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# MEASURING IMPROVEMENT IN THE ENERGY PERFORMANCE OF THE U.S. CEMENT INDUSTRY

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*MAY 2011*



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## CONTENTS

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Figures.....	3
Tables .....	3
Acknowledgments.....	3
ENERGY STAR Industrial Program.....	4
Identifying a Key Barrier to Energy Efficiency .....	5
Energy Performance Indicator.....	6
Data.....	8
PCA Data Preparation and Summary.....	8
Benchmark Statistical Modeling.....	9
Summary.....	16
References .....	16

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## FIGURES

---

Figure 1 Regression of the Square of the Residuals Against Average Kiln Capacity .....	12
Figure 2 Kernel Density for Different Measures of Energy Efficiency.....	14
Figure 3 Comparison of Original EPI with Updated EPI.....	15

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## TABLES

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Table 1 Summary Statistics .....	8
Table 2 Regression Results - Updated EPI .....	11
Table 3 Regression Results for 1997 Original EPI using New Data.....	13
Table 4 Summary Statistics in Each Quartile of the New EPI.....	14

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## ACKNOWLEDGMENTS

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This report was prepared for the U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Atmospheric Programs, Climate Protection Partnership Division. We would like to thank the Portland Cement Association, which provided the plant-level data from their annual *Labor and Energy Survey*, under a non-disclosure agreement with Duke University. The research results have been screened to insure that no confidential data are revealed. We would like to thank the energy managers from companies participating in the ENERGY STAR Cement Industry Focus for their willingness to test and provide comments on earlier versions of the analysis. This process was invaluable to producing a useful tool. The report has benefited from helpful comments from Josh Smith (ICF International), Walt Tunnessen (US EPA), and Elizabeth Dutrow (US EPA). Any errors or omissions remain the responsibility of the authors.

## ENERGY STAR INDUSTRIAL PROGRAM<sup>1</sup>

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The U.S. industrial sector was responsible for 26% of energy-related greenhouse gas (GHG) emissions in 2009,<sup>2</sup> and 29% of all U.S. GHG emissions. Carbon dioxide (CO<sub>2</sub>) is predominant among those emissions, mainly due to energy consumption for manufacturing processes. CO<sub>2</sub> comprises 80% of manufacturing GHG emissions on a CO<sub>2</sub>-equivalent basis.<sup>3</sup>

An important strategy for reducing CO<sub>2</sub> emissions is to improve energy efficiency. In manufacturing, energy efficiency is usually understood as using less energy to produce the same amount of product. Reducing energy requirements can result in lower combustion-generated CO<sub>2</sub> emissions; hence, energy efficiency is the most cost-effective strategy for reducing CO<sub>2</sub> emissions since it lowers both emissions and fuel costs.

Recognizing the potential of energy efficiency to reduce CO<sub>2</sub> emissions, the U.S. Environmental Protection Agency (EPA) launched ENERGY STAR for Industry to educate manufacturers on steps to improve their energy efficiency. EPA examined many of the market barriers to adoption of cost-effective practices and technologies, and determined that an approach focused on information and energy management strategy offered a new opportunity to overcome market barriers and transform decision making.

EPA observed that the absence of information on whole-plant energy intensity and lack of a system for benchmarking industrial plant energy efficiency represented a major obstacle to improving U.S. industrial energy efficiency. While energy efficiency standards and measures were sometimes available for specific technologies, there was no way to determine how well these technologies operated as a system when measured at the whole-plant level. Moreover, the actual operational efficiency of one plant versus another could only be captured by benchmarking the energy efficiency of the whole plant and not by looking at its components. Because of competitiveness issues among companies, the data necessary for benchmarking industrial energy efficiency was usually considered proprietary, and thus very few industrial plant energy efficiency benchmarking systems had been developed.

By offering a tool that would enable a corporation or industrial plant to compare energy performance to the rest of its industry, EPA hoped to help manufacturers answer key questions:

*How do I know whether my plants are energy-efficient?*

*How much can my plants improve?*

*Which plants should I target for efficiency improvements?*

*Which plants should I examine for best practices?*

By helping companies answer these questions, EPA also believed it could arrive at a “best in class” type of energy efficiency benchmark that could help strengthen overall energy management practices within

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<sup>1</sup> This background information on the ENERGY STAR Industrial program is taken from Boyd 2010.

<sup>2</sup> The latest data available at the time of this report.

<sup>3</sup> EPA 2011.

an industry. Energy management strategy is a key component of the ENERGY STAR approach.<sup>4</sup> This paper focuses primarily on development of the ENERGY STAR industrial energy performance benchmarking system and the change in the industry observed when the benchmarking system was updated.

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## IDENTIFYING A KEY BARRIER TO ENERGY EFFICIENCY

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An inability to determine whether a manufacturing facility is energy-efficient is common to most industries. Within an industry, some companies can determine the performance of similar plants in a single portfolio. However, few companies can determine how well their plants perform compared to similar plants outside their own portfolios across the United States. This missing piece of information limits a company's ability to set competitive goals for a plant's improvement, and prevents understanding how well the best plants in that industry are performing. The cement industry is unique, in as much as the Portland Cement Association (PCA) collects data on energy, labor, and production for the benefit of its members. With support from the PCA and its member companies, ENERGY STAR is able to expand on PCA's own use of this data to provide a detailed analysis of energy performance. EPA set out to develop a new set of tools for the industrial marketplace that would enable industry to judge plant energy performance and set goals for improving energy efficiency. These tools, known as the ENERGY STAR Energy Performance Indicators (EPI), fulfill the need that many industries have for obtaining objective, quantitative information on whether a manufacturing facility is energy-efficient within its industry.

To develop an EPI for U.S. cement plants, EPA engaged cement manufacturers with plants in the United States in a collaborative initiative called the ENERGY STAR Focus on Energy Efficiency in Cement Manufacturing (the Focus). The objectives for the Focus were to produce an "energy guide"<sup>5</sup> for the industry, develop the cement plant EPI, and foster discussions of energy management best practices.

EPA's first step was to engage a group from the industry to guide them in implementing corporate energy management programs within their companies. EPA approached senior executives to establish the business case for energy management and secure assignment of a responsible energy director for each corporation where one was lacking, toward enabling the companies to build or improve the necessary internal energy management functions and networks. ENERGY STAR energy management tools (such as simplified program evaluation checklists, energy management guidelines, and information on forming energy management teams) guided refinement of the energy management programs at each participating company.

The Focus gave particular attention to messaging and promoting early energy achievements, as these served as motivation for expanding energy management for senior executives and production-line employees alike. EPA guided the corporate energy managers in implementing the elements of their energy management systems, from setting goals to creating action plans and communicating success.

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<sup>4</sup> For more information on ENERGY STAR energy management resources, visit [www.energystar.gov/industry](http://www.energystar.gov/industry).

<sup>5</sup> See Worrell and Galitsky, March 2008

EPA learned early on that there is great benefit to the industry when energy directors network to share best practices and discuss management strategies. Through ENERGY STAR, EPA facilitated discussions among directors that led to greater dissemination of knowledge throughout the industry. All of these activities have contributed to facilitating the improvement in energy efficiency that is now being observed in the industry.

The first EPI for the cement manufacturing industry was released in 2006. Since then, companies participating in the Focus have benchmarked multiple sites. Many companies have also made the EPI an integral part of their corporate energy management programs. Development of the first cement EPI began more than a decade ago. With genuine effort over time, the companies improved the energy efficiency of their plants using the EPI to gauge energy performance. Over time it became clear that a new version of the EPI, based on more recent data, was needed to continue to motivate energy improvement. EPA agreed to develop a new EPI based on new data, and released it to the industry so further improvement could be achieved.

By updating the cement manufacturing EPI and comparing the two versions, we are able to quantify the improvement in the industry and better understand how the industry has strived to improve energy efficiency. The remainder of this paper describes the data and underlying statistical analysis used to update the ENERGY STAR EPI for cement plants, and how the parameter estimates of the original and updated models have changed over time (in particular, the treatment of clinker-cement production ratios and capacity utilization). Several measures are computed to illustrate how the distribution of energy efficiency has shifted over time.

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## ENERGY PERFORMANCE INDICATOR

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The EPI is a statistical model of plant-level energy use that enables comparison across sites with different levels and types of production-related activities that influence energy use. EPIs are developed for a specific type of manufacturing plant (in this case, cement). An EPI is designed to enable identification of the “best in class” energy performance for the industry. The EPI assigns a plant a specific energy performance score on a scale of 1 to 100. EPA defines average performance as the 50<sup>th</sup> percentile, while efficient performance is in the 75<sup>th</sup> percentile or higher. This section describes the history of the model development, the underlying data and statistical analysis, and estimates of the shift in the energy intensity distribution over time.

Tracking energy performance is a fundamental component of good energy management. *Base lining* and *benchmarking* are two complementary approaches for performance tracking. Base lining involves comparing plant<sup>6</sup> performance over time, relative to measured performance in a specific year. Benchmarking involves comparing performance relative to average or an established best practice level of performance against an appropriate peer group. Benchmarks can be based on a variety of information, including engineering estimates or observed performance. When observed performance is

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<sup>6</sup> Throughout this report we consider the relevant entity to be the entire plant. Performance tracking can be more or less aggregate, i.e. at the firm or at the process unit level.

used to create a benchmark, then data on actual performance for an appropriate group of plants is needed to support the benchmarking analysis. The data tie the benchmark to the corresponding year(s) of the data; setting the *benchmark year* or *period* if multiple years of data are used. If the industry improves over time, then the benchmark is not representative of current industry performance, requiring periodic updates.<sup>7</sup> To reach EPA's goal of enabling an industry to continuously self-improve through use of information on plant energy performance, regular updates to the underlying data for the EPI are necessary.

ENERGY STAR for Industry has conducted analysis to support the development of the EPI, a plant-level statistical energy benchmark for various industrial sectors. The analysis is based on statistical modeling of plant-level, industry-wide data. The analysis identifies major factors such as input choice, product mix, location (weather), capacity and utilization that influence energy use and create differences between plants that are not attributable to energy management practices and technology. The benchmark analysis "normalizes" for these factors to create a statistical "peer group" against which to compare the performance of any specific plant. This benchmarking tool is named the ENERGY STAR *Energy Performance Indicator* to distinguish it from the more general practice of "benchmarking" which may involve a different scope, e.g., process units, or use different methods, e.g., engineering estimates. In other words, the EPI embodies a specific (statistical, plant-level) benchmarking approach.

In 2006, after working in close cooperation with companies in the cement manufacturing industry for nearly two years, the U.S. EPA released the EPI for cement plants. This benchmarking tool allows companies to compare the actual performance of an individual plant to the range of performance in the industry in the benchmark year. Development of that tool is documented in Boyd (2006). The data for this original benchmark analysis are confidential, plant-level data from the 1997 Census of Manufacturing and 1998 Manufacturing Energy Consumption Survey, combined with 1997 data from PCA on waste-derived fuel use. 1997 was the most recent, detailed data that was available from the Census Bureau at that time. The PCA data were felt to provide more accurate measures of waste fuels than the Census data.<sup>8</sup> This data period (beginning in 1997) was useful in capturing the change in the industry during the period of time when EPA was engaging companies in building energy management programs from the late 1990s and early 2000s. With the passage of time and improvement in the industry, EPA thought it was time to update the data. This paper describes the data and analysis used to update the ENERGY STAR EPI for cement manufacturing plants. The paper also compares the results of the original 1997 EPI with the updated analysis. The comparison provides insights into how the industry has changed during the last decade. The first section describes the data and the analysis used for the update. The second section compares the two models to show how the energy performance of this industry has changed over time.

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<sup>7</sup> In addition to the updates, EPIs are being developed each year for additional industries.

<sup>8</sup> Comparison of Census and PCA data for other energy, e.g., electric, natural gas, etc, found close agreement between the two sources.

## DATA

The Portland Cement Association (PCA) *U.S. and Canadian Labor-Energy Survey* is a proprietary annual survey of the members of PCA detailing the U.S. and Canadian cement industry's labor and energy usage. The survey focuses on energy consumption by fuel type (including waste fuels) to compile aggregated historical labor and energy efficiency trends as well as data by type of process, size of kiln, and age of plant. Individual plant detail is not presented in the publically available report from the PCA. In cooperation with Duke University and EPA ENERGY STAR, and with the support of the PCA member companies, the confidential, plant-level version of the PCA database was made available for this study. This data is provided to Duke University under a non-disclosure agreement to support the benchmark analysis and update the cement plant EPI as a service to their member companies. All analysis presented in this report is screened to assure that no confidential information is revealed.

### PCA DATA PREPARATION AND SUMMARY

All variables in the data were screened visually for "reasonableness" by examining plots of ratios such as labor-energy, energy-production, production-capacity (i.e., utilization), clinker-cement, etc. The PCA survey also includes plants from Canada; these were excluded from the analysis. Table 1 presents the summary statistics for major variables in this paper.

TABLE 1 SUMMARY STATISTICS

Variable	Mean	Standard Deviation	Lower Decile	Upper Decile
Energy (trillion Btu)	4.93	2.39	2.69	7.75
Capacity (million tons)	1.01	0.54	0.47	1.64
Clinker (million tons)	0.90	0.47	0.45	1.44
Cement (million tons)	0.97	0.50	0.47	1.58
Labor (thousand hours)	293.97	101.10	184.00	423.85
Number of Kilns	1.75	1.08	1	3
Wet Kiln Ratio	0.23	0.41	0.00	1.00
Clinker-to-Cement Ratio	0.93	0.11	0.83	1.01
Clinker-to-Capacity Ratio	0.91	0.12	0.77	1.01
Energy Usage per Clinker (mmBtu/ton)	5.73	1.19	4.44	7.44
Average Capacity (million tons)	.730	.463	.235	1.44

All data are on an annual basis for an individual plant  $i$  in year  $t=2000-2008$ . *Energy* is defined as total source energy in trillion Btu; the sum of all combustible forms of energy in trillion Btu and electricity use

converted at 11,362 Btu/kWh (i.e., accounting for U.S. average power plant conversion, transmission, and distribution losses). Production related data is reported in million tons, with energy reported in trillion Btu. *Capacity* is the annual capability of all kilns (in million tons) in the plant for producing clinker. *Clinker* is the production amount of clinker. *Cement* is the annual production of cement. *Kiln* is the number of kilns located at the plant. *Wet Kiln Ratio* is the ratio of number of wet kilns to total number of kilns in a plant. *Labor* is the labor usage in thousand hours. *Clinker-to-Cement* is the ratio of clinker production to cement production. *Clinker-to-Capacity* is the ratio of clinker production to clinker-producing capacity. *Energy Usage per Clinker* measures annual source energy usage divided by the annual production of clinker. *Average Capacity* is the annual capability of all kilns in the plant for producing clinker divided by the number of kilns. The final data set included data for approximately 96 plants over a 9-year period, for a total of 862 plant-year observations.<sup>9</sup>

## BENCHMARK STATISTICAL MODELING

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The EPI uses a statistical model to control, or “normalize”, for aspects of production that systematically influence the energy use. The regression error term is treated as a measure of plant-specific efficiency. This approach is commonly used to measure the dispersion of total factor or labor productivity, however in this case we focus on energy. Several versions of the statistical model were estimated and provided to the representatives of cement companies for comments.<sup>10</sup> The final version of the model reviewed is the one presented here.

The cement EPI model is an ordinary least squares (OLS) regression of the natural log of total source energy, natural log of capacity, natural log of labor and several operating ratios. This means that the error term,  $\varepsilon$ , the difference between actual and predicted average energy use, is assumed to be log-normal, i.e., the percentage differences between actual and average are normally distributed.<sup>11</sup> The statistical estimate of the variance error term,  $\sigma^2$ , is used as a measure of the plant-level dispersion of energy efficiency.

$$\ln(\text{energy})_{i,t} = f(*;\beta) = \beta_0 + \beta_1 \ln(\text{capacity})_{i,t} + \beta_2 \ln(\text{labor})_{i,t} + \beta_3 \text{wtr}_{i,t} + \beta_4 \text{cl\_ce}_{i,t} + \beta_5 \text{cl\_ca}_{i,t} \\ + \beta_6 \text{cl\_ca2}_{i,t} + \beta_7 \text{int}(\ln\text{ac\_kl2})_{i,t} + \beta_8 \text{int}(\ln\text{ac\_kl3})_{i,t} + \varepsilon_{i,t} \quad \text{EQUATION 1}$$

where some of the independent variables are defined as:

- energy           = annual total source energy
- capacity         = annual capacity of kilns to produce clinker

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<sup>9</sup> A small number of data points were dropped because of missing values and an erroneous plant result.  
<sup>10</sup> Their comments led to revisions in the way capacity and utilization were represented, corrections in the labor measure, and identification of outliers.

<sup>11</sup> The ENERGY STAR EPI approach also uses Stochastic Frontier Analysis (SFA), e.g., in Gale A. Boyd, (June 2010). Statistical testing found that the error term in the cement industry is distributed approximately log-normal. We do not report the SFA results here, but focus on the OLS.

labor	= total annual person hours, including production and non-production workers
wtr	= Wet Kiln Ratio = number of wet kiln / number of total kiln
cl_ce	= Clinker-to-Cement Ratio = clinker / cement
cl_ca	= Clinker-to-Capacity Ratio = clinker / capacity
cl_ca2	= Squared Clinker-to-Capacity Ratio = (clinker / capacity) <sup>2</sup>
int(lnac_kl2)	= interaction between log of average capacity and 2 kilns dummy = ln(capacity/kiln)*dummy_kiln2
int(lnac_kl3)	= interaction between log of average capacity and 3 and more kilns dummy = ln(capacity/kiln)*dummy_kiln3

The error term,  $\epsilon$ , is initially assumed to be normally distributed with zero mean and variance  $\sigma^2$ . We will return to this assumption below. The dependent variable is the natural logarithm of total energy usage for plant  $i$  in year  $t$ . The independent variables include the natural logarithm of producing clinker capacity, the natural logarithm of labor usage, wet kiln ratio, clinker-to-cement ratio, clinker-to-capacity ratio, squared clinker-to-capacity ratio, interaction between the logarithm of average capacity and 2 kilns dummy, and interaction between the logarithm of average capacity and 3 and more kilns dummy. The regression has 862 firm-year observations. Table 2 gives the results from the above regression. The new model captures the joint effect of producing clinker and finish grinding cement. Normally clinker and cement would be produced in a relatively fixed ratio, but changes in the industry allow for additional additives in the final cement product. It is also possible for plants to ship clinker for grinding elsewhere or grind cement from clinker produced at another plant. Finally, since the data are annual, differences in inventories may cause the clinker-cement ratio to deviate from the “typical mix.” The negative coefficient implies that grinding more cement (with fixed clinker production) raises energy use as expected.

During testing of the proposed EPI, it was noticed that there were differences in performance between large and small capacity plants. In addition to the fact that there were economies of scale, i.e., large plants tended to have lower energy intensity, it was also observed that the range of performance, represented by the residuals from the above regression, was wider for small plants and narrower for large ones. In statistical terms this means that the error variance,  $\sigma^2$ , is not constant, but a function of some other variable. When the error variance is not constant, the error term is called heteroscedastic. Usually the concern over heteroscedastic error is that the standard errors of the coefficients are not correct. However, in this case, we use the estimate of the error variance to compute the range of performance in the industry, the ENERGY STAR Plant Energy Performance Score (EPS) as well as the quartiles used to determine eligibility for ENERGY STAR recognition (i.e., at or above the 75<sup>th</sup> percentile). A regression of the square of the residuals against average kiln capacity (total capacity/number of kilns) is illustrated in Figure 1. It shows the declining relationship described above. For purposes of representing the error variance for plants of different sizes, the squared residuals were regressed

against the inverse of the average capacity without an intercept, i.e.,  $\sigma_i^2 = \beta \frac{1}{\text{average capacity}_i}$ . The coefficient for  $\beta$  was 0.00346 and was significant at the 99% confidence level. Using this relationship and the upper and lower deciles of average capacity in Table 1, the variance of performance is estimated to range from 0.017 (smallest plants) to 0.002 (largest plants).

TABLE 2 REGRESSION RESULTS - UPDATED EPI

Variable	Coefficient	Standard Error	t-Statistical Ratio
ln(Capacity)	0.7918	0.0129	61.2300
ln(Labor)	0.1276	0.0191	6.6900
Wet Kiln Ratio	0.2028	0.0105	19.3500
Clinker-to-Cement Ratio	-0.1613	0.0369	-4.3800
Clinker-to-Capacity Ratio	2.2051	0.2367	9.3200
Squared Clinker-to-Capacity Ratio	-0.6925	0.1465	-4.7300
Interaction between ln(avercap) and 2 Kilns Dummy	0.0083	0.0007	11.3500
Interaction between ln(avercap) and 3 and more Kilns Dummy	0.0133	0.0009	14.1700
Constant	16.1910	0.1594	101.6000
Adjusted R <sup>2</sup>	0.9273	$\sigma^2$	0.0127

Given data for any plant  $i$  in year  $t$ , we can compute the difference between the actual energy use and the predicted average energy use from equation (1).

$$\ln(E_{t,i}) - f(*; \beta) = \hat{\varepsilon}_{t,i}$$

Since we have estimated the variance of the error term of equation (1) above as a function of capacity, we can compute the probability that the difference between actual energy use and

predicted average energy use is no greater than this computed difference under the assumption that the error,  $\varepsilon$ , is normally distributed with zero mean and heteroscedastic error variance  $\sigma_i^2$

$$\Pr(\varepsilon \leq \hat{\varepsilon}_{t,i})$$

This probability is the *Energy Performance Score* (EPS) and is the same as a *percentile ranking of the energy efficiency of the plant*.

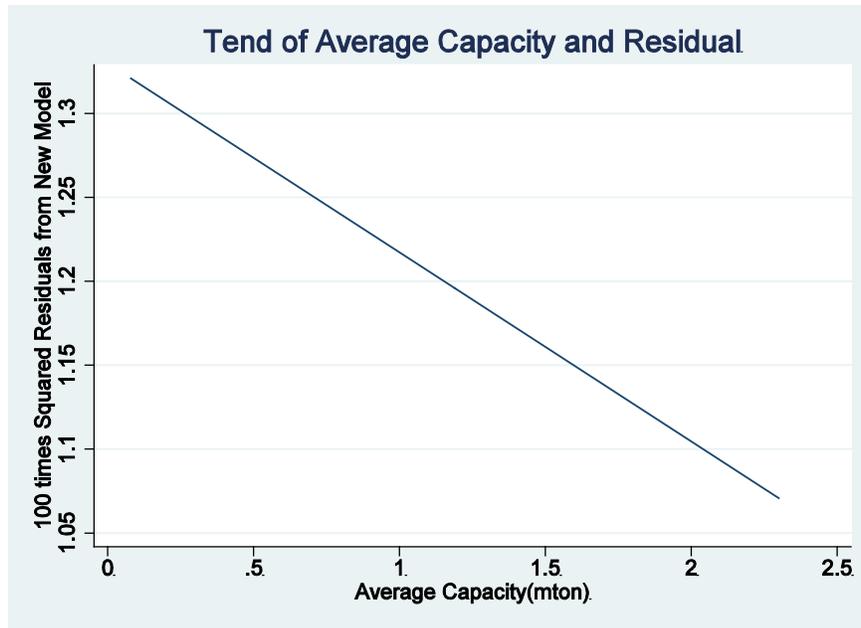


FIGURE 1 REGRESSION OF THE SQUARE OF THE RESIDUALS AGAINST AVERAGE KILN CAPACITY

The original EPI was based on equation (2). It is difficult to directly compare the coefficients of the two models, but one of the most important characteristics is the estimate of the error variance. The variance represents how much difference there is between the “best” and “worst” performing plants, after accounting for differences in capacity, production, etc.

$$\ln(\text{energy})_{i,t} = \beta_0 + \beta_1 \ln(\text{capacity})_{i,t} + \beta_2 \ln(\text{kiln})_{i,t} + \beta_3 \ln(\text{labor})_{i,t} + \beta_4 \ln(\text{cement}) + \beta_5 \text{wet}_{i,t}$$

EQUATION 2

The error variance in the new model<sup>12</sup> is 0.0127, compared to 0.0264 in the old model. This implies that the range of performance in the industry has narrowed substantially. Another way to quantify the difference in the variance is by the interquartile range. The interquartile range is the spread between the 25<sup>th</sup> and 75<sup>th</sup> percentiles. The interquartile range is ~20% for the original model and ~10% for the new model. Either the range of performance across the industry has narrowed substantially or the new model accounts for important differences in energy use that the old model did not. One way to assess which is more likely is to fit the old model (equation 2) to the new data. The results are shown in table 3. We see that the error variance is slightly higher, 0.0155 compared to 0.0127, so that the differences between the new and old modeling approach applied to the new data do not result in as high an error variance (0.0264). We conclude that only a small part of the reduced variation is from the difference in the two modeling equations (0.0155-0.0127=0.0028), and that most of the reduced variation (0.0264-0.0155= 0.0109) is due to changes in industry performance.

<sup>12</sup> For purposes of comparison between the new and old model, we focus on the average estimated error variance, rather than the model complex heteroscedastic form.

TABLE 3 REGRESSION RESULTS FOR 1997 ORIGINAL EPI USING NEW DATA

Variable	Coefficient	Standard Error	t-Statistical Ratio
ln(Capacity)	0.1372	0.0251	5.4700
ln(Kiln)	0.1452	0.0094	15.4000
ln(Labor)	0.1055	0.0214	4.9300
ln(Cement)	0.6631	0.0248	26.7000
Wet Kiln Ratio	0.2054	0.0114	17.9800
Constant	17.4870	0.1345	129.9800
Adjusted R <sup>2</sup>	0.9114	Sigma	0.0155

Another difference between the original EPI and the update relates to the type of cement produced. Specialty cements can take additional energy to produce. The CM data used for the 1997 EPI included information on the type of cement produced; specifically, ASTM 4 and Masonry cements were found to have higher energy use. For purposes of the updated model we assume that this relationship still holds, so we adjust the intercept term,  $\beta_0$  in equation 1 to reflect the 1997 estimates of the impact of specialty cement production.

$$\beta_0^* = \beta_0 + 0.7263577 \times (\text{ASTM 4/Cement}) + 0.6398759 \times (\text{Masonry/Cement})$$

EQUATION 3

These two additional terms account for the share of these specialty cements relative to total production.

The following table presents summary statistics for energy usage per ton of clinker and average capacity in each quartile. Here we set up our quartile as the following steps: first, the differences between actual and average energy use from new model regression; second, normalize the residual by heteroscedastic error variance; last, calculate its reversed probability under normal distribution. Very high quartile is above 75%, high quartile is between 50% and 75%, median quartile is between 25% and 50% and low quartile is below 25%.

Figure 2 shows the kernel density<sup>13</sup> of residuals from different models in 2000, 2003, 2006, 2008. The two different residuals are respectively generated from new model (blue line) vs. previous use (red line). The residuals are a measure of efficiency relative to the predicted average energy use. The figure shows the distribution of actual plant energy use against each model's predicted average energy use, measured as a percentage change. For example, a result of -0.5 means that the actual energy use is ~50% lower than the predicted average. We can see from the two distributions that in the original EPI (red line) the majority of plants are shown to have energy performance well above average. This

<sup>13</sup> A kernel density is a statistical estimate that is best thought of as a smoothed histogram.

tendency increases over time as the distribution of efficient plants moves more and more to the left. The updated model (blue line), representing the current data, shows that the industry performance has changed and illustrates the shift in the benchmark.

TABLE 4 SUMMARY STATISTICS IN EACH QUARTILE OF THE NEW EPI

Variable	Energy Usage per Clinker (mmBtu/ton)		Average Capacity (10 <sup>3</sup> ton)	
	Single Kiln	Multiple Kilns	Single Kiln	Multiple Kilns
Very High Quartile	4.61	5.33	960.56	552.26
High Quartile	5.15	6.20	931.50	376.77
Median Quartile	5.34	7.01	1015.27	309.16
Low Quartile	5.84	7.00	1067.14	414.39

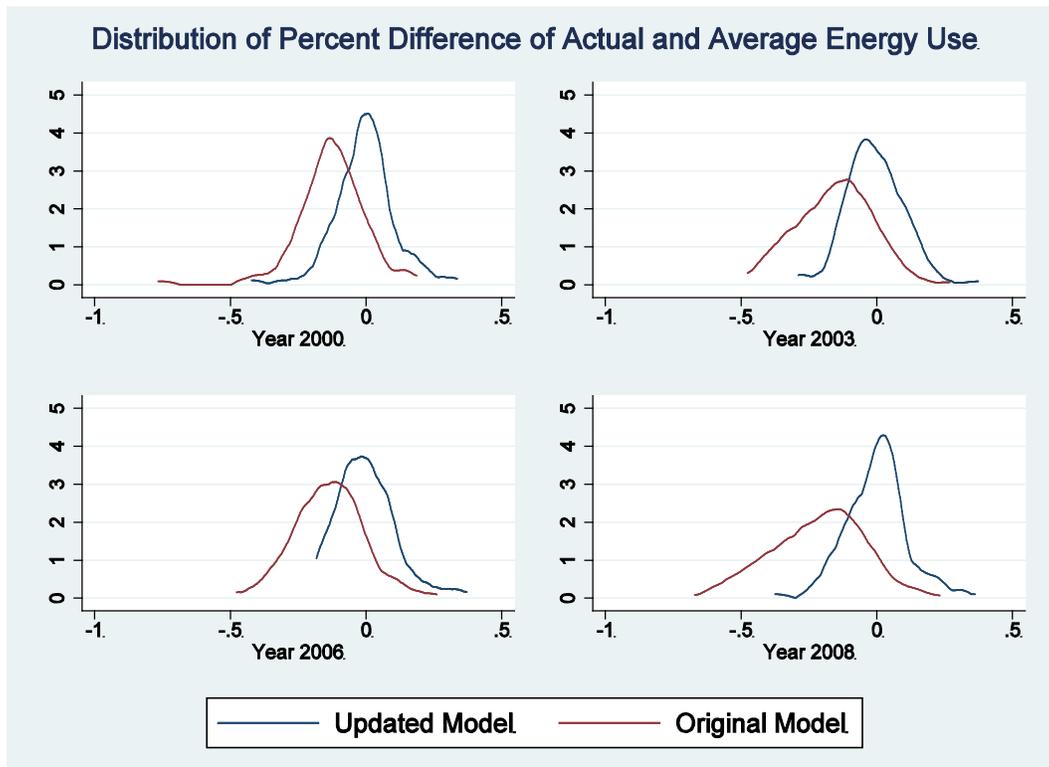


FIGURE 2 KERNEL DENSITY FOR DIFFERENT MEASURES OF ENERGY EFFICIENCY

Another way to illustrate how the industry has changed is to compare the results from the original and updated EPI. The EPI shows the predicted range of performance, across the entire industry, for any given plant. Figure 3 compares the original 1997 (red) against the updated model (blue). The results show the percentile distributions per mmBtu/ton of clinker for a plant with two kilns, total capacity of 815,750 tpy clinker, at 96% utilization and producing 900,000 tons of ASTM 1 cement per year. For

example, the figure shows that the average (50<sup>th</sup> percentile) plant in the original EPI was 6.3 mmBtu/ton, but the updated EPI is 5.2 mmBtu/ton; 0.9 mmBtu/ton lower. One interesting characteristic of the update is that it illustrates that the best are not getting better, but the long tail (representing the inefficient plants) is smaller and the “middle of the pack” has also improved. This figure is an example taken from just one “typical” plant.

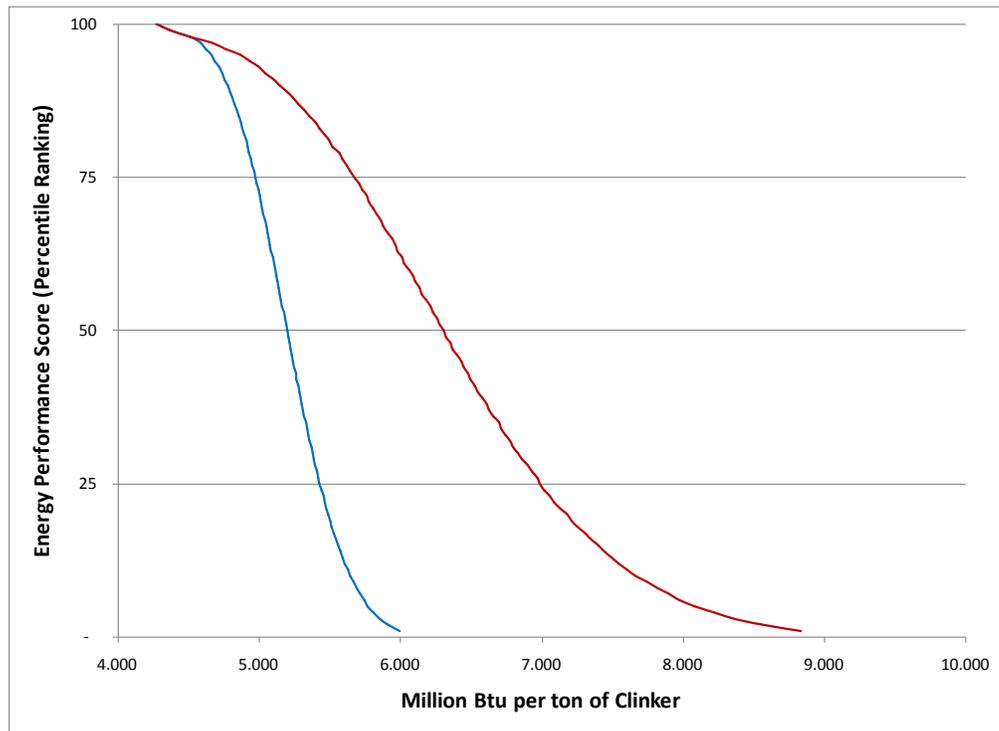


FIGURE 3 COMPARISON OF ORIGINAL EPI WITH UPDATED EPI

Figure 3 shows the industry distribution for a typical plant. Each plant in the database would have its own “curve” and its own “place” on each curve, represented by the EPS or ranking. If we compute the EPS using the old model for each plant, then compute the energy use per ton of clinker that it would take to maintain the same level of performance using the new model, we have a plant specific shift. For example, suppose plant X would score a “40” under the old EPI at approximately 6.55 mmBtu per ton. Under the new EPI a “40” would require 5.29 mmBtu per ton, a 1.26 mmBtu per ton reduction. If we compute the shift in the benchmark for every plant in the database and we can estimate the change in the 75<sup>th</sup>, 50<sup>th</sup>, and 25<sup>th</sup> percentiles to be 0.34, 0.51, and 0.75 mmBtu per ton of clinker, respectively. If we multiply this plant specific change in energy intensity by the level of clinker production for each plant operating in the industry in 2008 and total over all plants, this is a reduction of 60.5 trillion Btu in energy use. This is relative to an average annual total source energy consumption of 473 trillion Btu per year; an almost 13% reduction. This represents an annual reduction of 5.4 billion kg of energy-related CO<sub>2</sub> emissions.

## SUMMARY

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EPA assists the U.S. cement industry to improve its energy efficiency with energy management guidance and by providing a plant benchmarking tool that enables a corporation to compare the energy performance of its plants across its industry. This approach has demonstrated results. Through the updated cement plant EPI, we are able to estimate the improvement in the industry's performance between 1997 and 2008. While aggregate data could be used to estimate an average rate of improvement in terms of total industry energy use and production, such an estimate would be misleading. If one computes the ratio of total energy costs to total value of shipments (adjusted for inflation) in 1997 and 2007 from data collected in the Economic Census, one would conclude that this measure of energy intensity has *fallen* ~16%, from 0.184 to 0.158. Aggregate data also give the impression that all plants have made the same steady improvements. The picture that emerges from our plant-level statistical analysis is somewhat different and more subtle; poorer-performing plants from the late 1990s have made efficiency gains, reducing the gap between themselves and the top performers, whom have changed only slightly. The results from this study also focus on *energy efficiency* and controls for other structural changes in the industry, e.g., increases in average plant size, which tend to lower energy use. Our estimate of *the overall energy efficiency improvement* in the 96 plants in our database represents a 13 percent change in total source energy, equivalent to an annual reduction of 5.4 billion kg of energy-related carbon dioxide emissions.

Updating the ENERGY STAR cement plant EPI will enable U.S. cement plants to continue to strive for better energy performance in coming years. The whole-plant benchmarking approach employed by ENERGY STAR, as is demonstrated by the experience of the cement industry, is useful for aiding an industry to shift its energy performance through informed goal setting. EPI tools exist or are under development for more than 20 industries. EPA will continue to work with industries to help them improve energy performance through this unique approach to environmental protection.

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