# The Impact of Industrial Sector Programs on Electricity Use: Econometric Estimates at the National Level

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## ABSTRACT

This paper describes the specification and estimation of an aggregate energy demand model that focuses on industrial electricity use in the U. S. from 1992 to 2002. The panel model is designed to investigate long-run economic effects as well as long-run energy efficiency program impacts. The preliminary findings of this study indicate that publicly-funded energy efficiency programs have had a noticeable impact on annual industrial electricity use; in 2002, the combined programs appear to be responsible for savings of 3.7 percent of industrial electricity use, or over 39.1 million MWh, relative to the level of industrial electricity use in year 2000.

## Introduction

Energy efficiency programs for the industrial sector have operated in the United States for almost three decades, the oldest and largest of which are sponsored by the federal government. A major focus of these public efforts is on saving electricity, but substantial efforts have also gone into targeting energy efficiency for other fuels, especially natural gas. For example, since 1977 DOE has been providing detailed multi-fuel energy audits to small and mid-size industrial plants through their industrial assessment centers. Currently, DOE funds research on industrial system optimization in energy-intensive industries while EPA offers a national benchmarking and energy ratings system as part of the ENERGY STAR® program that encourages manufacturers to skillfully manage energy and financial resources. At the local level, in the early 1990s electric utilities increased their commitments to industrial sector demand side management programs, and more recently, a number of state and regional agencies have intensified their efforts to promote industrial energy efficiency through a variety of innovative demonstration projects and programs.

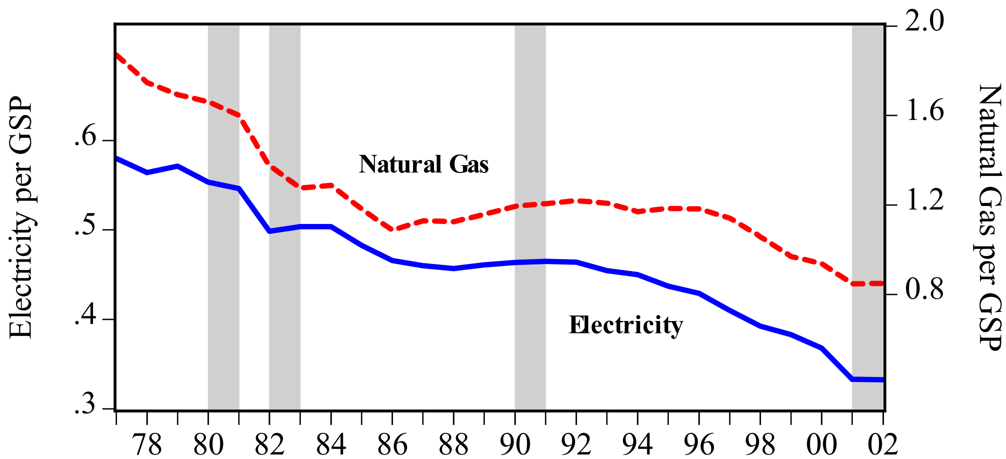
The focus of this paper is on empirically determining the extent to which these public programs, in aggregate, have influenced national trends in industrial energy use. At the core of the problem of estimating national energy efficiency program benefits is the necessity to differentiate between changes in energy use that would have occurred in the absence of public programs versus changes in energy use that would not have occurred *but for* public programs. The former changes are often referred to as naturally-occurring or market-driven effects. They occur due to the influence of prices and other economic variables. It stands to reason that it is essential to control for these factors before public programs impacts can be isolated.

Reliable quantitative estimates of public program effects are essential not only for improving existing energy efficiency programs and for designing future programs, but for long-range supply-side resource planning and national security planning. Moreover, in-depth exploration of industrial energy use is timely now that the Kyoto Protocols are beginning to be implemented world-wide, with the notable exceptions of the United States and Australia. As our national debate over the future of greenhouse gas emissions, climate change treaties, and national energy policies expands with each passing session of Congress, better information about the factors affecting energy use is needed.

One topic in particular that continues to receive a great deal of attention, and about which there has been substantial disagreement, is the extent to which declining national energy intensity reflects progress in energy productivity -- and if so, what the drivers of energy productivity might be. In the recent past, numerous research papers have compared energy intensity trends across different nations, and many have described useful methods for controlling for differences in structural change in economies over time and between countries. Nevertheless, most of the mysteries behind the trends remain, particularly when energy consumption and energy intensity are disaggregated by economic sector and by fuel.

For example, for the 48 contiguous states from 1977 to 2002, Figure 1 shows a consistent, declining trend in the consumption of electricity, and natural gas, in the industrial sector as a function of gross state product (GSP) in constant dollars. GSP is the state-level equivalent of gross domestic product; it measures the value added of each state, by industry, to the national production of goods and services. National economic recessions are indicated by the vertical shadings.

**Figure 1: Industrial Electricity and Natural Gas Intensity**




These trends have generated many different hypotheses regarding the progress of national energy consumption, each of which has different implications for energy and environmental policy. For some they have supported the notion that energy is being used more productively in the industrial sector. Others see these trends as indicating that the overall mix of domestically-produced goods has been evolving towards those that are less energy intensive. In short, there are many alternative explanations for the causes of declining energy intensity and none are mutually exclusive.

Unraveling these broad trends is not possible without studies that go below the surface details. As can be seen in Figure 2, energy intensity is not declining because energy use is declining -- the trend in industrial consumption of electricity and natural gas, in absolute terms, is rising. Indeed, this may come as no surprise given the trends in energy prices. As shown in Figure 3, industrial sector energy prices are, in real terms, not very different in 2002 than they were in 1977.

**Figure 2: Industrial Electricity and Natural Gas Consumption**

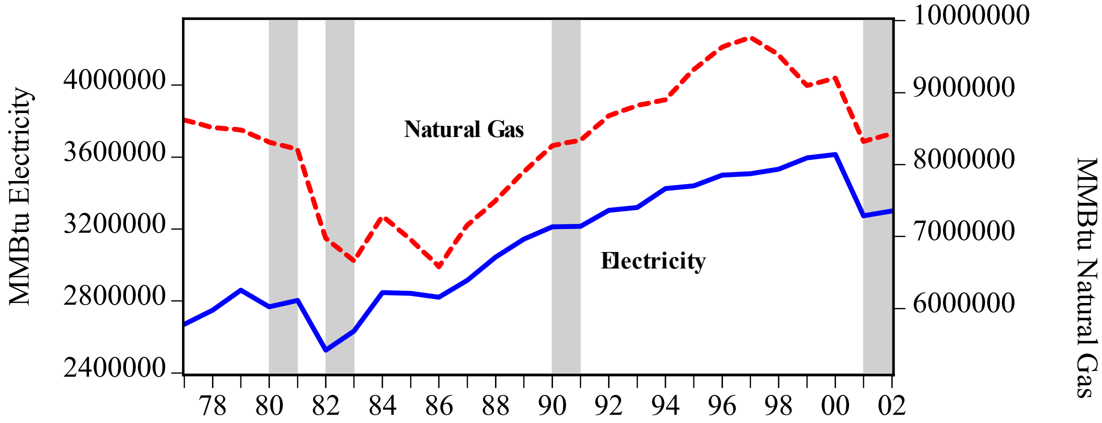
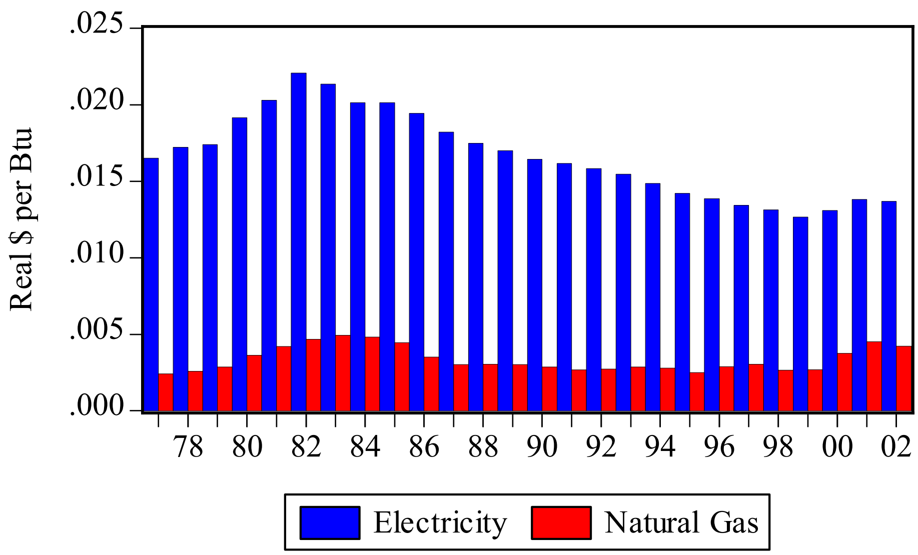
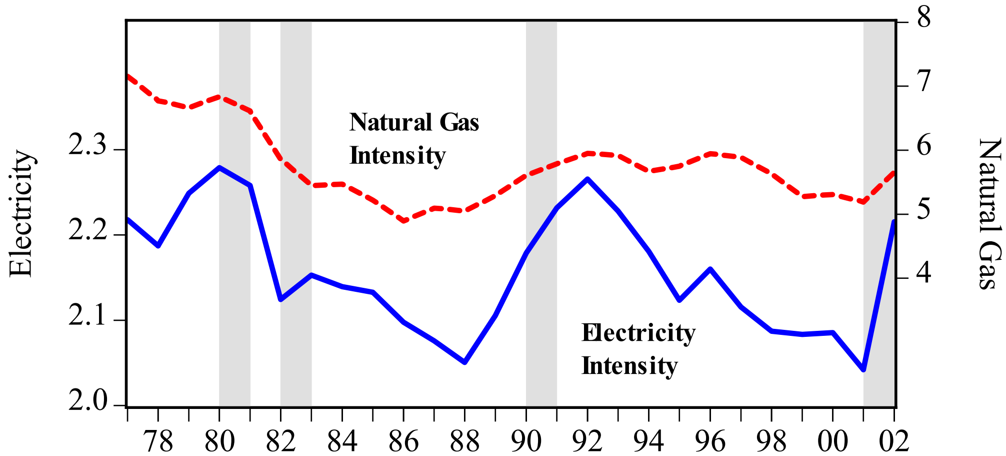



**Figure 3: Industrial Electricity and Natural Gas Prices**




Moreover, as can be seen in Figure 4, when industrial electricity and natural gas use are shown relative to manufacturing production, as opposed the combination of mining, agriculture, construction, services, and manufacturing production, a different story emerges. Energy intensity now seems to show greater volatility but an absence of trend; the intensity level for electricity is not much different in 2002 than it was in 1977, and for natural gas not much different in 2002 than it was in 1982.

**Figure 4: GMP-Based Industrial Energy Intensity**




In summary, the interpretation of energy-related trends is elusive, and simple explanations are not forthcoming. Do these trends mean that there has been no change in energy productivity in the private sector? Do these trends argue that structural change within the industrial sector has not occurred, or is unimportant? Have publicly-funded energy efficiency programs and policies been effective? This paper begins to address some of these important issues. The key feature of the research approach is that it uses cross section (state-level) time series (annual) data to control for market conditions and economic trends that affect energy consumption. After pre-testing to ensure that the specified model yields unbiased and consistent parameter estimates, net changes in industrial electricity use due to energy efficiency programs are derived. An overview of the model findings reveals that as well as providing useful insights into the determinants of industrial electricity demand, this study raises further issues for investigation.

## Advantages of Aggregate Program Evaluation

Energy efficiency program evaluation research, be it in the industrial or buildings sectors, is typically conducted for individual programs on the micro level. This means that data pertaining to program-related changes in energy consumption are collected at the individual equipment, building, or plant level, collectively referred to by economists as capital stock, or simply *stock*. Once the microdata are analyzed the evaluation is completed by expanding the statistical findings to the program population. For engineers of most stripes, whose training emphasizes understanding and measuring the physical characteristics of stock, the microdata approach to program evaluation seems to make the most sense. As one engineer who was both a metering expert and experienced program evaluator remarked to me not long ago, " I want to get as close as possible to the *thing*."

The value of intimacy notwithstanding, an evaluation of energy efficiency programs in aggregate, based on energy consumption rather than stock, has certain advantages over microdata-based evaluations of individual programs. For one thing, with free and rapid flows of information and goods nationwide, a critical mass of individual energy efficiency programs may result in aggregate market transformations in which total program impacts are greater than the sum of individual program impacts. Without taking a broad view, these transformative impacts may never be perceived. For another, microdata collection tends to be expensive whereas aggregate data tends to be free.

Technically, the most immediate downside to the microdata approach to program evaluation is that its relies on two sampling assumptions that are unrealistic. First, it assumes that the observed stock is representative of the entire program stock. This is rarely the case; the sample is almost always opportunistic due to physical barriers and technical constraints, not to mention the limited cooperation of owners and managers. Second, the usage of the stock -- from which is derived the flow of services from the stock -- is usually monitored over a short period of time despite the fact that usage may be as critical to measuring energy savings, or even more critical, than the physical characteristics of the stock itself. As such, even a year of monitoring may not represent behavior over a three to fifteen year lifetime. An obvious consequence of the first limitation is that the evaluation findings may be biased towards stock with better than average energy savings; an obvious consequence of the latter is that the true variance of the program energy savings may be far greater than it appears.

Microdata evaluations also raise issues concerning which parameters of the stock are measured versus assumed, the value of high versus low frequency data and large versus small samples, interaction effects and synergies, and so forth. But even putting aside the myriad metering and monitoring issues -- about which there are numerous studies in both the industrial and buildings literature -- microdata studies tend to be of limited use for shedding light on critically important issues related to national energy and economic policy. Specifically, microdata program evaluations are not designed to provide insight into the effects of economic trends on energy-related investment and consumption behavior. Economic and policy questions that are not addressed in typical program evaluations include:

- does energy savings change if energy prices change?
- does energy savings change with changes in economic development and economic growth?
- is there substitution between energy, labor, and capital?
- is there substitution between different fuels?
- how does energy use adjust to a fixed stock of equipment?
- what is the net effect of the program, after removing all market-related effects including free ridership, snapback and interactions?

Unfortunately, it has been a rare evaluation that has addressed these questions. Admittedly, many program evaluations worry about short-term free ridership and use consumer surveys to estimate its impact; still others use non-participant or comparison samples as a baseline for netting out undifferentiated short-term non-program related factors affecting consumers. However, evaluations are typically static, providing a single, timeless snapshot of program impacts -- usually for the first-year savings, only. Long-term factors, most of which tend to be closely related to market forces, tend to be ignored. This is especially true in the industrial sector with its high degree of heterogeneity vis-à-vis capital equipment and manufacturing processes, not to mention its acute competitive pressures.

Given these difficulties, to the extent that comprehensive long-term program effects are of interest, different approaches to program evaluation are required. One approach that has its origins in highly-regarded econometric research involves using panel data, that is, a combination of cross section and time series data, to explore aggregate demand. The cross sections used in these studies are typically states, although studies have on occasion used higher levels of geographic aggregation, such as regions or countries, or lower levels of geographic aggregation, such as utility service territories or counties. The time series are over continuous, equally-spaced intervals and are usually of low frequency, such as annual, so that many variables are available for analysis.

In this tradition, the present study examines aggregate energy use in the U. S. manufacturing sector. Specifically, it explores the economic determinants of electricity -- and the impact of publicly-funded energy efficiency programs -- in the 48 contiguous states, focusing specifically on the 11 years from 1992 through 2002. The three main sources of the publicly available data used for this research are the Energy Information Administration's (EIA) State Energy Database (SEDS), the GSP database and the National Income and Products Accounts (NIPA) database, both maintained by the Bureau of Economic Analysis (BEA). In addition, a variety of variables are drawn from different federal government databases, including those of the Federal Reserve Board, the Bureau of Labor Statistics, EIA's electric utility survey, Census's Current Industrial Reports, the National Climatic Data Center, and DOE's Industrial Assessment Center. With few exceptions, all the data in the study vary over time and over state. Those data series that only vary over time -- such as the prime lending rate -- represent national trends whose influences, after controlling for idiosyncratic state fixed effects, are assumed to be geographically uniform.

## Model Variables and Diagnostics

Controlling for fixed cross sectional effects involves estimating a model that contains a separate intercepts for each state. Given the proliferation of energy-related local policies and regulations, this procedure appears called for to explicitly account for the factors in each state that are not directly observable, but that differentially affect state energy use. The set of variables used in the industrial electricity demand are:

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|---|---|---|
| *ES* | = | industrial electricity consumption (site) |
| *FLOWADJUST* | = | one period lag of *ES* |
| *ES PRICE* | = | unit price of industrial sector electricity |
| *NG PRICE* | = | unit price of industrial sector natural gas |
| *GMP* | = | the manufacturing sector portion of GSP |
| *GMPSHIFT* | | *GMP* intercept shift for 1997 and beyond |
| *GMPPOST* | | *GMP* slope shift for 1997 and beyond |
| *RECESSION* | = | dummy variable for economic recession in 2001 |
| *HDD* | = | annual heating degree days |
| *CDD* | = | annual cooling degree days |
| *WAGE* | = | average wage per wage-worker |
| *USPRIME* | = | national average annual prime lending interest rate |
| *DSM&IAC* | = | annual cumulative DSM and IAC savings as % of ES |
| *MTX* | = | index of energy efficiency market transformation activity |

Within the model, all of the continuous variables are in log form and all energy-related units are standardized to Btu. The variables in the model that are denominated in dollars, such as average electricity and natural gas prices, are deflated to constant dollars using the GDP chained implicit price deflator with year 2000 as the base. The national average annual prime lending rate is adjusted to a real rate using the annual percentage change in the GDP price level.

One of the key features of this model specification is that it controls for economy-wide structural changes by using industrial sector product exclusively, or *GMP*, as an explanatory variable. *GMP* is defined as the manufacturing sector portion of gross state product, *GSP*, meaning *GSP* less the mining, agriculture, construction, and services sectors. It may be noted that a small but unavoidable degree of measurement error exists in this variable because classification of some industries changed for 2002 when the federal government shifted from the Standard Industrial Classification system (SIC) to the North American Industry Classification System (NAICS). However, a test for measurement error finds the effects of the changes to be negligible.

A major advantages in using *GMP* rather than the broader measure of *GSP* is that it isolates the industrial sector's energy inputs and production output. This avoids the typical confusion that is caused when different economies have unequal proportions of manufacturing, mining, agricultural and service sector activity, each sector having differing energy needs. However, using *GMP* only solves a part of the problem since, even after controlling for sector proportions, there remains the possibility of intra-sector structural change may also lead to differential energy use. To address this issue a preliminary analysis was conducted of the mix of manufacturing industries from 1992 to 2002. This analysis indicated that there have not been dramatic changes in the mix of manufacturing industries over the past decade. Nevertheless, to guard against intra-sector change an additional independent variable, *GMPSHIFT*, is included in the model to test, and if need be control for, the changed mix of industries from 1997 forward.

Two independent variables related to publicly-funded energy efficiency programs distinguish this model specification from conventional investigations of energy consumption and energy price elasticities. The first combines reported annual cumulative electricity savings from demand-side management (DSM) industrial programs with reported cumulative annual savings from implemented measures suggested by DOE's Industrial Assessment Centers (IAC) program. To avoid double counting, implemented IAC measures that received utility rebates were excluded from the estimates. Further, both the DSM and IAC statistics were constructed as a cumulative annual sum under the assumption that an installed measure represents permanent savings, not merely savings for the lifetime of the measure. In this way, the data series give credit to these programs for transforming the energy efficiency markets, as well as for their immediate resource acquisition impacts. Finally, the sum of these two data series is expressed as a percentage of annual state industrial sector consumption.

A second energy efficiency program variable, *MTX*, is a proxy for federal and regional market transformation program impacts. It is constructed from historical information on the evolution of the national lighting market after discounting market-related effects and DSM program effects. Anecdotal and quantitative evidence indicate that this index is highly correlated with a broad spectrum of non-utility energy efficiency program activities, and hence non-utility program-related energy savings, especially those focused on energy efficiency voluntary partnership programs.

Prior to finalizing the model specification, pre-testing was necessary for determining which model features and modeling procedures offered the likelihood of attaining the most unbiased and consistent parameter estimates. In particular, six aspects of the specification were investigated; the significance of fixed effects, the presence of heteroscedasticity, the presence of serial correlation, the presence of a unit root in the dependent variable, the endogeneity of electricity prices and *GMP,* and measurement error in *GMP*. Of these six issues, a corrective measure was needed for heteroscedasticity, only, as a test of the pooled model error term decisively rejected the null hypothesis of equal variance across states. Since heteroscedasticity violates a key assumption of the fixed effect model, a feasible GLS specification was estimated using groupwise weights constructed from the cross-section residual variances.

After finalizing the model specification and estimating it parameters, the adjusted R-squared of the model was derived by transforming all of the state-level variables into deviations from their respective state means. This procedure, which has no effect on the original model findings, is needed to eliminate misleading between-state correlations caused by the initial starting points of the data. After performing this procedure, the model adjusted R-squared was found to be approximately 0.84.

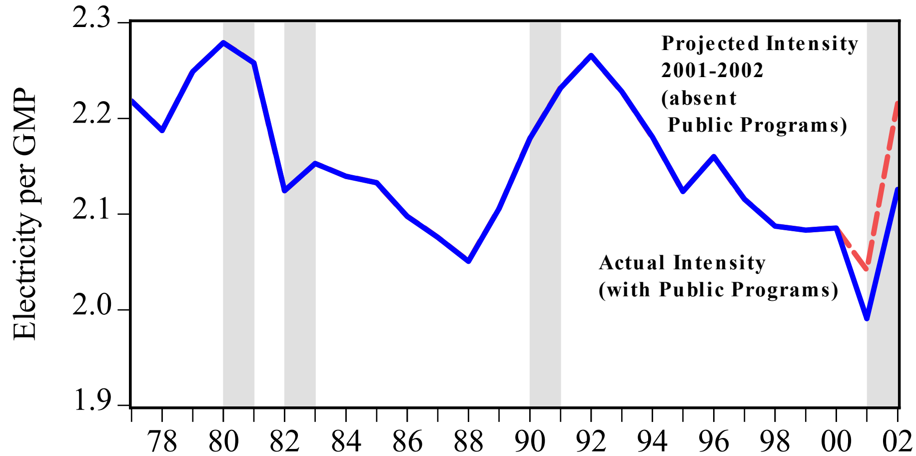
## Summary of Industrial Electricity Model Findings

The industrial sector electricity model indicates that with the exception of the coefficients of average wage, heating degree days and cooling degree days, all of the coefficients of the independent variables are statistically significant at the 95 percent level or higher. The lack of a wage effect suggests that at the aggregate level there is little substitution between labor and industrial electricity use. On the other hand, interest rates appear to be strongly related to electricity use. The model suggests that a 10 percent (relative) change in the real prime is associated with an approximately two-tenths of a percent change in industrial electricity use. This may imply that when capital expenditures are less expensive, old equipment stock is more likely to be replaced with newer, more energy efficient stock.

The findings related to publicly-funded programs suggest that, controlling for all other factors, the combined programs combined were responsible for a 3.7 percent decline in industrial electricity use from 2000 through 2002. Of this impact, the model attributes 1.6 percent to the implemented measures promoted by DOE's IAC program and electric utility DSM programs, and 2.1 percent to federal and regional market transformation programs. In terms of absolute savings, the model findings indicate that the combined energy efficiency programs are responsible for a reduction of almost 39.1 million MWh in 2002. Figure 5 illustrates how aggregate program-related savings affected electricity intensity in the manufacturing sector of the economy.

In addition, the model indicates that the long-run price elasticity of industrial demand for electricity is approximately unity, whereas the long-run elasticity of demand for electricity with respect to natural gas prices is a positive 0.10 percent. This implies that electricity is a substitute, albeit slight, for natural gas. Further, broad economic conditions appear to have strong influences on industrial electricity demand. Prior to 1997, a 10 percent increase in gross manufacturing product led to an increase in industrial electricity use of approximately 3.8 percent; from 1997 forward this relationship shifted to where a 10 percent change led to a decline in industrial energy use of 0.4 percent. The softening of the relationship between economic growth and electricity use may be due to autonomous energy efficiency or it may be ascribed to changes in industry and/or product mix -- or, it may be ascribed to a little bit of both. However, at least superficially, the industrial mix interpretation is not supported by annual comparisons of the proportions of the 10 major manufacturing categories within the industrial sector; at the national level they appear to be relatively stable over the study period. Finally, controlling for all other market factors, the model finds that the national recession of 2001 led to a decrease in industrial electricity use of about 5 percent.

**Figure 5: Historical Industrial Electricity Intensity**




## Conclusion

There remain a considerable number of important issues to address within the context of this research, not the least of which is the allocation of impacts across federal and regional market transformation programs. Among the other challenges to be met is the possibility of adapting this modeling approach to studying the impact of publicly-funded programs on other fuels, such as natural gas and petroleum, and perhaps adapting this approach to the state and regional studies. However, it should be noted that employing this approach requires special care. Data supporting these analyses may not be readily available, or may require substantial resources to acquire, process, and test. Moreover, particular difficulty surrounds the availability and reliability of energy efficiency program data. These obstacles notwithstanding, this line of research has already yielded valuable findings that are worth pursuing further.