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Are They Effective?

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Utility Rebates for Energy Star Appliances: Are They Effective? *

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September, 2011

Abstract

In this paper we estimate the increase in the market share of ENERGY STAR-qualified appliances that can be attributed to targetted cash rebates offered by utility companies. To estimate the impact of these incentives we use the variation in timing and size of the utility rebates across the US states. We then use these estimates along with information on the average energy saved by using an ENERGY STAR appliance relative to a non-ENERGY STAR appliance to provide an estimate on the cost per tonne of carbon saved by the rebate program. Our results show that a dollar increase in the rebate leads to a 0.3% increase in the share of ENERGY STAR-qualified clothes washers while the effect of rebates is not significant for dishwashers and refrigerators. Assuming a redemption rate of 40%, we calculate the cost of saving a tonne of carbon through the clothes washer rebate program to be around $158. The corresponding cost of a megawatt hour saved (about $32), is lower than the estimated cost of building and operating an additional power plant and the average on-peak spot price. We conclude that the ENERGY STAR clothes washers rebate programs are a cost-effective way for utilities to reduce energy demand.

Keywords: Eco-labelling; Energy efficiency; Appliances; Utility rebates; Carbon saving; Energy saving.
JEL Classification Codes: C13, C33, L68, L94, Q4.

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"Efficiency is the steak. Renewables are the sizzle." – Carl Pope, executive director of the Sierra Club [1]

1 Introduction

It is now widely accepted that anthropogenic greenhouse gas (GHG) emissions are the main cause of climate change. The energy sector accounts for approximately 65% of our output of GHGs (International Energy Agency, 2009) and thus reducing emissions in this sector is a crucial element of GHG reduction. To reduce GHGs increasing energy efficiency is considered a "low-hanging fruit" because of its low marginal cost. The World Energy Outlook 2009, published by the International Energy Agency (IEA), highlights the huge potential of CO_2 reductions from increased energy efficiency. The quote by Carl Pope further highlights the importance of energy efficiency. In this paper we analyse a policy in the US that uses financial incentives to encourage the adoption of energy efficient household appliances.

Federal and local governments and utility companies across the US and Canada promote the adoption of energy efficient appliances identified by a voluntary eco-labelling program, the ENERGY STAR label, by offering financial incentives. These incentives are usually in the form of rebates. Some US states have also introduced sales tax holidays on energy efficient appliances.[2] However, in the majority of the cases these sales tax holidays are offered only over an extremely short period of time, e.g. a weekend. The ENERGY STAR label is designed to promote the use of energy-efficient products and thus help to reduce the emissions of greenhouse gases by reducing energy consumption. The adoption of energy efficient appliances has public (reduced GHG emissions) and private (savings in utility bills) benefits.[3] In this paper we ask two questions. First, what is the sales impact of these rebates? Second, is it cost effective for a utility company to offer rebates to its consumers to buy ENERGY STAR labelled appliances?

To study the impact of rebates on the sales of energy efficient ENERGY STAR appliances we use quarterly sales data on the percentage of ENERGY STAR labelled appliances (clothes washers, dishwashers, and refrigerators) for all 50 US states. We combine this with a detailed utility-level and state-level dataset on rebate programs between 2001 and 2006. Our aim is to identify the impact of rebates on sales of ENERGY

[1] Wald (2007)

[2] Connecticut, Delaware, Florida, Georgia, Missouri,North Carolina, South Carolina, Texas, Vermont, Virginia and West Virginia have introduced sales tax holidays.

[3] According to calculations made by D&R International Ltd. the lifetime cost for clothes washers, using the product database from 2007, was $1,883 for a standard model and $1,726 for an ENERGY STAR model. While the median purchase price for a standard model ($573) was much lower than an ENERGY STAR model ($966) the average energy costs for the former were much higher at $1,310 than the latter ($760).

STAR appliances by correlating differences in the market share of ENERGY STAR appliance sales with variation in rebate values across and within appliances and across and within US states over time. The panel nature of our dataset allows us to ensure that we do not attribute state level differences, or national level common time effects to the rebate variable. Our results indicate that, on average, a weighted utility rebate of $15 increased the market share of ENERGY STAR-qualified clothes washers by 4.5%. We also find that the utility rebates had no significant impact on the sales of ENERGY STAR-qualified dishwashers and refrigerators.

We then use the above estimates to evaluate the cost of a tonne of carbon emissions saved as well as the cost of a megawatt hour saved. The former cost calculation will enable us to compare the cost with that of the social opportunity cost of carbon while the latter cost will be informative in comparing with the cost of constructing and operating a power plant or the average price of additional electricity bought in the spot market. Both costs depend on the assumption for redemption rates of mail-in rebates, which are the main avenue for these rebates. The cost ranges from $158 to $395 depending on a redemption rate of 40% and 100% respectively. We also calculate the cost of a megawatt hour saved due to having the rebate programs in place for comparisons with the estimated cost of building and operating a power plant as well as the cost of on-peak spot prices. This cost of a megawatt hour saved ranges from around $32 to $80 depending on the redemption rate being 40% and %100 respectively. The lower estimate of $32 per megawatt hour saved is much lower than the cost of constructing and operating the cheapest power plant.[4] Average on-peak prices at $60 are also higher than the cost of rebate programs which means that buying electricity in case demand exceeds supply is more expensive than reducing electricity demand through increased efficiency.

There has been, to the best of our knowledge, no research on evaluating the impact of utility rebates to promote the sale of ENERGY STAR appliances. The utility rebate programs we study in this paper are a part of demand-side management (DSM) initiatives undertaken by utility companies. DSM refers to the "planning, implementation, and monitoring of utility activities designed to encourage consumers to modify patterns of electricity usage, including the timing and level of electricity demand" (Energy Information Administration, 2009). They were initiated in the late 1970s primarily due to rising gas and oil prices.[5] The Energy Information Administration (2009) reports that the total actual peak load reduction achieved in 2007 through DSM was 30,276 MW with 58% being attributed to energy efficiency while the total DSM cost was $2.5 billion. Gillingham et al. (2006) provide a review of, among other things, DSM activities and report the

[4] The cost of a coal-fired power plant, according to Du and Parsons (2009), is the lowest at $62 per megawatt hour.
[5] See Eto (1996), Nadel and Geller (1996) and Nadel (2000) for a history of utility DSM programs in the US.

range of negawatt[6] costs calculated in the existing literature to be between $8 and $229 per megawatt hour saved. A recent paper by Arimura et al. (2009) finds that DSM expenditures over the last couple of decades have cost utilities around $60 per MWh saved.

Our focus in this paper is on a specific component of DSM, namely, the utility rebate programs promoting the purchase of energy efficient household appliances. Very few studies have looked at the cost-effectiveness of rebate programs in the residential sector. Revelt and Train (1998) estimate the impact of rebates and loans on the choice of efficiency of refrigerators by residential customers of Southern California Edison (SCE) using stated preference data. They predict that the rebate program has led 8.5% customers to switch from a standard-efficiency refrigerator to a high-efficiency one. They also find that loan programs have a greater impact with 22.6% of buyers switching from standard to high efficiency.[7] In a survey of the literature on the various kinds of DSM programs Nadel (1992) shows that the cost per kilowatt hour incurred by a utility in rebate programs ranges from low to moderate[8] and is generally between $14 to $50 per megawatt hour.[9] Nadel (1990) reports the cost to utilities for rebate programs in the commercial and industrial sectors to be $20-30 per megawatt hour.

The rest of the paper is organized as follows. In the next section, we provide a brief overview of the ENERGY STAR program. We then discuss the rebate programs offered by utility companies in section 3 and follow it up with a description of the data, its sources and limitations in section 4. The empirical strategy is laid out in section 5 and the econometric results are discussed in section 6. The penultimate section uses the results from our regression model to calculate the energy saving and cost of the rebate programs while the final section has concluding remarks.

2 A Brief Overview of ENERGY STAR

The ENERGY STAR program was introduced in 1992 by the United States Environmental Protection Agency (EPA) as a voluntary labelling program designed to promote the use of energy-efficient products and thus help to reduce the emissions of greenhouse gases. Research on the ENERGY STAR program has focused almost exclusively on the energy, dollar and carbon savings or the overall success of the ENERGY STAR program. Howarth et al. (2000) find that the Green Lights and ENERGY STAR Office Products programs

[6] "Negawatt" is a term coined by Amory Lovins of the Rocky Mountain Institute to refer to a watt of electricity that does not have to be produced due to an energy saving process in place.

[7] See Train and Atherton (1995) for a similar paper.

[8] This is based on rebate programs for commercial and industrial as well as residential sectors.

[9] We hereon, convert all figures originally reported in kilowatt hours to megawatt hours for consistency. 1 megawatt hour (MWh) = 1,000 kilowatt hours (kWh).

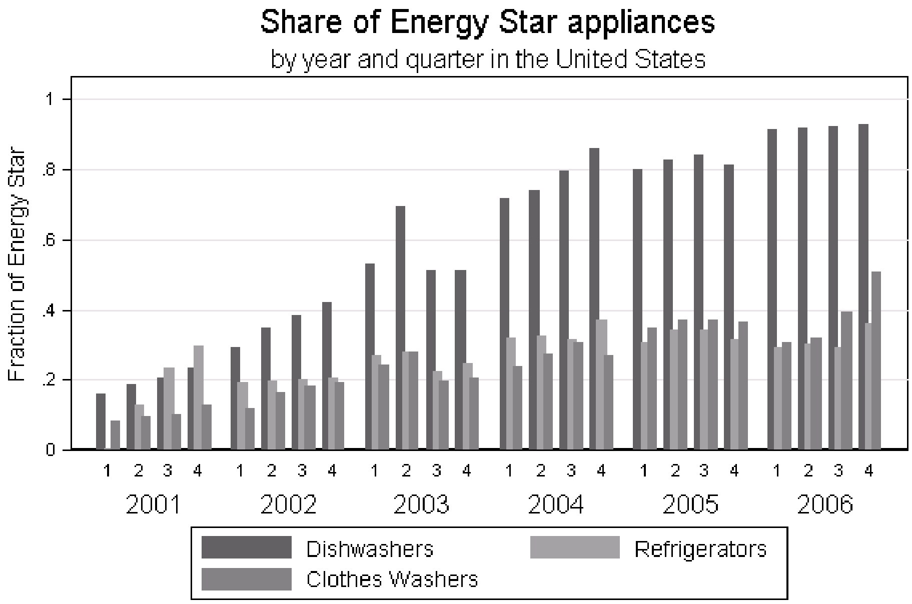

Figure 1: SHARE OF ENERGY STAR QUALIFIED DISHWASHERS, CLOTHES WASHERS AND REFRIGERATORS (SOURCE: ENERGY STAR)

have very little effect on the demand for energy but improvements in energy efficiency lead to one-to-one reductions in energy use. In terms of calculating savings estimates, Webber et al. (2000) conclude that 740 petajoules of energy has been saved[10] and 13 million metric tons of carbon avoided due to the ENERGY STAR program. In a more recent study, Sanchez et al. (2008) estimate that ENERGY STAR-labelled products have saved 4.8EJ of primary energy and avoided 82Tg C equivalent.[11].

In this paper, we focus on the ENERGY STAR program for clothes washers, dishwashers and refrigerators. The market share of ENERGY STAR qualified clothes washers has increased from 10% in 2001 to almost 38% in 2006. ENERGY STAR qualified dishwashers have captured a little more than 92% of the market in 2006 as compared to around 10% in 2001 (Figure 1). Figure 1 shows the high penetration of ENERGY STAR qualified dishwashers when compared to clothes washers and refrigerators.

3 Utility Rebates

In 1998, ENERGY STAR qualified clothes washers in the northwestern part of the United States were promoted through rebates and incentives offered by the Northwest Energy Efficiency Alliance. Supplemental

[10] 1 petajoule = 10^{15} Joules. 740 petajoules is equivalent to 205.5×10^6 MWh. 1 MWh = 3.6×10^9 Joules.

[11] 1EJ (Exajoule)=10^{18} Joules. 4.8EJ is equivalent to 1.3×10^9 MWh. 1Tg (Teragram) = 10^{12} grams

rebates and financing was offered by a number of utilities in Washington, Oregon, Montana and Idaho (ENERGY STAR Sales Report, 1999). Similarly, most utility companies in California and several utility companies in New England (through the Northeast Energy Efficiency Partnerships, Inc.) and Wisconsin also supported the sale of ENERGY STAR appliances (ENERGY STAR Sales Report, 1999). The same regions experienced a much larger penetration of ENERGY STAR qualified clothes washers than other regions.

While the savings to consumers, in terms of lower utility bills, are quite obvious there are a number of reasons why utilities would want to promote the use of ENERGY STAR products.[12] The literature on DSM argues that promoting energy efficiency costs less than building new power plants. There are also environmental reasons. Utility companies need to follow a number of environmental regulations. There are emissions control strategies in place and saving energy on the margin will allow the more polluting plants to be removed from producing electricity. Reducing electricity demand also reduces the need to upgrade the transmission and distribution network. Lastly, reducing peak demand combined with reducing energy demand can lead to grid reliability.

4 Data Description

We use data from a number of sources. The sales data of ENERGY STAR-qualified appliances are from the US Department of Energy (2008a). Information about the utility rebates on ENERGY STAR products is from D&R International Ltd. Demographic data come from the Current Population Survey, the Bureau of Economic Analysis and the US Census. Electricity price data are from the Energy Information Administration of the US Department of Energy.

4.1 ENERGY STAR Sales

The ENERGY STAR website[13] has data on sales of the four major appliances, viz. clothes washers, dishwashers, air conditioners and refrigerators. The data are disaggregated by the type of major appliance in each US state by quarter from 2001 to 2006. We exclude air conditioners from our analysis due to missing data. Sales of appliances are categorized into ENERGY STAR and non-ENERGY STAR units. The appliance manufacturers report the sale of ENERGY STAR units to the US EPA every year. For obtaining sales figures

[12] Benefits to consumers can be seen by comparing the average energy use of an ENERGY STAR and a non-ENERGY STAR qualified appliance. See Table 6 for information on the energy used by an average ENERGY STAR versus an average non-ENERGY STAR clothes washer and Table 8 for dishwashers and refrigerators.

[13] http://www.energystar.gov/index.cfm?c=manuf_res.pt_appliances

of non-ENERGY STAR units the EPA uses the difference of the sales figures of total ENERGY STAR units sold and the total US sales obtained from industry reports.

4.2 Utility Rebates

Financial incentives are in the form of rebates that vary in amount as well as form across utility companies and across different appliances. Information about rebates and incentives provided by utilities between 2001 and 2006 was obtained from D&R International Ltd. This includes details of the incentive type, the program name, the amount of rebate offered, a summary of the rebate with the period of time the rebate is offered and the appliances or products to which the rebate applies. Table 1 provides details on the number of utility companies providing rebates to its customers from 2001 to 2006 for various appliances. Rebates are concentrated mostly in the northwestern states and California as well as northeastern states. We have considered only mail-in and instant rebates that constitute 91% of the total incentives on offer. Our dataset has a total of 602 financial incentives out of which 546 are mail-in and instant rebates. Of those, 95% are mail-in and 5% are instant rebates.Table 2 provides a detailed breakdown of the various types of financial incentives offered by utility companies. Figure 2 shows the rebate amounts and corresponding frequencies in our sample. Most of the rebate amounts have a $50 or $100 value for clothes washers. Rebates for dishwashers and refrigerators in our sample are typically $25 or $50.

The disadvantage of not having sales figures by smaller geographic entities is that rebates provided by utility companies are local in nature and, usually, do not apply to the entire state. That leads to an aggregation problem when we are trying to estimate the effectiveness of rebates on the sales of ENERGY STAR units for the state as a whole. Consider a situation where we have rebates in two states with a similar population, and preferences. The rebates are assumed, for the sake of simplicity, to be of equal value. However, the extent of the rebates differ with one state having it in, say, just one county served by a utility company and the other state having it in many more counties. This should not lead to the same effect on the state-wide sales share of ENERGY STAR appliances. In this situation we would expect the latter of the two states to have a bigger impact on the sales share. To rectify this we assign weights to the rebates. The weights that we use are the share of the residential customers served by the utility company providing the rebate to the total number of residential customers in a state. The number of customers served by each utility company are from the Energy Information Administration (2006) of the US Department of Energy. Using weighted rebates means that utilities serving a larger customer base will have higher weights

Table 1: NUMBER OF UTILITY REBATES FOR ENERGY STAR APPLIANCES (2001–2006)

State	Clothes Washers	Dishwashers	Refrigerators
California	28	23	36
Colorado	8	1	2
Connecticut	6	0	3
Iowa	12	11	13
Idaho	12	8	5
Illinois	2	0	0
Massachusetts	21	2	0
Minnesota	19	6	7
Missouri	1	0	0
Montana	7	6	6
New Hampshire	8	0	0
Nevada	10	3	8
New York	2	0	0
Oregon	51	35	30
Rhode Island	3	0	0
South Dakota	2	0	0
Texas	0	0	1
Utah	0	0	1
Washington	60	26	21
Wisconsin	2	2	3
Wyoming	1	1	1
Total	255	124	137

Note: Numbers indicate total number of utility rebates offered.

Table 2: TYPES OF FINANCIAL INCENTIVES OFFERED BY UTILITY COMPANIES (2001–2006)

Type of Dollar Incentive/Rebate	Frequency	Percent
Instant Rebate (at point of sale)	14	2.56
Instant Rebate (as credit on bill)	15	2.74
Mail-in Rebate	517	94.69

assigned to their rebates. [14]

4.3 Demographic and Electricity Data

We use state quarterly personal income estimates from the US Bureau of Economic Analysis to measure income.[15] The Current Population Survey (CPS) is a monthly household survey conducted by the Bureau

[14]Our preferred specifications use weighted rebates. However in the text we also report results from using a simple average of utility rebate offered. We have also analysed the impact of utility rebates after controlling for state level sales tax rebates on ENERGY STAR appliances. Unlike the utility rebates, which last typically for an year or more, most state level rebates typically lasted for a few days during a year. These results are not reported in the text and can be requested from the authors. We find that the results of regressions controlling for the sales tax rebate are essentially the same as those reported in this paper. Coefficients on the sales tax rebates are not significant. This is because these rebates were in place only for a few days and since we are using quarterly sales data it is hard to identify their impact.

[15]Personal income is the income received by all persons from all sources.

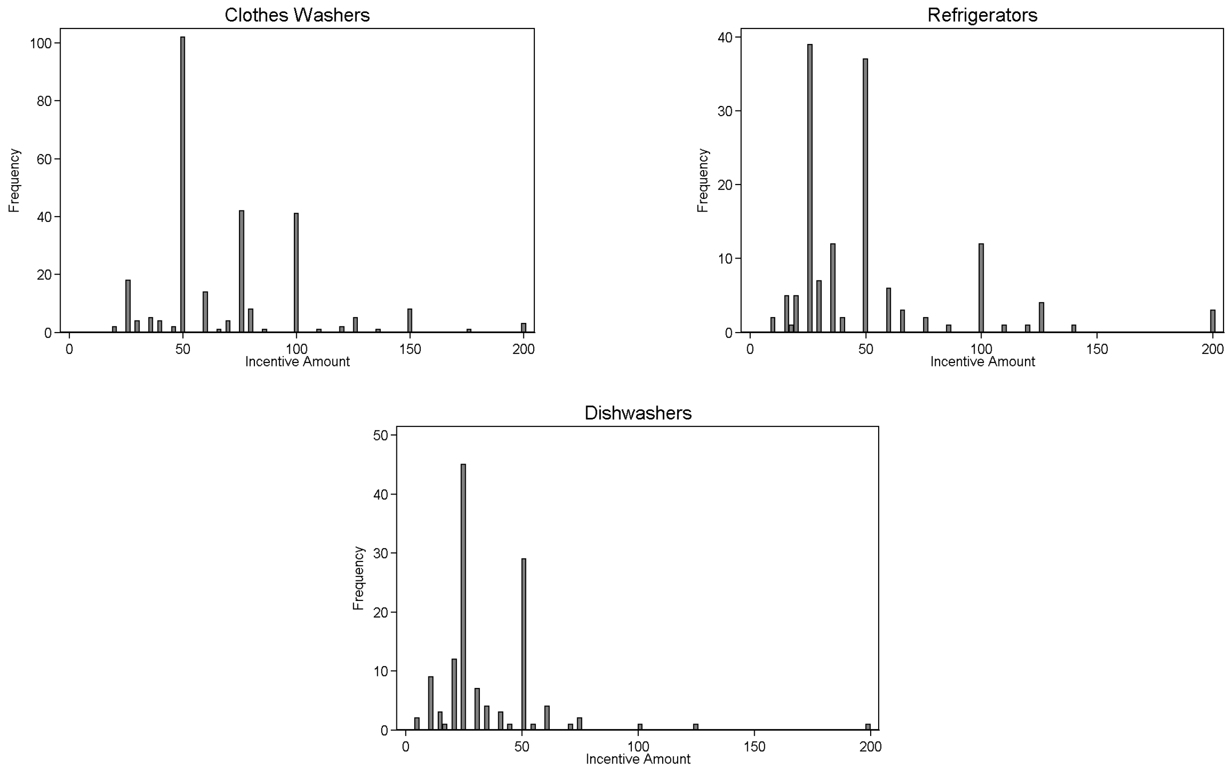

Figure 2: HISTOGRAM OF ENERGY STAR REBATE AMOUNTS (2001–2006)

of Labor Statistics to measure participation and employment of the US labour force. The CPS has details on the highest level of education obtained. We construct a measure of education, 'Having a degree', that gives us the fraction of people in a particular US state to have completed a degree of any kind. [16]

Electricity prices are from the (Energy Information Administration, 2008) of the US Department of Energy. We calculate the quarterly price for each state from 2001 to 2006 using the monthly retail price for electricity in the residential sector.

5 Empirical Strategy

The timing and size of rebates varies across states and time. We use these variations to estimate the impact of the utility rebates on the sales of ENERGY STAR labelled clothes washers, dishwashers and refrigerators. In addition there are several states that did not provide any such incentives to its customers. Our depen-

[16] Associate Degree-Occupational/Vocational, Associate Deg.-Academic Program, Bachelor's Degree(ex: BA, AB, BS), Master's(ex: MA, MS, MEng, MEd, MSW), Professional School Deg(ex: MD, DDS, DVM) or Doctorate Degree(ex: PhD, EdD).

Table 3: SUMMARY STATISTICS (2001–2006)

Variable	Mean	Std. Dev.	Min.	Max.	Obs.
Clothes Washers Share	0.274	0.138	0.026	0.842	1200
Log of Clothes Washers Share	-1.460	0.626	-3.663	-0.173	1200
Dishwashers Share	0.607	0.286	0.056	1.000	1200
Log of Dishwashers Share	-0.663	0.641	-2.875	0.000	1200
Refrigerators Share	0.273	0.108	0	0.595	1200
Log of Refrigerators Share	-1.473	0.838	-6.847	-0.520	1199
Log Average Personal Income	11.628	1.055	9.595	14.203	1200
Share of people with degrees	0.317	0.049	0.174	0.468	1200
Log Electricity Price in current quarter	-0.261	0.262	-0.761	0.762	1200

dent variable is the logarithm of the market share of ENERGY STAR appliances. Formally, our empirical specification is:

$$\log(\text{ENERGY STAR share})_{cit} = \beta_0 + \sum_{c=1}^{3} \beta_{1c}\text{Appliance dummy}_{cit} + \sum_{c=1}^{3} \beta_{2c}\text{Appliance dummy}_{cit}\text{*Util. Reb.}_{cit} + \beta_3 \text{X}_{cit} + \varepsilon_{cit}, \quad (1)$$

where c is the index for the appliance type (i.e. clothes washer, dishwasher or refrigerator), i is the US state index and t is the year-quarter time index. The β_{2c} coefficients on the right-hand side are our variables of interest since they indicate the effect of the rebate offered on a particular appliance on the market share of that particular appliance. X_{cit} is a vector of controls and ε_{cit} is the standard i.i.d. error term.

This specification enables us to estimate the impact of incentives provided by utility companies as well as control for various other factors that may affect the share of ENERGY STAR appliances.[17] A positive estimate for all three β_{2c} coefficients would imply that the rebates are having a favourable impact and that the utility companies are being successful in encouraging people to switch to more energy-efficient technologies. In our set of controls, among other time and state dummies, we also include the fraction of the population having at least a degree, the average personal income (in logarithmic form) for each US State, and the price of electricity. Summary statistics are presented in Table 3.

Recall that data on rebates are at the utility level. For our aggregation to the state level we present results of two indicators. We first use the average rebate amount in a state. We construct this by calculating the simple average of all the rebates given by utility companies in a state in a particular quarter for a particular

[17]Note that even though the individuals coefficients on the impact of the rebate can differ, our regression pools all three appliances together. This is because we believe that the same underlying utility function determines the choice between an ENERGY STAR and a non-ENERGY STAR appliance.

Table 4: REBATE STATISTICS FOR US STATES PROVIDING REBATES (2001–2006)

Variable	Mean	Std. Dev.	Min.	Max.	Obs.
Clothes Washers					
Avg. Rebate Amount	69.699	27.547	25	200	239
Avg. Weighted Rebate Amount	15.215	21.722	0.057	100	239
Dishwashers					
Avg. Rebate Amount	34.746	13.505	10	62.5	158
Avg. Weighted Rebate Amount	1.588	4.365	0.019	35	158
Refrigerators					
Avg. Rebate Amount	50.640	26.324	15	117.5	177
Avg. Weighted Rebate Amount	6.826	15.524	0.022	100	177

appliance. Our second, and preferred, measure of the utility rebate variable attaches weights to the rebate values. These weights are calculated by dividing the number of residential customers served by the utility company providing the rebate with the total number of residential customers in a state. We do this to ensure that areas with a higher residential customer base in a state have larger weights attached to the utility rebates.

We provide summary statistics of the different rebate measures in Table 4. The last column in the table, **Obs.**, indicates the number of data points in our dataset that the rebates imply. For example, there are 239 state-quarter rebates for clothes washers. Since our panel has 50 US states that we track over four quarters for a period of six years between 2001 and 2006 there are 1200 observations for clothes washers alone. For clothes washers, out of those 1200 observations, 239 data points have rebates. The table shows us that the number of utility rebates available for clothes washers far exceeds that for dishwashers and refrigerators. If we consider the average rebate amount and the average weighted rebate amount we see that clothes washers get a much higher rebate amount when compared to dishwashers and refrigerators. The number of rebates as well as the average amount of a rebate is lowest for dishwashers.

We use both fixed and random effects panel data regression models. In the specifications we first observe the effects of the utility rebates on the market share of ENERGY STAR appliances without controlling for any other factors. We then introduce demographic variables, namely the average personal income (in logarithmic form), the fraction of people having degrees and also electricity prices. In the third specification we interact the appliance dummies with quarter dummies to control for any seasonality that may exist. Lastly, we introduce year-quarter time dummies interacted with the appliance dummies that will capture all changes over time. Since we have state fixed effects in our fixed effects specification introducing year-quarter dummies will take into account most of the variation that may occur. This is, therefore, the most comprehensive and our preferred specification.

6 Results

We now present the results of the specifications and describe the methods used to estimate the coefficients. The dependent variable in all the specifications is the log of share of ENERGY STAR appliances.

It is often customary while reporting panel regression results to report the results from the pooled OLS specification. In the interest of preserving space we have left out the pooled OLS results. This is because the F-test of the null hypothesis that the constant terms are equal across all the states is rejected. In other words, there are significant state level effects which implies that pooled OLS would be inappropriate. In the main text of this paper we only present results from a fixed effects panel data specification with our preferred weighted average rebate variable (see Table 5). The fixed effects specification with the simple average rebate variable is in Table 9 of Appendix A. The alternative random effects estimation (presented in Tables 10 and 11 in Appendix A.1) assumes exogeneity of all the regressors with the random individual effects.[18] This is a strong assumption that may not be realistic in our case. We use a test for overidentifying restrictions to test for fixed versus random effects and find that the hypothesis of the regressors being orthogonal to the state-level fixed effect is rejected.[19] For this reason the fixed effects specification is our preferred specification.

The columns FE1, FE2, FE3 and FE4 in Table 5 estimate eq.(1) using a fixed effects panel data model. In column FE1 we do not have any controls for demographics or the effect of time. In FE2 we introduce demographics, FE3 has dummmy variables for quarters while FE4 is the most comprehensive specification with dummies for each of our time periods. Since we are using market shares of all three household appliances, viz. clothes washers, dishwashers and refrigerators, we have appliance dummies to control for the type of appliance. As mentioned before, the coefficients of interest are the ones for the appliance type interacted with the average rebate amount. The baseline is the case where there are no rebates. A positive coefficient for the interaction of appliance type with average rebate amount would indicate a favourable effect on the ENERGY STAR sales share of the appliance due to the rebate.

The results in Table 5 show that while utility rebates for clothes washers show a positive and significant effect the effect is not the same for dishwashers and refrigerators. The effect, while positive and significant

[18] Random effect models are better suited to estimating models that have time-invariant independent variables. They are also more efficient than fixed effects models.

[19] We use the `xtoverid` command (Schaffer and Stillman, 2006) in `STATA`.

for dishwashers in FE1, FE2 and FE3 loses its significance in FE4. The impact of rebates is not significant for refrigerators. The FE4 specification indicates that the effect is not as robust for dishwashers and refrigerators as it is for clothes washers.

We choose the FE4 specification over FE2 and FE3 because it is the most comprehensive specification. Results from our preferred specification, FE4 from Table 5, show that a $1 increase in utility rebates will lead to a 0.3% increase in the share of ENERGY STAR clothes washers but the effect is not significant for dishwashers and refrigerators.

We should note, however, that the average weighted clothes washer rebate is around $15. Therefore, a $15 increase leads to a 4.5% in the share of sales of ENERGY STAR clothes washers. We can conclude that the rebate programs have had a positive and significant effect on clothes washers but they have not made much impact on the other appliances.

If we consider other controls in explaining the sales of ENERGY STAR appliances we see that there is a positive effect of average personal income. We expect wealthier people to buy ENERGY STAR appliances since they are, on average, about $350 more expensive than non-ENERGY STAR models. Our result is similar to that in the literature of tax incentives on the sales of hybrid cars, e.g. in Gallagher and Muehlegger (2008), which have shown that the effect of income is positive. The effect of earnings in our regressions results is positive and significant. We also look at the effect of education on the purchase of energy-efficient appliances. We find that the higher is the fraction of people having a degree in a state the more likely they are to purchase an ENERGY STAR clothes washer. This could be due a greater awareness of ENERGY STAR products and appliances, or a greater concern for the environment. Note that these two effects, become insignificant when we include time dummies. We expect the coefficient for the price of electricity to be positive implying that a higher cost of running appliances would cause people to switch to more energy-efficient ones. This is borne out in our specification. However, on including quarter dummies, this coefficient becomes insignificant.

The coefficients for dishwasher rebates and refrigerator rebates are negative but insignificant and positive but significant respectively. However, the significance for refrigerator rebates is significant at only 10%. Also, the sign is not consistent over all our specifications which is the reason why we have not considered refrigerators in the implications for policy. There are a couple of reasons why we believe that rebates for dishwashers are not effective. The efficiency standard for dishwashers has not been changed very frequently to allow for changes in efficiency of the dishwashers in the market. As a result, a huge percentage of dishwashers in the market were ENERGY STAR-rated and therefore, rebates may not have had an im-

Table 5: REGRESSION MODELS WITH AVERAGE WEIGHTED UTILITY REBATES (2001 – 2006)

	Fixed Effects			
Variable	**FE1**	**FE2**	**FE3**	**FE4**
CW*Rebate	1.250* (.201)	.549* (.184)	.576* (.180)	.320* (.122)
DW*Rebate	2.132* (.587)	.892* (.240)	.917* (.204)	-.508 (.421)
RF*Rebate	1.311* (.450)	-.0002 (.280)	-.058 (.238)	.238 (.130)
DW dummy	.823* (.054)	.808* (.055)		
RF dummy	.004 (.035)	.0001 (.035)		
Log Personal Income		3.926* (.732)	4.115* (.837)	.144 (.231)
Share of People with Degrees		4.427* (1.220)	4.078* (1.267)	.111 (.217)
Log Electricity Price		.434 (.479)	-.035 (.619)	-.186 (.078)
Quarter dummies*Appliance dummies			Yes	
Year-Quarter dummies*Appliance dummies				Yes
State Fixed Effects	Yes	Yes	Yes	Yes
Obs.	3599	3599	3599	3599
Groups	50	50	50	50
Adjusted R^2	.263	.541	.569	.920

Significance level at 1% denoted by *.

Dependent variable is Log (Share of sales of ENERGY STAR Appliances).

Standard errors (in parentheses) are clustered at the state level.

Utility rebate amounts re-scaled, CW: Clothes Washers, RF: Refrigerators, DW: Dishwashers

pact. Secondly, the frequency and average amount of rebates for both dishwashers and refrigerators were lower than rebates for clothes washers. The rebates may not have persuaded the marginal consumer to make the switch from a non-ENERGY STAR-rated machine to an ENERGY STAR-rated one. However, these are merely hypotheses and it may prove to be a future area of research to isolate the causes, if any, of a difference in the effects of rebates for different appliances.

7 Policy Implications

We use estimates from our preferred specification, FE4 from Table 5, to examine the effect of utility rebates. Since the coefficient for clothes washers rebates is robust over specifications FE2 to FE3 we only consider clothes washers and exclude dishwashers and refrigerators for calculating the cost of the rebate programs. We first perform a counterfactual exercise in which we assume that none of the states have a utility rebate in place, i.e. $\beta_{2c} = 0$ in Eq.1. This gives us the market share of ENERGY STAR clothes washers if no utility rebate had been offered, say $\tilde{y}$. Since the estimated coefficient of the effect of the utility rebate variable is positive, the market share for ENERGY STAR clothes washers will be lower than the fitted values using the original estimating equation, say $\hat{y}$. We use the ratio of these fitted values, $\frac{\tilde{y}}{\hat{y}}$ and multiply it with the actual market share to obtain the counterfactual market share if there had been no rebate. The difference between the counterfactual and the actual market shares is the effect of the utility rebates.

Note that we have used the share of ENERGY STAR appliances in our regressions. But to carry out the counterfactual exercise we need unit sales. We have yearly but not quarterly unit sales figures of clothes washers in every US state from 2001 to 2006. However, we do have the quarterly unit sales figures for the overall US. Therefore, to get an approximate value of the quarterly unit sales in each US state we use the overall US quarterly unit sales figures to get an approximate value of the quarterly unit sales. This will account for the seasonality in sales that may exist. So, e.g., the yearly unit sales in California in 2001 were 766,500. The first quarter unit sales overall in the US were approximately 26% of the annual unit sales in 2001. We assume the first quarter unit sales in California (in 2001) to be 26% of 766,500.

We use these imputed values to obtain the increase in the units of ENERGY STAR clothes washers sold in each state, i, in time t given by

$$\text{IUS}_{it} = \text{AUS}_{it} - \text{CUS}_{it} \qquad \text{where CUS}_{it} = \frac{\tilde{y}}{\hat{y}} * \text{AMS}_{it} \tag{2}$$

where IUS_{it} is the increase in units sold of ENERGY STAR clothes washers, AUS_{it} is the actual imputed units sold, AMS_{it} is the actual market share and CUS_{it} is the counterfactual imputed units sold.

The total carbon saving, TCS_{it}, is

$$\text{TCS}_{it} = \text{IUS}_{it} * \Delta\text{Energy Use} * \text{Average Life} * \text{Carbon Emissions Factor} \tag{3}$$

where ΔEnergy Use is the difference in the energy use between an average ENERGY STAR and an average non-ENERGY STAR clothes washer. The 'Average Life' is the average lifetime of a clothes washers which is typically 11 years (US Department of Energy, 2008b). Annual estimates of the average energy used by ENERGY STAR and non-ENERGY STAR clothes washers have been obtained from D&R International, Ltd. and are listed in Table 6. The figures indicate the average energy consumed in a year under normal usage. To transform the energy saved into the amount of carbon equivalent saved we use the carbon emissions factor obtained by Sanchez et al. (2008) from the Cadmus Group. The carbon emissions factor is assumed to be 0.203 kg C/kWh.[20] Therefore, total energy saving is in terms of kg carbon equivalent forgone. We find that the energy saved leads to an equivalent carbon saving of around 78 thousand tons.

The total rebate outlay, Total Rebate_{it}, in state i in time t is given by

$$\text{Total Rebate}_{it} = \text{Utility Rebate}_{it} * \text{AUS}_{it} \tag{4}$$

where $\text{Utility Rebate}_{it}$ is the average weighted rebate amount. This assumes that redemption rate for rebates is 100%. However, according to Spencer (2002), the redemption rate of mail-in rebates for typically high-value products having a high rebate value is around 40%.[21] After accounting for instant rebates we calculate the cost of carbon emissions forgone using both redemption rates to get a range of the cost. A 100% redemption rate on mail-in rebates leads to a rebate spending of $36.34 million while assuming a 40% redemption rate reduces that figure to $14.54 million.

The cost of carbon emissions forgone, Total Cost, is

$$\text{Total Cost} = \frac{\sum_{i,t} \text{Total Rebate}_{it}}{\sum_{i,t} \text{Total Carbon Saving}_{it}} \tag{5}$$

[20] This means that to produce 1 kWh of electricity, on average, 203 kg of carbon equivalent is produced.

[21] According to personal interviews conducted by Silk and Janiszewski (2008), promotion managers said that "redemption rates tend to be "very low" when the reward is below $10, that rebates of $10 to $20 on a $100 software product range between 10% and 30%, and that redemption rates on consumer electronics average approximately 40%".

Table 6: AVERAGE ENERGY USE OF CLOTHES WASHERS (IN KWH/YEAR)

Year	non-ENERGY STAR	ENERGY STAR
2001	854	290
2002	829	297
2003	829	297
2004	615	254
2005	529	243
2006	531	234

Source: D&R International Ltd.

Using the figures for the rebate outlay this translates to a cost of $426 for every ton of carbon emissions forgone when the redemption rate is 100% while the cost falls to $171 with the lower redemption rate of 40%. If we compare the cost of reducing a ton of carbon to the social cost of carbon as estimated by Nordhaus (2007), which is $17 per ton, we find that utility companies end up paying much higher for greenhouse gas reductions. However, our lower estimate of $171 per ton compares favourably with the larger estimate of the social cost of carbon ($350 per ton) obtained by Stern (2007).

There may be concerns of a "rebound effect". This could happen when the purchase of a high-efficiency clothes washers results in higher usage and, therefore, eliminates the energy saving made by switching from a standard efficiency machine. However, Davis (2008) uses household-level data from a field trial to show that the gains from the energy saving are not offset by higher usage. The field trial in Bern, Kansas (population approximately 200) was conducted to estimate the energy and water savings of h-axis clothes washers by replacing the more inefficient v-axis washers of the participating households (Tomlinson and Rizy, 1998). Davis (2008) estimates a demand function for clothes washing and finds the price elasticity of utilization to be very low at -0.06. We can, therefore, assume that the "rebound effect" is not significant in terms of estimating the energy saving.

As mentioned before, one of the reasons why utilities have Demand Side Management programs, like rebates, in place is to reduce peak demand. For utility companies in a state with very little electricity supply, like California, the cost of buying peak power when demand exceeds supply is very high. The other option is to start peaking plants that are usually natural gas and are very expensive to start up and run. Assuming a redemption rate of 40% the cost, per megawatt hour, of the utility rebate programs comes to around $32 while it is $80 for a 100% redemption rate. These are obtained by multiplying the cost per ton ($158) with the carbon emissions factor (0.203 kg C/kWh). The lower estimate cost compares very favourably to the

Table 7: COSTS OF ELECTRIC GENERATION ALTERNATIVES ($/MWH)

Type	Base Case	with Carbon Charge $25/t$CO_2$	with same cost of capital
Nuclear	84		66
Coal	62	83	
Gas	65	74	

Source: Du and Parsons (2009), original values are in cents/kWh.

average on-peak spot prices for electricity. Table 12 shows the figures for on-peak as well as off-peak spot prices at different pricing points. The mean of average on-peak prices from 2003 to 2006 is $60 which is considerably higher than the cost of the rebate programs. The mean of the minimum average on-peak spot prices over the four years, $48, is also higher than the cost of the rebate programs. We can, therefore, conclude that the rebate program for clothes washers has been successful for utility providers that are looking to reduce the demand for electricity by providing incentives to consumers for switching to more energy-efficient models.

Since utilities are also concerned about the costs involved to build and operate additional power plants we can compare the costs of the rebate programs to that of building one. Du and Parsons (2009) have calculated the cost of electric generation for the three major types of power plants, viz. coal-fired, gas-fired and nuclear. Their calculations, in Table 7 are an updated version of the figures published in Deutch et al. (2003). Du and Parsons (2009) find that the cost of constructing and operating a nuclear power plant is highest, at $84 per megawatt hour. Coal and gas-fired power plants are more cost-effective at $62 and $65 per megawatt hour. However, if the social cost of carbon is considered to be $25 per ton of CO_2 emitted then the costs rise substantially to $83 and $74 for coal- and gas-fired plants respectively. Having utility rebate programs in place are, therefore, a cost-effective alternative to building and running additional power plants.

8 Conclusion

In this paper we have looked at the effectiveness of rebates provided by utility companies on the sales of ENERGY STAR appliances by utilizing the variation in timing and size of the utility rebates across US states. The results indicate that these programs have had a positive and significant impact on the market share of high efficiency clothes washers but not on refrigerators and dishwashers. We find that an increase in a dollar value of rebate leads to a 0.3% increase in the share of ENERGY STAR-qualified clothes washers. Since the average (weighted) rebate for a clothes washer is around $15 this translates to a 4.5% increase in the share of energy-efficient clothes washers. In terms of the impact of these rebates in terms of the cost of carbon emissions forgone we find that utility rebates lead to a reduction of 78 thousand tons of carbon equivalent. Using the amount spent by utility on providing rebates we find that, over the lifetime of a clothes washer, this leads to a cost of $158 for each ton of carbon equivalent emissions forgone. The cost-effectiveness of clothes washer rebate programs in terms of megawatt hour is $32. Utilities are, therefore, better-off providing incentives to their customers instead of having additional power plants that are costlier to build and operate. This figure is consistent with the cost-effectiveness of DSM initiatives that, according to various authors, range from between $8.9 and $253.7.

An important feature of this paper is the use of utility-level rebate programs that have been aggregated up to the state level. This allows us to capture the effect of these DSM programs on the market share of energy-efficient ENERGY STAR appliances. However, this is also a limitation of our analysis since we would, ideally, have preferred to use utility-level sales data to capture the effect more precisely. There have been relatively few papers that have an *ex post* analysis of specific DSM programs. Our aim was to take one particular aspect of DSM and analyse its cost-effectiveness. The study of other DSM components should be the agenda for future research. There are many supporters and a few opponents of DSM and it is important to resolve the argument about the benefits of DSM.

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A Appendix

A.1 Tables

Table 8: AVERAGE ENERGY USE OF DISHWASHERS & REFRIGERATORS (IN KWH/YEAR)

	Dishwashers		Refrigerators	
Year	non-ENERGY STAR	ENERGY STAR	non-ENERGY STAR	ENERGY STAR
2001	700	555	540	450
2002	700	555	558	502
2003	574	455	558	502
2004	439	336	520	442
2005	413	341	520	442
2006	448	341	525	457

Source: D&R International Ltd.

Table 9: REGRESSION MODELS WITH AVERAGE UTILITY REBATES (2001 – 2006)

	Fixed Effects			
Variable	**FE1**	**FE2**	**FE3**	**FE4**
CW*Rebate	.978*	.419*	.432*	.249*
	(.138)	(.091)	(.091)	(.066)
DW*Rebate	1.571*	.260	.281	-.376*
	(.206)	(.161)	(.161)	(.085)
RF*Rebate	1.049*	.225	.213	.031
	(.159)	(.110)	(.115)	(.083)
DW dummy	.860*	.843*		
	(.058)	(.059)		
RF dummy	.043	.028		
	(.037)	(.037)		
Log Personal Income		3.855*	4.045*	.147
		(.731)	(.836)	(.230)
Share of People with Degrees		4.340*	3.988*	.098
		(1.192)	(1.237)	(.216)
Log Electricity Price		.407	-.071	-.185
		(.468)	(.605)	(.077)
Quarter dummies*Appliance dummies			Yes	
Year-Quarter dummies*Appliance dummies				Yes
State Fixed Effects	Yes	Yes	Yes	Yes
Observations	3599	3599	3599	3599
Groups	50	50	50	50
Adjusted R^2	.291	.545	.573	.923

Significance level at 1% denoted by *.

Dependent variable is Log (Share of sales of ENERGY STAR Appliances).

Standard errors (in parentheses) are clustered at the state level.

Utility rebate amounts re-scaled, CW: Clothes Washers, RF: Refrigerators, DW: Dishwashers

Table 10: Regression Models with Average Utility Rebates (2001 – 2006)

Variable	Random Effects RE1	RE2	RE3	RE4
CW*Rebate	.861*	.656*	.657*	.280*
	(.127)	(.116)	(.113)	(.070)
DW*Rebate	1.248*	.866*	.859*	-.298*
	(.218)	(.236)	(.233)	(.073)
RF*Rebate	.848*	.516*	.483*	.072
	(.171)	(.197)	(.177)	(.073)
DW dummy	.858*	.848*		
	(.058)	(.058)		
RF dummy	.042	.039		
	(.037)	(.036)		
Log Personal Income		.047	.049	.016
		(.028)	(.027)	(.012)
Share of People with Degrees		3.010*	2.999*	1.139*
		(.513)	(.506)	(.168)
Log Electricity Price		.595*	.550*	.084
		(.111)	(.110)	(.042)
Quarter dummies*Appliance dummies			Yes	
Year-Quarter dummies*Appliance dummies				Yes
Obs.	3599	3599	3599	3599
Groups	50	50	50	50
R^2	.267	.331	.374	.907

Significance level at 1% denoted by *.

Dependent variable is Log (Share of sales of ENERGY STAR Appliances)

Standard errors (in parentheses) are clustered at the state level

Utility rebate amounts re-scaled, CW: Clothes Washers, RF: Refrigerators, DW: Dishwashers

Table 11: Regression Models with Average Weighted Utility Rebates (2001 – 2006)

	Random Effects			
Variable	**RE1**	**RE2**	**RE3**	**RE4**
CW*Rebate	1.340* (.218)	.888* (.132)	.893* (.137)	.336* (.127)
DW*Rebate	2.329* (.643)	2.027* (.538)	1.999* (.517)	-.431 (.379)
RF*Rebate	1.408* (.478)	.842 (.346)	.681 (.342)	.235 (.150)
DW dummy	.824* (.054)	.814* (.054)		
RF dummy	.006 (.035)	.0004 (.035)		
Log Personal Income		.084* (.029)	.086* (.027)	.020 (.013)
Share of People with Degrees		4.012* (.515)	3.984* (.494)	1.108* (.166)
Log Quarterly Price		.566* (.115)	.517* (.114)	.069 (.044)
Quarter dummies*Appliance dummies			Yes	
Year-Quarter dummies*Appliance dummies				Yes
Obs.	3599	3599	3599	3599
Groups	50	50	50	50
R^2	.240	.309	.352	.901

Significance level at 1% denoted by *.

Dependent variable is Log (Share of sales of ENERGY STAR Appliances)

Standard errors (in parentheses) are clustered at the state level

Utility rebate amounts re-scaled, CW: Clothes Washers, RF: Refrigerators, DW: Dishwashers

Table 12: PEAK SPOT PRICES FOR MAJOR PRICING POINTS (IN $/MWH)

	On-Peak Spot Prices				Off-Peak Spot Prices			
	2003	2004	2005	2006	2003	2004	2005	2006
Northeast								
Mass Hub	59.05	61.47	89.87	70.33	41.80	42.94	61.79	47.45
NY Zone G	61.73	61.74	92.46	76.53	42.12	42.86	63.70	50.54
NY Zone J	77.82	76.63	110.03	86.47	48.70	48.28	72.61	55.05
NY Zone A	51.36	52.49	76.04	59.34	35.78	36.82	53.26	42.20
PJM West	48.49	51.10	76.64	62.92	24.14	30.15	40.72	36.36
Southeast								
VACAR	41.60	48.27	71.88	57.20	19.44	25.23	38.13	34.96
Southern	41.55	48.67	70.88	56.15	19.51	26.01	37.54	33.86
TVA	38.90	44.23	67.39	53.91	18.73	22.14	34.24	32.76
Florida	52.21	58.31	84.95	65.06	22.25	29.02	42.88	39.78
Entergy	41.47	45.76	69.95	56.65	18.39	23.04	38.02	34.06
Southeast								
Cinergy	37.57	43.31	63.76	52.39	15.91	19.88	29.12	29.93
ECAR North	38.41	45.58	67.13	55.94	16.54	21.00	30.84	29.30
MAIN North	43.14	47.94	64.70	58.67	16.47	20.28	28.78	25.73
NI Hub	37.11	42.03	61.76	53.15	15.44	17.57	28.71	28.35
MAIN South	38.43	42.85	63.38	51.73	16.06	18.41	28.70	25.54
MAPP North	45.18	47.06	65.06	58.67	17.22	19.12	28.57	25.73
MAPP South	43.29	45.90	65.48	55.56	16.93	19.00	28.01	32.61
South Central								
SPP North	41.66	45.19	67.44	56.23	18.48	20.55	34.82	33.91
ERCOT	46.49	47.32	70.95	58.74	30.51	31.45	47.95	39.09
Southwest								
Four Corners	48.55	50.51	69.39	58.79	32.28	35.45	46.74	36.45
Palo Verde	49.10	50.09	67.39	57.85	32.84	35.44	47.10	36.91
Mead	50.65	51.91	70.18	59.79	33.75	37.43	49.02	38.44
Northwest								
Mid- Columbia	40.73	44.54	62.95	49.52	34.04	39.27	50.21	37.23
COB	44.49	49.09	66.95	55.08	35.23	40.58	51.71	39.14
California								
NP 15	49.13	54.46	72.49	60.81	35.76	41.35	51.35	39.17
SP 15	51.25	55.20	73.03	61.77	35.15	39.26	51.22	40.07

Source: Federal Energy Regulatory Commission