Promoting Energy Efficiency through Industrial Sector Benchmarking: The ENERGY STAR Approach

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ABSTRACT

Benchmarking energy performance is key for driving energy efficiency. While most industrial energy managers understand this, access to industry-wide energy performance benchmarks are usually unavailable. Consequently, energy managers frequently do not know if their most efficient plants are actually efficient when compared to the entire industry.

To overcome this issue and to encourage greater energy performance within an industrial sector, the United States Environmental Protection Agency's (EPA) ENERGY STAR program works with selected industries to develop plant-level energy performance benchmarking and rating tools called Energy Performance Indicators (EPI). The EPIs enable energy managers to evaluate the relative performance of their plants as compared to the industry and provides the basis for recognition for superior achievement in the form of the ENERGY STAR plant label.

To address difference between plants, the ENERGY STAR approach to "benchmarking" draws on statistical methods to develop an underlying "model" that is the foundation of the EPI tool. This approach requires that the most important drivers for energy use within an industry be identified and normalized in order to provide a meaningful comparison. While the specifics vary across sectors, the approach typically considers four major effects:

- Product mix;
- Process inputs;
- External variables, such as weather and utilization rates;
- Physical plant size or productive capacity.

This paper describes the collaborative approach with industry that the ENERGY STAR program uses through *"Industry Focuses*" to develop these empirical comparisons. The paper provides examples from glass, pharmaceuticals, food, paper, and other Industrial Focus initiatives and discusses the steps used to insure confidentiality of the plant/company data, but allows a plant to compare itself against its peers in the industry. Lastly, the paper describes how the EPI benchmarking tool is used for awarding the ENERGY STAR to qualifying industrial plants is discussed.

Introduction

The term "Industrial competitiveness" describes a process of firms striving to attain higher levels of performance and profitability than their peers. They do so by producing and selling more products at lower costs and higher profits. Firms compare themselves to their peers using basic metrics in this race to achieve higher performance. The performance metrics of production and sales is more readily apparent in the market place, but the comparison of costs is more elusive.

Firms use a variety of benchmarking approaches to develop the cost comparisons. Since energy is one of the many costs faced by industry, benchmarking energy performance is critical to driving energy efficiency in the race for competitiveness. While this understood by most industrial energy managers, access to industry-wide energy performance benchmarks is usually unavailable. Consequently, energy managers frequently do not know if their most efficient plants are actually efficient when compared to the entire industry.

By not having an industry-wide energy performance benchmark, many energy managers also do not know what is potentially achievable. As a result, some firms and energy managers may believe that additional cost savings from greater energy efficiency are not possible or even necessary. This lack of information of what is achievable in effect becomes a barrier to greater energy efficiency.

To overcome this issue, the United States Environmental Protection Agency's (EPA) ENERGY STAR program has developed tools to enable meaningful plant level benchmarking of energy performance within a variety of industries. The ENERGY STAR Energy Performance Indicators (EPI) enable the evaluation of relative performance and provides the basis for public recognition for superior achievement in the form of the ENERGY STAR plant label.

To develop the EPIs, the EPA's ENERGY STAR program uses a collaborative process with companies in several industries. This paper describes the collaborative approach with industry that the EPA uses through the *"ENERGY STAR Industry Focuses*" to develop these empirical benchmarking tools.

The paper also:

- discusses the steps used to insure confidentiality of the plant/company data, but allows a plant to compare itself against its peers in the industry.
- provides examples from glass, pharmaceuticals, food, paper, and other Industrial Focus initiatives; and
- Lastly, how the EPI benchmarking tool is used for awarding the ENERGY STAR to qualifying industrial plants is discussed.

The Industry Focus Process

The detailed nature of energy use in manufacturing is very industry specific, but the basic interest in benchmarking is not. To address the industry specific nature of energy management issues and the specific needs for a benchmarking tool tailored for individual manufacturing sectors, EPA organizes ENERGY STAR Industrial Focuses. The focus process involves direct interaction between the ENERGY STAR team with energy managers from companies within a sector via a series of conference calls and an annual workshop. As described on the ENERGY STAR web site:

> *Focuses build upon the energy management resources available through ENERGY STAR, and within an industry:*
>
> - *Engage energy managers in discussions of strategic, corporate energy management*
> - *Provide tools to enhance energy management and performance*

- *Uncover energy-saving opportunities and practices*
- *Encourage sharing of energy management techniques*[1]

The collaborative nature of the Industrial Focus is critical for creating an energy-benchmarking tool that will be accepted and used by the industry. The process begins by introducing the basic concept of a plant level energy benchmark that takes into account major difference between plants that influence energy use. Energy managers are briefed on the data sets available to the ENERGY STAR team through existing sources such as the Census Bureau Industry energy managers are then asked to help identify these major plant differences and ways to capture and measure such variables using existing available data. If existing data sets are considered insufficient then additional sources, including voluntarily supplied industry data, are often considered.

To address differences between plants, the ENERGY STAR approach to "benchmarking" uses a statistical analysis[2]. This requires that the most important drivers for energy use within an industry be identified to provide a meaningful comparison. While the specifics vary across sectors, the approach typically considers four major effects:

- Product mix;
- Physical plant size or productive capacity.
- Process inputs;
- External variables, such as weather and utilization rates;

Each one of these broad categories may have a specific measurable impact on the energy use of a manufacturing plant. The analysis to determine the magnitude and significance of each of these impacts and the process of normalizing these effects to determine the range of industry performance is conducted by the ENERGY STAR statistical team. Statistical methods are used to measure how far any plant in the data is from a predicted level of energy use, based on the plant level data for the basic energy drivers. This gives a measure of performance for every plant from the industry model predicted norm, i.e. normalized energy efficiency. The range of normalized performance from the best plant to worst plant is summarized as a statistical distribution that assigns a percentile score of 1 to 100 to every plant. This process is used to develop the underling equations and statistical distributions that result in a set of multivariate relationships that is the EPI. The equations and distributions in the EPI is presented as Excel spread sheet and is designed to be user friendly.

When the ENERGY STAR team completes a draft version of the EPI the industry testing and review process begins. To test the EPI, Industry participants are asked to put either representative or actual data from plants in their companies into the EPI spreadsheet and consider the results. Typical data inputs include production, capacity, utilization, products, materials, and, of course, energy.

The results of the EPI reflect the metrics the industry typically uses or is interested in seeing. Typically these performance metrics are based on a unit of production, such as MMBTU per vehicle in the auto assembly EPI. Additionally, all EPIs generate an ENERGY STAR rating

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[1] *http://energystar.gov/index.cfm?c=in_focus.bus_industries_focus* as referenced on 3/13/2007

[2] The statistical approach used to develop the EPI is described in more detail for automobile assembly, cement, and wet corn refining (Boyd 2006a, b, 2005a, b).

which is provided on a scale of 1 to 100, with a score of 100 representing the highest performance currently achievable. The rating provides the benchmark for gauging the energy performance of a given plant. The rating reflects what percentile of energy performance the plant is operating in, i.e. a plant with an EPI rating of 80 is considered to be performing better than 80% of similar plants in the industry.

Once energy managers run the numbers in the EPI spread sheet, they are asked to consider the following general questions to evaluate the EPI results:

- Are the results "intuitive"? Why or why not?
- Do you observe patterns, e.g. plant producing similar products lend to be rated as more (less) efficient?
- Do the scores from the plant data used in testing conform to your expectations, e.g. does a plant viewed as a "poor" performer score low?
- Does the ranking of multiple plants conform to your expectations?
- Does the change over time in a specific plant conform to your expectations?

The development and testing is an iterative activity. Energy managers provide feedback and suggestions of additional measures to include in the model. Additional or different factors are considered and adjustments to the model are made. The statistical methods are used to test if hypothesized effects identified by energy managers are statistically significant and if the estimated impact on energy use conforms to general expectations. If so, then it is included in the next version of the model. When the industry and ENERGY STAR are both satisfied that the model works and provides a fair gauge of energy performance, the EPI version is considered "final[3]" and distributed via the ENERGY STAR web site.

Protection of Confidential Information

Companies typically view plant data on energy and other costs as confidential business information (CBI). Energy Star has worked to eliminate the need for CBI and provide protections to companies that participate in the focus. The first way Energy Star does this is to make use of existing government collected data that is protected by law from disclosure. The second way is to construct the EPI so that no individual plant information is embodied in the equations or spreadsheets and that companies can use the EPI without disclosing the data or results to anyone else.

The EPI analysis typically uses confidential plant level data from the Center for Economic Studies (CES), U.S. Bureau of the Census. Data from CES includes the non-public, plant-level data, which is the basis of the government statistics on manufacturing. Title 13 of the U.S. Code protects this data, CES allows researchers with Special Sworn Status to access these confidential micro-data at a Research Data Center (RDC). Census confidentiality rules and procedures prevent the disclosure of any information that would allow for the identification of a specific plant or firm's activities[4]. The advantage of using available data is that there are no

[3] The analysis may be subsequently updated. This allows for the benchmark to evolve as industry changes and newer data that reflects those changes becomes available.

[4] Duke University is an institutional partner with CES which provides access to this research project to this confidential data. Members of the Energy Star team have special sworn status from CES, which has reviewed and approved the use of the data for this purpose.

burdensome reporting requirements, the information is reported on a consistent basis for all plants, and most importantly confidentiality is assured.

The final form of the EPI results and corresponding spreadsheets do not contain any plant level data, only the statistical relationships described above. Company energy managers can use the spreadsheets "in the privacy of their offices" and do not need to reveal CBI to anyone else when using the model. Additional protections for CBI are discussed below regarding plant level recognition.

Examples of Normalization in the EPI

A basic metric for normalization for benchmarking is a ratio of energy use to some common activity. This is the simplest example of normalization. This ratio captures the link between energy use and the most basic difference between plants or within plants over time. The denominator may be production output, physical size, or amount of materials processed. The EPI uses a multivariate approach to normalization where multiple effects are simultaneously considered. The next sections give industry specific examples of the four basic categories of effects that are commonly considered.

Product Mix

Energy is the derived demand for energy services used in support of various manufacturing processes. The results of these processes are various intermediate and final products produced by the plant. It is common to evaluate the efficiency of energy use in terms of the intensity of energy input relative to a desired energy services (e.g. per lb of compressed air), relative to a particular intermediate process (e.g. per lb of crushed limestone), or relative to the final product of the plants (e.g. per ton of finished cement shipped). Each of the energy services or intermediate processes contributes to the overall energy use, hence energy efficiency, of the entire manufacturing plant. However, not all plants produce exactly the same product. In fact, many plants themselves produce multiple products. The diversity within and between plants gives rise to a mix of derived demands for specific processes and energy services. To the extent that the final product is the results of a series of energy using steps the energy use of the plant will depend on the level and mix of products produced. Rather than specifying each process step individually the approach used here is to identify those products that use significantly more (or less) energy and measure those energy requirements with a statistical comparison. Note that an understanding of the production process is needed in order to identify what products to consider and how to specify the relationships we wish to estimate. This understanding comes from related energy star research, from group meetings, and one-on-one discussions with focus participants from the respective industries.

One approach to controlling for product mix is to segment the industry into natural product categories. This works best when there is no overlap between plants that produce the various basic products and there are sufficient numbers of plants to conduct the statistical comparison between those resulting groups. This means each sub-group is effectively treated as a separate industry for evaluation proposes. The glass industry is a good example, since flat, container, and fiberglass are distinct products and each sector can be treated in a "stand alone" manner, although within group variation may still exist. When such natural sub sectors do not exist and multiple products are produced within a plant, additional approaches are needed.

Even though the cement industry primarily produces a single well-defined commodity, some plants produce smaller amounts of specialty cements, e.g. for masonry or oil well applications. If specialty products require different energy use the statistical approach can estimate these differences. Corn refiners have a common underlying process involving separation of the gluten from the starch. This separation and resulting preparation of the animal feed by-products for shipment results in similar basic energy demands for corn refineries. The difference arises from the further treatment of the intermediate product, cornstarch. It may be dried as a final product, further processes and "modified," or used as a feedstock for sugar or ethanol production. It is the mix of these downstream products that can be used to identify differences in process energy service demand and the benchmark for a plant with a specific product mix.

For some sectors the diversity of products is so large that it is necessary to consider broad groups of products or activities. For example, fruit and vegetable canning and freezing involve a diverse range of foodstuffs and final products. To make the benchmarking tractable it may be appropriate to literally add up apples and oranges, so long as they are both being made into frozen fruit juice!

The statistical approach used by ENERGY STAR is well suited to testing if a particular grouping of products is appropriate for benchmarking differences in energy. Other industries like pharmaceuticals or autos that also have a diverse range of products may be treated differently for benchmarking. For automobile assembly the size of the vehicle turns out to be a good measure for product differences when evaluating energy use. This is because the painting process dominates energy consumption in auto assembly. For pharmaceuticals there is enormous product diversity, but major differences in energy use arise between the three basic activities in pharmaceuticals, R&D labs, active ingredient preparation, and fill & finish. While there are many products within those areas, these basic production activities are viewed as principle drivers of energy use in this sector.

Physical Size

In order to include size as a normalizing factor in the EPI a meaningful measure of size or capacity is needed. It may be measured on an input basis (corn refining and cement), output basis (auto assembly), or physical size (pharmaceuticals). In some cases there may be advantages to larger scale of production. If it is the case that a larger production capacity or larger physical plant size has less than proportionate requirements for energy consumption then there are economies of scale with respect to energy use. For several sectors, including auto assembly, corn refining, and pharmaceuticals, the EPI development tested models that would capture the "bigger is better" phenomenon. This was not found to be the case for auto and corn, and the results are not final for pharmaceuticals. For cement it was found that larger kilns are an advantage, but larger numbers of kilns are not. Regardless of the industry specific results obtained to date, size and economies of scale remains an important area for normalization in the benchmarking approach.

Process Inputs

Other process inputs can be helpful in developing a statistical benchmark of energy use. Process inputs like materials, labor, or production hours may be good proxy measures of overall production activity when measures of production output are not available or have specific shortcomings[5]. If a physical measure of output is not readily available and pricing makes the value of shipments a questionable measure of production then physical inputs can be a useful proxy. For some industries the basic material input is so ubiquitous that it makes sense to view energy use per unit of basic input rather than (diverse) outputs. Process inputs may also be useful in measuring utilization, either directly or indirectly.

Corn refining is an example of a sector where the energy use per unit of material input, i.e. corn processed, is appropriate. The energy use at the plant, expressed in terms of bushels of corn processed, will be influenced by the mix of final products but include the energy use for processing by-products common to all plants. In this manner the level of corn processed captures a number of common energy components in a succinct fashion. The level of corn processed is also a good way to capture plant utilization, since the capacity of a plant is commonly expressed in terms of volume of corn processing capability per day.

Sometimes physical production data is lacking in some way but material flows can be used instead. For example, sand, lime, soda ash, and cullet (scrap glass) are the primary inputs to glass manufacturing. Since the Census only collects data on the value of glass shipped these basic materials provide a good control for the level of physical production at a glass plant. Moreover, if the materials mix to produce different types of glass directly impacts energy uses, then the statistical model can apply different weights to the materials mix in the same manner that it does with product mix. In other words, product/process level differences in energy use are inferred from the volume and types of materials used in production. Differences in material quality may also be considered in the statistical normalization, if they are measured on a consistent plant-level basis across the industry. For cement plants the hardness and moisture content of the limestone may influence energy use, but no consistent data is available for this, leaving it the subject of future analysis if data can be collected.

When levels of materials or outputs are not measured in common units and value units may introduce other problems, production labor rates may also control for differences in production activity between plants and differences in utilization rates within plants. While the link between energy and labor is not as direct as energy and production, the fact that it takes both labor and energy to manufacture a product allows an indirect link to be estimated. One advantage is that labor hours can provide a common denominator in terms of measurement.

External Factors

There are many things under the control of a plant or energy manager, but one they cannot control is “the weather.” In most manufacturing plants heating, ventilation and cooling (HVAC) contributes to energy demand and weather determines how much is required to maintain comfort. Since the benchmarking approach used here is annual seasonal variation does not enter into the analysis, but differences due to the location of a plant and annual variation from the locations norm will play a role. The approach that has been taken for all sectors under study is to include heating and cooling degree days (HDD and CDD) into the analysis to determine how much these location driven differences in “weather” impact energy use.

In principle all plant have some part of energy use that is HVAC related, but when the HVAC component of energy use is small relative to total plant consumption the statistical

[5] If complex or highly variable pricing are used to compute the total value of shipments (TVS) of a plant, then TVS may not be a good measure of production to compare energy use (see Freeman, et al 1997)

approach may not be able to measure the effect accurately enough to meet tests for reliability. For sectors like automobile and pharmaceutical manufacturing the approach finds statistically significant impacts of HDD and CDD on energy use. For sectors like cement, glass, food processing, and corn refining we have not been able to estimate any impact so these factors are treated as de-minis for the purposed of annual, plant level benchmarks.

Other location dependent impacts can be included, or at least tested, using the statistical approach. As part of the focus review process the altitude was proposed as having an effect on cement kiln energy use, because of combustion oxygen differences. The altitude was included in the analysis of the cement energy data, but no measurable effect was seen. This type of hypothesis testing that the statistical approach allows provide for a dialogue between the researchers and the industry participants to understand the drivers of energy use in the various sectors.

This last example underscores the role that the focus process provides in developing the EPI. The analysis is not conducted in a vacuum. This understanding comes from related energy star research (e.g. the Energy guides – insert reference) and from group and one-on-one discussions with focus participants from the respective industries. Industry participants provide guidance on what factors they feel are significant contributors to energy use in their respective sectors. The energy star research teams suggests ways that these may be measured or proxied and represent those effects in a statistically testable form. If the effect can be reliably measured in a statistical sense, using the data available the effect is included in the EPI.

Recognizing Efficient Plants

In addition to offering industrial energy managers a tool to gauge their plant's energy performance to the industry, the EPIs provides the basis for providing public recognition of superior energy performance. Rating and recognizing products, homes, buildings, and industrial plants that are energy efficient has been the hallmark of the ENERGY STAR program. By earning the ENERGY STAR, plants can distinguish themselves within their industry and demonstrate effective energy management to their customers and the community. Corporate energy managers can use the ENERGY STAR to reward efficient plants and motive less efficient ones. Today, the ENERGY STAR brand is one of the most widely recognized brands in the United States with a brand recognition rate that exceeds 65%.

As discussed earlier, the EPI provides an energy performance rating on a scale of 1 to 100, with 100 being the best energy performance possible. This rating reflects the plant's energy performance when compared to the industry. For example, a plant that scores a 75 or higher would be in the top quartile of observed energy performance within the industry. EPA uses a rating of 75 as the demarcation of an "efficient plant". If a plant's rating in the EPI is a 75 or higher, the plant is considered by the EPA to be energy efficient and is eligible for being awarded the ENERGY STAR.

In August 2006, the EPA established procedures for companies whose plants have an EPI score in the 75th percentile or higher to apply for the ENERGY STAR. To be awarded the ENERGY STAR, the plant's EPI score must be based on 12 months of recent production and energy data, the data used to generate the EPI score must be verified as accurate by a

Professional Engineer, the score must be EPI verified by the EPA or a designated reviewer[6], and the plant must not be involved or have had any major violations of the federal Clean Air Act.

On September 13, 2006 EPA officially announced the first seventeen plants to receive ENERGY STAR recognition for superior energy efficiency in their respective industry. At that time, seven companies from three industries, automobile assembly, wet corn milling, and cement manufacturing received awards. Several more companies are either in the application process or stated their intent to apply in the near future. For just those seventeen plants, the difference between the actual energy use and the energy use of a similar plant performing at the 50th percentile in terms of energy efficiency amounts to 3 billion lbs. of annual CO2 emissions that would have otherwise been produced. Since then several other facilities have been awarded the ENERGY STAR. Currently there are over 25 industrial plants in the United States that have been awarded the ENERGY STAR. As additional industry specific analyses are completed, ENERGY STAR recognition will be extended to those industries as well.

Summary

This paper provides an introduction and overview to the process of developing manufacturing plant energy efficiency benchmarks. The process involves interaction with representatives from companies within a selected industry in an industry focus. This focus includes many activities, one of which is the development of the EPI. The analytic approach to the EPI is based on a statistical methodology, but the focus process is a critical component. Energy Star does not develop the EPI in a vacuum. Industry testing and feedback is critical to the EPI development process. The result is a "bird's eye view" of plant energy performance relative to the range of comparable plants in the industry. Since "no plant is the same as another" the statistical approach provides the normalization and distribution used to rank a plant from 1 to 100. This percentile score allows energy managers to assess individual plants on an industry wide basis. The percentile score is also the basis for EPA recognition through awarding a manufacturing plant Energy Star.

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[6] The designated third party reviewer provides protection of CBI to the company under a legal non-disclosure agreement.