Daily Energy Use Index (DEUI)

Using Daily Meter Readings to Improve Operating Efficiency for Buildings, Plants, and Processes

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ABSTRACT

This article describes a technique to monitor and analyze daily energy use patterns and develop a daily energy use index (DEUI) as an operations target. The technique can also identify abnormal daily energy use of buildings, plants, and processes. The technique is to use daily use meter readings, statistically analyze them, and use the average of a statistically significant number of readings as a DEUI. The daily use readings can be used with statistical process control (SPC) techniques to calculate the upper and lower control limits (DEUI range). These are used to detect unusual energy use from operations and provide an indicator for immediate investigation and correction by building or process operators.

DAILY ENERGY USE INDICATORS (DEUI)

Mixing Behavior, Energy, and Statistical Process Control

Do you know how many miles you put on your car each day? Or can you make a good guess? Probably you can. And if you were paying attention over a few days, you'd notice if your teenager used the car for an unusual 100-mile trip!

The behavior part of this article refers to the learning process one might go through to recognize unusual information like the 100-mile trip. It is simple, intuitive, and low-tech, and it might go something like this:

How many miles do I drive the car each day? I'd track the mileage at the same time each day in a log and subtract the entries to get the difference, which would be the miles per day. After a few days, I'd

have a good feel for how many miles per day I was using the car—and it wouldn't involve any statistics. At this point, I'd notice when my teenager put on the extra 100 miles by comparing the unusual mileage for that day to the more typical use (or average).

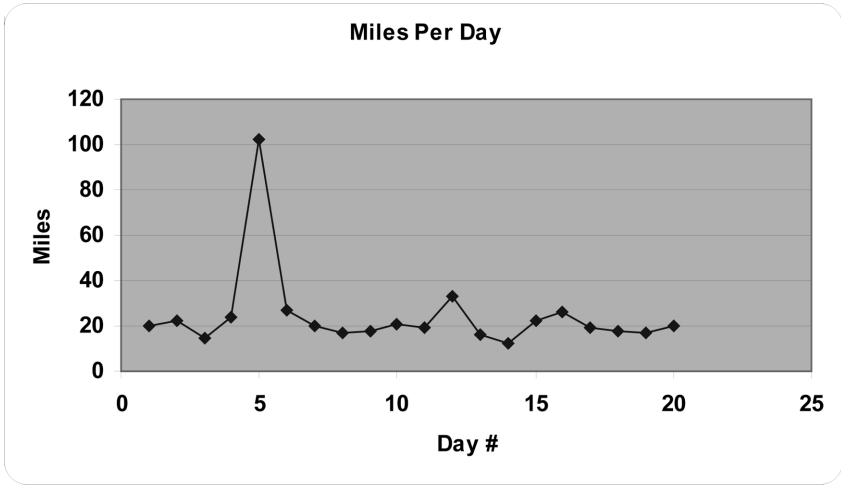

Figure 1.

This little story contains the essence of a simple energy management tool called the daily energy use index or DEUI. The DEUI is a single number that represents the typical energy use per day. In the example above, the DEUI is about 20 miles per day based on visual inspection of the chart. Many aspects of our lives have a daily cyclic pattern, and most energy use has a daily cycle as well. A daily measurement of energy use is simple to understand and use.

The DEUI tool can be used to monitor usage of water, natural gas, oil, steam, electricity, or whatever commodity one wishes.

Examples of DUI in Use

The simplicity, power, and intuitive nature of the DEUI tool were demonstrated in a Kansas City school district when a shop teacher became the district's energy czar. He explained his process to me as follows: First he decided readings from the energy and water meters were the measurement of success for the program, so he concentrated

on getting data from the meters and understanding what was happening, when, why, and what could be done, if anything. His technique was to ask the custodians to write down the meter readings at the same time each day for electricity, natural gas, and water, and calculate the usage daily. Initially, he called each custodian every day to discuss the readings and understand what had happened in each facility on the previous day that might have affected the readings.

Very quickly, the metered effects of evening classes, public meetings, weekend events, games, etc., became obvious, but so did unusual operations such as leaving the gym lights on or an air handling unit in operation. The czar had used the readings to build his and the custodians' understanding of building operations and to establish accountability for energy and water use with the custodians. The custodians quickly became sensitized to the effects of unusual operations and changed or managed operations to improve the numbers. This approach resulted in a 25 to 30 percent savings for the district within three years.

A second example of using the technique comes from a massive poultry processing plant where increasing water consumption was a major cost and environmental issue. In discussions with the plant manager, the plant engineer was asked how they could reduce water use from 1.25 million gallons per day. The engineer, who had been tracking the daily water usage for some time, replied, "Set the goal at 900,000 gallons per day, support it, and it will get done." The engineer obviously had prepared for the discussion and used the daily use number to get management support for his plans. He focused his maintenance and plant operations on improving water practices, provided processing managers with the daily usage for their management efforts, and provided staff training in ways to reduce water use. Near the end of the year, the plant was averaging 900,000 gallons per day!

Others[1] have found that daily use information has limited value if the building or plant operations vary significantly and predictably by the day of the week. One technique in this case is to pre-sort data by the day of the week, e.g., Monday or Tuesday, etc., and then perform DEUI and statistical process control (SPC) analyses for Mondays or Tuesdays, etc. Michael Brambley[3] has refined the technique further by segmenting hourly meter readings (9 a.m. Tuesdays) for each weekly hour and temperature bin (45-50°F).

Statistical Tools

The power of the DEUI comes from applying rigorous statistical tools to daily-metered energy information from buildings, industrial processes and/or energy intensive processes, and equipment.

The good news is that the rigorous statistical tools are well developed and currently in wide use in most industrial production applications worldwide. We in the energy management business don't have to reinvent this wheel; we just need to learn to use these tools in a multitude of ways that will enhance the credibility, results, and power of our work.

And more good news: information from the statistical tools is intuitive and user friendly (really). The quality control (QC) industry has had many years to develop these tools and, while energy management applications don't challenge some of the statistical capabilities, the QC industry has refined the tools so they are simple to understand and intuitive to use, even on the shop floor.

The purpose of this article is to suggest a method to improve energy management practices and conservation in buildings and processes using the DEUI concept and statistical tools. It works this way:

1. A meter is read at the same time each day.

2. The reading is put into a database.

3. The daily meter readings are subtracted, giving the difference or the usage for the day.

4. After 40 or so readings, the data are sufficient to provide a statistically significant basis for calculation of the DEUI.

5. A sliding window of the last 40 readings is averaged to provide the DEUI.

6. The daily usage is tracked and analyzed with a statistical toolbox called statistical process control (SPC).

7. SPC analyzes data and detects when meter readings are within or outside a set of statistical limits (upper and lower control limits, UCL and LCL). The UCL and LCL are tests that compare the daily

readings to the DEUI and calculate the number of standard deviation units the actual reading is from the average (between the LCL and UCL).

8. If the latest reading is within the selected UCL/LCL range, the reading is judged to be normal, but if it falls outside the UCL/LCL range, it is judged to be unusual.

9. An automatic communication system may be used to notify the responsible person when an unusual reading is recognized. This should be the start of an analysis process by the operator to determine what occurred the day before to cause the unusual reading. Further diagnostic information may be available if more frequent data readings have been taken, e.g., 15-minute, 30-minute, or one-hour intervals.

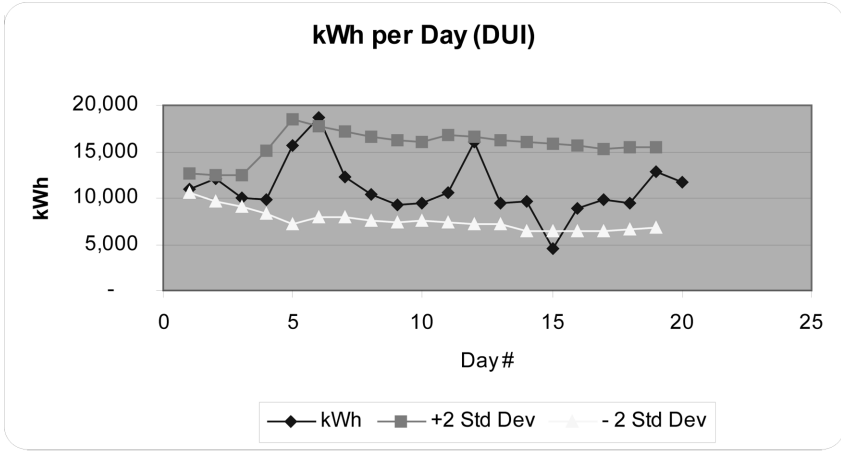

Figure 2.

SUMMARY

The DEUI is an intuitive, logical, and powerful tool for managing energy operations in buildings or processes. Detecting daily excursions allows energy managers to investigate, diagnose, and correct energy problems before they become embedded and part of normal operations. The DEUI can become a target to beat for motivated building

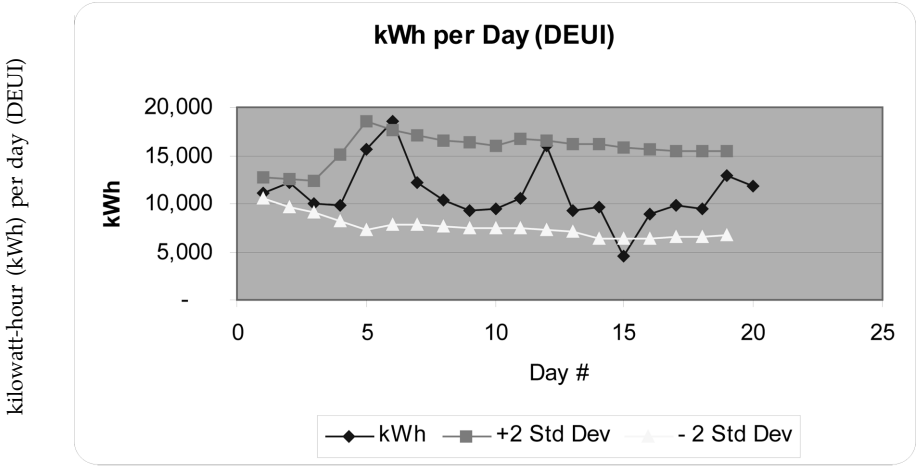

Figure 3.

and process operators, thus contributing to the energy efficiency of the enterprise or organization.

The DEUI may be the result of more complex analytics if and when adjustments are made for weather and "production" variables. However calculated, its value as an operating target remains.

What is Std Dev?

Std. dev. stands for standard deviation units, a statistical measure of how far a particular reading is from the average of the group. Statistically, for a "normal," "bell shaped" group, about 68 percent of the measurements will lie within +/-1 std. dev. unit from the average, 95 percent within +/-2 std. dev. units, and essentially all readings will be within +/-3 std. dev. units.

When the statistical calculations for standard deviation units are applied, a new term and function have been developed by quality control practitioners called the upper and lower control limits. The statistical range between the upper control limit (UCL) and the lower control limit (LCL) represents conditions where the readings from the process are "in control." This is set at +/- 2 std. dev. in this example and is represented by the upper points (UCL/squares) and the lower points (LCL/triangles). Note that the readings could be from a building, process measurement, or other consistent data source.

In this application, by specifying +/-2 std. dev. units for our control limits, we are saying that if a reading is outside the range that includes 95 percent of the readings, it is "out of control." A common setting for control limits is +/- 2 std. dev. units, but they can be set as close or as wide as desired.

Interpreting the Graph

In Figure 3, the central graphic points (diamonds) represent the kilowatt-hour (kWh)/day readings. We see consumption rising sharply on Day 5, and exceeding the UCL on Day 6. Trends in these lines should be interpreted more strongly than individual points, so we would expect some unusual condition or problem that caused the results on Days 5 and 6. Similarly, Day 15 is below the LCL, but this is a one-time point so the cause may be a singular event such as shutting down production or heating, ventilating, and air conditioning (HVAC) for some time. Generally, the UCLs and LCLs are useful in screening the daily data to identify only those points that seem to be unusual enough to warrant notice and investigation, thus saving operator time.

The other useful feature of the graph is the plot of the actual kWh/day of the facility. In this case, looking at the graph, the daily use is about 10,000 kWh/day (+/-). Averaging about 40 recent measurements of this number can become a useful "target" for operators to judge performance on any typical day. Over time, if operators drive the "target" lower, they will achieve significant conservation. Non-typical days may require additional analyses as above.[1,2,3]

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