Sustainable Manufacturing:

Design and Construction Strategies for Manufactured Construction

Second Edition, August 2017

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TRAMCON Training for Manufactured Construction

THIS COURSE WAS DEVELOPED THROUGH A COLLABORATION OF THE FOLLOWING HIGHER EDUCATION INSTITUTIONS:

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This material was funded in whole by a $9.9M TAACCCT grant awarded by the U.S. Department of Labor's Employment and Training Administration. The product was created by the grantee and does not necessarily reflect the official position of the U.S. Department of Labor. The U.S. Department of Labor makes no guarantees, warranties, or assurances of any kind, express or implied, with respect to such information, including any information on linked sites and including, but not limited to, accuracy of the information or its completeness, timeliness, usefulness, adequacy, continued availability, or ownership.

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DESIGN AND CONSTRUCTION STRATEGIES FOR MANUFACTURED CONSTRUCTION

1.0 OVERVIEW OF SUSTAINABLE CONSTRUCTION

In this course on Manufactured Construction, we will address future topics that will likely be important for the growth and progress of the manufactured construction industry. Although there are clearly many possible issues that will impact the industry, topics in sustainable construction are most likely to be a prime area of change.

Buildings and infrastructure such as power plants, highways and water distribution systems require significant energy and materials for their construction. The result of this is a high demand for resources and the disruption and destruction of ecological systems, causing enormous impacts both on nature and people. As the industry with the greatest consumption of materials and energy, construction also provides the greatest opportunity for addressing environmental problems and improving human quality of life. Therefore, this module will describe how sustainable construction is addressing these problems and how it is transforming the built environment. As a result, you will be prepared for the future and also able to prepare yourself for these transformative changes.

2.0 THE BASICS OF SUSTAINABLE CONSTRUCTION

2.1 HUMAN ACTIVITIES AND THE ENVIRONMENT

Changes are always taking place in the natural environment. Some changes are natural and independent from human activities; others, however, are directly associated with human interventions. Unfortunately, the growing scale of the built environment and global economy is causing an imbalance that is negatively affecting the green environment.

While there is a constant increase in both global population and the demand for natural resources, buildings have become larger and more complex in order to meet human needs. The pressure from the human race to build, furnish, transport and operate buildings creates several impacts on the green environment

According to the National Association of Home Builders, the average American house size has almost doubled in the past 40 years, while the average family size has decreased around 50%.

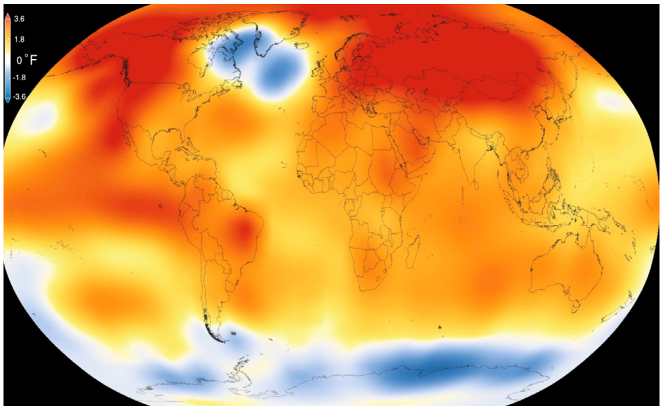

FIGURE 1- NASA RECORDED THAT THE 16 WARMEST YEARS ON RECORD OCCURRED SINCE 2001, WITH 2015 BEING THE WARMEST YEAR SINCE 1880.

that are now becoming obvious, most prominently in the form of climate change. The major environmental impacts from human activities include the following:

► **Global climate change**: The increase in greenhouse gas emissions (GHG) due to the burning of fossil fuels is causing an overall increase in global temperatures. This increase is affecting sea levels because the ice is melting at an enormous rate, affecting global climatic conditions and increasing the severity and frequency of hurricanes, storms and droughts.

► **Deforestation**: Excess wood harvesting causes soil depletion, soil erosion, loss of natural habitat, urban heat islands and has a direct effect on the global climate change.

► **Reduction of potable water supplies**: The rise in temperature has caused desertification in the dryer places of the world. In other areas, the overuse of water has led to aquifer depletion. The rise in sea level also threatens continental water bodies due to salination.

► **Pollution of air and water**: Industrial and daily human activities contribute to water and air pollution. The combination of air pollution from fossil fuel emissions and its absorption by water may cause acid rain, which threats water bodies and destroys natural and built environments.

► **Soil contamination**: The contaminants from human activities may eventually migrate to water bodies. Ground vegetation alleviates the soil contamination and erosion.

► **Destruction of the ozone layer**: Chlorine-based emissions, such as refrigerants, have led to the depletion of the ozone layer, directly effecting the global temperature and damaging marine and terrestrial ecosystems.

2.2 THE ROOTS OF SUSTAINABILITY AND THE SHIFT TO SUSTAINABLE CONSTRUCTION

The concept of Sustainability or Sustainable Development was created to describe the process of meeting human needs without compromising the ability of the green environment to provide the natural resources on which society depends. Initially, the concept was mostly considered as an ethical duty because the effects of human activities on the green environment will, most probably, last for many generations. The following group of classical ethical principles are considered the foundation of sustainable development:

► **Intergenerational justice**: Our choices will directly affect the quality and quantity of resources for future generations.

- **Distributional equity**: The obligation to ensure a fair distribution of resources among people in the world.
- **The precautionary principle**: The exercise of caution when making decisions that may adversely affect the environment.
- **The reversibility principle**: Making decisions that can be undone by future generations.
- **The polluter pays responsibility**: The responsibility to address the consequences and implications of implementing technology.
- **Protecting the vulnerable**: Those who are relatively wealthy have a special obligation to protect the vulnerable, which includes species from the natural world, people who are powerless due to economic and governmental issues, and future generations.
- **Rights of the non-human world**: This principle refers to the right of plants, animals and other living organisms.

As the concept grew, sustainable development began to include other factors. Currently, it is described in terms of three dimensions, which are the economic, ecological, and social. For most people, the three-legged stool model must include the environment, because none of the other three dimensions could exist without the environment (Figure 2).

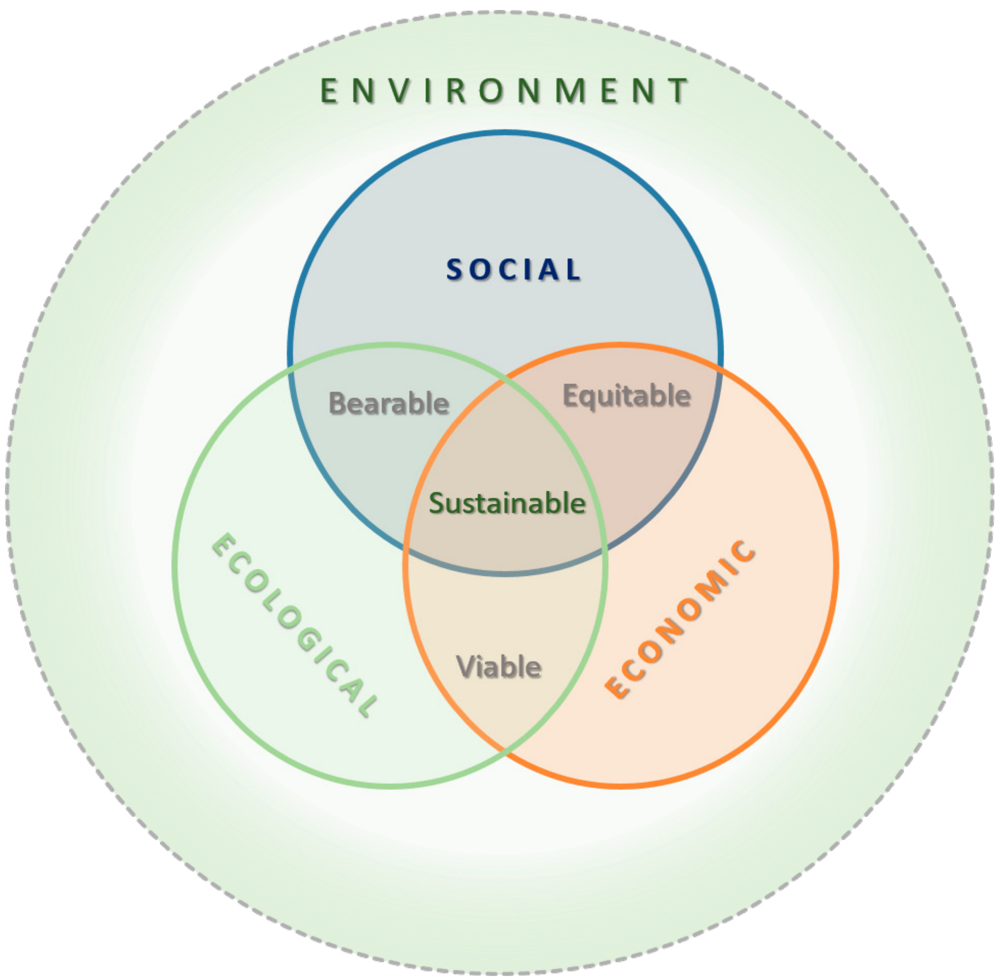

FIGURE 2 - THE THREE-LEGGED STOOL MODEL FOR SUSTAINABLE DEVELOPMENT.

FIGURE 3 - EXAMPLES OF VERNACULAR ARCHITECTURE.

THE GREEN BUILDING MOVEMENT

Although the term "sustainable construction" has recently become a popular concept, the question that remains is when did designers first become interested in building green. The answer is actually very easy: ecological design has always been included in building design and construction. In ancient times, people built vernacular buildings, a type of architecture based on local needs, materials and tradition, which is still used in some remote places (Figure 3). However, because of the green movement, which emerged after the energy crisis of the early 1970's, builders and designers began to look for ways to reduce reliance on fossil fuels. Therefore, the green building movement is the response of the construction industry to human-caused environmental problems and the increasing demand for natural resources.

During the early phases of their development, sustainable construction practices were not evaluated and the final building performance was often unknown. The biggest breakthrough in thinking occurred in 1989, when a system was designed in United Kingdom to rate a building's performance. BREEAM (Building Research Establishment Environmental Assessment Method) was the first rating system that proposed a definition for green buildings and ways of evaluating the building's performance based on several aspects, including energy performance, water consumption, indoor environmental quality, materials and location.

In the United States, the first rating system was developed by the U.S. Green Building Council (USGBC) in 1998 and is known as "Leadership in Energy and Environmental Design" (LEED). Other rating systems also began to appear worldwide, such as the CASBEE in Japan (2004), Green Star in Australia (2006), Deutsche Gesellschaft fur Nachhaltiges Bauen (DGNB) in Germany (2009), among others.

2.3 TRENDS FOR HIGH-PERFORMANCE GREEN BUILDINGS

Recently, there has been dramatically increased interest in green buildings. This shift started with federal initiatives to promote high-performance buildings, such as Executive Order 13514 that requires all new federal buildings to meet strict environmental standards. In addition, state and local governments have modified their building codes to be based on strict sustainable standards.

There are also several initiatives focused on transforming the built environment. On the urban scale, there is a strong shift from the conventional urban sprawl development to a denser, smarter growth. The "New Urbanism" is a planning development approach focused on a human-scaled design, where mixed-use buildings create a walkable atmosphere reducing the need of private vehicles (Figure 4).

FIGURE 4 – THE CONVENTIONAL URBAN SPRAWL LEADS TO SEVERAL ENVIRONMENTAL IMPACTS SUCH AS AN INCREASE OF TRANSPORTATION AND INFRASTRUCTURE REQUIREMENTS. ON THE OTHER HAND, THE NEW URBANISM HAS A MORE EFFICIENT USE OF THE LAND. ABOVE IS A RESIDENTIAL DEVELOPMENT IN RIO RANCHO, NEW MEXICO. BELOW IS A LARGE-SCALE MIXED-USE URBAN DEVELOPMENT IN KAZAN, RUSSIA.

A Carbon neutral building consumes very little energy and uses low carbon energy sources to meet the remaining demand.

On a building scale, the "Architecture 2030 Challenge" program addresses the GHG emissions of building materials and products and sets a goal for reducing the building carbon footprint. According to the program, all new buildings must be designed to reduce carbon emissions and energy consumption by 70% compared to the regional average for that type of building. Future targets are to reduce emissions up to 80% in 2020, 90% in 2025, and to achieve **carbon neutral goals** in 2030.

As building research and technologies evolve, new concepts related to sustainable construction continue to appear. Knowledge of basic sustainable construction concepts and advanced terms will be necessary for those who design and construct buildings. Some key vocabulary related to sustainable construction is provided below.

► **Sustainable construction**: Also referred to as high-performance or green buildings, this term addresses the ecological, social, and economic issues of a building in contexts of its community. The basic principles include reducing consumption, reusing resources, recycling, protecting nature, eliminating toxics, applying life-cycle assessment and cost analysis, and providing quality.

► **Whole-building design**: The collaborative work between building professionals, owners, suppliers and specialist to analyze the build-

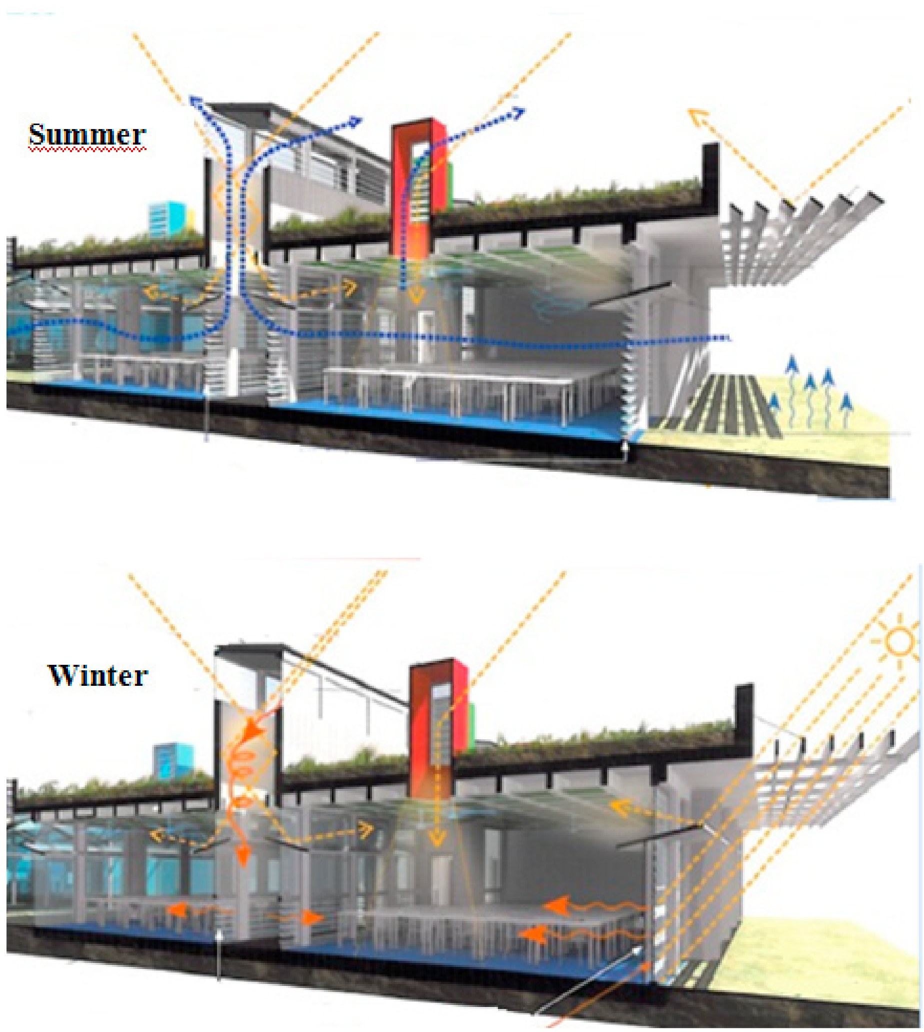

FIGURE 5 - PRINCIPLES OF PASSIVE DESIGN DURING SUMMER AND WINTER.

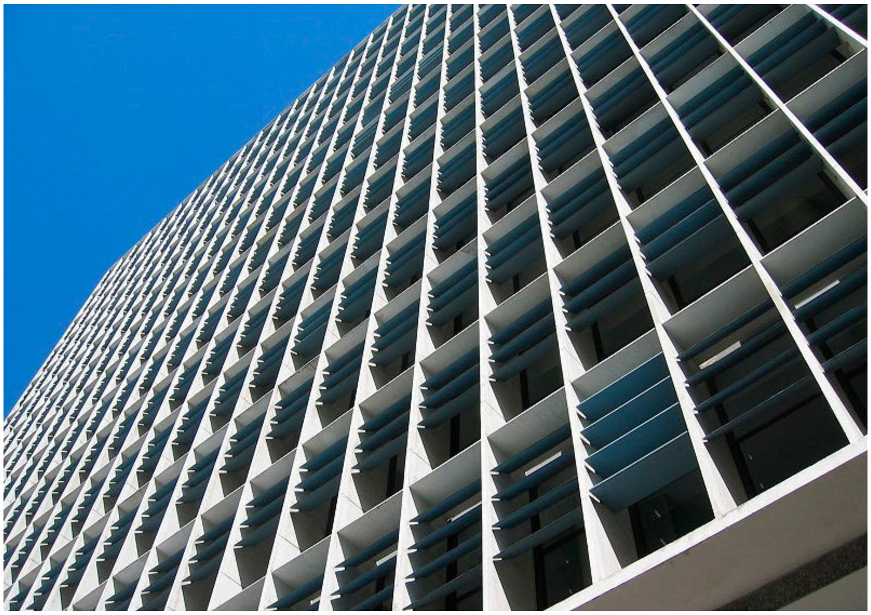

FIGURE 6: MINISTRY OF EDUCATION AND HEALTH BUILDING, RIO DE JANEIRO/BRAZIL

Brise soleil is an architectural feature that provides shading, reduces heat gain, and allows natural daylight to enter the building

ing systems and determine the most efficient solution. The analysis may include the site, energy, water, materials, indoor air quality, acoustic, natural resources and the interrelations among all elements.

► **Passive design**: A design that uses natural energy sources to minimize the consumption of energy and maximize human comfort (Figure 5). Passive design strategies include building orientation, natural ventilation and illumination, selection of appropriate materials for a specific climate condition, maximizing solar energy to heat spaces, or use **brise soleil** to reduce heat gain (Figure 6).

► **Net-zero energy buildings (NZEBs)**: A building that uses high-performance strategies to reduce the amount of resources needed for its operation and uses a renewable energy system, for example photovoltaic (PV) panels, to meet its annual energy needs. Buildings have become net-zero energy by rethinking the design, adding efficient strategies, and integrating renewable energy sources, such as solar panel or wind turbines. A net-zero water building can be achieved by reusing and recycling wastewater.

► **Biomimicry**: The use of biological principles for solving human-made problems. Some examples are the study of cockroaches as a way to improve robotic technologies,

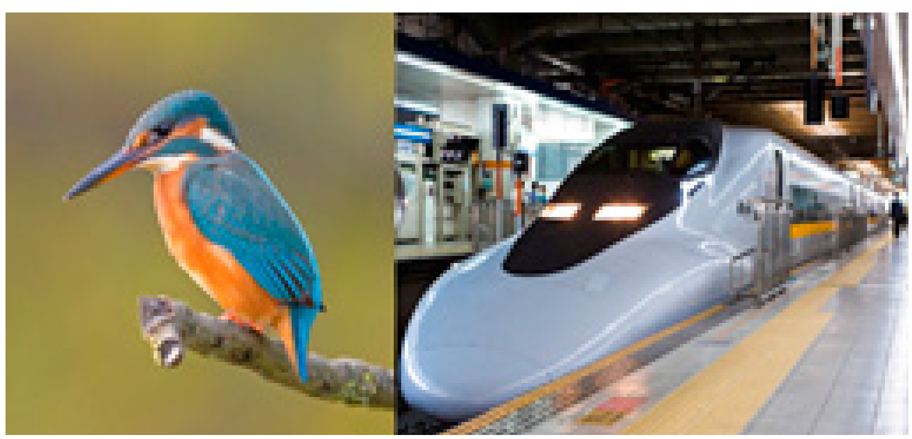

FIGURE 7 - THE ULTRA-FAST TRAIN DESIGN WAS BASED ON THE KINGFISHER BIRD'S ABILITIES TO DIVE DOWN THROUGH THE AIR AND GO INTO THE WATER WITHOUT CREATING SIGNIFICANT SPLASH.

biomechatronic handling systems based on an elephant's trunk, a government surveillance device inspired by bats, resistant and light structures based on skull shapes, and the inspiration of the Kingfisher bird's geometry to design an ultra-fast and efficient bullet train (Figure 7).

- **Biophilia**: The design of environments, places and buildings connected to the natural environment to improve well-being and enhance health.

- **Resilience**: The ability to adapt to changes. Resilient strategies are becoming an important tool for future buildings, since the effects of climate change will be greater and require stronger, adaptable materials and building systems.

- **Life-cycle assessment (LCA)**: A method used to evaluate the health, environmental and resource impact of materials, products or even the whole building during their entire life cycle. The method examines several factors, such as water, energy and materials consumption, carbon emissions and ozone depletion, to name but a few. The data set provided by the LCA is similar to a nutrition label of the material and can be summarized by a third-party in a document known as an Environmental Product Declaration (EPD). Currently, the State of California includes LCA as a voluntary measure in the 2010 Green Building Code. But in the future, it is possible that LCA will become mandatory for most jurisdictions.

- **Environmental Product Declarations (EPDs)**: Documents known as a "Type III Environmental Product Declaration" that make the Life-Cycle Assessment (LCA) information accessible to building professionals. The environmental impacts are divided into impact categories, which include global warming potential, acidification potential, depletion of ozone layer, fossil fuel resources and mineral resources, to name a

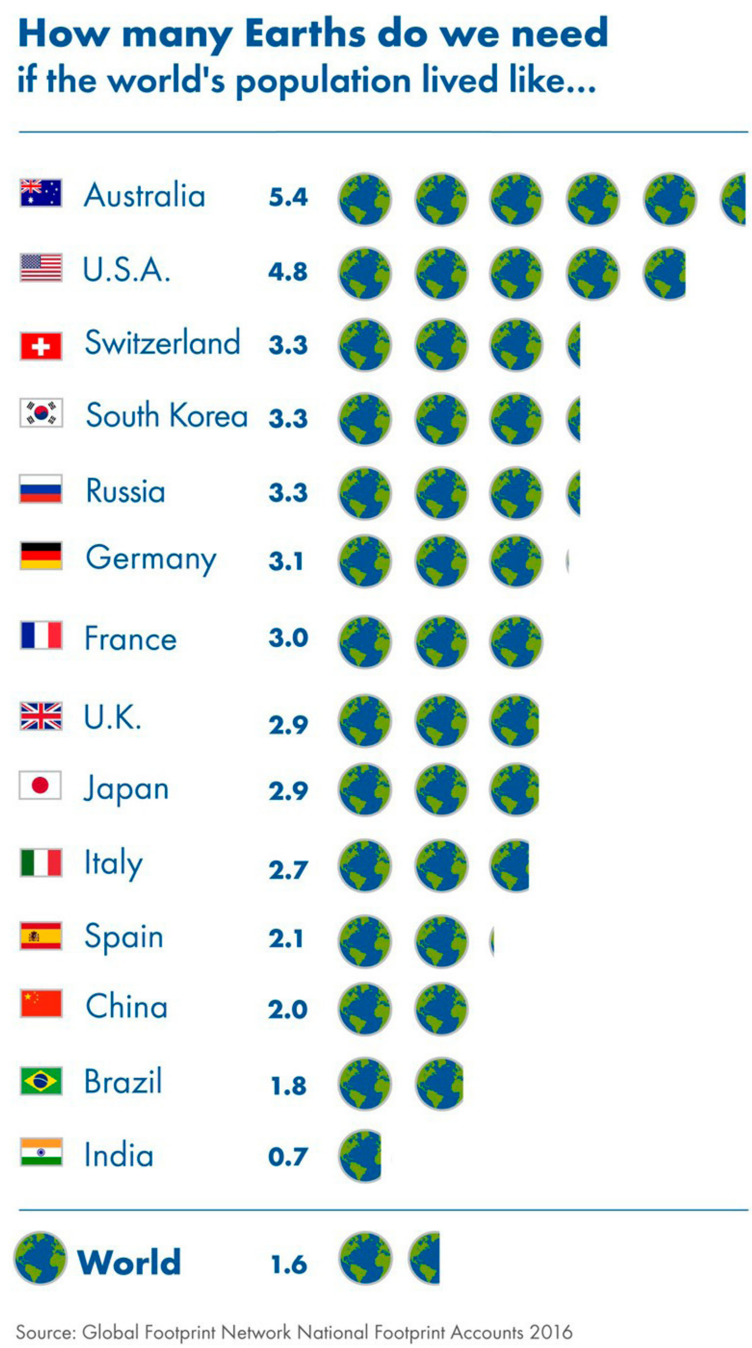

FIGURE 8 - NATIONAL FOOTPRINT ACCOUNTS 2016. SOURCE: GLOBAL FOOTPRINT NETWORK

few. EPDs are transparent documents that do not correspond to a certification, but they provide useful information about the product's environmental impacts.

In addition to green building trends, there are several other terminologies that deserve special attention for high-performance projects.

► **Ecological footprint**: The amount of land needed to support a given population. For example, almost 5 planet Earths would be needed if everyone lived according to the North American lifestyle (Figure 8).

► **Ecological rucksack**: The quantity of materials that must be moved in order to extract a specific resource. The greater the mass to be moved, the greater the environmental impact. For example, 300 tons of raw material must be mined and processed to extract 10 grams of gold.

► **Embodied energy**: The amount of energy consumed from the extraction of raw materials until the acquisition of a product, which includes manufacturing, transportation and the final installation. The greater the embodied energy, the greater the environmental impact. However, if a product is more durable, it may have a lower embodied energy per time in use when dividing the product's total embodied energy by the product's life time.

2.4 THE CUTTING EDGE OF SUSTAINABLE MANUFACTURED CONSTRUCTION

It is well known that manufactured construction has several advantages. Among them are affordability, faster construction time and a reduced need for craftsmen. Recent technological developments in building construction research, including materials and systems, make it possible to achieve high-performance manufactured buildings. These buildings have improved energy and water performance, higher life-cycle affordability and lower operational costs. The cutting edge practices for sustainable manufactured buildings can be applied during all phases of construction (Figure 9), but mainly during the design and manufacturing processes.

DESIGN

The first step in creating high-performance building standards is to include sustainable strategies into the building's design. In addition to considering passive design strategies for the building, manufactured construction offers several opportunities to increase sustainability in the built environment. Due to controlled manufacturing conditions, this process type offers an immense opportunity to reuse materials and include a waste management plan. Also, several multi-functional prefabricated systems are being developed to reduce consumption of different types of materials and increase building efficiency. Manufacturers can achieve high-performance standards for buildings materials by performing a Life Cycle Assessment in the selected products and using certified green products.

Energy efficiency is another big trend for future buildings. The cutting edge of manufactured buildings pays special attention to the building envelope, including the use of tight and well-insulated walls and energy-efficient windows. Buildings may also be designed to integrate renewable energy sources to meet net-zero energy standards.

MANUFACTURING PROCESS

The biggest trend in the manufacturing process is the inclusion of automation technologies. An automated factory that uses CAD-CAM technologies can increase the efficiency and speed of the construction process, minimize the use of skilled craftsmen, and create and test various building prototypes. Currently, Japan is at the forefront of applying robotics in manufactured construction. Automation can be used for a variety of processes such as painting, welding, floor finishing, packaging, unmanned forklifts and manipulators arms.

CAD/CAM stands for Computer-Aided Design and Computer-Aided Manufacturing and refers to the use of computer software to design and/or manufacture products.

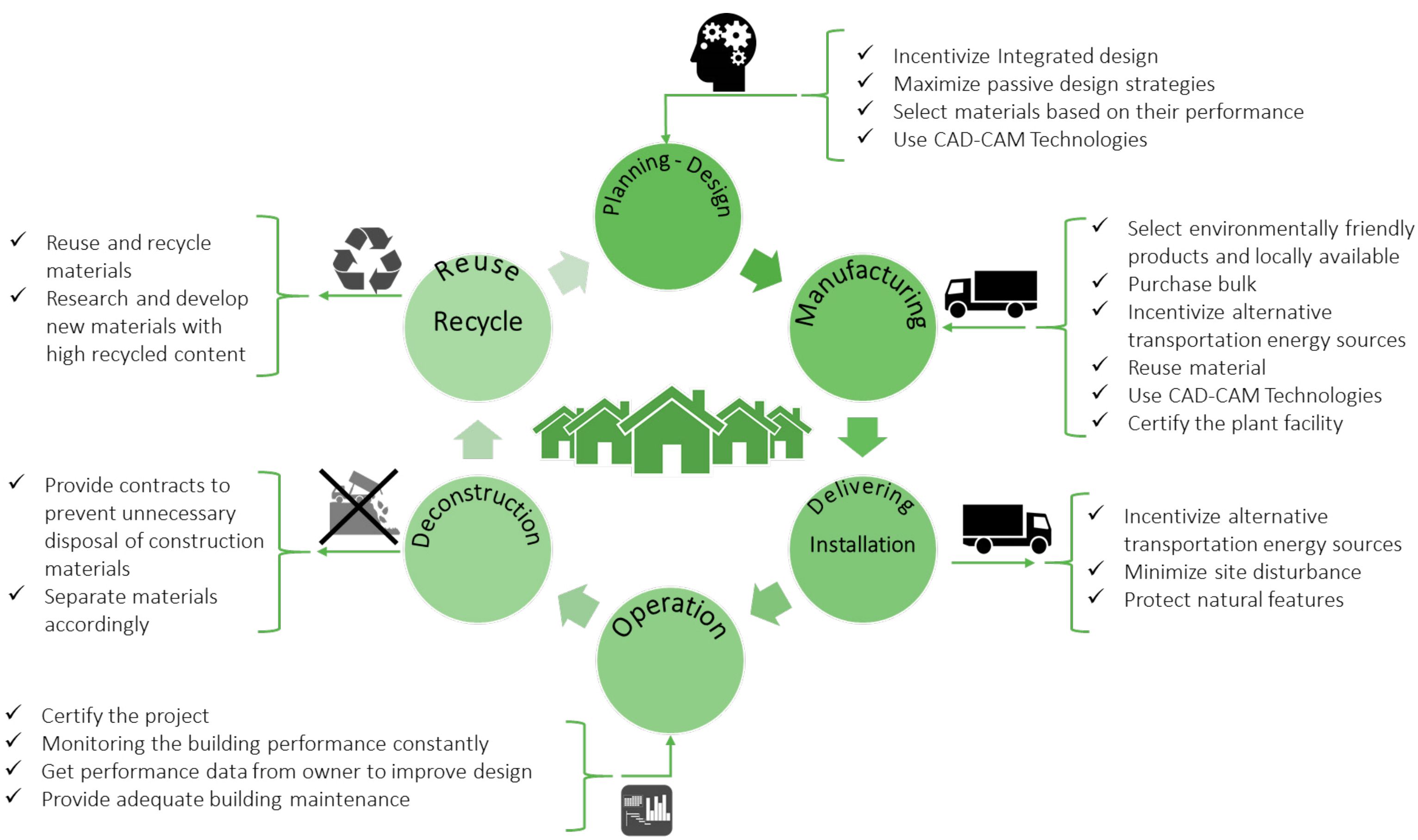

FIGURE 9 – CLOSED-LOOP EXAMPLE OF A SUSTAINABLE MANUFACTURED CONSTRUCTION.

REVIEW QUESTIONS

1. Identify at least 3 major environmental changes that you have seen recently and explain how can it impact your community.
2. Describe the major classical ethical principles that are considered to be the foundation of sustainable development.
3. Explain the transition from "sustainable development" to "sustainable construction."
4. Describe at least 3 green building trends, explain how each can be used in new constructions and include the major limitations of each.
5. What is Life-Cycle Assessment and how can it be used in the manufactured construction industry.

3.0 BEST PRACTICES FOR GREEN BUILDING PROJECTS

3.1 INTEGRATED DESIGN PROCESS

The emergence of high-performance buildings promoted several changes in the building design process. The delivery process now differs from the conventional practice mostly because the use of integrated design process, also known as charrette. This delivery system engages design team members, specialists, contractors and stakeholders during the whole design project and construction. Furthermore, there is more focus on integrated building performance than on the individual building system, substantial emphasis on environmental protection, special attention to worker and owner health, and reductions in material waste.

The pre-design and design process is perhaps the most demanding task. Not only is the project design decided, but the quality of a product or the building performance depends largely on the success of this phase. A lack of communication among team members and stakeholders during the definition of the sustainability targets will directly interfere on the final product. Team members with specific expertise in green building systems play an important role during the pre-design and design phase in ensuring every member understands the project goals and that the project will be built as designed.

3.2 SITE AND LANDSCAPE

PRE-DESIGN AND DESIGN PHASE:

Although manufactured projects are built in a manufacturing facility and transported to the construction site, the project site still needs to be carefully analyzed during the design phase. The reason is that the project site has a significant impact on the green environment and on the building's performance.

Depending on the building's orientation on the project site, its design and materials, the building may need more energy to provide sufficient lighting, cooling/heating and thermal comfort. The use of passive design strategies can take advantage of the natural characteristics of the site to reduce energy consumption. For example, windows can be oriented to take advantage of prevailing winds, providing natural ventilation and daylighting. Also, unprotected walls may absorb more energy and naturally heat the building when desired. The type of material and its color also determines the amount of energy the building absorbs.

However, it is important to note that different climate conditions require different solutions. For example, colder locations may need to take greater advantage of solar energy for heating and provide a super-insulated building. Conversely, temperate locations may need to block direct sun light and maximize natural ventilation. Also, the distance from the manufacturing facility to the site location increases the total GHG emissions from transportation and, consequently, the total **carbon footprint** of the building.

While not affected by the manufacturing process, there are some sustainable practices connected to the site selection that should be well-known by the sustainable supervisors

Carbon footprint is the sum of greenhouse gases produced to support an activity during a given time frame. In buildings, carbon footprint is measured considering the lifespan of the building.

100-year flood zones or floodplains are spaces that have 1% probability to be affected by a flood event in any given year.

since they can be used for acquiring points during green building rating evaluations. For example, building codes and assessment systems are requiring buildings to be constructed above the **100-year flood zones**, which are urban areas that represent a potential disaster for buildings and communities. Also, sustainable supervisors should pay attention to the current condition of the specific piece of land that the building will be located, which can be classified as follows:

- **Greenfields** are land parcels not previously developed and disturbed by human activities. Using these areas typically destroys the natural ecosystems and causes more environmental impacts.
- **Brownfields** are abandoned or underused industrial/commercial spaces that have certain levels of contamination. Restoring brownfields has several advantages for the builder, since the sites typically have connections with urban infrastructure.
- **Grayfields** are spaces that became economically blighted and need investment to be restored. For instance, big box store buildings are often abandoned by large retailers that move to larger spaces. Such facilities can be reused or adapted as valuable community assets.
- **Blackfields** are abandoned coal mines.

FIGURE 10 - URBAN BIOWALE UNDER CONSTRUCTION. THESE SYSTEMS HELP TO ABSORB AND TREAT STORMWATER RUNOFF FROM THE BUILT ENVIRONMENT AND CAN BE USED TO PROVIDE A BETTER URBAN SPACE.

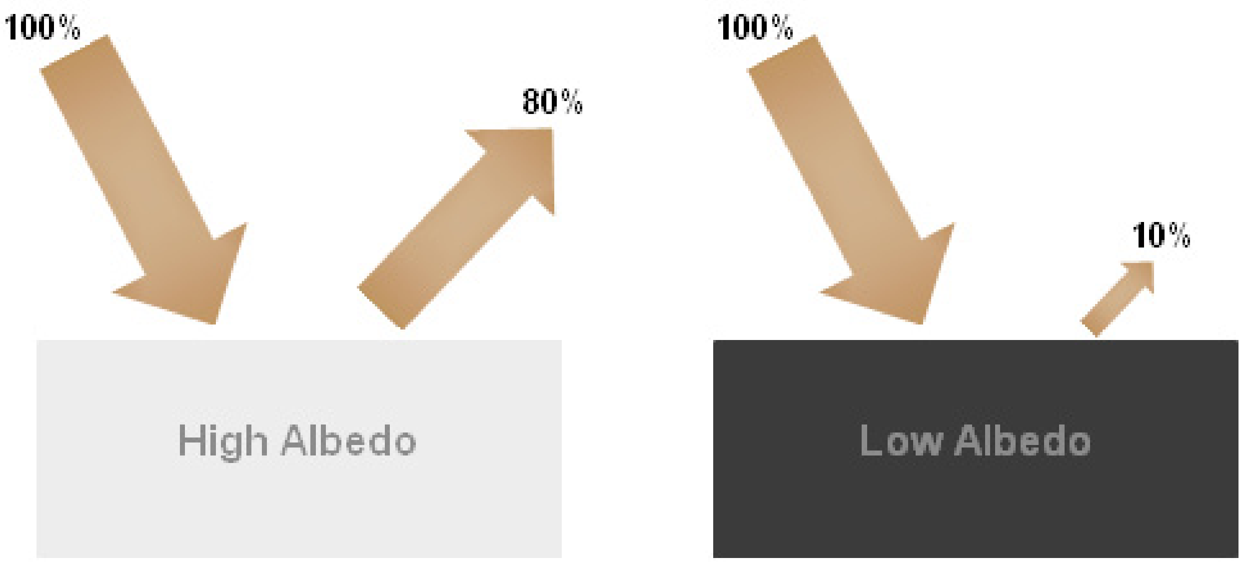

FIGURE 11 – DIFFERENT MATERIALS HAVE DIFFERENT ALBEDOS. A HIGH ALBEDO SURFACE PREVENTS THE OVERHEATING SINCE THE SURFACE REFLECTS THE MAJORITY OF THE SOLAR RADIATION. WHILE A LOW ALBEDO SURFACE ABSORBS THE MAJORITY OF THE SOLAR RADIATION.

Landscaping practices included in the design phase can also be used to reduce the environmental impacts of the project. For example, biowales with vegetated areas can absorb and treat stormwater runoff from the building and the project site (Figure 10). Permeable pavement areas also allow water absorption and minimize the heat island effects. Light-colored pavements, also known as pavements with high albedo, may be used to minimize the amount of heat absorbed from the sun. Dark paved areas, or low albedo surfaces, reflect a small amount of solar radiation and are the main cause of the urban heat island effect (Figure 11).

CONSTRUCTION PHASE

Site development activities generally have high environmental impacts. Ideally, the site development should avoid disturbing natural ecosystems by planning carefully the construction process.

Generally, manufactured buildings tend to have very small impacts on the site compared to normal construction. Even though, manufacturers are encouraged to protect existing trees, wetlands or streams with barricades. Strategies to prevent erosion from disturbed soil are essential for every project.

Due to the increasing concern about CO_2 emissions, alternative and more efficient options for fossil-fuel-dependent equipment should be considered to reduce the disturbance of the existing landscape and greenhouse gas emissions. Several green standards and building codes include incentives to reduce emissions, such as the "Clean Construction USA," which encourages reducing idling time for heavy equipment and installing treatment technologies. In manufactured construction, emissions from the transportation of manufactured buildings or components is extremely important and should be considered by sustainable supervisors.

POST-CONSTRUCTION PHASE

Restoring natural ecosystems and preserving undisturbed spaces are sustainable strategies for the post-construction phase. The construction professional does not have

FIGURE 12 - SITE PREPARATION WITH HEAVY CONSTRUCTION EQUIPMENT.

FIGURE 13 - MODULAR HOUSING ARRIVING TO MCCLELLAN AIRBASE TO HELP WILDFIRE DISASTER SURVIVORS. SOURCE: FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)

control over this phase, since it is under the owner's control. But the owner should be educated about these issues providing the required information for managing these natural systems.

3.3 WATER

Water conservation is becoming a very important topic for high-performance buildings and is predicted to have even more importance in the future due to climate change and shrinking potable water bodies. Sustainable strategies together with high efficiency technologies are resulting in substantial water reduction. Water conservation strategies include the following steps:

► **Reduction of overall water consumption**: Water consumption limits are established by building codes or legislation. For example, the Energy Policy Act (EPA) of 1992 requires all plumbing fixtures in the United States to meet water reduction targets. Beyond the code requirements, the EPA WaterSense program certifies buildings and fixtures that use at least 20% less water than the EPAct 1992. Water reduction can be achieved by using high-efficiency and low-flow fixture such as toilets, showers and faucets. Waterless urinals are also available in the market.

► **Alternative water sources**: The adoption of alternative water sources should be considered as soon as potable water consumption is reduced to the maximum extent possible. Rainwater harvesting systems and graywater from showers, sinks and laundry facilities could be used for non-potable systems such as irrigation and toilets/urinals. Buildings can reduce potable water consumption, help to indirectly recharge groundwater and aquifers, and save money for the owner when adopting these strategies. It is important to note that graywater must flow in different piping systems than the potable water.

High-performance building in U.S. can reduce potable water consumption by 50% simply by using high-efficient fixtures.

► **Wastewater treatment**: The last step involves the treatment of wastewater, which includes blackwater from toilets and urinals. Nature-based systems, such as constructed wetlands and Living Machines (Figure 14), can be used for this purpose. Wetlands are natural, self-maintaining and self-organizing ecosystems that process and treat wastewater before releasing it into the green environment. A Living Machine is a system that uses plants, bacteria and organisms to convert wastewater into safe nutrients and clean up the wastewater. There are several buildings that are successfully using Living Machines to recycle and reuse wastewater and, consequently, achieving Net-zero water standards. However, it must be noted that the reuse of wastewater is subject to local building codes and legislation.

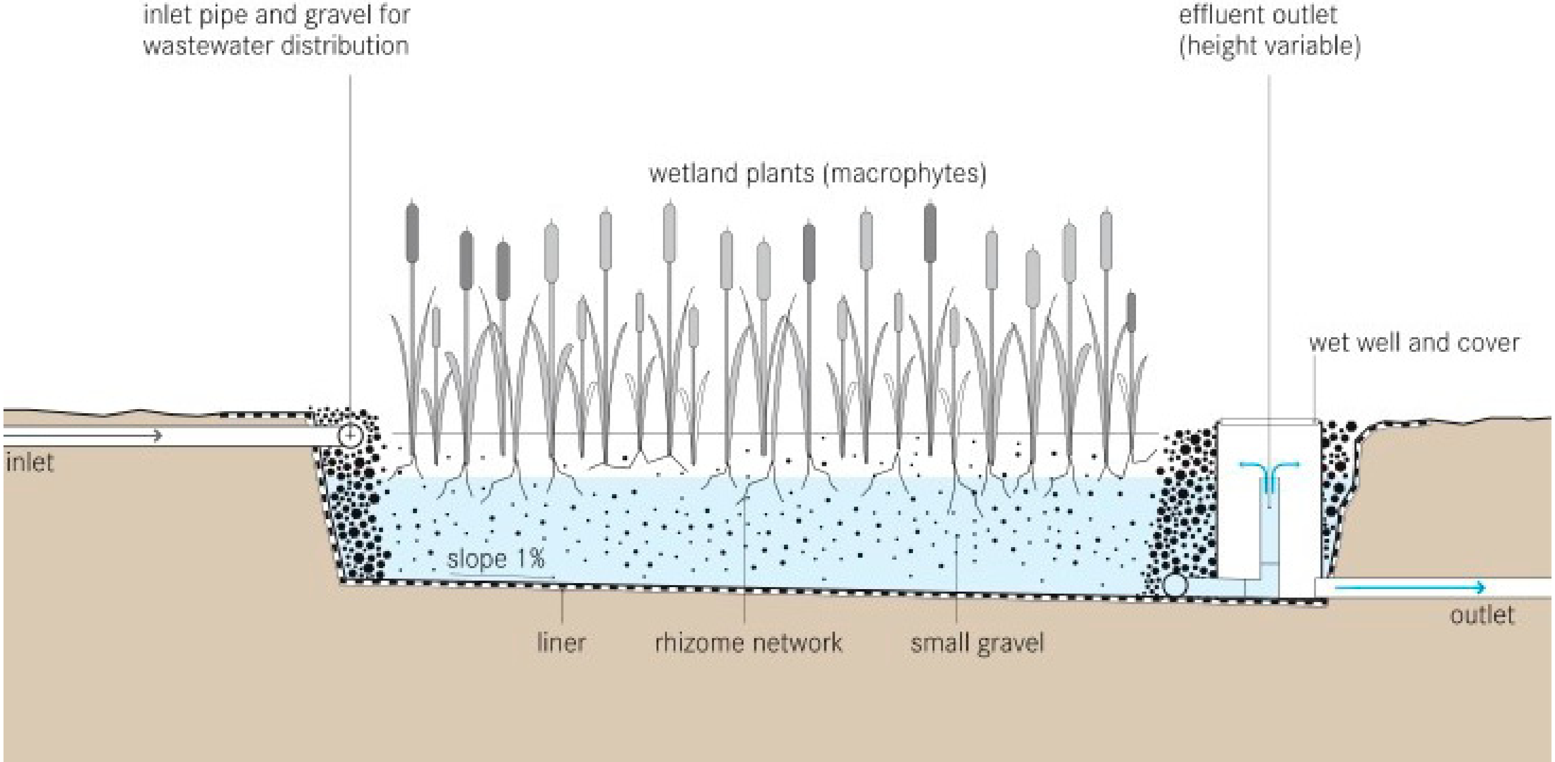

FIGURE 14 - NATURAL-BASED WASTEWATER TREATMENTS SYSTEMS.
ABOVE: CONSTRUCTED WETLAND. BELOW: A LIVING MACHINE SYSTEM

3.4 ENERGY

Designing high-performance buildings with a reduced energy consumption and carbon footprint is perhaps the most important and challenging sustainable strategy. A typically misleading concept involves the idea that electrical energy is the only type of energy consumed by buildings. As a matter of fact, buildings do consume most of the electric energy produced, but they also demand a substantial amount of primary energy, fuel sources such as oil, coal and natural gas. For example, building materials or even modular homes require a considerable amount of energy to be manufactured and to be transported to the building site, which is referred as the embodied energy.

Did you know? Buildings consume around 40% of the total primary energy in the US.

United States Primary Energy Conssumption by Source (2015)

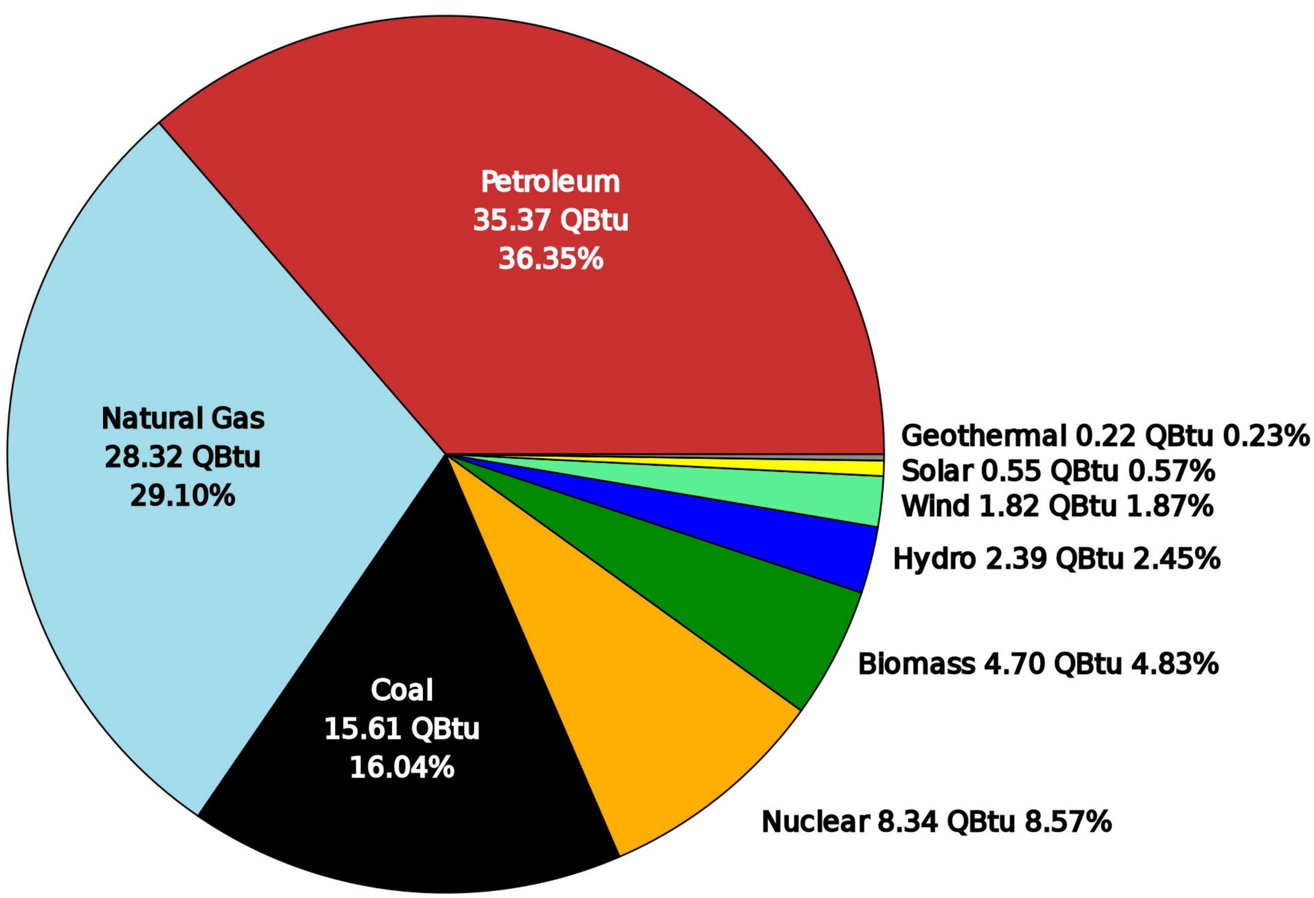

FIGURE 15 - UNITED STATES ENERGY CONSUMPTION BY PRIMARY SOURCE IN 2015. SOURCE: ENERGY INFORMATION ADMINISTRATION

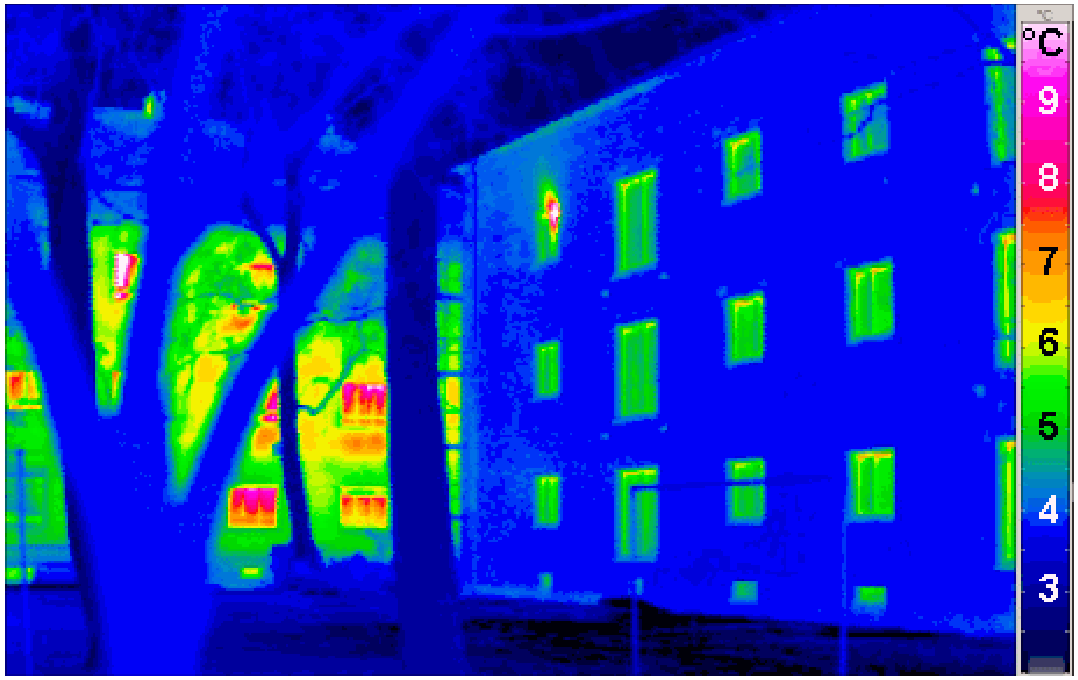

FIGURE 16 - THE DARK BLUE COLOR FROM THIS PASSIVE HOUSE BUILDING MEANS THAT THE BUILDING ENVELOPE IS NOT LOSING MUCH HEAT COMPARED WITH A TRADITIONAL BUILDING LOCATED ON THE BACKGROUND.

The upside is that most energy consumption can be reduced through better design and more stringent building codes. The very first step in reducing overall energy consumption is to maximize the passive design features during the design phase. An outstanding passive design selects materials depending on sun exposure and climate conditions. It considers the insulation levels required for the project and also the colors of the materials since color affects the amount of energy reflected or absorbed by that material. The building envelope must be carefully analyzed in order to control the solar heat gain/loss and the infiltration or leakage of heat. Walls, windows and roof materials must provide adequate thermal resistance based on their material content and the insulating value of these materials (Figure 16). Using passive design strategies contributes to reducing the amount of energy consumed to cool/heat the building and for artificial lighting. The remaining building internal energy load can be reduced by using high-efficiency electrical equipment, updating lighting fixtures, using lighting controls, and upsizing the electrical wiring to reduce resistance and energy losses.

By using these strategies, buildings can significantly reduce energy consumption. In addition, alternative and renewable energy sources can be implemented to produce the remaining energy needed. A net-zero energy standard is achieved when the building is able to produce the same amount of energy or even more than needed for its operation. The excess of energy can be sent to the utility grid and converted into credits or discounts for the owner.

Alternative energy is any source of energy that provides an alternative to a fossil-fuel source and is naturally restocked. Currently, technology and costs are significant obstacles for the wide use of renewable energy.

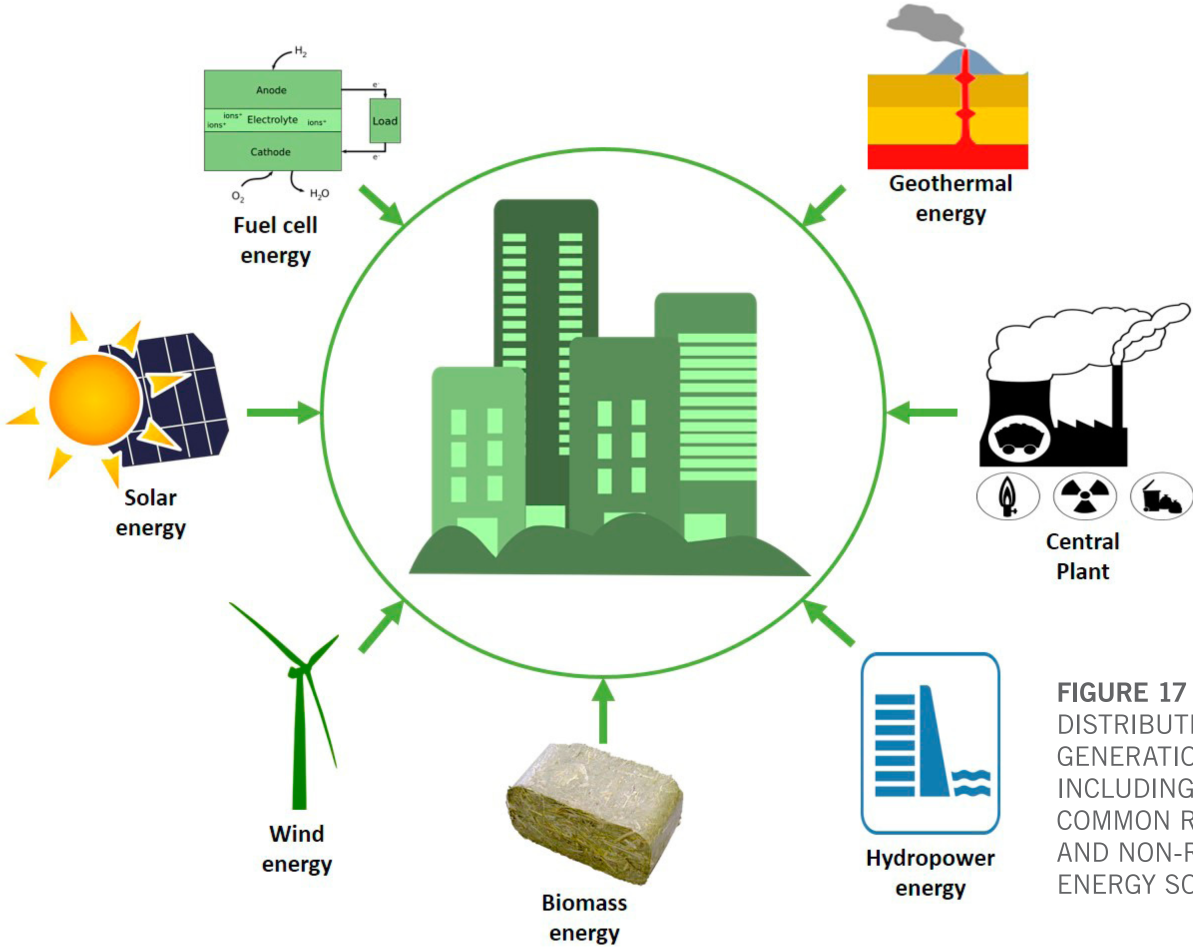

FIGURE 17 - DISTRIBUTED POWER GENERATION SYSTEM INCLUDING THE MOST COMMON RENEWABLE AND NON-RENEWABLE ENERGY SOURCES.

With advances in alternative energy sources, the energy grid is becoming more distributed or decentralized (Figure 17), meaning that the system incorporates several small power generating facilities rather than depending on a single energy source. Typically, photovoltaic cells and wind turbines are used to generate renewable energy for buildings. But there are several other renewable approaches that can be used to reduce energy consumption or generate energy for buildings, as follows:

- **Radiant cooling**: Since water can absorb more energy than air and requires much less energy to move, many projects are using cold water to cool buildings. The system circulates cold water trough tubes installed in floors, ceilings and walls, which then absorb heat from the interior spaces.
- **Ground coupling:** Ground coupling is the use of the Earth energy to cool and heat the building. When using ground source heat pumps, the system uses the ground as an energy source providing heat for the building.

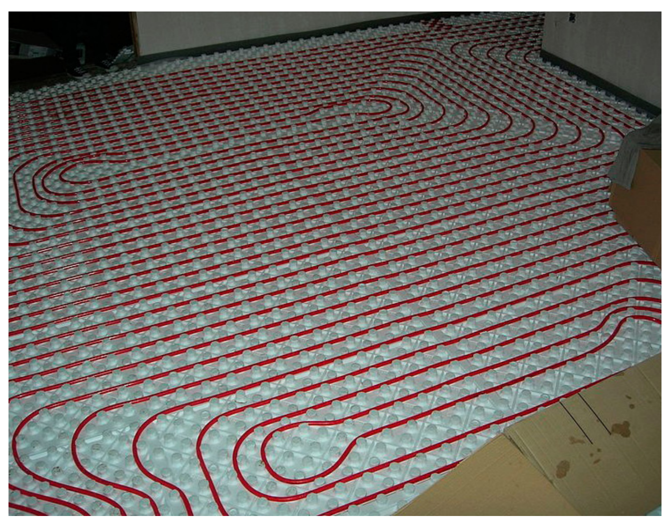

FIGURE 18 - ROOM RADIANT FLOOR CIRCUIT FOR HEATING AND COOLING THE SPACE. CONCRETE OR RAISED FLOOR COVER CAN BE USED ABOVE THE SYSTEM

At this point, water can be used to cool the air before releasing it into the building, minimizing the use of HVAC systems.

► **Fuel cells:** The system converts the chemical energy from a reaction into electricity, becoming economically viable for residential and commercial projects.

Computers, often referred as Building Automation Systems (BAS), can be used to control the energy consumption of equipment and ensure the building operates as designed (Energy Management System). These systems are becoming essential due to the high amount of complex systems involved in high-performance buildings.

FIGURE 19 - MODULAR AND MANUFACTURED HOMES OFFER GREAT OPPORTUNITIES FOR BUILDING AUTOMATED SYSTEMS SINCE THEY CAN BE DESIGNED AND INSTALLED DURING THE MANUFACTURING PROCESS. THIS PICTURE IS A MODULAR HOME CONSISTING OF 6 PREFABRICATED MODULES IN VALENCIA, SPAIN.

3.5 CARBON EMISSIONS

Among all environmental impacts, climate change is perhaps the most notorious and challenging. The increase in carbon emissions from fossil fuel combustion is contributing to the significant decrease of biomass that sequesters CO^2 from the atmosphere, preventing the Earth from maintaining a stable temperature balance. There are several greenhouse gases that are known to cause climate change such as methane, nitrous oxide and fluorinated gases, but CO^2 emissions are typically 10 times greater than any of these other gases.

The building industry is by far the greatest emitter of carbon gases. The total carbon footprint from buildings can be divided into operational carbon, embodied carbon and transportation carbon. Best practices to reduce the carbon footprint are as follows:

- Reduce primary energy consumption by designing buildings with low-energy needs.
- Maximize the use of renewable energy sources such as photovoltaic cells and wind turbines.
- Emphasize urban density, reduce transportation emissions, preserve greenfield and restore ecosystems.
- Incentivize mass transportation.
- Design for durability and select recyclable materials.

Carbon can be released from different sources during building construction. Emissions from equipment during the use phase of a building is known as operation carbon. The amount of carbon emissions to manufacture or produce building materials is called embodied carbon. Emissions coming from all types of transportation during the lifecycle of the building is called transportation carbon, and has a large connection with the way buildings are spread in the city.

3.6 INDOOR ENVIRONMENTAL QUALITY

Indoor Environmental Quality (IEQ) has become an important aspect for current high-performance buildings. There are several factors that compromise IEQ, such as ineffective ventilation systems, occupant activities, the quality of the outdoor environment and chemical emissions from equipment, building products, materials and furniture. Although air quality is the most prominent factor, IEQ analysis also includes other aspects such as:

Did you know?

Indoor Air Quality of buildings can be up to 100 times worse than the quality of the air outside buildings. This is an important issue because we tend to spend around 90% of our time inside buildings.

- **Lighting quality and external views:** The healthiest indoor environment maximizes daylight into the building and provides visual connections with the outdoors. Artificial lighting also contributes to indoor quality. Some light sources and colors may cause loss of productivity, headaches and irritate occupants. Halogen incandescent lights give the best natural visual for interior purposes, while sodium-based lights are often used in the exterior. Fluorescent and LED lighting fixtures are also used for commercial spaces. In general, lighting systems are designed based on the activities in each building space.

► **Noise transmission:** Noise from HVAC systems, lights and equipment can cause discomfort and even health problems for occupants. High levels of noise may decrease productivity, irritate, distract and even increase morale problems. Therefore, spaces should be designed taking into account the acceptable sound levels for that specific building area.

► **Thermal comfort:** The sense of temperature varies from person to person. Typically, indoor comfort ranges from 68°F to 75°F and relative humidity between 30-60%.

► **Odors:** This may be the most common and difficult IEQ problem because the human olfactory system is highly complex and the sense of odor may vary for each person.

► **Volatile organic compounds (VOCs):** VOCs are a common IEQ problem. They contain carbon that can be released by paints, perfumes, aerosols, cleaning and automotive products, solvents, wood preservatives or any chemical product. Common VOCs are formaldehyde, benzene and toluene. Indoor VOCs can be reduced by selecting products manufactured to contain low or no VOCs.

► **Asbestos:** Asbestos is a silica-based mineral found in old insulating materials. The material was banned in the 1970s after it was found to damage human health and cause lung cancer. However, major renovations and maintenance of old buildings may still release asbestos into the air.

► **Radon:** This colorless and odorless gas binds to dust particles and may cause lung cancer when inhaled. In buildings, radon mainly comes from the underlying subsoil, entering the building through small cracks and other pathways.

► **Combustion by-products:** Carbon dioxide, carbon monoxide, nitrogen dioxide, sulfur dioxide and other particulates may be released in the indoor environment due to incomplete combustion of heating fuels. Their health effects will depend on the type of the chemical and the quantity. For example, high quantities of carbon dioxide may not have as much effect as carbon monoxide, which can cause nausea, dizziness, confusion and weakness. Nitrogen dioxide may irritate the eyes and skin, and alter lung function, while sulfur dioxide may cause bronchoconstriction.

Due to the many potential health problems related to building materials, both industry and public agencies are promoting the use of products with low emissions. Currently, both the LEED and Green Globes building rating systems provide credits for using low-emission materials.

Building materials release VOCs in different ways and with different frequencies. For example, adhesives and sealants offer the greatest threat during application, while adhesives for particleboard and plywood may emit most of their VOCs after installation. Low-emitting water-based finishes, such as paints and varnishes, are now available in the market, but contain other chemical hazards that also require attention during installation. Low- or zero-emitting materials are also available for floor and wall coverings, such as carpet and resilient floorings.

Providing abundant and frequent natural ventilation is primordial to removing pollutants from indoor air, especially during manufactured construction. Many construction activities, such as sanding, cutting and installing products, produce dust, airborne particles or release VOCs. Segregating construction activities in the manufacturing facility and providing separate ventilation for each of these spaces will improve workers' health and safety and prevent pollutants from spreading in the workplace.

During construction and before occupancy, manufacturers should provide temporary high-efficient filters in the HVAC system. Filters will trap air contaminants and prevent them from entering the system. The Environmental Protection Agency recommends a two-week ***flushout*** period and replacement of all filters prior to occupancy.

Providing natural daylighting and ventilation improves indoor environmental quality, but these options should be efficiently managed to prevent unnecessary energy expenses and thermal discomfort. Controlling systems for lighting, ventilation, humidity and temperature are becoming more sophisticated in modern buildings and are helping owners control their environment according to their needs and improve indoor quality.

3.7 MATERIALS

The selection of building materials for high-performance buildings is perhaps the most important and difficult task for the project team. This is due to the high capacity that materials have to affect the building's IEQ, energy consumption, carbon emissions and site development.

Also, building materials typically have a large footprint, meaning they consume significant amounts of energy and resources during production and generate a significant amount of waste during their entire life-cycle. The energy used from the extraction of resources, transportation to manufacturing plant, and manufacturing process (cradle-to-gate) is called indirect embodied energy and is measured in units of energy per

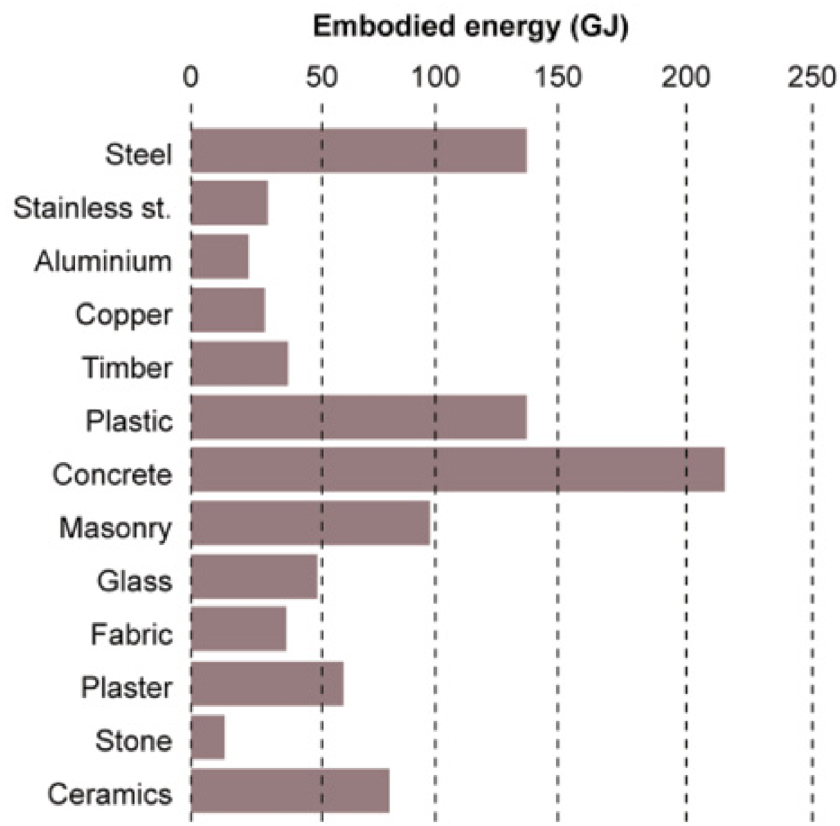

FIGURE 20 – EMBODIED ENERGY FROM TYPICAL BUILDING MATERIALS. SOURCE: CSIRO

unit weight (Figure 20). The material waste can occur during several phases of the product life-cycle including the harvesting of raw materials, manufacturing, transportation and final disposal. Manufacturers are able to analyze the environmental impacts associated with a product's life through a Life-Cycle Assessment analysis.

Even though the concept of green building materials has been discussed for a long time, there is still no consensus about the criteria that makes a specific material environmentally preferable or green. Several product certifications have been used to evaluate materials performance. However, each certification has its own evaluation criteria. New product labels have been introduced into the market recently, such as EPDs and HPDs that provide detailed information about the product environmental impacts on several requirements using LCA analysis (Figure 21).

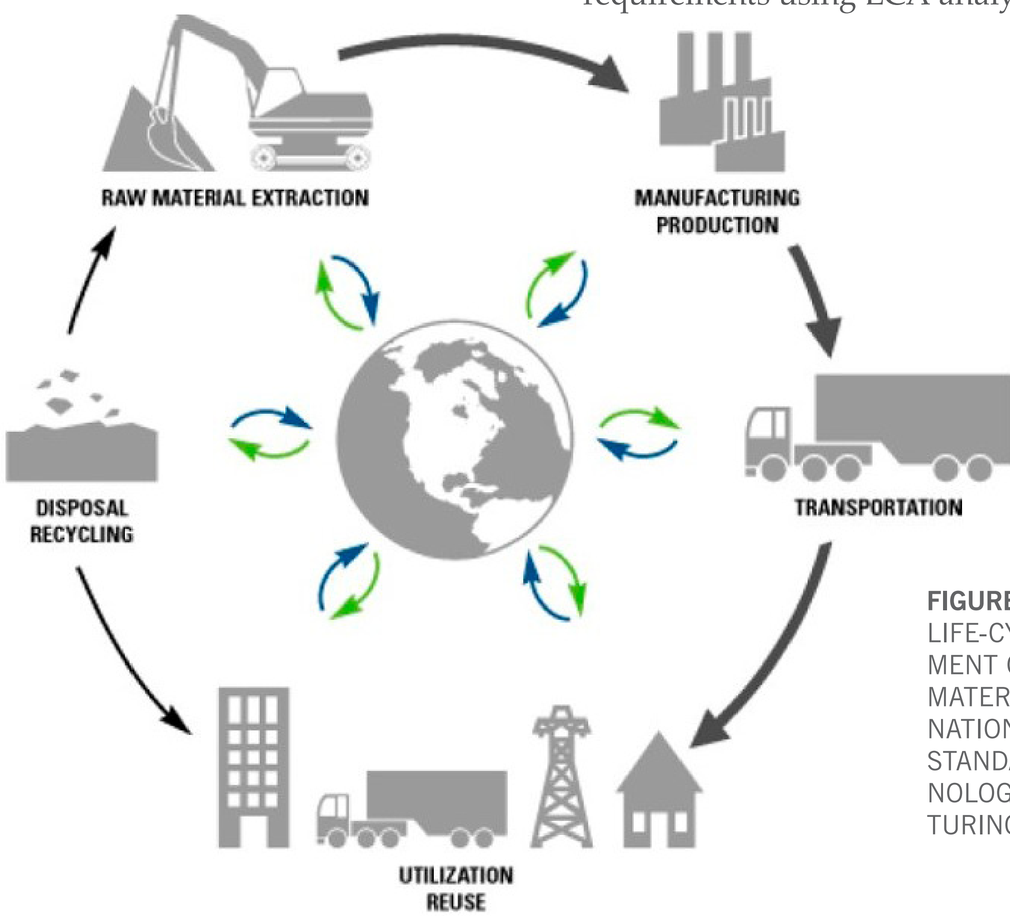

FIGURE 21 - A GENERIC LIFE-CYCLE ASSESSMENT OF BUILDING MATERIALS. SOURCE: NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY'S MANUFACTURING ENGINEERING

Building products may also affect building performance and contribute to indoor air quality. Therefore, it is extremely important to consider product durability and its fitness for purpose. Life-cycle cost simulations are becoming common practices for high-performance building, especially for products that require high investments and may have high impacts in the overall building performance, such as super-insulated walls or high-efficient windows. Attention to the chemical composition of building products is also becoming a new trend for high-efficient building. Some products, especially synthetic ones such as adhesives and finishes, may release pollutants in the air that can have adverse health effects. Several low-emitting products are already available in the market and should be selected whenever possible.

Best practices for material selection and management are:

► **Reduction of materials**: This lowers the total environmental impacts of the project and requires the project team to find new and more efficient alternatives. Multi-functional products may be used to accelerate construction, save building materials and reduce waste. Examples include Structural Insulated Panels (SIPs), aerated autoclaved concrete and insulated concrete forms (Figure 22).

Did you know? People often confuse the terms recyclable and recycled. Recyclable means that the product itself can be recycled. Recycled means that the product contains materials that have been previously used.

► **Reuse and recycle**: Selecting materials with recycled content is the first step in promoting recyclability. Reusing intact building components during major renovations potentially reduces the total material waste and contributes to minimizing the quantity of new materials. For example, prefabricated steel and timber have the ability to be disassembled and reused for a new building while concrete can be crushed and the aggregate reused in new concrete or as a base for pavement.

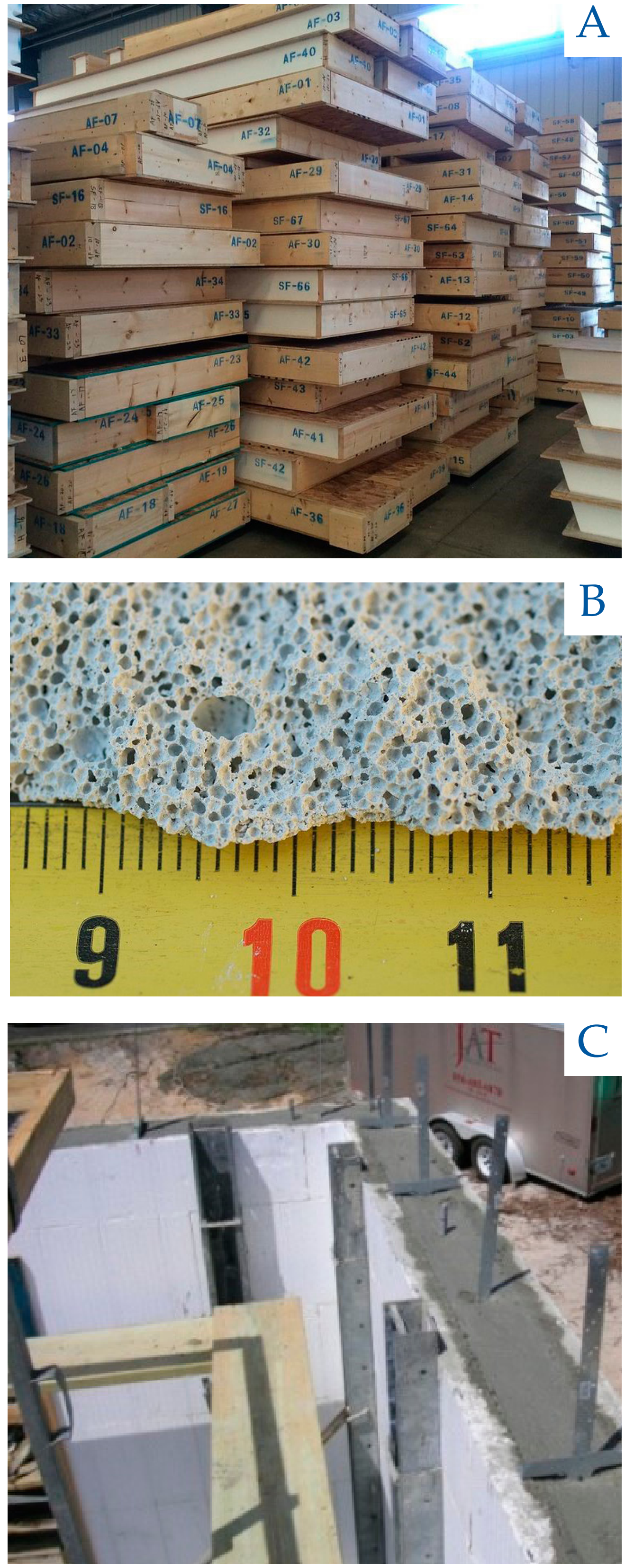

FIGURE 22 - (A) PREFABRICATED STRUCTURAL INSULATED PANELS, (B) AERATED AUTOCLAVED CONCRETE, AND (C) INSULATED CONCRETE FORMS.

There are several opportunities to implement recycling and reusing strategies in building construction. The manufactured industry, specially, has the best environment to achieve very low or even zero material waste during construction. Unfortunately, few practices can be seen in factories across the country. Recycling and reusing construction elements can also be extended to the end of the building life-cycle, reducing the environmental impacts of material disposal and providing new opportunities for the manufactured industry.

Materials from existing buildings or leftovers can also be donated to local nonprofit organizations. Habitat for Humanity, for example, has several retail outlets called "ReStore" that sells donated building materials and uses these resources to build homes for needy families. By donating building materials, companies can take advantage of charitable contribution tax deductions.

► **Use locally available materials**: Reducing the distance between the manufacturing facility and the building site will have a direct effect on total transportation emissions. Alternative energy sources, such as biodiesel, could also be prioritized for transportation, reducing the overall transportation emissions.

REVIEW QUESTIONS

1. Explain the Integrated Design Processes and compare it with usual delivery practices.
2. How can the building site affect the natural environment and the building performance?
3. Explain how an effective passive design can be used in new buildings and how can it affect overall building performance.
4. Which strategies can be implemented to reduce a building's consumption of potable water?
5. What approach can reduce a building's energy consumption and carbon emissions?
6. Which major strategies should be used to improve Indoor Environmental Quality?
7. Describe the manufactured construction opportunities that can reduce overall material waste.

4.0 GREEN CERTIFICATIONS

4.1 THE ROLE OF GREEN ASSESSMENT SYSTEMS

Today, building owners often use green assessment systems to evaluate the environmental impacts of buildings and for analyzing their performance in several categories. Building assessment systems are generally third-party programs that rate or score the building's performance in a range of categories such as energy and water consumption, material selection, indoor environmental quality and ecological system protection. This evaluation process results in a total score or grade, which is then translated into an award. For the U.S. Green Building Council's LEED rating system, awards are (highest to lowest): Platinum, Gold, Silver, and Certified. A plaque signifying this award is offered as part of the process. It can be attached to the exterior or interior of the building. Buildings carrying this designation have proven to be superior in terms of operational performance, such as reduced operating costs and improved occupant health. Also, the rating translates to greater market value and higher rents. These systems offer valuable information about the project and provide a way to help the building construction industry improve product performance and achieve sustainable goals.

Did you know?

A recent study by the National Institute of Occupational Safety and Health found over 40 different rating systems worldwide. While rating system certification is required in some locations, certification in most places is a voluntary process.

4.2 MAJOR U.S. CERTIFICATIONS FOR BUILDINGS AND PRODUCTS

4.2.1 LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN (LEED)

LEED is a rating system developed by the U.S. Green Building Council and is used to evaluate the environmental impacts of buildings. Currently, LEED is being referenced in several standards and is mandatory for some governmental agencies at the federal, state and local levels.

LEED certification applies to a wide range of building projects and is designed to be applicable in different climates and contexts. There are four different certifications based on the construction type: LEED for Building Design and Construction (BD+C), LEED for Interior Design and Construction (ID+C), Building Operations and Maintenance (O+M), LEED for Neighborhood (ND).

The LEED v4 certification is divided into nine categories, which include integrative process, location and transportation, sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation and design, and regional priority. Some categories require prerequisites that must be met in order to pursue certification. Significant improvements can also earn points in the Innovation and Design category in addition to the respective category. The LEED v4 certification has three mandatory requirements:

FIGURE 23 - EXAMPLE OF A LEED PLATINUM CERTIFICATION

► **Permanent location or existing land**: All projects must be built and operated on a permanent location. Movable buildings, such as boats and mobile homes are not eligible. Modular structures are only certified after permanent installation.

- **Reasonable LEED boundaries**: Projects must define the boundaries to ensure the project is accurately evaluated.
- **Comply with project size requirements**: Buildings must meet minimum size requirements. For example, for LEED BD+C requires at least 1,000 square feet of buildable area, while LEED for Homes is subjected to local building codes.

LEED BD+C VS. LEED FOR HOMES

LEED for Homes presents some differences in general requirements from the LEED BD+C, which is used for a variety of building typologies such as commercial, schools, data centers, warehouses, hospitals, healthcare facilities and retail. There are 12 prerequisites and 110 possible points. Certification can be achieved at four different levels:

- Certified: 40-49 points
- Silver: 50-59 points
- Gold: 60-79 points
- Platinum: 80 points and above

On the other hand, LEED for Homes has around 18 prerequisites that vary according to the residential typology. This rating has 110 possible points and uses the same four-tiered ranking above. Residential buildings are referred in two different standards:

- LEED BD+C: Homes and Multifamily Low-rise.
- LEED BD+C for Multifamily Midrise.

The following sections describes the major differences between LEED BD+C and LEED for homes according to the LEED v4 categories:

Integrative Process

Residential projects may achieve points by including team members in several phases of the project, developing a design charrette or providing training for hired trades before the construction stage. For BD+C, the integrative design requires a water budget analysis and preliminary energy modeling with potential strategies to reduce the energy load.

Location and Transportation

LEED for Homes requires the avoidance of floodplain areas. The system also promotes land protection, compact development, access to public transportation and a bicycle network.

Sustainable Sites

Both residential and commercial/institutional projects are obliged to provide a construction pollution prevention plan. In addition, residential projects must prevent the introduction of invasive species in the landscaping. Both standards may award points for rainwater management and heat island reduction through several options. Residential projects can also apply for points when the project reduces exposure to pest problems, while BD+C projects receive credits for reducing nighttime light pollution.

Water Efficiency

While water metering is the only prerequisite for residential projects, BD+C projects must also reduce outdoor water consumption by at least 30% from the baseline or eliminate irrigation and reduce indoor water consumption by 20% compared to code. Credits are awarded for residential projects for a reduction of at leaste 10% in total water consumption, the use of high-efficiency fixtures and efficient landscaping practices. Credits are awarded in BD+C depending on the percentage of water reduction for indoor and outdoor uses.

Energy and Atmosphere

Both residential and BD+C projects are obliged to achieve a minimum energy performance and provide energy metering. In addition, residential projects must provide a maintenance manual for owners and conduct a walkthrough to train occupants. BD+C projects must provide fundamental commissioning and verification of the owner's project requirements and must reduce stratospheric ozone depletion by refrigerant management. Homes can be awarded points by reducing energy consumption, increasing the efficiency of the hot water system and installing a real-time monitoring system for energy and water use. In addition, points are awarded to low-rise homes for installing renewable energy systems, using high-efficiency lighting and appliances, promoting passive design strategies, reducing energy consumption by designing compact living spaces, reducing air leakage and heat transfer from conditioned spaces through efficient envelope insulation, and increasing the energy performance of windows.

Materials and Resources

Residential projects must use certified wood and promote durability of the building components. BD+C projects must provide space for storage and collection of recyclables, and develop a construction and demolition waste management plan. BD+C points are awarded for encouraging reuse and optimization of building materials, and for using products and materials that provide information about the life-cycle analysis for source of materials and ingredients. Residential projects can apply for points when the project promotes durability and high performance of the building components, uses materials that are recycled or have recyclable content and reduce construction waste. Low-rise homes can earn points for recycling unnecessary framing materials.

Indoor Environmental Quality (IAQ)

Residential projects must provide ventilation in kitchens and bathrooms to exhaust pollutants, and limit the leakage of combustion gases into occupied spaces. They must also place ductwork and air-handling equipment outside of the fire-rated envelope of the garage, reduce exposure to radon gas and other soil toxic gases, provide air filters to reduce the entrance of particles from the air supply system, prohibit smoking in common areas of the building, and provide compartmentalization to limit leakage between units. Points are awarded for enhancing ventilation systems and compartmentalization, providing contaminant controls, balancing the heating and cooling systems, and selecting products and materials with reduced chemical contaminants. BD+C projects must comply with the minimum standards for IAQ and prohibit smoking in common areas of the building. Credits are awarded for enhancing IAQ, selecting products and materials with reduced chemical contaminants, providing a IAQ management plan for construction and renovations, assessing the quality of the air, promoting quality thermal comfort, high-quality indoor lighting, maximizing daylight and natural outdoor views, and improving acoustic performance. Credits are also awarded for exceptional innovative performance and addressing regional-specific priorities.

4.2.2 GREEN BUILDING INITIATIVE: GREEN GLOBES CERTIFICATION

The GBI is a non-profit organization established in 2004 to administer the Green Globes certification system. The online building design management program was first launched in 2005 to promote construction of sustainable commercial buildings. Green Globes for New Construction has two assessment stages(Figure 24). The first occurs when construction documents have been completed at the end of the design phase. The second assessment occurs when construction is complete. The Web-based system consists of questions about green building practices. A complete report is available at the end of the questionnaire, providing ways to analyze sustainable achievements. An accredited GBI assessor is assigned to evaluate the online report and documentation, and conduct on-site inspections. The Green Globes assessor will be involved from the beginning of the project to help clarify misunderstandings regarding program requirements.

The Green Globes certification has 1,000 points available for every type of project. Different from the LEED system, the total amount of points may change if some points are not applicable for that building type. Green Globes categories include: policies and practices of project management, site development, energy, water, building materials and resources, emissions and effluents, and indoor environment. The rating system is divided as follows:

- 35-54% of applicable points – 1 Globes
- 55-69% of applicable points – 2 Globes
- 70-84% of applicable points – 3 Globes
- 85-100% of applicable points – 4 Globes

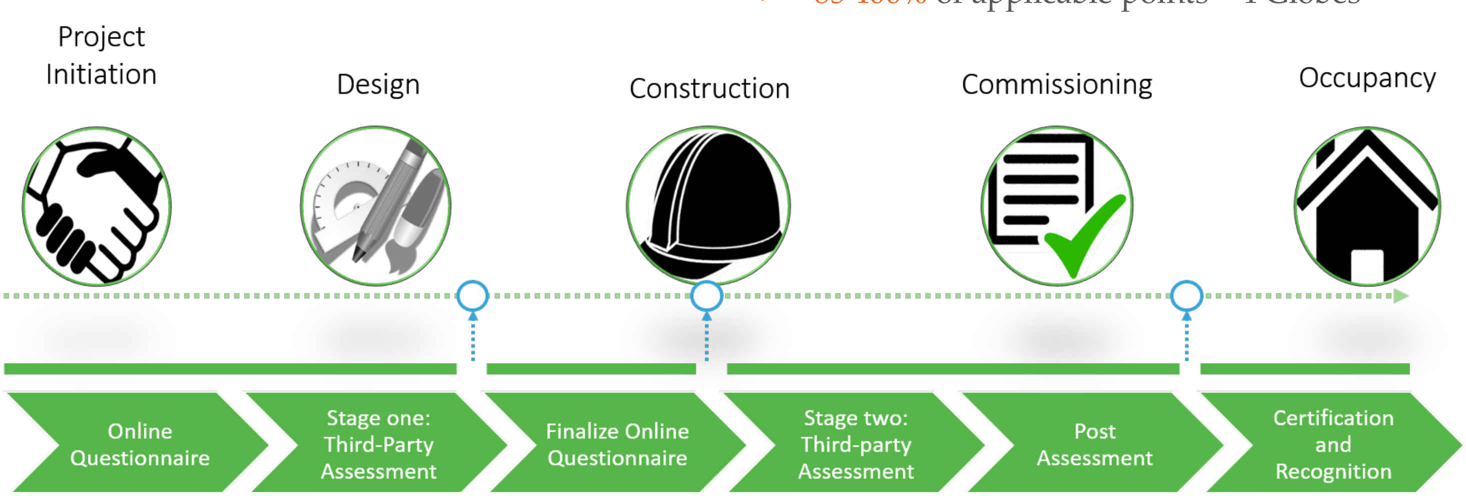

FIGURE 24 - GREEN GLOBES FOR NEW CONSTRUCTION RATING AND CERTIFICATION PROCESS

4.2.3 LIVING BUILDING CHALLENGE

The Living Building Challenge (LBC) is a movement created in 2006 by the Cascadia Green Building Council and is considered the most rigorous built environment performance system in use. In contrast with other rating systems, such as LEED and Green Globes, the LBC does not measure or rate buildings. The certification is solely based on compliance with all the requirements of the program.

LBC's Version 3.1 has 20 requirements across 7 groups or "petals:" place, water, energy, health and happiness, materials, equity and beauty. Despite this straightforward format, some LBC requirements are considered the cutting edge of sustainable construction and require substantial design and construction efforts. For example, the water and energy petals require the building to achieve net-zero standards.

4.2.4 FLORIDA GREEN BUILDING COALITION (FGBC)

The FGBC is a non-profit organization promoting sustainable construction in the State of Florida. It developed a program for construction and governmental sectors, certifying the following products and services:

- Homes: Single-family and multi-family up to 3 stories.
- Commercial Buildings
- High-Rise Residential Projects with 4 or more stories
- Land Development
- Local Governments

Homes and Commercial Buildings

Homes submitted under the Florida Green Home Designation Standard must meet or exceed the minimum standard for the Florida Energy Code, meet the Home Energy Rating System (HERS) Index requirement (Figure 25), achieve at least 100 credit points and be certified by a FGBC accredited certifying agent. The checklist for homes and commercial buildings is organized into categories, including project management, energy efficiency, water conservation, site preservation, health, materials selection,

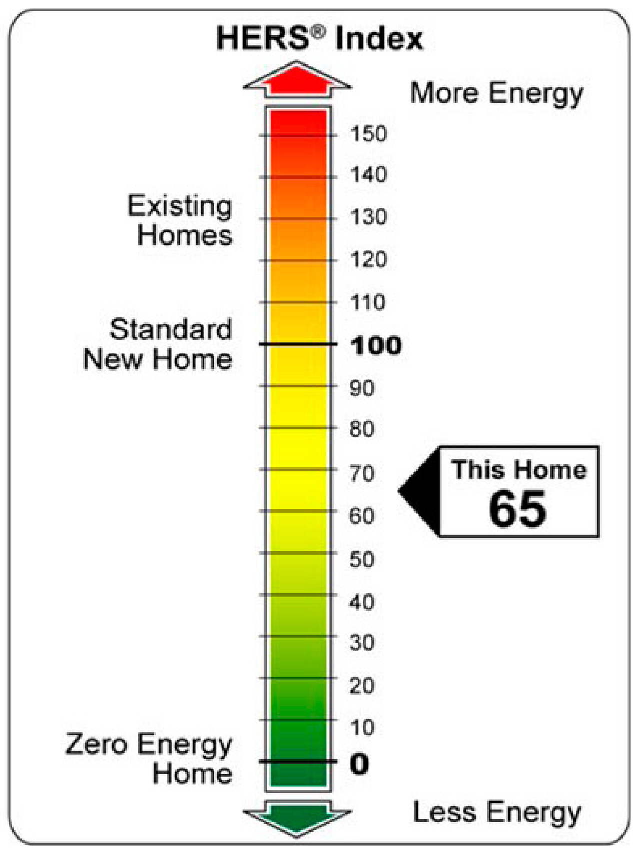

FIGURE 25 - THE HERS INDEX COMMUNICATES THE ENERGY EFFICIENCY OF A BUILDING TO BUILDERS, DEVELOPERS AND CONSUMERS. THE LOWER THE VALUE, THE BETTER THE BUILDING'S PERFORMANCE.

disaster mitigation and environmental innovation. Each category has a minimum and a maximum for points awarded or allowable.

4.2.5 ENERGY STAR

ENERGY STAR is a voluntary labeling program developed by the U.S. Environmental Protection Agency (EPA) that is designed to identify and promote energy-efficient products and services. Computers and monitors were the first products to receive the label when the program started in 1992. Today, the program covers major appliances, office equipment, lighting, home electronics, new homes and commercial spaces, and industrial building plants.

FIGURE 26 - THE ENERGY STAR LABEL.

Buildings and industrial plants are divided into 21 different types of facilities. An ENERGY STAR label means the building or plant uses significantly less energy than a typical facility and has met strict requirements during inspection, testing and verification. The score (1-100) measures the energy performance of the building compared to peer facilities nationwide, where 1 is the least efficient and 100 is the most efficient. For example, a score of 40 means that the building is 40% more efficient than its peer facilities. A score of 75 or higher is required for ENERGY STAR certification.

New Homes and Apartments

To earn the ENERGY STAR designation, a home must be certified under Version 3 of the program requirements or meet regional specifications, if required. For example, new homes in Florida will be certified under Version 3.1 of the program requirements for the State of Florida. To earn a certification, ENERGY STAR requires a design analysis, HVAC design report, HVAC commissioning checklist and adherence of water management system requirements. Furthermore, the EPA requires builders, raters and HVAC contractors to complete Version 3 training. An "ENERGY STAR Reference Design Guide" provides detailed instructions about modeling efficiency features to determine the Home Energy Rating System (HERS) index.

Manufactured Homes

Manufactured HUD homes can be certified only after meeting all ENERGY STAR requirements, and an on-site inspection and verification. Currently, the requirements

Did you know?

By using Structured Insulated Panels, builders can meet ENERGY STAR requirements that dictate new homes are made 15% more energy efficient than those built under the 2009 International Energy Conservation Code (IECC).

for manufactured homes differ from those for site-built homes, but the EPA is in the process of harmonizing these requirements. A manufactured home can achieve energy performance requirements by incorporating pre-approved design packages according to climate region or use approved software for designing and developing computer analysis.

There are two ways a manufactured home can earn the ENERGY STAR certification:

- ► If each home is rated by a third-party Home Energy Rater who verifies if the ENERGY STAR-related features of the home were installed both in the plant and on-site.
- ► Or if the manufactured homes are built under the supervision of a Quality Assurance Provider (QAP) in the facility plant. This involves a plant certification process to certify that the facility plant has incorporated ENERGY STAR requirements and is able to produce homes that achieve ENERGY STAR requirements. An on-site inspection certifies that all ENERGY STAR requirements have been met.

Modular Homes

A modular home is a prefabricated house made of multiple modules or sections assembled in a manufacturing plant (Figure 27). These pre–built sections are transported to the building site and assembled by a builder who ensures all applicable building codes are met. The program requirements for modular homes are the same as those for site-built homes, however the home is only certified after an on-site inspection and verification.

Modular homes can receive an ENERGY STAR label by a third-party Home Energy Rater or through a plant certification. Plant certification includes these three main elements:

FIGURE 27 - MODULAR HOUSE UNDER CONSTRUCTION BY CG ARCHITECTS, CROSSBOX.

- ► Plant Certification: Manufacturing plants must develop procedures for personnel education, use approved modular designs from a third-party, perform periodical plant and design inspections, and test modules both on plant and on-site..
- ► Builder Qualification: Builders have to demonstrate the ability to consistently meet ENERGY STAR requirements by establishing specific on–site inspection and testing procedures. Each test must include the use of an independent third–party who can visually verify and document that each home has met all program requirements prior to earning the ENERGY STAR label.
- ► Compliance Verification: ENERGY STAR requirements compliance for each home must be verified both in the plant and at the site.

4.2.6 INTERNATIONAL WELL BUILDING INSTITUTE

The WELL certification is administered by the WELL Building Institute and provides third-party certification from Green Business Certification Inc., a company that also administers LEED certification. A high-efficiency building can be certified as:

- Silver: If the building achieves 100% of the WELL preconditions for that specific building typology.
- Gold: If the building achieves all preconditions plus 40% of Optimized features.
- Platinum: If the building achieves all preconditions plus 80% of Optimized features.

The WELL certification requires an assessor to visit the building site to verify documentation and perform tests. The evaluation will analyze the air and water quality, acoustic performance, lighting attributes and thermal aspects. The project team will have opportunities to make improvements if the report does not meet the project's sustainable goals. A WELL certification for new and existing buildings is valid for three years. The recertification process ensures the building maintains the same levels of performance while operating.

4.2.7 HOME INNOVATION NGBS GREEN CERTIFICATION

Home Innovation Research Labs (HIRL) was founded in 1964 as an independent subsidiary of the National Association of Home Builders (NAHB) to perform product tests, research, consulting and issue certifications. HIRL uses the national Green Building Standard (NGBS), the only residential green building system approved by the American National Standards Institute (ANSI). The standard defines practices for residential buildings, renovations and land developments and is designed to minimize conflicts with local codes. HIRL assigns points for NGBS requirements so projects can be certified as Bronze, Silver, Gold and Emerald according to the points awarded. NGBS mandatory requirements must be achieved for any level of certification.

NGBS requirements are divided into six green categories: lot and site development, resource efficiency, energy efficiency, water efficiency, IEQ and homeowner education. The evaluation considers design practices, construction and operations performance. HIRL provides an excel-based spreadsheet for architects, builders and developers to fill the project information and claim for points. An accredited verifier will perform analysis at least two times during the construction: before drywall installation and after the building is complete.

4.2.8 PROMINENT CODES AND STANDARDS

Building rating systems mostly rely on independent or third-party organizations that produce standards, conduct testing and provide important information for high-performance buildings. These organizations provide labels that meet the requirements of green buildings and can be used to award points for building certification.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

ASHRAE was created in 1894 to conduct research, write standards and promote the use of efficient building system practices that encourage energy efficiency, indoor air quality and sustainability. ASHRAE standards are often referred to in building codes and green building rating systems. Some important standards include:

- ASHRAE Standard 62.2/2016 outlines acceptable ventilation levels for Indoor Air Quality in residential buildings.
- ASHRAE Standard 90.1/2013 (I-P) describes energy standards for all buildings, except low-rise residential.
- ASHRAE Standard 90.2/2007 describes energy-efficient designs for low-rise residential buildings.
- ASHRAE Standard 189.1/2014 describes the design standard of high-performance green buildings and provides minimum requirements for site, design, construction and operation.

An "Advanced Energy Design Guide" provides guidelines for 50% or 30% energy reduction compared to buildings that meet the minimum requirements of the Standard 90.1/2004 and 90.1/1999, respectively.

ASHRAE also awards personal certifications for a variety of trades including Building Assessment Professional, Building Energy Modeling Professional, Commissioning Process Management Professional, High-Performance Building Design Professional, and Operations and Performance Management Professional.

International Code Council (ICC)

The ICC is a non-profit organization dedicated to developing model codes and standards used in design and construction phases. International codes are used by several federal agencies, states and jurisdictions. For example, the Department of Defense uses the International Building Code for military facilities projects.

The 2015 International Green Construction Code (IgCC) is intended to be used by state and municipal jurisdictions for new construction and major renovations. The code sets requirements for high-performance projects. Projects should use the IgCC and the ICC 700 National Green Building Standard (NGBS) for residential projects. The IgCC also references ASHRAE 189.1/2014, High-Performance Green Building Design.

The ICC also develops personal certifications through examination programs. There are several categories of certifications that depend on specific roles or trades, such as the residential and building Contractor/subcontractor, master and journeyman plumbing, electrical, gas, fire sprinkler, and mechanical exams. For the state of Florida, there are certifications for Modular Building Inspector or commercial building inspector.

National Sanitation Foundation – NSF

NSF International is an independent global organization that writes standards, provides tests and certifies products for a variety of industries, such as construction, food, water, health sciences and consumer goods. NSF International can certify products, services or management services that can be proved to minimize adverse health effects and protect the environment. Standards for quality, safety, performance, efficiency and sustainability are used for building materials and interior products. The program can also verify the product performance based on recycled content, energy performance and water conservation. Certified products/services receive the NSF mark and are subjected to regular re-testing of products and on-site inspections of the manufacturing facilities.

The NSF certification process is specific to the product, process or service being certified and the type of certification. Generally, the certification involves a complete product evaluation, the product testing in lab facilities, a manufacturing facility inspection, an annual plant inspection, and retesting.

NSF standards have been applied to building construction materials since 2015, when the International Green Construction Code (IgCC) included NSF standards for carpets, wallcoverings, flooring, textiles, roofing and natural dimension stones. In 2015, some standards also included NSF requirements for water reuse systems used for residential toilets and urinals.

Forest Stewardship Council (FSC)

The FSC is an international non-profit organization established in 1993 to design standards that promote responsible management of forests. The FSC developed a set of 57 criteria for forest management certification that are divided into 10 major principles. The standard includes workers' and indigenous right, environmental impacts, wood management plan, monitoring and assessment, maintenance of high conservation and efficient plantations. The forest management certification is voluntary and made by a third-party agency. The FSC label means that a specific product is made from responsible forestry practices.

4.3 YOUR ROLE IN THE GREEN ENVIRONMENT — PERSONNEL CERTIFICATION PROGRAMS

With the ongoing changes in the building industry, especially because of the green building movement, it is essential that professionals stay current with building codes and green practices. One of the best ways to acquire information and training is through certifications. A personnel certification affirms that an individual possesses a solid foundation and specific knowledge on that specific field. This section will present some green building personnel certifications designed for sustainable supervisors at several levels of the green building industry.

Did you know?

The PHIUS+2015 Passive Building Standard is the only passive building standard on the market based upon climate-specific comfort and performance criteria. Buildings designed and built with this standard perform 60-85% better (depending on the climate zone and building type) on an energy consumption basis when compared to a code-compliant building (International Energy Conservation Code IECC 2009).

4.3.1 PASSIVE HOUSE INSTITUTE US, INC. (PHIUS)

The PHIUS is a non-profit organization designed to promote high-performance passive buildings around North America. The program develops passive building standards, performs research and tests, provides training, and certifies buildings and professionals.

The current personnel certifications related to building supervision include:

- PHIUS Certified Passive House Consultant: Principles of passive building design, modeling tools and energy modeling programs.
- PHIUS Certified Builders Training: Real-world problems during passive building constructions, craftsmanship, and risks and liabilities for the contractor.
- Quality Assurance/Quality Control Training Programs: Ways to verify plans and energy models at the design state, and perform on-site testing and inspection during multiple site visits to ensure a project is built as designed.
- WUFI Passive Training: Passive house principles and ways to meet the PHIUS+ Certification performance standard.

4.3.2 NATIONAL ASSOCIATION OF HOME BUILDERS (NAHB)

The NAHB was founded in the early 1940s to ensure that all Americans have access to safe, decent and affordable housing. Most members are home builders or remodelers, but there are specialists in marketing, sales, finance, manufacturing and suppliers.

Through its Certified Green Professional program, the NAHB provides recognition for building professionals who incorporate sustainable concepts into home projects. The program requires students to have a minimum of two years experience in the building industry and complete courses related to green building methods. The program is based on the ICC 700 National Green Building Standard, which includes topics such as indoor air quality, site development, water and energy consumption and owner education. It also requires 12 hours of continuing education every 3 years to maintain the designation.

Did you know?

A University of Florida study found that a larger percentage of Green Advantage certified workers are more likely to recognize significant environmental, health and attitudinal improvements, positively affecting green building performance.

4.3.3 GREEN ADVANTAGE PERSONNEL CERTIFICATION

The Green Advantage is a non-profit organization created in 1996 with funding from the EPA. Its certification covers several topics, including building techniques and practices, green building materials, construction efficiency from environmental, social, safety, and budgetary perspectives. The certification is recognized by many institutions, including but not restricted to American Institute of Architects, the U.S. Green Building Council, Green Building Certification Institute and the National Association of Home Builders. Furthermore, the Green Advantage is applicable to multiple green building systems, such as LEED, Green Globes, Passive House and Living Building Challenge.

The Green Advantage offers two construction personnel certifications:

- GA Certified Associate: Valuable for tradespeople who wish to demonstrate their capability in green construction. The program focuses on basic construction field principles, means and methods that help ensure successful green building projects.
- GA Certified Practitioner: Designed for construction supervisory personnel.

Candidates are responsible for understanding green building best practices. The certification also requires a general understanding of green building rating systems, standards and codes.

A certified Green Advantage professional is expected to understand green building commissioning and performance requirements, ensure team collaboration and productivity, improve the building design, and meet environment, health, budgetary and safety goals.

REVIEW QUESTIONS

1. Explain the major differences between LEED, Green Globes and the Living Building Challenge.

2. How can the Florida Green Building Coalition and the Energy Star certification be used for the manufactured construction industry?

3. What is the National Sanitation Foundation and how is it used in building construction?

4. What is ASHRAE and what are the major standards for buildings?

REFERENCES

KIBERT, C. J. (2016). SUSTAINABLE CONSTRUCTION: GREEN BUILDING DESIGN AND DELIVERY. JOHN WILEY & SONS.

NCCER (2015). YOUR ROLE IN THE GREEN ENVIRONMENT TRAINEE GUIDE. PEARSON

NCCER (2011). SUSTAINABLE CONSTRUCTION SUPERVISOR. PEARSON

USGBC, L. (2014). REFERENCE GUIDE FOR BUILDING DESIGN AND CONSTRUCTION V4. US GREEN BUILDING COUNCIL.

GREEN GLOBES FOR NEW CONSTRUCTION (NC). RETRIEVED FROM: http://www.thegbi.org/green-globes-certification/how-to-certify/new-construction

LIVING BUILDING CHALLENGE. RETRIEVED FROM: http://living-future.org/lbc

FLORIDA GREEN BUILDING COALITION (FGBC). RETRIEVED FROM: http://floridagreenbuilding.org/

NATIONAL SANITATION FOUNDATION (NSF). RETRIEVED FROM: http://www.nsf.org/

INTERNATIONAL WELL BUILDING INSTITUTE. RETRIEVED FROM: https://www.wellcertified.com/

ENERGY STAR. RETRIEVED FROM: https://www.energystar.gov/

HOME INNOVATION NGBS GREEN CERTIFICATION. RETRIEVED FROM: http://www.homeinnovation.com/green

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE). RETRIEVED FROM: https://ashrae.org/

INTERNATIONAL CODE COUNCIL (ICC). RETRIEVED FROM: http://www.iccsafe.org/

FOREST STEWARDSHIP COUNCIL (FSC). RETRIEVED FROM: https://us.fsc.org/en-us

PASSIVE HOUSE INSTITUTE US, INC. (PHIUS). RETRIEVED FROM: http://www.phius.org/home-page

GREEN ADVANTAGE. RETRIEVED FROM: https://www.greenadvantage.org/

NATIONAL ASSOCIATION OF HOME BUILDERS (NAHB). RETRIEVED FROM: https://www.nahb.org/

NOTES

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Second Edition, August 2017

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