This guide brings forth, in a simplified way, solutions to comply with LEED strategies. Without going into highly technical concepts, what is offered is a knowledge that serves as orientation for the sustainable buildings consultant.

LEED and KNX pursue the same goals, but at different levels. The future users of the homes and buildings as well as the environment and society in general benefit from the union of the two.

KNX can help to implement LEED strategies with the aim of obtaining a high score in the process of certification, which means a more sustainable and more energy efficient building.

The success, ease and acceptance with which the KNX technology has been met in the last few years indicates a hopeful future for energy efficiency in buildings and homes, led by a mature standard that defends the concept of a common language.

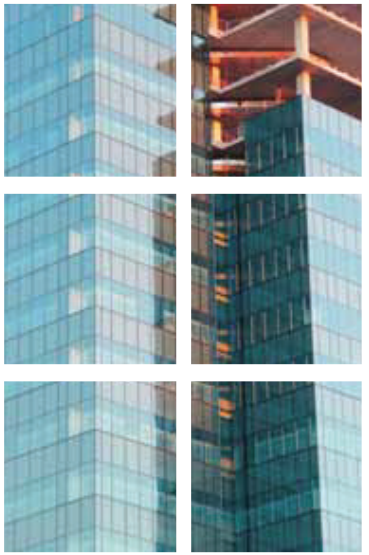
It is not possible to separate technology from sustainable buildings. Just as passive architecture is essential to obtain energy efficiency, the management of the active part through control systems guarantees the adequate and optimised use of the services required for the habitability and efficient use of the whole building.

Both LEED certification and the KNX standard have many base philosophical elements in common, which cover all aspects from training systems to support for energy efficiency.

ISBN-13 978-84-616-6137-4

2013

KNX for LEED / Enhancing LEED certification through implementing KNX technology



KNX for LEED

Enhancing LEED certification through implementing KNX technology

KNX for LEED

Enhancing LEED certification through implementing KNX technology

Publisher:

© 2013 1st edition
ISBN-13 978-84-616-6137-4

Production and distribution
by courtesy of:
KNX Association cvba
De Kleetlaan 5 Bus 11
B - 1831 Diegem-Brussels, Belgium

General contact:
Phone: +32 - (0)2 - 775 85 90
Fax: +32 - (0)2 - 675 50 28
E-mail: info@knx.org
Web: www.knx.org

Name of co-author and merits:

Jiménez Ibiricu, Miguel Ángel (Santacara, Navarra, Spain, 1972)

Industrial Engineer, KNX Partner and regular user of control systems, renewable generation systems (solar photovoltaic, solar thermal, solar thermodynamic) and their practical application in the control and real enhancement of energy efficiency since 2003.
Director since 2007 of the portal on control systems www.domoprac.com, for which he has published many articles on control systems and their practical applications in energy comfort, safety and efficiency.

Acknowledgements
'To my parents, for how they brought me up, and for their values; to my wife and daughters for their love and the time they gave me to be able to carry out this project.'

Name of co-author and merits:

Arias García, Jesús (La Adrada, Ávila, Spain, 1983)

Telecommunications Engineer, KNX Partner and KNX Tutor, with PMP certification, Jesús has developed his professional career working in relevant positions within important and innovative companies of the home and building automation sector and, most importantly, in different continents, contexts and cultures.
Currently he manages his own consultancy business, with the aim of generating synergies among different related sectors, and with the final goal of sustainable development, so that the children of planet Earth inherit a world in which it is worth living in.

Acknowledgements
'To all my loved ones, who help and inspire me with their unconditional love and support.
Any dream is possible, pursue it.'

"This book provides an interesting and innovative framework analysis between KNX standard and LEED certification. Active and passive actions that require efficiency in sustainable 21st century buildings, can be defined in LEED strategies and easily implemented using KNX standard technology, resulting in Intelligent Buildings which can already be glimpsed amongst us."

Ms. Mila Plaza
Architect LEED GA
Vice President Global Business Development
Onyx Solar

INDEX

1. Preface

The KNX standard – perfect synergy with LEED certification

Any professional used to working with the principles proposed in LEED certification will be able to detect, when going deeper into the matter, that the standard KNX technology can help in the implementation of numerous strategies that are taught in the official LEED training, as well as in complying with numerous credits in order to obtain a particular level (platinum, gold…). This is precisely the base on which this guide stands: concrete solutions for LEED strategies, through the use of standard KNX technology. This technology is the only standard in the context of home and building automation. This is accredited by its compliance with the main international standards.

LEED Strategies

The KNX standard is an effective tool to implement the strategies proposed in LEED certification, from a technical point of view.
Its 'standard' nature fits in with the USGBC philosophy. The solutions do not depend on a specific mark, but on the technical implementation based on a technology.

These two characteristics, STANDARD and EFFICIENCY, will accompany the reader throughout the whole guide; they are features worth highlighting that form the perfect synergy with LEED certification.

This guide brings forth, in a simplified way, solutions to comply with LEED strategies. Without going into highly technical concepts, what is offered is a knowledge that serves as orientation for the sustainable buildings consultant. The main features that make this guide an essential tool for any consultant are that it is:

- **Clean**
  This guide is not based on any trademark or manufacturer, but rather on a technology standard.

- **Enjoyable**
  It has been avoided the use of too many technical terms, since the goal is to lay the foundations required to be able to understand possible solutions from a wide perspective, and where it is necessary, to not lose the broadest sense of the project and the purpose of LEED certification.

- **Tuned in**
  Solutions to the strategies proposed are offered directly in the LEED 201 course: Core concepts and strategies. Just like the strategies, the solutions are practical examples of application; there are also many other solutions for many other problems.

It is worth highlighting that LEED certification, in an effort to achieve the most sustainable buildings possible – from the moment the building is conceived, to the variables of the environment, to the materials used, it does not focus solely on the automation part. However, many of the aspects indicated are feasible with the standard KNX technology. That is why the synergy between the two worlds is so favourable. KNX, bearing the 'standard' flag, fills in where there is a lack of concrete specifications by LEED certification.

LEED and KNX pursue the same goals, but at different levels. The future users of the homes and buildings as well as the environment and society in general benefit from the union of the two. KNX can help to implement LEED strategies with the aim of obtaining a high score in the process of certification, which means a more sustainable and more energy efficient building.

The technological democratisation of homes and buildings

The need to save energy is becoming more and more imperative, due to the fact that fossil fuel costs increase each month, and the transition to clean energies is still uncertain. But future development does not only consist of achieving other methods of energy production, it is essential to improve the energy consumption in all the systems that obtain energy from the electric power grid. This means that all homes and buildings should join this trend towards sustainability. It is precisely at this point that LEED and KNX converge.

LEED and KNX, similar philosophies

Both LEED certification and the KNX standard have many base philosophical elements in common, which cover all aspects from training systems to support for energy efficiency.

A better management in energy consumption is the key to supporting a transition towards other types of energies, such as renewable ones.

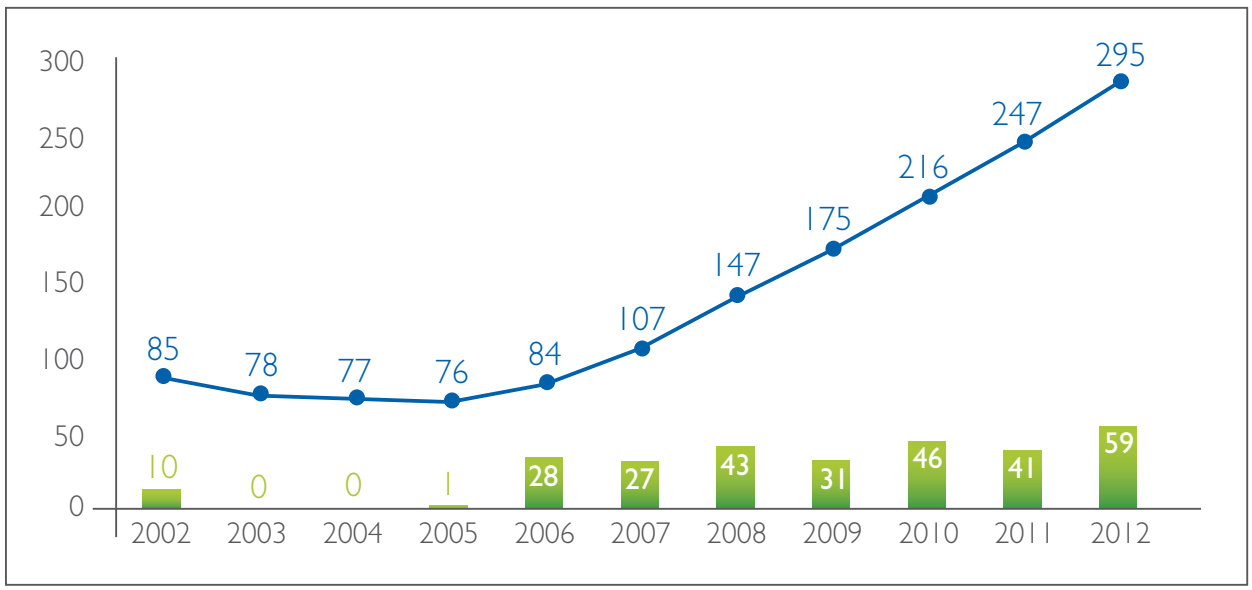


Figure 1.1 *Evolution of KNX members up to 2012.*

As with LEED certification, its intention is to create a sustainability pattern in buildings and homes, in an attempt to justify the effort invested in materials from sustainable sources or water treatments. The KNX standard has created a pattern of communication between electronic devices related to construction, with the purpose of making the best use possible of the energy available and the existing resources.

This whole process requires, as in the case of LEED, establishing certain knowledge and an acceptance of this knowledge by the collectives involved in the sector. This acceptance does not happen by imposition, but by the need to improve and advance in matters of construction. Moreover, since this type of technology has been gradually incorporated in the set of elements that compose a building, the environmental culture of our society has also changed, especially in the last few years, out of the need to save energy. This whole cocktail results in a democratisation of technology, with the aim of using it rationally. The application of technologies such as the KNX standard in homes and buildings is not a luxury, it is a necessity; just as it is not something of the future, it is part of the present.

During the last two decades, this kind of technology has sold the aspect that is associated to luxury. This should not be discarded, but it is not the only aspect worth pointing out. The final goal of systems that make a home or building intelligent is not to provide them with 'high-end' finishes, they are actually related to greater comfort and savings due to energy efficiency, thus linking the environmental element to the comfort element. Although the finishes available mean adapting an installation based on the KNX standard to a luxury environment, this does not mean it is the end purpose. Conventional and intermediate alternatives can be found.

As with all technologies, prices are becoming democratised as more and more companies come into play. They seek new solutions, investments in R&D occur, and a demand is generated. Up until then, prices remain high and are only accessible to the wealthier classes, hence the image of luxury associated with this sector. But this has happened also with other technologies, such as mobile phones. At the beginning they were brick mobile phones that were only affordable to the most important businessmen. With time, mobile phones have gone through a surprising evolution, reaching levels of technological development, as well as astonishing and almost unpredictable rates of penetration.

A sector associated to luxury

The systems that provide homes and buildings with intelligence have been advertised from an aesthetic and elitist perspective, therefore linking it to luxury. This is far from reality; these systems can and should focus on comfort and energy saving.

The problem in the case of homes and buildings is that it has been associated with a slower development of this technology, as it is not of mass consumption. Now, the worlds of niche technology and consumption technology come together and strengthen each other.

The number of technology manufacturers has increased in general, and manufacturers of KNX technology in particular. With this happening on several continents, a healthy competition is being fostered, where the most benefitted party is the end user, and a positive effect occurring on the market in general. This competition is beneficial because it works within the standard framework, where shortcuts are not a matter of economising on components or technology. The bases of investing in R&D and taking advantage of the tendencies occurring in related sectors, such as the sector of consumption electronics, are laid down.

Significant increase of KNX manufacturers

The data speaks for itself. More than 300 manufacturing companies are associated to the KNX standard, with a two-digit percentual growth each year. Among the latest, large companies such as Philips or AMX.

This increase in the sector presents exponential growths, because the more it grows, the more pull effect it has, even on large multinationals. Not only the more traditional companies of the sector, others too. For example, a manufacturer of weather stations will be much more visible if they manufacture under the KNX standard, thanks partly to the KNX Association's noteworthy marketing. Due to the fact that more and more projects include this technology, not producing under this standard reduces the possibilities of participating in such projects.

In summary, this effect has attracted, and continues to attract, many manufacturers. This has had an obvious effect on the variety of products available, which facilitates the design tasks for the turn-key project system integrators, resulting in a higher general quality of the whole.

KNX in figures

The success, ease and acceptance with which the KNX technology has been met in the last few years indicates a hopeful future for energy efficiency in buildings and homes, led by a mature standard that defends the concept of a common language.

The KNX Association has gained a lot of ground as an entity, thanks to its good work in terms of marketing. But this marketing is not empty, it is supported and backed by successes obtained daily, with a growing number of KNX Partners (already more than 32,000), KNX Members (more than 300), and with successful cases that serve as worldwide references. KNX is the main technology behind the largest airports, office buildings, stadiums and hospitals, responsible for energy efficiency and comfort. Terminal 5 at London's Heathrow airport, terminal 3 at Indira Gandhi International Airport in New Delhi, or Hongqiao airport in Shanghai, are examples that come up often thanks to their size. It is, however, not necessary for the project to be that large to enjoy the advantages that this standard offers. Its scalability is absolute.

Spectacular numbers

More than 32,000 KNX Partners (project system integrators) and more than 300 KNX Members (manufacturers of products under the KNX standard) make up the driving force of this standard, present in all continents.

It is as viable to find a KNX installation in a 50 m^2 apartment as it is in the largest building thanks to the flexibility that allows project system integrators to create the most adequate designs for each situation and requirement.

Thanks to the increase in KNX Members, the product catalogue available to the KNX Partners is very extense. The consequence advantages are the many possibilities in terms of adaptation to designs and projects, as well as significantly more competition that allows the market to adjust prices. As already mentioned, this sector has its eye on consumption technology, which implies taking advantage of its dynamism and adapting methods of production and development, all of which results in lower prices and greater competitiveness, without ever sacrificing in quality.

2. Purpose of the guide

LEED and control systems, compatible and necessary

One of the most significant challenges in construction these days is the change of model for one that ensures sustainability in buildings, from its design phase, to its construction and then its subsequent use.

There are diverse criteria to distinguish each building according to its level of sustainability, from its energy label (e.g. on home appliances) indicating its degree of energy efficiency, to ISO 50001 standards or certifications such as LEED (Leadership in Energy and Environmental Design). LEED is considered to be the most complete because it measures not only energy efficiency criteria, but also other equally important criteria, like the degree of environmental impact of the construction materials used, water consumption, its integration with the environment or the environment's protection.
In order to meet sustainability requirements in every construction there are different strategies:

- **Passive strategies**
  They aim to minimise energy consumed, without it affecting the level of comfort, by studying the application of the energy resources from the building's environment. An example of this is the Passhivauss system or the bioclimatic concepts, that take into account the insulations, ventilations, orientations, temperatures, precipitation and climate of the place, for the purposes of a correct design and choosing adequate insulations and ventilations. These help to maintain a comfortable temperature naturally at any time of the year.

  There are next-generation materials that help to achieve these objectives with minimum energy, such as electrochromic glass (EC), which allows a dynamic control of heat and light, or the insulations of mixed paraffins that melt at different temperatures in such a way that they naturally cool the walls in summer and warm them in winter.

  The purpose of the passive technologies is to reduce energy consumption, but on their own they are not able to obtain an optimal level of comfort for the building, which is why artificial sources of light, heat and cold that consume more or less energy are required. This depends on the effectiveness of the passive strategy applied and the level of comfort desired.

- **Generator strategies**
  It is a fact that the generation of energy in the construction itself raises the sustainability of the building enormously, since many of the energy demands can be met (zero energy buildings) with the appropriate generator systems (e.g. sun, wind, geothermal energy) where these are found. All this occurs within

a context of sustainability that ensures a return on investment, making up an important part of the electric distribution grid (Smart-Grid). This implies a better use, lower transport costs, supply cuts and losses for electricity companies.

In the last few decades, since the signing of the Kyoto Protocol, electricity production based on renewable energies has experienced a great boost at a large scale. But energy generation has also grown at a smaller scale, thanks to new government policies establishing the net consumption (Net-Metering) between the energy generated and the energy consumed. This makes incorporating energy-generator systems in buildings very attractive, contributing to them being as self-sufficient as possible.

One of the main barriers when implementing this type of generator systems has been not only the decreasing investment, but also the architectural integration of generating elements in the buildings.

The diversification of companies in the photovoltaic sector has achieved that some companies focus on the architectural integration of photovoltaic solar energy, creating multiformat, multicolour (even transparent) photovoltaic glass, known as BIPV (Building Integrated Photovoltaic), that can be incorporated into building façades. However, the vertical façade of a building does not present the optimal angle for maximum energy capturing due to the aesthetic and insulation of the second or third layer these solutions include.

- **Active strategies**

  Constructions are designed to be inhabited, and depending on the different uses for which they are intended, the times and presence in their areas, a lower or higher consumption of resources is produced. Efficiency can be improved by applying a logical control on the active part of the building, without losing any comfort in the services required (lighting, HVAC, irrigation, air quality).

  Changes in the global energy model make efficient construction one of the highest priorities at a global level. Today, the technology, the materials and the techniques that can make this change possible are available.

Technology in buildings

It is not possible to separate technology from sustainable buildings. Just as passive architecture is essential to obtain energy efficiency, the management of the active part through control systems guarantees the adequate and optimised use of the services required for the habitability and efficient use of the whole building.

Passive building vs. active building

It is in the use of services (e.g. water, energy) where resources are really consumed, which is why not controlling the active part of a building results in a waste of resources that the passive systems cannot avoid.

A well-insulated façade tries to avoid heat loss, but does not achieve real saving if the heating mechanism is not acted upon with the opening of windows, switching the thermostat off for that area automatically, while the windows stay open:

Consumption derived from use

The automated control of buildings, from the active point of view, is only possible through the use of control systems.

Control systems in buildings optimise its use of resources, paying attention to:

- **Times**
  If it is known when certain areas will be occupied, an automatic response can be obtained in services that have a specific use during a specific time.

  In buildings where a specific work schedule is followed, the HVAC can be programmed to switch on according to the staff's times of arrival and exit, and different modes on the thermostat can be established (comfort, night, standby) that have a more or less strict setpoint temperature according to whether the building is occupied or not. These modes can be activated automatically according to times and dates, acting integrally with other controls such as the detection of presence in areas. This will change the mode to a more efficient one if it detects the lack of activity during a particular interval of time.

- **Presence**
  The lack of presence is a key indicator to act on the lighting and HVAC systems. Its correct measurement, together with adequate programming in the control system, ensures that resources are only consumed when they are going to be used, thus avoiding a waste of energy.

  If presence and especially the absence of presence are controlled by means of appropriate sensors, an automatic response to changes in lighting can be achieved. Unoccupied areas can be switched off, or minimised, and at the same time the HVAC system can be acted upon. Similarly, the setpoint temperature can be lowered to a more cost-effective mode if there is nobody in the area, or the thermostat can be switched off if the absence time is prolonged.

All these actions combined create control strategies with a hierarchy, paying attention to efficiency, without losing the functionality in the service rendered by the systems controlled.

A good HVAC strategy may consist of subjecting its operation to schedules – such as in the case of office buildings – but ruled by the detection of presence, in such a way that if an employee wants to make use of an office outside of the normal working hours, their presence activates the climate in the area they are occupying. This presence would prevail over the set time control.

The manual control may be at the top of the hierarchy, as long as the absence control is vigilant. In other words, it is possible to switch on the HVAC manually, but if presence is not detected at a particular time, the setpoint is automatically changed to a more cost-effective mode or switched off, according to the design requirements.

- **Interaction with elements or parts**
  With adequate sensors the diverse elements or parts can interact and react automatically to the different control situations. It can be detected when windows and doors are open and proceed to reactions in the climate systems. It is possible to control the switching on and off of thermostats that rule each part of the building, depending on windows being opened or closed. Therefore, the HVAC will stop automatically, and start up again when the area becomes isolated again, thus making the HVAC effective in the optimal conditions of its application.

  These detectors can generate useful alerts (open windows: HVAC shut down) in the climate control devices, such as touchscreens, and can even be integrated in the intrusion system to trigger the alarm system if it is connected.

- **Environmental conditions**
  Having measurements of elements such as temperature, humidity and brightness, enables automatic reaction in order to maintain certain pre-established levels of comfort and efficiency.

  With the measurements of interior and exterior temperatures, automatic mechanisms can be established to give a logical response, in order to obtain the same effect with less resources and adequate programming.

  Thus, ventilations can be programmed in the building to renew the air inside. They can also be programmed according to times, when the interior and exterior temperature differential is appropriate to cool the building without consumption by HVAC devices (free cooling).

  On the other hand, the optimal control of a lighting system occurs, in one room, when an exact amount of artificial light intensity is achieved, using natural light as much as possible.

This way it is possible to reduce the quantity of artificial light that illuminates an area of the building if there are sensors that measure the mixture of interior (artificial) and exterior brightness. Target brightness thresholds are established, which the control system will try to reach, prioritising the use of natural light and therefore reducing the consumption of artificial light.

Energy and consumption auditing, Smart Metering and feedback

One of the main energy control and consumption strategies should be the ability to prove how efficient the building is in time. Measuring, acting and re-measuring the effect of the actions performed should be a must.

Efficiency in time

The passive part of a building does not need to be re-audited, but the active part of energy generation and efficiency should.

The actions can only be performed by the control systems according to the efficiency strategies planned in the building. Moreover, with these control systems it is possible to measure and act according to the measuring, should it be necessary to perform a direct action due to an excess of consumption or a particular threshold being passed.

A gas or electric power meter integrated in the control system provides measurements of aspects such as consumption, voltages and intensities, just as a sensor sends values of brightness or presence, to then act accordingly. Consumption limitation rules may be established so that when certain thresholds are exceeded, some less critical areas can give an alert and be deactivated.

Studying the consumption charts will assist in modifying the strategy according to the efficient use of the building and therefore change the programming of the control systems so that they act in alignment with the objectives set.

This is why it is not only important to measure, but to do it in an integrated way, as another element of the control system.

Equally, for the control of water consumption, water meters in the control system are needed, which will report measurements of irrigation water consumption in the building's green areas. They are also necessary for the building's water consumption and other efficiency strategies, such as the recovery and use of rainwater and greywater, which can be managed by the control system. This control sys-

tem in the building acts in conjunction with the technical alarm sensors (smoke, water, gas, CO_2) that assist in alerting of possible leaks. At the same time automatic responses can be given, such as valve cuts or the activation of the fire-protection system.

The weather station in turn indicates the exterior temperature, whether it is day or night, if it is raining, the solar azimuth and the level of exterior brightness. All these variables are useful in the efficient programming of the lighting and HVAC systems. They are also useful in irrigation control, stopping it if it is raining or activating it at night to avoid excessive losses due to evaporation.

In short, it is considered good practice to have a control mechanism in place that complies with the energy efficiency strategy's objectives and the building's consumption, and it is also necessary to be able to demonstrate it.

Integrated control systems, all for one and one for all

There is an infinite number of control systems on the market. In most cases they are geared towards the control of only one particular system, such as lighting or climate. This means that although they perform their task adequately, they are not able to integrate with other control systems to apply an optimal and unified control, making the maximum use of the connected devices.

An isolated control system can have control over the lighting system of a building through the activation/deactivation of lights by movement sensor detection. This is similar to how another isolated control system can be responsible for climate control. Both are compatible when it comes to sharing functions, such as reducing the thermostat's setpoint temperature when there is no movement for a particular period of time.
These kinds of isolated systems do not facilitate the centralised control of all the

Optimal integration

The optimal operation of a control system derives from the integration of the devices it includes, through the selection of devices belonging to a standard.

variables of a building, nor do they help to create a common programming strategy, combining the signals and actions that the devices should run for an optimised control.

As an example, an integrated control system – such as the international KNX standard

– can combine devices of EnOcean standard wireless and self-powered systems with its own wired bus communication devices, thanks to the KNX-ENO two-way communication gateways that organise its programming and control in displays via touchscreens in the KNX installation.

This interrelation between different control systems will be examined in detail in Chapter 7 of this guide.

Centralising vs. distributing

One concept that should be clear when selecting an integrated control system is its capacity of distributed intelligence. In other words, each device has its own intelligence without having to depend on a central control unit to be able to operate. Therefore, if this device fails, only the control elements connected to it fail while the rest continue to operate.

Let's imagine a building with a central control system. Should the central control unit fail, the building would have no services. No lights or HVAC. Should there be a failure in a building with a control system that has distributed intelligence, on the other hand, it would only affect the area of the device that failed. The impact and the response time to a breakdown are therefore minimised, the damaged element is replaced and its operation re-establish, and the rest of the installation is unaffected.

Distributed intelligence has nothing to do with the centralisation of devices in certain places of the building (such as switchboards), because this way the installation can be better organised and there is a better access to these elements. As explained in more detail in Chapter 3, the KNX standard complies perfectly with this essential requirement.

A very useful functionality for supervision and control in maintenance tasks in buildings is the representation of all the control functions in a floor plan display, or SCADA (Supervisory Control and Data Acquisition). In other words, a Building Management System (BMS) is available with a very graphic control of the whole installation and on which one can act upon from multi-devices (PC, tablet and cell phone).

Integrated control systems should be considered in the building's contingency plan, at the same level as the loss of data or critical machine failure. These control services without which daily activities are not possible. Therefore a good policy in the selection of a control system, together with a homogenous choice of devices that allows for replacements according to the criticalness of areas within the installation itself, ensures any failure can be corrected in a short space of time.

If the actuators for load control are chosen homogenously, in an emergency they

Standard protocol

It is considered appropriate to choose integrated standard technology control systems, such as KNX, that ensure interoperability among different manufacturers and protocols. This prolongs the system's lifespan, as one can replace devices at any time for others with similar functionalities without this affecting the installation's operability.

can easily be replaced. For example, if the actuator of a critical system fails, the irrigation actuator could be used (considered as secondary) until the replacement part arrives. This way, having a critical system shutdown can be avoided.

3. Introduction to KNX

KNX technology, standard philosophy

Before talking about the KNX standard from a descriptive and detailed point of view, it is worth highlighting the points that make it the perfect ally for any building that pursues energetic excellence, such as the buildings that aspire to obtain LEED certification.

As in the case of LEED certified professionals, the KNX standard certified professionals encounter inadequate designs or obsolete technologies on a daily basis. Just as the market is saturated with the concept of 'energy efficiency', green methods of classification referring to sustainable constructions, the same occurs in the technology sector of intelligent home and building control. It is becoming more and more difficult to differentiate real advances and differentiating elements, from what is purely marketing. Although it is hard to admit, 'green' trends are being used for both good and bad, making it almost compulsory for any company to be associated to this trend. Very often, marketing campaigns and commercial purposes hide behind environmental and responsible awareness. In order to help the reader of this guide to discern when it comes to all the systems that saturate the market these days, the most important concepts, related to these technologies in general and the KNX standard in particular, are explained.

What the reader will find in this chapter is basic information about the KNX standard, which is recommended, as it helps to understand why KNX and no other technology is the perfect partner for any LEED certified building.

KNX fits in with the LEED certification philosophy, since one of the main objectives of applying this technology in buildings and homes is simply to achieve maximum energy efficiency, from the savings and the environmental points of view, without neglecting the comfort and health of the building's inhabitants. All this bearing in mind the behaviour and type of operation of the systems to be integrated, as well as the appropriate user interface.

This last point, the user interface (HMI or Human Machine Interface), is an essential aspect that is in line with the LEED philosophy, and with the fact that the KNX standard contributes to improvements in a sensitive way. KNX enables the application of different levels of action, and the possibility of having the appropriate formulae for each situation, thus obtaining the best system/user interaction possible. This is greatly responsible for the final energy balance of a building.

- **Limiting human action**
  As explained in the course 'LEED 201: Core Concepts & Strategies', the largest energy expenditure derives from the use of the heating system. It is deduced