DEVELOPMENT OF ENERGY STAR® ENERGY PERFORMANCE INDICATORS FOR PULP, PAPER, AND PAPERBOARD MILLS

GALE A. BOYD AND YI FANG GUO

DUKE UNIVERSITY DEPARTMENT OF ECONOMICS

BOX 90097, DURHAM, NC 27708

SPONSORED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY AS PART OF THE ENERGY STAR PROGRAM.

ACKNOWLEDGMENTS

This work was sponsored by the U.S. EPA Climate Protection Partnerships Division's ENERGY STAR program. The research has benefited from comments by participants involved with the *ENERGY STAR Pulp, Paper, and Paperboard Industry Focus* meetings. The research in this paper was conducted while the author was a Special Sworn Status researcher of the U.S. Census Bureau at the Triangle Census Research Data Center. Research results and conclusions expressed are those of the authors and do not necessarily reflect the views of the Census Bureau or the sponsoring agency. The results presented in this paper have been screened to insure that no confidential data are revealed.

CONTENTS

DEVELOPMENT OF ENERGY STAR® ENERGY PERFORMANCE INDICATORS FOR PULP, PAPER, AND PAPERBOARD MILLS

GALE A. BOYD AND YI FANG GUO

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 pulp, paper, and paperboard (PP&PB) industry to provide a plant-level indicator of energy efficiency for facilities that produce various types of paper products in the United States. Consideration is given to the role that performance-based indicators play in motivating change; the steps necessary for indicator development, from 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 the EPI for plants within selected segments of the pulp, paper, and paperboard industry: specifically pulp mills and integrated paper & paperboard mills. 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 associated with energy use through increased energy efficiency. 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. Drawling from management standards for quality and environmental performance, EPA developed the ENERGY STAR Guidelines for Energy Management that identifies the components of successful energy management practices (EPA 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 audits 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
- Provision of 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 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, and Tunnessen (2008) describe the evolution of a statistically based plant energy performance indicator for the purpose of benchmarking manufacturing energy use for ENERGY STAR. Boyd and Tunnessen (2007) describe 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. This report describes the basic concept of benchmarking and the statistical approach employed in developing performance-based energy indicators for several segments of the pulp, paper, and paperboard industry, the evolution of the analysis done for these segments of 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 might perform.

In 2000, EPA began developing a method for developing 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 particular industry, create a statistical model of energy performance for the industry's plants based on these data along with other available sources for the industry, and establish the benchmark for the comparison of those best practices, or best-performing plants, to the industry. The primary data sources would be the Census of Manufacturing, Annual Survey of Manufacturing, 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.

2.1 SCOPE OF AN INDICATOR — EXPERIENCE WITH THE PULP, PAPER, AND PAPERBOARD INDUSTRY

In 2008, EPA initiated discussions about developing a plant-level benchmark with the pulp, paper and paperboard industry. Companies with facilities located within the United States were invited to participate in discussions. When EPA first launched the ENERGY STAR for Industry in 2001, the term "plant benchmark" was used. Companies that were first engaged in the program said that industry engineers routinely develop benchmarks at many levels of plant operation, but they expressed concern that using the word "benchmark" would be confusing and could imply a particular process or tool. For this reason, it was decided that a simple descriptive term would be clearer; thus, ENERGY STAR plant Energy Performance Indicator (EPI) was adopted and has been used ever since. The scope for the EPI is a plant-level indicator, not process-specific, and it relates plant inputs in terms of all types of energy use to plant outputs as expressed in a unit of production and/or material processed. Discussion with industry representatives helped to define the scope of the EPI.

The EPI uses a statistical model to account and normalize for major, measurable impacts that affect a plant's energy use in order to make fairer comparisons between plants. The starting point for EPI development is Census data for industrial plants. For the pulp, paper and paperboard industry, the basic inputs included information on energy use, total production (physical), amount of material input in the form of preprocessed inputs, the total value of shipments, the shares of product types, and production labor person hours. The actual data used for each of the industry segments depended on the information available from Census and on the results of the statistical analysis.

Ideally the approach to developing an EPI identifies those factors that most directly influence energy use and applies them to normalize the energy use. The most basic normalization is for production level, i.e., energy use per unit of product. Other factors may influence the level of energy use per unit of product, including specific product types, and quality and choice of materials used in production (e.g., amount of raw vs. preprocessed inputs). Including these other factors in the statistical model allows one to construct alternative “benchmarks” of the basic concept of energy use per unit of product. This ideal situation may be limited due to the availability of data, or simply by limits of the methodology’s capacity to incorporate all of the possible options. The options and data under consideration for the analysis of pulp, paper and paperboard industry energy use are as follows.

Production: The industry can be grouped into a wide range of product segments. The initial focus was stand-alone pulp mills and “integrated” mills, i.e., those that produce paper or paperboard via the on-site production of pulp. While separating plants into the two groups effectively controls for the broad differences in plant configuration, there are still issues regarding the measurement of production and differences in product type within plant type. The Census data provide total value and quantity of product shipped for each plant; physical measures of production are preferred. The different product types may have different energy requirements. The role of product types is explored for each plant type listed above.

Materials: Data on the use of raw and preprocessed materials can also be included in the analysis to the extent that they have direct correlation with energy. However, the level of raw material use may not reflect what types of downstream processing different products may require. Since some plants produce products from raw instead of preprocessed materials, this is likely to have a different energy impact.

Capacity: A source of industry-wide data on plant capacities was not available. If trade associations or other industry sources have this type of information, it could be incorporated in a future analysis. The book value of capital is available from the Census, but would be difficult to apply in this setting.

Utilization: Without direct measurement of plant capacity and physical product, a simple measure of utilization is not possible. However, labor hours may provide a proxy of plant utilization. Labor data may also capture differences in downstream product processing, i.e., differences in the raw production and a fabricated final product. These data are available from Census and can be tested during model development.

The primary focus of this analysis is plants that produce pulp, paper and paperboard from raw materials in order to manufacture intermediate or final products. The U.S. Bureau of Census defines pulp, paper, and paperboard in several segments, and we draw the analysis from several different categories. The first category, Pulp Mills (NAICS 32211), comprises establishments primarily engaged in manufacturing wood pulp for further processing at non-integrated mills or finishing mills. The 10-digit NAICS product types as defined in the Census of Manufacturing are shown in Table 1.

Table 1 Pulp Mill Product Categories

NAICS 10-digit	Descriptions
322110 1100	Special alpha and dissolving wood pulp
322110 3111	Sulfate, bleached and semi-bleached, including soda
322110 3121	Sulfate, unbleached
322110 5111	Sulfite, bleached and unbleached
322110 5121	Ground wood pulp (stone, refiner, and thermo-mechanical)
322110 5131	Semi-chemical
322110 5141	Other
322110 7123	Pulp, other than wood

The second category is Integrated Paper mills (NAICS 32212) and Paperboard Mills (NAICS 32213). Only those plants that produce a final product from primarily pulp fiber produced on-site from wood and wood chips are considered integrated mills. Mills primarily using recycled fiber were not included in the scope of the analysis. Mills using a mix of sources of pulp fiber to produce the final product were included only if the fiber sources were 50% or more from wood or wood chips. We consider the following 7-digit NAICS product types as defined in the Census of Manufacturing and shown in Table 2 (see the appendix for assigning 10-digit products to the 7-digit categories).

Table 2 Integrated Paper and Paperboard Product Categories

NAICS 7-digit	Descriptions
3221211	Clay-coated printing and converting paper
3221213	Uncoated freesheet paper (containing not more than 10 percent mechanical fiber)
3221215	Bleached bristols (weight more than 150 g per sq meter), excluding cotton fiber index and bogus
3221217	Cotton fiber paper (containing 25 percent or more cotton or similar fibers) and thin paper
3221219	Unbleached kraft (not less than 80 percent) packaging and industrial converting paper
322121A	Packaging and industrial converting paper, except unbleached kraft
322121C	Special industrial paper, except specialty packaging, including absorbent, battery separator, electrical papers, etc.
322121E	Construction paper
322121G	Tissue paper and other machine-creped paper
322121K	Disposable diapers and similar disposable products, made in paper mills
322121N	Sanitary tissue paper products, made in paper mills
3221301	Unbleached kraft packaging and industrial converting paperboard (80 percent or more virgin woodpulp):
3221303	Bleached packaging and industrial converting paperboard (80 percent or more virgin bleached woodpulp)
3221305	Semi chemical paperboard, including corrugating medium (75 percent or more virgin woodpulp)
3221307	Recycled paperboard
3221309	Wet machine board, including binders' board and shoe board

Initially, the scope of the EPI included all integrated plants. Initial industry comments found this approach to be much too broad. The scope was then modified and defined as mills that produce primarily uncoated free sheet and/or linerboard, relative to other products. After review of the more narrowly defined model, it was decided that it would be appropriate to expand the scope to include all integrated plants. Results for those earlier analyses are not presented here.

ENERGY STAR Energy Performance Scales and EPIs use total source energy, defined as the total Btus of purchased/transferred fuels, the total Btus consumed to produce purchased/transferred steam and hot/chilled water, plus the total amount of purchased/transferred electricity converted from kWh to Btu at roughly the average rate of conversion efficiency and T&D losses for the entire U.S. electric grid, 11,396 Btu/kWh. Source energy is used to more closely align our energy measure with the underlying goals of the EPA ENERGY STAR program: energy and emissions reductions at the source. For this reason, a kWh of electricity is treated as the equivalent energy at the production source.[1]

Because paper plants often use biomass to generate steam, the question of whether to aggregate across fuel types based on a lower heating value (LHV) or higher heating value (HHV) was discussed. This is important because of the large difference in the efficiency of generating steam from biomass relative to other fossil fuels (due to moisture content, etc.). The conversion of electricity to its source energy value is made on a HHV basis, so use of LHV for fuels would be inconsistent. To account for the difference in the relative efficiency of generating steam from biomass, it was proposed that all energy be converted to a natural gas (HHV) steam equivalent basis. This is discussed further in section 3.2.

2.2 DATA SOURCES

The analysis conducted to create the EPIs uses confidential plant-level data from two sources: the Census of Manufacturers (CM) and the Manufacturing Energy Consumption Survey (MECS) maintained by the Center for Economic Studies (CES), U.S. Bureau of the Census (Census). The CM includes the non-public, plant-level data that are the basis of government-published statistics on manufacturing. The CM includes economic activity — for example, labor, energy, plant and equipment, materials costs, and total shipment value of output —for all plants during the years of the Economic Census. The MECS is also used. MECS is a detailed survey of energy use for a sample of plants in the CM.

Under Title 13, Sections 9 & 214, of the U.S. Code, these data are confidential; however, CES allows academic and government researchers with Special Sworn Status to access these confidential micro-data under its research associate program at one of nine designated Census Research Data Centers.[2] The confidentiality restrictions prevent the disclosure of any information that would allow for

[1] See http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_benchmark_comm_bldgs for details.

[2] For more information, see http://www.census.gov/privacy/data_protection/title_13__protection_of_confidential_information.html

the identification of a specific plant's or firm's activities. Aggregate figures or statistical coefficients that do not reveal the identity of individual establishments or firms can be released publicly.

The variable specific data sources and transformations are given below.

- Production of different product types (using 10-digit NAICS product codes) was taken from the 2002 CM product trailer files.
- Material input (using 7-digit NAICS material codes) was taken from the 2002 CM material trailer files.
- Electricity use was taken from the 2002 ASM, which was available for every plant in the dataset.
- Fuel use was taken from the 2002 MECS for those plants included in the MECS sample by converting the physical units for every fuel type into Btu content and summing.
- Onsite water treatment was inferred from the US EPA Permit Compliance System.

3 STATISTICAL APPROACH

The goal of this study was to develop an estimate of the distribution of energy efficiency across the industry. Efficiency is defined as the difference between the actual energy use and predicted "best practice," i.e., the predicted lowest energy use observable. What is actually observed is influenced by operating conditions that vary between plants, so the estimate of predicted best practice must take these conditions into account. Statistical models are well-suited for accounting for these types of observable conditions and the variability relative to those observable conditions. This section provides the background on the statistical approach, a discussion on the review process and evolution of the model's equations, and the final model estimates.

3.1 MEASURING THE DISTRIBUTION OF ENERGY EFFICIENCY

The concept of the stochastic frontier analysis that supports the EPI can be easily described in terms of the standard linear regression model, which is reviewed in this section. A more detailed discussion on the evolution of the statistical approaches for estimating efficiency can be found in Greene (1993). Consider at first the simple example of a production process that has a fixed energy component and a variable energy component. A simple linear equation for this can be written as

$$E_i = \alpha + \beta\, y_i \tag{1}$$

where

E = energy use of plant *i* and

y = production of plant *i*.

Given data on energy use and production, the parameters α and β 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 may be 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 Eq. 1 are "random." This implies that the actual relationship, represented by Eq. 2, includes a random error term ε that follows a normal (bell-shaped) distribution with a mean of 0 and variance of σ^2. In other words, about half of the actual values of energy use are less than what Eq. 1 would predict, and half are greater.

$$E_i = \alpha + \beta\ y_i + \varepsilon_i \tag{2}$$

$$\varepsilon \sim N\,(0,\sigma^2)$$

The linear regression gives the average relationship between production and energy use. If the departures from the average, particularly those that are above the average, are due to energy inefficiency, we would be interested in a version of Eq. 1 that gives the "best" (lowest) observed energy use. For example, consider that capacity utilization can influence the energy use per unit of production due to the fixed and variable components of plant energy use (see Figure 1). A regression model can find the line that best explains the average response of energy use per unit of production to a change in utilization rates. The relationship between the lowest energy consumption per unit of production relative to changes in utilization can be obtained by shifting the line downward so that all the actual data points are on or above the line. This "corrected" ordinary least squares (COLS) regression is one way to represent the frontier.

While the COLS method has its appeal in terms of simplicity, a more realistic view is that not all the differences between the actual data and the frontier are due to efficiency. Since we recognize that there may still be errors in data collection/reporting, effects that are unaccounted for in the analysis, and that a linear equation is an approximation of the complex factors that determine manufacturing energy use, we still wish to include the statistical noise, or "random error," term v_i in the analysis – but also add a second random component u_i to reflect energy inefficiency.[3] Unlike the statistical noise term, which may be positive or negative, this second error term will follow a one-sided distribution. If we expand the simple example of energy use and production to include a range of potential effects, we can write a version of the stochastic frontier model as energy use per unit of production as a general function of systematic economic decision variables and external factors,

$$E_i = h(Y_i, X_i, Z_i;\ \beta) + \varepsilon_i \tag{3}$$

$$\varepsilon_i = u_i - v_i \qquad v \sim N\,[0,\sigma_v^2]\,,$$

where
E = TSE, total source energy (or other measure of total fuel and electricity);
Y = production, measured by dollar shipments or physical production;
X = systematic economic decision variables (i.e., labor-hours worked, materials

[3] By random we mean that this effect is not directly measurable by the analyst, but that it can be represented by a probability distribution.

processed, plant capacity, or utilization rates);

Z = systematic external factors (e.g., heating and cooling loads); and

β = all the parameters to be estimated.

We assume that energy (in)efficiency u is distributed according to one of several possible one-sided statistical distributions,[4] for example exponential, half normal, or truncated normal. It is then possible to estimate the parameters of Eq. 3, along with the distribution parameters of u.

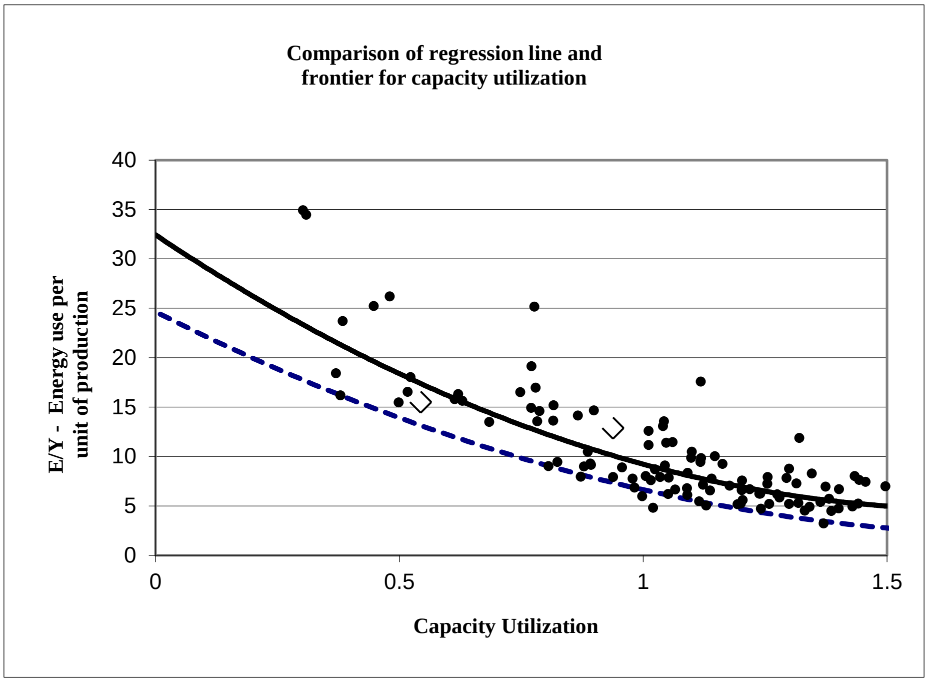


Figure 1 COLS and Frontier Regression of Energy Use per Unit of Production against Capacity Utilization

One advantage of the approach is that the parameters used to normalize for systematic effects and describe the distribution of efficiency are jointly estimated. The standard regression model captures the behavior of the average (see solid line in Figure 1), but the frontier regression (the dotted line in Figure 1) captures the behavior of the best performers. For example, if the best performing plants were less sensitive to capacity utilization because they use better shutdown procedures, then the estimated slope of the frontier capacity utilization curve would not be as steep as the slope for the average plants.

Another advantage of this method is that we can test if the differences in energy use, represented by the terms u and v, are statistically significant. If the estimated variance of u is small, we can conclude that the simpler statistical model in Eq. 2 is valid, and base our measurements on those results. Therefore, the frontier yields a more general analysis that allows for either a one-sided (skewed) distribution representing efficiency or a more "normal" (bell-shaped) distribution. If the former is the case, then we interpret that as meaning the many plants are close to one another in terms of energy use,

---

[4] We also assume that the two types of errors are uncorrelated, $\sigma_{u,v} = 0$.

with a smaller number being "further" from the group of good performers. In the latter case, that of the bell-shaped, normal efficiency distribution, we have a few "good performers," a large number of "average" plants, and a few "poor performers." In either case, we have a statistical approach to assign a ranking for the plants.

For simplicity, we assume that the function *h( )* is linear in the parameters, but allow for non-linear transformations of the variables. In particular, production, materials, and labor enter the equation in log form, as does the energy variable. This means that the terms *u* and *v* can easily 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. When there is wide variation in plant scale, this seems appropriate and may avoid possible heteroscedasticity in either or both error terms.

Given data for any plant, we can rearrange Eq. 3 into Eq. 4 to compute the difference between the actual energy use and the predicted frontier energy use:

$$E_i - \left[h(Y_i, X_i, Z_i;\, \beta)\right] = u_{\mathrm{i}} - v_{\mathrm{i}} \tag{4}$$

In the case where the frontier model is appropriate, we have estimated the probability distribution of *u*. Eq. 5 represents the probability that the plant inefficiency is greater than this computed difference:

$$\begin{gathered}\text{Probability}\left[\textit{energy inefficiency} \geq E_i - \left(h(Y_i, X_i, Z_i;\, \beta)\right)\right] = \\ 1 - F(E_i - h(Y_i, X_i, Z_i;\, \beta))\end{gathered} \tag{5}$$

F( ) is the cumulative probability density function of the appropriate one-sided density function, i.e., gamma, exponential, truncated normal, etc. The value 1 - *F( )* in Eq. 5 defines the EPI score and may be interpreted as a *percentile ranking of the energy efficiency* of the plant. In practice, we only can measure $E_i - h(Y_i, X_i, Z_i;\, \beta) = u_{\mathrm{i}} - v_{\mathrm{i}}$, so this implies that the EPI score $1 - F\left(E_i - h(Y_i, X_i, Z_i;\, \beta)\right) = 1 - F\left(u_{\mathrm{i}} - v_{\mathrm{i}}\right)$ is affected by the random component of v_i; that is, the score will reflect the random influences that are not accounted for by the function *h(*).*

In the case where the frontier model is not appropriate, there is no *u* term and corresponding estimate, only *v.*

$$E_i - \left[h(Y_i, X_i, Z_i;\, \beta)\right] = v_{\mathrm{i}} \tag{6}$$

We can drop the minus sign for *v* since the normal distribution is two sided. The estimate of the variance $v \sim N\,[0, \sigma_v^2]$ can be used in Eq. 5 where *F( )* is now the cumulative probability density function of a standard normal distribution.

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 plants in my industry, *if all other plants* were similar to mine?"

3.2 EVOLUTION OF THE MODEL

The model evolved over a period of time, based on comments from industry reviewers and subsequent analyses. The initial models were based on data from 1997 and subsequently updated to 2002, which is the current base year for the model described below.[5] Industry participants were given an opportunity to test and comment on each version of the model via the annual focus meetings, quarterly conference calls, and personal communications. Companies were asked to input actual data for all of their plants and then to determine whether the results were consistent with any energy efficiency assessments that may have been made for these plants. The resulting comments improved the EPI. This section summarizes this review process and the actions taken vis-à-vis the EPI analysis.

Defining the Boundaries of the Energy System

Unlike many industries, the PP&PB industry generates a significant portion of the energy it uses to make final products from the by-products of the manufacturing process. These by-products come from wood preparation (converting whole tree to wood chips generates bark that is used as "hog fuel") and wood pulping (converting wood into pulp generates the fuel black liquor). Since these by-products represent a significant fuel source for the plant, it is necessary to establish the energy accounting approach that will be used for measuring energy intensity and efficiency. To do this, it was necessary to consider the energy boundaries for the EPI. Two alternatives for the boundary of the system that defines the energy input into the process were considered. The first is Net Energy Demand (see Figure 2). In this approach, only energy purchases into the system, net of energy sales, are considered.[6] The efficiency of the conversion and use of by-products is included in the measure of system energy efficiency. In other words, if a plant recovers a higher amount of by-products from production and/or uses it more efficiently (in some internal sense) then the net demand on the outside energy system will be lower, i.e., the plant will require less energy input.

---

[5] The Census of Manufacturers is collected every five years. Plant-level data are made available to researchers with a significant lag from the year of collection and Census publication.

[6] In this context we use the term purchases and sales synonymously with any type of transfer into and out of the plant (energy system boundary)

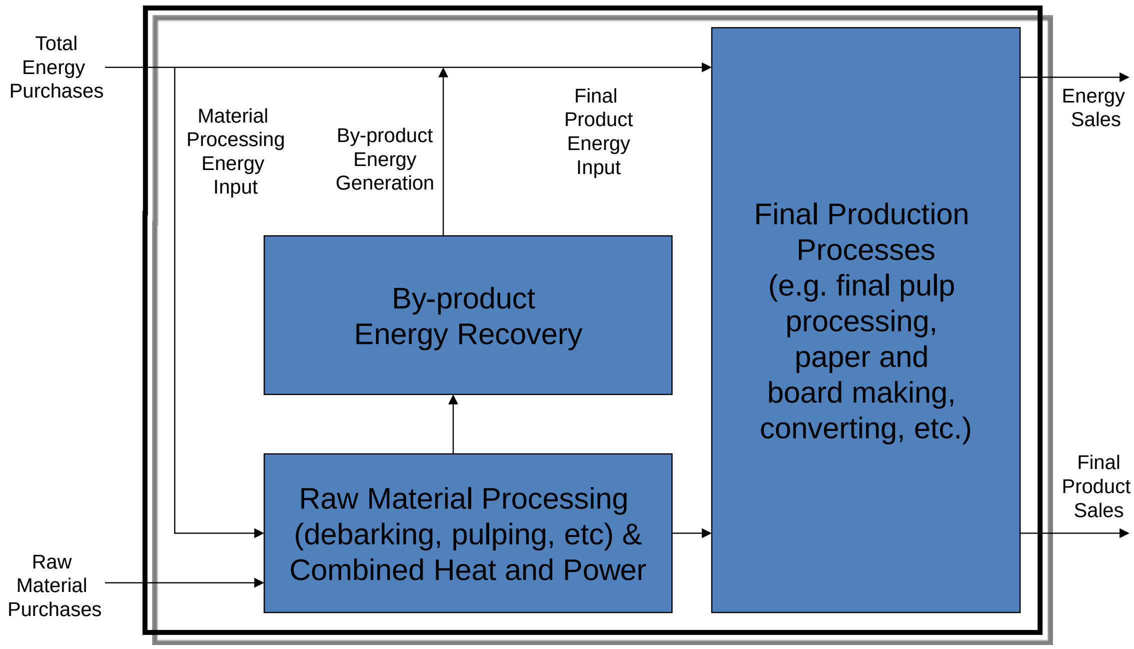


Figure 2 Net Energy Demand (purchases – sales)

The second approach is Net Energy Consumption. In this case, the system boundary accounts for the energy generated from by-product as an input (transfer in) and energy is still net of sales (transfers out). This is shown in Figure 3. This approach requires a higher level of information accounting for the by-product energy, with corresponding questions about unit conversion and possible double counting.

Given the issues with Net Energy Consumption, the Net Energy Demand approach was adopted because:

- Is consistent with how co-generation (combined heat and power) is treated in other industries by the EPI;
- Captures the availability of biomass in some pulp and paper plants; and
- Avoids problems associated with the measurement issues of heat value of biomass.

Both of these accounting approaches provide a useful definition of energy and energy efficiency. The choice of Net Energy Demand as the accounting definition means that "energy efficiency" is defined as both the efficient *use* of energy inputs as well as the efficient *generation and utilization* of internally generated by-product forms of energy.

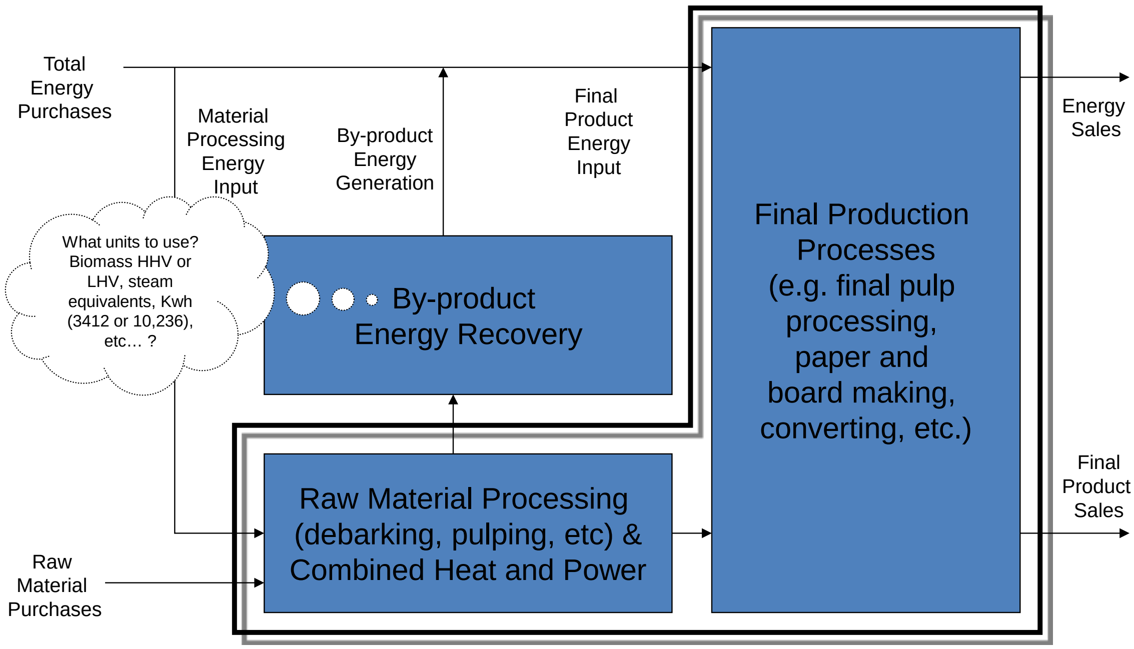


Figure 3 Net Energy Consumption (purchased + generated – sales)

Computing BTU from Purchased Biomass

Even though we use a Net Energy Demand accounting approach, some plants purchase biomass (typically bark or "hog fuel"). Bark has high moisture content and is not directly comparable on a Btu basis with fossil fuels when generating steam. Industry participants provided confidential operating statistics on the boiler at their plants. Table 3 shows the results. It is clear that the net Btu delivered as steam per Btu on HHV basis is much lower for coal and various types of biomass. We normalize the HHV Btu for each fuel type relative to natural gas on a steam equivalent basis. This means, for example, that a Btu of purchased biomass (HHV) is treated as 64% / 85% = 0.75 Btu Natural Gas (HHV) equivalent. This approach does NOT allow companies to use plant-specific boiler efficiency in the computation. Industry averages are used for the energy accounting.

Product Mix and Measurement Unit

A wide range of products is produced in the PP&PB industry, with different characteristics for different applications. The EPI analysis examines all of the different product classes shown in Table 3 to determine if they differ in terms of energy requirements. However, even within a product class there can be additional difference, particularly for some types of paper and paperboard. The production of paper and paperboard is commonly reported in weight, but the surface area of the product is another way that paper and paperboard are sold and used. Paper and paperboard with identical commercial properties except for one being lighter and thinner for a given surface area may be considered a rival, or even superior product. The ratio of weight to surface area is the "basis weight" of the paper or paperboard product. Measuring paper and paperboard production in terms of weight alone will overlook this important product characteristic. Census data, like most government and trade groups, collects and reports data on a tonnage basis. Duke University attempted to get basis weight data from the American Forest & Paper Association (AF&PA) under a non-disclosure agreement from their member companies, but AF&PA was not able to share these data.

Table 3 Steam Equivalent Conversion Rates

	AVERAGE Net Btu/ HHV	MEDIAN Net Btu/ HHV
Solid Fuels		
Bituminous Coal	80%	77%
PRB Coal	68%	68%
Tire Derived Fuel(2" chips)	88%	90%
Petroleum Coke(pulverized)*	85%	85%
Mill Bark & Screenings	68%	69%
Purchased (Pur) "Biomass"	64%	64%
Pur. 50% Black Liquor (DCE)	49%	49%
Pur. 50% Black Liquor (NDC)	53%	53%
OCC Rejects (Freeman Press)	74%	74%
Purchased Steam(600 psi)	100%	100%
Liquid Fuels		
No. 6 Fuel Oil	85%	85%
No. 2 Fuel Oil	83%	83%
Gaseous Fuels		
Natural Gas	85%	85%

Waste Water Treatment

Reviewers' comments identified on-site waste water treatment as a major energy load that creates intra-plant differences. Mills may use a municipal or other third party to treat waste water instead of operating on-site treatment facilities. This means that some mills' energy consumption include the water treatment, while others do not. One company provided internal data that clearly demonstrated that the amount of energy was non-trivial and should be accounted for in the EPI. Plants that operate on-site water treatment must have a discharge permit from EPA. These data are public record in the EPA Permit Compliance System (PCS).[7]

Information on all plants with discharge permits was obtained from the PCS and merged with the Census data. Companies were invited to review the data from EPA to verify their consistency with individual company operations. While this did not provide a comprehensive review (not every company participated), the consensus was that the data were an accurate representation of whether mills used on-site treatment. Some concerns were raised that the data did not reflect the level or type of treatment that

[7] For more details see http://www.epa.gov/enviro/facts/pcs-icis/index.html

was required/used. However, more details on this were not readily available and the reviewers decided that this approach was much better than not including water treatment considerations at all.

Product Differences

Census data have a wide range of product types for PP&PB. We expect that some of these products are more energy intensive than others. One broad class of PP&PB that tends to require more energy is white or "bleached" products. For pulp mills, bleached pulps are explicitly identified as separate products, as are a few specialty types of pulp. This allows the product-specific production statistics to be included in the EPI. For integrated P&PB mills this issue is more complex. Some NAICS product categories are clearly defined as "bleached," while others may have varying levels of whiteness within a given category. To address this important product-level energy issue, data on the amount of chemicals used in the whitening process were included in the model as a proxy for the unobservable product characteristics. These chemicals include chlorine compounds (predominantly, but not limited to sodium chlorate) and caustic soda (used in chemical recovery generally, but used more intensively in the bleaching process). One reviewer conducted detailed counterfactual analysis using internal company data and felt that the estimates presented below were a reasonable proxy for the energy use related to the bleaching process.

Analysis of Census product data (see Table 4) shows that the correlations between plant-level product shares and the chemical use have the expected signs with respect to products that are typically “white” and “brown.” While the correlations are not particularly high, they provide support for the interpretation that the chemical use does act as a proxy for product characteristics. For example, unbleached kraft and special industrial are “brown products” and other paper types tend to be “white.” Conversely, bleached packaging is a “white” paperboard product and the other three tend to be “brown.” One anomaly is for clay-coated paper, where the correlation for the chemical has opposite signs. Overall the pattern for the correlations follow expected signs.

Raw Material Differences

Type of wood (hard vs. soft) and form (chips vs. whole tree or "round wood") can impact the energy intensity of a mill. The type and form of wood may increase the processing energy requirements, but may also increase the by-product energy generated internally by the mill. The anticipated impact of wood type is ambiguous as to which type of wood might be more or less energy intensive, but this was included in the analysis. Use of wood chips would lower the energy use for material handling, but also lower the by-products that the mill would have available for energy. Reviewers felt that round wood would be a net energy producer. It is important to account for this since a mill using chips may have to purchase more energy, but this does not mean they are less efficient, given the choice of inputs used. One company that operates off-site wood preparation to ship to its mills conducted counterfactual analysis of the results of the model estimates for integrated mills (see below). They concluded that the estimates were consistent with their internal data – i.e., the estimates did capture the differences between plants using chips vs. those using round wood.

Table 4 Correlation between Chemical Use and Product Types

	NaOH	Total Chlorine
Clay-Coated Printing And Converting Paper	-0.12	0.11

Uncoated Freesheet Paper	0.18	0.23
Bleached Bristols	0.17	0.16
Unbleached Kraft	-0.04	-0.06
Packaging And Industrial Converting Paper	0.11	0.07
Special Industrial Paper	-0.05	-0.14
Tissue Paper And Other Machine-Creped Paper	0.05	0.08
Paperboard	-0.27	-0.35
Bleached Packaging	0.43	0.34
Semichemical Paperboard	-0.13	-0.24
Recycled Paperboard	-0.15	-0.22

Moisture of Pulp

Reviewers raised questions about pulp mills that ship product "wet" in slurry form. This would mean that those plants use much less energy than their counterparts. Census data do not allow for measurement of moisture content and no other sources were forthcoming. However, there was little evidence that this practice was widespread so further analysis of this issue was not conducted.

3.3 MODEL ESTIMATES

This section presents the current model estimates for each of the two industry segments: pulp and integrated P&PB mills. Several alternatives for specification of *h( )* and for the distribution of the error term *u* were tried. Only the "preferred" model estimates are presented.

Stand-alone Pulp Mills:

The final version of the pulp mills equation is

$$\ln(energy) = A + \beta_1 \ln(production) + \beta_2 Share\,of\ fiber\,as\,round\ wood + \beta_3 Share\,of\ production\,as\,Special\ Alpha + \beta_4 Share\,of\ production\,as\,Unbleached\ Sulfate + \varepsilon \quad (7)$$

where

Energy	= total source energy (MMBTU)
Production	= production of pulp (short tons)
Share of fiber as round wood	= Ratio of round wood (whole tree) as a percentage of total fiber input
Share of production: Special Alpha	= Ratio of Special Alpha as a share of production
Share of production: Sulfate, unbleached	= Ratio of unbleached Sulfate as a share of production

The variable ε is distributed as N(0, σ^2) and β is a vector of parameters to be estimated.

The estimated parameters of the model are shown in Table 5. Sample size is 28 plants. All variables except those for unbleached sulfate and the constant are significant at the 95% level or higher. The variable for unbleached Sulfate is only significant at the 90% level in a one-tailed test, but has the expected sign. The variable for water treatment is not significant, but has the expected sign and magnitude. Estimates of the frontier resulted in extremely small variance estimates of *u*, so the simpler OLS model is used in this segment.

Table 5 Pulp Mill Model Estimates

Variable	Estimate	Standard Error	t-ratio
Log Production*	1.051082	0.1206943	8.71
Share of fiber as round wood*	-1.079867	0.4420925	-2.44
Share of production: Special* Alpha	1.309212	0.4093806	3.2
Share of production: Sulfate, unbleached	-0.7259908	0.5532731	-1.31
Water Treatment	0.075191	0.286776	0.26
Constant	1.56077	1.389814	1.1

Error Distribution Parameters	
σ^2	. 4333
R – square	.8153
F(5, 22)	19.42

Integrated Paper and Paperboard Mills:

The final version of the integrated paper and paperboard mills energy equation is

$$
\begin{aligned}
&\ln(energy) = A + \beta_1 \ln(production) + \beta_2 Share\,of\;\; purchased\;\; pulp \\
&+ \beta_3 Share\,of\;\; clay\,coated + \beta_4 Share\,of\;\; tissue \\
&+ \beta_5 Share\,of\;\; softwood + \beta_6 Share\,of\;\; chlorine + \beta_7 Share\,of\;\; NaOH \\
&+ \beta_8 Share\,of\;\; woodchips + \beta_9 Share\,of\;\; bleached + \beta_9 water\,treatment + \varepsilon
\end{aligned}
\tag{8}
$$

where

Energy	=	total source energy (MMBTU);
Production	=	total P&PB production (tons)
Share of Purchased pulp	=	ratio of Purchased pulp to production
Share of Clay coated	=	Ratio of Clay-coated printing and converting to production
Share of Tissue	=	Ratio of Tissue and other creped plus sanitary to production
Share of soft wood	=	Ratio of soft wood to production
Share of Chlorine	=	Ratio of Total Chlorine Compounds to production
Share of NaOH	=	Ratio of Sodium Hydroxide to production
Share of wood chips	=	Ratio of wood chips to production
Share of recycled fiber	=	Ratio of recycled fiber to production
Share of Bleached	=	Ratio of Bleached packaging and industrial converting paperboard to production
Water treatment	=	Dummy variable (yes=1, no=0) for onsite water treatment plant, discharge permit

The variable ε is distributed as N(0, σ^2) and β is a vector of parameters to be estimated.

The estimated parameters of the model are shown in Table 6. Sample size is 99 plants with one dummy variable to control for an outlier (estimate suppressed for disclosure). All variables are jointly significant from zero. All variables listed with an asterisk are significant at 95% confidence for a two-tailed test, while the remainder are only significant at a 90% level in a one-tailed test, and have the expected sign. Estimates of the frontier resulted in extremely small variance estimates of *u*, so the simpler OLS model is used.

Table 6 Integrated Paper and Paperboard Energy Model Estimates

Variable	Estimate	Standard Error	t-ratio
Log Production*	0.706826	0.047991	14.7
Ratio of Purchased pulp to production*	1.119146	0.276065	4.05
Ratio of Clay coated printing and converting to production*	0.402983	0.141269	2.85
Ratio of Tissue and other creped plus sanitary to production*	0.324073	0.191126	1.70
Ratio of soft wood to production	0.206176	0.108605	1.90
Ratio of Total Chlorine Compounds to production*	0.046937	0.022145	2.12
Ratio of Sodium Hydroxide to production*	0.090371	0.033306	2.71
Ratio of wood chips to production	0.110788	0.076606	1.45
Ratio of recycled fiber to production	0.269367	0.166928	1.61
Ratio of Bleached packaging and industrial converting paperboard to production	0.171476	0.111948	1.53
Water treatment (yes/no)	0.110855	0.075578	1.47
Outlier dummy	suppressed		
Constant*	5.782308	0.602323	9.60

Error Distribution Parameters	
σ^2	0.1013
R – square	0.8334
F(12, 86)	36.01

4 SCORING PULP, PAPER, AND PAPERBOARD PLANT ENERGY EFFICIENCY

4.1 HOW THE EPI WORKS

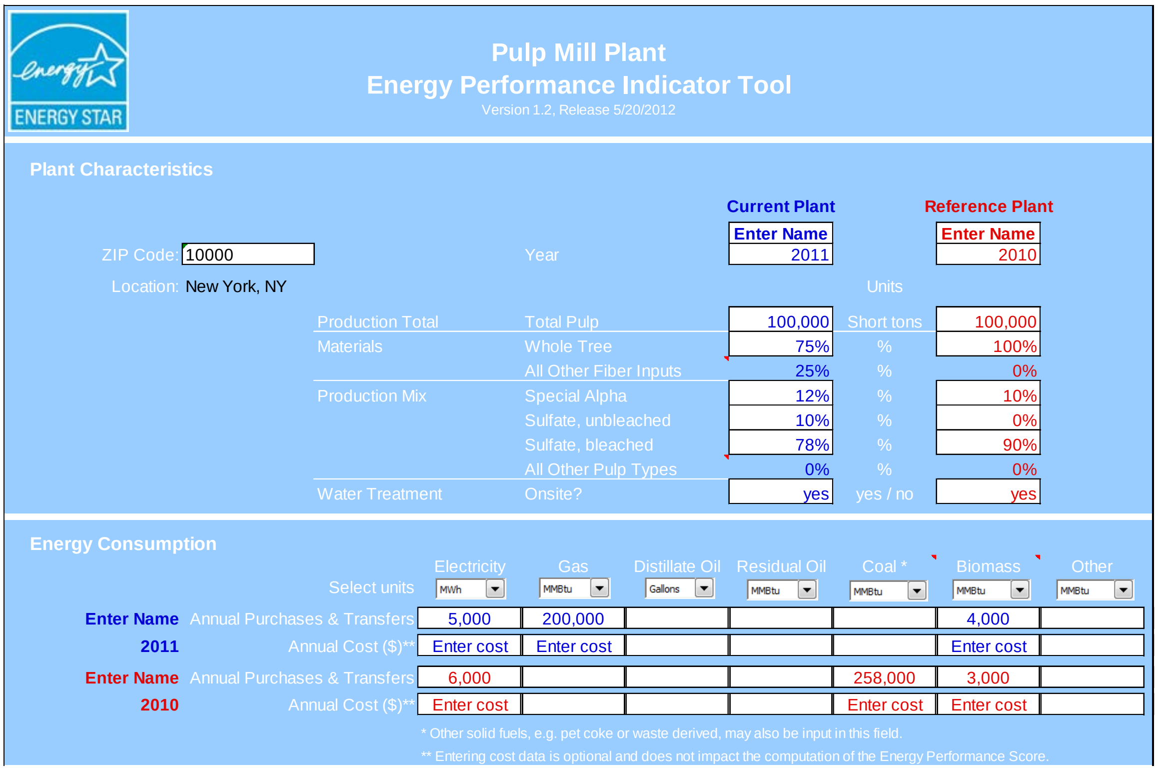
The pulp, paper, and paperboard plant EPIs rate the energy efficiency of two segments – pulp mills, and integrated paper and paperboard mills – based in the United States. To use the tool, the following information must be available for a plant.

- Total energy use
    - Electricity in kWh (converted to Btus by the spreadsheet tool)
    - Fuel use for all fuel types in physical units or Btu
- Pulp mills
    - Total production
    - Share of fiber as round wood
    - Share of production: Special Alpha
    - Share of production: Sulfate, unbleached
    - Water treatment (yes/no)
- Integrated mills
    - Total production
    - Ratio of Purchased pulp to production
    - Ratio of Clay-coated printing and converting to production
    - Ratio of Tissue and other creped plus sanitary to production
    - Ratio of soft wood to production
    - Ratio of Total Chlorine Compounds to production
    - Ratio of Sodium Hydroxide to production
    - Ratio of wood chips to production
    - Ratio of recycled fiber to production
    - Ratio of Bleached packaging and industrial converting paperboard to production
    - Water treatment (yes/no)

Based on these data inputs, these two 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. 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.

4.2 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[8] set of plant-level inputs. The spreadsheet accepts the raw plant-level inputs described above, computes the values for *h( ),* and then displays the results from the appropriate distribution functions for the models presented in Eqs. 7 and 8. The energy managers were encouraged to input data for their own plants and then provide comments. A version of these spreadsheets corresponding to the results described in this report is available from the EPA ENERGY STAR web site.[9] Examples of spreadsheets are shown in Figures 4-7.



Pulp Mill Plant
Energy Performance Indicator Tool
Version 1.2, Release 5/20/2012

Plant Characteristics

ZIP Code: 10000
Location: New York, NY

		Current Plant	Units	Reference Plant
		Enter Name		Enter Name
	Year	2011		2010
Production Total	Total Pulp	100,000	Short tons	100,000
Materials	Whole Tree	75%	%	100%
	All Other Fiber Inputs	25%	%	0%
Production Mix	Special Alpha	12%	%	10%
	Sulfate, unbleached	10%	%	0%
	Sulfate, bleached	78%	%	90%
	All Other Pulp Types	0%	%	0%
Water Treatment	Onsite?	yes	yes / no	yes

Energy Consumption

		Electricity	Gas	Distillate Oil	Residual Oil	Coal *	Biomass	Other
	Select units	MWh	MMBtu	Gallons	MMBtu	MMBtu	MMBtu	MMBtu
Enter Name	Annual Purchases & Transfers	5,000	200,000				4,000	
2011	Annual Cost ($)**	Enter cost	Enter cost				Enter cost	
Enter Name	Annual Purchases & Transfers	6,000				258,000	3,000	
2010	Annual Cost ($)**	Enter cost				Enter cost	Enter cost	

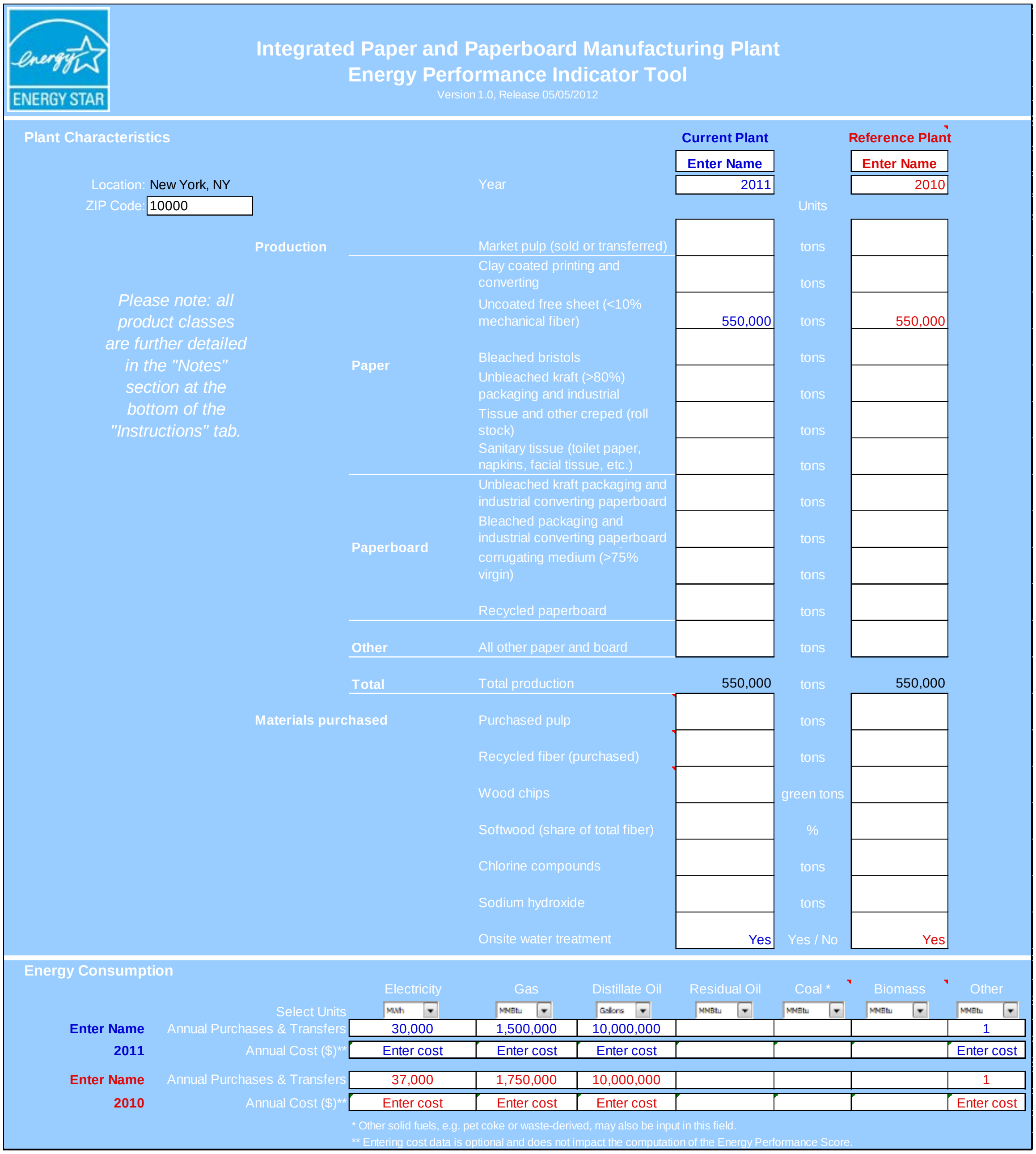
* Other solid fuels, e.g. pet coke or waste derived, may also be input in this field.
** Entering cost data is optional and does not impact the computation of the Energy Performance Score.

Figure 4 Input Section of the Pulp Mill EPI Spreadsheet Tool

---

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

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



Integrated Paper and Paperboard Manufacturing Plant
Energy Performance Indicator Tool
Version 1.0, Release 05/05/2012

Plant Characteristics

Location: New York, NY
ZIP Code: 10000

Please note: all product classes are further detailed in the "Notes" section at the bottom of the "Instructions" tab.

			Current Plant	Units	Reference Plant
			Enter Name		Enter Name
		Year	2011		2010
Production		Market pulp (sold or transferred)		tons	
	Paper	Clay coated printing and converting		tons	
		Uncoated free sheet (<10% mechanical fiber)	550,000	tons	550,000
		Bleached bristols		tons	
		Unbleached kraft (>80%) packaging and industrial		tons	
		Tissue and other creped (roll stock)		tons	
		Sanitary tissue (toilet paper, napkins, facial tissue, etc.)		tons	
	Paperboard	Unbleached kraft packaging and industrial converting paperboard		tons	
		Bleached packaging and industrial converting paperboard		tons	
		corrugating medium (>75% virgin)		tons	
		Recycled paperboard		tons	
	Other	All other paper and board		tons	
	Total	Total production	550,000	tons	550,000
Materials purchased		Purchased pulp		tons	
		Recycled fiber (purchased)		tons	
		Wood chips		green tons	
		Softwood (share of total fiber)		%	
		Chlorine compounds		tons	
		Sodium hydroxide		tons	
		Onsite water treatment	Yes	Yes / No	Yes

Energy Consumption

		Electricity	Gas	Distillate Oil	Residual Oil	Coal *	Biomass	Other
	Select Units	MWh	MMBtu	Gallons	MMBtu	MMBtu	MMBtu	MMBtu
Enter Name	Annual Purchases & Transfers	30,000	1,500,000	10,000,000				1
2011	Annual Cost ($)**	Enter cost	Enter cost	Enter cost				Enter cost
Enter Name	Annual Purchases & Transfers	37,000	1,750,000	10,000,000				1
2010	Annual Cost ($)**	Enter cost	Enter cost	Enter cost				Enter cost

* Other solid fuels, e.g. pet coke or waste-derived, may also be input in this field.
** Entering cost data is optional and does not impact the computation of the Energy Performance Score.

Figure 5 Input Section of the Integrated Paper and Paperboard Mill EPI Spreadsheet Tool

Results	Your Current Plant Enter Name 2011	Your Reference Plant Enter Name 2010	Average Plant Enter Name 2011	Efficient Plant Enter Name 2011
Energy Performance Score (EPS)	79	59	50	75
Annual Energy Cost ($/year)	$0	$0	$0	$0
Purchased Source Energy (MMBtu)	260,043	306,615	441,101	281,924
Purchased Site Energy (MMBtu)	220,123	258,710	373,386	238,645
Energy Intensity (MMBtu/Tons of Pulp)	2.60	3.07	4.41	2.82

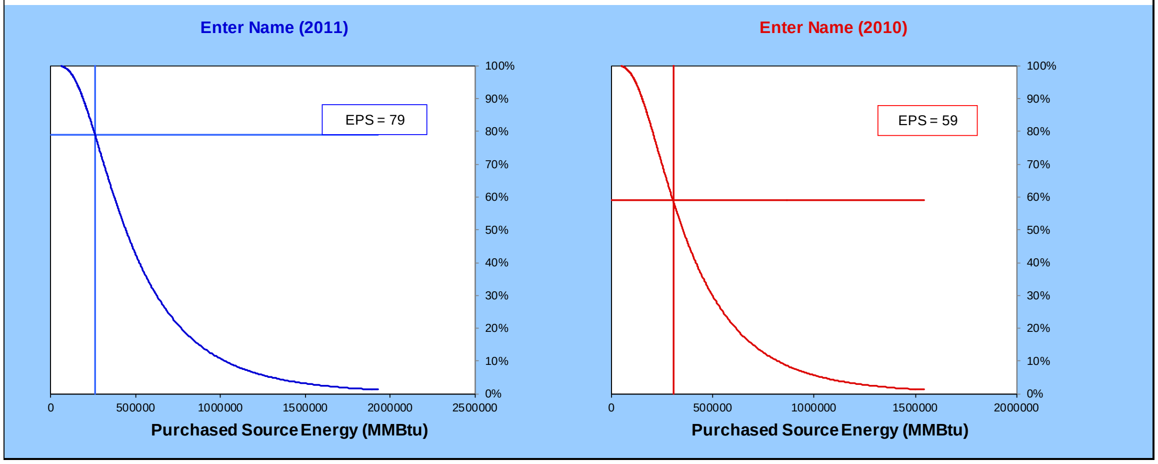


Figure 6 Output Section of the Pulp Mill EPI Spreadsheet Tool

Results	Your Current Plant Enter Name 2011	Your Reference Plant Enter Name 2010	Average Plant Enter Name 2011	Efficient Plant Enter Name 2011
Energy Performance Score (EPS)	78	68	50	75
Annual Energy Cost ($/year)	$0	$0	$0	$0
Energy Cost ($/Ton of Paper)	$0.00	$0.00	$0.00	$0.00
Purchased Source Energy (MMBtu)	3,228,788	3,558,561	4,138,125	3,332,899
Purchased Site Energy (MMBtu)	2,989,266	3,263,150	3,831,145	3,085,653
Energy Intensity (MMBtu/Ton of Paper)	5.87	6.47	7.52	6.06

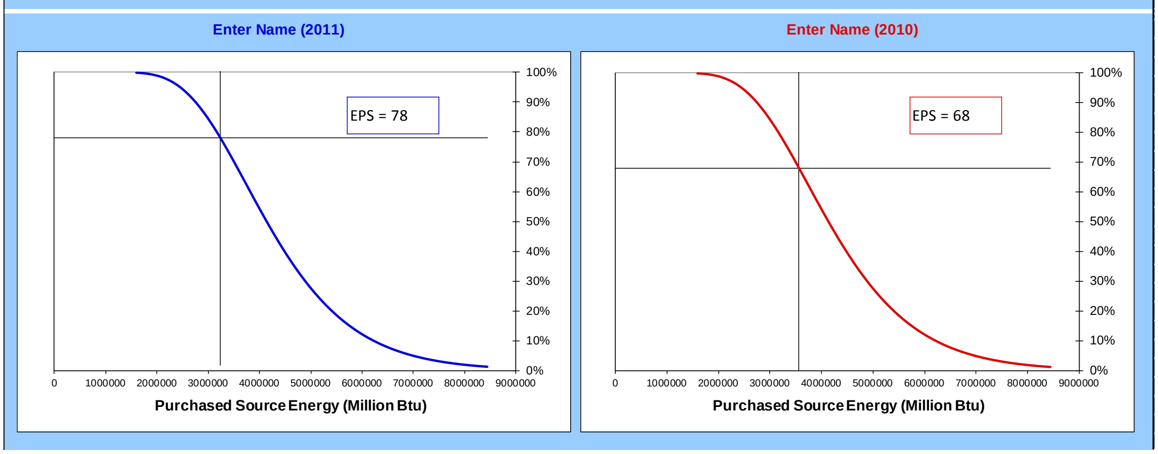


Figure 7 Output Section of the Integrated Paper and Paperboard Mill EPI Spreadsheet Tool

4.3 USE OF THE ENERGY STAR PULP, PAPER, AND PAPERBOARD 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 score 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 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 update these models every few years, contingent on newer data being made available and industry use and support of the EPI tools.

4.4 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 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"[10] 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.
- 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.

5 REFERENCES

Boyd, G., E. Dutrow, et al. (2008). "The Evolution of the Energy Star Industrial Energy Performance Indicator for Benchmarking Plant Level Manufacturing Energy Use." *Journal of Cleaner Production Volume* 16 (Issue 6): 709-715.

Boyd, G. A. and W. Tunnessen (2007). "Motivating Industrial Energy Efficiency through Performance-based Indicators." *ACEEE Summer Study On Energy Efficiency In Industry Improving Industrial Competitiveness: Adapting To Volatile Energy Markets, Globalization, And Environmental Constraints*, White Plains, New York, ACEEE.

EPA, 2003, *Guidelines for Energy Management*, U.S. Environmental Protection Agency, Washington, DC; available online at http://www.energystar.gov/index.cfm?c=guidelines.guidelines_index.

Greene, W.H., 1993, "The Econometric Approach to Efficiency Analysis," pp. 68–119 in *The Measurement of Productive Efficiency: Techniques and Applications*, H. Fried, et al., (editors), Oxford University Press, NY.

[10] 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).

6 APPENDIX

322121 PAPER

3221211 CLAY-COATED PRINTING AND CONVERTING PAPER

3221211111 Clay-coated groundwood printing and converting paper (containing more than 10 percent mechanical fiber), including prime-coated body stock
3221211221 Clay-coated freesheet printing and converting paper, coated one side (containing not more than 10 percent mechanical fiber), including prime-coated body stock
3221211231 Clay-coated freesheet printing and converting paper, coated two sides (containing not more than 10 percent mechanical fiber), including prime-coated body stock

3221213 UNCOATED FREESHEET PAPER (CONTAINING NOT MORE THAN 10 PERCENT MECHANICAL FIBER)

3221213111 Bond and writing paper, including protective check, uncoated freesheet
3221213115 Form bond paper in rolls, uncoated freesheet
3221213221 Body stock for communication, copying, and related papers, uncoated freesheet
3221213225 Other uncoated freesheet technical and reproduction papers, including mimeograph and gelatin and spirit process duplicating
3221213231 Writing tablet paper, uncoated freesheet
3221213235 Other writing paper, including ledger, onion skin, papeterie and wedding, etc., uncoated freesheet
3221213341 Plain publication and printing paper, uncoated freesheet, including machine finish, English finish, antique, bulking, eggshell, and supercalendered
3221213345 Offset publication and printing paper, uncoated freesheet
3221213351 Other uncoated publication and printing freesheet paper
3221213461 Cover and text papers, uncoated freesheet
3221213471 Envelope (white wove) paper, uncoated freesheet
3221213481 Kraft envelope (bleached kraft and brown kraft) paper, uncoated freesheet
3221213491 Uncoated freesheet body stock paper for coating (base or raw stock for conversion of off-machine coating) and all other miscellaneous uncoated freesheet

3221215 BLEACHED BRISTOLS (WEIGHT MORE THAN 150 G PER SQ METER), EXCLUDING COTTON FIBER INDEX AND BOGUS

3221215111 Uncoated bleached bristol tag stock (weight more than 150g per sq meter)
3221215121 Uncoated bleached bristol file folder stock (weight more than 150 g per sq meter)
3221215131 Other uncoated bleached bristols, including tabulating card, index, printing, and postcard stock (weight more than 150g per sq meter), excluding cotton fiber index and bogus
3221215141 Coated bleached bristols (weight more than 150 g per sq meter), excluding cotton fiber index and bogus

3221217 COTTON FIBER PAPER (CONTAINING 25 PERCENT OR MORE COTTON OR SIMILAR FIBERS) AND THIN PAPER

3221217111 Cotton fiber paper (containing 25 percent or more cotton or similar fibers)
3221217121 Thin paper including carbonizing, Bible, mimeograph and duplicating stencil tissue, India, tipping, condenser, cigarette paper, etc.

3221219 UNBLEACHED KRAFT (NOT LESS THAN 80 PERCENT) PACKAGING AND INDUSTRIAL CONVERTING PAPER

3221219111 Unbleached kraft shipping sack paper (meets minimum Federal specifications UU-S-48) and other unbleached kraft shipping sack paper
3221219121 Unbleached kraft bag and sack paper (except shipping), including grocers' and other unbleached kraft bag and sack for notion, millinery, etc.
3221219131 Unbleached kraft wrapping and specialty packaging paper (92 lb or less), including flour, sugar, dog food, fast foods, dairy products, etc.
3221219191 Other unbleached kraft converting paper, including creping (92 lb or less), asphalting paper, coating and laminating, gumming, etc.

322121A PACKAGING AND INDUSTRIAL CONVERTING PAPER, EXCEPT UNBLEACHED KRAFT

322121A111 Shipping sack paper (except unbleached kraft), including combination kraft and rope, bleached and semibleached
322121A121 Other bag and sack paper, except unbleached kraft and shipping, including grocers', liquor, millinery, notion, variety, etc.
322121A13 Specialty packaging (92 lbs or less) and wrapping paper, except unbleached kraft (butcher, flour, sugar, fast foods, confectionery, etc.)
322121A141 Other converting stock, including asphalting and creping stocks (not more than 92 lbs), coating and laminating, gummed, twisting and spinning stock (19 lbs or more), and waxing stock (18 lbs or more)
322121A151 Glassine, greaseproof, and vegetable parchment, all grades regardless of end use (92 lb or less)

322121C SPECIAL INDUSTRIAL PAPER, EXCEPT SPECIALTY PACKAGING, INCLUDING ABSORBENT, BATTERY SEPARATOR, ELECTRICAL PAPERS, ETC.

322121C100 Special industrial paper, except specialty packaging, including absorbent, battery separator, electrical papers, etc.

322121E CONSTRUCTION PAPER

322121E111 Roofing felts, saturating and dry
322121E121 Other construction paper, including sheathing paper, floor covering felts, automotive, insulating paper blankets, etc.

322121G TISSUE PAPER AND OTHER MACHINE-CREPED PAPER

322121G111 Toilet tissue stock
322121G221 Toweling paper stock, except wiper stock
322121G331 Facial tissue stock, except toweling, napkin, and toilet
322121G341 Napkin paper stock, except sanitary napkin stock wadding
322121G351 Wiper tissue stock, regular, facial, and wadding stock
322121G361 Other sanitary paper stock, including sanitary napkin stock wadding, aseptic paper stock, reinforced paper stock, etc.
322121G371 Wrapping tissue, including florist tissue stock, hosiery paper, interleaving, antitarnish, etc.
322121G391 Other tissue paper stock, including waxing tissue stock, creped wadding for interior packaging (excluding sanitary and thin)

322121K DISPOSABLE DIAPERS AND SIMILAR DISPOSABLE PRODUCTS, MADE IN PAPER MILLS

322121K100 Disposable diapers and similar disposable products (including sanitary napkins, tampons, training pants, and incontinent pads), made in paper mills1 millions

322121N SANITARY TISSUE PAPER PRODUCTS, MADE IN PAPER MILLS

322121N111 Facial tissues and handkerchiefs, including sputum wipes, made in paper mills
322121N201 Paper table napkins, industrial and retail packages, bulk and dispenser types, made in paper mills
322121N331 Toilet tissue, retail packages, rolls and ovals, facial tissue type, two-ply or more, made in paper mills
322121N433 Toilet tissue, retail packages, rolls and ovals, regular type, single-ply, made in paper mills
322121N661 Paper towels, industrial packages (rolled, folded, and interfolded), made in paper mills
322121N701 Paper towels, retail packages (rolled, folded, and interfolded), made in paper mills
322121N901 Other sanitary paper products (including industrial packaged toilet tissue (all types), paper wipers (except nonwoven), absorbent pads, etc.), made in paper mills

322130 PAPERBOARD

3221301 UNBLEACHED KRAFT PACKAGING AND INDUSTRIAL CONVERTING PAPERBOARD (80 PERCENT OR MORE VIRGIN WOODPULP)

3221301111 Unbleached kraft linerboard
3221301221 Other unbleached kraft packaging and industrial converting paperboard, including tube, can, and drum paperboard, corrugating medium, folding carton-type board, etc.

3221303 BLEACHED PACKAGING AND INDUSTRIAL CONVERTING PAPERBOARD (80 PERCENT OR MORE VIRGIN BLEACHED WOODPULP)

3221303111 Bleached folding carton-type paperboard
3221303221 Bleached milk carton board
3221303331 Bleached linerboard
3221303341 Bleached heavyweight cup and round nested food container paperboard
3221303351 Bleached plate, dish, and tray paperboard stock
3221303361 Other solid bleached paperboard, including paperboard for moist, liquid, and oily foods

3221305 SEMICHEMICAL PAPERBOARD, INCLUDING CORRUGATING MEDIUM (75 PERCENT OR MORE VIRGIN WOODPULP)

3221305100 Semichemical paperboard, including corrugating medium (75 percent or more virgin woodpulp)

3221307 RECYCLED PAPERBOARD

3221307111 Recycled corrugating medium
3221307221 Recycled linerboard
3221307231 Recycled container chip and filler board
3221307341 Recycled clay-coated folding carton board
3221307451 Recycled unlined folding carton chipboard
3221307461 Recycled lined folding carton board, including kraft and white
3221307571 Recycled setup board
3221307575 Recycled tube, can, and drum paperboard stock
3221307581 Recycled gypsum linerboard

3221307591 Other recycled paperboard, including panelboard and wallboard stock and other special combination packaging and industrial converting paperboard

<u>3221309 WET MACHINE BOARD, INCLUDING BINDERS’ BOARD AND SHOE BOARD</u>

3221309100 Wet machine board, including binders’ board and shoe board