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The market of smart building technologies: barriers and opportunities

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MARKET OVERVIEW

The market for SMART building technologies can be considered as being divided into three distinct categories:

- Devices and systems for building automation and energy management, i.e. dedicated controllers, building management systems, sensors, actuators, communication network, etc.
- Engineering tools used in the design, construction, commissioning and maintenance of intelligent buildings.
- Services associated with the design, construction, commissioning and maintenance of intelligent buildings.

This market is covered globally by a limited number of producers and suppliers operating worldwide and supported in local markets by a myriad of engineering consultancies and specialist hi-tech companies which implement systems design and integration. The products reach the market either as standard integrated parts of the basic building management systems offered by the global players, or as components of tailored systems for specific applications and requirements. The customer base for the SMART building technologies market consists of building owners and administrators and the market is characterised as being highly competitive.
In Europe, despite growth rates ranging from just under 1% in developed markets to as high as 10% in the developing markets, the contribution of SMART building technologies to the overall turnover of the construction industry remains small. Today the market of these technologies is very competitive, but the barriers to market penetration remain sufficient to maintain this market status quo for the near future. At any rate and in all cases, the application of SMART technologies is perceived, on different levels, as giving an important added value to the building and its occupants. This added value, and the necessity for its inclusion within today's buildings, has implications on the design, construction and use of the buildings we will be occupying tomorrow.

TODAY'S SMART BUILDING TECHNOLOGY MARKET

The supply chain

Figure 3.1 illustrates the process of business acquisition in the IB industry. It shows the whole chain of the market, including the following major phases:

- Development: to define the project with given budget and time scale.
- Design and Engineering: to design the building and systems.
- Supply chain: components, devices, systems, services from pertinent suppliers to the site.
- Construction: to build the building and to install the systems.
- Commissioning: to commission the systems so that they can efficiently work.
- Operation and maintenance: to use and maintain the building.
- It also shows that technologies and services are applied to all the phases. This clearly shows how the market should be approached.

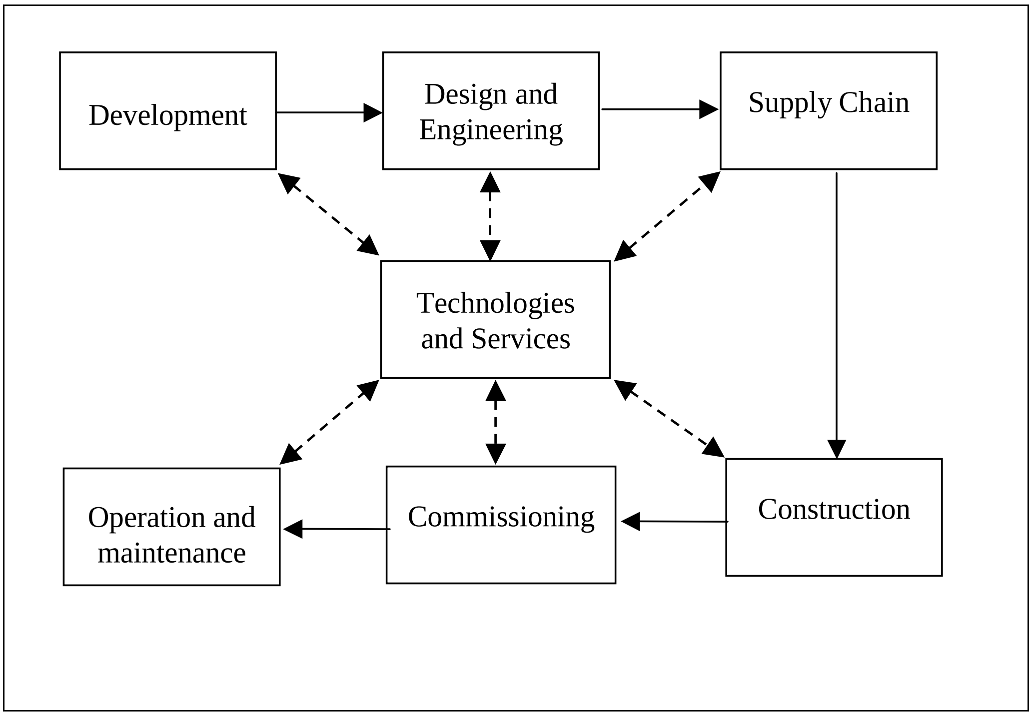

Figure 3.1 *SMART Building Business Acquisition Process*

Throughout the procedure, relevant policies and regulations should be complied with. In addition, supporting processes need to be adapted to penetrate the market, such as:

- Quality control
- Financial control and performance monitoring
- Health and safety
- Environment assessment
- Security assessment
- Information management
- Organisation and people

A more detailed picture of the chain of the IB industry is given in Figure 3.2, where the players involved in the construction process are linked with the different phases of the process.

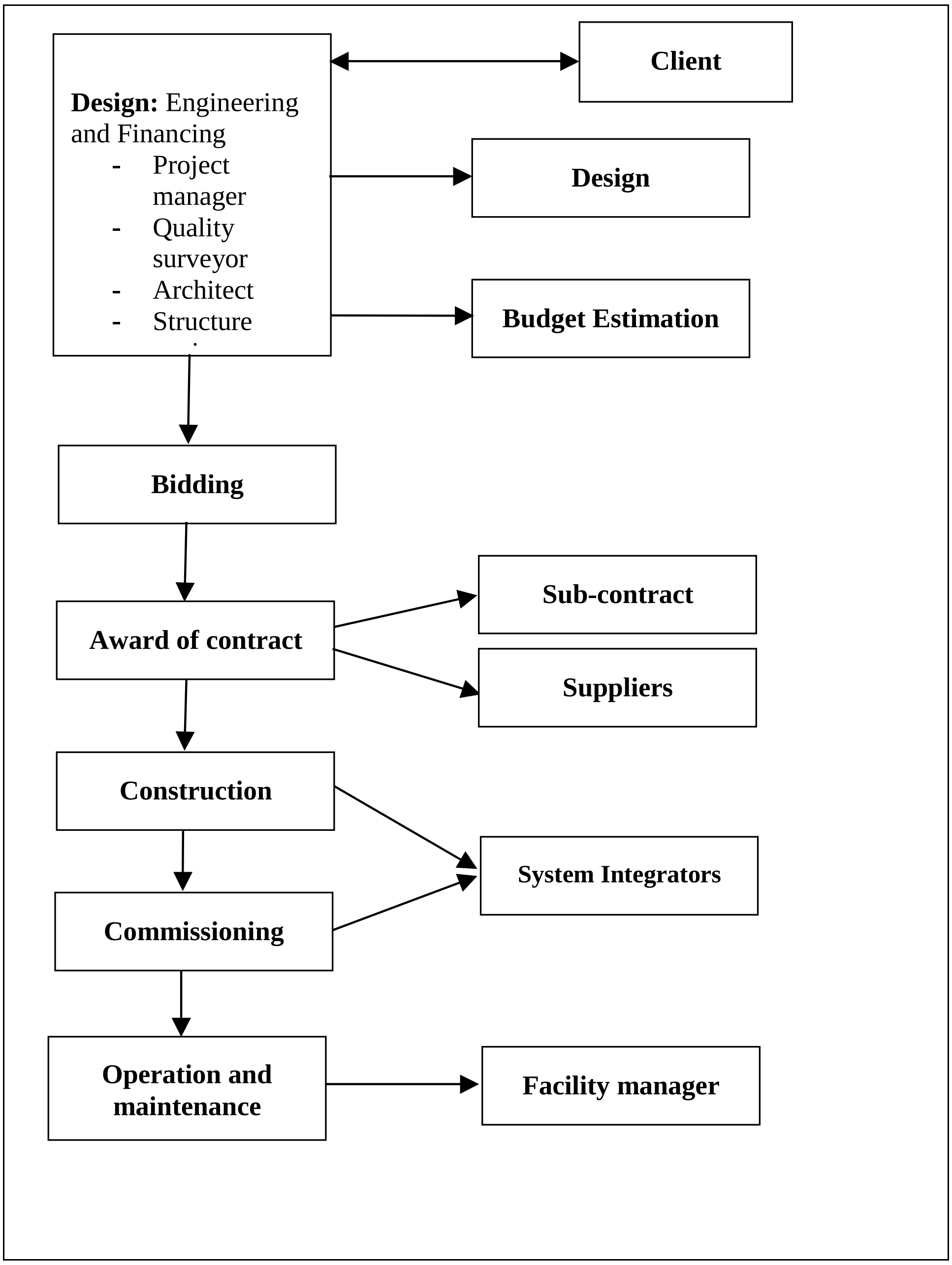

Figure 3.2 *An overview of the IB construction procedure*

The European market

In recent years, the development of low cost sensing and processing capabilities worldwide has permitted the design of comfort systems that can do a much better job of monitoring and controlling space conditions throughout buildings. These technologies also permit occupant adjustments that do not disrupt the HVAC system. However, such technology enhancements have not been widely employed in products and are rarely sought out for system designs. Many engineers continue to declare that they are not

necessary. If a system is properly designed, it is often argued, the building will be comfortable and the occupant will require no direct control. Other engineers argue that such features will be too complicated for operations staff to support. Such arguments may have been true long ago when comfort standards were much more flexible and controls were not, but in the era of the "knowledge worker" and digital controls, these arguments have become far less persuasive.
In Europe, the market for BMS continues to grow, mainly for installation in office buildings and industrial buildings, in order to meet the following design requirements:

- HVAC control
- Lighting control
- Shading control
- Air quality control
- Integration of renewable energy sources
- Communications
- Security
- Monitoring

Control of the cooling component of HVAC is becoming more and more important, particularly in commercial buildings, whilst home automation systems, mainly concentrating on heating, lighting, security, control of home appliances and monitoring is another increasing market sector.
Since the European market is dominated by large companies and their conglomerates, a common marketing system and the customer approach is identified. Many large companies operate in the SMART building technologies market continent (Appendix B)
Beside the large corporations operating at a European level, many companies exist at national level operating in development, commercialisation and service for integrated systems and/or for single components. Because of the length of the eventual list, they are not presented here.
Evaluation of the actual size of the SMART building technologies market is exacerbated by the following problems:
The market across the different European Nations varies considerably, with differing procurement procedures, regulations and construction techniques.
A significant proportion of the products used in SMART buildings are common products between different companies and the participation of other products from other business fields (as cables, switches, simple thermostats e.t.c).
Major diversification of the energy market and the energy management profession still exists.
The result of this variety is that products and services are grouped and marketed through different national associations Such association generally include different kind of companies and it is, as a consequence, very difficult to understand how much of the declared turnover is really due to SMART building technologies. As an example, the most important Italian association is ANCISS, which represents small, medium and large companies operating in the security and building automation sector. The aggregated data does not permit establishing the weight of the security system and that of the SMART building products (of which security may, or may not, be considered as an integral part). The market data for security and building automation in Italy is shown in Table 3.1.

Table 3.1 Market data of security and building automation in Italy

	2000 M€	2001 M€	2002 M€	2001/2000 Change [%]	2002/2001 Change [%]
Internal market	1494	1546	1549	3.5	0.2
Turnover	1613	1670	1700	3.5	1.8
Exports	180	193	206	7.2	6.7
Imports	61	69	55	12.3	-20.7

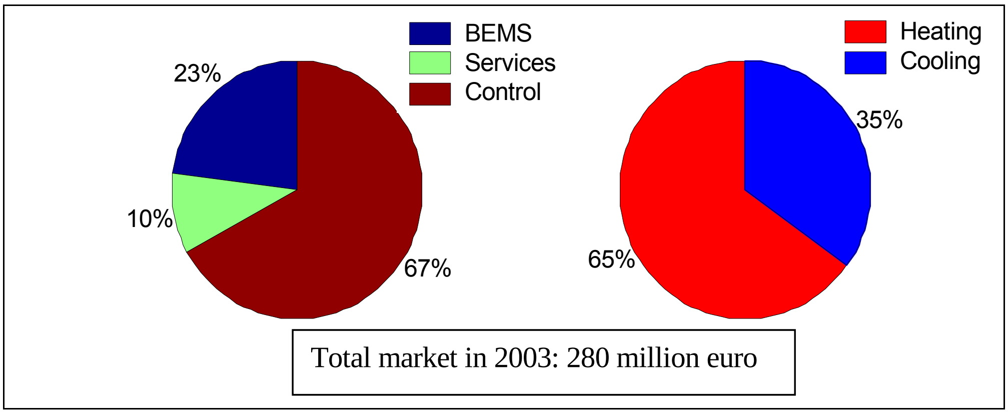

Figure 3.3 *Total French Market in 2003*

An overview of the SMART building technology market in some European countries is presented in the following figures. Figure 3.3 reports the turnover in France in 2003 and how it is split in the different categories, whilst Figures 3.4, 3.5 and 3.6 report the general trend of the building automation market for Germany, Greece and Italy, respectively. The general increasing trend of the market can be seen.

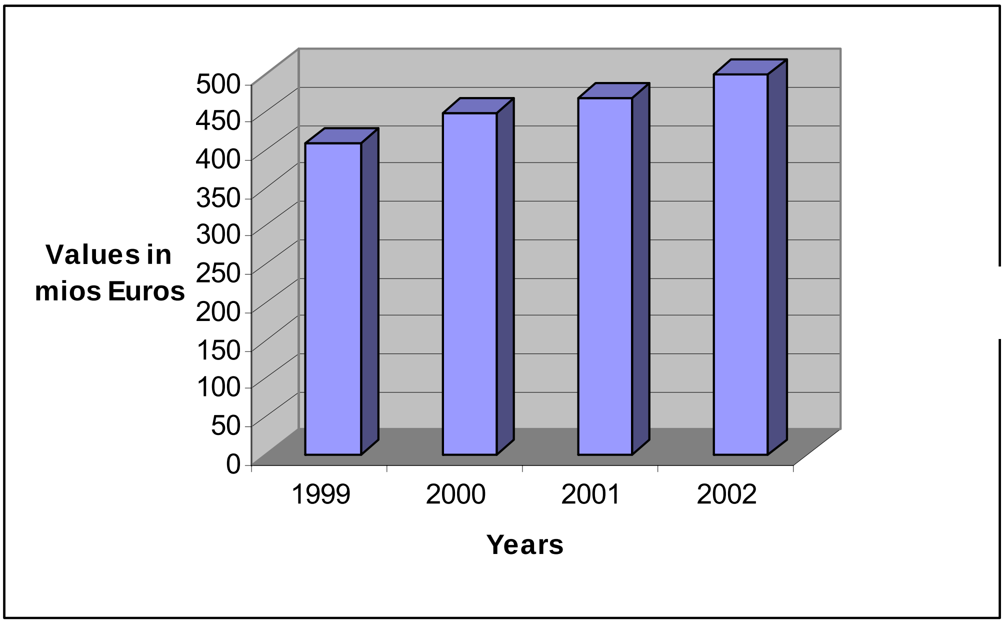

Figure 3.4 *Market trend in Germany*

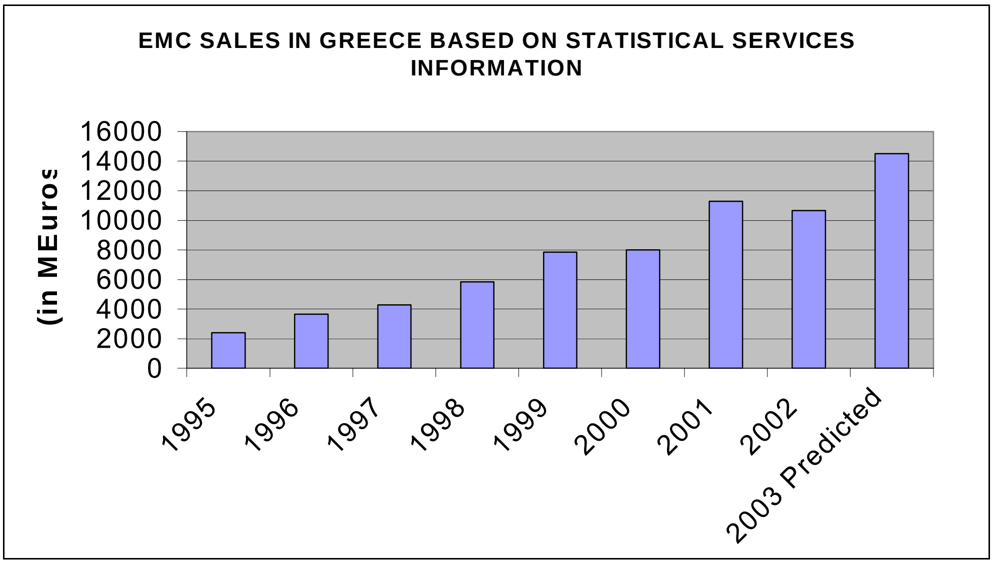

Figure 3.5 *Market trend in Greece*

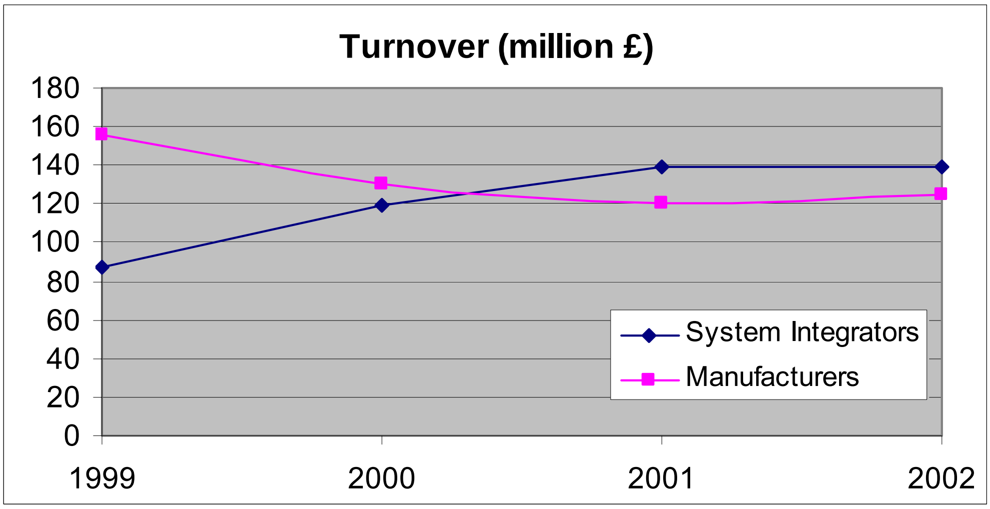

Figure 3.6 *Market trend in Italy*

Market considerations

According to the situation described in the above sub-paragraph, the following conclusions, on the single project participant States can be drawn:

- In the UK, the construction industry has maintained a consistent growth over the last ten years while the number of enterprises has been fairly stable, indicating that the efficiency and productivity of the industry has been improved. However the contribution of IB to the overall turnover of the industry is only less than 1%. The annual turnover of IB has hailed to maintain a similar growth enjoyed by the UK construction industry over the last four years.
- In France, the IB market achieved an annual growth of 1.2% to 1.3% from year 2001 to 2003. The services progressed by 14% but the sale of BMS hardware decreased by 3%.

- In Greece, the BMS market has maintained an average annual growth of 10%. In 2003, there was a significant increase in BMS sales due to the construction works for the ATHENS 2004 Olympic Games.
- In Italy, the IB market has maintained an annual growth of greater than 3.5% from year 2000 to 2002.

Based on the snapshots of the market of individual European member states, and considering the global marketing approach adopted by the main players, a number of conclusions can be made regarding the European market for SMART building technologies.

Firstly, and concerning the availability of data to make more detailed market analyses, several associations exist in each Member State grouping companies operating in the building automation system (including safety, security and so on), but it is difficult to get detailed data for the building services and energy management sector only.

Secondly, the market of intelligent building technologies is very competitive in all participating countries, with the presence of major manufacturers and services providers.

Finally, the current market size is small in absolute terms in all participating countries compared with the size of their construction industry and there is no evidence that the market size of intelligent building technologies is growing rapidly. It should be noted that such growth may depend more on casual events (e.g. ATHENS 2004 Olympic Games) than on structural change in the building market.

Anyway, the SMART building technologies market is in constant evolution, different BMS systems are used in current practice, new technologies are being developed to improve the performance and engineering-ability. The supply chain of IB industry is dynamic and therefore flexible marketing strategies, taking into account the existing barriers to market penetration, are important for accelerating the penetration of the technologies.

The SMART building technologies market is on the one hand constrained by market barriers, which maintain the turnover of the segment with respect to the whole construction sector at very limited levels, whilst on the other hand appears to be on the verge of proliferation, since these technologies constitute the backbone of the building of the future.

BARRIERS TO EFFECTIVE MARKET PENETRATION

Overview

The barriers to the market penetration of SMART building technologies and to the effective use of IT for energy management in buildings can be grouped into four basic interrelated categories: technological, behavioural, economic and legislative. Each group of barriers is affected by the others. The technological barriers, for instance, are strongly interrelated with the economic barriers in terms of the cost, maintenance and replacement of hardware and software, whilst they are also affected by legislative concerns, in terms of the rate of change of technology compared to the rate of change of legislation.

Technological barriers

The concept of the Intelligent Building has been developing, in a technological sense, since the early 1980s, although prior to this all forms of automated control could be considered as a form of building intelligence. Since then, the concept of the Intelligent Building has continued to involve, mainly driven by the development of relevant technologies and the changing needs for the built environment. It is commonly accepted that the short history of the Intelligent Building can be summarised as below:

- Early-mid ‘80s: intelligent buildings are buildings automatically controlled to function.
- Mid ‘80s – early ‘90s: intelligent buildings are buildings capable of responding to the changing needs.
- Early ‘90s to present: intelligent buildings are buildings with features effectively satisfying the changing needs.

The classical centralized commercial BEMS architecture consists of the central station and a number of outstations. The outstation accepts inputs from sensors monitoring the values of variables, such as flow and return temperatures of a heating system. Then the inputs are processed and the outstation sends output signals to control items of a plant, i.e. actuators or a valve. The outstation contains a small circuit board, the communication board, which allows it to interface with the central station, usually using modems or a Local Area Network (LAN). As microprocessors become even smaller and cheaper, it has become common practice for computers to be used to control and monitor building facilities, such as Heating Ventilation and Air Conditioning Systems (HVAC), fire detection, security control, lights, lifts, etc.

The aim of the specific section is the description of the technological barriers in the Indoor Environment and Energy Management Sector.

The past decade attempts have been made throughout the world to establish a standard communication protocol. Progress is slow bearing in mind the many different candidates for standards: Profibus, Batibus, EIBus, Echelon, BACnet, (Appendix C). Beyond this, the main technological barriers can be summarized as follows:

- Most of the systems need central computers to operate and they are connected in a classical architecture using major wiring. Only a limited number of systems operate on power lines and radio frequency.
- The existing systems readily available on the market are incompatible with each other due to the different protocols which they use, resulting in a closed market and systems which cannot be expanded or adjusted easily.
- The technology is not readily understandable by technicians and installation and commissioning is difficult and often wrongly implemented.
- The rate of change of technology is such that systems can quickly become obsolete.

Benefits and drawbacks of available systems

As far as BEMS and Energy Management and Control systems architecture is concerned, the centralized architecture continues to play a significant role. From a technical perspective, centralized control architectures serve with advantage in application systems where time critical closely coupled synchronization and high data flow are required. When devices and systems are loosely coupled and the synchronization is less time-

critical, the advantages in adopting distributed control architecture are likely to become apparent. Being physically distributed is perhaps the major feature of such systems, with key advantage derived from simplified wiring, related cost savings and improved maintenance. The distribution of intelligence is in fact very limited as the lack of design tools still prevails. The design paradigms of a distributed control system are simple and not over sophisticated. This leads to the adoption of the components-based approach . The term 'components' as a design concept is relatively familiar to the software industry as a deviation from object-oriented design. Components in a distributed architecture are the 'smart' sensors and actuators and controllers that aim to transform the simple on/off operation of micro-switches to a more sophisticated operation e.g. counting, time delay, response, etc .
Summarizing, a distributed system must have the following characteristics:

- Interface with a broad range of sensors and actuators.
- Incorporate application programs that blur the distinction between legacy sensors and actuators and intelligent networked devices.
- Include a design and installation tool that can interconnect everything in the control network.
- Incorporate software that simplifies hardware configuration and reduces commissioning time.
- Include an open I/O driver that can be used with a variety of third party human – machine interface tools.

By the previous analysis it is obvious that a competitive BEMS should have the following characteristics:

- It must be an advanced open system, respecting common standards.
- It should have the possibility to mix and match components from various manufacturers.
- It should be easy to install in existing buildings without a major retrofitting effort.
- It should possess the possibility of industrial programmable central unit with advanced capabilities.
- Should be low cost.

Economic barriers

The SMART building technologies market is a push market. This market is covered globally by a limited number of producers and suppliers operating worldwide and supported in local markets by a myriad of engineering consultancies and specialist hi-tech companies which implement systems design and integration. The products reach the market either as standard integrated parts of the basic building management systems offered by the global players, or as components of tailored systems for specific applications and requirements. The customer base for the SMART building technologies market consists of building owners and administrators.
Given that the highest market penetration can be achieved by addressing the largest sector of the customer base, the findings of a study of 38 building owners and administrators covering almost 450,000 offices and apartments are presented. This information has been integrated and collated with the data from the overall review of the market study of intelligent buildings technologies in the participating countries.

Of the companies approached 70% didn't have intelligent building technologies installed, whilst only 20% stated that they would be unwilling or unlikely to install such systems.
The economic benefit of an intelligent system is the most important factor in the decision to install such a system, with approximately half of the companies stating that operational cost reductions of 20% in the first year of installation would be the expected performance and, furthermore, in response to the question "How did you obtain your system?" and "How would you have liked to have obtained your system?" the response indicated a major preference for third party financing or systems leasing. In particular the first answer said that the 83.3% bought the system, but the 61.5% would have preferred a leasing solution.
With respect to the cost of systems, almost all of the companies (approximately 85%), insisted that any such system to be installed must be easily upgradeable. Finally, the major expectations for next generation systems concern lighting control (62.5%), alarm facilities (68.8%) and fire alarm facilities (87.5%), indicating a trend in expectations towards globalised control or fully Computer Integrated Building technologies.
Despite dynamic growth rates of just under 1% in developed markets to approximately 10% in the developing European markets, the contribution of IB technologies to the overall turnover of the construction industry remains small. The market of these technologies is very competitive and the barriers to market penetration sufficient to maintain this market status quo for the near future. From a systems marketing point of view, increased market penetration of intelligent building technologies will be attained if the following economic factors can be addressed: in addition to the :

- It gives an added value to the building
- The system gives at least 18% energy savings
- The system has a pay back period less than 8 years
- The producers offers the after sales service and maintenance in a reasonable price
- The system can be upgraded
- The system can be offered with other methods than direct sales i.e. TPF , energy performance contracting, leasing.

And in addition:

- The producer or systems integrator visits the building owner or administrator directly
- The producer is well known in this sector.

Legislative barriers

Barriers in the project participant countries

Different building regulations and construction practices, combined with consumer expectations and national idiosyncrasies, often means that products, as well as promotional tools, for SMART Building technologies are restricted in their use to one particular country or region. Outdated legislation and complicated bureaucracy procedures, combined with the slow rate of change of legislation in comparison to the rate of change of technology, means that the existing status of legislation acts as a barrier to the effective use of SMART building technologies.
France. In the French construction market, and in the case of public buildings, the project is specified by the contracting authority, which also assigns a project manager for follow-up. The organisations involved are the local building authorities of the Ministry of Infrastructure, Transport, Spatial Planning, Tourism and Maritime. In the case of a

private project, the organisations involved are the private developer and their chosen technical contractors.

There is a significant difference between the market for public and private sector buildings under French legislation due to a direct consequence of the difference between the public and private laws. The laws governing the market for public buildings aim to assure proper management of public assets and to provide equal opportunities for bidding for public contracts. The guidelines for the construction sector are defined in the Books of General Technical Clauses, latest version published in 2004.

Concerning the building energy systems, the Clauses, or similar legal instruments for the private sector, contain the standard for the design, installation and operation of heating systems. The project manager is in charge of contracting the construction works with the general contractor for the design and the installation of the heating systems. For the public market of design and installing of heating systems, there are three types of contracts:

- Design and construction contract – the scope of which is the design and the construction of the heating systems.
- Construction contract – the scope of which is to ensure the works for heating systems are carried out according to the design.
- Results obligation contract (M.O.R.) – the scope of which is the design and the construction of the heating systems to fulfil the contracted objectives defined by the conditions existing on the market. The commissioning is included in the contract.

The contracts for operation and maintenance of heating systems of public buildings are done between the client, who is a legal entity and the service provider which is a company specialised in operation and maintenance.

The operation contract has different forms:

P1 Provide and manage the energy – covering the provision and invoicing of energy.

P2 Operation and minor maintenance services – covering the optimal operation of the heating system and minor maintenance (start-up, tuning, etc.).

P3 Total guarantee - covering the refurbishing and the important maintenance works.

A contract may be a combination of the three types mentioned. The P1-type contract may be accompanied by a profit sharing clause that should normally encourage the parties to save money but not necessarily energy. The principle here is to compare the real energy consumption of the heating season with the theoretical consumption.

Greece. Current legislation was enacted many years ago, and for a variety of reasons, is often unrelated. Furthermore it deals principally with the construction and not the operation phase. Legislation has covered separately many functions of the Building Regulations themselves and more widely fire, health, safety and security, and for a variety of reasons, legislation has been put together without particular regard for cohesion and integration with measures already on the statute books.

As a result, the overlapping and conflicting requirements of existing legislation create waste and inefficiency, since there is no integrated approach concerning and affecting the 'whole-life' of buildings.

Although as such there are no prohibitive provisions concerning effective penetration of SMART building technologies, or integrated systems in buildings, there is no specific legislative framework to support or accelerate them.
Furthermore, the lack of an integrated approach concerning the whole life of buildings, can act as a barrier, as SMART buildings and integrated systems have an advantage over conventional buildings at this point: total life-cycle costs for SMART buildings are generally lower than costs for conventional buildings, due to significant reductions in energy and other cost savings.
It is clear that the eagerly expected new legislation in Greece (EPR) reflects National and International policy intention and objectives towards a sustainable approach in the "whole-life" cycle of buildings. But new legislation takes time and moreover, sustainability measures that have the potential to accelerate SMART building technologies, depend on expenditure for which investors often receive no direct return. Benefit accrues for third parties or the community as a whole.
However, without a modern and integrated Legislative Framework, that encompasses provisions for a sustainable and whole-life cycle approach to construction, and until there is a collective acceptance that this may entail an initial financial burden, the voluntary inclusion of SB technologies and integrated systems will be very slow.
Italy. The Italian building sector is regulated by many normative and technical documents which were continuously amended over the years, resulting in an enormous amount of legislative documentation with consequent negative impact of bureaucracy on the whole construction process. The Testo Unico (Unique Text) was issued as a decree in 2001, gathering together all the legislative and regulative documentation in the building sector in an attempt to simplify and control the whole process.
Part I of the Text contains documentation regarding building construction activities, in particular:

- General documentation, with reference to: application framework, regional authority, authorisation of construction activities and responsibilities, construction procedures, etc.
- Building accessibility, with the related certification documents.
- Urban planning and building construction surveillance, with the related penalties.

Part II of the Text gathers all the technical normative for the building sector. The most important categories are:

- General documentation covering the definitions of building types as function structure, use and financing source.
- Normative documentation related to concrete and metal structure works, including design, execution, inspection, control, responsibilities and penalties.
- Normative documentation related the architectonic barriers removal for both new and existing private and public buildings.
- Normative documentation related the building construction in seismic zones, including the definition of competences at regional and national level.
- Normative documentation related the energy efficiency in buildings.

Part III of the Text contains the detail about abrogation of the old normative legislation still in force and important dates related to the official issue of the Text.
The technical specifications related to the building sector are not, in general, contained in the laws, which are more broad, but in specific technical documents that can be issued by governmental decree or implemented in the technical national and international

standardisation bodies as UNI (the Italian Institute), EN, CEI, etc. The case of air conditioning is typical, although it is not covered by the Italian energy performance of building calculation methodology, it is regulated by a number of UNI standards.

The first energy performance building regulation was issued in Italy in the mid-seventies as a consequence of the oil crisis. In the following years it was reinforced by new laws and decrees. However, the normative was not effectively implemented in either existing buildings or new build projects. The actual energy performance regulation is quite simple since it deals with the heating system only, the major contents of the regulation are related to the building envelope and the heating system. More specifically, the actual normative fixed minimum requirements concern: the thermal insulation of the whole building envelope (as function of geometry and climatic zone); the performance of boilers and of the whole heating system; and the regulation of the system in order to respect the thermal comfort conditions for users (this is the only indication for an eventual automated control!). The normative also gives the procedure for the inspection and testing of boilers and technological spaces and furthermore laid down the basis for building certification, but the implementing decree was never put out.

According to the previous description, it is clear that the actual normative is very simple and does not take into account cooling, hot water, lighting and so on. Various activities are currently carried out in a different framework, in order to develop a new methodology in line with the ED. The new methodology should gather and enlarge the old one, including the whole energy needs of the building. At the same time, no normative supports the use of intelligent technologies for building applications in order to reduce the energy use in the building sector. If it is not a barrier, it is surely a restraint to the wider application of such advanced solutions.

United Kingdom. The power to make Building Regulations is contained in the Building Act 1984. Building regulations are designed to ensure the health and safety of people in and around buildings by providing functional requirements for building design and construction. The regulations also promote energy efficiency, contribute to meeting the needs of disabled people and preventing waste, undue consumption, misuse or contamination of water.

In 2002 new regulations governing the conservation of fuel and power were introduced, which represented an important contribution to the Government's overall objective of reducing carbon dioxide emissions and of conserving energy.

There are 27 building regulations that are arranged in six parts:

General (Citation and commencement, Interpretation).

1. Control of Building Work (Meaning of building work, Requirements relating to building work, Meaning of material change of use, Requirements relating to material change of use, Materials and workmanship, Limitation on requirements, Exempt buildings and work).
2. Exemption of Public Bodies from Procedural Requirements
3. Relaxation of Requirements (Power to dispense with or relax requirements)
4. Notices and Plans (Giving of a building notice or deposit of plans, Particulars and plans where a building notice is given, Full plans, Consultation with sewerage undertaker, Notice of commencement and completion of certain stages of work, Energy rating, Provisions applicable to replacement windows, roof lights, roof windows and doors, Completion certificates).
5. Miscellaneous (Testing of building work, Sampling of material, Supervision of building work otherwise than by local authorities, Sound insulation testing, Unauthorised building work, Contravention of certain regulations not to be an offence, Transitional provisions, Revocations).

There are fifteen Approved Documents issued by the Office of the Deputy Prime Minister (ODPM) intended to give practical guidance on how the technical requirements 1 may be complied with. These Approved Documents are regard: Structures, , Fire Safety, Site Preparation and Resistance to Moisture, Toxic Substances, Resistance to the Passage of Sound, Ventilation, Hygiene, Drainage and Waste Disposal, Heat Producing Appliances, Protection from Falling, Collision and Impact, Conservation of Fuel and Power, Access and Facilities for Disabled People, Glazing – Safety in Relation to Impact, Opening and Cleaning.
Concerning the regulations relevant to intelligent building technologies, even if there is not any regulation on intelligent buildings or intelligent building technologies, there are a few regulations or Approved Documents that are relevant to the general objectives of intelligent buildings and associated technologies: to improve the energy efficiency, to enhance the flexibility, to reduce the operation costs of buildings. These relevant regulations and Approved Documents are summarised as follows.

- Fire Safety, concerned with means of fire safety in buildings.
- Four types of fire alarms and detection system for: the protection of life, manual alarm systems, the protection of property, for multi-occupancy buildings

Automatic fire detection and alarm systems involve a sensor network and associated control and indicating equipment. Sensors may detect heat, smoke or radiation and it is usual for the control and indicating equipment to operate a fire alarm system. It may also perform other signalling or control functions, such as the operation of an automatic sprinkler system.
For what concerns the conservation of fuel and power, the following Approved Documents provide practical guidance for meeting the requirements:

- Guidance on controls of space heating where heat is distributed from a central heat source. No guidance is given on stand-alone heaters. It details the requirements on temperature zone controls, timing zone controls and boiler interlock controls.
- Commissioning, operating and maintenance for heating and hot water systems and controls.
- Lighting systems and the controls. The aim of lighting controls should be to encourage the maximum use of daylight and to avoid unnecessary use of lighting when spaces are not occupied. However, this should not endanger the passage of building occupants.

There are no building regulations on intelligent buildings or intelligent building technologies in the UK. The Building Regulations Advisory Committee's annual report indicates that there are no activities currently being carried out leading to creation of such regulations. However, there are a few existing Building Regulations and Approved Documents that cover the issues that intelligent buildings or intelligent building technologies intend to address in the built environment.

Energy legislation in Europe

On a European level, most of the discussion related to the improvement of the energy efficiency in buildings is, naturally, related the European Directive (ED) on this issue.

The Directive 2002/91/EC brought out on the 16th of December 2002 directly addresses energy efficiency in buildings and the principles contained therein must be brought into force no later than the beginning of 2006. The basic requirements set by the ED are related to:

- A calculation methodology for an integrated energy performance of buildings.
- Minimum requirements of energy performance of new and, under some conditions, existing buildings.
- Energy certification of buildings
- Inspection of heating and cooling systems.
-

One of the most important aspects of the ED is the integrated approach to the calculation procedure and the selection of indicators (i.e. kilowatt-hour per square metre per year and CO_2 emissions per square metre per year) that may characterise the building performance in terms of both energy end environment. It is interesting to present what the new energy performance calculation should take into account according to the Directive:

- Thermal and solar characteristics of the envelope
- Heating, cooling, ventilation, hot water systems
- Natural and artificial lighting
- Passive and active solar technologies and systems
- Indoor comfort conditions
- Advanced energy production and distribution systems (i.e. CHP, active solar, district heating)

The methodology calculation will be applied on the basis of well defined categories of buildings, such as: detached houses, apartment buildings, education, hotels, offices and so on.
Even if the Directive lays down general and qualitative aspects concerning the application of SMART building technologies, it does not give any clear address or support on intelligent technologies applications. This would appear to undermine, or ignore, the potential of such technologies. On the other hand, the Directive explicitly states the importance of an integrated approach aiming at evaluating the whole energy performance of the building, and this addresses indirectly the importance of equipping the building with systems able to control, manage and optimise the systems and components in order to guarantee the minimum energy requirement throughout.
One of the first steps of the Commission was to give a mandate to CEN (European Committee for Standardization), CENELEC (European Committee for Electrotechnical Standardization) and ETSI (European Telecommunications Standards Institute) to elaborate and adopt a set of standards to comply with the ED in terms of the methodology to calculate the energy performance of buildings and the environmental impacts.
The standardisation activities will cover the following issues:

- Methodology for the energy performance of buildings, according to articles 4, 5 6 of the ED.
- Clear identification of the calculation procedure, using standard calculation methods for building products, installation and systems. Also standards developed for EU-labelled products might be taken into account.
- The method for building certification, in accordance with article 7 of the ED.

- Guidelines for inspection of boilers and cooling systems, as stated in the articles 8 and 9 of the ED.

These activities to be carried out will lead to the implementation of several working groups, in order to prepare new standards. One of these will be the "Calculation methods for energy efficiency improvements by the application of integrated building automation products and systems", under the responsibility of CEN Technical Committee 247 "Controls for mechanical building services". The standard will be published as prEN standard by the end of 2004. Considering the difficulty often faced in quantifying the actual benefits of building automation, the institution of this working group and the upcoming publication of this standard represent a first step for the institutional "acknowledgment" of SMART technologies, which will lead to a wider acceptance and effective penetration of such products on the European market in the near future.

Behavioural barriers

A general overview of the building process players

Behavioural barriers have been identified in the various phases of the construction, commissioning and operation of Intelligent Buildings. These barriers are implemented by the players, wittingly or unwittingly, in the IB process and have been identified in operational Intelligent Buildings, the energy performance of which is still far from optimal. The problem can therefore be addressed by assessing the function of the various actors involved in the process.

Designers. Architects and engineers involved in the specification and design of buildings are often wary of new technologies. For example, dynamic envelopes (double skin facades, moveable shading, natural and hybrid ventilated facades) present significant potential for the reduction of the energy loads of buildings, especially if intelligent control strategies are applied and integrated with those of the HVAC systems. However, such solutions are still seldom adopted. Also, advanced storage and heating/cooling systems are not so often used. Moreover, the approach to the building design is not carried comprehensively, with architectural and plant design seen as separate processes. This has an obvious negative impact on the energy saving design solutions. This method of addressing building projects eliminates the strong added value that SMART building technologies give to a building and the positive impact they can have if fully implemented.

Managers. It is often considered that the major investment in the life-cycle of a building is the construction phase. This is, of course not true, after a number of years the management investment is higher than the construction. Limited resources are allocated to the energy management of companies. This implies limited financial capacity of energy managers in implementing energy saving strategies and in influencing the company decisions, in terms of applying innovative solutions which also have the added benefit, in addition to the quantitative savings, of improving the "ecological" image of the company itself.

Decision Makers. Beside the necessary normative actions, lobbying and dissemination activities must be carried on. One of the real barriers, at this stage, seems to be an accurate quantification of the energy savings obtainable through the application of

SMART building technologies. Of course, the added value depends on the technological level of the building and, in this framework, important information will be brought out by the results the technical committee of CEN-TC247 "calculation methods for energy efficiency improvements by the application of integrated building automation products and systems".

Installers and dealers. These market players generally have competence regarding the products they deal with, but not necessarily a global overview of the sector in general. This lack of information is very dangerous in a world where integration is a fundamental issue. This leads to a situation where the client is encouraged towards a product without knowing if it will be possible to be integrated with other systems or will work as a stand alone system.

Users. They play an important role in accepting the presence of intelligent systems. It is clear that even the most advanced system has to work with boundary conditions that might not be accepted by 100% of the users in a building. A small percentage of unsatisfied people will always exist in terms satisfaction with their indoor environment. The real barrier in this case is the decision on what can be operated by the single user and what can be managed by the central system. In residential buildings the situation is harder, if possible, since the user is someway also the manager. Hence any kind of strategy and control must be implemented taking into account the comfort conditions, the energy needs and the economic savings. It is clear that user behaviour is a strong barrier, with different expectations as function of age, wealth, education level and so on. Many of these obstacles might be overcome by means of adequate education and dissemination activities.

A survey study in the smart buildings process players

It is widely accepted that energy management is a support/services function, marginal to the core activity of most organisations. In most organisations there is no top management interest and active support to activities associated with energy management. As a result, the energy consumption in their buildings is significantly higher than it otherwise would be if appropriate energy management was in place.

The study of behavioural barriers aims to identify the particular aspects of human awareness and response to SMART buildings and energy management in general that prevent the effective use of intelligent building technologies (IBT). As a consequence, the study of behaviour aims to investigate means and methods to overcome these behavioural barriers. The behavioural barriers significantly affect the manageability, flexibility and performance of buildings with IBT systems installed.

The intelligent building technologies considered herein are:

- Building management systems (BMS)
- Integrated building control schemes
- Dedicated smart home control systems
- Intelligent control of heating systems
- Lighting control

Other intelligent building technologies, such as fire detection and extinguishing, security detection and access control, structured cabling and networks, have not been adressed.

The structure of the intelligent building technology industry has been continuously changing, especially in the following aspects:

- Penetration of structured cabling
- The scale and value of single project

- Standard communication protocols ("Open Systems").
- The supply chain
- Distribution of "intelligence" inside a building (centralisation or decentralisation)
- Integration of different building services controls

With these changes affecting significantly the way architects and building services engineers regard these systems. Nowadays it has been widely accepted that the IBT industry in Europe is consisted of the following four parts:

- Product development and manufacture
- IBT system design and integration
- IBT system installation and commissioning
- IBT system maintenance and management

Accordingly this study has been carried out at three levels as follows:
Social level: any social factors relevant to the energy efficiency of buildings, such as energy efficiency programmes, activities to promote residences' awareness of energy efficiency, financial schemes to create incentives for utilising intelligent building technologies, etc. Issues related to product development and manufacture, IBT system design and integration, IBT system installation and commissioning are mainly investigated at the social level.
Building managerial level: behaviour of building managers and building management regime that influence the appropriate use of intelligent building technologies and the overall performance. IBT system maintenance and management is mainly investigated at the building managerial level.
Building end-user level: the behaviour of building occupants or end-users that affects the operation of intelligent building technologies and the overall performance.
An in-depth study of the three behavioural regimes has been carried out in the UK by BRE. Two buildings with SMART control have been studied in depth via a behavioural analysis methodology and the identified results have been collated and integrated with Case Studies carried out across Europe where similar trends have been identified in the Walk-through audits carried out.
The following methodology was used for collection of raw data:

- Walk-through survey. Surveys were carried out in a number of buildings with IBT system installed. The purpose of these surveys is to study the behaviour of energy managers and occupants and to investigate the overall performance of these buildings. The Matrix Tool and the associated questionnaire were used for the walk-through survey in two selected intelligent buildings. The relevant information used for this study are: general information about the buildings, historical energy data (i.e. electricity and heating), the energy management regime, list of major energy-consuming devices and systems and their controls, information of BMS, commissioning procedures of the control systems, and occupants' knowledge on the use of terminal devices such as room controllers and TRVs (thermostatic radiator valve).
- Telephone interviews with building operators and specialist facility management companies were made to investigate the business model of IBT industry and how IBT systems have been actually operated.
- Questionnaire surveys: a questionnaire designed to study the occupants knowledge on the use of IBT devices and systems was distributed to occupants accommodated in buildings with IBT systems installed.

- The main results of the walk-through survey are :
- Both of the two buildings are controlled by a Trend BMS. In one of the buildings, the BMS as well as the building system are maintained by a specialist facility management company. In the other building, no regular maintenance has been contracted but the building is maintained by a team of qualified building operators.
- The interviews with the building operators or the facility management company reveal that the control strategies implemented in the BMS have not been updated since the initial commissioning. This has caused major problems in both of the buildings. These problems include inappropriate operation of boilers and chillers, inefficient operation of terminal devices, and malfunction of the BMS. Consequently, the energy consumption is higher than it should be.
- The control of boilers in the two buildings is not energy efficient. In one building, the boiler is controlled using a thermostat that maintains the supply hot water temperature at a predefined fixed value. This results in enormous overheating in the building especially when the heating load is not high. In the other building, the boiler is controlled by a climate compensator, which determines the set-point of the supply hot water temperature according to the external temperature. In theory this compensator should be able to maintain a high efficient control of the boiler throughout the heating season. However, the compensator has never been commissioned properly. A discussion was made with the control engineer who designed and commissioned the BMS. It has been found that he has employed a wrong method to commission the climate compensator. He indicated that the method he had been used was also used by a lot of other control engineers. Eventually, we found that the climate compensator did not determine appropriate set-point for the supply hot water temperature.
- Thirty-six occupants in one building and thirty-nine in the other were asked whether they understood how to operate the terminal devices and to use zone controllers properly. Only thirty-one said "yes". Twenty-nine said "no". And fifteen said "never care about that stuff".
- They were also asked about the comfort. Fifty-two were happy about the thermal comfort. Thirty-one complained about glare. It was noticed that these people were accommodated in south-facing rooms. Twelve complained about the high noise level. Our spot measurement showed that the highest sound pressure level is 73 dBA. In most cast the noise is caused by office devices and traffic.
- Only sixteen of these people care about and understand the energy efficiency in their building. But sixty-seven said they were willing to make effort to improve the energy efficiency but they needed training.
- The facility management company and the building operators are more concerned about comfort than energy efficiency. It is their highest priority to minimize complaints made by occupants. In one of the buildings, where the management is contracted to a specialist facility management company, efforts have been made to save energy and to reduce the operation cost.
- There is no technical support provided directly from the BMS manufacturer in the both buildings.
- There is no integrated control in either building. Apparently most of the BMS outstations are working properly but the whole BMS is not working as a system. The communication network is only used to commission outstations and to upload data from outstation to the central station for display only. Data exchanged is not used for controlling the building system and devices more efficiently. Furthermore, there is no intention to change the situation.

- The top management in one of the buildings expressed strong interest in energy efficiency but no specific strategy has been adapted to ensure the building is managed to achieve high energy efficiency. In the other building, the building owner does not worry about the energy consumption but the facility management company is very keen to save energy because by doing this the contract becomes more profitable.
- Two hundred and fifty telephone interviews with building operators and specialist facility management companies (referred to as the interviewed in the following) have been made. The results are described as follows.
- 42% of the interviewed work with buildings equipped with BMS.
- The percentage of building services systems automatically controlled by BMS is: 65% heating systems, 79% cooling systems, 81% lighting system. Only 18% of the buildings are equipped with automatically controlled solar shedding devices.
- 38% of the BMS have been regularly maintained and updated.
- The highest priority in day-to-day operation: 36% think is "reliability", 52% think is "indoor environment maintained to satisfy the requirement" and 12% think is "energy consumption and operation cost".
- In the heating systems, 75% of radiators are well controlled by TRVs, 25% of radiators are poorly controlled or uncontrolled. 61% of boilers are controlled by thermostat to maintain the supply water temperature at predefined set-point. 22% of boilers are controlled by climate compensators. And 17% of boilers are controlled by heating demand compensators [4]. 91% of boilers have been regularly inspected for safety but only 9% inspected for energy efficiency.
- In the cooling systems, 81% of terminal devices are well controlled and 19% are poorly controlled. 78% of air handling units are controlled to maintain the supply air at a predefined conditions and 22% are controlled according to the cooling demand. 91% of chillers are controlled to maintain the chilled water at a predefined value and 9% is compensated with the cooling load. 56% of refrigeration systems have been regularly inspected.
- In the lighting systems, 95% of lamps are fluorescent or compact fluorescent and only 5% are incandescent. 21% of lamps are dimmable and 79% have "on/off" control. There are presence sensors installed in 24% of the systems.
- Regular assessment of the energy performance is only carried out in 23% of the buildings. Among these assessments, 56% are done by the building management team, 21% by external specialists and 23% by facility management companies.
- The reasons why no assessment has been done are: 52% think it is unnecessary, 25% is due to lack of technical competence and 23% is because of insufficient information.
- Only 15% of occupants have been given training on the use of terminal devices and zone controllers.
- The most important thing to do in order to save energy and to reduce the operation cost: 13% think is "have the building systems inspected by a specialist to identify the potential", 22% think is "improve the day-to-day operation of energy consuming devices and systems", 29% think is "commission the control system regularly in order to optimise the control performance", 19% think is "replace low energy efficient devices by high energy efficient devices", 17% think is "offer sufficient training to the occupants".

Three hundred and twelve answered questionnaires are valid. The results are described as follows.

- Personal assessment of the overall performance in their offices. The results are shown in Figure 3.4. It shows that these people are more satisfied with thermal comfort than aural comfort. This is different from the result obtained through the walk-through survey.
- 95% said there is no particular person who has been assigned the responsibility of ensuring that all of the energy consuming devices and zone controllers are working appropriately. 93% said they have never taken any training on the use of the terminal devices and zone controllers. 55% said they understood how the terminal devices are controlled locally. 63% claimed that they knew how to operate the relevant zone controllers properly.
- 24% never change the setting of zone controllers. 12% change more than once per day. 11% change once per day. 17% change once per week. 12% change once per month. 24% make change whenever they feel necessary.
- What is the first thing you would do if you felt hot in your office: 16% said to change the setting of the TRV or to reduce the set-point of the fan-coil unit controllers, 18% said to open windows, 35% said to make a complaint, 21% said to change clothing, 10% said to do nothing.
- Regarding lighting control, 35% of the people totally rely on the automatic control system, 78% would switch off all lights when leaving office empty, 35% always turn on lighting when staying in office, 14% dim the lamps to achieve desired illuminance levels. Please note that these percentages do not add up to 100% because some people ticked more than one answer.
- 11% said that they always cared about the energy efficiency and operation cost of the building. 19% said that they would care about it if they did not have to make too much extra effort. 70% said that they did not care about it at all.
- 62% said there is nothing that they could do to improve the overall energy performance of the building. 15% said that the key is to use zone controllers appropriately. 71% said that they would consult the building managers when they felt a problem. A number of people have specified other things to do: turn off computers when not in use, use desk fans and removable heaters when possible, lower the setting of TRVs when the weather is not too cold, and make use of day-lighting and natural ventilation.

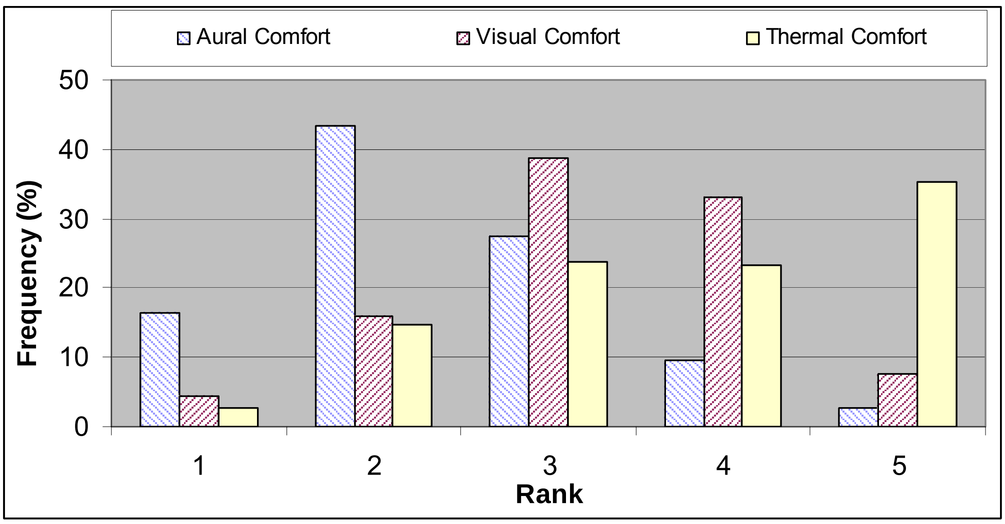

***Figure 3.4** Assessment of the overall performance in offices*

Conclusions and remarks

The conclusions of the above survey stress that several barriers still remain for a wider application of SMART technologies in buildings.
Concerning the major technological barriers it can be concluded that the existing systems readily available on the market are incompatible with each other due to the different protocols which they use, resulting in a closed market and systems which cannot be expanded or adjusted easily. Most of the systems need central computers to operate and they are connected in a classical architecture using major wiring. Only a limited number of systems operate on power lines and radio frequency. The technology is not readily understandable by technicians and installation and commissioning is difficult and often wrongly implemented.
The main behavioural barriers are summarised are: regular assessment of overall energy performance is only conducted in a small proportion of buildings, in most organisations, there is little interest on the overall energy performance from the top management, often building operators are not, regular assessment of overall energy performance is only conducted in a small proportion of buildings. Therefore the actual energy performance of most buildings is unknown. In addition, the majority of building end-users do not care about the energy efficiency and the operation cost of the buildings. Many of them do not understand how the terminal devices work and how to operate zone controllers properly. Very few occupants have taken training on the use of terminal devices and zone controllers. IBT manufacturers should maintain a much improved contact with both IBT system integrators and end-users.
The review of the legislative barriers to the market penetration of smart technologies in the building sector suggests the following conclusions: in all the countries the energy performance regulations is mainly limited to the heating season, other regulations are implemented for the correct design, construction, operation and maintenance of the other building technical systems, but the energy performance of such systems are not integrated in the existent energy performance regulations. Nowhere is clearly stated to support or neglect the application of smart technologies in the building sector. But the actual legislation structure throughout Europe does not help an effective penetration of smart technologies and products. The new European Directive on the energy performance of buildings, with its integrated approach to the energy performance, seems to be an interesting point of departure towards a wider application of intelligent systems. The "Calculation methods for energy efficiency improvements by the application of integrated building automation products and systems", under the responsibility of CEN Technical Committee 247 "Controls for mechanical building services", appears to be the first step for inclusion of consideration of SMART technologies in the new energy performance regulations, that must be implemented by the Members State of Europe by 2006, for the utilisation of smart technologies to improve the energy performance of buildings.

STRATEGIES FOR THE PENETRATION OF SMART BUILDING TEHNOLOGY

In the previous paragraphs it was stressed how the market of SMART technologies for building application is increasing, even if not with an excellent rate, or at least not as good as expected few years ago. It must be also kept in mind that, still today, a strong percentage of the building automation market is focused on the safety and security aspects more than on the energy management systems. From this point of view, it should be stressed that intelligent technologies gives consistent benefit and added values to buildings at two very important levels:

- Environmental and economic. In fact it is well known the importance of reducing the energy end uses in all sectors and in the civil one, in particular. New technologies, based on the automation of the various building system managed by central units and optimised algorithms, can lead to significant energy and environmental savings. Such benefits are also found in the economic balance of buildings, since it is estimated that extra costs are generally a pay back time of 8 years.
- User's comfort, safety and security opportunities. It exists an indubitable requirement of wellness and security. If the latter is not strictly related to the project, the former is. The unbelievable increase of domestic cooling system in many European countries is a typical phenomenon of the last year. Adaptable buildings, equipped with advanced technologies, able to give fast responses to the change of environmental conditions, are suitable to ensure the (thermal, visual, acoustic) comfort for the building occupants.

To reach a structural change in the thinking and constructing buildings these opportunities has to be taken. On the other side, there is mounting evidence that information systems in buildings only operate well at an operational level and offer limited assistance in the creation of a more strategic view of energy use. Perhaps the failure of energy management systems, and the more recent suggestions that intelligent buildings are not as intelligent as they are made out to be, is does not depend on the information systems only. A communication gap exists which cannot be overcome by technology alone. All the actors of the construction process must be involved: building owners and managements, energy managers, planners and designers, and building users have to be made aware of the existing barriers to the effective use of information technologies for energy management systems in buildings and of the available options to be eliminated.
To overcome these uncertainties, the following strategic actions in the IB market are required for the acceleration of the market penetration of SMART building products:

- Promotion of the development of open systems and protocols through standardization committees.
- Provision for training of technicians and designers through appropriate higher education and dissemination methods.
- Stimulation of the major manufacturers towards the development of systems which are expandable, interconnectable and upgradeable.
- Promotion of appropriate market finance mechanisms such as TPF, performance contracting and leasing.
- Promotion of energy efficiency awareness in the workplace and home through appropriate dissemination methods and awareness schemes.