UNIVERSITY OF BELGRADE
Faculty of Mechanical Engineering

10th International Scientific Conference

IRMES 2022

Research and Development of Mechanical Elements and Systems

PROCEEDINGS

"Machine design in the context of Industry 4.0 – Intelligent products"

ADEKO
Association for Design, Elements and Constructions

26 May 2022, Faculty of Mechanical Engineering, Belgrade, Serbia

10th International Scientific Conference - IRMES 2022

Research and Development of Mechanical Elements and Systems

PROCEEDINGS

Machine design in the context of Industry I4.0 – Intelligent products

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Dear Ladies and Gentlemen, Colleagues, Participants and Friends of IRMES 2022

The International Conference on Research and Development of Mechanical Elements and Systems – IRMES is organized under the auspices of the Association for Design, Elements and Constructions (ADEKO). The Conference has a long tradition of gathering scientists, researchers, academics, engineers and industry representatives, intending to exchange and share knowledge, ideas, experiences, innovations and research results in the field of engineering design, machine elements and systems.

So far, there have been nine editions, organized by several universities – members of the ADEKO association:

1995 – University of Niš, Faculty of Mechanical Engineering
1998 – University of Belgrade, Faculty of Mechanical Engineering
2000 – University of Podgorica, Faculty of Mechanical Engineering
2022 – University of East Sarajevo, Faculty of Mechanical Engineering
2004 – University of Kragujevac, Faculty of Mechanical Engineering
2006 – University of Banja Luka, Faculty of Mechanical Engineering
2011 – University of Niš, Faculty of Mechanical Engineering
2017 – University of Montenegro, Faculty of Mechanical Engineering
2019 – University of Kragujevac, Faculty of Engineering

More than a thousand authors participated in previous IRMES conferences, with more than a thousand papers published in total. The current IRMES conference was supposed to be held in 2021. However, due to the COVID-19 epidemic, it was postponed to 2022.

The main topic of the IRMES 2022 conference is „Machine design in the context of Industry 4.0 – Intelligent products". For sociologists and philosophers of science, the question remains whether the concept today, most commonly called Industry 4.0, is the true fourth technological revolution or the development/continuation of the third technological revolution – through further application of computers in production and logistics. It is indisputable that the essential question of this concept is the following: how do we introduce intelligent production in the industry? This consequently opens up new questions in the field of engineering design, theory and practice of technical systems and machine elements, and innovative product development – in the environment of the now global comprehensive Industry 4.0 concept or the Japanese answer to this concept – Society 5.0.

Teaching subjects and modules, such as Mechanical Elements, Machine Design, Innovative Product Development and others, has been the basis and generator of previous technological revolutions. Therefore, the question arises as to how to develop and improve the existing content of these subjects, but, also, what the best way for knowledge transfer is to keep the listed subjects as a driving force behind further development and improvement of philosophy and concept of Industry 4.0 (ie. how to implement new teaching methods, lessons, exercises, student projects, laboratory work, evaluation).

Taking into account the previously described facts, it is clear why an exchange of opinions, experiences and results between experts in the Industry 4.0 area is essential for social and industrial development. One of the best ways to do that is via public debate at international conferences, such as IRMES 2022, which we are very glad and proud to host and organize this year.

Belgrade, 26 May 2022

Prof. Dr. Radivoje Mitrović

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GREEN BUILDING TECHNOLOGIES FOR SUSTAINABLE FUTURE

Danijela NIKOLIĆ
Saša JOVANOVIĆ
Zorica DJORDJEVIĆ
Jasmina SKERLIĆ
Ana RADOJEVIĆ

Abstract: *The growing world energy needs in the last years have raised concerns over energy supply, exhaustion of energy resources and heavy environmental impacts such as global warming and climate changes. At the other side, buildings are recognized as big energy consumers which produce over a third of global greenhouse gas emissions. Building energy efficiency today is a prime objective for energy policy at regional, national, and international levels.*
Green building is a practical and intuitive approach to creating environmentally sound buildings, which combines age-old tradition and design processes, modern building science, and technology and materials application. Green buildings incorporate sustainable features in their design and construction. The main goals of green building development are to design buildings that use less energy, cost less for operation and maintenance, limit the impact on the environment, and create places for people to work and live that promote health and productivity. This paper represents the main green buildings standards for green building rating and classification of the categories for the achievement of the green building design, which are recognized by the green building community.

Keywords: *buildings; green building technology; green building standards; green building categories.*

1. INTRODUCTION

In the recent years, energy security and energy stability become the cardinal questions of the entire world economy, economic and social system. The rapid population growth causes a steady increase of energy needs, so the humanity is in the constant researching of the energy sources that would cover the growing energy needs. Energy needs in a modern world today are covered with conventional energy sources, mainly fossil fuels - non-renewable energy sources, which have a large number of negative impacts, especially on the environment.
In the most countries, buildings are the largest energy consumers and they have a significant CO_2 emissions. Approximately 160 million buildings of the EU are estimated to consume over 40% of total energy consumption and they are responsible for over 40% of CO2 emissions. The share of energy and greenhouse gas emissions associated with buildings is even larger in the US, amounting to 48% of total emissions [1].
In developed countries, emissions from buildings, and their portion in the total GHG emissions, have been increasing over the last fifty years. In developing countries, at the other side, the share of buildings on total energy consumption and total CO_2 emissions is much lower. However, with rapid industrialization and urbanization in these countries, energy use and the GHG emissions associated with buildings are increasing rapidly. Projections for GHG emissions associated with buildings estimate that worldwide GHG emissions will reach about 15 billion CO_2 by 2030, with Asian countries contributing to about 30 % of such emissions [1]. In Serbia, the building sector consumes more than 50% of the total energy consumption [2].
As the buildings consume a significant part of energy, it is necessary to investigate all aspects of energy consumption in order to minimize the total energy consumption. In EU countries, heating systems consumes around a third of the total building energy consumption, while in Serbia it is at the level of even 60 % [3]. The rest part of energy consumption is related to the ventilation, lighting and appliances. The building envelope is a critical component for the energy losses and heating energy consumption, so it is very important to design energy efficient buildings or implement the principles for improving energy efficiency of already existing buildings.
Reducing the energy and GHG footprint in both existing and new buildings represents therefore a key challenge and opportunity to tackle global warming.

2. GREEN BUILDINGS TECHNOLOGIES

Green development is becoming more business-savvy. The two most obvious benefits of green development are long-term financial savings and returns on investments (ROI). Benefits and rewards for constructing green buildings vary by type of ownership, type of use, owner's and project team's level of investment, and the team's drive to build a sustainable building.

Green buildings incorporate sustainable features in their design and construction. The four main goals of green development are to create buildings that use less energy, cost less to operate and maintain, limit the impact on precious natural resources and create places for people to work and live that promote health and productivity. Buildings can be considered green if they incorporate sustainable elements that satisfy the four main goals of green, or sustainable, real estate development. Project owners can design and construct healthy, efficient buildings, without having to compromise functionality. These built environments are designed to conserve water and energy; use space, materials, and resources efficiently; minimize construction waste; create a healthful indoor environment, and incorporate improvements and technologies that provide real cost savings [4].

Conducting a building life cycle cost analysis in the design stage of a project can help show the financial benefits of a green building versus a conventional structure. It is especially useful when project alternatives that fulfil the same performance requirements but differ with respect to initial costs and operating costs, have to be compared in order to select the one that maximizes net savings [5]. Figure 1 represents the benefits from green buildings, in accordance to the investigation of several authors.

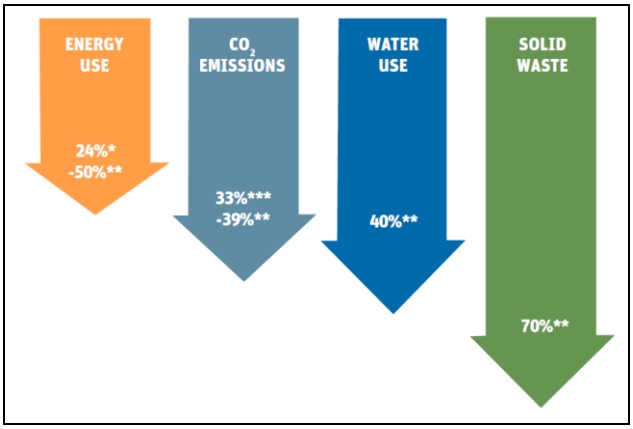

Fig.1. Green buildings benefits

Energy targets in new buildings are becoming more stringent and an increasing number of buildings are aiming to be carbon neutral. This means that the building generates sufficient energy from on-site renewable energy systems, such as photovoltaic systems, to meet its own needs. These buildings are very energy efficient and have large renewable energy and battery storage systems that are capable of generating and storing sufficient energy to enable the building to run continuously without mains power.

Incorporating more energy efficient greener technologies in buildings has a wide range of benefits, including:

- Reducing carbon emissions and therefore global warming impacts
- Reducing impact of mains power outages
- Reducing negative health impacts associated with pollution from coal-fired power stations
- Reducing operational costs
- Improving internal environments as a result of better daylighting, natural ventilation and local control.

As a result, there is an increasing choice of green technologies and techniques that can be applied in buildings to reduce energy consumption and environmental impacts.

Integrating green building technologies can be supported through a structured approach to the development of new buildings and the upgrading and refurbishment of existing buildings.

A very important consideration is ensuring that environmental impact and energy is considered, and addressed, at the onset of the project. The potential for addressing environmental impacts and energy efficiency and therefore achieving energy savings is very high at the beginning of the project. This, however, drops rapidly later, which means that significant additional effort, and often costs, are required if this is only addressed at a later stage in the development of projects.

If early strategic decisions are wrong, the potential energy savings will be reduced and significantly more effort will be required to achieve energy savings.

3. GREEN BUILDINGS STANDARDS

One of the unique qualities of green buildings is that no matter the budget, it is possible to incorporate some aspect of sustainability into every project. Different rating systems exist that evaluate the level of sustainability of a project. The more sustainable features included in a project, the higher the level of certification that could be awarded. Today, there are numerous rating systems worldwide that certify green buildings.

Several standards, methodologies, and tools have been put in place to assist organizations in delivering excellent environmental performance concerning their building stock. The document discusses alternative offerings such as LEED, Green Globes, Green Building (Europe), BREEAM, the International Green Construction Code, the German Sustainable Building Council, the Green Star from Australia, Estidama from the UAE, and CASBEE from Japan.

Figure 2 demonstrates the prevalence of these types of certifications – the yellow countries are in the process of developing certification programs [6]. This graphs shows that the demand for green buildings is growing and that certification programs are fast becoming the norm in the building construction industry.

In this paper, the standards that have the widest application will be discussed.

Fig.2. Green building certifications worldwide

3.1. LEED Standard

LEED (Leadership in Energy and Environmental Design) is a certification program, i.e. national standard developed by the United States Green Building Council (USGBC) to certify sustainable buildings. Since its inception in 1998, LEED has grown and become the widely used green building program across the globe, to encompass over 50000 projects in 50 US States and 135 countries worldwide.

The hallmark of LEED is that it is an open and transparent process where the technical criteria proposed by the LEED committees are publicly reviewed for approval by the more than 10,000 membership organizations that currently constitute the USGBC [7].

LEED is a third-party certification program and the nationally accepted benchmark for the design, construction and operation of high-performance green buildings. The USGBC operates 10 LEED Green Building Rating Programs for specific project types: for new construction (LEED-NC), for Existing Buildings (LEED-EB), for Commercial Interiors (LEED-CI), for Core & Shell (LEED-CS), for Schools, for Retail-New Construction, for Retail and Commercial Interiors, for Healthcare, for Homes, and for Neighborhood Development. LEED-NC (for New Construction) is the most widely used standard.

Fig.3. LEED credit categories

LEED standard promotes a whole building approach to sustainability by recognizing performance in five key areas of human and environmental health (Fig. 3):

- sustainable site development,
- water savings,
- energy efficiency,
- materials selection,
- indoor environmental quality.

Certification can be achieved in the four levels: Certified, Silver, Gold and Platinum. The level of LEED certification obtained is determined by the number of achieved credits (in points).

3.2. Green Globes

Green Globes is an online building assessment tool that evaluates and rates the environmental performance of new and existing buildings, and interior fit-ups. It is used by the federal government and the private sector.

The Green Globes assessment and rating system is the result of more than eleven years of research and refinement by a wide range of prominent international organizations and experts.

The genesis of the system was the Building Research Establishment's Environmental Assessment Method (BREEAM). In 1996, the Canadian Standards Association (CSA) published BREEAM Canada for Existing Buildings. In 2000, the system took a leap forward in its evolution, becoming an online assessment and rating tool under the name Green Globes for Existing Buildings. In 2004, Green Globes for Existing Buildings was adopted by BOMA (Building Owners and Managers Association of Canada), where it now operates under the name BOMA BESt [8].

Today, the Green Globes system is used by large developers and property management companies, including, the Canadian federal government, which has adopted the programme for its entire real estate portfolio.

The objectives of Green Globes are to:

- Evaluate energy and environmental performance of buildings.
- Encourage peer reviews of design and management practices.
- Increase awareness of environmental issues amongst building owners, designers and managers.
- Provide action plans for improvement at varying stages of project delivery.
- Provide certification and awards for green building design and management.

Green Globes assists in the design of buildings that are energy and resource efficient, achieve operational savings and which are healthier and more comfortable to work and live in.

Green Globes for New Construction (Green Globes NC) was designed to be a rating system designed specifically for new construction, major renovations, and additions.

Green Globes NC is a smart alternative for rating and certifying new construction designs owing to these four key attributes:

- A comprehensive environmental assessment protocol using accepted criteria

- Best practices guidance for designing sustainable new construction, major renovation, and additions
- A practical and cost-effective approach using licensed, independent third-party professionals as assessors to work with owners and design teams
- Based on the only national consensus green building standard for new commercial construction, developed in 2010 by the Green Building Initiative and acknowledged by the federal General Services Administration and the US Department of Defense.

3.3. Green Building (Europe)

The Green Building Programme (GBP) is a voluntary programme that started in 2005. It is meant to enhance the realization of cost-effective energy efficiency potentials by creating awareness and providing information support and public recognition to companies the top management of which is ready to show actual commitment to adopt energy efficient measures in non-residential buildings [1]. These are the important requirements for participation:

- an Energy Audit;
- an Action Plan;
- execution of the Action Plan;
- commitment to report energy consumption on a regular basis.

GBP provides documents defining the technical nature of an appropriate commitment for each energy service covered in the programme. GBP investments use proven technology, products and services for which efficiency has been demonstrated. Being a Green Building Partner gives a company the chance of presenting its actions for its organization's and the world's sustainable future to the broad public. The company will be an important multiplier to encourage other organizations to follow suit. The benefits are:

- Recognition and approval of the action for enhancing the energy efficiency of the building stock by the European Commission
- Competitive advantages as an organization being certified for its responsibility in the field of energy efficiency
- Presentation and communication of the organization and the Good-Practice-Example within the public relations of the GB Program.

GBP are complementary to the Building Energy Performance Directive as it stimulates additional savings in the non-residential building sector.

3.4. BREEAM – Europe

BREEAM (Buildings Research Establishment (BRE) Environmental Assessment Method) is a voluntary environmental assessment method for buildings established in the UK by BRE. BREEAM is one of the world's foremost environmental assessment methods and rating systems for buildings [4]. There are over 200 000 buildings with certified BREEAM assessment ratings and over a million registered for assessment since it was first launched in 1990.

BREEAM sets standards for best practice in sustainable building design, construction and operation and has become one of the most comprehensive and widely recognized measures of a building's environmental performance.

A BREEAM assessment uses recognized measures of performance, which are set against established benchmarks, to evaluate a building's specification, design, construction and use. The measures used represent a broad range of categories and criteria from energy to ecology. BREEAM addresses wide-ranging environ–mental and sustainability issues and enables developers, designers and building managers to demonstrate the environmental credentials of their buildings to clients, planners and other initial parties. The standard looks at environmental impacts in the areas:

- Management
- Health and Wellbeing
- Energy, Transport
- Water
- Material and Waste
- Land use and Ecology
- Pollution.

It can be used to assess the environmental performance of any type of building (new and existing). Credits are awarded in each of the above areas according to performance (Fig. 4). A set of environmental weightings then enables the credits to be added together to produce a single overall score. Certifications can be achieved in the levels: Pass, good, very good, excellent and outstanding.

Fig.4. BREEAM credit categories and points [9]

3.5. International Green Construction Code

In 2009, the International Code Council launched the development of a new International Green Construction Code (IgCC) initiative, subtitled "Safe and Sustainable: By the Book," committed to developing a model code focused on new and existing commercial buildings addressing green building design and performance.

The IgCC applies to all occupancy-types except low-rise residential buildings under the International Residential Code [10]. The IgCC is not applicable to equipment or systems used primarily for industrial or manufacturing purposes. The new code is intended to provide "minimum requirements to safeguard the environment, public health, safety and general welfare" and reduce the negative impacts and increase positive impacts of the built environment on the natural environment and building

occupants. As such, it covers natural resources, material water and energy conservation, operations and maintenance for new and existing buildings, building sites, building materials, and building components (including equipment and systems).

3.6. German Sustainable Building Council

The German Sustainable Building Council (DGNB) focuses heavily on the establishment and further development of its certification system. As a tool for the assessment and certification of sustainable buildings, it is one of the leading systems worldwide, mainly due to its comprehensive quality concept, which takes equal account of economics, ecology, and socio-cultural aspects and is based on a holistic view of the building's entire life cycle. It is therefore possible to define sustainability targets beginning in the planning phase [11].
The results are anticipated to be future-oriented buildings with high quality standards documented by the DGNB certificate in gold, silver, or bronze. The DGNB System can also be used outside of Germany. Due to its conformity with present and future EU regulations, it is a tool that can ensure high building quality and performance.
The criteria in the DGNB's core system define sustainable building in six fields:

- Ecological quality,
- Economic quality,
- Sociocultural and functional quality,
- Technical quality,
- Process quality,
- Site quality.

The site quality does not play a role in the assessment of the total performance index.

Fig.5. DGNB criteria [12]

3.7. Green Star (Australia)

Green Star is a voluntary environmental rating system for buildings in Australia. It was launched in 2003 by the Green Building Council of Australia - an organization that is committed to developing a sustainable property industry for Australia by encouraging the adoption of green building practices [13]. The system considers a broad range of practices for reducing the environmental impact of buildings and to showcase innovation in sustainable building practices, while also considering occupant health and productivity and cost savings.

Green Star is a comprehensive, national, voluntary environmental rating system that evaluates the environmental design and construction of buildings. With more than 4 million square metres of Green Star certified space around Australia, and a further 8 million square metres of Green Star-registered space, Green Star has transformed Australia's property and construction market.
Green Star was developed for the property industry in order to:

- Establish a common language;
- Set a standard of measurement for green buildings;
- Promote integrated, whole-building design;
- Recognize environmental leadership;
- Identify building life cycle impacts, and
- Raise awareness of green building benefits.

Green Star covers a number of categories that assess the environmental impact that is a direct consequence of a project site selection, design, construction and maintenance. The 9 categories included within all Green Star rating tools are:

- Management;
- Indoor environment quality;
- Energy;
- Transport;
- Water;
- Materials;
- Land use and ecology;
- Emissions;
- Innovation

Certifications can be achieved in the levels of 1-6 stars, where 6 is the highest level (Fig. 6).

Fig.6. Green Star rating [14]

3.8. Estidama (UAE)

Estidama, which means 'sustainability' in Arabic, is the initiative that will transform Abu Dhabi into a model of sustainable urbanization. Its aim is to create more sustainable communities, cities and global enterprises and to balance the four pillars of Estidama: environmental, economic, cultural and social (Fig. 7).
Estidama began in 2009 and is the first programme of its kind that is tailored to the Middle East region. In the immediate term, Estidama is focused on the rapidly changing built environment [15]. It is in this area that the UPC is making significant strides to influence projects under design, development or construction within the Emirate of Abu Dhabi.

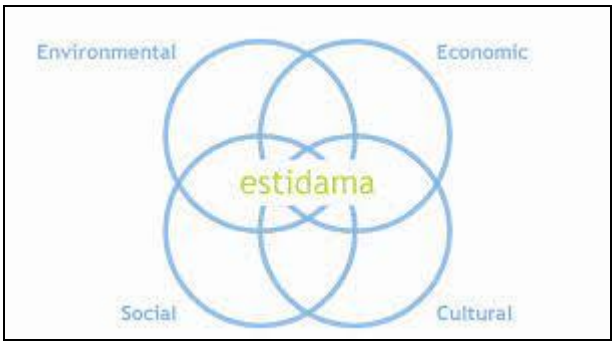

Fig.7. Four Pillars of Estidama

Estidama will continually evolve to embrace the rapidly changing concepts for sustainability, and ground them in the environmental, social, cultural, and economic needs of the Gulf Cooperation Council (GCC) region.

The Pearl Rating System for Estidama aims to address the sustainability of a given development throughout its life cycle from design through construction to operation. The Pearl Rating System provides design guidance and detailed requirements for rating a project's potential performance in relation to the four pillars of Estidama.

The Pearl Rating System is organized into seven categories that are fundamental to more sustainable development. These form the heart of the Pearl Rating System:

- Integrated development process: Encouraging cross-disciplinary teamwork to deliver environmental and quality management throughout the life of the project.
- Natural systems: Conserving, preserving and restoring the region's critical natural environments and habitats.
- Livable buildings: Improving the quality and connectivity of outdoor and indoor spaces.
- Precious water: Reducing water demand and encouraging efficient distribution and alternative water sources.
- Resourceful energy: Targeting energy conservation through passive design measures, reduced demand, energy efficiency and renewable sources.
- Stewarding materials: Ensuring consideration of the 'whole-of-life' cycle when selecting and specifying materials.
- Innovating practice: Encouraging innovation in building design and construction to facilitate market and industry transformation.

3.9. CASBEE (Japan)

Comprehensive Assessment System for Building Environment Efficiency (CASBEE) is a method for evaluating and rating the environmental performance of buildings and the built environment. CASBEE has been designed to both enhance the quality of people's lives and to reduce the life-cycle resource use and environmental loads associated with the built environment, from a single home to a whole city.

CASBEE was developed in Japan, at the beginning of 2001. The family of assessment tools is based on the building's life cycle: pre-design, new construction, existing buildings, and renovation. CASBEE presents a new concept for assessment that distinguishes environmental load from quality of building performance.

CASBEE was developed according to the following policies [16]:

1) The system should be structured to award high assessments to superior buildings, thereby enhancing incentives to designers and others.

2) The assessment system should be as simple as possible.

3) The system should be applicable to buildings in a wide range of applications.

4) The system should take into consideration issues and problems peculiar to Japan and Asia.

CASBEE major categories of criteria include the following:

1) Building Environmental Quality and Performance
   - Indoor environment (noise and acoustics, thermal comfort, lighting and illumination, and air quality),
   - Quality of services (functionality and usability, amenities, durability and reliability, flexibility and adaptability),
   - Outdoor environment on site (preservation and creation of biotope, townscape and landscape, and outdoor amenities).
2) Building Environmental Loadings
   - Energy (thermal load, use of natural energy, efficiency of systems, and efficient operations),
   - Resources and materials (water conservation, recycled materials, sustainably harvested timber, materials with low health risks, reuse and reusability, and avoidance of CFCs and halons),
   - Off-site environment (air pollution, noise and vibration, odor, sunlight obstruction, light pollution, heat island effect, and local on local infrastructure).

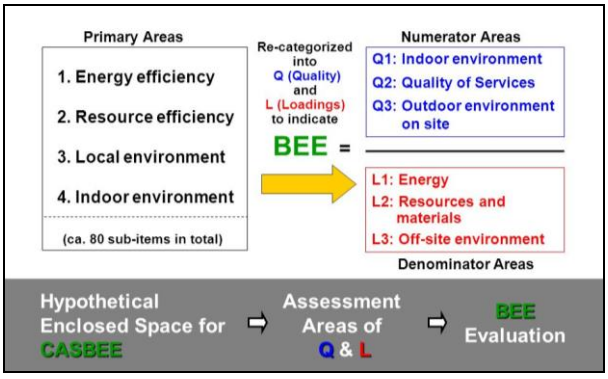

Fig.8. Assessment Area of CASBEE rating system

4. GREEN BUILDING CATEGORIES

In order to further define green buildings, categories for achievement are recognized by the green building community [4]. While they are not universal, they structure the different technologies and help to understand the broader concept. These categories are:

5. GREEN BUILDING CATEGORIES

In order to further define green buildings, categories for achievement are recognized by the green building community [4]. While they are not universal, they structure the different technologies and help to understand the broader concept. These categories are:

1) Site Selection

This area includes next elements: type of infrastructure available, the proximity to public transportation, storm water management options and roofing.

2) Water Efficiency

Water efficiency limit the use of water inside and outside the building by considering water demand reduction like low-flow restroom fixtures and high-efficiency irrigation systems and supply like use of storm water or grey-water (water used from showers, wash basins, and laundry) recycling.

3) Energy Efficiency

Energy Efficiency focuses on ways to reduce demand by incorporating energy efficiency features such as passive design like natural shading and lighting, high efficiency lighting, building controls, effective HVAC management and also includes supplying renewable energy by using technologies like solar photovoltaic panels, solar hot water heaters among others.

4) Materials and Resources

Material and resources include reduction of waste in construction and operation, the way the construction materials are disposed of and what materials are included in the building finishes with the objective to reduce waste to be disposed at landfills.

5) Indoor Environmental Quality

Indoor Environmental quality is focused on keeping the building healthy for the building occupants, by regulating thermal comfort, increasing natural lighting, improving indoor air quality, and minimizing noise levels, therefore reducing absenteeism and increasing occupant productivity.

These five categories can help designers and builders select which sustainable features to include in a building project. Often these categories are interrelated, e.g. improved natural lighting provides better indoor environmental quality and at the same time reduces electricity demand and cost for artificial lighting. If the goal is to save money on energy, then the best place to focus the project is on energy efficiency measures. When the cost-benefit analysis is completed, the owners and builders can determine which features to include in the final project.

6. CONCLUSION

Green building technologies describe technologies and techniques which are used in built environments for minimizing the environmental impacts while ensuring that buildings are able to accommodate the functions they have been designed for and are comfortable and productive to live and work in.

Green building technologies not only have to have a mitigation function (to reduce carbon emissions), they also have an adaptation function (to help building accommodate project climate changes) as the earth is already experiencing global warming.

Green building standards are available for almost every type of building and these standards are well developed and continuously being updated. These standards cover all phases of a building's life cycle from design through demolition. They are also available in a number of national standards and codes.

Buildings that have been designed with sustainability standards in mind need to be operated and maintained using sustainability standards. Buildings that were not designed to meet sustainability standards when they were built can also be upgraded to meet sustainability standards that have been put in place for existing buildings.

Green building technologies and appropriate building standards are essential for reducing energy consumption globally, as well as for reducing greenhouse gas emissions.

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