EM Magazine

ENERGY GUIDE

In Association With: CHAUVIN ARNOUX

MEASURING AND MONITORING:

THE KEYS TO EFFICIENCY AND PROFIT

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Control is the key to business success. But what is it that you need to control? Many things, of course, but two very important items are your energy bills and the working environment in your premises. Even if you don't care about these things – which is hopefully rather unlikely – there are rules and regulations which mean that take control of them you must!

Of course, before you can control something, you have to be able to measure it, which is why, with the help of industry experts Chauvin Arnoux, we've devoted this Energy Guide to guidance about measuring and monitoring. This is vital information you won't want to – and can't afford to – ignore!

Before we start looking at specifics however, let's clear up one important point. What's the difference between measuring and monitoring? The answer, for our purposes at least, is that a measurement is a one-off event – "the temperature in the office right now is 21 °C" – is a measurement. However, monitoring involves recording the temperature (or another parameter) over a period of time, which might be just a few hours, but it could also be months or even years.

The benefit of monitoring, which is usually performed by instruments that have a logging function, is that it provides much more useful information than individual measurements. It might reveal, for example, that the office temperature is still above 20ºC in the middle of a winter night, when it could be allowed to drop to, say 10ºC, which would save a lot of energy. Monitoring over extended periods will also allow circadian and seasonal effects to be detected and evaluated.

With that important distinction clarified, let's move on to look at specific parameters that you may want to measure and monitor, starting with those that affect the working environment.

Temperature can, of course, easily be measured with a simple and inexpensive thermometer. Indeed, employers are required by law to provide thermometers. Nevertheless, there are distinct advantages to using more sophisticated instruments, not least because they are likely to be more accurate, and if they are logging types like the Chauvin Arnoux C.A 1227, which also incorporates an anemometer for measuring air velocity and air flow, or the C.A 1246, which incorporates a hygrometer for measuring humidity, they will make it possible for monitoring to be carried out over extended periods.

The logging of temperature over extended time periods is particularly useful, as it can reveal when heating and cooling systems are being operated unnecessarily, when rooms are prone to overheating in sunny weather and when they cool too quickly in cold weather. These findings point the way to simple and often inexpensive remedial measures, such as fitting reflective foil on windows or installing additional thermal insulation, which can lead to big energy savings.

Measuring light levels to improve business productivity

Getting the temperature right in any kind of business premises brings enormous benefits in terms of efficiency and productivity. No one is at their best if they are shivering or sweltering – in either case, their work rate slows, and because they find it harder to concentrate, they're much more likely to make mistakes. What is perhaps less obvious is that poor lighting can have equally deleterious effects, even for seemingly mundane tasks like reading or operating a computer.

A quick internet search will produce a plethora of hits detailing investigations that show strong links between lighting and worker performance. Fortunately, measuring and monitoring light levels is easy with a logging luxmeter, such as the Chauvin Arnoux C.A 1110.

These instruments are typically small enough to be handheld, and the best will give accurate results with virtually any type of light source: daylight, LED, incandescent, fluorescent, etc. A good luxmeter will also provide a mapping function that allows the light levels over an area or room to be mapped to determine whether or not they are uniform. Some models have a sensor with a magnetic base, which is an added convenience as it allows the user to position the sensor and move away to avoid casting their shadow across it. The magnetic base is also an advantage when the sensor is installed semi-permanently for monitoring purposes.

Ventilation in a COVID world

Instruments for measuring temperatures and light levels need little justification, but what about anemometers, hygrometers and air quality meters?

In reality, these are also easy to justify. Not only do the Health and Safety at Work regulations require the provision of ventilation, the current COVID situation means that efficient ventilation has become more important and more necessary than ever, as it has an essential role to play in reducing the risk of disease spreading in indoor spaces. Unfortunately, providing effective ventilation without creating uncomfortable, energy-wasting draughts can be challenging. An anemometer is an almost essential aid in achieving the right balance, as it enables air movement to be identified and measured, which makes it much easier to plan and implement draught-free ventilation schemes.

Air quality meters, such as the C.A 1510, can monitor and log several parameters including CO_2 levels which is an indicator of the effectiveness

of the ventilation system. According to The Health and Safety Executive (HSE) “People exhale carbon dioxide (CO_2) when they breathe out. If there is a build-up of CO_2 in an area, it can indicate that ventilation needs improving. Although CO_2 levels are not a direct measure of possible exposure to COVID-19, checking levels using a monitor can help you identify poorly ventilated areas.”

Analysing humidity in the workplace

Closely associated with ventilation and air movement is humidity, which is another key parameter of the workplace environment. Excessive humidity can lead to sweating and discomfort, while insufficient humidity can lead to dry, sore eyes. For these reasons, the Chartered Institution of Building Services Engineers recommends that humidity in the workplace should be maintained between 40% and 70%. As always, the first step to achieving this is accurate measurement. This is readily achieved with a hygrometer, such as that incorporated in the Chauvin Arnoux C.A 1246 digital thermo-hygrometer.

Measuring and monitoring the working environment so that it can be controlled effectively is, as we have seen, vital to the success of every business. It’s equally important to

measure and monitor the amount of energy that's being used to control that environment, and more widely, the amount of energy the business is using for all of its operations.

In some businesses, such as retail outlets, the environmental services like lighting, heating and air conditioning may be the dominant users of energy, but in other businesses the situation is very different. In factories, the energy used by the production equipment is often many times greater than that used for environmental services. Irrespective of this, controlling energy usage and reducing energy costs is prime concern for those who wish to operate their business profitably – and to minimise the environmental impact of their operations. The need for the latter is becoming even more apparent with recent weather extremes and the UN's Intergovernmental Panel on Climate Change (IPCC) stating "the human-caused climate crisis is worsening extreme weather around the globe."

Measuring energy expenditure

Before we look at measuring and monitoring energy usage, however, which is a big topic in its own right, there's a crucial – if slightly peripheral issue – that needs to be discussed in relation to reducing expenditure on energy. This is the seductive appeal of addressing the problem by doing no more than switching to an energy supplier with a more competitive tariff. There's nothing intrinsically wrong with using low-cost suppliers, of course. In fact, every conscientious business manager should always be on the lookout for the most competitive energy deals. The problem arises when lower energy prices are seen as an alternative to reducing energy usage.

An analogy may help to make this clearer. If you discovered that your car was using more fuel than it should, and you found out that the fuel tank was leaking, what would you do? Would you try to keep your fuel costs under control by finding a garage that sold cheaper fuel, or would you have the leak fixed? The right answer, of course, would be to do both, but repairing the leak would surely have to be the priority! It is the same with energy usage. It is crucial to find the best energy prices, but it's arguably even more important to maximise energy efficiency, as doing so will protect your pocket (probably for much longer than those 'special' energy prices will last!), while at the same time helping to protect our planet.

With all of this in mind, let's return to the issue of measuring and monitoring energy. We'll be looking specifically at electrical energy, as this is by far the most used type of energy in the majority of businesses.

What doesn't get measured doesn't get managed!

Let's start by considering a couple of deceptively simple questions: in your own business, do you know where and when electrical energy is being used? If you can answer yes to both these questions, you are very much in a minority among business owners. Almost all of them know how much they're spending on electricity, but very, very few have an accurate picture of where that money is going. And without that information, they are unlikely to be able to take control of their energy bills.

The solution, as always, is to measure and monitor. The most convenient and effective way of doing this is to use a portable energy logger (PEL). The latest generation of PELs, such as those in the PEL 103 range from Chauvin Arnoux, are compact, lightweight electronic monitoring instruments that have been developed specifically to make it easy to collect electrical data. They can be temporarily placed in distribution panels or even around the premises, without difficulty and without the need to interrupt the mains supply or turn equipment off.

PELs gather data and calculate key electrical parameters such as three-phase current power and energy, along with phase angle, power factor, and harmonic levels. The best instruments

of this type can store millions of readings, collected automatically over time, and this data can be retrieved locally or remotely via a USB, Bluetooth or Ethernet connection, or even Wi-Fi and 3G on newer models.

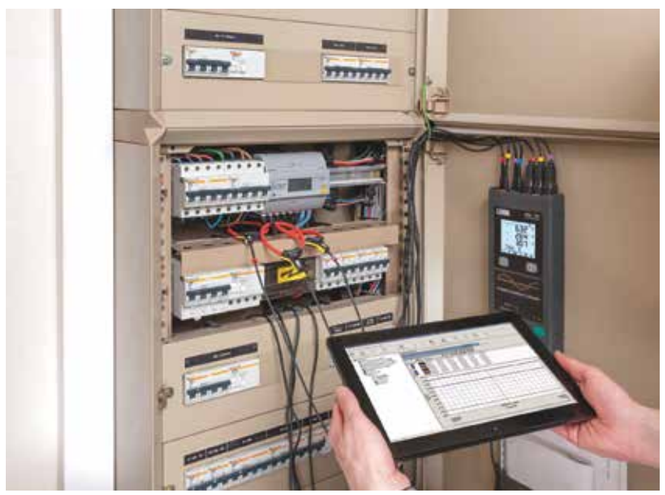
In large premises or where a business operates from multiple locations it's often convenient to install PELs in several different places. Data from all of them can be retrieved to a single location, without the need to visit each PEL to interrogate it. PELs can also be moved around an installation to provide convenient local monitoring of departments or even individual items of equipment.

Using a PEL for energy usage measurements

We'll look later at some of the more technical data that can be collected using a PEL, but for now let's confine ourselves to simple power measurements on individual circuits which will help answer questions about where and when energy is being used. When you look at the results of these measurements, be prepared for a surprise or two! You are, for example, likely to discover that lighting is responsible for a much larger proportion of your energy bill than intuition would lead you to expect.

In fact, lighting typically accounts for up to 40% of a building's electricity consumption, which makes it very worthwhile to look for ways of reducing this figure. Fortunately, this can now be achieved relatively straightforwardly by changing over to LED light sources. Admittedly, this is likely to involve some investment and some effort, but when you realise that LEDs use around 80% less energy than an incandescent lamp with the same light output, it's easy to see that the changeover costs will be recovered very quickly.

And there's another bonus. With a typical operating life of around 50,000 hours, LED light sources last about 25 times longer than regular halogen lamps. Therefore, as well as cutting energy usage, switching



to LED light sources will also deliver big savings in maintenance costs.

Changing to LEDs is not the only way to reduce lighting energy bills – switching the lights off can also yield big savings. The key, of course, is to turn lights off when they're not needed. Correlating the data from your PEL, which will tell you when the lights are being used, with data from your logging luxmeter, which will tell you when they need to be used, will provide useful insights.

You may well find that on winter mornings and in dull weather, when natural light levels are low, your staff turns the lights on which is, of course, perfectly justified. Later in the day, however, when the natural light levels are higher, how often do they remember to turn the lights off?

Systems that automatically turn off the electric lights when natural light levels are adequate are readily available and are well worth considering. However, even simply rewiring the lighting circuits such that lights near to the window could be switched off separately would enable savings to be made.

Your PEL energy usage logs may well have even more surprises in store for you when you start to consider the times at which energy is being

used in your business. Shockingly, a recent British Gas survey of 6,000 SMEs with smart meters found that no less than 46% of their electrical energy consumption occurred outside their normal business hours. This is not necessarily all wasted energy; most businesses need some out-of-hours lighting and heating especially in the winter months. But when almost half of their energy is used out of hours, there is clearly an opportunity to make savings.

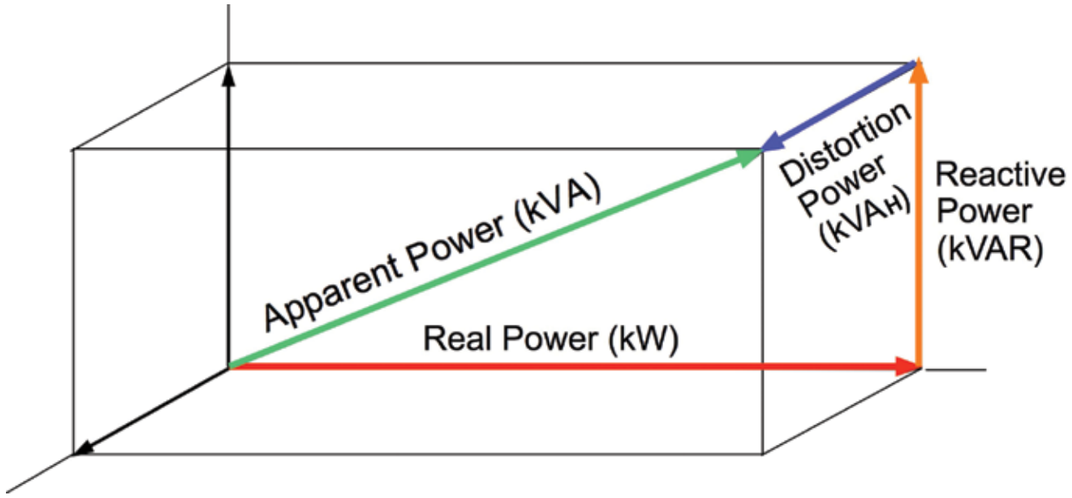
Effective time-controlled switching, which ideally adjusts on and off times according to the seasons and takes into account shutdown and holiday periods as well as weekends, is part of the answer. So is the use of occupancy-controlled switches that will turn off lights and reduce heating levels in intermittently occupied areas, like meeting rooms, when they are not in use. Be sure, however, to look in detail at the results of your energy monitoring exercise, as it may not be just the heating and lighting that's responsible for out-of-hours energy usage – in many cases, computers and office equipment, items often left on out of hours, are equally culpable.

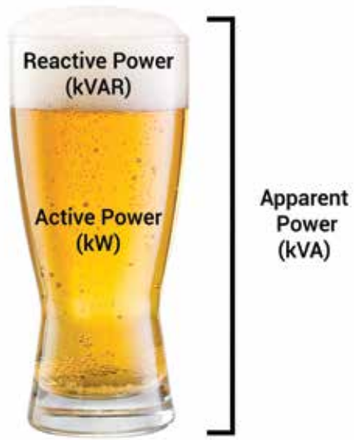
Power factor – real and apparent

Now it's time to turn to something a little more technical: power factor, which, along with energy usage, is one of the many parameters that a good PEL will measure and record. To be fair, power factor is not a concern for everyone; businesses like small shops and offices that have only a single-phase electrical supply are unlikely to be affected. Larger businesses with three-phase supplies may, however, be spending huge amounts of money and getting absolutely nothing in return if their electrical loads have a poor power factor. This is most likely to happen with businesses that use a lot of electric motors, either to drive machinery or even to power environmental control systems.

But what is power factor? Some types of electrical equipment used in industrial and commercial applications consume reactive power in addition to the real (or active) power they need to do the job for which they are intended. These are often inductive devices – that is, devices that incorporate coils of wire as part of their construction. Examples are motors, induction heaters, arc welders, compressors and most types of fluorescent lighting. It's important to understand that the reactive power doesn't, as far as the user of the equipment is concerned, do anything useful.

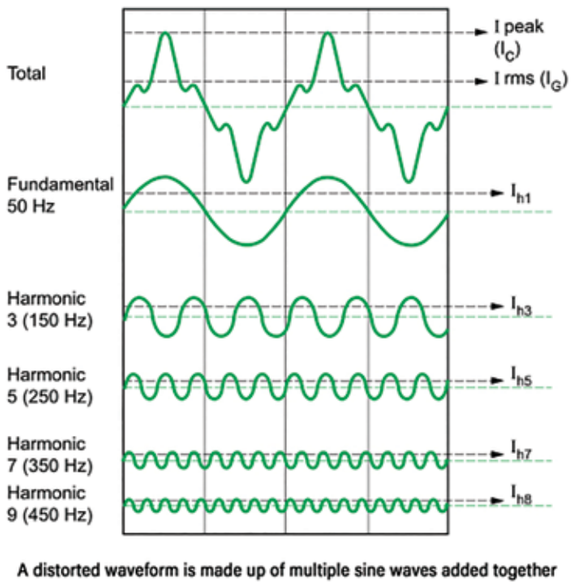
Technically speaking, reactive power is the vector difference between the real or active power used by a device and the total power it consumes, which is known as the apparent power. Power factor is the ratio of the real power to the apparent power. A device with a low power factor – which is more often called a poor power factor – draws more current than a device that's doing an equal amount of useful work but has a high (or good) power factor. Higher currents increase energy losses in the electricity distribution system, so energy suppliers penalise customers that have a poor power factor by charging them more for their electricity.





Speaking less technically, all of this can be made rather easier to understand by thinking about beer! If you order a pint of draught beer, the whole glass you pay for is equivalent to the apparent power. But take a closer look – that beer has got a frothy head on it! The beer is the part you really want, and that's equivalent to the active power, while the head, which makes no contribution to your refreshment, is equivalent to reactive power. A pint glass full of beer, with no head, would represent a power factor of 1 with no reactive power at all. In reality, that's usually impossible to achieve and a power factor of 0.95 (corresponding to less than 5% froth!) or better is usually considered acceptable.

So far, so good, but if electrical equipment inherently consumes active power, what can be done about it? Once again, the first step is to use your PEL to measure and monitor the power factor of your electrical installation and, in some cases, individual loads. You will then be in a position to decide whether it's worth installing a power factor correction (PFC) system, whether this should provide fixed or variable correction and whether it should be used to correct the overall power factor of the whole installation. An alternative might be to provide individual power factor correction for selected large loads – as before, data provided by the PEL will help you decide.



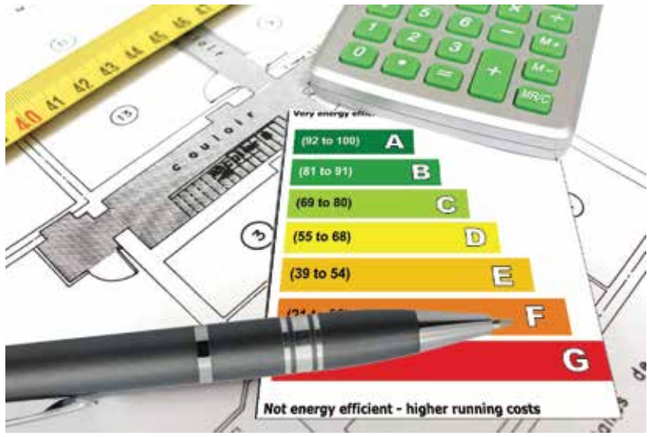
A distorted waveform is made up of multiple sine waves added together

Harmonics and how to deal with them

While power factor tends to be important only for larger businesses, there's another aspect of the electricity supply which affects all users, and which is becoming increasingly important. This is harmonics. Put simply, harmonics are currents in an electrical system at frequencies that are whole-number multiples of the supply frequency. In other words, if the supply is 50Hz, the harmonics are currents at 2 x 50Hz = 100Hz, 3 x 50Hz = 150Hz, 4 x 50Hz = 200Hz and so on.

To understand where harmonics come from, let's assume that the power delivered by an energy provider has a nice smooth sinewave voltage waveform. If this voltage is applied to a resistive load like a heating element, the current in the load will also be a nice smooth sinewave. But not all loads are resistive. Some, like computer power supplies and motor controllers are definitely not, and a sinewave voltage applied to these will produce a current that's a distorted version of a sinewave. Loads like this are called non-linear loads.

There's some complicated maths which shows that the distorted current waveform produced by non-linear loads is, in fact, made up of current at the supply frequency plus currents at harmonic frequencies. In other words, non-linear loads produce harmonics. If you want more details – and a bit more maths – take a look at the Chauvin Arnoux UK free resource website: https://cauk.tv.



Why have harmonics become such a widespread issue in recent times? The answer is simple – we are now connecting many more non-linear loads to our electrical installations. Almost all electronic devices are non-linear loads. That includes computers, printers, modems, televisions, phone chargers, microwave cookers, fluorescent lamps, LED lighting and any appliance with a motor speed controller. In addition to this, many homes and offices are now being equipped with EV charge points and have solar panels on the roof, which are also forms of non-linear load. Put simply, these days non-linear loads are everywhere, which means that harmonics are also everywhere.

Does this matter? Unfortunately, it does. Harmonics can disrupt the normal operation of electrical systems. They tend to produce excessive heat in conductors and components and can cause all sorts of issues with sensitive electronic equipment like computers and modems. They make lights flicker and motors buzz. And they're a common source of nuisance tripping in protective devices. Clearly harmonics are a bad thing and the effects they produce can disrupt almost any business, even the smallest. For these reasons, it's important to be aware of harmonics, and as you will have come to expect by now, the starting point for gaining awareness is to measure and monitor the harmonics.

A good PEL will provide you with all of the information you need about harmonics. It will show the total level of harmonics in a system, as well as the level of individual harmonics, which is often helpful in identifying the source. Once the principal sources of harmonics in your electrical installation have been found, steps can be taken to reduce the levels. Often this is done by fitting filters. This involves a certain amount of expense, but if the reduced harmonics means that your equipment – particularly

electronic equipment like computers – operates more reliably and potentially has a longer life, you will quickly recoup the modest cost involved.

The International Performance Measurement and Verification Protocol (IPMVP)

Hopefully the points we've discussed so far will be sufficient to encourage you to consider the roles that measuring and monitoring could profitably play in your own business. But just in case you're still wavering, let's conclude by looking at the International Performance Measurement and Verification Protocol (IPMVP), which is part of a very practical approach for controlling, optimising and reducing energy costs by measuring technical and economic performance.

The IPMVP methodology divides implementation into four phases:

- **PHASE 1: DEFINE REQUIREMENTS AND MAKE MEASUREMENTS**

It is essential to start by producing a historical, comparative analysis of consumption. The first step is to analyse the bills from electricity suppliers, but these will only provide information about the total consumption of the site. It is therefore necessary to subdivide the consumption and allocate it across the various users of electricity on the site – for example, factory, workshop, production line, office areas, etc. Doing this involves real-time monitoring and logging of consumption for each user, followed by the creation of reports, charts and summaries.

- **PHASE 2: PLAN AND IMPLEMENT SOLUTIONS**

On the basis of the measurements and analyses performed in Phase 1, an investment plan is developed which gives details of the energy-saving measures to be adopted and their expected outcomes. Once the investment is approved, the plan is implemented. Examples of the measures that frequently form part of such plans are: switching to LED lighting, changing electric motor control systems to allow variable speed operation, replacing old motors with modern high-efficiency types and taking steps to ensure that lighting and equipment is always turned off when it is not needed. Note that energy saving measures may also be needed for non-electrical systems, such as those that consume gas and compressed air. It is also worth remembering that eliminating waste is an important way to achieve energy savings, but it should always be accompanied by best possible energy efficiency in every situation.

- **PHASE 3: MEASURE AND VERIFY IMPROVEMENTS**

A measurement campaign is carried out to ensure that the expected savings are being achieved. Measurements should be made that allow the results of each energy saving measure to be compared directly with the initial objectives. Any measure that falls short of these objectives should be reassessed, and if necessary, modified.

- **PHASE 4: ONGOING PERIODIC TESTING**

Improving energy efficiency isn't a once-and-for-all-time action! Equipment can fail or degrade, and over time, operating conditions can change. To allow for this, a procedure must be set up for testing periodically – typically every six or twelve months. The tests must be exhaustive and should look at all of the elements of the on-site installations. In the case of the electrical systems, these will often include the lighting network, the general single-phase distribution network and the three-phase distribution network, as well as standby generators and uninterruptible power supplies (UPSs) in many cases.

It's easy to see that this protocol stresses the importance of measuring and monitoring, confirming that accurate and detailed measurements are an essential requirement for optimising energy efficiency, supervising electrical networks and allocating costs fairly. In a nutshell, regular measurement of performance is the only way to guarantee long-term energy efficiency.

Conclusion

Businesses exist to make a profit and to do so, they must operate efficiently. That means business owners and managers must make it possible for their staff to perform consistently and well, and they must also be careful – frugal, even – in their use of resources, particular energy. Effective control is the key to achieving these aims and we make no excuse for stating once again that effective control is impossible without accurate measurement and monitoring.

Fortunately, as we've seen, measuring and monitoring many of the key aspects of a business's operations doesn't need to be difficult, costly or disruptive – provided that appropriate modern measuring and logging equipment is used. Chauvin Arnoux has an enviable track record in developing, manufacturing and supplying such equipment – but that's not all. The company backs its products with proven, readily accessible expertise. So why not start now finding out how your business operations really measure up? And remember that if you need a little help in doing this, you know who to call – and no, it's not Ghostbusters!
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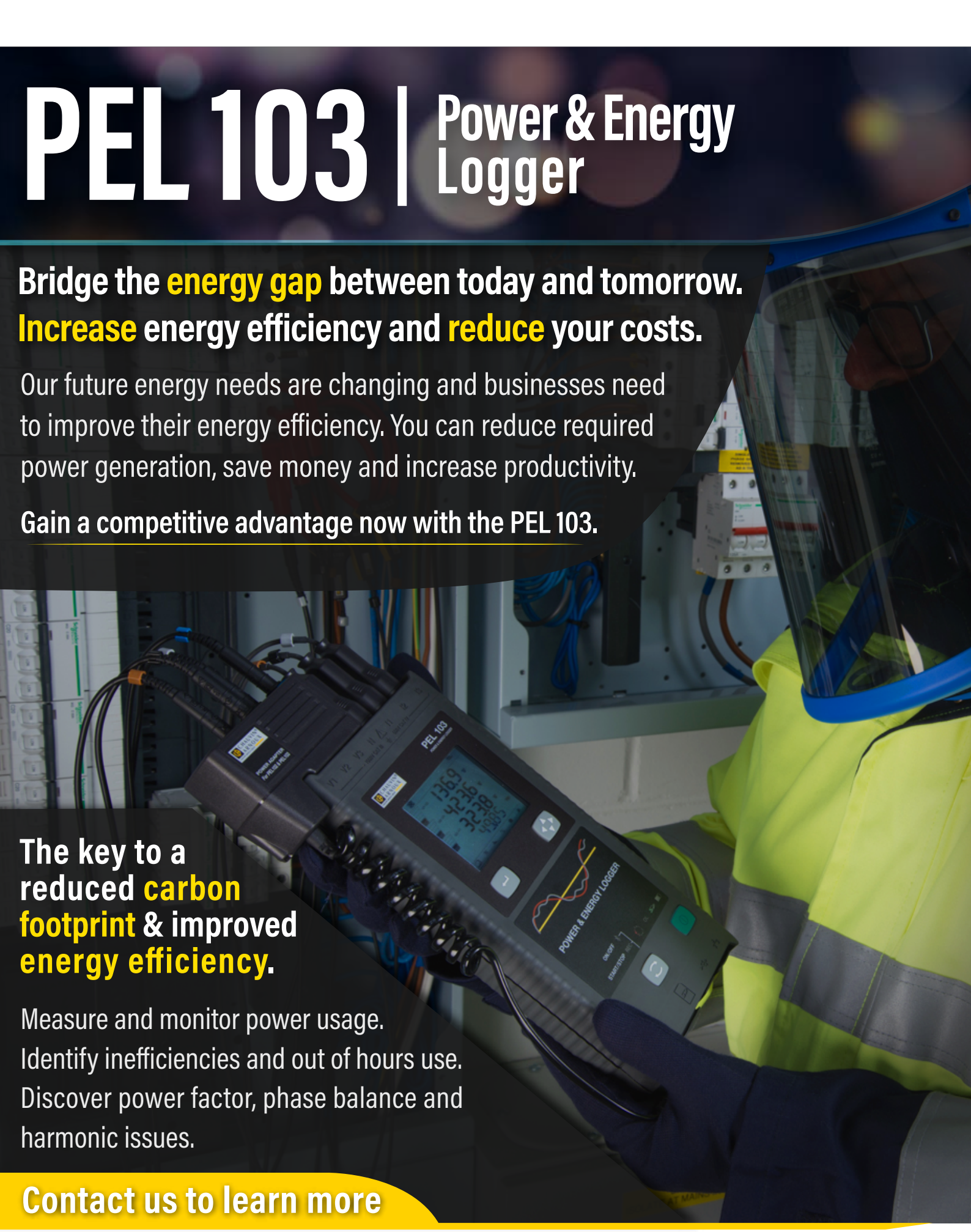

The key to a reduced carbon footprint & improved energy efficiency.

Measure and monitor power usage.
Identify inefficiencies and out of hours use.
Discover power factor, phase balance and harmonic issues.

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1 Flagship Square | Shaw Cross Business Park | Dewsbury WF12 7TH | T: 01924 460494 | E: info@chauvin-arnoux.co.uk