DEVELOPMENT OF ENERGY STAR® ENERGY PERFORMANCE INDICATORS FOR METAL CASTERS

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ABSTRACT

Organizations that implement strategic energy management programs undertake a set of activities that, if carried out properly, have the potential to deliver sustained energy savings. Energy performance benchmarking is a key activity of strategic energy management and one way to enable companies to set energy efficiency targets for manufacturing facilities. The opportunity to assess plant energy performance through a comparison with similar plants in its industry is a highly desirable and strategic method of benchmarking for industrial energy managers. However, access to energy performance data for conducting industry benchmarking is usually unavailable to most industrial energy managers. The U.S. Environmental Protection Agency (EPA), through its ENERGY STAR program, seeks to overcome this barrier through the development of manufacturing sector-based plant energy performance indicators (EPIs) that encourage U.S. industries to use energy more efficiently. This report describes work with the metal casting industry to provide a plant-level indicator of energy efficiency for facilities that produce various types of cast products made from iron, aluminum, and steel in the United States. Consideration is given to the role that performance-based indicators play in motivating change; the steps necessary for indicator development, including interacting with an industry in securing adequate data for the indicator; and actual application and use of an indicator when complete. How indicators are employed in EPA's efforts to encourage industries to voluntarily improve their use of energy is discussed as well. The report describes the data and statistical methods used to construct EPIs for plants within the metal casting industry, specifically those that produce iron, aluminum, and steel cast products. The individual equations are presented, as are the instructions for using those equations as implemented in an associated Microsoft Excel-based spreadsheet tool.

1 INTRODUCTION

ENERGY STAR was introduced by EPA in 1992 as a voluntary, market-based partnership to reduce air pollution and greenhouse gas emissions associated with energy use through increased energy efficiency (U.S. Environmental Protection Agency 2015). This government program enables industrial and commercial businesses as well as consumers to make informed decisions that save energy, reduce costs, and protect the environment. For businesses, a key step in improving energy efficiency is to institutionalize a strategic approach to energy management. Drawing from management standards for quality and environmental performance, EPA developed the *ENERGY STAR Guidelines for Energy Management* that identify the components of a successful energy management program (U.S. Environmental Protection Agency 2003).

These include:

- Commitment from a senior corporate executive to manage energy across all businesses and facilities operated by the company;
- Appointment of a corporate energy director to coordinate and direct the energy program and multi-disciplinary energy team;
- Establishment and promotion of an energy policy;
- Development of a system for assessing performance of the energy management efforts, including tracking energy use as well as benchmarking energy in facilities, operations, and subunits therein;
- Conduct of assessments to determine areas for improvement;
- Setting of goals at the corporate, facility, and subunit levels;
- Establishment of an action plan across all operations and facilities, as well as monitoring successful implementation and promoting the value to all employees; and,
- Pursuit and awarding of recognition and rewards for the success of the program.

Of the major steps in energy management program development, benchmarking energy performance by comparing current energy performance to a baseline or a similar entity is critical. In manufacturing, it may take the form of detailed comparisons of specific production lines or pieces of equipment, or it may be performed at a broader system level by gauging the performance of a single manufacturing plant with respect to its industry. Regardless of the application, benchmarking enables companies to determine whether better energy performance could be expected. It empowers them to set goals and evaluate their reasonableness.

(Boyd, Dutrow et al. 2008) describe the evolution of a statistically based plant energy performance indicator for the purpose of benchmarking manufacturing energy use for ENERGY STAR. Boyd (2016) describes the basic approach used in developing such an indicator, including the concept of normalization and how variables are chosen to be included in the analysis. To date, ENERGY STAR has developed statistical indicators for a wide range of industries (U.S. Environmental Protection Agency 2015). This report describes the basic concept of benchmarking and the statistical approach employed in developing performance-based energy indicators for multiple segments of the metal casting industry, the evolution of the analysis done for this industry, the final results of this analysis, and ongoing efforts by EPA to improve the energy efficiency of this industry and others.

2 BENCHMARKING THE ENERGY EFFICIENCY OF INDUSTRIAL PLANTS

Among U.S. manufacturers, few industries participate in industry-wide plant benchmarking. The petroleum and petrochemical industries each support plant-wide surveys conducted by a private company and are provided with benchmarks that address energy use and other operational parameters related to their facilities. Otherwise, most industries have not benchmarked energy use across their plants. As a result, some energy managers find it difficult to determine how well their plants are performing.

In 2000, EPA began developing a method for producing benchmarks of energy performance for plant-level energy use within a manufacturing industry. Discussions yielded a plan to use a source of data that would nationally represent manufacturing plants within a carefully defined industry, create a statistical model of energy performance for the industry's plants based on these data along with other available data sources for the industry, and establish an energy performance benchmark for the comparison of the best-performing plants to the industry. The primary data sources would be the Census of Manufacturing, Annual Survey of Manufacturers, and Manufacturing Energy Consumption Survey collected by the Census Bureau, or data provided by trade associations and individual companies when warranted by the specific industry circumstances and participation.

3 EVOLUTION OF THE METALCASTING EPIs

In late 2010, EPA decided to expand its existing work with heavy manufacturing industries by starting an industrial focus in metal casting. This was done with early involvement and interest from several industry trade associations: the American Foundry Society (AFS), the Steel Founder's Society of America (SFSA) and later from the North American Die Casting Association (NADCA). EPA also released an energy guide entitled *Energy Efficiency and Cost Saving Opportunities for Metal Casting* (Kermeli, Deuchler et al. 2016), which highlights cost saving energy efficiency opportunities throughout metal casters at the process level.

3.1 Initial Scope and Sector Breakdown

For the purposes of this report, metal casting manufacturing results in many different final products composed of three main material types: iron, aluminum, and steel. Non-ferrous products other than aluminum are not covered.[1] This complexity made it evident that considerable time and thought would be required in determining how the industry as a whole could be benchmarked. Starting with the broad Census Bureau definition of a foundry under the NAICS code 3315, initial efforts focused on how to construct one broad EPI that could cover a range of products and materials. Discussions with the AFS were essential during this early phase in determining process differences and providing energy usage estimates to be used as data checks. Welded and seamless steel pipe manufacturing was determined to be different from other processing and, therefore, would be excluded from the dataset. Ductile cast iron pipe shops use centrifugal cast processes, employ very small amounts of sand, and may have significant heat treating requirements. Conventional foundries use large amounts of sand and perform less heat treating of products. Handling of in-house and outsourced heat treating is discussed later.

After further analysis of Census data and energy differences per material types, it became evident that developing one comprehensive EPI was unrealistic. Processes and final product types prevented different types of material casts from being benchmarked together. Separate EPIs would need to be produced for iron, aluminum, and steel cast products to produce accurate benchmarks and capture the majority of the industry. Products within material sectors also varied greatly in size and total quantities, further preventing the feasibility of one comprehensive benchmarking tool. Ferrous castings became the initial focus, and a first draft of an EPI tool was produced for iron and two types of steel casting.[2]

Iron

The first draft of the Iron Casting EPI was based on data reported to the U.S. Census Bureau under the six-digit NAICS code 331511 that specifically covers iron foundries. There were 83 plants included in the sample that utilized 2006 data from the Manufacturing Energy Consumption Survey (MECS). After the initial analysis, the following variables were included in the model to account for energy usage:

- Total Iron Casting Production (Production)
- Production Worker Hours (Utilization)
- Share of Ductile Iron Pipe Production (Product Mix)
- Share of Other Ductile Iron Casting (Product Mix)
- Share of Gray Iron Casting (Product Mix)

Early results of the model seemed to indicate that most of the energy components of production were being taken into account. The variable "production worker hours" is being used as a proxy for plant utilization and captures the differences in downstream product processing. Greater processing and finishing requires more time in the plant and, therefore, more worker hours per product. These product types were the only ones that showed any significant impact on total energy. The effects of other variables were of the expected direction and magnitude. Additionally, the EPI did not reflect economies of scale, meaning there was not an inherent energy advantage for larger plants.

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[1] The EPA may revisit developing other types of metal casting EPIs in the future.
[2] Work on steel casting was ongoing as of the date of publication. If that model is finalized for certification, those results will be documented in a revised version of this report.

Focus participants were critical of the initial model for omitting a weather variable, a key component that had not been previously considered to have an impact on energy use within the plant. Weather plays an important role in total energy usage, as many plants use conditioned outside air, and temperature will greatly influence the amount of conditioning required. The second draft of the model included heating degree days (HDD) from plant ZIP codes to capture energy differences attributed to weather, as cooling degree days (CDD) did not appear to impact energy usage. The effect of HDD on total energy was statistically significant, confirming the comments for the industry. Another addition to the second draft model was an input for total value of shipments. Total value of shipments can address concerns that plants that produce more specialized products and have higher finishing requirements would be negatively treated in the model. Since more expensive products are generally ones that require more finishing and more energy, including the total value of shipments variable captured the effect that more expensive products have on total energy usage and energy intensity.

Aluminum

The first draft of the Aluminum Casting EPI was based on data reported to the U.S. Census Bureau under the six-digit NAICS codes 331523 and 331524 that specifically cover nonferrous metal die-casting and aluminum foundries. There were 390 plants included in the sample that utilized 2007 economic data from the Census for Manufacturers. Due to the similarity of casting industries, initial analysis in the aluminum model focused on similar variables used in the iron EPI model listed below:

- Total Aluminum Casting Production (Production)
- Production Worker Hours (Utilization)
- Total Value of Shipments (Process Requirements)
- Heating Degree Days (HDD)
- Share of Die Casting (Product Mix)
- Share of Sand Casting (Product Mix)
- Share of Mold Casting (Product Mix)

Testing of the model by focus participants provided positive feedback and appeared to deliver a good benchmark for the industry. Capacity data for facilities were not available within the Census data or through external data sources, and could not be included in the model although it has been recognized that this could improve the overall quality. No additional draft was created following extensive testing by the focus group and addressing of their multiple concerns. Since this model is based off of current industry practices, it will need to be revised if certain practices (for example, increased automation) become more prevalent.

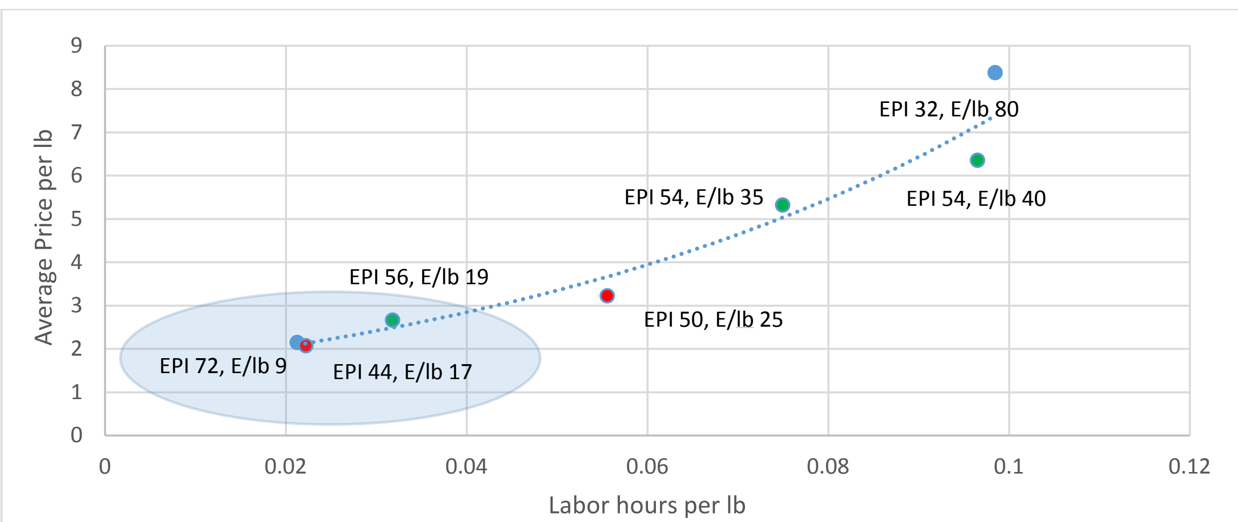
3.2 Industry Concerns

Following the completion of these two models, there were further industry concerns that were comprehensively discussed and researched but did not result in additional changes to the underlying analysis. These concerns involved a better understanding of the role of machining and finishing on energy use; the use of value of shipments and labor as production inputs vis-à-vis physical units; how to handle in-house and outsourced heat treating; how to handle in-house aluminum melting; and how companies that transfer cast products within an organization can provide an estimate for the market value for total value of shipments.

Value and labor as production inputs

There were many discussions about capturing the energy use in machining and in producing more complex products that involve multiple sprues and risers for their casting. Those products have more metal melted per unit of final product, and hence greater embedded energy in their production. Those products likely involve additional finishing as well. Census data specifically requests the weight reported in the data to exclude sprues and risers, so the data used in the EPI is the weight of the final product, not the weight of the material that is melted and cast. Some diversity of the types of products is included in the EPI, but the full range of product diversity and complexity would not be captured in any list of product types since the list would be far too long. Instead, the value of the product and the labor used to produce the product is a statistical proxy for the product's complexity. If higher value products with higher labor intensity are associated with complex molds, more metal melted and more energy in finishing, then there will be a statistical relationship between the energy use, higher value and labor intensity. The statistical analysis confirms this relationship. Additional testing of individual plant data, conducted by NADCA, also confirms this. The test data are shown in Figure 1. The curve is based on data compiled by NADCA from 7 actual plants. While the plants are all aluminum die-cast plants, they help illustrate how the differences in average price per pound (higher value added) and labor hours per pound (more labor intensive) products can have higher energy requirements, but similar EPI scores. The EPI accounts for differences in products in terms of value and labor intensity per pound and associates that with the higher energy requirements. The EPI score is based on the energy requirements for similar products. These products are likely more complex to cast, and have more finishing and associated energy use.

Figure 1 Aluminum Die Casting Plants with Diverse Energy, Labor, and Value per Pound



Heat Treating

Focus participants indicated an increasing trend towards performing heat treatment in-house as opposed to outsourcing the process. A concern was that if heat treating was outsourced the energy for heat-treated product would not appear on the energy accounting for the plant. Plants that outsource would appear more efficient and bias the benchmark. However, the current EPIs are based on data from 2006 and 2007 when heat treating was reported by participants as almost exclusively outsourced, meaning this new trend would not bias the existing model based on earlier years' data. In addition, engineering estimates and examples from individual facility data showed that heat treating accounted for 3-5% of total energy and had an impact on reported plant efficiency, but that the impact was relatively small. Heat treating may need to be accounted for in future versions of the model; however, facilities that heat treat in house will be allowed to "meter out" energy used in the process when using the EPI to determine its energy performance score consistent with the data used to develop the model. ***In other words, if a facility does in-house heat treatment and meters the energy use, that facility may subtract the heat treatment energy and use its EPI score to apply for ENERGY STAR plant certification.***[3]

Aluminum Melting

Industry participants reported during the review/comment period that some aluminum casters do not melt the aluminum within the facility and have molten aluminum imported for casting. Although this is not a common practice, plants that do not melt their own aluminum would be expected to have lower total energy usage and would appear to be very efficient when using the EPI. Either the molten metal would come directly from a smelter or from a dedicated third party in an "over the fence" transaction.

Public data sources were used to identify plants potentially in the latter category. For facilities in the Census data set that might get aluminum from a smelter, all aluminum smelters were identified and matched with any aluminum casters that were close geographically as molten aluminum cannot be transported long distances. After statistical analysis of these facilities, it was determined that the possible existence of these plants in the dataset did not bias results.[4] Published sources support these findings; increased finishing and machining processes can account for the energy savings from not melting the aluminum (see appendix B, table 10 as cited in (Kermeli, Deuchler et al. 2016)). ***Casting facilities that do not melt their own aluminum should be able to utilize the EPI tool for management purposes; however, to avoid appearances of possible bias, facilities that do not melt their own aluminum are ineligible for ENERGY STAR plant certification.***

Total Value of Shipments Markup Value

When the final cast products produced in a plant are sold at market prices, the value of shipments is known. However, when final cast products are transferred within a company, the reported shipments may not reflect a market price. Market prices would include profit margins that are factored into the total value of shipments of other companies, so plants whose products are instead transferred would be placed at a disadvantage from the perspective of inputting data into the EPI tool. To account for this, an industry average markup was calculated based on publically available Census data, enabling plants whose products are transferred to mark up the cost of goods sold to a market price equivalent.

Using published data from the 2007 Economic Census for NAICS code 3315 (including both iron and aluminum), a total cost of goods sold was computed for the industry. This includes the reported materials, energy, labor, contract services, etc. This industry-level total for cost of goods was then compared to the value of shipments, which is the market-based "sales" value. The ratio of the total

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[3] ENERGY STAR plant certification is available for plants whose EPI score is 75 or higher using an ENERGY STAR EPI and whose compliance history meets EPA specifications defined at www.energystar.gov/plants.
[4] Census disclosure rules prohibit revealing whether or not certain plants are included in the dataset.

value of shipments to cost of goods sold was 1.33. If a plant does not have a market-based sales value, but does have cost of goods sold, the total value of shipments can be estimated using "cost of goods sold" multiplied by 1.33, i.e., the industry-average markup.

3.3 Statistical Approach

The methodology underlying this analysis presumes that there is some reduced form of relationship between plant-level energy use and the various plant input and output characteristics examined above. We assume that this relationship can be approximated by a functional form that is amenable to statistical estimation using data from a cross section or panel of plants within some "reasonably defined" industry group, in this case aluminum, iron, and steel casters. Depending on the form of the statistical model, discussed in more detail below, the actual plant energy use can then be compared to the predicted average, given the plant's characteristics. How far the actual energy use is above or below the predicted average is the plant's measure of efficiency. In statistical terms, the difference between actual and predicted energy use is equal to the residual of the statistical model for plants that are in the sample; alternatively, this difference is an out-of-sample prediction when the statistical model is applied to other data. It is in this out-of-sample context that we expect the model to be most often used, i.e., to compute energy efficiency using data for plant-level operations that were not in the statistical analysis, possibly from a different year. If that is the case, then the model is measuring current performance against a prior "benchmark year." If we further assume that the estimated distribution of efficiency from the statistical model is static, then the out-of-sample prediction of efficiency can be converted to a percentile (ranking) of efficiency based on the estimated distribution. The approach applied here is similar to guidance from ISO 50001 regarding the creation of EnPI,[5] although the ENERGY STAR EPI approach predates the release of ISO 50001 (Boyd, Dutrow, & Tunnessen 2008).

The concept of the analysis that supports the EPI can be easily described in terms of the standard linear regression model, which is reviewed in this section. Consider at first the simple example of a production process that has a fixed energy component and a variable energy component. A simple equation for this can be written as

$$E = f(Y, X; \beta) + \varepsilon \qquad (1)$$

where E is the measure of total source energy (total Btu of fuel use, plus electricity use converted to Btu based on average U.S. thermal plant efficiency including line losses), Y is either production or a vector of production-related activities, X is a vector of plant characteristics, β is a parameter vector (the normalization factors), and ε is the measure of relative plant efficiency.

Given data on energy use and production, the parameters can be fit via a linear regression model. Since the actual data may not be perfectly measured, and this simple relationship between energy and production is only an approximation of the "true" relationship, linear regression estimates of the parameters rely on the proposition that any departures in the plant data from Equation 1, which cannot be directly observed, are randomly distributed within the population. This implies that the actual relationship includes a random error term ε that follows a normal (bell-shaped) distribution. For simplicity, we assume that the function f ( ) is linear in the parameters, but allow for non-linear transformations of the variables. In this case, production and capacity enter the equation in log form, as does the energy variable.

[5] Both ENERGY STAR and ISO 50001 use the term Energy Performance Indictor. Since ENERGY STAR began publically using the term first, ISO adopted the acronym "EnPI" to limit confusion.

$$ln(E) = f(ln(Y), X; \beta) + \varepsilon \qquad (2)$$

$$ln(E) = a + \sum_{i=1}^{n} b_i \, ln(y_i) + \sum_{i=1}^{m} c_i \, X_i + \varepsilon \qquad (3)$$

This means that ε can be interpreted as percentage deviations in energy, rather than absolute. This has implications for the model results since we now think of the distributional assumptions in terms of percent, rather than absolute level. In either case of a linear or log-linear functional form, standard measures of statistical significance provide a test for whether or not to include a particular characteristic. In other words, one can test if two different plant characteristics have different energy implications, in a statistically identifiable way.

Energy Performance Score (EPS)

Assuming we are using a model that has been estimated in one of the case studies in the out-of-sample context described above, and we have data for a plant in a year different from the study data year, we can compute the difference between the actual energy use and the predicted average energy use from equation (3).

$$ln(E) - (a + \sum_{i=1}^{n} b_i \ln(y_i) + \sum_{i=1}^{m} c_i \, X_i) = \hat{e} \qquad (4)$$

For the models using ordinary least square (OLS), we have also estimated the variance of the error term of equation (1), and 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 ε is normally distributed with zero mean and variance, σ^2.

$$\Pr(\varepsilon \geq \hat{e}) \qquad (5)$$

This probability is the Energy Performance Score (EPS), and is the percentile ranking of the energy efficiency of the plant. Since this ranking is based on the distribution of inefficiency for the entire industry, but normalized to the specific systematic factors of the given plant, this statistical model allows the user to answer the hypothetical but very practical question, “How does my plant compare to everyone else’s in my industry, if all other plants were similar to mine?”

Modeling Electricity and Fuels Separately

For this analysis, we considered two options for modeling energy: combining all sources for total energy use, and separating into electricity and fuels components. Modeling total energy use is the most appropriate approach where there are substantial opportunities to meet production energy requirements by substituting between fuels and electricity. This includes situations in which onsite electricity is generated from combined heat and power (CHP), typically resulting in more fuel use and less electricity purchased. This would result in a plant appearing very fuel inefficient and very electricity efficient; examples of the converse are possible. Separating the energy forms into electricity and fuel components may be preferable when energy sources are less substitutable. This may improve the ability to measure weather effects, since higher cooling degree days (CDD) likely will be associated with higher cooling loads and electricity use; conversely, heating degree days (HDD) likely will be associated with heating loads and fuel use.[6] For metal casting, options for both electric- and fuels-based melting mean that there are substantial opportunities for choice between electricity and fuel for process energy. Weather effects generally would be limited to the issue of cold outside air, so this is not expected to create difficulties. Therefore, for these industries, the EPI models are based on total primary energy use.

4 FINAL MODEL ESTIMATES

This section presents the final equations used for the EPI, based on the methods and evolution described above. Stylized results that provide additional interpretation are also given.

4.1 Statistical Estimates and Variable Impacts

Aluminum

The final equation for aluminum casting is shown below in **equation 6** and final results are shown in **Table 1**. For interpretation, the variables can be grouped into logged variables and product ratios as the effect on energy usage for these are interpreted differently. Logged variables, including total production, production worker hours, total value of shipments, and HDD, can be interpreted the same as elasticities. Using the coefficients, a 1% increase in each variable would lead to a total energy increase equal to the appropriate coefficient. For example, a 10% increase in total aluminum production would increase the predicted energy use by 2.2% given the coefficient value of 0.220. Product mix variables are measured in unit increases as opposed to percentages, and any increases are in comparison to a similar increase in cookware, the product type omitted to avoid perfect multicollinearity. For example, a 10% increase to die cast products would increase predicted energy by 3.05 units more than a 10% increase to cookware products. Since the coefficients on all the product mix variables are positive, this indicates that cookware products are the least energy-intensive products in our sample. These results are consistent with industry expectations regarding energy needed for different product types. **Table 1** provides a summary of the variable coefficients and their impacts on the EPI model.

$$\begin{aligned} \ln(energy) = {} & \alpha + \beta_1 \ln(total\ aluminum\ production) + \beta_2 \ln(production\ worker\ hours) \\ & + \beta_3 \ln(total\ value\ of\ shipments) + \beta_4 \ln(HDD) + \beta_5 \left({die\ castings}/{total\ production} \right) \\ & + \beta_6 \left({sand\ castings}/{total\ production} \right) + \beta_7 \left({mold\ castings}/{total\ production} \right) \\ & + \beta_8 yeardummy + \varepsilon \end{aligned} \tag{6}$$

Iron

The final equation for iron casting is shown below in **equation 7** and final results are shown in **Table 2**. For interpretation, the variables can be grouped into logged variables and product ratios as the

[6] There are exceptions to this pattern, e.g., electricity used in the heating system, fuels driving adsorption chillers, etc.

effect on energy usage for these are interpreted differently. Logged variables, including total production, production worker hours, total value of shipments, and HDD, can be interpreted the same as elasticities. Using the coefficients, a 1% increase in each variable would lead to a total energy increase equal to the appropriate coefficient. For example, a 10% increase in total iron production would increase the predicted energy use by 2.47% given the coefficient value of 0.247. Product mix variables are measured in unit increases as opposed to percentages, and any increases are in comparison to a similar increase in cast iron products, the product type omitted to avoid perfect multicollinearity. For example, a 10% increase to gray iron production would increase predicted energy by 8.21 units less than a 10% increase to cast iron products. Since the coefficients on all the product mix variables are negative, this indicates that cast iron products are the most energy-intensive products in our sample. These results are consistent with industry expectations regarding energy needed for different product types. **Table 2** provides a summary of the variable coefficients and their impacts on the EPI model.

$$\begin{aligned}\ln(energy) = \alpha &+ \beta_1 \ln(total\ iron\ casting\ production) + \beta_2 \ln(production\ worker\ hours) \\ &+ \beta_3 \ln(total\ value\ of\ shipments) + \beta_4 \ln(HDD) \\ &+ \beta_5 \left({}^{ductile\ iron\ pipe}/_{total\ production}\right) \\ &+ \beta_6 \left({}^{other\ ductile\ iron\ castings}/_{total\ production}\right) \\ &+ \beta_7 \left({}^{gray\ iron}/_{total\ production}\right) + \varepsilon \end{aligned} \tag{7}$$

Table 1 Aluminum Model Results and Variable Impacts

Variables	Coefficient	Standard Error
Log Total Aluminum Casting Production	0.220**	0.075
Log Production Worker Hours	0.435**	0.078
Log Total Value of Shipments	0.394**	0.105
Log Annual HDD	0.148**	0.055
Die Casting Product Ratio	0.305	0.232
Sand Casting Product Ratio	0.034	0.221
Mold Casting Product Ratio	0.211	0.236
Year Dummy	-0.103*	0.051
R-Squared	0.9007	

** Significant at the 99% level; * Significant at the 90% level

Table 2 Iron Model Results and Variable Impacts

Variables	Coefficient	Standard Error
Log Total Iron Casting Production	0.247	0.162
Log Production Worker Hours	0.462**	0.113

Log Total Value of Shipments	0.354	0.210
Log Annual HDD	0.250**	0.070
Ductile Iron Pipe Product Ratio	-0.742	0.276
Other Ductile Iron Casting Product Ratio	-0.727	0.246
Gray Iron Casting Product Ratio	-0.821	0.245
R-Squared	0.8774	

** Significant at the 99% level; * Significant at the 90% level

4.2 Stylized Results

When only examining the raw data on energy intensity (energy/total product) for both aluminum and iron castings, the range of performance is quite wide. The EPI analysis shows that this observation taken by itself is actually misleading; after accounting for additional factors, the range of performance is much narrower. Most of those differences come from differences that can be accounted for in the analysis, more or less of different product types, different climates, more working hours, etc. The range of actual efficiency, after these differences are accounted for, is narrower. This is consistent with the results of a meta-analysis of EPI studies for other industries (Boyd 2016). In the aluminum casting industry, the difference in total energy consumption between an "average" plant (score of 50) and an "efficient" plant (score of 75) is roughly 29%. For the iron casting industry, the difference between an "average" and an "efficient" plant is smaller at 21%. These results show a higher spread than other "heavy" manufacturing industries, but still fall in line with many other previously studied industries and illustrate the opportunity for energy efficiency improvements in the metal casting sectors.

5 SCORING METALCASTING PLANT EFFICIENCY

This section describes the spreadsheet tool that was created based on the above analyses. Suggestions for how to use the tool and interpret the results are also shown below.

5.1 How the EPIs Work

The metal casting EPIs score the energy efficiency of casting plants that have in-house melting operations. To use the tool, the following information must be available for a plant, regardless of casting material:

- Total energy use
    - Electricity (converted to source MMBtus by the spreadsheet tool)

- Fuel use for all fuel types in physical units or MMBtu (converted to source MMBtus by the spreadsheet tool)
- Weather
  - Heating degree days (HDD)
- Plant Operations
  - Total production worker hours
  - Total value of shipments

Specific product amounts are required for each metal casting EPI and are listed by cast material below.

Aluminum

- Product Mix Variables
  - Total production of aluminum
  - Percentage of total aluminum production that is die cast
  - Percentage of total aluminum production that is sand cast
  - Percentage of total aluminum production that is cast in permanent and semi-permanent molds
  - Percentage of total aluminum production that is cookware

Iron

- Product Mix Variables
  - Total production of cast iron
  - Total production of ductile iron pipe
  - Total production of other ductile iron castings
  - Total production of gray iron castings

Based on these data inputs, the EPIs 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. The EPS 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 the benchmark for efficiency, 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. This overall score is complemented with similar efficiency scores for electricity and fuels consumption. While the underlying model was developed from industry-supplied data, it does not contain or reveal any confidential information.

5.2 Spreadsheet Tool

To facilitate the review and use by industry energy managers, a spreadsheet-based tool was constructed to display the results of the EPIs for an arbitrary[7] set of plant-level inputs. Energy managers

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

in the casting industry were encouraged to test the EPIs by inputting data for their own plants and then provide comments on the results to the developers. After testing, a final version of this spreadsheet-based tool corresponding to the results described in this report was placed on the EPA ENERGY STAR web site for industry use.[8] Example inputs and outputs of the spreadsheet-based tool are shown in Figures 2-5.

[8] http://www.energystar.gov/epis

Figure 2 Input Section of the Aluminum Casting EPI Spreadsheet Tool

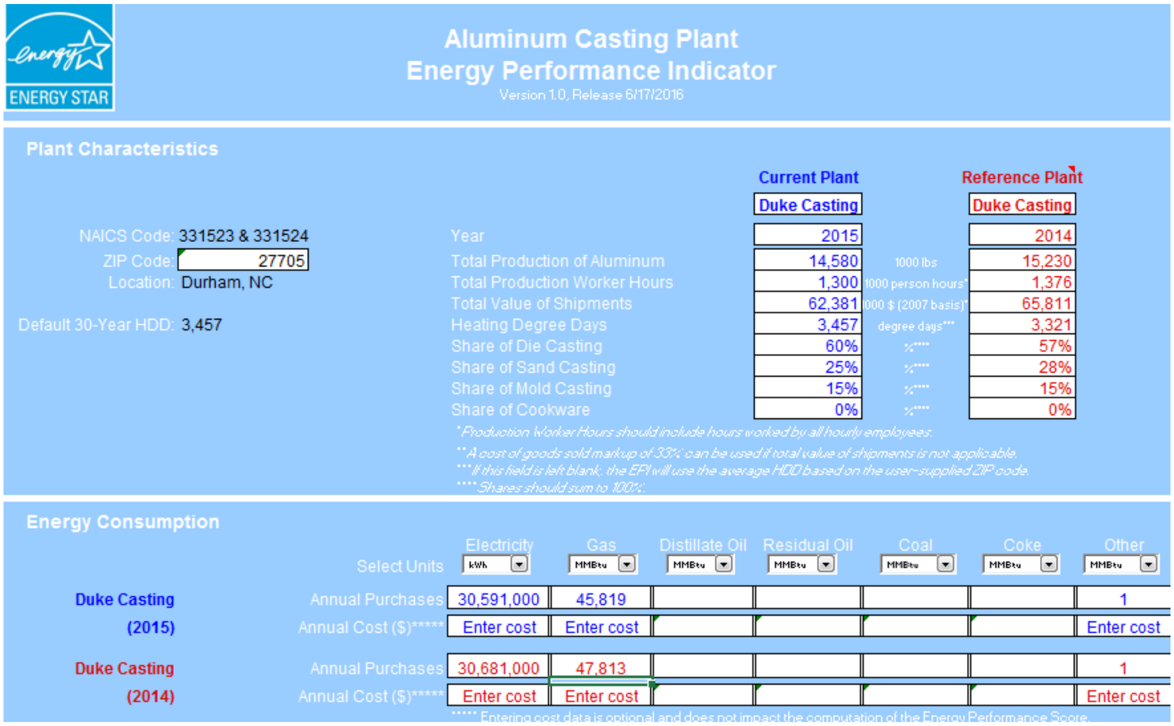


Figure 3 Output Section of the Aluminum Casting EPI Spreadsheet Tool

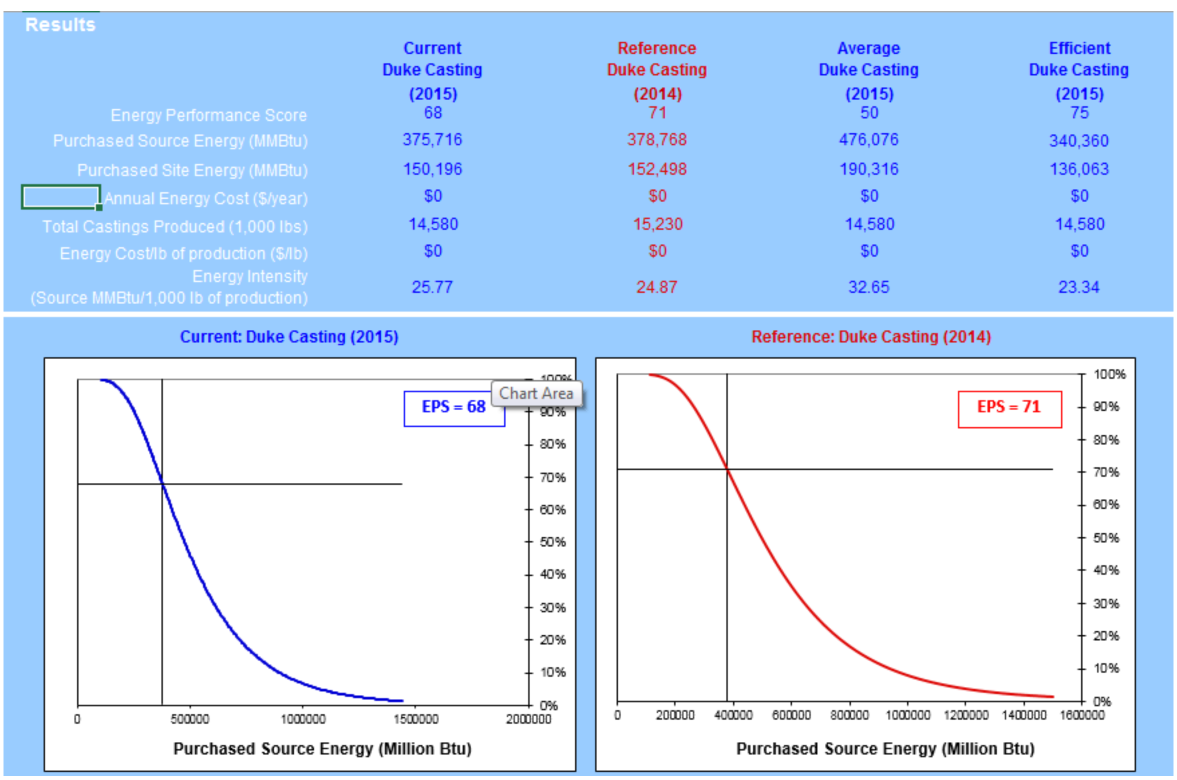


Figure 4 Input Section of the Iron Casting EPI Spreadsheet Tool

Iron Casting Plant
Energy Performance Indicator
Version 1.0, Release 6/17/2016

Plant Characteristics

NAICS Code: 331511
ZIP Code: 27705
Location: Durham, NC
Default 30-Year HDD: 3,457

	Current Plant		Reference Plant
	Durham Iron		Durham Iron
Year	2015		2014
Total Production Worker Hours	1,400	1000 person hours*	1,350
Total Production of Iron Castings	14,983	short tons	14,778
Total Value of Shipments	57,000	1000 $ (2006 basis)**	54,500
Cast Iron	7,347	short tons	6,832
Ductile Iron Pipe	0	short tons	0
Other Ductile Iron Casting	4,256	short tons	4,186
Gray Iron Casting	3,380	short tons	3,760
Heating Degree Days	3,457	degree days***	3,321

Detailed definitions of production categories and other inputs found on 'Instructions' tab.
**Production Worker Hours should include hours worked by all hourly employees.*
***A cost of goods sold markup of 33% can be used if total value of shipments is not applicable.*
****If this field is left blank, the EPI will use the average HDD based on the user-supplied ZIP code.*

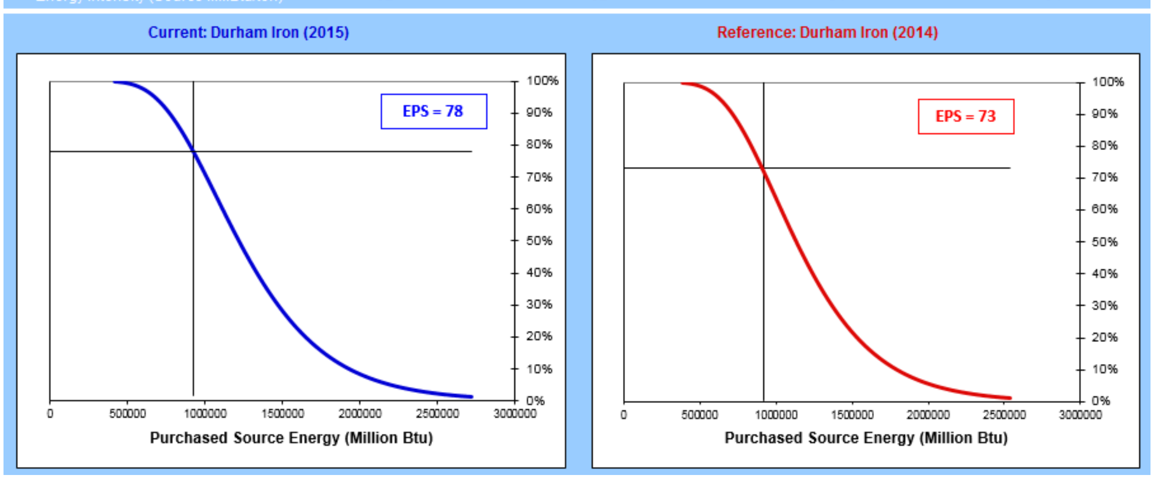
Energy Consumption

		Electricity	Gas	Distillate Oil	Residual Oil	Coal	Coke	Other
	Select Units	kWh	MMBtu	Gallons	Gallons	MMBtu	MMBtu	MMBtu
Durham Iron	Annual Purchases	71,268,913	105,678					1
(2015)	Annual Cost ($)****	Enter cost	Enter cost					Enter cost
Durham Iron	Annual Purchases	70,145,691	110,789					1
(2014)	Annual Cost ($)****	Enter cost	Enter cost					Enter cost

**** Entering cost data is optional and does not impact the computation of the Energy Performance Score.

Figure 5 Output Section of the Iron Casting EPI Spreadsheet Tool

Results	Current Durham Iron (2015)	Reference Durham Iron (2014)	Average Durham Iron (2015)	Efficient Durham Iron (2015)
Energy Performance Score	78	73	50	75
Purchased Source Energy (MMBtu)	922,832	915,383	1,219,303	955,364
Purchased Site Energy (MMBtu)	348,849	350,127	460,920	361,146
Annual Energy Cost ($/year)	$0	$0	$0	$0
Total Castings Produced (short tons)	14,983	14,778	14,983	14,983
Energy Cost/Ton ($/ton)	$0.00	$0.00	$0.00	$0.00
Energy Intensity (Source MMBtu/ton)	62	62	81	64



5.3 Use of the ENERGY STAR Metal Casting EPIs

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 within an industry 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. Plants 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 score be used to set energy efficiency improvement goals at both the plant and corporate levels. The EPIs also can be used to inform new plant designs by establishing energy intensity targets.

The models described in this report are 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. EPA plans to improve these models every few years, contingent on newer data being made available and industry use and support of the EPI tools.

5.4 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 steps detail how to compute 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 characteristics data. These characteristics are those included as independent variables in the analysis described above.

2. EPI computes the Total Source Energy (TSE) 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 site-to-source 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 "Average Practice"[9] TSE

- Predicted "Average 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 "typical" energy use for the plant, given its specific operational characteristics.

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

- A lookup table maps all possible values of TSE that are lower than the Predicted "Average Practice" TSE to a cumulative percent in the population.
- The table identifies how far above or below the energy use for a plant is from predicted level.
- 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.
- 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.

[9] The model computes the "best practice" for frontier models and "average practice" for ordinary least squares. Steps 3 and 4 are similar for the frontier models, except that the prediction is for the minimum energy use and the percentiles are relative to the best (i.e., 99th percentile).

6 REFERENCES

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