Towards the implementation of the Green Building concept in agricultural buildings: a literature review

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Abstract: The "Green Building" is an interdisciplinary theme, where the green building concept includes a multitude of elements, components and procedures which diverge to several subtopics that intertwined to form the green building concept. Generally, the green building is considered to be an environmental component, as the green building materials are manufactured from local eco-sources, i.e. environmentally friendly materials, which are then used to make an eco-construction subject to an eco-design that provides a healthy habitat built on the cultural and architectural heritage in construction while ensuring conservation of natural resources. This ensures disassembling the building components and materials, after a determined building lifetime, to environmentally friendly materials that can be either re-used or recycled. During their lifecycle, the green buildings minimize the use of resources (energy and water); reduce the harmful impact on the ecology, and provide better indoor environment. Green buildings afford a high level of environmental, economic, and engineering performance. These include energy efficiency and conservation, improved indoor air quality, resource and material efficiency, and occupant's health and productivity. This study focuses on defining green buildings and elaborating their interaction with the environment, energy, and indoor air quality and ventilation. Furthermore, the present study investigates the green building materials (e.g. biocement, eco-cement and green concrete), green designs, green roofs, and green technologies. Additionally, the present study highlights the green buildings rating systems, the economics of green buildings, and the challenges that face the implementation. Eventually, the interdependency between the green buildings and agriculture has been discussed.

Keywords: green building, agricultural buildings, biocement, eco-cement, green concrete, green roofs, low-energy building, zero-carbon building, eco-construction

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1 Introduction

The Intergovernmental Panel on Climate Change (IPCC) claimed that greenhouse gases generate impact large enough to change global climate. Some industries are beginning to reduce carbon emissions from their designs and manufacturing processes in order to comply with IPCC recommendations around the world. The construction industry generates the greatest environmental impacts among all the other industries. Green building designs and standards are developed to improve building operation energy and embodied energy efficiencies, and minimize energy and wastes (Kwok et al., 2011). Green building practices can play a key role in achieving sustainability in the construction industry (Chatterjee, 2009). Therefore, over the last two decades the construction industry has made efforts to develop green building practices (Gluch, 2006). Green buildings are about resource efficiency, lifecycle effects, and building performance. Smart buildings, whose core is integrated building technology systems, are about construction and operational efficiencies and enhanced management and occupant functions. There are several commonalities between integrating building's technology systems and constructing a sustainable or "green" building (Sinopoli, 2008).

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Many factors are promoting the rapid development of green buildings, including the increasingly serious environmental problems, the constant improvement of demands on architectural environment's quality, the introduction and development of a variety of green building technologies, the successive implementation of accompanying "green building evaluation criteria" and other relevant policies and regulations. All is well known, green building's design is the premise and necessary conditions of green building development, which is itself a concept of sustainable development, and it emphasizes the adaptation to local conditions, times and issues (Zhang et al., 2011).

Unfortunately, the implementation of green building concept in agricultural buildings (e.g. livestock barns, greenhouses, forage storages,etc.) are still limited. Some studies implemented similar approaches to that adopted by green buildings, but they neither fully addressed the concept of green buildings nor achieved its core. Therefore, this study aims at introducing the green buildings -into agriculture- and their properties as well as the different environmental, economic, and engineering aspects. Eventually, this study discusses the possibilities of coupling both green building and agriculture.

2 Definition of green building

The terms 'sustainable architecture', 'green building' and 'ecological design' have emerged, along with a host of similar permutations, in recent practice as environmentally friendly modes of design, construction and operation geared towards producing healthy enduring communities. However, the terms are still vague and lead to much ambiguity in their implementation (Zachariah et al., 2002).

Chatterjee (2009) defined the "green building practice" as a process to create buildings and infrastructure in such a way that minimize the use of resources, reduce harmful effects on the ecology, and create better environments for occupants. Green buildings exhibit a high level of environmental, economic, and engineering performance. These include energy efficiency and conservation, improved indoor air quality, resource and material efficiency, and occupant's health and productivity. Kamana and Escultura (2011) defined "sustainable building" or "green building" as an outcome of a design which focuses on increasing the efficiency of resource use - energy, water, and materials - while reducing building impacts on human health and the environment during the building's lifecycle, through better location, design, construction, operation, maintenance, and removal. Pan et al. (2011) added that a green building is an outcome of a design philosophy which focuses on increasing the efficiency of resource use. Deuble and de Dear (2012) stated that green buildings, often defined as those featuring natural ventilation capabilities, i.e. low-energy or free-running buildings, are now at the forefront of building research and climate change mitigation scenarios. Table 1 presents a comparison between "green buildings" and "non-green buildings" or "traditional buildings".

Table 1 Comparison between "green buildings" and "non-green buildings"

Building Type	Green Buildings	Non-Green Buildings
Energy Consumption	Low	High
Indoor Environment Quality	Very Good	Good
Emissions	Low	High
Waste Management	Highly Efficient	Efficient
Building Materials	Environmentally Friendly	Not Environmentally Friendly
Project Practices	Sophisticated	Normal
Feasibility	>5% than Threshold	Threshold

There is deference between "green building" and "eco-construction", where the concept of eco-construction is a part of the whole concept of green building. The charter of the network for the development and use of natural resources in local construction of the Mediterranean Cluster on Eco-construction and Sustainable Development defined the "eco-construction" as a holistic and integrated approach that aims to support access to a healthy habitat, primarily in rural areas, while ensuring conservation of natural resources and to build on the cultural and architectural heritage in construction. The eco-innovation in construction leads to the marketing of products, providing services and innovative solutions which include bioclimatic architecture, and enhancing use of local natural resource and highlight the skills of man and enterprise.

3 Green building and environment

"Sustainable Development" is a necessary condition for continuation of the earth; "Healthy and Comfortable" is a necessary condition for the continuation of life. Additionally, we are facing serious energy and natural resource shortage, where global climate change is the problem cannot be ignored (Hsieh et al., 2011). Green building concept has been adopted by many nations as the best way forward in preserving our resources and sustaining our environment (Al-Kaabi et al., 2009). This is about how to minimize environmental degradation caused by building practices and to learn how to deliver Planet Earth to the next generation so that it will be a cleaner and more energizing place than the planet we inherited (Kamana and Escultura, 2011).

Building sector is the largest source of greenhouse gas emissions around the globe (Wu and Low, 2010), e.g. the energy used for heating the building, lighting, operating devices etc. Therefore, being green or sustainable is one pressing issue coming from both internal and external drivers for construction and engineering companies. Accordingly, green building has experienced rapid growth in the past several years (Wu and Low, 2010). Environmental indicators for buildings have the potential to serve as a means of making the environmental impacts (and possibly benefits) of buildings visible to all relevant factors. In addition, indicators facilitate the consideration and management of an array of environmental issues in the relevant decision-making situations. The broad acceptance of indicators across different groups of decision-makers in different phases of a building's life cycle is especially important when indicators are not mandatory, but are to be used in voluntary bottom-up initiatives (Dammann and Elle, 2006). Assessing the environmental impacts of buildings is inherently an interdisciplinary issue. The concept of ecological capacity extends into an architectural context, and is developed as a time and area dependent tool to evaluate the effectiveness of environmental building design. By basing the measure of building impacts on the ecological capacity of a site, a common language between architectural and ecological disciplines can be found as well as useful analyses for establishing sustainability parameters can be generated. This method offers the additional benefit of generating environmental design criteria that can reduce the environmental impacts of construction. The use of ecosystems services criteria is a simple and effective method for objectively assessing the ecological impacts of a building. The overall size of the impact is measurable, as well as the ecological efficiency of the building (Olgyay and Herdt, 2004).

The changing environmental effects have an impact on building behavior and performance. Typical areas affected are energy use and emissions, inefficiency and malfunction caused by systems confronted with a shift in operation conditions, and problems caused by overloading. Furthermore the environmental effects might cause issues, like failures in the electrical grid, which can cause problems for buildings that in themselves are functioning properly (Editorial, 2012). The impact of climate change on buildings is deeply intertwined with consequences for the building occupants and key processes that take place in those buildings. As buildings have different functions, climate change impact assessment studies must be tailored towards the specific needs and requirements at hand. Complex interactions exist for instance between the comfort as experienced by occupants, control settings in the building, and energy consumption of heating and cooling systems (Nicol and Humphreys, 2002).

For the building sector, numerous energy-efficiency market changes and benchmarking resolutions, like the mandatory E.U. "nearly Net-Zero-Energy-Building (NET-ZEB's) 2018 and 2020 regulations" for all new buildings are now set up to help minimizing carbon emissions and reverse the negative impact (Spiegelhalter, 2012). In order to accommodate the global climate change, the idea of constructing zero-carbon green buildings has become the main stream and highest standard in building design in many countries. The energy consumption in the buildings can be reduced up to 70% by using three major design strategies: selection of a low air conditioning load location, using high energy efficient appliances, and application of energy conserving habits. Followed by renewable energy evaluation, it is possible to put zero-carbon green building into practice (Chang et al., 2011b).

Xing et al. (2011) stated that buildings account for almost half of energy consumptions in European countries and energy demand in building continues to grow worldwide. Fossil fuels are finite reserves. Impacts of peak oil will be perceived soon or later in the next decades. The scale of the challenge in reducing fossil fuel dependency in the built environment is vast and will require a dramatic increase in skills and awareness amongst the construction professions. Building refurbishment towards zero-carbon is established itself as one critical aspect to decouple from fossil fuels and tackle with future energy crisis. However, it is a very complex phenomenon cuts across disciplines. Xing et al. (2011) categorized a range of technologies for building refurbishment in a sequential manner. They presented a hierarchical process with embedded techniques (insulations, energy efficient equipment and micro-generation) as a pathway towards zero-carbon building refurbishment.

Terlizzese and Zanchini (2011) investigated two zero carbon plants, where the first is composed of air-to-water heat pumps for space heating and cooling, PV solar collectors, air dehumidifiers, thermal solar collectors and wood pellet boiler; in the second, the air-to-water heat pumps were replaced by ground-coupled heat pumps. The conventional plant was composed of a condensing gas boiler, single-apartment air to air heat pumps, and thermal solar collectors. The economic analysis showed that both zero carbon plants are feasible, and that the air-to-air heat pumps yield a shorter payback time. The exergy analysis confirmed the feasibility of both plants, and showed that the ground coupled heat pumps yield a higher exergy saving.

4 Energy and green buildings

Green buildings are designed to save energy costs by reducing the energy consumption. Traditional buildings consume more of the energy resources than necessary and generate a variety of emissions and waste. The solution to overcome these problems will be to build them green and smart. One of the significant components in the concept of smart green buildings is using renewable energy. Solar energy and wind energy are intermittent sources of energy, so these sources have to be combined with other sources of energy or storage devices. While batteries and/or super capacitors are an ideal choice for short-term energy storage, regenerative hydrogen-oxygen fuel cells are a promising candidate for long-term energy storage. A green building energy system should consist of renewable energy, energy storage and energy management, where the variety of energy source and storage devices can be managed very well (Jiang and Rahimi-Eichi, 2009).

4.1 Low-energy building

The Kyoto protocol committed the developed countries to reduce the greenhouse gas emissions at least by 5% by 2008–2012 to tackle global warming and climate change. Some of the measures of the governments to achieve this goal are to promote new building constructions and to retrofit existing buildings while satisfying low energy criteria. This means improving energy efficiency of buildings and energy systems, developing sustainable building concepts and promoting renewable energy sources. The design of a low energy building requires parametric studies via simulation tools to optimize the design of the building envelope and HVAC systems. These studies are often complex and time consuming due to a large number of parameters to consider. Chlela et al. (2009) developed a methodology that simplifies parametrical studies during the design process of a low energy building. The methodology is based on the Design of Experiments (DOE) method which is a statistical method widely used in industry to perform parametric studies that reduces the required number of experiments. Blackhurst et al. (2011) stated that costs and benefits of building energy efficiency are estimated as means of reducing greenhouse gas emissions.

Building designers are often limited in their ability to reduce the environmental impact of buildings, due to a lack of information on the environmental performance of building components as well as inconsistencies in the way in which this information is derived. Whilst numerous tools exist to help facilitate the low-energy building design process, these typically require large investments of time and money that are often beyond those available within any particular project. Therefore, Crawford et al. (2011) developed a comprehensive model for streamlining low-energy building design to reduce building life cycle energy consumption. Building assemblies are ranked based on an assessment of the life cycle energy requirements associated with their use within a building. This facilitates early stage assessment, negating the need for a resolved design before the relative energy requirements of alternate design solutions are known. They presented a sensitivity analysis of variations to the floor area, shape and orientation of the model, to test the reliability and applicability of the ranking approach across a broad range of circumstances. They found that these variations did not influence the ranked order of the assemblies in terms of their life cycle energy requirements. Thus, the ranking of assemblies appears to provide an appropriate approach for streamlining the selection of construction elements during the building design process. Mahdavi and Doppelbauer (2010) compared the performance of passive buildings with the performance of low-energy buildings. They found that passive buildings use significantly less heating energy and offer slightly better indoor conditions. Thereby, the required additional expenditure of resources and environmental impact (CO_2 emissions) are offset in a rather short period. Moreover, the required additional construction cost does not appear to be either excessive or prohibitive.

4.2 Net zero energy building

Sartori et al. (2012) stated that the term Net ZEB (Net Zero Energy Building) indicates a building connected to the energy grids. It is recognized that the sole satisfaction of an annual balance is not sufficient to fully characterize Net ZEBs and the interaction between buildings and energy grids need to be addressed. It is also recognized that different definitions are possible, in accordance with a country’s political targets and specific conditions. Additionally, they presented a consistent framework for setting Net ZEB definitions. Evaluation of the criteria in the definition framework and selection of the related options becomes a methodology to set Net ZEB definitions in a systematic way. The balance concept is central in the definition framework and two major types of balance were identified, namely the import/export balance and the load/generation balance.

The concept of Net ZEB encompasses two options of supplying renewable energy, which can offset energy use of a building, in particular on-site or off-site renewable energy supply. Currently, the on-site options are much more popular than the off-site; however, taking into consideration the limited area of roof and/or façade, the weather conditions, the growing interest and number of wind turbine co-ops, the off-site renewable energy supply options could become a meaningful solution for reaching ‘zero’ energy goal in the general context. Marszal et al. (2012) have deployed the life cycle cost analysis and took private economy perspective to investigate the life cycle cost of different renewable energy supply options, and to identify the cost-optimal combination between energy efficiency and renewable energy generation. Their analysis includes five technologies, i.e., two on-site options: (1) photovoltaic, (2) micro combined heat and power, and three off-site options: (1) off-site windmill, (2) share of a windmill farm and (3) purchase of green energy from the 100% renewable utility grid. The results indicated that in case of the on-site renewable supply options, the energy efficiency should be the first priority in order to design a cost-optimal Net ZEB. However, the results are opposite for the off-site renewable supply options, and thus it is more cost-effective to invest in renewable energy technologies than in energy efficiency.

4.3 Passive Building

Building energy efficiency can be improved by implementing either active or passive energy efficient strategies. Improvements to heating, ventilation and air conditioning (HVAC) systems, electrical lighting, etc. can be categorized as active strategies, whereas, improvements to building envelope elements can be classified under passive strategies. A building envelope is what separates the indoor and outdoor environments of a building. It is the key factor that determines the quality and controls the indoor conditions irrespective of transient outdoor conditions. Various components such as walls, fenestration, roof, foundation, thermal insulation, thermal mass, external shading devices etc. make up this important part of any building (Sadineni et al., 2011). Aksoy and Inalli (2006) added that passive design parameters include building shape and orientation. Badescu and Sicre (2003) stated that a passive house description uses a three-temperature zone approach. The structure and physical properties of both high and low thermal inertia components of building's thermal envelope should be considered.

Recent years have seen a renewed interest in environmental-friendly passive building energy efficiency strategies. They are being envisioned as a viable solution to the problems of energy crisis and environmental pollution (Sadineni et al., 2011).

5 Indoor air quality and ventilation of green buildings

Buildings and their related activities are responsible for a large portion of the consumed energy. It is therefore worthwhile to investigate methods for improving the energy efficiency of buildings. A hybrid ventilation system which employs both natural and mechanical ventilation can be used for the buildings even in severe climates. On the other hand, natural ventilation for the buildings is viable in the mid-seasons. The hybrid ventilation system is a feasible, low energy approach for building design, even in sub-tropical climates (Ji et al., 2009).

Khaleghi et al. (2011) concluded that, in general, mechanical ventilation can provide better indoor air-quality, but noise is an issue if the system is not properly designed. The results suggest that the acceptability of environmental factors in buildings depends on the degree of compliance of the design and its implementation with standards and design guidelines (i.e. for ventilation, air quality, thermal comfort, etc.), whether the original design concept is 'green' or non-'green'.

Gou et al. (2012) stated that green buildings can have a more significant impact on their occupant health and productivity through improving indoor environment quality (IEQ). However, post-occupancy studies invariably pointed out that green buildings were not always more comfortable and productive than non-green buildings. They presented a comparison study between three buildings (two green buildings and one non-green building) aiming to examine the actual performance of green buildings from occupant point of view. The two green buildings marked a higher satisfaction on the health and productivity perception. However, in-depth examinations on IEQs showed some weaknesses in the two green buildings. On the comfort and satisfaction with the indoor air and temperature, the two green buildings performed better in summer but worse in winter.

Indoor air quality (gaseous concentrations, temperature, humidity…etc.) and ventilation of green buildings and airflow, controlling natural light (building orientation; design, materials and area of windows) are very important for air quality and thermal comfort inside green buildings.

6 Construction of green buildings

Using less materials, modular design for deconstruction, long life structure, using recoverable materials are emerging concepts to reduce environmental impacts and increase the resource and economic efficiency of buildings (Aye and Hes, 2012).

6.1 Green building materials

The green building movement emerged to mitigate these effects and to improve the building construction process. This paradigm shift should bring significant environmental, economic, financial, and social benefits. However, to realize such benefits, efforts are required not only in the selection of appropriate technologies but also in the choice of proper materials. Selecting inappropriate materials can be expensive, but more importantly, it may preclude the achievement of the desired environmental goals. In order to help decision-makers with the selection of the right materials, a mixed integer optimization model that incorporates design and budget constraints while maximizing the number of credits reached under the Leadership in Energy and Environmental Design (LEED) rating system was proposed by Castro-Lacouture et al. (2009). There are different criteria that are applied to select materials to be used in green buildings. These criteria include materials made of recycled and recovered agro-industrial wastes and materials that reduce the quantity used without adversely affecting the durability, it is also important that the used materials can be recycled. Life cycle assessment (LCA) and green building regulations also play a key role in evaluating building materials and maintaining sustainability in the industry (Chatterjee, 2009).

Fulfilling the requirements of ecological, recycling, healthy, and high-performance attributes, the green building material may effectively reduce environmental impacts and improve the indoor environmental quality (IEQ), so as to gradually achieve health and global sustainability. Green Building Material (GBM) evaluation system incorporates low toxicity, minimal emissions, low-VOC, recycled content, resource efficiency, recyclable and reusable materials, energy efficiency, water conservation, indoor air quality (IAQ) improvement, and use of locally products among others. The criteria are systematically comprised of four categories, including Ecology, Health, High-Performance and Recycling. The GBM can typically contribute to a sustainable environment. Starting from energy saving and resource efficiency by combining an ecological circulatory system, corresponding local environment, community civilization, as well as historic and regional features, the GBM creates a core concept of sustainable built environment (Hsieh et al., 2011).

While the market for "green" building materials has been expanding rapidly, the susceptibility of these materials to fungal growth is not well understood. Increasing spore levels and the presence of external nutrients promote the growth of fungi on the surface of drywall, conventional ceiling tile, and gypsum wallboard. A strong correlation exists between the equilibrium moisture content (EMC) of organic-based materials and the time until 50% of the total surface area of a material is covered by fungi (T50%). Fungal growth rates on the top, back, and side surfaces of coated or composite green building materials are quite different. The presence of organic matter in a given building material and its EMC are more important predictors of fungal susceptibility than is the label of "green" or "non-green" (Hoang et al., 2010). Table 2 presents the characteristics of some green building materials.

Table 2 Characteristics of some green building materials

Material	Source	Recyclability	Natural Cycle	Reference
Biocement	Organic	Recyclable	Included	Hosseini et al. (2011)
Eco-cement	Organic	Recyclable	Included	Yen et al. (2011)
Green Concrete	Organic /Inorganic	Recyclable	Included with limitations	Kevern (2010)
Reed Mats	Organic	Recyclable	Included	Samer et al. (2012a)
Straw Mats	Organic	Recyclable	Included	Samer et al. (2012a)
Steel Sections	Inorganic	Recyclable	Not Included	Samer (2008)
Glass	Inorganic	Recyclable	Not Included	Hatem (1993)

6.2 Biocement, eco-cement and green concrete

Hosseini et al. (2011) mentioned that the cement industry produces about 5% of the global anthropogenic carbon dioxide (CO_2) emissions. Global demand for cement is forecast to grow by 4.7% annually, which will increase CO_2 emissions. Damtoft et al. (2008) argued that the cement and concrete industry should contribute positively to the climate change initiative by:

1) Continuously reducing the CO_2 emission from cement production by increased use of bio-fuels and alternative raw materials as well as introducing modified low-energy clinker types and cements with reduced clinker content.

2) Developing concrete compositions with the lowest possible environmental impact by selecting the cement type, the type and dosage of supplementary cementitious materials and the concrete quality to best suit the use in question.

3) Exploiting the potential of concrete recycling.

4) Exploiting the thermal mass of concrete to create energy-optimized solutions for heating and cooling residential and office buildings.

One way to mitigate the CO_2 generated during cement manufacturing is to use biocement. Biocement is a blend of bio-silica, produced from combustion of organic residues, with Portland cement. Biocement requires less energy intensive clinker, with its related carbon emission, to produce a good cementing agent. Small scale biocement production in tropical areas has shown that blending cement with bio-silica can have environmental, economic and technical benefits. It is also found that a number of crops grown in temperate regions with high silicon concentration and calorific content have the potential to make biocement. In addition, the combustion process can be integrated into energy production to simultaneously gain the energy and the bio-silica ash. The switch grass, barley, oat and sunflower produce silicon-rich residues and could be good candidates to consider for both energy and biocement production (Hosseini et al., 2011). Biocement could be a new green building-material and energy-saving material. Biocement is a mixture of enzymes or microbial biomass with inorganic chemicals, which can be produced from cheap raw materials. Supply of biocementing solution to the porous soil or mixing of dry biocement with clayey soil initiates biocementation of soil due to specific enzymatic activity. Different microorganisms and enzymes can be used for production of biocement (Jian et al., 2011).

Yen et al. (2011) used marble sludge, sewage sludge, drinking water treatment plant sludge, and basic oxygen furnace sludge as replacements for limestone, sand, clay, and iron slag, respectively, as the raw materials for the production of cement in order to produce eco-cement. They found that it is feasible to use marble sludge to replace up to 50% of the limestone and also that other materials can serve as total replacements for the raw materials typically used in the production of cement. The major components of Portland cement were all found in eco-cement clinkers. The eco-cement was confirmed to produce calcium hydroxide and calcium silicate hydrates during the hydration process, increasing densification with the curing age.

Flax stems are often considered waste material. However, since flax fiber has superior mechanical properties amongst natural fibers, it can be used as reinforcement in cementitious composites. Durability of flax, however, is endangered in alkaline environments by the deterioration of alkali-sensitive pectin and hemicellulose. Cottonization of flax divides the technical fiber into bundles of elementary fibers and partially removes the alkali-sensitive pectin and hemicellulose. Cottonization of flax enhanced the modulus of elasticity, the peak stress and the strength at first crack formation of cementitious materials, in comparison to technical flax fibers. Cracks narrower than 30 mm can be healed completely and crack widths between 30 mm and 150 mm can only be partly healed (Snoeck and De Belie, 2012).

Kevern (2010) mentioned that as green building rating systems such as LEED™ become more popular, the use of recycled materials in construction is increasing. Concrete can be produced with significant quantities of supplementary cementitious materials or recycled aggregate materials. However, modifying concrete mixture proportions for improved recycled content credits also impacts strength and long-term durability. Without properly understanding the effects recycled materials have on concrete, greener concrete can be less desirable from a lifecycle perspective from poor durability. Kevern (2010) investigated the impacts of different types and quantities of supplementary cementitious materials and recycled concrete aggregate on strength development and concrete durability, specifically deicer scaling. Improvements to deicer scaling resistance were investigated using a novel soybean oil sealer. The concrete mixtures were also evaluated within the LEED™ recycled materials criteria for selection based on economy and total contribution value.

6.3 Green roofs

Green roofs are a passive cooling technique that stops incoming solar radiation from reaching the building structure below. Many studies have been conducted over the past 10 years to consider the potential building energy benefits of green roofs and shown that they can offer benefits in winter heating reduction as well as summer cooling. Older buildings with poor existing insulation are deemed to benefit most from a green roof as current building regulations require such high levels of insulation that green roofs are seen to hardly affect annual building energy consumption. The case for retrofitting existing buildings is found to have strong potential for green roof retrofit (Castleton et al., 2010). Green roofs have a positive effect on the energy performance of buildings, providing a cooling effect in summer, along with a more efficient harnessing of the solar radiation due to the reflective properties found inside the foliage. The use of vegetation in the roof building improves not only thermal comfort conditions, but the energy performance of a building (Ouldboukhitine, 2011). Green roof could directly weaken the heat effect and greenhouse gases (use of CO_2 in photosynthesis). The temperature of roof inner surface is reduced, and indoor thermal comfort is effectively improved. The energy consumption in green roof buildings is not too great, but accommodation quality is very satisfactory. Green roof is one of effectively technical measures of developing low-carbon building (Cai et al., 2011). In the summer, the fluctuation amplitude of the roof slab temperature was found to be reduced by 3℃ due to the green roof. The roof passive cooling effect was three times more efficient with the green roof (Jaffal et al., 2012). In the winter, the green roof reduced roof heat losses during cold days; however, it increased these losses during sunny days. With a green roof, the summer indoor air temperature was decreased by 2℃, and the annual energy demand was reduced by 6%. Green roofs are thermally beneficial for hot, temperate and cold climates, i.e. for all climates (Jaffal et al., 2012).

Most water conservation and energy saving strategies for buildings have higher initial capital investment than traditional ones. Yet, the added benefits of these "green" building strategies should outweigh the increase of initial capital cost at the end of the house lifetime. Using green roof systems to cool houses gives rise to uncertainties from local precipitation patterns and the unstable market related costs and benefits (Chang et al., 2011a).

Sutton et al. (2012) mentioned that native prairie species have been both promoted and questioned in their ability to serve as vegetative covers for green roofs. The green roof environment with its exposure to intense sun and wind and limited moisture restricts the capacity for a large diversity of species. The result has been, in many cases, a standard; low-diversity mix of *Sedum* species often focused on ornament and minimizes the potential for wider environmental benefits. They reviewed the ecological literature on prairie and grassland communities with specific reference to habitat templates from stressed environmental conditions and examined analogs of prairie-based vegetation on twenty-one existing green roofs. They found that many, but not all prairie and grassland species will survive and thrive on green roofs, especially when irrigated as needed or given adequate growing medium depth. They raised several important questions about media, irrigation, temperature, biodiversity and their interactions requiring more study.

6.4 Green design strategies

Green Building helps to support a broader Sustainable Development agenda. If Sustainable Development goals are to be truly reached, it can be argued that buildings should consume no energy, water or materials, and should produce no emissions, noise or waste over their lifespan. While this is an interesting concept, it is likely that work towards more modest goals during the next 20 years has to be done. Even at a more realistic level, there is global interest in improving the performance of buildings. Governments want to reduce the use of scarce resources and airborne emissions, owners want to reduce operating costs, and developers are finding that customers are demanding higher quality and performance (Larsson, 2004).

Simulation-based optimization can assist green building design by overcoming the drawbacks of trial-and-error with simulation alone. Wang et al. (2005) developed an object-oriented framework that addresses many particular characteristics of green building design optimization problems such as hierarchical variables and the coupling with simulation programs. The framework facilitates the reuse of code and can be easily adapted to solve other similar optimization problems. Variable types supported include continuous variables, discrete variables, and structured variables, which act as switches to control a number of sub-level variables. The framework implements genetic algorithms to solve (1) unconstrained and constrained single objective optimization problems, and (2) unconstrained multi-objective optimization problems.

The greatest ability to influence the building process is found in green design. The five green design strategies identified are design for materials, design for recycling, design for efficiency, design for energy, and design for adaptability. The work operates at the interface of green building and sustainable building (Anderson and Silman, 2009). The green buildings design includes four main factors: natural factor, technical factor, social factor and economic factor. The realization of green building must take into account the specific characteristics of the definite period of time and the particular region, and must seek the strategies of green building's localization that are very well suited for self-development. Those strategies are as follows: the adaptation to local environment; the use of local technology; the choice of local materials; the heritage of local culture. In short, the development targets of green building are: focusing on tradition, keeping pace with the times, taking root in the local community and looking forward to the future (Zhang et al., 2011).

High-performance green buildings require close integration of building systems with a special focus on energy, day-lighting, and material analysis during their design processes. Design process modeling and use of visualization tools can facilitate better communication and collaboration between team members; hence better integration in the design process. A process modeling approach of key decisions, consultants, and virtual prototypes of the building should be used during the design development stages. Through the experience, process modeling and visualization tools were found to be useful mechanisms to achieve high performance design goals and minimize design process waste (Korkmaz et al., 2010).

The processes and features included in green design and construction may have positive and/or negative impacts on construction worker safety and health (Rajendran et al., 2009). According to the methods of reducing energy use in buildings and the latest experience of building technology, the trends have shown that building design should largely use renewable and recyclable materials (Sun et al., 2011).

6.5 Project management and decision-making

Pan et al. (2011) developed a conceptual model in simulating the risk behaviors of decision makers in influencing the decision making of selecting green building designs by using 3 different processes including benefit-cost analysis, multi-criteria decision-making, and Nash equilibrium game. The proposed approach allows the project owner and the consultant to assess the green building cost and effectiveness of performance for different design alternatives during the early design stage. They considered a two-person nonzero sum game to model the interactions between both players with respect to their different utilities and different risk behaviors.

Wu and Low (2010) stated that project management adopted in green building construction involves both the practice and the process. Although the practice -mainly represented through the project management body of knowledge- is currently the focus of green building construction, the importance of the process, such as managing people, organizational structure, building commissioning, performance documentation, and so on, cannot be neglected, as can be seen from the evolution of the green rating systems. It is recommended that the construction and engineering companies take project management in terms of both the process and the practice into consideration when fulfilling requirements of being green.

6.6 Training the staff

As knowledge of the built environment’s impact on resource and energy use increases, industry leaders are moving toward a healthier, more sustainable solution by building green. Though green buildings have the ability to improve occupant health and productivity, it is not clear what impact the behaviors of building occupants have on the building. New systems and technologies in green buildings require building occupants to think and operate differently in their new green environment, otherwise risking not fully gaining the benefits of the new facility. The new behaviors necessary to the success of the green building are not necessarily obvious or trivial. They cannot simply be learned on-the-job; rather the transformation will require formal education. It likely requires changing attitudes and beliefs in addition to building a robust understanding of new procedures such as changing the willingness of the staff to use new energy-efficient behaviors not followed in the conventional building. The knowledge of green building standards and the impact of energy saving behaviors are the information necessary to increase willingness to change behaviors (Steinberg et al., 2009). Occupant satisfaction levels on the post-occupancy evaluation (POE) are positively associated with environmental beliefs. Occupants with higher levels of environmental concern are more forgiving of their building, particularly those featuring aspects of green design, such as natural ventilation through operable windows. Despite their criticisms of the building's indoor environmental quality, the 'green' occupants are prepared to overlook and forgive less-than-ideal conditions more so than their 'brown' (non-green) counterparts. These results support the hypothesis that pro-environmental attitudes are closely associated with the stronger 'forgiveness factor' often observed in green buildings, but the question of causality remains moot (Deuble and de Dear, 2012).

6.7 Challenges and obstacles

Gluch (2006) stated that the project practices conflicts with the long-term principles of sustainable development and that environmental concerns have been narrowed down to a few targeted issues. Moreover, organizational structures and project practices of construction are mismatched with centrally controlled and generic environmental management practices. Additionally, the way environmental issues are dealt with in construction projects depends on their legitimization in the organization and how well interpretive and socio-cultural communication processes has created meaning and understanding for practitioners in relation to their specific situation and context. The author added that there is a need to go beyond the prevalent normative and rationalistic technological view by shifting to a perspective that integrates technical and social aspects of environmental management. To achieve green building it is necessary to take into account that individuals when acting take part in on-going processes of organizing and social practice which influence the way they act. Such a change of perspective is metaphorically illustrated by shifting the product-centered Green Building to the process-centered Building Green and thereby emphasizing the importance of not neglecting the influence of on-going processes on the outcome of construction projects.

7 Integrated technologies with green buildings

Zhai et al. (2007 and 2008) designed and constructed a solar-powered integrated energy system including heating, air-conditioning, natural ventilation and hot water supply. The system mainly contains 150 m^2 solar collector arrays, two adsorption chillers, floor radiation heating pipes, finned tube heat exchangers and a hot water storage tank of 2.5 m^3 in volume. It is used for heating in winter, cooling in summer, natural ventilation in spring and autumn, hot water supply in all the year for 460 m^2 green building area. The whole system is controlled by an industrial control computer and operates automatically. It is found that the average heating capacity is up to 25.04 kW in winter, the average refrigerating output reaches 15.31 kW in summer and the solar-enhanced natural ventilation air flow rate doubles in transitional seasons. The experimental investigation validated the practical effective operation of the adsorption cooling-based air-conditioning system. They showed that, for new buildings, solar collectors can be mounted on awnings besides roofs, on condition that solar systems become part of the general green building design. The solar-powered integrated energy system has the advantage of high utilization ratio with different functions according to different seasons. After 1 year operation, it was confirmed that the solar system contributed 70% of the total energy used for the involved space.

Ali and Al Nsairat (2009) developed a green building assessment tool (SABA Green Building Rating System) which is a computer based program that considers environmental, social and economical perspectives. Tang and Fan (2010) mentioned that the application of intelligent technology in green buildings can really help to improve people's living environment, the construction of energy-saving society and the promotion of sustainable development of construction industry.

8 Rating green buildings

Building assessment systems allow planners to examine whether buildings and developments meet sustainability goals. Although many building assessment systems appear at first to be quite similar, they have substantial differences, and could produce significantly different results when used to implement green building programs. Among the important differences are the scales at which they consider various issues, whether or not they emphasize communication, and how they prioritize and weigh concerns. While building assessment systems offer new tools to help communities meet sustainability goals, planners should consider the details of each system carefully before deciding on which to use in their communities. It would be very desirable for building assessment systems to become adaptable, so they will be more locally relevant and appropriate (Retzlaff, 2008). A number of green building rating programs and sustainable standards are playing a key role in the development and adoption of more sustainable buildings (Enright, 2008).

The US Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) green building rating program serve as an indicator of sustainability and an instrument for environmental management (Wedding and Crawford-Brown, 2008). Sustainable, or "green" rating systems, such as LEED, are leading to changes in the way owners, designers, and contractors approach the design, construction, and operation of buildings (Rajendran et al., 2009).

The most common approach for green building certifications is to rate the compliance of each green building standard through a point rating system. No green building system has yet correlated its rating to the level of "greenness" of buildings. The level of certification does not reflect corresponding reduction in environmental impact and carbon emission. One key issue is the framework to correlate green building standards with equivalent carbon emissions by, first, reviews the criteria of direct and indirect carbon emission measurement, second, identifies the focal point of carbon emission modeling, and finally, identifies the variables for carbon emission modeling of buildings (Kwok et al., 2011). Pyke et al. (2012) stated that buildings represent long-term, capital-intensive investments designed to perform for decades into the future. Consequently, the potential for changes in climate across the design lifetime of built environments represents an immediate challenge for planning, design, and construction. In their study, they considered the opportunities to assess Climate Sensitivity and adaptive opportunities associated with green building practice. They developed a pair of complementary indicators called the Climate Sensitivity Index (CSI) and Climate Adaptation Opportunity Index (CAOI). These indicators were applied to evaluate individual strategies ("credits") within the LEED for New Construction rating system. The indices provide two complementary scores for each strategy. The CSI reflects potential sensitivity to changing conditions (i.e., risks to performance outcomes), and the CAOI indicates potential adaptive opportunities (i.e., plausible strategies to adapt to changing conditions). They applied the indices to retrospectively examine the prevalence of potentially sensitive and adaptive practices among a global set of 2440 LEED-certified projects. Adaptive opportunities were more prevalent than sensitivities in the LEED-NC rating system. The CSI and CAOI indices illustrate how information can be derived by interpreting patterns of LEED credit achievement. The indices will be available within a suite of analytical tools in the Green Building Information Gateway (www.gbig.org).

The demand for developments that achieve green rating criteria continues to be strong despite the weakened economy. Many municipalities throughout the U.S. are adopting green development ordinances or policies with various environmental goals, often with an emphasis on addressing global climate change. At the same time, environmental advocates and state and federal storm water regulators are increasingly emphasizing low impact development (LID) design techniques to reduce long-term water quality impacts from new development and significant redevelopment projects, replenish groundwater resources, and provide for rainwater capture and reuse. Prickett and Bicknell (2010) paper explored opportunities for harnessing some of the momentum of the green building movement to further implementation of LID strategies in new development and redevelopment projects. They examined the extent to which LID designs can earn green building credits under LEED rating systems for new construction (LEED-NC) and neighborhood development (LEED-ND). They featured the results of a comparison of green building criteria in LEED and alternative rating systems with LID techniques that may earn green development credits. Gaps in credit availability for specific LID techniques are identified, along with opportunities to further integrate the LID approach and green building initiatives.

LEED is credited with inspiring innovation, driving demand for high performance buildings and communities, and changing the way that much of the building industry approaches design, construction, and operations. LEED's recognition of ASHRAE Standards 90.1, 62, and 55, and standards set by the California Air Resources Board and the Sheet Metal and Air-Conditioning Contractors' National Association, show its aim towards benchmarking against industry-accepted standards. The International Code Council (ICC) has launched the development of the International Green Construction Code (IGCC) in response to demands from stakeholder and communities. Widespread adoption of IGCC and its 189.1 compliance path is expected to take the building sector forward with achievements and results that are responsive to the economic, environmental, and health challenges (Owens and Sigmon, 2010).

Helgeson and Lippiatt (2009) stated that the building industry demands compelling metrics to justify sustainable building designs. This can be addressed by developing tools for assessing the life cycle economic and environmental performance of buildings. Economic performance is measured with the use of standard life cycle costing methods. Environmental performance is measured by life cycle assessment (LCA) methods that assess the "carbon footprint" of buildings, as well as 11 other sustainability metrics, including fossil fuel depletion, smog formation, water use, habitat alteration, indoor air quality, and effects on human health. Carbon efficiency ratios and other eco-efficiency metrics are established to yield science-based measures of the relative worth, or "business cases" for green buildings. Generally, the assessment should focus on different heating, ventilation, air conditioning technology and energy efficiency. Tatari and Kucukvar (2011) stated that built environment has a substantial impact on the economy, society, and the environment. Along with the increasing environmental consideration of the building impacts, the environmental assessment of buildings has gained substantial importance in the construction industry. They built an artificial neural network model to predict cost premium of LEED certified green buildings based on LEED categories. Sustainable Sites and Energy & Atmosphere LEED categories were found to have the highest sensitivity in cost premium prediction. They developed a decision model that can guide owners to estimate cost premiums based on sought LEED credits.

Green buildings have proven to promote public health and safety, and because of these benefits, a few states, and a few towns such as, Boston, and San Francisco have mandated buildings to have LEED Silver Certification. Such mandates will increase the growth of green buildings. The green wave is moving fast. At this time, about 5% of the buildings are green; this number is increasing mainly due to long term energy savings, and the mandates by the cities, states, and the federal government (Mohan and Loeffert, 2011).

9 Implemented research methodologies

A methodology is to consolidate the current foci of sustainable architecture through a review of several projects and institutional guidelines that are geared towards achieving sustainability in the built environment, to make a contemporary checklist of desirable design strategies and building practices for a green building, and to rank the importance of these strategies (Zachariah et al., 2002). The research methods range from theoretical discussions of the usefulness of environmental management tools and questionnaire study on environmental management in the construction industry, to text analytical studies of media's representation of green building and field studies on environmental management in construction projects (Gluch, 2006).

Retzlaff (2008) conducted a content analysis of the system documentation for several building assessment systems and interviewed the administrators of the systems. Al-Kaabi et al. (2009) outlined the roles of different engineering disciplines by which an existing building could be transformed to green. Particularly, they identified the roles of civil engineers in creating and implementing a model by which the rating of a particular building could be raised. The model focuses on calculating the extra structural loads, and introducing additional environmental friendly systems within the building. The model is then applied to an existing building to study the applicability of the suggested model and the degree to which it could raise the rating of the selected building. Two alternatives have been implemented through the design of two green buildings' components for an existing building, which are a green roof system and a gray water treatment system (Al-Kaabi et al., 2009). Another research method is that building monitoring equipment and energy models quantify building performance and enable researchers to compare it to a nominally identical traditional building baseline. Further assessment should investigate if a formal green building certification has a measurable impact on the long-term energy performance of a building (Thebault and Vlachopoulos, 2011).

Elvin (2007) stated that nanotechnology, the manipulation of matter at the molecular scale, is opening new possibilities in green building through products like solar energy collecting paints, high-insulating translucent panels, and heat absorbing windows. Even more dramatic breakthroughs are now in development such as spray-on solar collecting paint, windows that shift from transparent to opaque with the flip of a switch, and environmentally friendly biocides for preserving wood. These breakthrough materials are opening new frontiers in green building, offering unprecedented performance in energy efficiency, durability, economy and sustainability. A key issue is the energy conservation capabilities of architectural nanomaterials in green building.

10 Economics of Green Buildings

Buildings account for 40% of the greenhouse gas emissions, 70% of electric consumption, and 12% of water consumed in the United States; there is a need to change these trends, and in fact, the green building technology has proven that this is possible. Studies have shown that green buildings save approximately 30% reduction in utility bills over conventional buildings. Besides direct savings in energy costs, green buildings have the potential of lower insurance premiums, lower waste disposal charges, reduced water and sewer fees, and increased rental rates. Green buildings are designed to be environmentally healthy and energy efficient. However, their initial costs can be 1 to 5% higher than the conventional buildings. These additional initial costs are recouped in energy savings over a few years, and as the number of green buildings increases, the cost of green materials and green design will decrease, thus the initial cost of green buildings will decrease.

Chau et al. (2010) mentioned that as the number and complexities of green building developments are mainly driven by market demands, understanding of end-user behaviors towards their development eventually should play a crucial role on determining their successes. However, very few studies have been attempted to explore end-user behaviors towards green building development. They applied discrete choice experiments to reveal whether end-user with green experience will have different preference and willingness-to-pay values for enhancements on various aspects of environmental performance in green buildings. Generally, both green and conventional end-users have strong preferences and are willing to pay more for improving various aspects of environmental performance in green building developments. They are found to be willing to pay more for energy conservation, than indoor air quality improvement, noise level reduction, landscape area enlargement, or water conservation. They found no significant differences in the preferences between green and conventional end-users for energy conservation, indoor air quality improvement, indoor noise reduction, or water conservation. However, green end-users are willing to pay significantly less than the conventional end-users for enlarging the landscape area within a green building development, despite it was perceived by green end-users as one of the major elements that differentiate a green from a conventional development.

11 Green Buildings and Agriculture

In order to make the construction of green buildings cost-effective the agricultural wastes, e.g. plant residues, should be used as green building materials. This concept has been also supported by Barreca (2012) who stated that the utilization of local material in rural buildings minimizes the energy cost for its transport as well as its environmental impact, because, when the building is demolished, the material is reintroduced into the environmental system. Therefore, the green building and agriculture are interdependent. Precisely, the agricultural wastes and the biowastes (e.g. plant residues) can be used to make sustainable and recyclable green building materials (e.g., producing biocement, molding plant residues) on the one hand and green buildings provide sustainable agricultural structures on the other hand. Most of the green building materials should enter the natural cycle i.e. originate from the nature and turn back into the nature where it will break down. In order to invest this interdependence, the role of agricultural and biological engineers, in the green building context, should be defined. Another issue, no assessment and rating system for farm green buildings was found after an intensive literature review and web-based search. Therefore, an agricultural green building assessment and rating system should be developed in order to be implemented in assessing and rating the livestock barns and the greenhouses. Therefore, the role of agricultural and biological engineers –in cooperation with other disciplines can be elaborated as follows: (1) developing farm green building assessment and rating system; (2) investigating the local agricultural materials that can be used as green building materials, e.g. giant reed, straw, clay etc.; (3) manufacturing biomaterials, e.g. extracting bio-silica from plants, to be used for fabricating green building materials, e.g. biocement, eco-cement, and green concrete; (4) implementing the guidelines of green buildings when constructing new farm buildings; and (5) retrofitting old farm buildings to fulfill the green building criteria.

The studies on agricultural buildings have focused on research points that form a small part of the whole green building concept. Such studies need to be integrated together to make the baseline and the first milestone on the way to apply the green building concept in agricultural buildings. Research projects should be developed on the implementation of green buildings in agriculture. The existing livestock barns and greenhouses do not comply with the green building concept as they miss some or most of the properties that formulate the green building aspect. Hence, the implementation of the green building concept in agricultural buildings is still limited; and, therefore, should be conceptualized and initiated. Some studies implemented similar approaches to that adopted by green buildings, but they neither fully addressed the concept nor achieved its core. Several studies focused on the design of dairy farms and the construction of cowsheds (Samer et al., 2007; Samer, 2008; Samer et al., 2008a,b; Samer et al., 2013a), where some studies focused on using natural materials for roofing such as reed mats, straw mats, burnt-clay bricks, and green roofing (Hatem et al., 2009; Samer, 2010a,b,c; Samer, 2011a; Georg, 2007; Samer et al., 2012a). Additionally, Barreca (2012) investigated the use of giant reed *Arundo Donax* L. in rural constructions. Further studies investigated the interdependency and interaction between the control of indoor bioenvironment of dairy barns and the cowshed design as well as the reconstruction and renovation of old dairy barns (Samer, 2004; Hatem et al., 2004a,b; Hatem et al., 2006; Samer et al., 2008c; Bartali, 1999; Samer, 2011c; Samer, 2012a). Other studies dealt with safe manure handling systems (Burton and Turner, 2003; Samer et al., 2008d; Ghafoori and Flynn, 2007; Samer, 2010d; Godbout et al., 2003; Samer, 2011b; Samer, 2012b). Several studies carried out aerodynamic measurements and investigated different methods for estimation of ventilation rates and quantification of gaseous emissions from livestock buildings (Ngwabie et al., 2009; Snell et al., 2003; Samer et al., 2012b,c; Ikeguchi and Okushima, 2001; Samer et al., 2011a,b,c,d,e; Samer et al., 2013b). A study modeled the operating supply items, i.e. energy and water, of dairy farms without investigating the efficiency of the resource use (Samer et al., 2008e). Although several studies delivered highly promising results (Leinker, 2007; Reinhardt-Hanisch, 2008), the studies that investigate means of emissions reduction from livestock buildings still not enough to achieve almost zero-emissions, which is one of the green building features.

Von Bobrutzki et al. (2012) conducted an investigation in the frame of a feasibility study for a forced ventilated 200 dairy cow barn. As optimal living conditions for high-performance dairy cows (10,000 kg milk yr^{-1}) a constant air temperature of 10℃ and a relative air humidity of 80% were determined. Based on the approach of a simple balance model assuming ideal mixing conditions inside the barn, a ventilation concept with three different operating ranges was developed. The turned out airflow rates range between 22,000 and 100,000 $m^3 h^{-1}$ for 200 cows. In the range of an outside temperature between -6 and +5℃ the conditions inside the barn can be maintained just by controlling the airflow rate. Below or above this range, the inlet air has to be heated or cooled, respectively. In this way, it is possible to improve the ventilation management and using energy more efficiently. According to maximum NH_3 concentration limits, a minimum airflow rate of 22,000 $m^3 h^{-1}$ was determined. Up to a maximum airflow rate of 100,000 $m^3 h^{-1}$ it would be possible to keep constant conditions of 10℃ and 80% relative humidity inside the barn just by controlling the ventilation. These first results from the study show that the heat released from the cows can be used and integrated into the ventilation system. Further, the three different operating ventilation ranges enable to use energy efficiently to improve the ventilation management and create the possibility to adopt a forced ventilated barn to usual dairy cow husbandry with natural ventilation. This study constitutes a base to develop a ventilation management system that uses the energy efficiently while providing acceptable indoor air quality, where those are two of several conditions that allow to a building to be considered green. However, more conditions should be fulfilled for agricultural farm buildings to be considered green buildings.

Næss and Bøe (2011) stated that when investing in new or remodeling existing facilities for dairy cows, the functionality of the facilities and the labor input required must be considered in addition to the initial building costs. They investigated the labor input required for dairy work in different herd sizes, layouts and mechanization levels in small dairy cubicle barns. The studied layouts from 201 cubicle-stalled dairy herds with a mean herd size of 38.0±14.5 (range 17.6-80.2) cows. They found that the required labor input per cow decreased with increased herd size, up to approximately 60 cows. Barns with AMS had the same estimated labor input per cow independent of herd size. For herds with milking parlors, the estimated need for labor decreased with increasing herd size from 20 to 80 cows. The estimate of required labor input was higher for rebuilt barns up to a herd size of 39 cows. The comprehensive variation in labor input indicates that optimizing building layout, and developing good management routines and suitable mechanization levels, would considerably reduce the required amount of labor. Næss and Stokstad (2011) stated that on small dairy farms, high investment costs and lack of investment capital may delay the modernizing of facilities. They investigated the importance of economics of scale in building costs of barns compared to other sources of variation in costs. The study included 44 farms with a mean herd size of 49.5 ± 15.1 cows, built between year 1999 and 2006 and with a mean total area in the barns of 896 ± 454 m^2. Building cost data were obtained from farmers and merged with construction, mechanization and layout data from the same barns. They found that construction costs decrease up to approximately 1,250 m^2 while mechanization costs and total building costs decrease up to approximately 1,000 m^2. A further increase in building area has only limited effect on the building costs per m^2. Models including explanatory variables showed that milking and service area are significantly more expensive than other areas. AMS barns are all together not significantly more expensive than other barns, since the increased mechanization cost is offset by a lower requirement for milking area. Farmers remodeling their barns are able to realize a modernized building for a certain herd size for a lower cost compared to a completely new building. The use of their own effort varies considerably between projects. In many cases, farmers would be able to find alternative income sources with a higher hourly rate than the value of their own effort suggested by the model. The results of both studies (Næss and Bøe, 2011; Næss and Stokstad, 2011) should be considered when remodeling existing non-green farm building to green farm building taking into account the initial building costs, construction remodeling costs, labor input, mechanization level, and facility modernization.

Similar to the studies on the livestock buildings, the studies that investigated the design and indoor environment of greenhouses have not yet addressed the green building concept. For instance, the structural and functional characteristics of greenhouses reviewed by von Elsner (2000a,b) showed that the existing greenhouses do not comply with the green building concept as they missed some or most of the features that formulate the green building aspect. Vanthoor et al. (2011) developed a model-based method to design greenhouses for a broad range of climatic and economic conditions. Impron et al. (2007) developed a design tool for greenhouses in the tropics. Speetjens et al. (2010) developed a physics-based model for a water-saving greenhouse, which is a point under the main green building concept that cares about water use efficiency.

Jeong et al. (2012) stated that there is often a difficult relationship between rural buildings and the landscape. This may be overcome by methodologies that support a decision-making processes for establishing harmonious relationships and sustainable environment integrity within a unique framework. They investigated the possibility of designing and implementing a GIS-enabled web application, consisting of a general overview, a multi-criteria spatial decision support system, an interoperable knowledge map and a post-task questionnaire to identify spatial models for the different perceptions of building integration within the rural landscape and to certify the possible economic impact. This integration is one of the keys of green buildings, where a green building should be integrated with its surrounding environment by providing: (1) building design that fulfills the eco-construction criteria, (2) proper waste management which is safe to the surroundings, and (3) an implementation of the features of the surrounding landscape that allows alleviation of outdoor air before being introduced into the green buildings where high indoor air quality is anticipated. Astee and Kishnani (2010) stated that population and rapid urbanization have contributed to two challenges facing cities today: food security and an increasing carbon footprint due to food imports. They examined the viability of rooftop farming. A context-specific exploration looks at the challenges of building integrated agriculture. Their findings suggest that buildings are suitable for rooftop farming. Implemented nationwide, such a scheme could result in a huge increase in domestic vegetable production and satisfying domestic demand. Reducing food imports would also decrease carbon footprint by several tones of emissions annually, which is one of the purposes to initiate the green building concept where green roofs can be planted with vegetables.

Generally, all abovementioned studies on agricultural buildings have focused on research points that form a small part of the whole green building concepts. Such studies need to be integrated together to make the baseline and the first milestone on the way to apply green building concept in agricultural buildings. Research projects should be developed on the implementation of green buildings in agriculture.

12 Conclusions

According to the issues raised in this study, it can be concluded that:

1) The existing livestock barns and greenhouses do not comply with the green building concept as they miss some or most of the properties that formulate the green building aspect. Hence, the implementation of the green building concept in agricultural buildings is still limited; and, therefore, should be conceptualized and initiated.

2) In order to make the construction of green buildings cost-effective, the agricultural wastes, e.g. plant residues, should be used as green building materials.

3) The green building and agriculture are interdependent. Precisely, the agricultural wastes and the biowastes can be used to make sustainable and recyclable green building materials on the one hand and green buildings provide sustainable agricultural structures on the other hand.

4) An agricultural green building assessment and

rating system should be developed in order to be implemented in assessing and rating the livestock barns and the greenhouses.

5) Most of the green building materials should enter the natural cycle i.e. originate from the nature and turn back into the nature where it will break down.

6) The studies on agricultural buildings have focused on research points that form a small part of the whole green building concept. Such studies need to be integrated together to make the baseline and the first milestone on the way to apply the green building concept in agricultural buildings. Research projects should be developed on the implementation of green buildings in agriculture.

7) The role of agricultural and biological engineers can be defined as follows: (1) investigating the local agricultural materials that can be used as green building materials, e.g. giant reed, straw, clay etc.; (2) manufacturing biomaterials, e.g. extracting bio-silica from plants, to be used for fabricating green building materials, e.g. biocement, eco-cement, and green concrete; (3) developing farm green building assessment and rating system (4) implementing the guidelines of green buildings when constructing new farm buildings; and (5) retrofitting old farm buildings to fulfill the green building criteria.

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