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Measuring Improvement in the Energy Performance of the U.S. Corn Refining Industry

Gale A. Boyd*
Christian Delgado*

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*Department of Economics, Duke University

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ABSTRACT

Benchmarking is an important component of energy management, enabling goal setting and prioritizing of resources. The most useful benchmarks reflect the full range of performance within a sector; not only indicating whether a plant is simply above or below the “average” intensity, but considering how plants differ in terms of the products they produce so the benchmark accounts for differences in the energy intensity of the products. This paper discusses the development of a statistical benchmark of energy intensity for the wet corn refining industry using stochastic frontier analysis and confidential plant data. This analysis is the basis for developing the Energy Performance Indicator for the U.S. EPA Energy Star program, providing a tool to score the energy performance of the industry on a percentile basis, accounting for differences in product mix and moisture. A similar analysis was previously conducted for this industry using data from 1997, so the paper also compares the results from the current and previous models to assess the shift in performance of this industry. We estimate a reduction of 6.7 trillion Btu in annual energy use in 2009 relative to the levels of performance in 1997. This represents about a 4.3% reduction in overall energy use and 470 million kg of energy-related CO_2 equivalent emissions from improved energy efficiency by this industry.

ENERGY STAR INDUSTRIAL PROGRAM[1]

The U.S. industrial sector was responsible for 26% of energy-related greenhouse gas (GHG) emissions in 2009,[2] and 29% of all U.S. GHG emissions. Carbon dioxide (CO_2) is predominant among those emissions, mainly due to energy consumption for manufacturing processes. CO_2 comprises 80% of manufacturing GHG emissions on a CO_2-equivalent basis.[3]

An important strategy for reducing CO_2 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_2 emissions; hence, energy efficiency is the most cost-effective strategy for reducing CO_2 emissions since it lowers both emissions and fuel costs.

Recognizing the potential of energy efficiency to reduce CO_2 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 an industry. Energy

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[1] This background information on the ENERGY STAR Industrial program is taken from Boyd 2010.

[2] The latest data available at the time of this report.

[3] EPA 2011.

management strategy is a key component of the ENERGY STAR approach.[4] 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.

IDENTIFYING A KEY BARRIER TO ENERGY EFFICIENCY

Insufficient information 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. 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. wet corn mills, EPA engaged manufacturers with plants in the United States in a collaborative initiative called the ENERGY STAR Focus on Energy Efficiency in Corn Refining (hereafter, "the Focus").[5] The objectives for the Focus were to produce an "energy guide"[6] for the industry, develop the Wet Corn Mill EPI, and foster discussions of energy management best practices.

EPA launched the Focus in 2002 and engaged nearly all the companies operating wet corn mills in the United States. Through the Focus, energy managers from the corn refining industry were brought together for the first time to discuss best practices and energy-efficiency measures for wet corn mills. Since then, EPA has worked continuously with the industry through quarterly conference calls and the annual in-person Focus meeting to discuss energy management best practices and strategies. At the same time, EPA has worked with individual refining companies interested in strengthening their energy management program by providing energy management guidance and tools, and encouraging benchmarking with companies involved in the ENERGY STAR program. As of 2012, the majority of the companies participating in the Focus have joined the ENERGY STAR partnership.[7]

In 2003, the first "energy guide" for the Corn Refining industry was published after receiving input and feedback from energy managers within the industry. The emphasis of the Focus then turned to developing the first EPI for wet corn mills and promoting energy management best practices.

The first EPI for Wet Corn Mills was released in 2006. Since then, companies participating in the Focus have benchmarked multiple sites. Under the first EPI, seven mills qualified and were awarded ENERGY STAR certification. Many companies have also made the EPI an integral management tool within their corporate energy

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4 For more information on ENERGY STAR energy management resources, visit www.energystar.gov/industry.

5 Wet Corn Mills describes a type of the facility used in the corn refining sector. There are also dry corn mills.

6 See Worrell and Galitsky, March 2003

7 Joining the ENERGY STAR partnership is not a requirement for participating in the Focus.

management programs. Development of the first Wet Corn Mill 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 Wet Corn Mill EPI and comparing the two versions, we are able to quantify the improvement in the industry and better understand how the industry has adopted energy efficiency. The remainder of this paper describes the data and underlying statistical analysis used to update the ENERGY STAR EPI for Wet Corn Mills, and how the parameter estimates of the original and updated models have changed over time (in particular, the treatment of gluten feed moisture). Several measures are computed to illustrate how the distribution of energy efficiency has shifted over time.

ENERGY PERFORMANCE INDICATOR

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, wet corn mills). 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 50th percentile, while efficient performance is in the 75th 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[8] 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 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 used for the benchmark reflect the corresponding year(s) covered by these data; this sets 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.[9] (For another recent example see Boyd 2012.) 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 industries. 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

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[8] 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.

[9] In addition to the updates, EPIs are being developed each year for additional industries.

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 operating wet corn mills for nearly two years, the U.S. EPA released the EPI for Wet Corn Mills. 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, 2008). 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 industry-provided data on feed moisture content. 1997 was the most recent year of detailed data available from the Census Bureau at that time. 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 decided it was appropriate to update the data. This paper describes the data and analysis used to update the ENERGY STAR EPI for Wet Corn Mills. 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.

DATA

In cooperation with Duke University and EPA ENERGY STAR, and with the support of the Corn Refiners Association, confidential, plant-level data were made available for this study. Data were voluntarily provided by seven companies: Archer Daniels Midland Company; Cargill, Incorporated; Corn Products International, Inc.; National Starch LLC; Penford Products Co.; Roquette America, Inc.; and Tate & Lyle Americas. These data were provided to Duke University under non-disclosure agreements with each company to support the benchmark analysis and update the cement plant EPI as a service to the industry. All analysis presented in this report is screened to assure that no confidential information is revealed.

DATA PREPARATION AND SUMMARY

All variables in the data were screened visually for "reasonableness" by examining plots of ratios such as energy-production, production-capacity (i.e., utilization), etc.

All data are on an annual basis for an individual plant *i* in year *t=2006-2009*. *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). *Max grind rate* is the maximum bushels (bu) per day the plant can process. Production data were originally collected from the following categories:

- Glucose Syrup Type I (20 to 38 dextrose equivalent)
- Glucose Syrup Type II (38 to 58 dextrose equivalent)
- Glucose Syrup Type III & IV (58 and up dextrose equivalent)
- Dried Glucose Syrup & Maltodextrins (less than 20 dextrose equivalent)

- Dextrose (mono & anhydrous)
- HFCS (20 to 50% fructose)
- HFCS (50% and greater fructose)
- Crystalline Fructose
- Modified Starch
- Non-Modified Starch
- Total Alcohol
- Gluten Feed with % Moisture Content (commercial/dry substance basis)
- Corn Gluten Meal with % Moisture Content (commercial/dry substance basis)

These categories are similar to those collected by the U.S. Census Bureau and used for the previous version of the EPI. Industry comments on the energy impacts of producing various sugars (the first eight product types) led to a consensus that the important product distinctions were between fructose and "other sugars," and whether these other sugars were in syrup or dry form. Additional data were provided on dextrose production to distinguish between syrup and dry, and based on these supplemental data, the following set of product categories was created.

- Glucose and Dextrose Syrup
    - Glucose Syrup Type I (20 to 38 dextrose equivalent)
    - Glucose Syrup Type II (38 to 58 dextrose equivalent)
    - Glucose Syrup Type III & IV (58 and up dextrose equivalent)
    - Dextrose (mono & anhydrous) – *syrup form*
- High-Fructose Corn Syrup (HFCS, 20 to 55% fructose)
    - HFCS (20 to 50% fructose)
- High-Fructose Corn Syrup (HFCS, 55% and greater)
    - HFCS (50% and greater fructose)
- Dry Dextrose, Glucose, and Fructose
    - Dried Glucose Syrup & Maltodextrins (less than 20 dextrose equivalent)
    - Dextrose (mono & anhydrous) – *dry form*
    - Crystalline Fructose
- Modified Starch
- Non-Modified Starches
- Total Alcohol (million non-denatured wine gallons)

While the original data specified fructose syrup to be distinguished between <>50%, industry practice is to produce fructose at 55% or greater as one product type and less than 55% as another. The final categories were aligned to reflect this practice. Statistical testing found it difficult to create a model that included all four of the resulting categories of sugar. To make the analysis tractable, "sugar-equivalent production" was defined as a weighted total of four types of sugars (Glucose and Dextrose Syrup - 0.70, HFCS (20 to 55% fructose) - 0.77, HFCS (55% and greater) - 0.89, Dry Dextrose, Glucose, and Fructose - 1.32). The weights are the relative energy usage to produce a pound of each type of sugar, based on engineering estimates made by one of the participating companies. The final data set included data for approximately 21 plants over a 4-year period, for a total of 83 plant-year observations.[10]

BENCHMARK STATISTICAL MODELING

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 the companies for review and comments.[11] The final version of the model reviewed is the one presented here.

The EPI model is a stochastic frontier analysis (SFA) regression of total source energy on total inputs, production mix, and feed moisture. For purposes of the model update, the same basic functional form and distributional assumptions for stochastic frontier used in Boyd (2006) was followed. The primary difference was the use of annual fixed effects, in the form of year dummy variable for the intercept term for 2006-2008, in order for the model to capture time-varying shifts in the frontier from the earlier years relative to the last year, 2008. This means that the error term, ε , the difference between actual and predicted average energy use, is assumed to be composed of two parts: a noise component, and a one-sided efficiency component.

$$\text{energy}_{i,t} = f(*;\beta) = \beta_0 + \beta_1 \text{ grind}_{i,t} + \beta_2 \text{ moisture}_{i,t} + \beta_3 \text{ sugar}_{i,t} + \beta_4 \text{ alcohol}_{i,t} + \beta_5 \text{ modified starch}_{i,t} + \beta_6 \text{ non-modified starch}_{i,t} + v_{i,t} + u_{i,t} \qquad \text{EQUATION 1}$$

where some of the independent variables are defined as:

energy	= annual total source energy
grind	= total grind
moisture	= feed moisture content * total grind
sugar	= production of sugar equivalent/total grind
alcohol	= production of alcohol/total grind
modified starch	= production of modified starch/total grind
non-modified starch	= production of non-modified starch/total grind

The variable *v* is statistical random error and is normally distributed as $N(0, \sigma_v^2)$. The variable *u* is the inefficiency and is distributed as a half-normal distribution with variance σ_u^2. Table 1 presents the summary statistics for major variables in this paper. Table 2 gives the results from the above regression.

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10 One observation was dropped due to inconsistent data.

11 Their comments led to revisions in the way feed moisture and product mix were represented, and identification of outliers.

Variable	Mean	Standard Deviation	Lower Decile	Upper Decile
energy (trillion Btu)	8.2	6.1	2.31	21.9
grind (million bu)	54.8	36.1	16.4	92.7
capacity million bu/day	.180	.110	.061	.288
energy intensity (thousand btu/bu)	152	40	111	220
moisture (%)	26	19	8	58
modified starch (lbs/bu)	7.10	11.74	0.00	29.33
non-modified starch (lbs/bu)	4.23	5.84	0.00	12.59
alcohol (gals/bu)	0.37	0.57	0.00	1.40
sugar equivalent (lbs/bu)	15.96	12.23	0.00	32.68

Table 1 Summary Statistics

Variable	Coefficient	Standard Error	t-Statistical Ratio
grind	0.1324	0.0124	10.71
moisture	-0.0007	0.0002	-3.05
sugar	0.0267	0.0301	0.89
alcohol	1.3879	0.7941	1.75
modified starch	0.0353	0.0123	2.87
non-modified starch	0.0096	0.0027	3.64
constant	-1.2923	0.7315	-1.77
σ_u^2	3.606223	σ_v^2	3.87E-07

Table 2 Regression Results - Updated EPI

Likelihood-ratio test of $\sigma_u^2=0$: $chibar^2(1) = 32.88$ Prob>= $chibar^2= 0.000$

To put these coefficients into perspective, we compute Btu/bushel for each product type and compare them to the energy use to produce non-modified starch (NMS), since all products use non-modified starch as a precursor. Table 3 summarizes these results.

	Btu/bu	Δ NMS	Ratio to NMS
Glucose and Dextrose Syrup	106,457	15,852	1.17
HFCS (20 - 55% fructose)	108,278	17,672	1.20
HFCS (55+% fructose)	111,032	20,427	1.23
Dry Dextrose, Glucose, and Fructose	114,949	24,344	1.27
Modified Starch	113,000	22,395	1.25
Non-Modified Starch	90,605	-	1.00
Ethanol	159,000	68,395	1.75

Table 3 Difference in Btu/bu by product classes (relative to NM Starch)

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). Since we have estimated the variance of the efficiency error term of equation (1), 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 efficiency, $v_{i,t}$, is half-normally distributed with zero mean and error variance σ_u^2

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

One way to illustrate how the industry has changed is to compare the results from the original and updated EPIs. The EPI shows the predicted range of performance, across the entire industry, for any given plant. Figure 1 compares the original 1997 (red) against the updated model (blue). The results show the percentile distributions per thousand Btu per bushel for a plant with 50 million bushel per year throughput producing modified starch and dry gluten feed (10% moisture). For example, the figure shows that the average (50^{th} percentile) plant in the original EPI was 182 thousand Btu/bu, but the updated EPI is 168 thousand Btu/bu; 14 thousand Btu/bu lower. One interesting characteristic of the update is that it illustrates that the best have improved the most, but the long tail (representing the less-efficient plants) is largely unchanged. This figure is an example taken from just one "typical" plant.

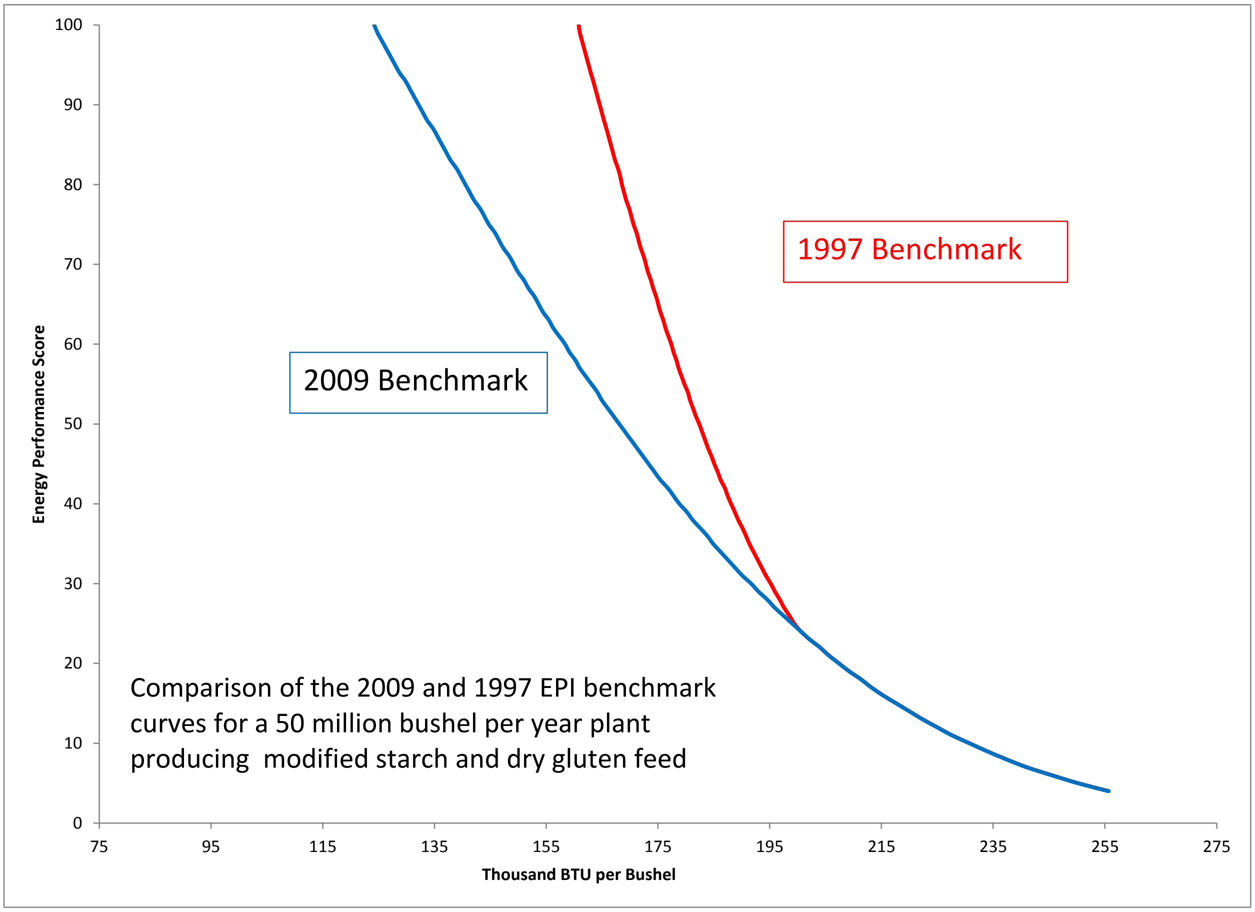

Figure 1 Comparison of Original EPI with Updated EPI

Figure 1 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 Energy Performance Score (EPS) or ranking on the left axis. If we compute the EPS using the old model for each plant, then compute the energy use per bushel that it would take to maintain the same level of performance using the new model, we have a plant-specific shift. For example, suppose a plant would score a "40" under the old EPI with an energy intensity of approximately 188 thousand Btu/bu. Under the new EPI , scoring a "40" would require an energy intensity of 179 thousand Btu/bu, which represents a 9 thousand Btu/bu reduction. If we compute the shift in the benchmark for every plant in the database then we can estimate the change for the entire industry. If we multiply this plant-specific change in energy intensity by the level of corn input production for each plant operating in the industry in 2009, and total across all plants, we observe a reduction of 6.7 trillion Btu in annual energy use. Relative to an average annual total source energy consumption of 155 trillion Btu in 2009 for all the plants in our data set, this represents about a 4.3% reduction in overall energy use by this industry. When energy-related greenhouse gas emissions are considered, this represents an annual reduction of 470 million kg of energy-related CO_2 equivalent emissions from improved energy efficiency.

SCORING CORN REFINING PLANT ENERGY EFFICIENCY

HOW THE EPI WORKS

The Wet Corn Mill EPI rates the energy efficiency of wet corn mills based in the United States. To use the tool, the following information must be available for a plant.

- Total energy use
    - Electricity in kWh (converted to Btus by the spreadsheet tool)
    - Fuel use for all fuel types in physical units or Btu
- Production
    - Total grind
    - Glucose and Dextrose Syrup
    - High-Fructose Corn Syrup (HFCS, 20 to 55% fructose)
    - High-Fructose Corn Syrup (HFCS, 55% and greater)
    - Dry Dextrose, Glucose, and Fructose
    - Modified Starch
    - Non-Modified Starches
    - Total Alcohol (million non-denatured wine gallons)
    - Moisture Content of the Gluten Feed

Based on these data inputs, the EPI will report an Energy Performance Score (EPS) for the plant in the current time period that reflects the relative energy efficiency of the plant compared to that of the industry. It is a percentile score on a scale of 1–100. An EPS of 75 means a particular plant is performing better than 75% of the plants in the industry, on a normalized basis. ENERGY STAR defines the 75th percentile as efficient, so plants that score 75 or better are classified as efficient. The model also estimates what the energy use would be for an "average" plant (defined as the 50th percentile), with the same production characteristics. While the underlying model was developed from data for U.S.-based plants, it does not contain or reveal any confidential information.

SPREADSHEET TOOL

To facilitate the review and use by industry energy managers, a spreadsheet was constructed to display the results of the EPI for an arbitrary[12] set of plant-level inputs. The spreadsheet accepts the raw plant-level inputs described above and then displays the results from the appropriate distribution functions for the models presented above. The energy managers were encouraged to input data for their own plants and then provide comments. A version of these spreadsheets, dated 05/16/2012 (corresponding to the results described in this report), is available from the EPA ENERGY STAR web site.[13] Examples of spreadsheets are shown in Figures 2 and 3.

12 In other words, for plant data that may not have originally been in the data set used to estimate the model equations.

13 http://www.energystar.gov/epis

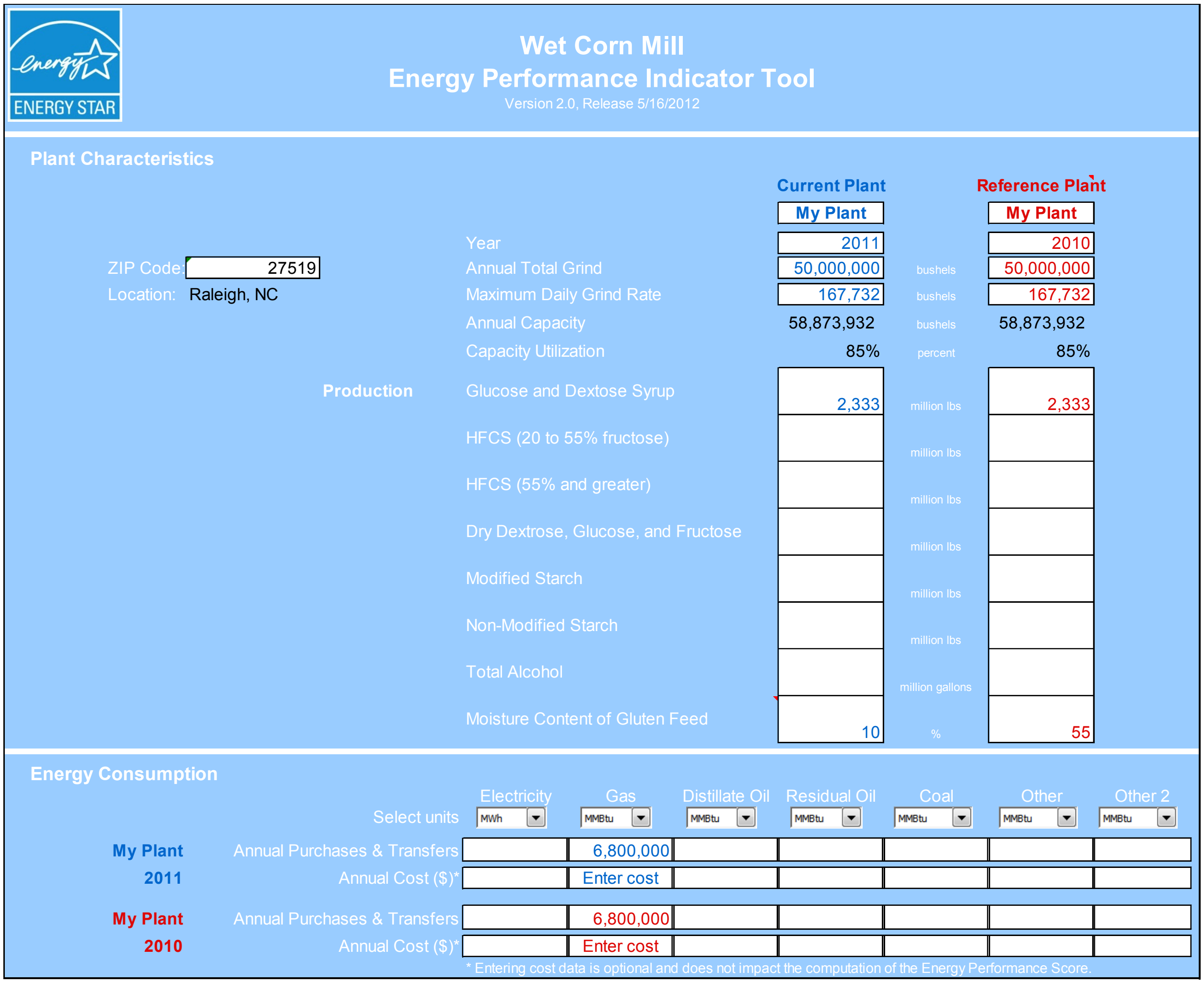

Figure 2 Input Section of the Wet Corn Mill EPI Spreadsheet Tool

Results	Your Current Plant My Plant 2011	Your Reference Plant My Plant 2010	Average Plant My Plant 2011	Efficient Plant My Plant 2011
Energy Performance Score (EPS)	71	39	50	75
Annual Energy Cost ($/year)				
Energy Cost/Total Grind ($/Bushel)				
Purchased Source Energy (MMBtu)	7,119,600	7,119,600	8,087,121	6,920,016
Purchased Site Energy (MMBtu)	6,800,000	6,800,000	7,724,089	6,609,376
Energy Intensity (Purchased Source MMBtu/Bushel)	0.142	0.142	0.162	0.138
Energy Intensity (Purchased Site MMBtu/Bushel)	0.136	0.136	0.154	0.132

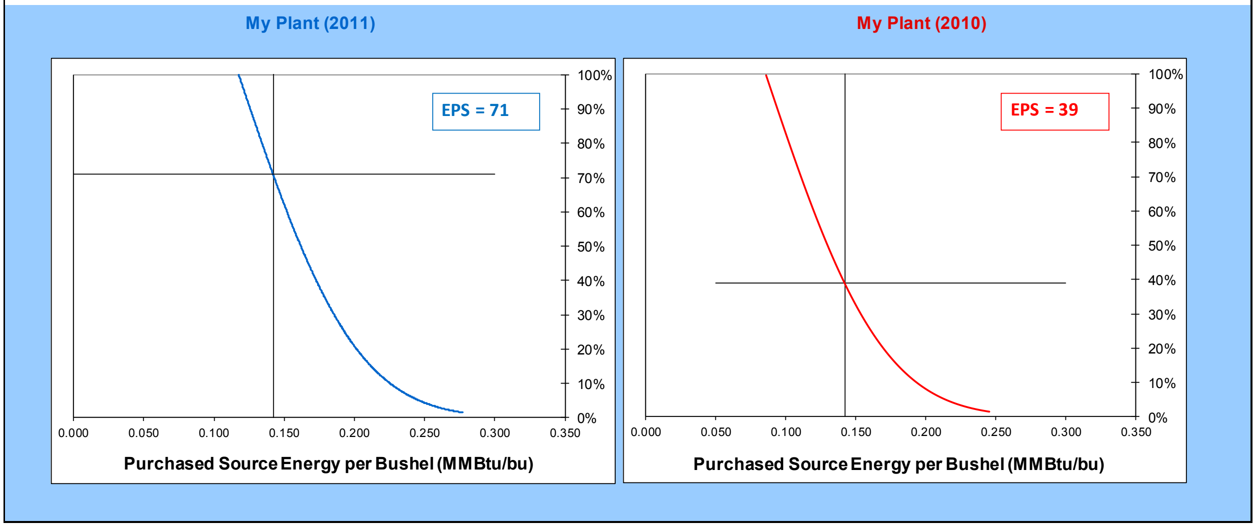

Figure 3 Output Section of the Wet Corn Mill EPI Spreadsheet Tool

USE OF THE ENERGY STAR WET CORN MILL EPI

EPIs are developed to provide industry with a unique metric for evaluating energy performance that will lead plants to take new steps to improve their energy performance. To promote the use of EPIs, EPA works closely with the manufacturers, through an ENERGY STAR Industrial Focus on energy efficiency in manufacturing, to promote strategic energy management among the companies in this industry. The EPI is an important tool that enables companies to determine how efficiently each of the plants in the industry is using energy and whether better energy performance could be expected. The EPI and the Energy Performance Score also serve as the basis for ENERGY STAR recognition. Mills that score a 75 or higher become eligible for ENERGY STAR certification.

EPA recommends that companies use the EPIs on a regular basis. At a minimum, it is suggested that corporate energy managers benchmark each plant on an annual basis. A more proactive plan would provide for quarterly use (rolling annual basis) for every plant in a company. EPA suggests that the EPI rating be used to set energy efficiency improvement goals at both the plant and corporate levels. The EPIs can also be used to inform new plant designs by establishing energy intensity targets.

The model described in this report is based on the performance of the industry for a specific period of time. One may expect that energy efficiency overall will change as technology and business practices change, so the models will need to be updated. This version reflects this updating process. EPA plans to update these models every few years, contingent on newer data being made available and industry use and support of the EPI tools.

STEPS TO COMPUTE A SCORE

All of the technical information described herein is built into spreadsheets available from EPA (http://www.energystar.gov/epis). Anyone can download, open the EPI spreadsheets, and enter, update, and manage data as they choose. The following details each step involved in computing an EPS for a plant.

1. User enters plant data into the EPI spreadsheet

- Complete energy information includes all energy purchases (or transfers) at the plant for a continuous 12-month period. The data do not need to correspond to a single calendar year.
- The user must enter specific operational characteristic data. These characteristics are those included as independent variables in the analysis described above.

2. EPI computes the Total Source Energy Use

- TSE is computed from the metered energy data.
- The total site energy consumption for each energy type entered by the user is converted into source energy using the source to site conversion factors.
- TSE is the sum of source energy across all energy types in the plant.
- TSE per relevant unit of production is also computed.

3. EPI computes the Predicted "Best Practice"[14] TSE

- Predicted "Best Practice" TSE is computed using the methods above for the specific plant.
- The terms in the regression equation are summed to yield a predicted TSE.
- The prediction reflects the expected minimum energy use for the building, given its specific operational constraints.

4. EPI compares Actual TSE to Predicted "Best Practice" TSE

- A lookup table maps all possible values of TSE that are lower than the Predicted "Best Practice" TSE to a cumulative percent in the population.
- The table identifies how far the energy use for a plant is from best practice.
- The lookup table returns a score on a scale of 1-to-100.
- The Predicted TSE for a median and 75th percentile plant is computed based on the plant-specific characteristics.

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[14] The model computes the "best practice" for frontier models and "average practice" for ordinary least squares. Steps 3 and 4 are similar for the OLS models, except that the prediction is for the average energy use and the percentiles are relative to the average (i.e., 50th percentile).

- A score of 75 indicates that the building performs better than 75% of its peers.

Plants that earn a 75 or higher may be eligible to earn the ENERGY STAR.

SUMMARY

EPA works with the U.S. corn refining industry to improve its energy efficiency through 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 EPI, we are able to estimate the improvement in the industry's performance between 1997 and 2009. 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 to total value of shipments (adjusted for inflation) in 1997 and 2006 from data collected in the Economic Census and the Manufacturing Energy Consumption Survey, one might conclude that the energy intensity of this industry has *fallen less than 1%,* from 23.5 to 23.4 thousand Btu per dollar. Aggregate data do not reveal whether all plants have made the same steady improvements. However, controlling for plant-specific production reveals a different story, in which we observe a reduction of about 4.3% in overall energy use by this industry, holding production constant. These results also suggest that these gains are driven by improvements in the best practice rather than steady improvements at all levels of performance.

Updating the ENERGY STAR Wet Corn Mill EPI will enable U.S. corn refiners 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 this 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 continues its work with industries to help them improve energy performance through this unique approach to environmental protection.

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