






# Sustainable Constructions Supported by Ecological Smart Technologies

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**Abstract.** We are currently witnessing an increasing demand for residential, office or multifunctional buildings. Customer requirements are not focused only on the economic parameters of the construction, but also on the parameters related to the sustainability and environmental aspect of the construction. In addition, sustainable constructions can be supported by the latest smart technologies. An application of the sustainable approach to constructions is demonstrated by environmental assessment systems.

A brief analysis of knowledge in the field of construction sustainability and smart technologies supporting especially the ecological aspect of sustainability is prepared. These findings represent the theoretical basis for comparing the sustainability of construction on selected construction projects. The aim of the paper is to point out the use of ecological smart technologies that affect the sustainability of buildings. The research was carried out on selected sustainable buildings in Europe which received an outstanding rating within the environmental assessment of buildings by significant certification systems.

**Keywords:** Sustainability · Construction · Smart technology · Environmental assessment system · Comparison

## 1 Introduction

Building performance in sustainability is now a major concern of professionals in the building industry. According to Cole [1] the specific definition of the term “building performance” is complex, since different actors in the building sector have differing interests and requirements in the economic, environmental and social field in sustainability. Raynsford [2] provides a detailed definition for sustainable construction - “Sustainable construction is the set of processes by which a profitable and competitive industry delivers built assets (buildings, structures, supporting infrastructure and their immediate surroundings) which: (i) enhance quality of life and offer customer satisfaction, (ii) offer flexibility and the potential to cater for user changes in the future, (iii) provide and support desirable natural and social environments, (iv) maximize the efficient use of resources.”

Sustainable development embraces the three broad themes of environmental, social and economic accountability, often known as the key points of sustainability.” Interactions among each other of effective parameters of sustainability which are protection of environment, economic progression, and social fair are demonstrated in Fig. 1. The sustainability of construction is demonstrated through the environmental assessment of buildings.



**Fig. 1.** Key points of sustainability [3]

### 1.1 Environmental Assessment of Buildings

Currently, there are several sustainable assessment systems focused on ecological, economic, energetic, social and cultural, technical aspects of construction materials, building as a whole or building and its surroundings [4]. The three main certification schemes are the most widely used in Central Europe - BREEAM certificate (developed in United Kingdom), DGNB certificate (developed in Germany), LEED certificate (developed in the United States) [5]. In addition, a number of national certification systems are used: in Slovakia BEAS, in the Czech Republic SBToolCZ, in Austria Klima: aktiv. A common features of certification systems is that they evaluate selected building parameters in environmental, social and economic field (see Table 1). Building is certified to an assessment level that reflects its environmental, social and economic quality by meeting these criteria. The most important areas on which sustainable construction focuses are sustainable construction methods, sustainable construction materials and recycling and waste reduction [6].

The assessment of the environmental performance of buildings is mainly focused on parameters location of building, construction project management, construction project architecture, indoor environmental quality (thermal and humidity environment, light environment, indoor air quality), energy efficiency (energy for building operation, alternative systems for the use of renewable energy sources), water and waste management, user comfort, hygiene, safety, etc. [7, 8].

**Table 1.** Assessed parameters within certification systems [9]

Economic parameter	Social parameter	Environmental parameter
Investment costs for the construction	Visual comfort in the building interior	Materials used for construction
Operating costs	Visual comfort in the building exterior	
	Spatial building solution	
	Quality of housing	
	Health safety of the building	
	Quality of construction	Acoustic comfort in construction
	Occurrence of failures at the beginning of building use	Light comfort in building
	Occurrence of failures during building use	Air quality in the building
	Construction time	
	Thermal comfort in winter	
	Thermal comfort in summer	

### 1.2 Ecological Smart Technologies in Buildings

At present, the software user interface and computer hardware components are gaining more and more attention. This solution presents an integral part of our life and work. A number of past manual settings have been handled by automation. Informatics takes on a new dimension because computers start working in a stand-alone mode, where they can anticipate errors and avoid them, detect, analyze and evaluate them. The user is not involved to problem solutions. These processes, which take place in the background of the software, simplify the user’s life. Software are becoming intelligent, smart because they know how to assess the situation themselves and are able to react to it. According company Siemens [10], smart technologies present “a cognitive, contextually conscious computing system that is able to make decisions without human intervention”. SMART stands for acronym Self-Monitoring Analysis a Reporting Technology.

Smart technologies also hold their significant place in the field of construction. We can see smart technologies in design, construction or usage phase of buildings. Smart technologies can be used for any type of buildings.

An integral part of the new modern housing are smart technologies of controlled heating, security, camera system, shading elements, control of artificial lighting, irrigation system, air conditioning, control of various appliances as well as the electrical installation. These technologies can be controlled from a single device via wall touch screen, tablet, mobile phone, computer or TV with a network connection by software or application. Smart technologies used in buildings can be divided into [11, 12]:

- technologies for heating control (thermostats, heating controls, smart radiator heads),
- cooling control (air conditioning control and temperature sensors),

- shading control (blinds and shutters controls),
- smart technologies to ensure security (IP cameras, video intercoms, alarms, garage doors and gates, door locks),
- smart sensors and detectors (motion sensors, door opening sensors, flood sensors, fire detectors, CO<sub>2</sub> sensors, etc.),
- smart lighting control technology (smart bulbs),
- smart technologies in electrical installations (Smart sockets, switching relays and modules, consumption meters),
- smart irrigation technology,
- smart technologies for multimedia control (IR control devices).

Smart technologies in an ecological building perform a large number of activities and can significantly affect the condition of the building, safety, its energy consumption and many other features. Smart technologies in the building by the collected data (such as the weather) can make activities focused on reducing the temperature and elimination of heat loss; further smart irrigation technology, based on the evaluation of weather forecast, can turn the lawn irrigation. Ecological smart technologies in construction affect the indoor environment:

- thermal and humidity environment (smart technologies used for heating and cooling),
- lighting environment (smart technologies used for indoor lighting by natural or artificial light),
- indoor air quality (smart technologies used for ventilation in buildings) [7, 11].

## 2 Research Material and Methodology

The current trend in construction is the implementation of sustainable buildings, which are supported by smart technologies. Respect for the objectives of Agenda 21 is evidenced by the today's buildings which minimize the negative impact of constructions on environment.

The aim of the paper is to point out the use of ecological smart technologies that affect the sustainability of buildings.

### 2.1 Research Material

The research was carried out on selected sustainable buildings in Europe which received an outstanding rating within the environmental assessment of buildings by significant certification systems. Buildings involved in the research were selected on the basis of the following criteria:

1. building intended primarily for administrative purposes (possible additional residential purposes),
2. building was evaluated by the BREEAM assessment system and received an outstanding or excellent rating,
3. building achieves the best evaluation score in environmental aspects of sustainability, particularly focused on the quality of indoor environment,

4. building is located in Europe,
5. building is built or renovated only after year 2010,
6. building uses smart technology for their operation.

## 2.2 Research Methodology

The research methodology consists in the analysis and synthesis of information related to the identification of ecological smart technologies in selected buildings. Then, the number of smart solutions in the examined buildings was determined. The achieved analytical data were evaluated and the conclusions of the observation were expressed. The knowledge survey was conducted in 2019.

## 3 Results and Discussion

The research sample consisted of 10 office buildings, which were awarded a BREEAM certificate, specifically – 4 buildings in the Great Britain, 1 building in the Netherlands, 2 buildings in the Czech Republic and 3 buildings in Slovakia. Buildings located in the UK and the Netherlands received the highest BREEAM assessment at the time of the survey. The buildings included in the research in the Czech Republic and Slovakia achieved the highest environmental rating in these countries.

The BREEAM method for the environmental assessment of buildings built in the United Kingdom is also the most widespread. The BREEAM system evaluates many office buildings in the UK. Some buildings rated by the BREEAM certificate achieve the highest score (very good, excellent, outstanding). Only buildings that received an outstanding rating were included in the research. The BREEAM certification system is also the most widely used in the Netherlands. In the Czech Republic, buildings are environmentally assessed by the SBToolCZ [23] system adapted to the conditions of the country, but the BREEAM and LEED methods are widely used. Only buildings that were evaluated by the BREEAM system were included in the research. Unfortunately, certified buildings in the Slovak Republic do not achieve the highest level of Outstanding certification in the system of environmental assessment of buildings using the BREEAM method. The best rated building with the BREEAM system in Slovakia is the Zuckermandel project. However, it reaches a slightly lower level than the world level, specifically the level of certification very good.

### 3.1 Brief Description of the Analyzed Buildings – Environmentally Sustainable Solutions

#### *20 Fenchurch Street, London, UK*

Building presents, the office building in London, built in 2011, received scores 80,2% by BREEAM certification. Designers and architects set out to ensure the 38-storey tower, known as ‘The Walkie Talkie’ was one of the most sustainable buildings of its type in London, and have deployed a number of innovative measures throughout the design, construction and operational phases. Highlights in design approaches to environmental:

- UK's largest green wall valuable green infrastructure,
- low zero carbon (LTC) technologies – roof mounted solar PV (photo voltaic) panels,
- certified sustainable sourced concrete and structural steelwork was used,
- noise and air quality monitoring – real time monitoring of noise and dust during construction [13].

*Five Pancras Square, King's Cross, London*

Building obtained highest rated BREEAM Bespoke Building in the UK at 97,5% rating achieved. Environmental features involved:

- low carbon heating and electricity to the building,
- smart steps taken in the facade design to maximise daylight factors throughout the occupied areas, and to minimise artificial lighting requirements through adopting daylight linking/dimming,
- monitoring of energy and water use,
- photovoltaics to achieve zero carbon status [14].

*One Angel Square, Manchester, UK*

This office building in Manchester is one of the most sustainable buildings in the UK and Europe. It also confirms its environmental qualities by obtaining an excellent certification level by the BREEAM system with a score of 95,16%. Like previous buildings, building ensures its ecological sustainability by using natural resources, maximizing thermal solar gains, rainwater harvesting, greywater and rainwater recycling systems for toilet flushing and irrigation [15].

*Bloomberg, London, UK*

Construction was built as one of the world's highest BREEAM-rated major office buildings. In 2014 Bloomberg received a score of 99.1% in the environmental assessment. The innovation highlights involve:

integrated ceiling panels which combine air supply, cooling, lighting and acoustic functions in an innovative petal-leaf design,

- rainwater from the roof, cooling tower blow-down water, and grey water sources, like basins and showers, is captured, treated and recycled to serve vacuum flush toilets,
- the building breathes - when ambient weather conditions are temperate, the building's distinctive bronze blades can open and close, allowing the building to operate in a "breathable" natural ventilation mode,
- smart airflow by smart CO2 sensing controls allow air to be distributed according to the approximate number of people occupying each zone of the building at any given time [16].

*The Edge, Amsterdam, the Netherlands*

The Edge is the office building constructed in 2016 in Amsterdam which obtained outstanding rating 98,3% in BREEAM evaluation. A number of intelligent technologies, with their ability to adapt autonomously to the user, his requirements as well as the influence of the external environment, create intelligent workspaces without disturbing the

users they try to make as satisfied as possible in this environment, ensuring comfortable working in a productive and healthy environment. The degree of technical excellence of the Edge office building accelerates the development of sustainable buildings using intelligent technologies. The Edge consumes 70% less energy compared to buildings of the same type [17].

*Tower B, Spielberk Office Center, Brno, the Czech Republic*

Tower B contains a number of technological innovations that help to make it highly valued. It has a sophisticated façade that provides adequate lighting as well as protection against overheating. Ventilation and air exchange is solved using fan-coil units. Smart technologies in the building move it to a higher level of information and thus ensure its sustainable operation with energy savings [18].

*Blox, Prague, the Czech Republic*

A sustainable office building, which also received the highest level of certification in the environmental assessment by the BREEAM system in in Prague. The building is equipped with the latest technologies that continuously monitor the indoor environment via sensors and then perform autonomous interventions to ensure user comfort as much as possible [19].

*Zuckermandel, Bratislava, Slovakia*

The Zuckermandel project is the construction of a new city district which consists of the construction and renovation of the historic area in Bratislava. During the BREEAM environmental assessment, the building received an assessment – excellent [20].

*Twin City, Bratislava, Slovakia*

The advantages of the building include 30% energy savings due to the increased thickness of the thermal insulation of the facade and roof, triple glazing on all transparent surfaces or intelligent shading. Of course, there are also technologies in the field of ventilation with heat recovery and humidification systems or charging stations for electric vehicles, the use of rainwater and intelligent lighting [21].

*Forum Business Center I, Bratislava, Slovakia*

This building belonged among the first buildings in Slovakia rated by the BREEAM environmental rating system as excellent. It uses shading, ventilation or cooling technology, the building also includes a green roof made of local trees or other ecological parameters contributing to its excellent evaluation. The building, uses various devices for its operation in order to minimize manual interventions and save energy [22].

All presented buildings are shown in on Fig. 2.

### 3.2 Brief Description of the Analyzed Buildings – Smart Solutions

The research was not only focused on exploring ecological sustainable building solutions, but primarily on identifying smart solutions that support this aspect of construction. Then, the environmentally sustainable and smart solutions of building were compared (see Table 2).

All evaluated buildings contained the environmentally sustainable solutions. Their number and innovation was also reflected in the level of BREEAM rating:

- outstanding more than 85%,
- excellent 70%–85%,
- very good 55%–70%.

The sophisticated solution for the eco-sustainability of buildings is directly proportional to the use smart elements in constructions.



**Fig. 2.** Analyzed buildings with the ecological sustainable solutions: a) 20 Fenchurch Street [13], b) Five Pancras Square, King's Cross [14], c) One Angel Square [15], d) Bloomberg [16], e) The Edge [17], f) Tower B, Spielberk Office Center [18], g) Blox [19], h) Zuckermanel [20], i) Twin City [21], j) Forum Business Center I [22]

**Table 2.** Comparison of environmentally sustainable and smart building solutions.

Building/Country	BREEAM rating in %	Environmentally sustainable solution									Smart solution (number)
		1	2	3	4	5	6	7	8	9	
20 Fenchurch Street/UK	80,2	*	*	*	*	NA	*	*	*	*	1
Five Pancras Square/UK	97,6	*	*	*	*	*	*	*	*	*	1
One Angel Square/UK	95,16	*	*	*	*	*	*	*	*	*	3
Bloomberg/UK	99,10	*	*	*	*	*	*	*	*	*	5
The Edge/NL	98,36	*	*	*	*	*	*	*	*	*	7
Spielberk Office Center/CZ	76,8	*	*	*	*	*	NA	NA	NA	*	0
Blox/CZ	86,9	*	*	*	*	*	*	NA	NA	*	0
Zuckerman del/SK	82,3	*	*	*	*	*	*	*	*	*	3
Twin City/SK	80,19	*	*	*	*	*	NA	*	*	*	0
Forum Business Center/SK	73,0	*	*	*	*	*	NA	NA	*	*	0

Notes: 1 - heating, 2 - cooling, 3 - air exchange, 4 - shielding, 5 - lighting, 6 - renewable energy sources, 7 - photovoltaic panels, 8 - use of rain and gray water, 9 - energy saving; \* - eco-sustainable solution is used; NA – data is no available; \*- smart solution is used

Building *20 Fenchurch Street* boasts the first hydrogen fuel cell (as an eco-smart solution) to be installed in a commercial building. The fuel cell, which will be switched on later this summer, produces heating cooling and electricity, generating 300kW of low carbon, low emissions electricity, reducing the building's carbon dioxide emissions by at least 270 tonnes per annum.

*Five Pancras Square*'s smart steps taken in the facade design to maximise daylight factors throughout the occupied areas, and to minimise artificial lighting requirements through adopting daylight linking/dimming.

Another smart approaches to environmental building performance is used in *One Angel Square*, specifically:

- heat recovery from the IT systems that will also help to heat the building,
- low energy LED lighting and IT equipment and systems,
- high-efficiency passenger and service lifts.

One of the most sophisticated building in the world, *Bloomberg*, involved many smart elements:

- smart natural air exchange, where exterior blades that allow the building to breathe, and at the same time ensure its optimal shading, lighting,
- a shell ceiling that ensures optimal light distribution,

- smart use of rain and gray water,
- smart use of renewable energy sources.

The smart approach in building *The Edge* is applied in all researched areas. Environmental smart features involved:

the orientation of the building and the facade are based on the path of the sun, smart lighting which consists of 30,000 sensors to continuously measure occupancy, movement, lighting levels, humidity and temperature, allowing it to automatically adjust energy use,

- solar panel roof which use of neighborhood level energy sourcing,
- energy reuse,
- rain water reuse,
- thermal energy storage.

Moreover, personalised workspaces by mobile application, i.e. every employee is connected to the building via an app on their smartphone. Using the application, they can find parking spaces, free desks or other colleagues, report issues to the facilities team, or even navigate within the building.

In the Czech Republic and Slovakia, the examined buildings received a lower BREEAM rating. It was also reflected in the analysis of used smart solutions. Except for building *Zuckerman*, none of the evaluated buildings used the smart elements for supporting of environmentally sustainability of buildings. Building *Zuckerman* in Bratislava used smart solutions and technologies. One of these autonomous intelligent devices is a meteorological station located on the roof of the building, which evaluates the weather and, through an intelligent system, positions the blinds so that the interior does not overheat and at the same time lets in enough light.

## 4 Conclusion

Sustainability of construction is currently another aspect that affects the planning of construction projects [24]. Architects and designers respect the ecological operation of office buildings, as evidenced by the excellent and outstanding results of certification by environmental assessment of buildings. Smart technologies supporting the ecological performance of buildings are able to increase the ecological potential of newly designed buildings. Smart technologies significantly save energy and resources, responsibly approach the protection of the environment and human health and significantly increase user comfort. The paper analyzed used environmentally sustainable solutions and smart solutions which supported the eco-sustainability. The survey shows that the leaders in the field of ecological smart solutions are buildings in the United Kingdom and the Netherlands. Buildings in the Czech Republic and Slovakia lagging behind in this area.

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