Designer's Guide to Energy Efficient Electrical Installations

Wiring Matters Series

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Why have energy efficiency in electrical installations?

Part 1 of 3

A background to Appendix 17

In summer 2018, BS 7671:2018 (the 18th Edition of the UK's IET Wiring Regulations) included a new Appendix (17) concerning energy efficiency in electrical installations. The current proposals for Amendment 2 of BS 7671:2018 develop the initial provisions that have been derived from the international standard IEC 60364-8-1 *Low Voltage electrical installations – Part 8-1: Energy Efficiency*.

The UK building regulations provide a focus on reducing energy consumption. Most national and international legislative initiatives on energy efficiency focus on the design, construction, and commissioning of new buildings. It is now commonplace that the designs of new installations align with various internationally recognized accreditation schemes.

Relying solely on the implementation of new buildings that reduce energy consumption, to achieve national or international targets, is not enough. To really succeed in reaching global energy targets, energy efficiency measures should be applied to both existing buildings and to new building stock.

The replacement of the existing buildings with new stock is relatively low and is estimated to be around 2 % to 5 % per annum. Applying a new standard retrospectively to an existing building is always difficult and can be controversial, but IEC 60364-8-1 recognizes this and states that it is "… *in the refurbishment of existing buildings that significant overall improvements in energy efficiency can be achieved*."

Design hierarchy

Whether it is a new build or a refurbishment project, there is the need to achieve the lowest possible consumption of electrical energy. Appendix 17 of BS 7671 is an informative section so its contents are not mandatory, but there is clearly a moral imperative to ensure electrical installations do not waste energy. How does this affect the traditional role of the Wiring Regulations?

Within the built environment, the requirements for designing and maintaining safety in electrical installations are governed by national and international standards. International standards may be adopted as they are or might be adapted for local needs by national organizations.

Historically the main two principles of BS 7671 Requirements for Electrical Installations (IET Wiring Regulations) have been safety and capacity. This ensures that an installation should:

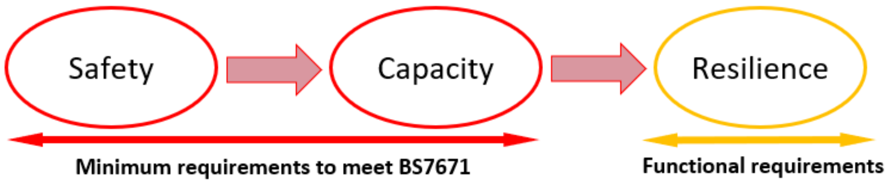
1. be safe enough to keep operators and users safe from the dangers of electric shock and allow satisfactory maintenance operations; and

2. have sufficient design capacity for the existing needs of the installation and to prevent damage to the installation caused by the dangers of heat from overcurrent.

Meeting the requirements of these two basic principles has typically been all that is required for most domestic, commercial, industrial and infrastructure installations.

Some installations, with safety critical operations, will also consider resilience as an additional design principle. The requirement might be because of life safety risks, such as acute hospital care, or business continuity in data centres for example. The main purpose is to avoid single points of failure and to provide system continuity.

Embracing safety, capacity and resilience, the traditional model of an electrical installation design hierarchy has typically been:



As the energy demands of our built environment rise, more burdens are placed on existing electrical distribution infrastructure that could be using quite old equipment and is already overstretched. This will only become more of an issue with the decarbonization of heating/hot water and the adoption of electric vehicle charge points. This is not just an electrical distribution network issue, this is an issue that needs holistic solutions. We need to reduce energy consumption at the point of use, reduce loses in the distribution network and improve quality and quantity of supply.

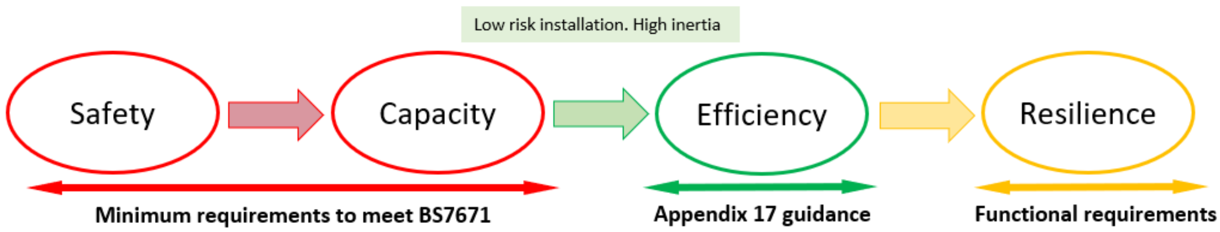
IEC 60364-8-1 considers design and maintenance from the context of reducing inefficiency in electrical installations, whilst still adhering to the original concepts of safety and operational control. Originally published in 2014, it was republished in 2019 and the draft Appendix 17 in the proposed Amendment 2 of BS 7671 addresses this document update.

The inclusion of energy efficiency will require a rethink on the hierarchy of design, but it is important to note that the priorities of safety and capacity will not alter.

A risk assessment approach is required and will vary from a low-risk installation to a high-risk installation. For installations with a low operational risk, the need for energy efficiency may be considered more important when compared to the requirements of infrastructure resilience.

In low-risk installations any critical loads may be small and supported by localized uninterruptible power supplies (UPS) facilities for specific equipment in a specific area.

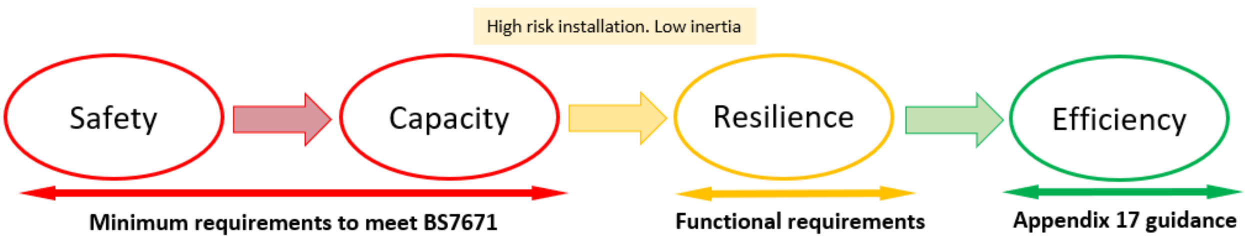
Other low risk loads might not be badly affected by interruptions in supply, or load shedding activities, and can quickly resume normal service (known in IEC 60364-8-1 as high inertia loads). In this instance the traditional design hierarchy may change to this:



Electrical installations with a high operational risk may have a different approach, for example where there are greater risks to the critical healthcare of patients, or in financial institutions with major business continuity considerations.

In high-risk installations, critical loads will be significant, with large UPS facilities and back-up generators to support an array of equipment across a large part of the installation. These types of loads will be badly affected by interruptions in power supplies, or load shedding activities, and cannot quickly recover (known in IEC 60364-8-1 as low inertia loads).

Interruptions in electrical supplies are always inconvenient. However, in high-risk installations this could also lead to dangerous situations for hospital patients or loss of significant business in an international bank. Here the traditional design hierarchy will probably need to place much more emphasis on the principle of resilience and make energy efficiency a necessary but lower priority.



Whichever approach is ultimately adopted, there should still be a change of emphasis at the design stage to incorporate energy efficiency into electrical installation designs, and by default into operations as a prerequisite, not just as an aspiration. However, with the guidance offered, this does not need to be overly onerous or complicated. Indeed, many of the measures highlighted are common sense to aid efficient operations and others are already considered as part of a safety approach to electrical designs and installation.

The implications of energy efficiency on designs

Energy efficiency has not been addressed in an obvious way within previous editions of BS 7671, including the 2015 amendment of the 17th Edition.

Requirements for reducing volt drops on distribution and sub-circuit cables are primarily focussed on ensuring proper operation of equipment at the point of use. However, having the correct voltage at the point of use can also affect the operational efficiency of some electrical equipment.

Requirements on correct current carrying capacity reduces the risk of undersized cables and subsequent fire risks. However, having the correct sized cables is also a useful tool for addressing inefficiencies caused by harmonics of certain types of electrical equipment.

Within the Wiring Regulations, any discussion on controls and circuit switching has been about safe systems of work and functional operations. However, there has previously been no explicit mention of controls in the context of automatically reducing energy consumption. Sensors to control lighting have been become commonplace in recent years and used in conjunction with functional switching. It is these automatic switching and controls that are highlighted with the electrical energy efficiency standard.

Designing for power factor correction (PFC) has been considered previously, but usually just at the intake switchboard to improve load characteristics at the point of supply. The premise of energy efficiency is to reduce stresses throughout the electrical distribution infrastructure, from the point of use to the point of supply. The designer should think about energy efficiency in a holistic way, through the whole installation. For instance, just focusing on power factor correction at the main switchboard may no longer be sufficient. Now other methods of power factor correction should be considered, including:

(a) small PFC units connected directly to large plant such as chillers;
(b) use of more efficient equipment meaning less PFC is actually required; or
(c) small PFC directly connected to local switchboards.

Although not addressing energy efficiency, surge protection devices follow a similar integrated model and are increasingly being used throughout electrical installations. Using the surge protection model, localized PFC, and harmonic filters, should be considered throughout the electrical distribution system to assist with energy efficiency. Such an approach will optimize the whole installation and potentially reduce oversizing cables.

Design factors

IEC 60364-8-1 considers various design and operational factors for energy efficiency in electrical installations. Each of these factors approach the energy efficiency question from a slightly different perspective to provide a holistic view.

1. **Load energy profile (active and reactive energy)**
   This looks at the type of electrical loads and what measures can be put in place at the point of use to mitigate and reduce energy losses on the electrical distribution caused by equipment connected to it. By monitoring, measuring and analyzing energy consumption, patterns of typical use, and misuse, can be recognized so that action can be taken
2. **Availability of local generation (PV, wind turbine, generator, etc.) and storage**
   This looks at the availability of on-site generation of electricity to reduce the demand of the installation on the wider grid. It will also include local electrical energy storage. Controls should be considered carefully to make best use of on-site generation or storage, especially at times of peak grid demand and higher prices.
3. **Reduction of energy losses in the electrical installation**
   This looks at active measures such as power factor correction and harmonic filters and also passive measures to ensure cable infrastructure and other components are sized correctly to minimize losses. The proximity of the point of supply to the point of use should also be assessed, using the barycentre technique if applicable, to minimize losses on the distribution system by reducing distance between intake and load. The correct selection of energy efficient electrical appliances that are permanently connected to the installation is also important.
4. **The arrangement of the circuits with regard to energy efficiency**
   This looks at how the circuits are grouped through zones, usages or meshes. Requirements for zones focus on geography of circuits and loads, while usages deal with particular types of loads that are heavy users of electricity e.g. motors, air conditioning or lighting. Meshes consider how the zones and usages integrate and how this is all monitored and controlled.
5. **The customer's power use distribution over time**
   This assesses which electrical loads are active at what times. Scheduling can be initiated to avoid capacity issues at the electrical intake and to avoid punitive costs for unnecessary energy consumption at peak times. Shifting the energy consumption of some loads to off-peak periods could be rewarded of cheaper tariffs at the time of use using contractual incentives from the electricity supplier. Load shedding may also be considered necessary.
6. **The tariff structure offered by the supplier of the electrical energy**
   The roll-out of smart meters allow for the introduction of dynamic tariffs that vary throughout the day. Traditional tariffs can feel like they are one-size-fits-all and have higher costs. Newer entries to the electricity supply market, like Octopus Agile, offer half-hourly rates to the market allowing customers to plan their consumption through the whole 24-hour period. Loads like electric vehicles and electrified heating can be supported through off-peak hours when tariffs are significantly cheaper.

The case for energy efficiency in all electrical installations

Most legislative initiatives and associated benchmarking schemes on energy efficiency focus their outcomes primarily on new buildings. In order to improve, or promote, their environmental credentials, many newly built installations seek accreditation from international organizations such as BREEAM, LEED or similar benchmarks. These awards are driven during the design stage of new construction projects.

Refurbishment has not always had the attention or emphasis it needs. For refurbishment projects, similar benchmarks have not always been available. Changes in recent years to the UK Building Regulations, including Part L, which focuses on energy consumption, means that if a large enough part of the building is refurbished the other parts of the same refurbished building must also be considered for upgrade too – the idea of beneficial improvements.

Another driver for change in the UK is in the commercial rental sector. This means that commercial buildings must achieve minimum energy efficiency standards before they can be let.

An energy efficient electrical installation has many potential benefits:

(a) it generally has less impact on the environment;
(b) it reduces energy losses overall and hence lowers energy costs;
(c) it has better controls and uses energy only when it is actually required and potentially at a lower (off-peak) tariff;
(d) it means less reactive maintenance throughout the electrical infrastructure by reducing the adverse effects of heat loss; and
(e) it optimizes the electrical system performance throughout its life cycle.

Conclusion

Safety and capacity are still the most important criteria for electrical installations covered by BS 7671. Resilience should always be considered especially on life safety systems.

However, energy efficiency is a necessity and can no longer be ignored as we move to a low-carbon future. The guidance within Appendix 17 and in IEC 60364-8-1 should underpin all electrical installations by design and by operation.

Designers and operators should be aware that there is now a duty of care to make their electrical installations as efficient as possible without reducing safety or compromising the needs of users or activities within the buildings. Design risk assessments of electrical energy consumption are likely to become as important within the built environment as health and safety or reducing single points of failure.

The framework for energy efficiency in electrical installations

Part 2 of 3

Energy efficient design and control as a process

The international standard IEC 60364-8-1 *Low Voltage electrical installations – Part 8-1: Energy Efficiency* provides a system diagram which provides an overview of the various energy sources and control inputs to an electrical installation. Analysis of this shows how energy efficient electrical installations should have an optimum energy path and a comprehensive control path.

The purpose is to ensure that the electrical infrastructure is designed to safely support the load whilst being located correctly and minimise unnecessary losses in the distribution system. The controls should be configured to ensure the electrical installation operates when the user requires it, whilst also minimising wasted energy consumption when the user is away. There are two key areas to consider when designing and operating an energy efficient electrical installation: the energy path and the control path. How these are set up and work together will determine how successful the efficiency will be.

The energy path is from the main intake through the main switchgear, distribution infrastructure and finally to the point of use e.g., a fixed electrical machine, water heater, luminaire, socket outlet. Historically the electrical supply would always be from a grid connection and some specialist installations, such as hospitals, would also have a standby generator for essential services.

Now electrical supplies may come from multiple sources including from a traditional grid connection, or via local onsite generation (including wind turbines or photovoltaic), or perhaps local on-site energy storage facilities. With careful controls an optimised installation may use a combination of all these supplies. Monitoring of these energy sources allows users to adjust their requirements, or to deploy automatic controls, and optimise the energy to the electrical installation. For those installations with standby generators there could also be revenue opportunities, through special contracts, to supply their electricity at times of peak demand on the mains electrical grid.

Electrical distribution systems should be carefully designed to avoid wasted energy. Using a barycentre approach to locating the supply near to distribution switchboards and onwards to electrical loads can reduce copper infrastructure costs and lower energy losses too. In practice energy efficient distribution means the point of supply should be as close as possible to the point of use. The reality is that a DNO will invariably provide a supply on the boundary of a site sometimes far from the point of use. For larger sites there may be opportunities to negotiate this with the DNO to provide a compromise solution.

An analysis of electrical load power factor and harmonics is necessary. Local measures to deal with this, instead of a centralised approach at the main intake, can improve the overall site efficiency. Adverse effects from power factors and harmonics also reduce efficiency and ideally should be dealt with at the point of use, especially with larger loads such as chillers and air handling units. Ensuring that electrical cables are correctly sized has always been necessary to improve safety and reduce fire risks. Correct cable sizing will also mitigate the effects of harmonics, although the connection of filters may be required.

The concept of load inertia describes the load's reaction to first being switched off to shed load and subsequently being reinstated; however, this may have consequences and effects on the levels of service to the end users.

For example, from an energy efficiency perspective, shutting down a large or complex plant for only a short period could be counterproductive, as it would require more energy to bring it back up to speed than was saved by shutting it down. This load would be known as a low inertia load. Other examples may include:

- Manufacturing machinery with fine tolerances might not respond well to a loss of power either to save energy at peak times or though line faults.
- Safety critical loads could be described as low inertia loads and should not be used to shed load and save energy. They should ideally have UPS back up too.

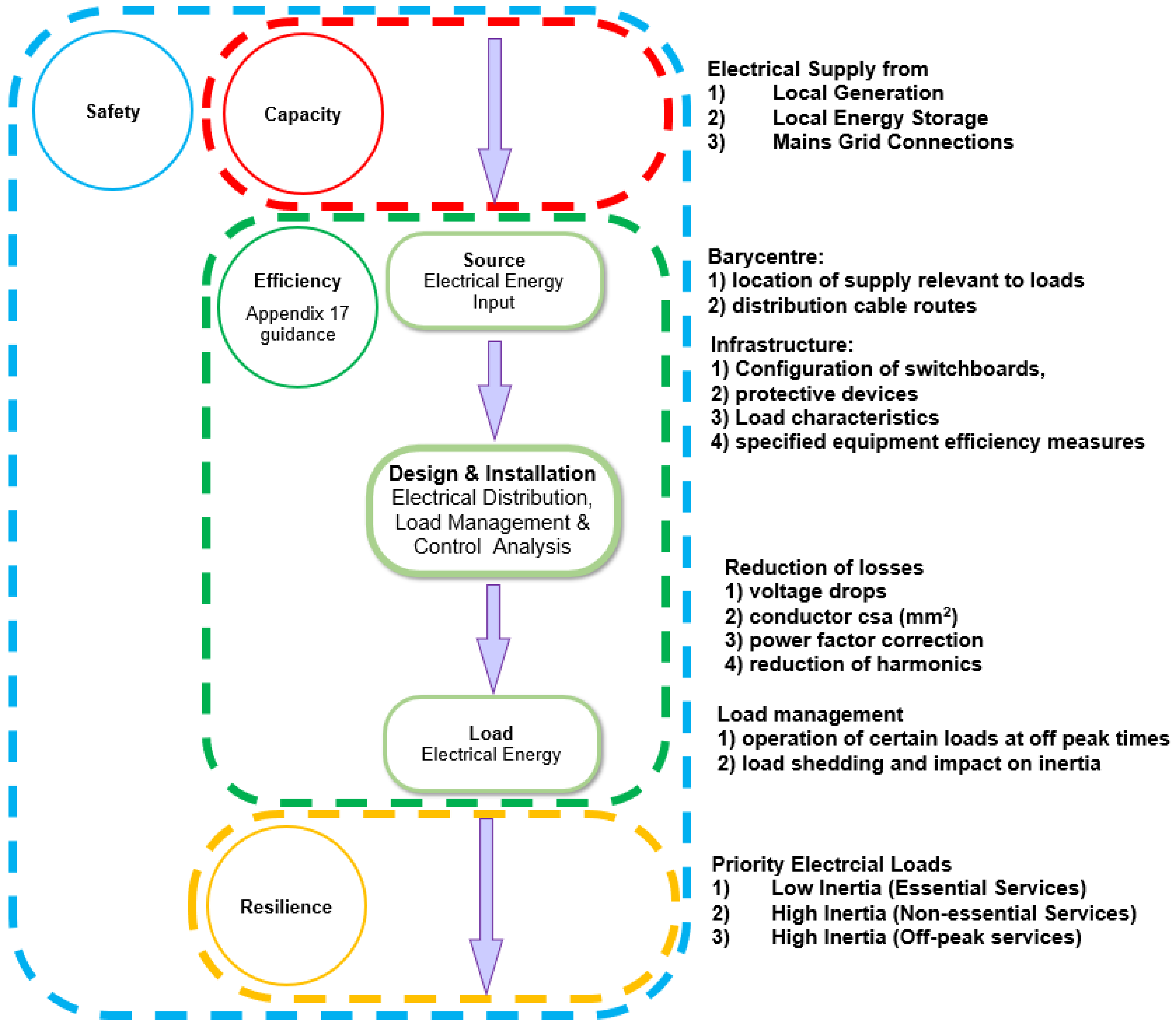
On the other hand, most LED lighting installations would be known as high inertia because of their ability to energise quickly after an interruption on supply. Some older lighting technologies, such as those using inert gas, would be low inertia because they need to cool down sufficiently before being reused.

Instantaneous water heaters would be high inertia because they will operate satisfactorily as soon as the electrical supply is restored. Other hot water systems using storage tanks are by definition low inertia because of the length of time it takes to reheat. However, for short interruptions in supply they might be largely unaffected.

Operating characteristics of electrical loads can be varied too. They will react differently to a temporary loss of power and subsequent reinstatement of supply. This can affect their response to load management when an installation's maximum capacity is reached (ability to load shed) or pause operation when if electrical tariffs change adversely.

The energy path below shows the energy sources through the electrical installation and on to the point of use – the electrical loads.

Figure 1 – Energy Path



The control path shows the influence of the control inputs on the use of energy through the energy management systems and on to any control outputs such as billing or just user feedback interfaces.

Control inputs to an electrical installation are increasingly important in a modern installation. They provide analysis, in real time, of the environmental conditions, the availability of different types of electrical energy source and the local demand.

Electrical energy demands need to be controlled as much as possible at the point of use and should respond to local requirements when the area is occupied. Whilst automatic controls should be considered to optimise energy efficient operation, where necessary the needs of end users must be taken into account. Local override controls may be necessary, for instance on lighting or local direct electrical heaters in certain situations. Occupancy detectors can reset the system from manual control back to automatic control to prevent wasted energy.

Influences on controls might be the availability of an energy source, the energy tariff (cost) at any particular time of day, automated responses to changes in environmental conditions or the need of the end users to use the space differently from the predefined automated settings (controls override).

Controls design philosophy should respond to how the building is to be used:

- what is being used – types of loads or usage
- where it is used – zones
- integration of load types and geography – meshes
- technical constraints and risks
- economic requirements

The controls philosophy of an energy efficient electrical installation should provide a number of outputs that enable the user to monitor performance of usage, zones and meshes, and then make informed decisions to improve those operations. Three key outputs would be:

- trends and monitoring – as an energy management tool to track normal and abnormal energy use;
- energy billing – using appropriate fiscal meters only to track energy costs and cost recovery in multi-user installations
- user guidance or alerts – using controls to assist with first line maintenance monitoring and local alerts of equipment still in use when not needed.

Operational requirements for controls should be carefully considered. The outputs from control systems can assist with monitoring energy consumption. Tracking trends can highlight wasted energy consumption and areas for improvement. Energy monitoring can provide granular details of usage in various cost centres and assist with local billing mechanisms.

Controls are an integral part of electrical energy efficiency; however, it is important to note that

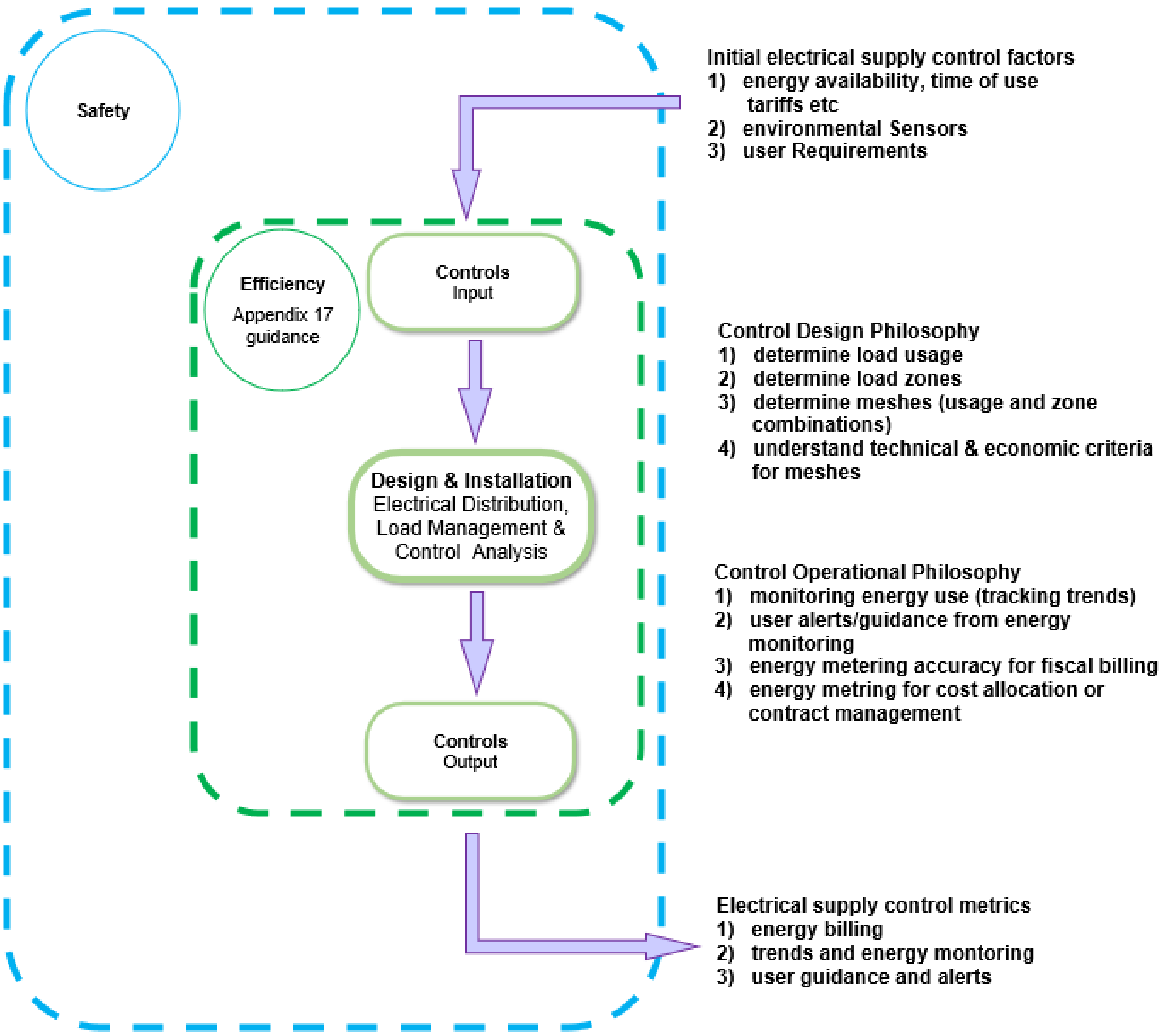
- they should not compromise safety
- they should respond to user requirements. Overrides to automatic energy efficiency controls to adapt to immediate user needs may be necessary.

Critically, all energy efficiency controls should still be subject to safe systems of work and work in conjunction with normal electrical isolations for the purposes of reactive and planned maintenance. Safety remains of primary importance and any measures taken to make an electrical installation more energy efficient must not compromise the safety of any occupants, property or livestock.

Likewise efficiency of an installation should not impair the acceptable levels of service for a user or the availability of an electrical supply at times of maximum demand.

The control path below shows the influence that controls will have on an electrical installation from the point of supply, through the infrastructure to the point of use.

Figure 2 – Control path

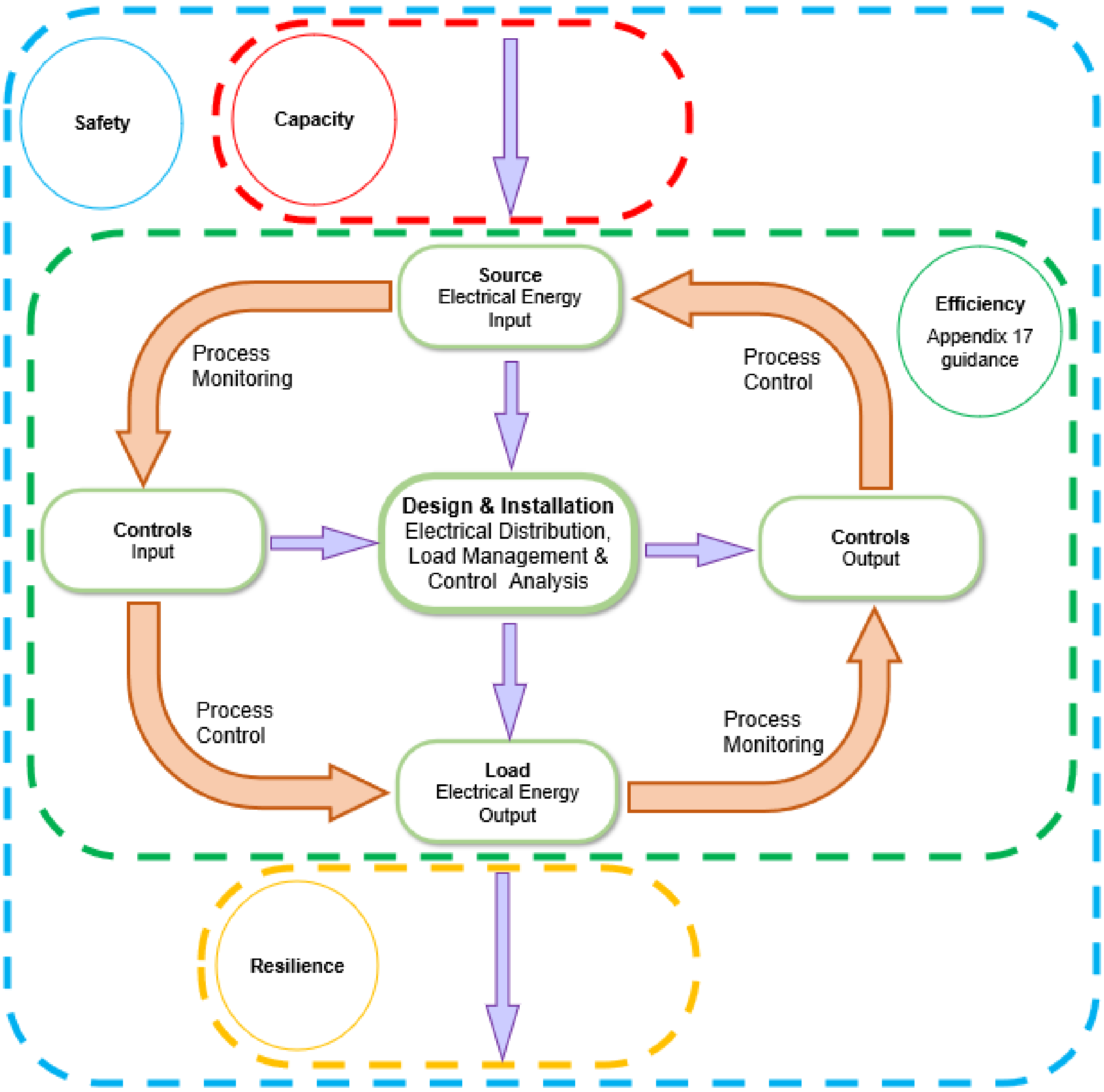


The energy path and the control path interact closely and integrate as a typical circular "plan, do, check act" process: energy input at the top, control inputs on the left, energy outputs on the bottom and control outputs on the right.

From top to bottom the requirements of an energy efficient design can be fulfilled ensuring that the electrical distribution and electrical installation are satisfactory and meet the necessary criteria. From left to right, the control process ensures that control over energy consumption is carefully considered and correctly commissioned.

An ongoing control sequence of process control and process monitoring should ensure that electrical energy efficiency is optimised and has the opportunity to be gradually improved. Maintenance activities are periodic checks on the continued safe and satisfactory operation of an electrical installation. It should also be a check on the operational efficiency of the electrical installation and a reminder to recommission as necessary.

Figure 3 – Process



Other design tools and techniques

Load management

The designer, the early stages of the project, should consult with key stakeholders, such as the client and end user, to categorise relevant zones, usage and meshes throughout the electrical installation to identify opportunities for energy efficiency.

1) Zones: this identifies where electrical equipment or appliances will be used. Typically based on the geography of the building, for example a paint shop in a factory, main staircase or corridor in a building, a zone could be controlled as one entity and switched off without necessarily impacting on the use of neighbouring zones.
2) Usage: this identifies what type of appliances, or particular electrical loads, will be operated not just in any one zone but across the whole installation. IEC 60364-8-1 identifies the largest electrical consumer usages as
   - hot water production
   - heating, ventilation and air conditioning
   - lighting
   - motors,
   - appliances

   The designer should use the consultation period to ensure that all major loads are identified in respect of their rating (kW) and their hours of operation.

3) Meshes: this identifies what common control inputs will be provided for electrical equipment. This could be across one or more zones with one or more usages. An example could be interleaved lighting circuits in adjacent hospital corridors, with separate zones, single usage, multiple circuits and one mesh for energy efficiency purposes.

Meshes are an important component with any electrical energy efficiency regime. Another example could be a hotel suite with a bedroom being one zone and a bathroom being another. Various usages can be identified in both spaces. However, an energy saving control system by the room main entrance will simultaneously switch off agreed circuits, with a number of usages, as the occupant withdraws their card key. Another mesh, though, will retain power to other circuits such as the fridge that should not be switched off or some lighting for reassurance.

IEC 60364-8-1 describes a number of criteria that are relevant to the development and implementation of meshes. Ensuring these criteria are all considered correctly demonstrates the efficiency of the installation. Using these criteria the designer must consider how the installation loads will be managed to optimize the electrical energy efficiency measures. This includes responding to

a. defined time controls to stop certain loads at certain times, or moderate maximum demand, or run at off peak periods
b. daylighting in the case of lighting especially externally and near windows
c. external temperature in the case of electrical heating

d. wasteful switching by the occupants (occupancy detection);
e. the connection of loads (absence detection)
f. switching using inputs from external sources (environmental sensors, thermostats, humidity sensors, air quality sensors); and

Load management, using meshes, is the process by which the electrical supply to the installation is distributed to the connected loads. These may have multiple usages and be located across several zones. To be energy efficient the load management process will activate them at the right time, with appropriate automated controls and measurements, to optimise the use of the energy and reduce wasted energy.

Purpose of electrical meters

The deployment of electrical meters throughout the installation will assist with both Building Control compliance (Approved Document Part L) and operational energy efficiency through the lifetime of the installation. Electrical designs should consider metering for fiscal purposes at the head end of the installation and for energy management.

Fiscal metering for electrical supplies for larger installations will be subject to half hourly monitoring. This data can be requested as an aid assess energy consumption through certain points of the day or week. This information in turn can aid improvements in energy efficiency.

On smaller installations analysis of just the main intake energy meter may be justified. However, on more complex installations with multiple tenants or internal departments, it will be necessary to provide load profile analysis closer to the point of use at sub-distribution level. In Part L of the UK Building Regulations new installations over a certain size require 90% of the installation to have specific sub-meters. The use of meters throughout the installation demonstrates the ability to closely control the load and will score additional points in the design appraisal of the electrical installation. It will improve the operational efficiency of the installation too

Sub-meters should be embedded throughout the installation to:

a. measure and record the load profile for the installation to understand when the energy is being used during set periods, for zones, usage or meshes; and
b. measure the load characteristics to understand what effect the load has on efficiency of the incoming power supply infrastructure. This involves periodically measuring the demands placed on the supply by the electrical loads' power factor, energy consumption, current, voltage and harmonics.

IEC 60364-8-1 cross references several other standards to define the type of meters that would be used at different parts of the installation and the level of information that may be required.

Ethernet connections for embedded metering systems enable all meters to be monitored remotely and data to be collected. This allows loads to be analysed in real time and monitoring of trends and patterns of load behaviour. Result of this analysis can influence when the load is connected to the grid and hence use cheaper electrical tariffs where possible or load shed non-essential loads at times of supply constraints.

Some electrical meters assist with power quality analysis (PQA). This is important for understanding power factors and harmonics and the associated energy losses with these aspects. Harmonics caused by non-linear loads are a major concern. Measuring power quality is important so a solution can be provided where harmonic distortion is found.

Evaluation and metrics

Part 3 of 3

The design framework of IEC 60364-8-1 provides guidance on a more energy efficient electrical installation through careful placement of electrical supplies, considered infrastructure design, controls and energy management. All of this is designed to minimise energy loss in the distribution of electricity and reduce energy consumption at the point of use in the electrical installation, whilst still maintaining a suitable and comfortable environment for the end users.

It should be noted that this is not just about embedding energy efficiency into the design phase though. An electrical installation needs to be fit for purpose throughout its lifespan.

We are all familiar with the requirement of BS 7671 to carry out regular inspection and testing to certify continual electrical safety. The IEC standard suggests an updated energy efficiency assessment at intervals not exceeding three years for industrial and infrastructure installations and five years for commercial installations. Realistically a fresh assessment is advisable when any installation undergoes a significant change in use or load addition.

The introduction to IEC 60634-8-1 states that "this document is intended to provide requirements and recommendations for the electrical part of the energy management system addressed by ISO 50001." Energy management is the focus of ISO 50001 and it describes a process of regular checks, identifying improvements, remedial works, and further reassessments to ensure that energy management measures remain on track.

Section 4.2 of IEC 60634-8-1 discusses regular assessment of energy efficiency and states particular periods for commercial and industrial installations when reassessments should take place.

Annex B provides scoring matrices and overall energy efficiency evaluation methods to demonstrate just how efficient the electrical installation is. These are used during the design, installation, and commissioning phases of a project and to provide a benchmark for future improvements. It is worth noting that Annex B is published as "Normative", so required activity, except in Austria and the UK where it is deemed as "Informative" (refer to Annex C for country specific information).

The design team should determine the level of energy efficiency measures required. The implementation of these measures should then be monitored through the installation and commissioning stages. The operational team subsequently provide continual assessment and monitoring until the installation is subsequently decommissioned.

Annex B of IEC 60634-8-1 highlights four principal energy efficiency themes that apply to electrical installations and should be assessed including:

- initial installation
- energy management

- performance maintenance
- power monitoring

There is also a bonus theme for the inclusion of low carbon technologies.

There are four sectors considered with each of these themes: industrial, commercial, infrastructure and residential. All aspects should be considered for the first three.

An abridged version should be used for the residential and only highlighted energy efficiency measures are applicable. The points allocation is also different for residential installations. For each of the categories there is a short assessment process, sometimes with a calculation where the output is a percentage whilst others are straight yes/no assessment.

If a particular measure is not directly applicable to an installation, it is typically given a score of 0. Where the installation has an LV supply and does not involve a transformer (II04 and MA04 refer) then maximum points are given as it is assumed that the supply authority have already dealt with transformer efficiencies.

Initial Installation (II) has five categories (II01 to II05) that evaluate the efficiencies within the fixed wiring electrical infrastructure.

II01 assesses, as a percentage, the coverage of energy consumption sub meters so that downstream energy use can monitored. Comprehensive sub-metering is also a factor in Part L of the UK Building Regulations.

II02 looks at the efficiency of the location of the substation and compares distances from the point of supply to the principal switchgear and also to the furthest load using the barycentre calculation method.

II03 looks at voltage drop and is a natural extension of BS 7671 design activities. Circuits which carry 80 % or more of the total energy consumption should be assessed collectively and installations with overall low volt drops score higher points.

II04 is for installations with their own transformer and examines manufacturers data. Higher declared efficiencies will gain higher scores.

II05 assesses the efficiency of the fixed electrical installation and equipment at the point of use. The example in the tables is lighting and ensuring that the same lighting performance is achieved when the energy consumption is minimised. This is also a requirement of Part L of the UK Building Regulations.

		Maximum points available				
Category	Table	Industrial	Commercial	Infrastructure	Table	Residential
II01	B.3	7	6	7	B.31	20
II02	B.4	6	4	6		
	B.5	6	4	6		
II03	B.6	6	6	6		
II04	B.7	3	3	3		
II05	B.8	4	4	4		

Energy Management (EM) has nine categories and evaluates the deployment and operation of efficient controls at the time of use.

EM01 assesses zones of control and compares the zoned areas (in m^2) to the total installation. The requirement is that the installation should ideally have more than 80 % of the electrical installation within control zones.

EM02 assesses usage. Points are awarded where there is comprehensive use of energy meters for a number of usages across the installation and within zones.

EM03 looks at demand response and load shedding controls. There are two aspects covered, the amount of load and the duration. Greater numbers of points are awarded when larger percentage loads are disconnected from the mains grid supply. Similarly, a load that is shed for more than 10 minutes is rewarded under the points system.

EM04 focuses on meshes and refers back to the criteria discussed earlier in IEC 60634-8-1. Where evidence exists of control criteria being considered to determine the meshes, more points can be awarded.

EM05 also assess usages and examines, as a percentage, how comprehensive sub-metering is across the installation for different usages compared to the energy consumption of the whole installation.

EM06 has a couple of tables to check and focuses on the deployment of automatic occupancy controls to reduce operation of the fixed installation when the areas are empty. There are tables for the total area of coverage and for level of occupancy.

EM07 is concerned with the Electrical Energy Management System (EEMS) and assesses how much energy is monitored by the EEMS compared to the overall electrical energy consumption. Bear in mind that an EEMS may form part of a wider energy management system if there are other energy sources.

EM08 assesses controls for heating, ventilation and air conditioning across the installation and points are awarded for general temperature control or room level temperature control or room level time and temperature control.

EM09 focuses attention on lighting controls and compares the amount of automatic lighting controls to the total energy consumption of the lighting across the whole installation.

		Maximum points available				
Category	**Table**	**Industrial**	**Commercial**	**Infrastructure**	**Table**	**Residential**
EM01	B.9	1	1	1	B.32	3
EM02	B.10	2	2	2		
EM03	B.11	5	5	5	B.33	16
	B.12	1	1	1		
EM04	B.13	6	6	6	B.34	20
EM05	B.14	4	6	4	B.37	20
EM06	B.15	4	10	8		
	B.16	2	2	2		
EM07	B.17	12	12	8		
EM08	B.18	6	6	6	B.35	18
EM09	B.19	2	6	4	B.36	6

Performance maintenance (MA) has five categories and looks at the processes and procedures to ensure continuous monitoring of energy consumption. Electrical installations will only remain energy efficient if they are maintained regularly and correctly. This is an important aspect of ISO 50001 as well.

MA01 is a "yes or no" assessment and only awards points if there is proof of a satisfactory and auditable maintenance regime in place

MA02 checks the frequency of the checks made on energy performance. Manual checks can be tie consuming, so it is possible that these checks could be automatic and driven by a network of meters connected to a central computer system.

MA03 is about data management and retention of historical data. This is important to track energy consumption trends and could highlight potential issues relatively early. A track record of energy consumption over several years can be an important comparative tool.

MA04 is for installations that have their own transformers and assesses the performance of the transformers. It does this by comparing the actual power used to the optimum working point declared in the manufacturers data sheets. An underutilised transformer will not work quite as efficiently.

MA05 looks at continuous monitoring of large loads (typically more than 10% of the installation's total energy requirement) coupled with automatic warnings of any variance so that anomalies can be addressed at the earliest opportunity. Large loads could include heating or cooling systems.

		Maximum points available				
Category	**Table**	**Industrial**	**Commercial**	**Infrastructure**	**Table**	**Residential**
MA01	B.20	8	8	8		
MA02	B.21	6	8	8		
MA03	B.22	10	8	8		
MA04	B.23	1	1	1		
MA05	B.24	5	5	5		

Power monitoring (PM) has two categories that look at how real time power quality analysis is conducted, using appropriate devices, to check power factors and harmonics.

PM01 focuses on power factor correction. It does not specify whether power factor correction should be deployed centrally or at the point of use. The main stipulation is that it is measured at the origin of the installation and maximum points are awarded for a power factor of over 0.95.

PM02 assess total harmonic distortion (THD), again at the origin of the installation. There are tables for THD_u (voltage) or THD_i (current) and points are awarded depending on the outcome from either table but not both.

It is worth bearing in mind that electricity supply companies typically state the maximum impact they will allow from installations with poor power factors or harmonic distortion.

		Maximum points available				
Category	**Table**	**Industrial**	**Commercial**	**Infrastructure**	**Table**	**Residential**
PM01	B.25	6	4	6		
PM02	B.26	4	3	4		
	B.27	4	3	4		

Bonus (BS) provides two further categories to demonstrate deployment of low carbon technologies. These can improve energy efficiency but not all installations will be in a position to use them.

BS01 discusses the deployment of on-site electricity generation through renewable energy sources and compares the output of the renewable source to the total energy consumption of the installation. Renewable sources mentioned include photovoltaic panels and wind turbines. It also includes hydro power, geothermal and biomass.

BS02 looks at electrical energy storage provided it is associated directly with a renewable electrical energy source as described in BS01.

		Maximum points available				
Category	**Table**	**Industrial**	**Commercial**	**Infrastructure**	**Table**	**Residential**
BS01	B.28	5	5	5	B.38	6
BS02	B.29	3	3	3	B.39	3

Once each of the categories are assessed all of the points awarded can be added together to provide an overall assessment. It is worth noting where the emphasis on the five themes is for energy efficiency in electrical installations

	Maximum points available			
Category	**Industrial**	**Commercial**	**Infrastructure**	**Residential**
Initial Installation	32	27	32	20
Energy Management	45	57	47	83
Performance maintenance	30	30	30	0
Power monitoring	14	10	14	0
Bonus	8	8	8	9
Total points available	**129**	**132**	**131**	**112**

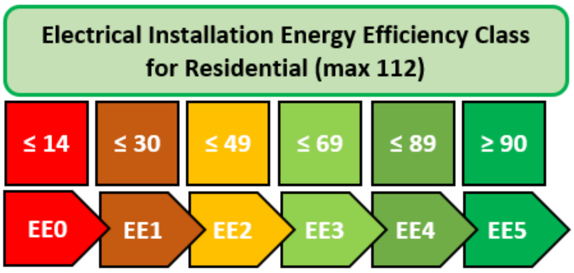
There is a strong emphasis on the initial installation design and on robust energy management including controls at the point of use. The numbers also stress the importance of a satisfactory maintenance regime.

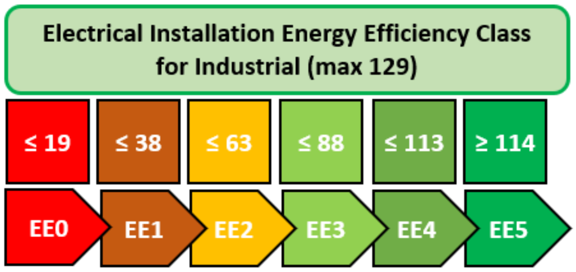
	Theme focus on overall efficiency			
Category	Industrial	Commercial	Infrastructure	Residential
Initial Installation	25%	20%	24%	18%
Energy Management	35%	43%	36%	74%
Performance maintenance	23%	23%	23%	0
Power monitoring	11%	8%	11%	0
Bonus	6%	6%	6%	8%

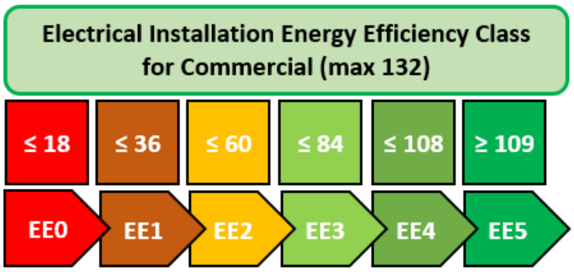
It is interesting to note that on-site renewable energy supplies and energy storage do not attract high scores. The main focus is on getting the energy efficiency of the electrical installation set up correctly in the first place, monitoring its performance regularly and maintaining that performance.

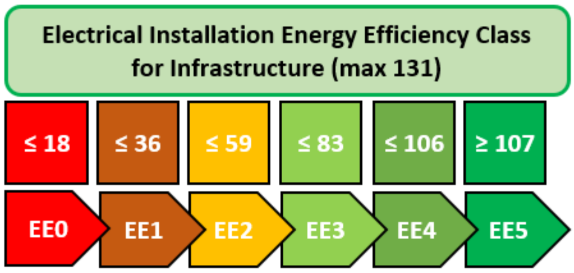
Renewable energy supplies and energy storage act as an added bonus to installations that are already energy efficient. They should not be seen as a carbon off set for poorly performing installations.

The cumulative score provides the overall electrical installation efficiency classes (EE). The electrical installation efficiency classes are rated from EE0 (low efficiency) to EE5 (high efficiency).









It is important to remember that when a building is occupied and working the EE rating should be regularly monitored and checked. Iterative changes to control settings, maintenance upgrades and improvement projects can always help to set new targets and improve ratings. Examples of these can include

- additional metering and sub-metering,
- more efficient equipment (e.g., high efficiency motor specifications, LED lighting)
- controls (e.g., better motor controls and automatic lighting controls)
- introduction of local renewable generation and energy storage.