be observed directly is the actual hourly quantity consumed at a price equal to the fixed retail rate (RR_0) paid.[3] Taking this point as an anchor, the rest of the demand curve can be drawn if the slope is known. The slope can be approximated using the equation for the elasticity of demand evaluated at the anchor point, *i.e.*, the value of dP/dQ implied by the equation for demand elasticity: $\varepsilon = (dQ/Q_0)/(dP/RR_0)$, where ε is an assumed short-term elasticity of demand.

The demand function is thus the equation for a line passing through (Q_0, P_0), the actual quantity of consumption and the actual LMP from historical data, with constant slope given by $dP/dQ = (RR_0/Q_0)*1/\varepsilon$, which is derived from rearranging the elasticity equation above. The hourly equation for demand becomes:

$$Q^d(P^d) = Q_0*\{1+\varepsilon*[P^d-RR_0]/RR_0\} \qquad (1)$$

where P^d is the hourly price the consumer pays at the margin, which is constant under fixed retail rates but varies hourly in different ways under the various DR compensation options. Q_0 also varies hourly based on the historical data, so the equation is different in every hour.

The value of the elasticity parameter, ε, plays a key role in the demand equation and in this study. It is a parameter that relates changes in hourly demand to changes in price. The value of this parameter was derived from a careful review of the literature on price elasticities dealing with dynamic pricing rates. The literature consists of a variety of studies carried out in a variety of geographies using primarily two analytical approaches. In one approach, changes in load shape are represented with an elasticity of substitution, and changes in energy consumption are represented separately with a daily price elasticity. In the other approach, a single parameter is used to capture both effects. The two sets of elasticities can be related to each other through *Brattle*'s PRISM software, which provided the foundation for the dynamic pricing simulations in FERC's National Assessment of Demand Response Potential.

[3] To maintain consistency when comparing the economic performance of alternative DR compensation options, the retail rate for each option (including the Base Case) is assumed to be the annual load-weighted average LMP, as described in section 2.1.4. The "retail rate" is volumetric (per kWh) and refers only to the generation component of the customer's bill. For simplicity, this rate does not include the cost of capacity, ancillary services, or other services or risk premiums that may or may not be charged on a volumetric basis.

Since the model used in this study does not consider whether load reductions in one hour are eliminated or shifted, a single elasticity parameter is needed. Hence, we had to focus on studies that similarly relied on a single parameter. In the case of residential customers, only a single such study is available from Commonwealth Edison, which estimated a range of values from -.015 to -.096. For commercial and industrial customers, no study was available that estimated a single elasticity parameter. Instead, the available studies estimated elasticities of substitution that range from -0.05 to -0.082 and a daily price elasticity of -0.02. Using our experience in working on numerous projects with PRISM, we concluded that the range of single elasticities across the studies can be captured by using a low end value of -0.025 and a high end value of -0.10.

Finally, the elasticity of the aggregate demand curve representing both DR participants and non-participants is computed by taking a weighted average. Participation levels analyzed are 3%, 6% (corresponding to the amount of active DR already providing capacity to the ISO-NE market), and 60%[4] of total load. As discussed above, the DR participants are assumed to have an elasticity between -0.025 and -0.10. Non-participants are assumed to have an elasticity of zero.

Supply Curves

Linear supply curves were constructed based on publicly available ISO-NE supply offer data from 2007. Like the construction of demand curves described above, these data were used to identify a point on the line and a slope for the line, which is enough information to draw a line to represent a linear supply curve. The anchor point is (Q_0, LMP_0), the quantity and LMP where the real-time wholesale energy market actually cleared. The slope is derived from parts of the actual hourly bid curves as follows: (1) split the hourly curves into three segments, with cutoffs based on the bottom quartile of annual load levels, the middle 50%, and the top quartile; (2) perform a linear regression analysis for each hour to find a least-squares fit to the data in the section containing the actual consumption quantity; and (3) use the slope of the estimated regression line for the analysis. In the model, the slope of the relevant section of the piecewise-linearized hourly supply curve is translated into a point elasticity of supply, η, which is used in the subsequent computations.[5] Using a derivation similar to that used for the demand equation, the hourly equation for supply becomes:

$$Q^s(LMP) = Q_0 * \{1 + \eta * [LMP - LMP_0]/LMP_0\} \qquad (2)$$

where LMP is the hourly wholesale energy market price, which is determined endogenously in each hour for each case, as explained in section 2.1.3. LMP_0 also varies hourly based on the historical data, so the equation is different in every hour.

2.1.2 Determine when DR payments would be available

In Option 1 "LMP-RR," customers that opt to reduce load would get paid only when the LMP exceeds the generation component of the retail rate, since payments for load reductions would be

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4 60% corresponds to the "Achievable Participation" level of demand response potential in the ISO-NE market from the FERC's National Assessment of Demand Response Potential.

5 The result is the same as using the slopes directly in the equations since there is a one-to-one correspondence between slope and point elasticity at any given (P,Q) combination.

negative when RR exceeds LMP (and we assume that customers would not be offered wholesale payments of RR-LMP for *increasing* load in low-LMP hours). In Option 2 "RTP," the customer would be exposed to the LMP in all hours and would optimize consumption accordingly, but would not receive a payment from the wholesale market for DR. In Option 5 "Full LMP," the customer would be paid the LMP to reduce load in every hour.

In Option 3 "Full LMP in High-Priced Hours," DR payments are available only in the subset of high-priced hours that correspond to ISO-NE's present Day-Ahead Load Response Program hours. These hours are easily identified by comparing the Day-Ahead LMP to the published minimum offer price threshold for that month. In 2007, there were 895 such hours. (Note that the hours with the highest day-ahead LMPs are not necessarily the same as the hours with the highest real-time LMPs, although they are highly correlated.)

In Option 4 "Full LMP When Price Savings > DR Payment," DR payments are available only when the following test is satisfied: the residual load would incur less cost (the wholesale cost of energy consumed and the cost of funding DR payments, both of which ultimately contribute to retail rates) than what it (the non-reducing load) would have paid without DR. This test is carried out within the model in each hour, although how it would be implemented in practice is unclear.

2.1.3 Identify wholesale market clearing prices and quantities

For each DR compensation option, the cleared quantity is determined by the point on the demand curve where the price is equal to the effective marginal price realized by consumers, including any DR payments they receive. In the Base Case, the retail rate is the marginal price for customers on fixed rates with no ability to sell load reductions as DR. Since fixed rates correspond to the predominant rate structure in the historical data, the quantity consumed in this case is the quantity observed in the actual market data.[6] For "RTP" (Option 2), the effective marginal price is the LMP. For "LMP-RR" (Option 1), the customer's effective marginal price is the full LMP, since the customer is paid LMP-RR for reducing consumption by one MWh while also incurring retail savings equal to RR (*i.e.*, LMP-RR+RR = LMP). This produces the same effect as paying real-time prices, but only in high-priced hours where the LMP exceeds RR. For the "Full LMP" options (Options 3, 4, and 5), the customer's effective marginal price is LMP + RR because the customer is paid the full LMP for load reductions while also incurring retail savings equal to the retail rate. The various marginal price signals are reflected in the model by using the relevant expression for P^d in equation (1) above, *i.e.*, P^d becomes LMP in high-priced hours under "LMP-RR," LMP+RR under "Full LMP," and RR when DR is not active.

The hourly wholesale LMP varies hourly and depends on the price signals customers face. In the Base Case, the wholesale price is the actual LMP observed in the market data. In the other cases, the LMP is lower in hours with load reductions. The LMP may be higher in hours with load increases, which occurs in low-LMP hours in Option 2 "RTP." LMPs can also increase slightly in non-DR hours in Options 3 and 4 ("Full LMP in High-Priced Hours" and "Full LMP When

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6 If some consumers are already on dynamic rates, the marginal effect of introducing DR compensation may be lower, although some of the DR compensation options may have more incremental effect than others.

Price Savings > DR Payment," respectively) due to reduced annual retail rates that reflect suppressed LMPs in hours when DR is active. For each option, the hourly market clearing price is determined by the point on the linear supply curve at the quantity consumed by customers.

Market clearing is performed hourly by solving simultaneously the equations for supply and demand. The hourly supply equation does not vary across DR compensation options, but the demand equation does, due to the different expressions for the marginal price seen by consumers, P^d. Hence, the market clearing quantity and the LMP are different under each DR compensation option.

2.1.4 Iterate the retail rate until it is consistent with LMPs and DR payments

Retail rates are an important part of the analysis since they determine the amount customers pay for all non-reduced energy (*i.e.*, the calculated amount of energy consumed under each DR compensation option). Retail rates differ among DR compensation options since they reflect LMPs and the need to fund DR payments, which differ among DR compensation options.[7]

Except for the RTP option, retail rates cannot be calculated at the hourly level since they depend on annual energy costs, and they were assumed to apply to the entire year. Yet retail rates are an input to the hourly market clearing calculations, since they determine baseline consumption (the point on the demand curve where marginal consumer benefits equal the retail rate). Baseline consumption is the realized consumption in non-DR hours. In hours when DR is active, the baseline is the level from which load reductions are measured for determining DR payments. Being both an input to each hour's calculations and an output from all hours' calculations, the retail rate for each DR compensation option must be calculated iteratively.

In the first iteration, the retail rate for each DR compensation option is assumed to be the same as in the Base Case. All hours are solved using that rate, then the model checks for revenue sufficiency. That is, the model compares the total annual payments by load (given by the product of the annual quantity consumed and the retail rate, summed across all hours) to the total annual wholesale cost of serving load and paying DR providers (given by the product of the hourly load and LMP, plus DR payments, summed across all hours). If the payments are not equal to the costs within a narrow convergence threshold, the retail rate is adjusted (upwards or downwards as appropriate) to what it would have to be to achieve revenue sufficiency, then the entire analysis is repeated until convergence is achieved.

2.1.5 Quantify the short-term effects on economic surplus

The metrics used to estimate the relative economic efficiency of alternative DR compensation options are derived from the standard metrics used in welfare economics: principally, the change in total economic surplus (relative to fixed retail rates). The total economic surplus measures the total value achieved in excess of production costs, and it is the most important metric of overall economic efficiency. Economic surplus can be calculated from the area between the supply and

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7 Here, the "retail rate" is a volumetric charge ($ per kWh) and refers only to the generation component of the customer's bill. For simplicity, this rate does not include the cost of capacity, ancillary services, or other services or risk premiums that may or may not be charged on a volumetric basis.

demand curves to the left of the cleared quantity (for every hour). Equivalently, the economic surplus is the sum of the consumer surplus and the producer surplus. Consumer surplus is the total value consumers achieve in excess of their total payments, and producer surplus expresses the revenues suppliers receive in excess of their short-term production costs.

For each DR compensation option, the *change* in economic surplus relative to the Base Case is calculated as the sum of the change in consumer surplus and the change in producer surplus. Demand response programs affect short-term consumer surplus in three ways: first, reductions in consumption reduce the value received from the energy market. Second, reductions in wholesale prices (and the need to fund DR payments) impact annual retail rates that customers pay on all residual load.[8] And third, the DR payments provide a benefit to participating customers. The change in consumer surplus produced by each DR compensation option is calculated as follows:

- The change in value received is calculated as the difference in areas under the demand curve to the left of the consumption points between the DR compensation option being evaluated and the Base Case. The differential area is the trapezoid under the portion of the demand curve where consumption was foregone. The calculation is relatively straightforward because the demand curve has been linearized.

- The change in amount paid is the product of the quantity consumed and the scenario retail rate minus the corresponding product in the Base Case. The derivation of these variables is described in sections 2.1.3 and 2.1.4 above.

- The value of any DR payments participating customers receive is a side payment that is calculated at the hourly level by multiplying the amount of load reduction by the assumed payment rate for demand reductions, *i.e.*, LMP-RR in Option 1 "LMP-RR," and the full LMP in each of the three "Full LMP" options.

A similar approach can be used to calculate the change in producer surplus, assuming that the supply curve represents marginal costs in a competitive market. A change in the quantity consumed (due to different DR incentive and/or different retail rate levels) changes the wholesale clearing price (LMP) that producers receive, as discussed in section 2.1.3. At a lower clearing price and quantity, there is less producer surplus, which is the lost area above the supply curve up to the LMP in each case. The lost area is a trapezoid (with horizontal parallel sides at the two price levels, bounded on the left by the y-axis and on the right by the supply curve) whose area is calculated algebraically. Similar calculations apply to non-DR hours when customers may consume more than in the Base Case due to reduced annual retail rates reflecting suppressed LMPs in hours when DR is active.

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[8] The effects of changes in LMPs and the need to fund DR payments directly affects load serving entities (LSEs), not retail customers. This analysis assumes a competitive market in which forward prices converge with expected real-time prices, and LSEs immediately incorporate their savings into the rates they offer retail customers. Delays associated with standard offer procurement timing or retail contract terms are not considered.

The calculations described above are performed at the hourly level. Since the consumer surplus calculation involves the retail rate, which reflects annual average wholesale costs (not the hourly LMP), the change in consumer and producer surplus does not match the change in deadweight loss at the hourly level. However, they are equal on an annual basis. On an annual basis, a decrease (increase) in consumer surplus plus producer surplus is equal to the increase (decrease) in deadweight loss.

2.1.6 Quantify the long-term effects on economic surplus

In a competitive market, generation suppliers can be expected to bid into the capacity market their going-forward costs (*i.e.*, including new investment and/or ongoing fixed costs) not covered by energy margins and ancillary services. If suppliers earn less revenue in the energy market due to DR, they will need to raise their bids in the capacity market, which would raise capacity prices if generators are on the margin in that market. Higher capacity prices will increase consumer costs, offsetting the short-term benefit of DR suppressing LMPs in the energy market. The offset could be less than complete if the marginal generation capacity resource setting the capacity price does not expect to operate in some of the hours when DR would suppress LMPs (although even peaking generation would likely run in most of the high-priced hours in which DR is expected to operate, where price impacts from DR are most pronounced). The offset could be more than complete if the marginal generation resource does expect to operate in all of the hours when DR would suppress energy prices. Whereas the customer value of lower energy prices applies only to energy actually consumed (which is less than peak consumption on average), the customer value of higher capacity prices applies to all capacity purchased, which is roughly 1.15 times actual peak load.

This adjustment mechanism does not apply in the near-term when capacity prices have already been determined through forward auctions, or in any years when a price floor is in effect and sets the price. Nor does it apply when active DR is on the margin in the capacity market, since enabling it to participate in energy markets would provide a new revenue source and help to lower its net going-forward cost that DR would need to recover through capacity markets. Our analysis assumes generation is on the margin, an assumption that is relevant in the long term when capacity prices have to rise to a level sufficient to attract new capacity and/or retain existing capacity in the face of increasing environmental pressures to either install costly controls or retire. We have not analyzed when this is likely to occur or how capacity prices would be affected by DR in the interim.

The mechanism and timing by which DR affects capacity prices also depends on whether the DR in question is providing new capacity. Additional capacity supply can suppress capacity prices while also displacing generation and thereby increasing energy prices. However, this study considers only DR assets that are already providing capacity (such as that which is already providing active DR through ISO-NE's Forward Capacity Market) in order to isolate the incremental effect of engaging DR in the energy market with energy-based payments. New DR assets would obviously provide capacity in addition to energy, but their capacity value can be considered separately since its capacity value would be compensated through the capacity market. Any peak reductions that appear in this study are not in addition to the capacity value that is already recognized in the capacity market.

Our long-term analysis accounts for energy-capacity price interactions as follows: first, assume generation sets capacity prices in the long term. Second, assume energy market conditions and customers' marginal incentives are the same under each DR compensation option as in the short-term analysis. Third, allow capacity prices to adjust such that they shift consumer surplus back to producers by exactly eliminating the short-term benefit of the price reduction. The effect was calculated by transferring back to the producers an amount equal to the product of the short-term price reductions and the quantity actually consumed. Finally, the net economic benefit (*i.e.*, economic surplus) is the sum of consumer surplus and producer surplus, which turns out to be the same as in the short term since transfers do not affect overall net benefits.

2.2 Modifications Made Since the Technical Conference

Initial results of the economic study described in this report were presented as part of ISO-NE's presentation at the Commission's September 13, 2010 Technical Conference. Since the Technical Conference, the *Brattle* team prepared revised results of the economic study of DR compensation options. These revised results are presented herein and replace those prepared for ISO-NE for the Commission's September 13, 2010 Technical Conference.

In preparing to submit the final analysis for ISO-NE's comments in response to the Supplemental Notice of Proposed Rulemaking issued on August 2, 2010, we conducted an additional review of the analysis that was presented by ISO-NE at the Technical Conference. Our review validated all aspects of the analysis presented at the Technical Conference except for the way transmission and distribution ("T&D") charges had been incorporated. Conceptual and implementation errors regarding T&D require corrections to the record and the submission of revised numerical results.

As part of correcting the identified errors, we had to reconsider the structure of T&D rates and whether T&D costs should be considered fixed or variable. T&D rates had been treated as volumetric (estimated at $0.06/kWh) while T&D costs had been inconsistently treated as variable in some aspects of the model and fixed in others. The revised analysis treats T&D rates as non-volumetric and T&D costs as fixed. Non-volumetric T&D rates (*e.g.*, monthly demand-based) are much more common for the types of customers that are likely to provide the majority of demand response in the energy market, especially initially: medium to large commercial and industrial customers that already provide most of the active demand response capacity. These customers already have interval meters and possibly other enabling technology, as well as a relationship with an LSE or curtailment service provider who helps them to profitably leverage their operational flexibility.

Since T&D rates are non-volumetric for these customers, T&D would not impact their marginal energy consumption decisions. Nor do marginal consumption decisions significantly affect T&D costs. Therefore, T&D costs were excluded from the model in the revised results presented herein. Removing T&D from the model produces different numerical results from the ones presented at the Technical Conference, but it does not change the rank ordering of DR compensation options in terms of economic efficiency. The revised results are presented in the tables attached to this letter. All of the non-T&D aspects of the analysis are the same as before. The revised tables now also present results for a range of elasticities of demand, rather than only a single value of -0.05.

2.3 AUDITING PROCEDURES TO ENSURE MODEL ACCURACY

The model results presented by ISO-NE at the Technical Conference were audited by the *Brattle* team through both a top-down review and a bottom-up review. The top-down approach involved the Principal Investigator, Dr. Samuel Newell, reviewing the results for reasonableness, focusing particularly on the differences among DR compensation mechanisms and the relationships between numbers within each mechanism. The results passed the reasonableness test. The bottom-up approach involved an associate, who had not developed the model, reviewing the mechanics of the code. It also involved a research associate systematically checking that the input data had been entered properly into the model. This process revealed several minor errors that were corrected before submitting results to ISO-NE for presentation at the Technical Conference. However, the initial audit of the model failed to catch the T&D errors described above, due to an oversight in this complex part of the model by the Principal Investigator and the code auditor. The errors have since been corrected, as described in Section 2.2.

To ensure the accuracy of the revised model results presented in this report, the model was re-audited with three processes: first, the Principal Investigator worked with the associate who had developed the model and the one who had audited the computer code to review every aspect of the model from the ground up. The team walked through every element of the methodology, how it was implemented in the code, and how changes in inputs affected the results. Second, the Principal Investigator reviewed the entire code, all the formulas therein, and the inputs/outputs of the code at an hourly level. Third, the team passed the model to a separate Ph.D. economist who was not involved in the project for an independent review. These processes identified no errors in the final version of the model or the corresponding results being submitted herein. We can report with the highest level of confidence that the results are accurate, given the assumptions described in this report.

2.4 CAVEATS

The scope of this analysis does not include how energy and capacity market conditions might vary over time due to market entry, exit, extreme weather, or load growth. Further, the analysis does not account for environmental externalities or the possibility that customers might shift load – *i.e.*, increasing consumption in some hours as a result of decreasing consumption in others. The analysis also does not account for operational difficulties of trying to apply the hourly savings test in Option 4 before-the-fact, or trying to establish customer baseline load levels (*i.e.*, consumption that would occur without DR) under DR compensation options that induce load reductions in many or all hours.

The numerical results of this analysis depend on the assumptions and methodological choices. While the assumptions and methodological choices were intended to be reasonable, they were not designed to provide an expected value of future market conditions and DR impacts. As such, the results should be interpreted as directional and relative rather than absolute. As the next section will show, the absolute numbers depend strongly on several key variables (and undoubtedly other variables we did not vary, such as price volatility), whereas the conclusions about the relative efficiency of the alternative DR compensation options are robust.

3. FINDINGS

3.1 SHORT-TERM IMPACTS

Traditional retail rates do not vary as wholesale market conditions change from hour to hour. As a result, customers have no incentive to use less power when wholesale LMPs are much higher than the retail rate or use more power when LMPs are low. As a result, everyone pays more for the high cost of peak usage, and value is foregone in off-peak periods. If instead, customers were exposed to LMPs, presumably they would find cost-saving ways to change their consumption patterns. Overall costs could be lower and/or more value could be delivered. However, most states have not introduced dynamic retail rates to most customer classes for a variety of reasons.

Wholesale DR programs allow customers to respond to wholesale market conditions (by selling load reductions) even if their retail rate remains fixed. The ability to sell load reductions and earn compensation corresponding to the LMP incentivizes customers to reduce their consumption whenever the LMP exceeds the marginal value of their consumption, which is defined by their demand curve.

All of the DR compensation approaches examined may be intended to produce this result, but the analysis shows that some are substantially more efficient than others due to differences in customer marginal price signals. Under the "LMP-RR" approach (Option 1), the customer providing demand response would be paid LMP less its retail generation rate from the wholesale market while also avoiding paying the retail generation rate, which results in a net price equal to the LMP (*i.e.*, LMP-RR+RR = LMP), which is similar to real-time pricing. Under the "Full LMP" approaches (Options 3, 4, and 5), a customer that reduces load is paid the full LMP from the wholesale market but also saves the retail rate, and thus acts as if the cost of power is the LMP *plus* the avoided retail rate. Wholesale payments of "Full LMP" cause the customer to see a net price of LMP+RR for load reductions. The nomenclature used in the debate is somewhat misleading since the "LMP-RR" approach causes the customer to see a net price for load reductions equal to the full LMP, whereas "Full LMP" approaches cause the customer to see a net price for load reductions that exceeds the LMP (by the amount of the retail generation rate) during program hours.

The central question that this analysis attempts to answer is which approach to DR compensation produces the most economically efficient result. Economic efficiency is maximized when consumers adjust their consumption to the point where the marginal benefit of consumption equals the marginal cost of production. This result is intuitive. If instead, consumption occurred at a point where the marginal benefit of consumption is greater than marginal cost, it would be possible to improve economic efficiency by increasing consumption and achieving additional benefits that exceed additional costs; if consumption occurred at a point where the marginal benefit of consumption is less than marginal cost, it would be possible to improve economic efficiency by decreasing consumption and avoiding production with costs exceeding the value provided. The optimum is achieved when the marginal benefit of consumption equals marginal costs. Customers naturally move to the optimum consumption point if the price they realize is equal to the marginal cost, *i.e.*, the LMP. Accordingly, one would expect RTP – retail prices indexed to wholesale LMPs – to produce the most efficient result. Similarly, when the LMP exceeds the retail rate, the "LMP-RR" approach produces a net price of LMP at the customer level, which induces them to move to the optimum. However, "Full LMP" approaches produce a higher price for load reductions and thus induce customers to consume less than the optimal amount – customers forego consumption when the marginal value would have been higher than the marginal cost of production, which is economically inefficient.

The economic efficiency impacts are illustrated in Figure 1, below. Figure 1 shows the economic efficiency implications in four different cases:

- In the Base Case (upper left), demand is insensitive to wholesale LMPs. Consumption occurs at the point along the demand function where the marginal benefit equals the price that customers face. That price is the generation component of the fixed-price retail rate (RR), which does not vary hourly with the LMP in the wholesale market. This causes over-consumption in high-priced periods (at Q_{Pk}) and under-consumption in low-priced periods (at Q_{OffPk}), each leading to foregone economic benefits (often called "deadweight loss"), shown in shaded grey.

- In Option 2 "RTP" (upper right), customers are exposed to and are fully responsive to LMPs through their retail rates. Thus, consumption occurs at the point along the demand function where the marginal benefit equals the LMP, *i.e.*, where the supply and demand curves intersect. This achieves the optimum quantity of consumption (Q*), with no deadweight loss. There is no over-consumption, with value less than the marginal cost. There is no under-consumption with foregone value exceeding the marginal cost of production.

- In Option 1 "LMP-RR" (lower right), customers are on fixed retail rates, but are paid LMP-RR from the wholesale market while also avoiding retail payments, for a net "price" of LMP (*i.e.*, LMP-RR+RR=LMP) for load reductions. Thus, all demand is responsive to wholesale LMPs whenever the LMP exceeds the retail rate. Figure 1 shows how demand responsiveness during high-priced hours can eliminate inefficient over-consumption in those hours, achieving the same economic efficiencies as "RTP." However, this approach does not directly address under-consumption during low-priced hours, so some deadweight loss remains (unless the customer is *paid* RR-LMP for load *increases*, which is not part of the proposal being evaluated).

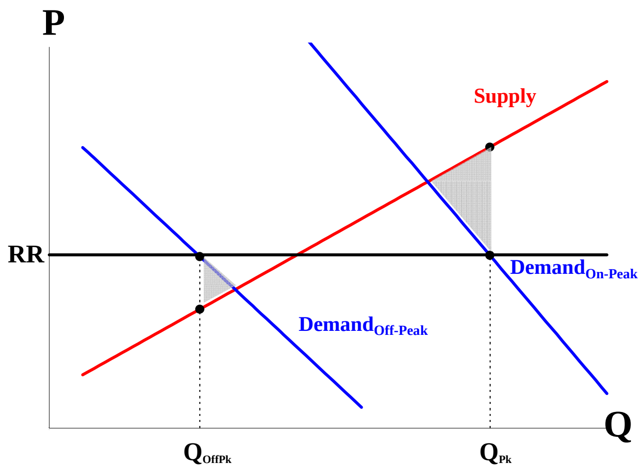
- In Option 5 "Full LMP" (lower left), customers are on fixed retail rates but are paid "Full LMP" from the wholesale market while also avoiding retail payments, for a net "price" of LMP + RR for load reductions. Figure 1 illustrates how the extra incentive always causes customers to consume below the optimum in every hour in which the incentive is provided, since the effective marginal price is always higher than the retail rate. The effect of this incentive is to eliminate excessive consumption during peak periods, but it overshoots, resulting in under-consumption, as indicated by the deadweight loss triangle on the right. Full LMP payments also exacerbate under-consumption in low-priced periods, as indicated by the deadweight loss triangle on the left.

- Option 3 "Full LMP in High-Priced Hours" is not shown separately in Figure 1, but it has similar properties to Option 5 "Full LMP" in the 895 high-priced hours when it is active, and similarities to fixed rates in other hours. Option 3 thus eliminates overconsumption in the high-priced hours, although it overshoots and results in under-consumption, which is economically inefficient.

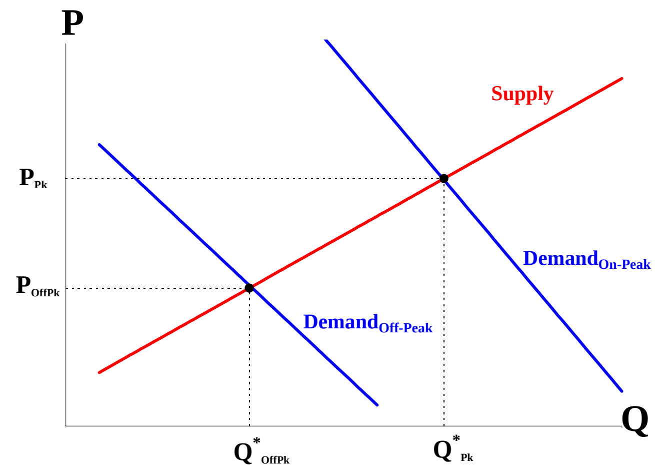
- Option 4 "Full LMP When Price Savings > DR Payment" is also not shown separately in Figure 1, but it has similar properties to Option 5 "Full LMP" in the hours when it is active and similarities to fixed rates when it is inactive. When it is active, Full LMP payments always induce under-consumption. When it is inactive, it leads to the same irresponsiveness and either over-consumption or under-consumption as in the Base Case. In our analysis, DR payments would have been available in 4,650 hours (*i.e.*, the hours in which price savings exceed DR payments). Those 4,650 hours capture most of the high-priced hours when the LMP exceeds the retail rate, but they also include many lower-priced hours.

Figure 1. Supply, Demand, Retail Rates, Market Clearing, and Economic Efficiency

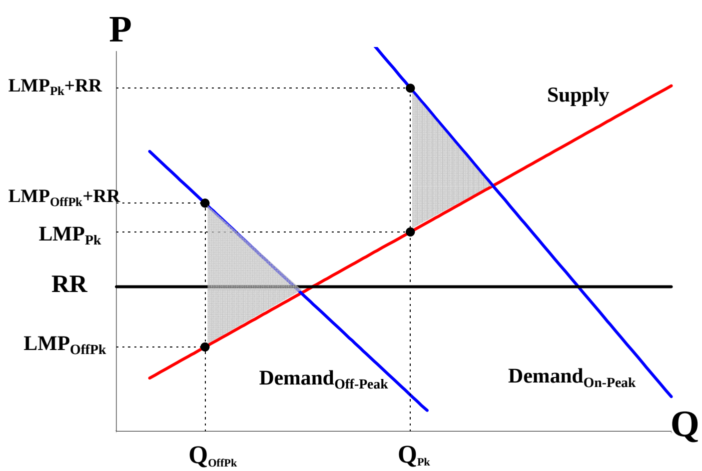
Base Case “Fixed Rates” with no DR



Option 2 “RTP”: Demand Responsive to LMP



Option 5 “Full LMP”: Demand Responsive to LMP + RR



Option 1 “LMP-RR”: Demand Responsive to full LMP when LMP > RR

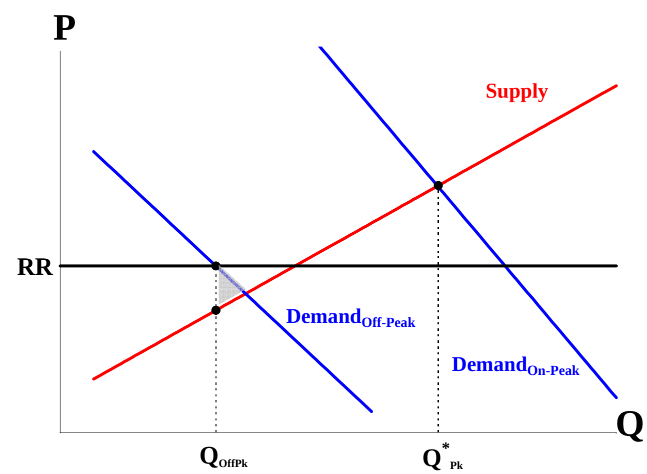


Table 1 summarizes our economic evaluation across a broad range of assumptions on DR participation and elasticities of demand. In all of the scenarios, full exposure to real-time prices (Option 2) is more efficient than Fixed Rates with no DR (Base Case). Responsiveness to LMPs in only the high-priced periods, achieved through "LMP-RR" payments for DR, also achieves efficiencies, but not as much as RTP overall since it does not avoid under-consumption during low-priced periods.[9]

Notably, Option 5 "Full LMP in All Hours," is the least efficient. The economic efficiency losses from inducing under-consumption in every period more than offset the efficiency gains from avoiding excessive consumption during peak periods. Option 4 "Full LMP When Price Savings > DR Payment" is also quite inefficient. Option 3 "Full LMP in High-Priced Hours" is also inefficient compared to the "RTP" and "LMP-RR," although only slightly less efficient than fixed rates. The details of the model results are tabulated in the Appendix.

Under all DR compensation options, especially those that provide greater incentives to reduce load, LMP price suppression increases consumer surplus, to the detriment of producers. This effect is likely to be transient, however. In a competitive market, the consumer benefits of LMP suppression will eventually disappear as producers adjust their capacity market offers, as discussed below.

Table 1. The change in economic surplus relative to the fixed rate Base Case over a range of levels of participation and elasticity of demand

	LMP-RR	RTP	FULL LMP IN HIGH-PRICED HOURS	FULL LMP WHEN PRICE SAVINGS> DR PAYMENT	FULL LMP IN ALL HOURS
ε=-0.025					
3% Participation	$305,447	$469,692	($269,308)	($1,528,042)	($3,033,147)
6%	$606,339	$932,052	($526,246)	($2,989,959)	($5,968,600)
60%	$5,394,841	$8,270,303	($3,739,670)	($21,785,756)	($47,276,172)
ε=-0.05					
3%	$606,339	$932,052	($526,246)	($2,989,959)	($5,968,600)
6%	$1,195,093	$1,835,935	($1,006,291)	($5,733,239)	($11,570,379)
60%	$9,753,198	$14,972,987	($5,760,031)	($34,360,465)	($79,489,772)
ε=-0.1					
3%	$1,195,093	$1,835,935	($1,006,291)	($5,733,239)	($11,570,379)
6%	$2,324,524	$3,567,589	($1,850,569)	($10,602,904)	($21,840,419)
60%	$16,813,406	$25,996,255	($8,334,841)	($51,267,054)	($128,215,284)

3.2 LONG-TERM EFFECTS INCLUDING CAPACITY MARKET PRICES

All else being equal, reducing or shifting load will reduce LMPs (especially during high-priced periods) to the benefit of consumers and to the detriment of producers. However, it is unrealistic to assume that all else will be equal in the long term. Producers can be expected to eventually adjust their behavior in ways that offset the short-term energy price benefits to consumers. In a

[9] If a consumer on RTP is offered wholesale payments for load reductions, the "LMP-RR" approach would provide no incentive to further reduce load from the optimum consumption point. The "Full LMP" approaches would incentivize under-consumption and thus decrease economic efficiency.

competitive market, generation suppliers can be expected to increase their capacity market offers to the extent that reduced margins earned in the energy market reduces recovery of fixed going-forward costs.

Assuming that, in the long term, generation is on the margin in the capacity market, the LMP suppression effects of DR would lead to a roughly commensurate increase in capacity prices. Thus, the LMP price suppression benefit consumers may enjoy from DR in the short term disappears, while the energy market efficiencies or inefficiencies remain.

As the bottom rows of Tables A.1 through A.9 illustrate, the net effect is to make consumers worse off in the long term, in addition to making producers worse off in every period. These findings obviously depend on the assumptions and methodological choices made, but the essential result is likely to remain: in a competitive market, consumers cannot expect to be able to permanently lower all-in prices (including energy and capacity) by giving each other side payments as incentive to reduce consumption. Suppliers will eventually have to respond in such a way that reflects their net going-forward costs.

4. SUMMARY OF CONCLUSIONS

The results of the analysis point to the following conclusions:

Economic inefficiencies arise from customer responses to prices that do not reflect true, real-time marginal energy costs:

- Fixed retail rates result in over-consumption in high-priced hours and under-consumption in low-priced hours;

- Customers receiving “Full LMP” compensation from the wholesale market while also avoiding retail generation rates will act on a price equal to LMP + RR. This induces participants to consume less than the economic optimum in every hour that wholesale DR payments are available. The mechanisms that offer “Full LMP” in more hours are more inefficient than the ones that offer “Full LMP” only in the higher priced hours. “Full LMP in High-Priced Hours” is substantially more efficient than the other two “Full LMP” options because it eliminates the instances of greatest overconsumption under fixed rates (albeit overshooting the optimum) without exacerbating under-consumption in low-priced hours.

- Wholesale payments of “LMP-RR” are more efficient than fixed rates (without DR) and more efficient than any of the “Full LMP” options. In combination with retail rate savings, wholesale payments of “LMP-RR” produce a net price equal to the full LMP, which is the efficient level. This eliminates overconsumption in high-LMP periods without causing customers to overshoot, as all of the “Full LMP” options do.

- Real-time pricing in all hours is the most efficient. Like “LMP-RR,” it achieves the optimum level of consumption in high-priced hours (unlike the “Full LMP” options). Its advantage over “LMP-RR” is that customers gain access to low prices in the majority of hours of the year and avoid under-consuming when LMPs are less than the retail generation rate.

Extra incentive payment mechanisms involving "Full LMP" have distinctive short- and long-term effects:

- In the short term, consumers (or LSEs) may benefit from reduced LMPs even if consumption whose value exceeds the marginal cost of production is foregone;

- In the long term, producer adjustments eventually offset energy price suppression effects. Yet the inefficiency impacts of "Full LMP" remain, causing both consumers and producers to suffer in the long term.

5. APPENDIX – MODEL RESULTS FOR ALL SCENARIOS ANALYZED

-0.025 Elasticity & 3% Participation		LMP-RR	RTP or BUY BASELINE	FULL LMP IN HIGH-PRICED HOURS	FULL LMP WHEN PRICE SAVINGS> DR PAYMENT	FULL LMP IN ALL HOURS
PARTICIPATION	Number of Program Hours	3,276	8,760	895	4,650	8,760
	Participation Level (MW)	784 (3%)	784 (3%)	784 (3%)	784 (3%)	784 (3%)
	Elasticity of Participants	-0.025	-0.025	-0.025	-0.025	-0.025
	Aggregate Elasticity	-0.001	-0.001	-0.001	-0.001	-0.001
LOAD IMPACTS	Peak Load (MW)	26,134	26,134	26,115	26,115	26,115
	Δ in Peak Load from Fixed Rates (MW)	-11	-11	-30	-30	-30
	%Δ in Peak Load from Fixed Rates	-0.04%	-0.04%	-0.11%	-0.11%	-0.11%
	Consumption (GWh)	134,453	134,466	134,448	134,410	134,367
	Δ Consumption from Fixed Rates (GWh)	-13.0	0.1	-18.8	-56.5	-99.7
	%Δ Consumption from Fixed Rates	-0.01%	0.00%	-0.01%	-0.04%	-0.07%
	Δ Consumption from Baseline (GWh)	-13.1	NA	-19.1	-57.0	-100.2
ECONOMICS	Load-Weighted Mean LMP ($/MWh)	$70.45	$70.47	$70.37	$70.14	$70.12
	Mean LMP plus DR Side Payments ($/MWh)	$70.46	$70.47	$70.39	$70.17	$70.18
	Side Payments to DR ($)	$603,833	NA	$2,116,605	$4,887,894	$7,946,174
	Avg. Side Payments to DR ($/MWh reduced)	$46	NA	$111	$86	$79
	Energy Market Only					
	Δ Consumer Surplus from Fixed Rates ($)	$12,996,845	$11,182,163	$23,183,912	$53,631,391	$54,065,926
	Δ Producer Surplus from Fixed Rates ($)	($12,691,398)	($10,712,472)	($23,453,220)	($55,159,433)	($57,099,073)
	Δ Net Benefits from Fixed Rates ($)	$305,447	$469,692	($269,308)	($1,528,042)	($3,033,147)
	Energy and Capacity Markets					
	Δ Consumer Surplus from Fixed Rates ($)	$308,971	$473,408	($255,224)	($1,500,114)	($3,004,454)
	Δ Producer Surplus from Fixed Rates ($)	($3,524)	($3,716)	($14,084)	($27,928)	($28,693)
	Δ Net Benefits from Fixed Rates ($)	$305,447	$469,692	($269,308)	($1,528,042)	($3,033,147)

-0.025 Elasticity & 6% Participation		LMP-RR	RTP or BUY BASELINE	FULL LMP IN HIGH-PRICED HOURS	FULL LMP WHEN PRICE SAVINGS> DR PAYMENT	FULL LMP IN ALL HOURS
PARTICIPATION	Number of Program Hours	3,290	8,760	895	4,650	8,760
	Participation Level (MW)	1,569 (6%)	1,569 (6%)	1,569 (6%)	1,569 (6%)	1,569 (6%)
	Elasticity of Participants	-0.025	-0.025	-0.025	-0.025	-0.025
	Aggregate Elasticity	-0.002	-0.002	-0.002	-0.002	-0.002
LOAD IMPACTS	Peak Load (MW)	26,124	26,124	26,087	26,087	26,087
	Δ in Peak Load from Fixed Rates (MW)	-21	-21	-58	-58	-58
	%Δ in Peak Load from Fixed Rates	-0.08%	-0.08%	-0.22%	-0.22%	-0.22%
	Consumption (GWh)	134,441	134,467	134,430	134,356	134,269
	Δ Consumption from Fixed Rates (GWh)	-25.5	0.4	-36.7	-110.7	-197.2
	%Δ Consumption from Fixed Rates	-0.02%	0.00%	-0.03%	-0.08%	-0.15%
	Δ Consumption from Baseline (GWh)	-26.1	NA	-37.6	-112.9	-199.3
ECONOMICS	Load-Weighted Mean LMP ($/MWh)	$70.36	$70.38	$70.20	$69.73	$69.70
	Mean LMP plus DR Side Payments ($/MWh)	$70.37	$70.38	$70.23	$69.80	$69.82
	Side Payments to DR ($)	$1,185,167	NA	$4,124,660	$9,560,536	$15,671,001
	Avg. Side Payments to DR ($/MWh reduced)	$45	NA	$110	$85	$79
	Energy Market Only					
	Δ Consumer Surplus from Fixed Rates ($)	$25,605,726	$22,041,156	$45,482,499	$105,361,393	$106,268,589
	Δ Producer Surplus from Fixed Rates ($)	($24,999,387)	($21,109,104)	($46,008,744)	($108,351,351)	($112,237,189)
	Δ Net Benefits from Fixed Rates ($)	$606,339	$932,052	($526,246)	($2,989,959)	($5,968,600)
	Energy and Capacity Markets					
	Δ Consumer Surplus from Fixed Rates ($)	$620,044	$946,517	($471,650)	($2,882,020)	($5,857,619)
	Δ Producer Surplus from Fixed Rates ($)	($13,706)	($14,465)	($54,596)	($107,939)	($110,981)
	Δ Net Benefits from Fixed Rates ($)	$606,339	$932,052	($526,246)	($2,989,959)	($5,968,600)

-0.025 Elasticity & 60% Participation		LMP-RR	RTP or BUY BASELINE	FULL LMP IN HIGH-PRICED HOURS	FULL LMP WHEN PRICE SAVINGS> DR PAYMENT	FULL LMP IN ALL HOURS
PARTICIPATION	Number of Program Hours	3,519	8,760	895	4,650	8,760
	Participation Level (MW)	15,687 (60%)	15,687 (60%)	15,687 (60%)	15,687 (60%)	15,687 (60%)
	Elasticity of Participants	-0.025	-0.025	-0.025	-0.025	-0.025
	Aggregate Elasticity	-0.015	-0.015	-0.015	-0.015	-0.015
LOAD IMPACTS	Peak Load (MW)	25,987	25,987	25,708	25,721	25,721
	Δ in Peak Load from Fixed Rates (MW)	-158	-158	-437	-424	-424
	%Δ in Peak Load from Fixed Rates	-0.60%	-0.60%	-1.67%	-1.62%	-1.62%
	Consumption (GWh)	134,269	134,502	134,226	133,654	132,793
	Δ Consumption from Fixed Rates (GWh)	-197.1	35.6	-240.8	-812.8	-1,673.7
	%Δ Consumption from Fixed Rates	-0.15%	0.03%	-0.18%	-0.60%	-1.24%
	Δ Consumption from Baseline (GWh)	-239.0	NA	-309.0	-975.3	-1,832.7
ECONOMICS	Load-Weighted Mean LMP ($/MWh)	$69.02	$69.20	$67.96	$64.35	$64.02
	Mean LMP plus DR Side Payments ($/MWh)	$69.09	$69.20	$68.17	$64.87	$64.99
	Side Payments to DR ($)	$8,964,842	NA	$27,751,078	$69,180,944	$129,252,032
	Avg. Side Payments to DR ($/MWh reduced)	$38	NA	$90	$71	$71
	Energy Market Only					
	Δ Consumer Surplus from Fixed Rates ($)	$201,564,605	$174,889,801	$334,944,453	$799,012,888	$812,885,554
	Δ Producer Surplus from Fixed Rates ($)	($196,169,763)	($166,619,498)	($338,684,123)	($820,798,644)	($860,161,726)
	Δ Net Benefits from Fixed Rates ($)	$5,394,841	$8,270,303	($3,739,670)	($21,785,756)	($47,276,172)
	Energy and Capacity Markets					
	Δ Consumer Surplus from Fixed Rates ($)	$6,276,565	$9,214,894	($380,416)	($15,432,453)	($40,650,462)
	Δ Producer Surplus from Fixed Rates ($)	($881,723)	($944,591)	($3,359,254)	($6,353,303)	($6,625,709)
	Δ Net Benefits from Fixed Rates ($)	$5,394,841	$8,270,303	($3,739,670)	($21,785,756)	($47,276,172)

-0.05 Elasticity & 3% Participation		LMP-RR	RTP or BUY BASELINE	FULL LMP IN HIGH-PRICED HOURS	FULL LMP WHEN PRICE SAVINGS> DR PAYMENT	FULL LMP IN ALL HOURS
PARTICIPATION	Number of Program Hours	3,290	8,760	895	4,650	8,760
	Participation Level (MW)	784 (3%)	784 (3%)	784 (3%)	784 (3%)	784 (3%)
	Elasticity of Participants	-0.050	-0.050	-0.050	-0.050	-0.050
	Aggregate Elasticity	-0.002	-0.002	-0.002	-0.002	-0.002
LOAD IMPACTS	Peak Load (MW)	26,124	26,124	26,087	26,087	26,087
	Δ in Peak Load from Fixed Rates (MW)	-21	-21	-58	-58	-58
	%Δ in Peak Load from Fixed Rates	-0.08%	-0.08%	-0.22%	-0.22%	-0.22%
	Consumption (GWh)	134,441	134,467	134,430	134,356	134,269
	Δ Consumption from Fixed Rates (GWh)	-25.5	0.4	-36.7	-110.7	-197.2
	%Δ Consumption from Fixed Rates	-0.02%	0.00%	-0.03%	-0.08%	-0.15%
	Δ Consumption from Baseline (GWh)	-26.1	NA	-37.6	-112.9	-199.3
ECONOMICS	Load-Weighted Mean LMP ($/MWh)	$70.36	$70.38	$70.20	$69.73	$69.70
	Mean LMP plus DR Side Payments ($/MWh)	$70.37	$70.38	$70.23	$69.80	$69.82
	Side Payments to DR ($)	$1,185,167	NA	$4,124,660	$9,560,536	$15,671,001
	Avg. Side Payments to DR ($/MWh reduced)	$45	NA	$110	$85	$79
	Energy Market Only					
	Δ Consumer Surplus from Fixed Rates ($)	$25,605,726	$22,041,156	$45,482,499	$105,361,393	$106,268,589
	Δ Producer Surplus from Fixed Rates ($)	($24,999,387)	($21,109,104)	($46,008,744)	($108,351,351)	($112,237,189)
	Δ Net Benefits from Fixed Rates ($)	$606,339	$932,052	($526,246)	($2,989,959)	($5,968,600)
	Energy and Capacity Markets					
	Δ Consumer Surplus from Fixed Rates ($)	$620,044	$946,517	($471,650)	($2,882,020)	($5,857,619)
	Δ Producer Surplus from Fixed Rates ($)	($13,706)	($14,465)	($54,596)	($107,939)	($110,981)
	Δ Net Benefits from Fixed Rates ($)	$606,339	$932,052	($526,246)	($2,989,959)	($5,968,600)

-0.05 Elasticity & 6% Participation		LMP-RR	RTP or BUY BASELINE	FULL LMP IN HIGH-PRICED HOURS	FULL LMP WHEN PRICE SAVINGS> DR PAYMENT	FULL LMP IN ALL HOURS
PARTICIPATION	Number of Program Hours	3,321	8,760	895	4,650	8,760
	Participation Level (MW)	1,569 (6%)	1,569 (6%)	1,569 (6%)	1,569 (6%)	1,569 (6%)
	Elasticity of Participants	-0.050	-0.050	-0.050	-0.050	-0.050
	Aggregate Elasticity	-0.003	-0.003	-0.003	-0.003	-0.003
LOAD IMPACTS	Peak Load (MW)	26,105	26,105	26,032	26,033	26,033
	Δ in Peak Load from Fixed Rates (MW)	-40	-40	-113	-112	-112
	%Δ in Peak Load from Fixed Rates	-0.15%	-0.15%	-0.43%	-0.43%	-0.43%
	Consumption (GWh)	134,417	134,468	134,396	134,253	134,080
	Δ Consumption from Fixed Rates (GWh)	-49.5	1.7	-69.9	-213.2	-386.1
	%Δ Consumption from Fixed Rates	-0.04%	0.00%	-0.05%	-0.16%	-0.29%
	Δ Consumption from Baseline (GWh)	-51.5	NA	-73.4	-221.4	-394.2
ECONOMICS	Load-Weighted Mean LMP ($/MWh)	$70.17	$70.22	$69.87	$68.97	$68.91
	Mean LMP plus DR Side Payments ($/MWh)	$70.19	$70.22	$69.93	$69.11	$69.14
	Side Payments to DR ($)	$2,285,650	NA	$7,843,283	$18,318,225	$30,514,989
	Avg. Side Payments to DR ($/MWh reduced)	$44	NA	$107	$83	$77
	Energy Market Only					
	Δ Consumer Surplus from Fixed Rates ($)	$49,726,005	$42,844,198	$87,598,305	$203,509,753	$205,467,155
	Δ Producer Surplus from Fixed Rates ($)	($48,530,912)	($41,008,263)	($88,604,596)	($209,242,992)	($217,037,534)
	Δ Net Benefits from Fixed Rates ($)	$1,195,093	$1,835,935	($1,006,291)	($5,733,239)	($11,570,379)
	Energy and Capacity Markets					
	Δ Consumer Surplus from Fixed Rates ($)	$1,246,987	$1,890,795	($800,845)	($5,329,428)	($11,154,532)
	Δ Producer Surplus from Fixed Rates ($)	($51,895)	($54,860)	($205,446)	($403,811)	($415,847)
	Δ Net Benefits from Fixed Rates ($)	$1,195,093	$1,835,935	($1,006,291)	($5,733,239)	($11,570,379)

-0.05 Elasticity & 60% Participation		LMP-RR	RTP or BUY BASELINE	FULL LMP IN HIGH-PRICED HOURS	FULL LMP WHEN PRICE SAVINGS> DR PAYMENT	FULL LMP IN ALL HOURS
PARTICIPATION	Number of Program Hours	3,714	8,760	895	4,650	8,760
	Participation Level (MW)	15,687 (60%)	15,687 (60%)	15,687 (60%)	15,687 (60%)	15,687 (60%)
	Elasticity of Participants	-0.050	-0.050	-0.050	-0.050	-0.050
	Aggregate Elasticity	-0.030	-0.030	-0.030	-0.030	-0.030
LOAD IMPACTS	Peak Load (MW)	25,895	25,895	25,461	25,495	25,494
	Δ in Peak Load from Fixed Rates (MW)	-250	-250	-684	-650	-651
	%Δ in Peak Load from Fixed Rates	-0.96%	-0.96%	-2.62%	-2.49%	-2.49%
	Consumption (GWh)	134,156	134,582	134,151	133,236	131,524
	Δ Consumption from Fixed Rates (GWh)	-310.8	115.6	-315.0	-1,230.2	-2,941.9
	%Δ Consumption from Fixed Rates	-0.23%	0.09%	-0.23%	-0.91%	-2.19%
	Δ Consumption from Baseline (GWh)	-446.0	NA	-522.7	-1,742.1	-3,442.9
ECONOMICS	Load-Weighted Mean LMP ($/MWh)	$68.08	$68.35	$66.62	$60.79	$60.07
	Mean LMP plus DR Side Payments ($/MWh)	$68.19	$68.35	$66.92	$61.60	$61.79
	Side Payments to DR ($)	$14,397,238	NA	$39,873,397	$108,166,458	$226,252,404
	Avg. Side Payments to DR ($/MWh reduced)	$32	NA	$76	$62	$66
	Energy Market Only					
	Δ Consumer Surplus from Fixed Rates ($)	$325,263,766	$284,204,219	$508,787,321	$1,260,141,351	$1,293,509,319
	Δ Producer Surplus from Fixed Rates ($)	($315,510,568)	($269,231,232)	($514,547,352)	($1,294,501,816)	($1,372,999,092)
	Δ Net Benefits from Fixed Rates ($)	$9,753,198	$14,972,987	($5,760,031)	($34,360,465)	($79,489,772)
	Energy and Capacity Markets					
	Δ Consumer Surplus from Fixed Rates ($)	$12,147,984	$17,582,140	$3,093,051	($18,189,946)	($62,351,013)
	Δ Producer Surplus from Fixed Rates ($)	($2,394,786)	($2,609,153)	($8,853,082)	($16,170,519)	($17,138,760)
	Δ Net Benefits from Fixed Rates ($)	$9,753,198	$14,972,987	($5,760,031)	($34,360,465)	($79,489,772)

-0.1 Elasticity & 3% Participation		LMP-RR	RTP or BUY BASELINE	FULL LMP IN HIGH-PRICED HOURS	FULL LMP WHEN PRICE SAVINGS> DR PAYMENT	FULL LMP IN ALL HOURS
PARTICIPATION	Number of Program Hours	3,321	8,760	895	4,650	8,760
	Participation Level (MW)	784 (3%)	784 (3%)	784 (3%)	784 (3%)	784 (3%)
	Elasticity of Participants	-0.100	-0.100	-0.100	-0.100	-0.100
	Aggregate Elasticity	-0.003	-0.003	-0.003	-0.003	-0.003
LOAD IMPACTS	Peak Load (MW)	26,105	26,105	26,032	26,033	26,033
	Δ in Peak Load from Fixed Rates (MW)	-40	-40	-113	-112	-112
	%Δ in Peak Load from Fixed Rates	-0.15%	-0.15%	-0.43%	-0.43%	-0.43%
	Consumption (GWh)	134,417	134,468	134,396	134,253	134,080
	Δ Consumption from Fixed Rates (GWh)	-49.5	1.7	-69.9	-213.2	-386.1
	%Δ Consumption from Fixed Rates	-0.04%	0.00%	-0.05%	-0.16%	-0.29%
	Δ Consumption from Baseline (GWh)	-51.5	NA	-73.4	-221.4	-394.2
ECONOMICS	Load-Weighted Mean LMP ($/MWh)	$70.17	$70.22	$69.87	$68.97	$68.91
	Mean LMP plus DR Side Payments ($/MWh)	$70.19	$70.22	$69.93	$69.11	$69.14
	Side Payments to DR ($)	$2,285,650	NA	$7,843,283	$18,318,225	$30,514,989
	Avg. Side Payments to DR ($/MWh reduced)	$44	NA	$107	$83	$77
	Energy Market Only					
	Δ Consumer Surplus from Fixed Rates ($)	$49,726,005	$42,844,198	$87,598,305	$203,509,753	$205,467,155
	Δ Producer Surplus from Fixed Rates ($)	($48,530,912)	($41,008,263)	($88,604,596)	($209,242,992)	($217,037,534)
	Δ Net Benefits from Fixed Rates ($)	$1,195,093	$1,835,935	($1,006,291)	($5,733,239)	($11,570,379)
	Energy and Capacity Markets					
	Δ Consumer Surplus from Fixed Rates ($)	$1,246,987	$1,890,795	($800,845)	($5,329,428)	($11,154,532)
	Δ Producer Surplus from Fixed Rates ($)	($51,895)	($54,860)	($205,446)	($403,811)	($415,847)
	Δ Net Benefits from Fixed Rates ($)	$1,195,093	$1,835,935	($1,006,291)	($5,733,239)	($11,570,379)

-0.1 Elasticity & 6% Participation		LMP-RR	RTP or BUY BASELINE	FULL LMP IN HIGH-PRICED HOURS	FULL LMP WHEN PRICE SAVINGS> DR PAYMENT	FULL LMP IN ALL HOURS
PARTICIPATION	Number of Program Hours	3,368	8,760	895	4,650	8,760
	Participation Level (MW)	1,569 (6%)	1,569 (6%)	1,569 (6%)	1,569 (6%)	1,569 (6%)
	Elasticity of Participants	-0.100	-0.100	-0.100	-0.100	-0.100
	Aggregate Elasticity	-0.006	-0.006	-0.006	-0.006	-0.006
LOAD IMPACTS	Peak Load (MW)	26,070	26,070	25,935	25,938	25,938
	Δ in Peak Load from Fixed Rates (MW)	-75	-75	-210	-207	-207
	%Δ in Peak Load from Fixed Rates	-0.29%	-0.29%	-0.80%	-0.79%	-0.79%
	Consumption (GWh)	134,373	134,473	134,340	134,070	133,725
	Δ Consumption from Fixed Rates (GWh)	-93.1	6.6	-126.8	-396.3	-741.7
	%Δ Consumption from Fixed Rates	-0.07%	0.00%	-0.09%	-0.29%	-0.55%
	Δ Consumption from Baseline (GWh)	-100.9	NA	-140.1	-427.2	-772.0
ECONOMICS	Load-Weighted Mean LMP ($/MWh)	$69.84	$69.92	$69.29	$67.59	$67.47
	Mean LMP plus DR Side Payments ($/MWh)	$69.87	$69.92	$69.39	$67.85	$67.90
	Side Payments to DR ($)	$4,269,879	NA	$14,258,008	$33,826,045	$58,124,734
	Avg. Side Payments to DR ($/MWh reduced)	$42	NA	$102	$79	$75
	Energy Market Only					
	Δ Consumer Surplus from Fixed Rates ($)	$93,989,029	$81,130,923	$162,977,090	$380,952,309	$385,372,787
	Δ Producer Surplus from Fixed Rates ($)	($91,664,505)	($77,563,334)	($164,827,659)	($391,555,213)	($407,213,206)
	Δ Net Benefits from Fixed Rates ($)	$2,324,524	$3,567,589	($1,850,569)	($10,602,904)	($21,840,419)
	Energy and Capacity Markets					
	Δ Consumer Surplus from Fixed Rates ($)	$2,511,441	$3,765,847	($1,118,894)	($9,180,338)	($20,370,838)
	Δ Producer Surplus from Fixed Rates ($)	($186,917)	($198,258)	($731,675)	($1,422,566)	($1,469,580)
	Δ Net Benefits from Fixed Rates ($)	$2,324,524	$3,567,589	($1,850,569)	($10,602,904)	($21,840,419)

-0.1 Elasticity & 60% Participation		LMP-RR	RTP or BUY BASELINE	FULL LMP IN HIGH-PRICED HOURS	FULL LMP WHEN PRICE SAVINGS> DR PAYMENT	FULL LMP IN ALL HOURS
PARTICIPATION	Number of Program Hours	3,974	8,760	895	4,650	8,760
	Participation Level (MW)	15,687 (60%)	15,687 (60%)	15,687 (60%)	15,687 (60%)	15,687 (60%)
	Elasticity of Participants	-0.100	-0.100	-0.100	-0.100	-0.100
	Aggregate Elasticity	-0.060	-0.060	-0.060	-0.060	-0.060
LOAD IMPACTS	Peak Load (MW)	25,792	25,792	25,188	25,260	25,257
	Δ in Peak Load from Fixed Rates (MW)	-353	-353	-957	-885	-888
	%Δ in Peak Load from Fixed Rates	-1.35%	-1.35%	-3.66%	-3.39%	-3.40%
	Consumption (GWh)	134,041	134,800	134,188	132,892	129,510
	Δ Consumption from Fixed Rates (GWh)	-425.0	333.2	-277.9	-1,574.1	-4,956.1
	%Δ Consumption from Fixed Rates	-0.32%	0.25%	-0.21%	-1.17%	-3.69%
	Δ Consumption from Baseline (GWh)	-812.7	NA	-817.9	-3,005.4	-6,356.1
ECONOMICS	Load-Weighted Mean LMP ($/MWh)	$67.00	$67.35	$65.46	$56.85	$55.32
	Mean LMP plus DR Side Payments ($/MWh)	$67.16	$67.35	$65.83	$58.04	$58.31
	Side Payments to DR ($)	$21,630,683	NA	$49,812,153	$158,090,599	$386,967,749
	Avg. Side Payments to DR ($/MWh reduced)	$27	NA	$61	$53	$61
	Energy Market Only					
	Δ Consumer Surplus from Fixed Rates ($)	$467,346,369	$411,776,328	$661,202,959	$1,771,131,715	$1,848,241,266
	Δ Producer Surplus from Fixed Rates ($)	($450,532,963)	($385,780,073)	($669,537,800)	($1,822,398,769)	($1,976,456,550)
	Δ Net Benefits from Fixed Rates ($)	$16,813,406	$25,996,255	($8,334,841)	($51,267,054)	($128,215,284)
	Energy and Capacity Markets					
	Δ Consumer Surplus from Fixed Rates ($)	$22,154,294	$32,024,168	$10,777,180	($17,951,433)	($91,676,547)
	Δ Producer Surplus from Fixed Rates ($)	($5,340,888)	($6,027,912)	($19,112,021)	($33,315,621)	($36,538,736)
	Δ Net Benefits from Fixed Rates ($)	$16,813,406	$25,996,255	($8,334,841)	($51,267,054)	($128,215,284)