New thinking on performance metrics

Vilnis Vesma explains why simple performance indicators are dangerously misleading, and how to replace them with something equally simple but more accurate and meaningful.

In much energy management literature there are references to the use of energy performance indicators (EPI) such as kWh per tonne of product. The root of the problem with EPIs expressed in this way is that they rely on the false assumption that energy consumption is directly proportional to production throughput or other 'driving factor'. This is very rarely the case. The truth is that there is usually some fixed base-load consumption which does not vary with throughput, and this makes the simple overall EPI variable and dependent on throughput. Let us take an example drawn from real life: a metals-processing operation which had a base-load electricity consumption of 10 MWh per month, plus a production-related load of 0.66 MWh per tonne.

Two months can be singled out which illustrate the problem very well:

Month	Electricity (MWh)	Production (tonne)	Energy performance indicator (MWh/tonne)
January 2008	96	118	0.814
March 2009	45	52	0.865

At first sight, performance in March 2009 with an EPI of 0.865 MWh/tonne appears to be worse than in January 2008, at only 0.814 MWh per tonne. But the eagle-eyed reader will note that production was much higher in the latter case. Could this account for its better EPI?

If we note that we expect to use 10 MWh per month regardless, and that each additional tonne processed should require only 0.66 MWh on top of this, the picture is different. We see that in March 2009 (52 tonnes) we would have expected to use 10 + 52 x 0.66 = 44.3 MWh; we actually used 45, just 0.7 MWh in excess. However, in January 2008 (118 tonnes) we would have expected to use 10 + 118 x 0.66 = 87.9 MWh whereas we actually used 96. This was 8.1 MWh in excess and therefore, in truth, a far worse outcome. So the month with the 'better' EPI was actually significantly worse than the other, which was close to target.

Without labouring the point any further, industrial energy managers who use EPIs for day-to-day management cannot actually see what is happening because the EPI is a moving target. Many are aware of this and struggle to find a solution which hopefully this article has already begun to suggest with the idea that we can estimate *expected* consumption by reference to a relevant driving factor. Indeed an expected-consumption formula (ECF) can be devised for most significant energy uses and can, in principle, accommodate any number of driving factors and variables – something an EPI can never do, as it relies on energy being dependent on a *single* factor.

Performance deficits

There is a further objection to EPIs even in those rare situations where they can legitimately be applied. It is the fact that they are only ratios, and as such contain no information about the *scale* of deviation from expected consumption. Most of us would like to know how many kWh we have lost or saved. Some simple examples will serve to illustrate the point. Let's suppose we have:

- a burner operating with 79.5% combustion efficiency;
- an air compressor using 0.18 kWh per m^3;
- a car giving 40 miles per gallon; and
- a building using 152 kWh of electricity per square metre of floor area.

How do we tell if these figures mean their performance is good or bad? And if it is bad, how bad is it? And here is a strange but perfectly legitimate question: which is worse, the car or the air compressor?

For the sake of argument let us say that all these cases have poor performance. Specifically, let us suppose that:

- The burner is capable of 82.3% combustion efficiency;
- The car should give 42 mpg;
- The air compressor ought to need only 0.14 kWh per m^3; and
- A typical building of the same type should only use 120 kWh/m^2

Does this leave us any better informed? Slightly, because we can at least estimate percentage deviations. But percentages don't help. We need to know the percentage of *what*. A small percentage of major energy consumption might be much more significant than a large percentage of a small one.

So let us now add in the final missing information – the scale of consumption. Starting with an easy case first, the air compressor, suppose that in a typical year it delivers 40,000 m^3 of air. With actual and target performance indicators of 0.18 and 0.14 kWh per m^3 respectively, it will use more electricity than necessary to the tune of (0.18 – 0.14) x 40,000 = 1,600 kWh per year.

Similarly if the building in question has a floor area of 3,000 m^2 its apparent excess annual consumption would be (152 – 120) x 3,000 = 96,000 kWh.

In each case we have, by taking note of the *scale* of consumption, converted the target and actual performance ratios into an absolute kWh figure which we could term the *performance deficit*. Performance deficits are expressed in terms of energy quantities (kWh in these examples) which in turn can be expressed as costs or carbon emissions. Here they were annual figures, but they can obviously be evaluated over any desired interval.

The other two examples can also be expressed as performance deficits although the arithmetic is a little more complicated. Take the combustion example. Suppose the burner is currently consuming 9,400 m^3 of gas per year, or 100,000 kWh. At its present efficiency of 79.5% it must be delivering 100,000 x 0.795 = 79,500 kWh of useful heat. To supply the same amount of useful heat at a combustion efficiency of 82% would require 79,500 ÷ 0.82 = 96,951 kWh, or 3,049 kWh less than at present. This, then, is its annual performance deficit. Note that the figure is more than you get when you multiply the 2.5 percentage-point shortfall by the annual consumption. When we describe performance as an efficiency ratio or percentage, the formula for the deficit is:

consumption x $(1 - \eta_{actual}/\eta_{target})$

where η represents the efficiency.

Lastly, to compute the performance deficit for the car, note that it should consume only 1/42 gallons per mile, but actually uses 1/40 gallons. So for 30,000 miles its excess fuel consumption will be 30,000 x (1/40 – 1/42) = 38.1 gallons, the equivalent of 411 kWh.

So there we are: we can not only compare these four disparate objects according to their annual performance deficit, but we can rank them as well in order of importance:

Object	**Performance deficit kWh per year**
Building	96,000
Burner	3,049
Compressor	1,600
Car	411

Ranking *annual* performance deficits in this manner echoes the principle of the overspend league table which I have long promoted as the most efficient approach to exception reporting. In the overspend league table, performance deficits are computed every week, month or day (according to the user's preference) and ranked in cost rather than energy terms. But the principle is exactly the same, with expected-consumption formulae used in conjunction with relevant driving-factor data to generate figures against which short-term actual consumption can be gauged – a procedure required for compliance with EN 16001, section 3.5.1.

Expressing savings

When we use the term 'performance deficit' to describe excess kWh consumption, it is relative to consumption that would be expected when the monitored object is operating at best achievable efficiency. What if consumption is less than expected? The preferred term here is 'avoided energy consumption'. This expression is used in the International Performance Measurement and Verification Protocol, a respected convention which sets out rules and procedures for objectively calculating the savings that have accrued from energy-efficiency measures[1].

Avoided energy consumption, however, is not exactly the same as a negative performance deficit because it is computed relative to *historical baseline* consumption. Historical baseline consumption is that which would have been expected at the outset of

[1] Available to download free at www.evo-world.org

your energy management programme, before improvements were put in place. It is usually calculated using the same basic expected-consumption formula, just with a different set of constants embedded in it so that given the production, weather, or other relevant driving-factor data, it yields an estimate of the consumption that would have been expected in the absence of subsequent energy-saving measures.

Conclusion

The concept of the 'performance deficit' provides a rational way to compare and rank performance, without the distortions introduced by simple ratio-based performance indicators, and in terms of the amount energy apparently lost.

With its counterpart 'avoided energy consumption' it offers the prospect of unifying two important energy-management activities: the detection of unexpected waste and the verification of savings.

To calculate either avoided energy consumption or performance deficits it is necessary to develop an expected-consumption formula for each monitored stream of consumption. This will often be as simple as a straight-line relationship with degree days or production output, but can be made more elaborate to cater for more complex scenarios.

Training in these techniques is available from the author: see www.vesma.com/training/mtworkshop50.htm

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