HI-SMART

HI-SMART: HIGHER EDUCATION PACKAGE FOR NEARLY ZERO ENERGY AND SMART BUILDING DESIGN

MODULE #6

ENVIRONMENTAL AND ECONOMIC IMPACT

Co-funded by the Erasmus+ Programme of the European Union

MŰEGYETEM 1782

STU SLOVAK UNIVERSITY OF TECHNOLOGY IN BRATISLAVA

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1 SUSTAINABILITY

1.1 INTRODUCTION

The European Commission has recently approved the so-called European Green Deal. In the construction sector, it is accompanied by the New European Bauhaus initiative, which aims in particular to bridge the gap between different backgrounds, cutting across disciplines and to promote participation at all levels, which would target transformation along sustainability, aesthetics and inclusion. Nevertheless, it seems that the Commission is not quite sure how to move forward in the construction sector, while at the same time being determined and willing to act in accordance with its precautionary principle as is usual in EU policy making.

For the time being, it is directing its efforts and finances mainly towards the renewal and modernization of the existing building substance. It is certainly also aware that, following the significant tightening of energy efficiency requirements for buildings, the further potential for reducing primary energy input (PEI) and global warming potential (GWP), especially for new buildings, lies in optimizing buildings in terms of securing the indoor comfort and the technological maturity of building envelope and also in reducing the amount of embodied energy. In order to demonstrate this reduction, there are considerations for the introduction of environmental product declarations for buildings (EPDBs).

Sustainable construction experts emphasize energy and material efficiency, as well as energy and resource efficiency. The determining factors of sustainable or ecological construction are - the use of renewable energy sources and their optimal use, the right choice of location and the choice of materials so as to minimize damage to air, water and soil during their production, use and disposal.

1.2 CASE STUDY

In the case study described, the expected energy demand of a detached house in the course of its service life and the energy input (embodied energy) necessary for its assembly and for the manufacture of the individual building products were compared. The operation of the building during its service life was described using a computer-aided building performance simulation. The input data related to the embodied energy were based on information from classical works on life cycle analyses. The authors compared two alternatives of the building envelope, massive and light construction, each for five average U-values of the envelope. The operation of the most energy efficient variant of a massive house (U-value = 0.28 $W/(m^2K)$) was also simulated using mechanical ventilation with heat recovery. Reducing the heat loss through ventilation obviously leads to a reduction in the need for operating energy. The possible use of renewable sources for heating and eventual cooling would make the house nearly zero energy building (nZEB). In the case of nZEB, therefore, the further potential for reducing PEI and GWP lies only in reducing the embodied energy. A similar assessment can be made for almost every building.

The PEI and GWP due to embodied energy are indicators that illustrate the overall energy intensity of a building and the burden caused by its greenhouse gas emissions well. However, there are currently no benchmarks to say when a building is still acceptable and when it is not. Such benchmarks are also very difficult to establish in the case of embodied energy. Hence, it would certainly be preferable if only environmentally friendly products in terms of low embodied/grey energy and associated CO_2 emissions were marketed. One possible way to contribute to this goal would be to strengthen and consistently promote emission trading to ensure that greenhouse gas emissions are reduced from the start of the construction process.

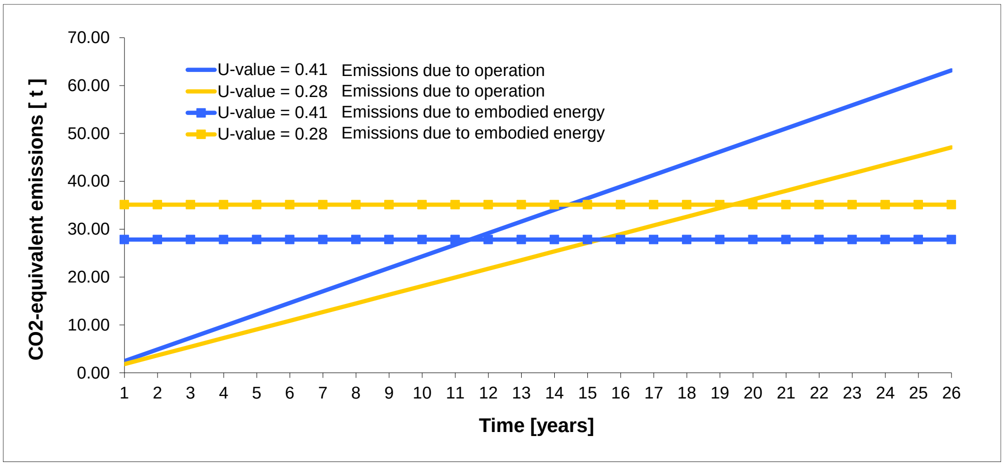

Figure 1 - Time needed to achieve the "break-even point" equalizing the CO_2-equivalent emissions due to the embodied energy with CO_2 emissions due to the building operation in dependence on the mean U-values of a brick-based house (Rabenseifer, R. & Jamnický, M., 2020). The CO_2-equivalent emissions due to the embodied energy are expressed by constant lines and the CO_2-equivalent emissions due to the building's operation are represented by ascending lines.

2 WHOLE LIFE COSTING AND LIFE CYCLE COSTING

One of the aims of sustainable building is also to keep the long-term overall costs of a building as low as possible. Planners used to take into consideration merely initial investment (building costs) required for a new construction. Costs of operation and deconstruction at the end of the service life were ignored. Today it is necessary to take into consideration also costs arising from the use stage (operation, maintenance, repair etc.) and final utilization or disposal of building structures and products. This should be determined during the planning stage in the form of Life cycle costing (LCC) or Life cycle cost analysis (LCCA).

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The first sustainability assessment systems began in the 1990s, with the aim of creating societal pressure to build environmentally friendly buildings that are both energy-efficient and resource-efficient. Evaluation systems take into account the impacts of buildings throughout the life cycle of buildings, from the extraction of raw materials, the production of building materials, their transport, the construction and operation of the building itself, the demolition of the building at the end of its life, waste management and recycling.

Figure 2 – Subjects and targets of protection of sustainability according to J. L. Moro: DETAIL practice Flooring Volume2, Edition Detail, 2016

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Economic performance of buildings consider cost or financial value over the life cycle of a building with the aim of reduction of life cycle costs and costs of sustainable conservation and increase of economic value of a building. Assessment of economic performance can be worked out as **Whole life cost or Life cycle cost**.

Both methods are used to **determine the most cost-effective option among comparable alternatives for purchasing, operating, maintaining and disposing any project or processes**

and for cost optimization strategies in early planning decision making process. Decisions are related to:

- to adapt /redevelop existing facility or to provide new one (investment planning stage)
- choice between alternative designs (design and construction stage)
- choice of alternative components (construction and in use stage)
- comparison of previous decisions
- estimation of future costs

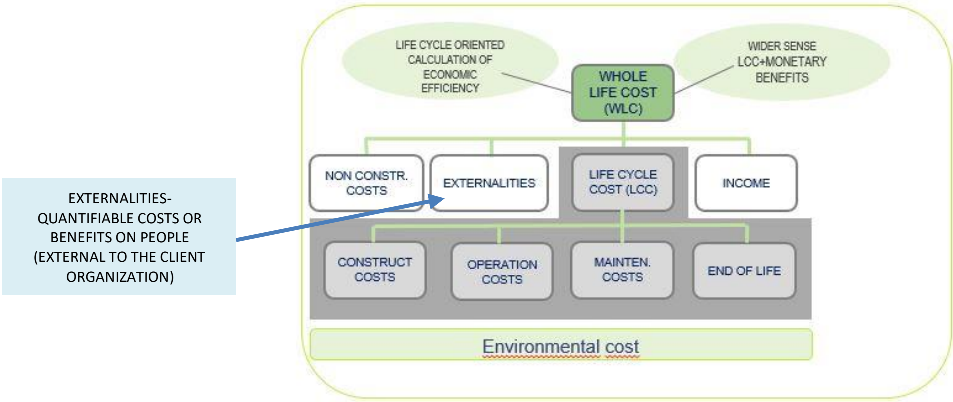

Figure 3 – LCC and WLC elements according to ISO 15686-5

In many construction projects, initial investments costs may only account for around 20% of the total costs which the owner will incur during the period of ownership – particularly when energy bills and maintenance costs are taken into account. Whilst many sustainable construction solutions may require higher initial investments, once running costs are taken into account they will generally provide a return on investment over time. This is further emphasised when a value is given to sustainability benefits, which may also include improving occupier performance through creating a more comfortable working environment. The strongest opportunity to use WLC is during early design stages. **Over the course of the project the authority's ability to influence cost decreases. It has been estimated that 80-90% percent of the cost of running maintaining and refurbishing a building is determined at the design stage.**

3 LIFE CYCLE ANALYSIS AND LIFE CYCLE COSTING

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European committee for standardization (CEN) established technical committee CEN/TC 350 Sustainability of construction works with the aim to develop voluntary harmonized method for the assessment of the sustainability aspects of new and existing construction works and for the assessment of construction products.

The requirements set out in the set of standards are voluntary, the main aim of the set of standards is to allow comparability of evaluation results. The standards do not specify reference values or property levels. Requirements to ensure the sustainability of construction are bound in EU directives and regulations, which are transposed into national legislation in the form of laws and decrees.

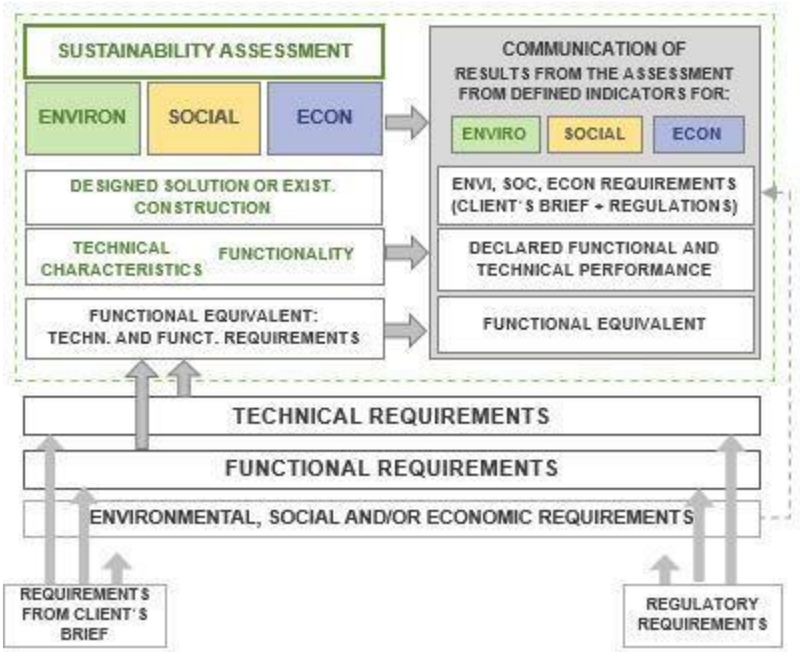

Figure 4 – Concept of integrated building performance of buildings according to CEN/TC350

Life cycle approach considers all stages from extraction of raw materials to the transport, from processing, manufacturing, packaging and distribution of construction products to their use and re-use, recycling and waste disposal.

Life cycle assessments of buildings are the basis for material or component alternatives comparison, related to life cycle scenario chosen by the planner with the aim to find the potential for improvement of the building. Life Cycle Assessment (LCA) is a method in order to analyze and quantify the environmental aspects and impacts of a product system over its life cycle. Basics and requirements are described in ISO Standards 14040 and 14044. The lifecycle assessment method according to ISO 14040 is divided into 4 phases (Fig. 10):

- Goal and scope definition
- Inventory analysis
- Impact assessment
- Interpretation

Example of life cycle assessment – Goal and scope definition (according to S. El Khouli et al: Sustainable construction techniques,Detail, 2015, p. 25):

- **Question**: Throughout the total building life cycle, which building life cycle, which building components and life cycle phases have the most influence on the total building´s environmental impact?
- **Goal**: identification of the building components and life cycle phases with the greatest potential for improvement.
- **Procedure**: examination of 12 different multi-unit dwellings. The same system boundary is used for all buildings in order to ensure better comparability of the results.
- **System boundary**: at the end of service life, most materials are usually disposed of (that cannot be reused). These materials are disposed of at a landfill during construction site preparation.
- **Allocation method**: cut off approach at end of life. (so called cut off criteria determination means which materials due to their small amount can be excluded from the evaluation, except of hazardous compounds)
- **Functional unit**: $1m^2$ of treated floor area per year of the building’s design life.
- **Data source and data quality**
- **Assumptions**: e.g. thickness of layers in components, service life of individual materials, transport distances etc.
- **Impact categories and impact indicators**:
    - **Embodied energy** (non-renewable energy for production, transport and disposal of building materials) and non-renewable energy for building operation
    - **Embodied emissions** (from production, transport and disposal of building materials) and emissions from building operation (GWP 100a).

4 NEW CONSTRUCTION AND RENOVATION

Sustainable construction (SC) provides an ethical and practical response to issues of environmental impact and resource consumption. Sustainability assumptions encompass the entire life cycle of the building and its constituent components, from resource extraction through disposal at the end of the useful life of the materials. Detailed conceptual model for SC (Fig. 1) is based on principles and resources applied for the build environment during continuous phases. It is a decision-making tool for use in examining the options that may occur during the entire building life cycle.

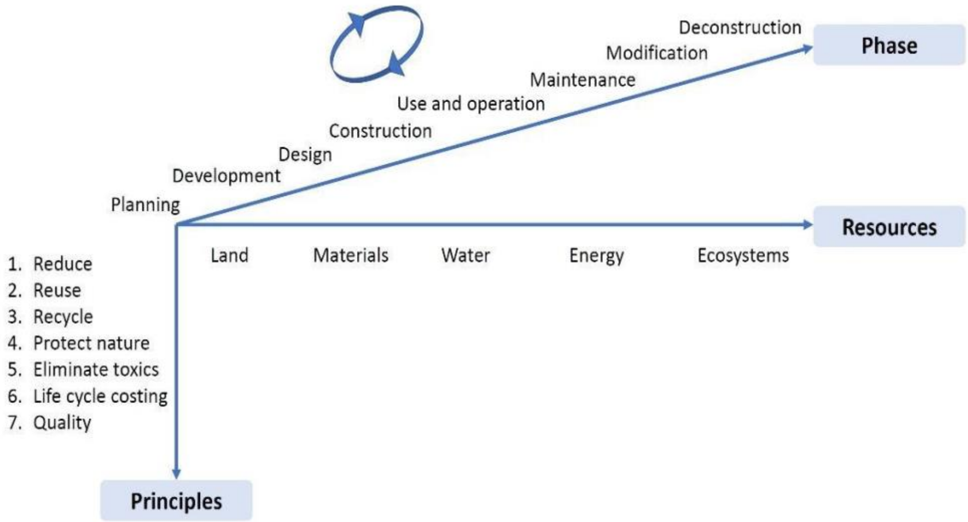

Figure 5 – Framework for sustainable construction developed in 1994 by the CIB Task Group 16.

The green building strategy focuses on the use of plants on and around urban buildings (Fig. 2). Direct integration of plants in a building envelope can induce the transformation of the solar energy into biomass, oxygen, and air humidity, as well as reduce urban heat islands.

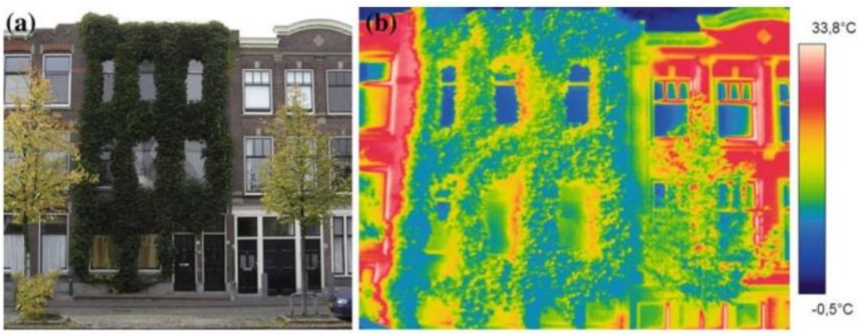

Figure 6 – a) Green façade in Delft summer 2009. b) Infrared photo of the façade. Source: Marc Ottelé, A Green Building Envelope: A Crucial Contribution

The main building blocks can be composed as sustainable structural timber-straw wall elements - The EcoCocon (Fig. 3) wall system with both Passivhaus and Cradle to Cradle certifications. An integral part of the system is the use of an airtight, yet diffusion-open membrane on the outside of the panels.

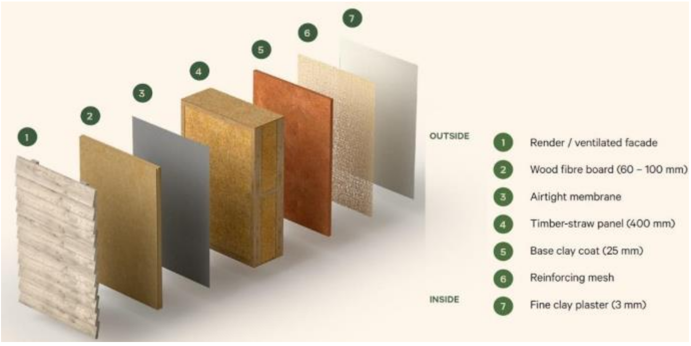

Figure 7 – The EcoCocon wall system. Source: ecococon.eu

5 CERTIFICATION SCHEMES

The certification schemes share a series of common approaches and aims:

- Energy and environmental evaluation of buildings based on criteria concerning site potential, building structures and materials, energy efficiency, water conservation, indoor air quality, operation and maintenance.
- Inspiration to find innovative solutions that minimize the impact on the environment.
- Design a system to help reduce running costs, improve working and living conditions.
- Market recognition for low environmental impact buildings.

The certification schemes typically consist of three major components:

- **the structure** – a declared set of environmental performance criteria organised in a logical fashion.
- **the scoring** – the assignment of several possible points or credits for each performance issue that can be earned by meeting a given level of performance.
- **the output** - a means of showing the overall score of the environmental performance of a building or facility.

BREEAM is currently world's leading sustainability assessment method for the sustainability of buildings. The appropriate BREEAM assessment tool or calculator is selected and then adjusted the scoring and weightings to reflect the categories and individual credits assessed. For each of BREEAM's nine categories the number of credits awarded is determined according to the number of credits available when the criteria of each assessment issue have been met. The percentage of available credits achieved is calculated for each section. The percentage of credits achieved in each section is multiplied by the corresponding weighting for each section to give the overall environmental category score. The section scores are added together to give the overall BREEAM score. The overall score is compared with the BREEAM rating benchmark levels and, provided all minimum standards have been met, the relevant BREEAM rating is achieved. An additional 1% can be added to the final BREEAM score for each innovation credit achieved (up to a maximum of 10% with the total BREEAM score capped at 100%).

Table 1 – Example BREEAM UK score and rating calculation. Source: www.breeam.com

BREEAM section	Credits achieved	Credits available	% of credits achieved	Category weighting (fully-fitted)	Section score (%)
Management	14	21	66.67	0.11	7.33
Health and Wellbeing	12	22	54.55	0.14	7.64
Energy	15	31	48.39	0.16	7.74
Transport	8	12	66.67	0.10	6.67
Water	4	10	40.00	0.07	2.80
Materials	8	14	57.14	0.15	8.57
Waste	3	6	50.00	0.06	3.00
Land Use and Ecology	5	10	50.00	0.13	6.50
Pollution	8	12	66.67	0.08	5.33
Innovation	2	10	20.00	0.10	2.00
Final BREEAM score				57.58%	
BREEAM Rating				VERY GOOD	

6 ENVIRONMENTAL, COMFORT, FIRE PROTECTION ASPECTS

6.1 INTRODUCTION

The environmental and economic impact of buildings falls mainly under the social and economic pillars of sustainability assessment. The design of buildings in terms of environmental and economic impact is defined by a large number of legislative and standard requirements, which have been developed to ensure the basic functionality of the building in terms of health, safety and comfort. The assessment criteria for these two aspects are rather difficult to establish when assessing the sustainability of buildings, although some certification schemes attempt to do so. The complexity of the issue is illustrated by the case study presented.

6.2 EXTENSIVE ROOF GREEN IN CENTRAL EUROPEAN CLIMATE

The green roofs are mostly seen as architectural components having a positive influence on quality of life, particularly in urban settlement structures. This positive effect is manifested at the macro level through improving air quality and also reducing effect called urban heat islands and at the very buildings by raising their interior comfort, especially floors directly under the roof. The precondition for effectiveness at macro level is particularly healthy green converting carbon dioxide to oxygen, casting a shadow on the flat roof and moisturizing surroundings in summer. In winter, it has particularly aesthetic and psychological importance. Care of greenery is of paramount importance, while in larger areas it may also be quite costly affair. Operation of green roofs may over time exceed possibilities of small investors, which is then reflected in a gradual decline of greenery and counterproductive change of the roof into a dusty surface with negative impacts in the environment. A correct design of greenery reflecting the roof structure and location of the building is therefore very important.

In terms of the quality of the internal environment the greenery itself is more or less insignificant factor, a more important role plays the substrate, which can contribute to the thermal protection of the internal environment in the summer and winter as well. In summer, it is especially its ability to accumulate solar radiation and thus prevent overheating of the under-roof space. In winter time period, the substrate is contributing to the improvement of thermal resistance of the roof structure, even though it has to be ignored within calculation of the roof's thermal resistance as it is not its integral part. From legal point of view, hence, an improved thermal protection of under-roof spaces is a secondary effect of green roof and as such should not play a major role in the decision-making process during the green roof design (even though in case of wooden roofs it can be quite an important factor).

More important is to consider whether the cost of its construction and operation will return in the form of more attractive and healthier environment, but this is easier said than quantified. The essence of green roof is greenery and its positive health and aesthetic effects on humans. It can, however, only be achieved, if the greenery is truly functional. Under the climatic conditions of Central Europe with four approximately equal seasons, cold winters and relatively warm, and often dry, summers are the plants in artificial conditions, under which the green roof can be considered, subject to extreme temperature fluctuations. Even plants typical for the Central European area that thrive in this environment can be difficult to survive. In contrast to the plant roots in the normal ground, the temperature of which oscillates at one meter depth under the ground surface between 0° and approx. 16° of Celsius, i.e. in the range of approx. 16 Kelvin, the roots of greenery planted in roof's substrate are exposed to a much wider temperature range.

6.3 CASE STUDY

Using an example of typical green roof with extensive greenery the case study (Kravka, Daněk and Rabenseifer, 2016) shows the course of temperatures in the substrate of green roof

during the common winter and summer days and compares it with the temperature course at the same depth below the surface of the common ground. From the study is obvious that the temperature course in the substrate of the green roof has in summer (fig. 1) far greater fluctuations than the temperature course in the soil of the surrounding terrain at the same depth below the surface (fig. 2). The selection of suitable plants is therefore extremely important. Their root system is significantly exposed to contradictory requirements. On the one hand, it must withstand dry periods with high temperatures and on the other hand long periods of cold and wetness. Despite the fact that extensive green roofs are often designed without an irrigation system, we recommend to think about it in the project - also with regard to climate change towards higher atmospheric temperatures.
When using subtle plants, it is advisable to plan the vegetation layer thickness of a few centimeters higher than recommended. The period, during which an extensive green roof has primarily fulfill its function i.e. reduce dust and ambient temperature, oxidize and humidify the air, is namely summer.

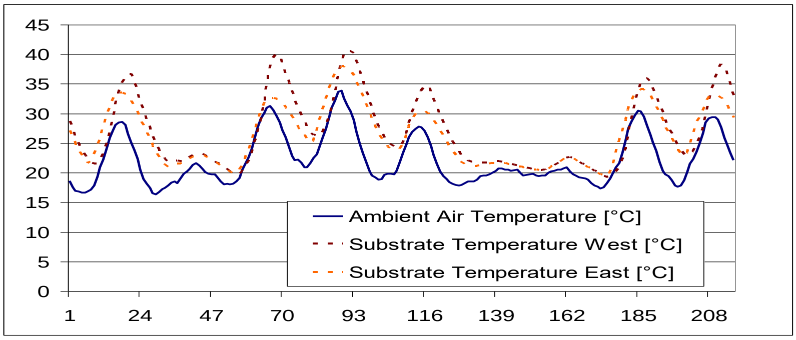

Figure 8- Substrate temperatures in 6 cm depth below surface during peak summer days (the time is indicated in hours)

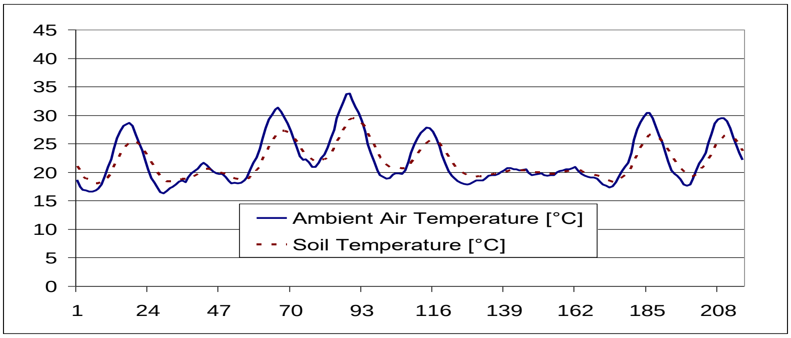

Figure 9- Temperatures in 6 cm depth below soil surface of the terrain ground surrounding the building during peak summer days (the time is indicated in hours)

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EN 15643-1 Sustainability of construction works. Sustainability assessment of buildings. Part 1 General framework

EN 15643-2 Sustainability of construction works. Sustainability assessment of buildings. Part 2 Framework for the assessment of environmental performance

EN 15643-3 Sustainability of construction works. Assessment of buildings. Part 3 Framework for the assessment of social performance

EN 15643-4 Sustainability of construction works. Assessment of buildings. Part 4 Framework for the assessment of economic performance

EN 15643-5 Sustainability of construction works - Sustainability assessment of buildings and civil engineering works - Part 5 Framework on specific principles and requirement for civil engineering works

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