Aggregate Efficiency Index

An ENERGY STAR® Guide for Evaluating Energy Performance in Diverse Organizations

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aggregate efficiency index

PURPOSE OF THIS GUIDE

Few manufacturing companies produce just one product. Instead, many make a variety of dissimilar goods. This guide describes how organizations[1] with diverse operations or products can accurately calculate and report aggregate energy intensity. Using the aggregate efficiency index (AEI) approach can help companies judge changes in energy efficiency.

Companies will benefit from using an AEI to evaluate energy performance if they have:

- A range of production activities and products.
- Different sizes and types of facilities.
- Varying energy use levels across facilities.
- Recently opened or acquired facilities.
- Recently closed or sold facilities.
- Multiple business units.
- Different production or growth rates across a portfolio of facilities.

Although this guide focuses on an index for reporting ***energy***, this approach works with any quantifiable sustainability metric, such as carbon dioxide emissions.

[!] THE PROBLEM

The energy manager of Apple & Orange Co., a food processing company that produces fresh apple and orange juices, must produce a single number to represent the company's improvement in energy efficiency over the past two years. The energy program has seen some successes as well as challenges: Parts of the company have grown, but others have not. Total energy use has increased, as have revenue and production.

How does the energy manager report a single number for such a diverse organization when some activities are very energy intensive and others are not?

Energy use per dollar of revenue conflates the effort of the energy program with product market changes; energy use per pound of product is equally meaningless because orange juice is more energy intensive than apple juice. The energy manager already tracks energy intensity at a detailed level. She just needs a way to "'add up' apples and oranges" in a consistent and justifiable manner. She needs an AEI for her entire organization.

[1] Throughout this guide, the term "organization" is used synonymously with company or corporation, because companies and corporations, public entities, and nonprofit organizations all can use this approach to address the differences listed in this section.

INTRODUCTION

Measuring energy performance is an energy management best practice that can provide valuable financial and tactical insights into the operation of an organization.

Many companies produce a diverse combination of products and services under conditions that vary from year to year, so it is often difficult to calculate a single value that reflects energy performance of the organization over time. To address this issue, the U.S. Environmental Protection Agency's (EPA's) ENERGY STAR® program for industry prepared this guidance for developing an AEI approach for energy managers who seek to create a single organization-wide energy performance metric. This approach summarizes changes in energy and activity in a diverse organization between any two reporting periods and presents the changes in the form of a percentage improvement called the AEI.

Why measure energy performance at an organizational level?

Tracking and monitoring energy performance is fundamental to energy management. ENERGY STAR recommends organization-wide evaluation of an energy or sustainability program's impacts and the use of organization-wide metrics because they are important for communicating the following:

- Progress toward meeting organizational energy goals.
- Overall return on investment of the energy program.
- Changes in sustainability metrics and performance over time.
- Shifts in product mix within existing facilities to more or less energy-intensive products due to market changes or technological shifts (e.g., material substitutions).

Energy management programs often effectively track energy performance at the facility level but face difficulty summarizing organization-wide performance when there are wide variations in facility types, products, or even energy performance metrics. Organizations that have changing portfolios, particularly as a result of adding or closing facilities, face additional challenges in accurately capturing changes in energy performance. The AEI addresses these situations by providing an easy-to-communicate, organization-wide metric that reflects the total change in energy performance across the organization over a defined period of time.

Energy use, especially for manufacturers, is often the primary source of greenhouse gas emissions. Having an AEI for energy provides more insight, whether those changes are the result of energy management practices and projects[2] or some other factor.

Methods for measuring performance: Absolute energy vs. energy intensity

One method of measuring organization-wide energy performance is using ***absolute energy***: the total amount of energy consumed over a defined period of time. For example, an organization may set an absolute energy goal to reduce the total amount of energy used by 10 percent over the next five years.

While the absolute level of energy use can serve as a proxy for environmental impacts, there are circumstances that may reduce an organization's aggregate energy use that do not reflect improved performance. For example, selling a facility may reduce aggregate energy use but will not reflect

[2] This approach can be applied to reporting carbon as well as energy.

better management practices or investments in sustainability. Conversely, acquiring new operations may raise overall energy use but will not necessarily mean the organization is less efficient or sustainable, only that it has expanded. This also applies to companies that may grow as a result of increased production and market share. The impact of growth or decline should be compared to the corresponding energy consumption. If energy use grows more slowly than the activities of the organization, energy performance is reflected as an improvement.

Another method of measuring energy performance is using ***energy intensity***: the amount of energy the organization consumes per unit of activity. Energy intensity can be calculated by dividing total energy use by a metric that reflects an organization's activities. For manufacturers, this metric may be total production (energy/total production). If the ratio of energy use to production decreases over time, the company's operations may have become more energy efficient because less energy was used for production.

Not every factor that affects energy intensity corresponds to a change in "efficiency." Weather is a prime example. To normalize for these impacts, statistical models are sometimes created at the facility level to track performance. The AEI approach can incorporate results from regression models. For information about adjusting for non-efficiency effects, see the use case "Using Regression Normalization to Enhance Efficiency Estimates at Individual Plants" on page 15.

The challenge of energy intensity: Finding an activity measure for an entire organization

Finding a single measure that represents an entire organization's activities is the biggest challenge to using energy intensity to track energy performance. Most companies are too diverse to settle on a simple denominator such as a physical quantity or count of services. Trying to force a one-size-fits-all approach that measures the aggregate activity of an organization will have major limitations.

Absolute Energy

Total energy consumed during a time period.

\+
- Easy to calculate.
- Easy to compare over time.

−
- May not reflect efficiency gains or losses.
- Does not adjust for major changes in operations.

Energy Intensity

Total energy consumed per unit of activity.

\+
- Reflects energy efficiency gains or losses.
- Adjusts for changes in operations.

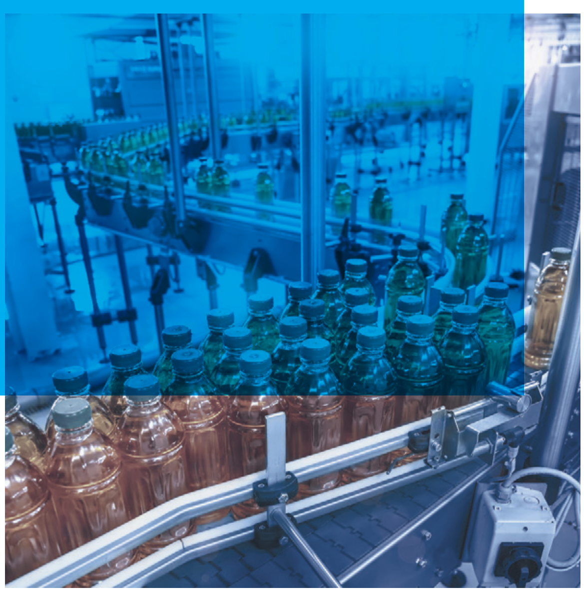
−
- Can be hard for sites and companies with multiple activities to use a single unit.

CHOICE OF ACTIVITY TO MEASURE ENERGY INTENSITY

Apple & Orange Co. could choose to add up "juice," including the apple juice from the Washington site and the orange juice from the Florida site. In this case, juice could be measured via a *financial metric*, such as total sales, or a *physical metric*, such as total pounds or total volume. But neither measurement may account for the full scope of the activities in the organization. How does Apple & Orange Co. include their warehouses or farming activities?

Even when a financial metric is possible, it may not always accurately represent energy use. If apple juice becomes more popular, prices and revenues per unit could rise while energy use could remain the same. This outcome might be good for the organization but does not reflect a change in energy efficiency.

Similarly, a common physical metric for the company's activities—orange juice, apple juice, warehousing, and farming—is not obvious. Even if juice accounts for most production, calculating for "total juice" would not be appropriate because different types of juices have different energy requirements for production.



Some companies try to compensate for the lack of a single physical or business activity measure by using a financial metric, such as one that measures total revenue or sales. However, financial metrics may not reflect the energy intensity of a business activity because revenues of individual activities can change with the market for those activities, and they do not provide evidence of an energy efficiency change. Further, if the *mix of activities in the organization changes* from year to year between more and less energy-intensive activities, the metric selected can understate or overstate the success of energy management actions because of market factors beyond an energy manager's control. If activity mix shifts toward more energy-intensive activities in a year, the financial metric may indicate an overall increase in energy intensity rather than indicating an actual decrease achieved by the energy management program.

In most cases, these simple approaches do not reflect the intricacies of the organization's operations and may be misleading. To know whether energy management efforts are succeeding, organizations need an approach that captures the complexity of their changes.

THE AEI APPROACH

The AEI approach addresses the limitations of using absolute energy or energy intensity based on simplistic financial or physical measures.

This approach does not require the organization to pick a single measure of activity for the entire organization. Instead, the most appropriate, location-specific metric for each facility is selected to represent the energy consumption activities at each location within the organization. The AEI incorporates as many different energy intensities as the organization has diverse operations. The AEI then weighs all of these location-specific energy intensities and production activities in a systematic way, allowing the organization to determine whether the aggregate, organization-level energy intensity has grown or declined, and by how much.

The AEI focuses on comparing ***any two points in time***. This guide uses two years in the examples as the sample time period, but organizations can use months, quarters, or any other relevant tracking period. Additionally, multiple time periods can be incorporated by computing the AEI sequentially and combining the results. The choice of the time period matters only to the extent that the period reflects the changes and results that occur during that period.[3]

The index approach is not a new method for tracking trends over time. The AEI uses a method similar to that used by the U.S. Bureau of Labor Statistics (BLS) to calculate aggregate prices for the purpose of measuring inflation. BLS bases this calculation on the "total cost" of a "basket of goods" in which prices change over time. In the analogy between the BLS Price Indices and the AEI, "total cost" is analogous to energy, the "basket of goods" is analogous to the products and services of the organization, and "prices" are analogous to energy intensity.[4]

Benefits of using the AEI

Using an index approach allows an organization to overcome the limitations of using a simple energy intensity approach. Within an AEI there is no need to use a denominator that may not reflect energy performance across all operations. Use of an AEI enables the company to *choose the reporting levels* so that energy intensities with different denominators are used *at whatever reporting level the data are available* (e.g., at a business unit, a site, a building within a site, a process unit within a site or building). In addition, the AEI:

- Accounts for multiple products with different energy intensities.
- Accounts for acquisitions and divestitures.
- Incorporates more complex site-level metrics, such as normalized regression-based energy forecasts.

The AEI approach combines the benefits of multiple index approaches by averaging two calculations of energy performance, because one calculation alone would not provide all these benefits.

[3] Intervals of different duration can be combined (e.g., one year and two quarters for a total of 18 months), but care should be taken when computing rates of change over those different time steps.

[4] The detailed foundation and formulas underpinning the AEI can be found in: Gale Boyd and Jay Golden, "Enhancing Firm GHG Reporting: Using Index Numbers to Report Corporate Level Measures of Sustainability," *International Journal of Green Technology 2*, (2016): 29–37, https://www.researchgate.net/publication/301651085_Enhancing_Firm_GHG_Reporting_Using_Index_Numbers_to_Report_Corporate_Level_Measures_of_Sustainability.

Developing an AEI

Step 1. Obtain energy and activity data for all levels of reporting in the organization for two years: a base year and a performance year.

The AEI approach begins similarly to any other benchmarking activity: It collects energy use and activity data and then calculates the intensities. The steps for this initial data collection follow:

1a. Define your reporting levels.

Reporting levels divide all the company's operations into segments that can be represented by a common activity and that have separate energy data. Companies may define business units by market or geography, but for an AEI, a finer level of disaggregation is possible. For example, a location that has multiple buildings or process units with different activities can be represented by multiple reporting levels, as long as each building or process unit has its own unique activity and sub-metered energy.[5]

1b. Define the activity at each reporting level.

For each reporting level, choose a denominator to represent the activity most related to energy use. The denominator can be a measure of production, building size, or any other metric that best represents the activity of that reporting level.

1c. Calculate reporting-level energy intensity.

For the two years, collect the total energy and activity data for each reporting level such that the total energy for the organization is represented. The energy intensity for the reporting level is total energy for that reporting level divided by the chosen activity. The activities of the reporting levels do not need to be added.

CHOOSING REPORTING LEVELS AND UNITS

Apple & Orange Co. has both apple and orange juice plants. They know that orange juice is more energy intensive, so they do not want to add up apples and oranges, or combined volumes of apple and orange juice. They could have each business unit report energy and juice production, but energy and production are available at the plant level, so they select plant-level reporting for juice manufacturing. They use pounds of orange juice and gallons of apple juice to represent production activity. They choose to include two large warehouses located at two of the manufacturing sites as separate reporting levels since they are refrigerated and submetered, using square feet (ft^2) as the activity measure. Because farm energy use is very low and not actively tracked as part of the energy program, they choose to exclude the orchards for now.

5 In the absence of metering at each reporting level, it is possible that energy use could be allocated to the various reporting levels based on engineering estimates and reasonable assumptions, but some loss of accuracy will result.

To illustrate these steps, Table 1 includes a simple example with three reporting levels.[6] This hypothetical organization has several characteristics that qualify the company to benefit from the AEI method. The company chooses three reporting levels. Reporting Level A has a very energy-intensive manufacturing plant, and Reporting Level B has a less energy-intensive plant. Both these plants have a warehouse; these warehouses are aggregated into a single reporting level, C, because they represent comparable operations. The two manufacturing sites can be separated from their respective warehouses because the energy for warehouses is submetered.

Separating the manufacturing sites from warehouses is appropriate because variable production is the main energy driver at each manufacturing site, while warehouse energy is thought to be fairly constant and measured against the "activity" of its area in square feet. The first plant (Reporting Level A) more than doubled its activity in the second year when its production line was upgraded to expand capacity and improve efficiency. Reporting Level B shows that the second plant's production declined slightly. Total corporate energy use has increased; however, the energy intensity for Reporting Level A declined, while the intensities for the others rose slightly. The organization believes energy efficiency has improved overall, but the question is, by how much?

Table 1. Basic Energy and Activity Data

Year 1

	Energy: *Actual*			Activity			Energy Intensity
Report Level A: Oranges	5,000	MMBtu	÷	1,000	lbs.	=	5.00
Report Level B: Apples	1,000	MMBtu	÷	1,000	gals.	=	1.00
Report Level C: Warehouses	500	MMBtu	÷	5,000	sq. ft.	=	0.10
Organization-wide	**6,500**	**MMBtu**		*			

Year 2

	Energy: *Actual*			Activity			Energy Intensity
Report Level A: Oranges	12,000	MMBtu	÷	2,500	lbs.	=	4.80
Report Level B: Apples	990	MMBtu	÷	900	gals.	=	1.10
Report Level C: Warehouses	550	MMBtu	÷	5,000	sq. ft.	=	0.11
Organization-wide	**13,540**	**MMBtu**		*			

*Total activity cannot be calculated because units are different.

[6] The example is entirely hypothetical and does not represent actual energy intensity in juice manufacture or refrigerated warehouses.

Step 2. Compute the index inputs for each reporting level.

As explained earlier, an organization's activities often change from year to year. To account for these changes in energy performance, the AEI approach requires that the organization *creates an alternative scenario that is a counterfactual measure of what energy use would have been if some aspects of the organization "stayed the same."* Because multiple activities or data points may change at the same time—for example, the reporting-level activity and energy intensity—the AEI uses two alternative scenarios.

The first scenario assumes energy intensity remains the same between year 1 and year 2, but the activity increases or decreases. This is called ***static intensity (SI)***[7] and represents what energy use in year 2 would have been if all reporting levels performed *at the same level of energy efficiency as year 1*, but the activity changed.

$$\text{SI (Year 2)} = \text{Energy Intensity (Year 1)} \times \text{Activity (Year 2)}$$

In the example on the following pages, the SI measures how much energy would be needed for orange juice production if the amount manufactured increased (which it did between years 1 and 2), but the energy efficiency of production remained the same.

The second scenario assumes activity remains the same between years 1 and 2, but energy intensity changes. This is called ***static activity (SA)***.[8] The SA represents what energy use would have been if *activity in year 2 stayed the same as year 1* but all reporting levels performed at the same level of energy efficiency achieved in year 2. It is important to note that SA calculates an energy use alternative scenario for comparison to the actual energy in *year 1* because the measured activity is from year 1.[9]

$$\text{SA (Year 1)} = \text{Energy Intensity (Year 2)} \times \text{Activity (Year 1)}$$

In the example on the next page, the SA measures how much energy would be needed for orange juice production if the amount manufactured stays the same between years 1 and 2 but the energy efficiency of production changes.

[7] The SI index uses the same formula as a Laspeyres price index.

[8] The SA index uses the same formula as a Paasche price index.

[9] It may be more intuitive for some readers to consider the SA scenario as the same as SI, only backward. In other words, SI carries year 1 intensity forward to be multiplied by year 2 activity, while SA carries year 2 intensity backward to be multiplied by year 1 activity.

[!] COMPUTE REPORTING LEVEL RESULTS

The energy manager is not surprised that the expansion of the orange juice plant lowered energy intensity because new, state-of-the-art technology was used. The manager is convinced that energy use would have gone up even more had the plant increased production using the plant's older, existing-line technology. The manager can test her theory using a static intensity scenario, in which she multiplies the energy intensity of year 1 (before the new technology) by the amount of production in year 2.

Described another way, the manager is also quite sure that energy use would have been lower in year 1 had the plant implemented the new technology for year 1. The manager tests this theory using a static activity scenario, multiplying the energy intensity of year 2 by the amount of production in year 1.

While production declined in the apple juice plant, energy was almost constant. The resulting increase in intensity could be due to poor shutdown procedures. Warehouse energy intensity also increased slightly; it is less than 3 percent of the total in year 2 but still worth checking. If the apple juice plant and warehouse intensities had stayed the same, energy use would have been lower. The energy manager needs a consistent way to quantify these alternative scenarios to accurately capture the energy program's results. The question is, which alternative scenario is the right one?

Compute the two alternative scenarios for each reporting level to complete Step 2. For each reporting level:

2a. Compute the SI by multiplying the energy intensity in year 1 by the activity in year 2.

- This is the energy use that would have occurred in year 2 if there was no change in energy intensity across time periods.
- This is an alternative scenario of energy use in year 2 using year 1 intensity as the reference.

2b. Compute the SA by multiplying the activity in year 1 by the energy intensity in year 2.

- This is the energy use that would have occurred in year 1 if there was no change in activity across time periods.
- This is an alternative scenario of energy use in year 1 using year 2 intensity as the reference.

On the next page, table 2 illustrates these steps with results from the example above.

Recap of Table 1. Basic Energy and Activity Data

Year 1

	Energy: *Actual*			Activity			Energy Intensity
Report Level A: Oranges	5,000	MMBtu	÷	1,000	lbs.	=	5.00
Report Level B: Apples	1,000	MMBtu	÷	1,000	gals.	=	1.00
Report Level C: Warehouses	500	MMBtu	÷	5,000	sq. ft.	=	0.10

Year 2

	Energy: *Actual*			Activity			Energy Intensity
Report Level A: Oranges	12,000	MMBtu	÷	2,500	lbs.	=	4.80
Report Level B: Apples	990	MMBtu	÷	900	gals.	=	1.10
Report Level C: Warehouses	550	MMBtu	÷	5,000	sq. ft.	=	0.11

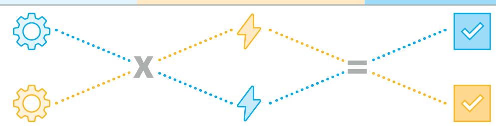
Table 2. Computing SI and SA

Activity (Year 2) X Energy Intensity (Year 1) = Static Intensity

Activity (Year 1) X Energy Intensity (Year 2) = Static Activity

Year 1

	Energy: *Actual*		Activity		Energy Intensity: *Actual*	Energy: *Static Activity*	
Report Level A: Oranges	5,000	MMBtu	1,000	lbs.	5.00	4,800	MMBtu
Report Level B: Apples	1,000	MMBtu	1,000	gals.	1.00	1,100	MMBtu
Report Level C: Warehouses	500	MMBtu	5,000	sq. ft.	0.10	550	MMBtu



Year 2

	Energy: *Actual*		Activity		Energy Intensity: *Actual*	Energy: *Static Intensity*	
Report Level A: Oranges	12,000	MMBtu	2,500	lbs.	4.80	12,500	MMBtu
Report Level B: Apples	990	MMBtu	900	gals.	1.10	900	MMBtu
Report Level C: Warehouses	550	MMBtu	5,000	sq. ft.	0.11	500	MMBtu

Step 3. Compare organization-level alternative scenario energy values to actual energy totals.

The next step is to roll up all the reporting-level values to an organization-level total and then compare the alternative scenarios against the actual energy use. These steps are:

3a. Sum up the actual energy use, SI energy use, and SA energy use values for each reporting level to generate an organization-level total for each year.

3b. Divide organization-level SA energy use by total actual energy use in year 1.

A result less than one reflects improvement in energy efficiency, while a result greater than one reflects a decrease in energy efficiency.

3c. Divide organization-level actual energy use in year 2 by SI energy use.

A result less than one reflects improvement in energy efficiency, while a result greater than one reflects a decrease in energy efficiency.

Steps 3b and 3c compare the organization-level alternative scenarios that are analogous to the reporting-level alternative scenarios calculated in Step 2. SA reflects the possible energy use in year 1 if there were no changes in organization-wide activity at every reporting level; SI reflects the possible energy use in year 2 if there were no changes in organization-wide energy intensity at every reporting level.

Therefore, this analysis answers two related but different questions:

1. *How much would energy have changed between years 2 and 1 if intensity changed but activity stayed the same?* (SA)
2. *How much would energy have changed between years 1 and 2 if activity changed but intensity stayed the same?* (SI)

Both the SA and SI measure how much change occurred, but each holds a different element constant.

To illustrate these steps, Table 3 shows the results from the example on page 12. Here, the SA scenario indicates that organization-level energy use would have been 6,450 million Btu (MMBtu) in year 1 absent any activity change, but the actual energy use was 6,500 MMBtu. This result implies an intensity change of –0.77 percent, or an improvement in efficiency of 0.77 percent, between year 1 and year 2. The SI scenario indicates that organization-level energy use would have been 13,900 MMBtu in year 2 absent any intensity change, but the actual energy use was 13,540 MMBtu. This finding implies an intensity change of –2.62 percent, or an improvement in efficiency of 2.62 percent.

An organization's energy intensity and activity change over time. Both factors must be incorporated into a metric to get an accurate understanding of performance. In comparing these two scenarios to actual energy use, the AEI measures the combined impact of the changes in energy intensity and changes in activity.

[!]

COMPARE ORGANIZATION-LEVEL TOTALS

The energy manager knows that changes in activity and intensity have happened at all reporting levels that assess energy use and that each alternative scenario answers different questions about what would have happened "if production expanded at the orange juice plant but used the old technology" and "if new technology was implemented but production had not grown." Both approaches show the energy program had a positive impact, but one implies an impact that is three times larger than the other.

Table 3. Computing the Organization-level Alternative Scenarios for SA and SI

Energy: *Static Activity* ÷ Energy: *Actual* = **SA Index**

Energy: *Actual* ÷ Energy: *Static Intensity* = **SI Index**

Year 1

	Energy: *Actual*		Energy: *Static Activity*		Activity		Energy Intensity: *Actual*
Report Level A: Oranges	5,000	MMBtu	4,800	MMBtu	1,000	lbs.	5.00
Report Level B: Apples	1,000	MMBtu	1,100	MMBtu	1,000	gals.	1.00
Report Level C: Warehouses	500	MMBtu	550	MMBtu	5,000	sq. ft.	0.10
Total Energy	6,500	MMBtu	6,450	MMBtu			
SA Index	6,450	÷	6,500	=	**0.9923**		

Index: Change based on alternative scenarios.

Description: Change in energy efficiency between years based on holding year 1 activity constant.

Interpretation: If year 1 activity was accomplished at year 2 intensity, how much would an organization's energy intensity change?

Year 2

	Energy: *Actual*		Energy: *Static Intensity*		Activity		Energy Intensity: *Actual*
Report Level A: Oranges	12,000	MMBtu	12,500	MMBtu	2,500	lbs.	4.80
Report Level B: Apples	990	MMBtu	900	MMBtu	900	gals.	1.10
Report Level C: Warehouses	550	MMBtu	500	MMBtu	5,000	sq. ft.	0.11
Total Energy	13,540	MMBtu	13,900	MMBtu			
SI Index	13,540	÷	13,900	=	**0.9741**		

Index: Change based on alternative scenarios.

Description: Change in energy efficiency between years based on holding year 1 intensity constant.

Interpretation: If year 2 activity was accomplished at year 1 intensity, how much would an organization's energy intensity change?

Step 4. Compute the organization-level AEI.

The final step is to calculate the organization-level AEI. To reconcile these two alternative scenarios, the AEI combines them by using the *geometric average*[10] of the **SA** and **SI** index.

$$\textbf{AEI} = \sqrt{\text{SA Index} \times \text{SI Index}}$$

If the AEI is less than one (i.e., energy intensity has declined), the company's energy efficiency has improved.

Table 4 shows the results for the example on this page.

Table 4. Computing the Organization-level AEI

	AEI
Static Activity (SA)	0.9923
Static Intensity (SI)	0.9741
AEI (geometric average of SA & SI)	0.9832

Organizations may use the AEI to determine percent changes in energy intensity, as shown in Table 5.

Table 5. Computing the Organization-level Change

	AEI	Percentage Change (1 - AEI)	Rate of Change [ln(AEI)]
Static Activity (SA)	0.9832	1.68%	-1.70%

Calculating a simple percentage change is achieved by taking 1 minus the AEI, for an improvement in efficiency of 1.68 percent (1 - 0.9832) between year 1 and year 2. Calculating the annualized rate of change involves taking the *ln(AEI)*. Here, the ln(0.9832) equals -1.70 percent annualized rate of change in intensity.[11]

[!] COMPUTE THE AEI

The Apple & Orange Co. energy manager might be tempted to report the larger result from the two scenarios, but she knows that both activity and intensity have changed and wants the program results to be credible with all the stakeholders. She takes the average of the SA and SI rates of change in energy efficiency as a compromise. After reading the ENERGY STAR guidance for reporting organization-level intensity, she can justify her choice because this approach is the one that best reflects the changing circumstances in her company. With an AEI of 0.9832, she can report a simple percentage change of 1.68 percent, and an annualized rate of change of -1.70 percent.

[10] Geometric average is the correct way to average ratios. An arithmetic average will not produce consistent results.

[11] The annualized rate of change is a continuous compound rate.

Other use cases

The above example used to illustrate Steps 1 through 4 focused on changes in production and differences in products, but the AEI method can accommodate other changes in business operations and activities.

Opening or closing locations

A company can incorporate the impact of opening new locations or closing existing locations by taking the following steps:

1. Including a separate reporting level for the location.
2. Inputting the energy intensity for the year the site was open into both analysis years (e.g., years 2 and 3).
3. Inputting the activity and energy use as zero for the year the site was not operating in the company's portfolio.
4. Inputting actual activity and energy use for the year the site was operating in the company's portfolio.

All other calculations for the AEI remain the same.

Computing the AEI over multiple years

To compute the AEI over more than two years, such as between years 1, 2, and 3, there are two options:

1. The first is to simply compute the AEI between years 1 and 3 directly. This finding would reflect the change in organizational energy intensity relative to year 1.
2. The second provides a more dynamic and accurate approach for an organization that is constantly evolving. In this alternative, compute the AEI between years 1 and 2 and then between years 2 and 3. This will result in two indices: **$AEI_{1,2}$** and **$AEI_{2,3}$**, and their associated rates of change in energy efficiency (Tables 6 and 7).

[!] EXPANDING THE AEI FOR OTHER USES

The following year (i.e., year 3), Apple & Orange Co. opened its first tomato juice plant. The energy manager has new data for production and energy use and can compute the tomato juice plant's energy intensity, along with data from the other reporting levels for the new year. She can update the company's AEI quite easily. She simply adds a new reporting level to represent the tomato juice plant to compare year 2 and year 3.

For activity, she uses zero production in year 2 but uses the energy intensity she computed in year 3 for both years. She computes the SA, SI, and AEI in the same manner as before. This approach will measure the company's energy intensity change that accounts for the new plant. To find the total change for the two years, she adds the AEI rates of change in energy efficiency from each time period.

To calculate the AEI Index, multiply $AEI_{1,2}$ x $AEI_{2,3}$. This result in Table 6 shows the "chained" $AEI_{1,3}$. In this example, the chained $AEI_{1,3}$ is 0.9754.

$AEI_{1,2}$ X $AEI_{2,3}$ = **AEI Index**

0.9832 X 0.9921 = **0.9754**

Table 6. Computing the Organization-level AEI Over Multiple Years

Time Period	AEI
Years 1–2	0.9832
Years 2–3	0.9921
Years 1–3 ($AEI_{1,2}$ x $AEI_{2,3}$)	0.9754

Using the annualized rate of change, Table 7 shows the organization improved its energy efficiency by 2.49 percent between years 1 and 3.

Table 7. Computing the Organization-level Rate of Change Over Multiple Years

Time Period	AEI	Rate of Change [ln(AEI)]
Years 1–2	0.9832	-1.70%
Years 2–3	0.9921	-0.79%
Years 1–3 ($AEI_{1,2}$ x $AEI_{2,3}$)	0.9754	-2.49%

Using regression normalization to enhance efficiency estimates at individual plants

Statistical methods, such as regression modeling, can be helpful for accounting for factors that may impact energy use independent of operational activity. These approaches are frequently used at the facility level.

The AEI can incorporate normalized energy intensity metrics (e.g., weather-normalized energy use intensity) and regression model metrics. If using a regression model for a facility, substitute the regression-based results into the Static Intensity column for that facility's row in Step 2.

Other sustainability metrics

Any kind of sustainability metric (e.g., carbon, water, solid waste) that can be measured consistently at all reporting levels can be used as the numerator in place of energy. Applying the AEI approach will result in an aggregate index for that corresponding sustainability metric.

JUSTIFYING THE AEI TO STAKEHOLDERS

The Apple & Orange Co. energy manager submits her program results for the company's annual sustainability report. The vice president in charge of the report wants to understand how the energy manager arrived at this result. The energy manager can first explain that while there are alternatives, the AEI consistently handles a wide range of changing circumstances in the company, such as the major expansion of the orange juice plant and the opening of the tomato juice plant next year. Because the company is diverse, the AEI allows her to choose the reporting levels that reflect that diversity. She also can tell the VP that the AEI was not something she just "made up" but is based on a similar approach for "adding up apples and oranges" used by the federal government to measure inflation. Finally, she can close with the fact that the approach is based on guidance from the ENERGY STAR program for organization-level reporting of energy efficiency.

CONCLUSION

This guide has introduced the AEI as one approach for measuring energy performance in organizations that combine a mix of diverse activities and changes in those activities over time. While no single metric is perfect for all circumstances, the guide demonstrates the AEI's flexibility to accommodate many situations, including diverse product mixes, multiple space types, expansive geographies, acquisitions, and divestitures. For another example of how a highly diverse manufacturer has successfully integrated the AEI into its energy management program and culture, see the case study from Corning Incorporated in the appendix.

As energy managers gain experience applying the AEI approach, they may choose to add more sophisticated components, such as normalization, and apply them to a broader set of uses. For more help in assessing these opportunities, contact energystrategy@energystar.gov.

ABOUT THE DEVELOPER OF THE AEI

Dr. Gale Boyd is an associate research professor at Duke University. With more than 30 years of experience, Dr. Boyd's areas of expertise include indices for measuring energy intensity changes; microeconomic modeling of industrial energy demand, emissions, and productivity; forecasting activity and energy demand in various economic sectors; and integrating these analyses into models of the energy market.

As a member of the ENERGY STAR team, Dr. Boyd has worked closely with a subset of ENERGY STAR partners who have particularly diverse product and facility portfolios. His goal is to understand the approaches these partners use to measure energy intensity and to assess their metric needs and any shortcomings of existing approaches. All participants have tested the ENERGY STAR AEI and added it to their toolboxes.

APPENDIX: CORNING INCORPORATED CASE STUDY[12]

Corning Incorporated manufactures a variety of products, ranging from life science labware to fiber optic cable to glass screens for smartphones. Corning has organization-wide sustainability goals, including improving energy efficiency. To help achieve these goals, Corning's Global Energy Management (GEM) team was tasked with developing and tracking energy performance metrics for its plants around the world. Using both production data and the energy data it collects, GEM developed a variety of key performance indicators (KPIs), including energy intensities for each reporting level. Although these KPIs were useful for tracking the performance of each reporting level over time, GEM struggled to provide senior management with a metric to track the company's overall progress on becoming more energy efficient. While some business units might normalize energy use by square footage, other units used pounds or other measures of production. To make matters more complicated, the production demand for certain products changed significantly over time.

For total organization-level reporting, GEM considered using total energy per dollar of revenue as the overall metric, but that metric fluctuated and showed no clear trend despite energy changes being observed at all the reporting levels. The GEM team realized that there would not be one perfect metric for normalizing energy at the organizational level. Their business units were simply too disparate.

GEM needed a way that accounted for the uniqueness of their operations and that would be conducive to rolling up into one organizational metric. The team decided to use an AEI approach. The AEI calculated the energy intensity of each business unit and then modeled how each unit would perform if conditions (i.e., production demand) stayed the same and no new buildings or plants were added or removed between the baseline and the performance years.

GEM tracked quarterly data from several reporting levels between 2008 and 2012. Corning already tracked units of saleable product (UoSP) for each reporting level for other KPIs across the company. Although the UoSP is different for each operational segment of the company, this standard corporate UoSP metric allowed GEM to compute the energy intensity for the different segments of the company but not for the company overall. Total energy per dollar of revenue remained largely unchanged over the four years. No simple trend was evident from the seven reporting levels' energy intensities: Some increased, some declined, and some stayed the same. The UoSP for the different segments of the company were all growing at different rates. While energy per dollar of revenue was roughly constant over the four years, the AEI showed that energy efficiency improved at an average quarterly rate of 0.8 percent, with aggregate fuel intensity declining at 1.2 percent and aggregate electricity intensity at 0.4 percent.

This reduction aligned with performance they were seeing on a business unit level and with energy savings opportunities they were implementing. The GEM program had clear success over the four years but needed the AEI to demonstrate GEM's value to Corning. Since 2012, much has changed at Corning, but the AEI has continued to provide the company with the ability to consistently measure its energy performance over time.

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[12] Adapted from Gale Boyd and Jay Golden, "Enhancing Firm GHG Reporting: Using Index Numbers to Report Corporate Level Measures of Sustainability," *International Journal of Green Technology 2*, (2016): 29–37, https://www.researchgate.net/publication/301651085_Enhancing_Firm_GHG_Reporting_Using_Index_Numbers_to_Report_Corporate_Level_Measures_of_Sustainability#fullTextFileContent.

Aggregate Efficiency Index

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