# *A Novel Approach to Improve the Estimation of Customer Baseline Loads in Residential Demand Response Programs*

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## Overview

According to FERC Order 745, demand response owners can sell their load reduction in the wholesale market. Nevertheless, it is a very complex task to build a foundation in order to adopt this law. The major implementation obstacle for ISOs and utilities in this regard is to establish Customer Baseline Load (CBL) calculation methods with acceptable accuracy to determine the load reduction, which has proven very challenging to do so far.

We investigate error performance of current methodologies to estimate residential Customer Baseline Loads (CBLs) as well as a novel approach to improve the estimations. CBLs are used as part of a number of electricity rates including real-time pricing and demand reduction (DR). CBLs have been applied mostly to industrial and commercial rates, but with smart grids, electric utilities have the capability of using these types of rates for residential customers as well. We examine DR, where customers receive payment for reducing use below the CBL. Using the CBL to estimate load reduction gives customers an incentive for gaming in order to inflate their baseline, which increases their payoff but results in a social welfare loss. We examine the issue theoretically and empirically. There is also reason to believe that the CBL estimation for residential customers has limited accuracy due to stochastic characteristics in their consumption. We provide evidence for this lack of accuracy. Our theoretical foundation shows that clustering customers mitigates the effect of randomness. The theory also shows that clustering can remove the incentive to game the baseline. We apply clustering to empirically examine the improvement. We also include a sensitivity analysis to study the impact of the number of customers in each cluster on the error and financial performance of CBL calculation methods.

## Methods

For the theoretical analysis of CBL's role on creating the possibility of gaming and inefficient consumption, we set out a model of consumer utility maximization. We extend this model to incorporate the effect of the inherent inaccuracy of the CBL due to its counterfactual nature, since it is not possible to examine what consumption would have been had the customer not been on the DR rate. We then expand the analysis to examine the impact of the proposed clustering method on net benefit.

In the empirical analysis, we provide evidence for inadequate accuracy of CBL estimation methods when applied to residential customers by using an actual residential load dataset and applying currently popular CBL calculation methods developed for industrial and commercial customers and showing their inaccuracy for residential customers. Furthermore, we show the effectiveness of our proposed approach by clustering the customers and estimating their CBL and comparing accuracy to existing methods.

## Results

The theoretical analysis shows that incorporating the proposed changes in the model of consumer utility maximization yields new marginal prices that eliminate customer incentive to under-consume during event periods and inflate the baseline during non-event periods. Event periods are peak periods when the DR rates are in effect and non-event periods are when DR is not in effect, but that utilities use to determine the baseline.

In the empirical analysis, we provide evidence for the weak error performance of residential CBLs. In addition, we show that by applying the proposed clustering approach, the accuracy and error performance improve significantly. Also, we include a sensitivity analysis to show the relationship between the number of customers in each cluster with the error performance of the estimated CBLs. We find that increasing the number of customers in each cluster reduces the rebate as a percent of utility revenues paid to the customers, indicating better baseline accuracy.

## Conclusions

In this paper, we apply CBL calculation methods to residential customers theoretically and empirically. Our theoretical model shows that in order to give the correct price signals, the event day price should be the wholesale rate minus the retail rate, as proposed by some other investigators but in contrast to FERC's use of the wholesale rate. Our model also shows the need to cluster individual residential customers to overcome gaming and avoid compensating illusory load reductions. In effect, determining CBL based on averages of each cluster decouples the determination of the CBL from individual behavior during the pre-event period when the CBL is determined.

We then compare individual and clustered results empirically by simulating a peak time rebate. The proposed clustering method improves the accuracy, reduces bias and achieves better overall performance values for the selected CBL methods. Moreover, a sensitivity analysis finds that increasing the number of customers in each cluster reduces the error and improves the financial performance of CBL calculation methods.