Chapter 55
Green, Smart, Sustainable Building Aspects and Innovations

Abdul Salam Darwish

Abstract Buildings of the future should be designed with features that meet the anticipated challenges of technological, environmental, and societal progress. When increasingly sophisticated communications and control systems are integrated into a building's design, the door is opened to endless innovations; when incorporated into construction procedures, energy consumption is contained and the environment is better protected. Through smart construction, a more comfortable built environment can be created while simultaneously reducing a site's carbon footprint. Green building melds technology and living practices to modify water efficiency and increase energy efficiency. The use of eco-friendly materials and innovative procedures will result in optimized energy performance, extra commissioning measurements and verification, and continual carbon dioxide monitoring. This is essential as LEED and BREEAM schemes are expected to become future requirements of any construction project, large or small. Self-sustaining buildings will be the best solution for meeting the ever-growing technological demand on energy, as well as many countries' stated goals of independence from carbon-based energy sources.

Keywords Green buildings • Smart buildings • Sustainable buildings • Energy efficiency buildings • Building design

1 Introduction

Green building, a term used all over the world, has become synonymous with sustainability. This common connection, however, does not mean that all green building is, in fact, sustainable. Green building is a very important step toward sustainable building and is defined as the practical application of sustainable methods that takes into account not only the building site's environmental conditions but also strives to make the best use of resources throughout the building's phases. These phases include site selection, design, construction, operation,

A.S. Darwish (✉)
Phoenix Renewable Energy Centre, PO Box 470, Manchester M40 0ED, UK
e-mail: darwish@renewableenergycentre.org

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maintenance, and demolition. Green building strives not only for sustainability and environmental consideration but also to meet economic needs, including comfort, style, and high performance.

Over the last several decades there has been an increasing awareness of the disparaging connection between traditional economic development and the overexploitation of the world's natural resources. Pollutants and harmful residues from land stripping and the production of building materials are putting the environment under increasing stress. After a century of postindustrial expansion, urban centers now have an acute sense of the impact continual construction wreaks [1]. According to some estimates, the worldwide construction industry consumes about 40 % of total raw materials, at a rate of about three billion tons per year. In the USA alone, buildings account for around 65 % of the total energy consumption and cause 30 % of greenhouse emissions [1]. Since built environments comprise such a large and ever-increasing portion of the world's total greenhouse emissions, and since the majority of those emissions are derived from a building's life cycle, this is obviously the area of urban development where meaningful and long-term change must immediately be implemented. This awareness, and the outcry for the reduction of the impact of human activities, the concept of sustainable development has matured and is defined as "meeting the needs of the current generation without compromising the ability of future generations to meet their own needs" [2].

Smart buildings signify intangible built-up development that utilizes all the latest technological instrumentation and inventions to facilitate modern efforts toward energy-efficient cities and Society with Energy saving awareness and Smart. Mapping out smart buildings requires strategic planning, which relies on many factors. Stakeholders (e.g., local governments, research institutions, grass-roots movements, technology vendors, and property developers) are often driven by conflicting interests [3]. To create better environmental, social, and economic conditions and enhance cities' attractiveness and competitiveness, upgrades to building infrastructures and services must be made. Smart buildings/cities are defined in a multitude of ways, and solutions to building-related issues are proposed without an existing prevalent or universally acknowledged definition of smart building [4, 5]. Many new categories of *city* have entered policy discourse: sustainable cities, green cities, digital cities, smart cities, intelligent cities, information cities, knowledge cities, resilient cities, eco cities, low-carbon cities, livable cities, and combinations thereof [6].

2 Gulf Cooperation Council Energy Situation

Gulf Cooperation Council (GCC) countries, which constitute a major portion of the wealth in the Middle East, face major energy and environmental challenges, as the continuously growing population creates a huge demand for energy. The area is experiencing a high rate of economic growth and modernization. Figure 55.1 shows the annual per capita electricity consumption [7] and demonstrates that GCC

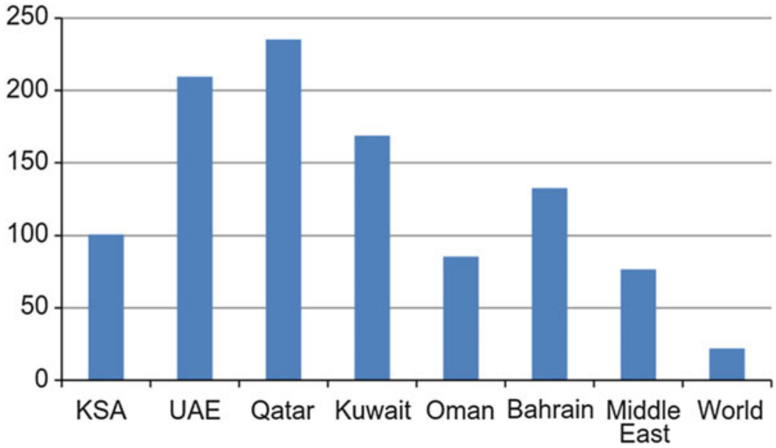

Fig. 55.1 Annual per capita electricity consumption (MW-h) [7]

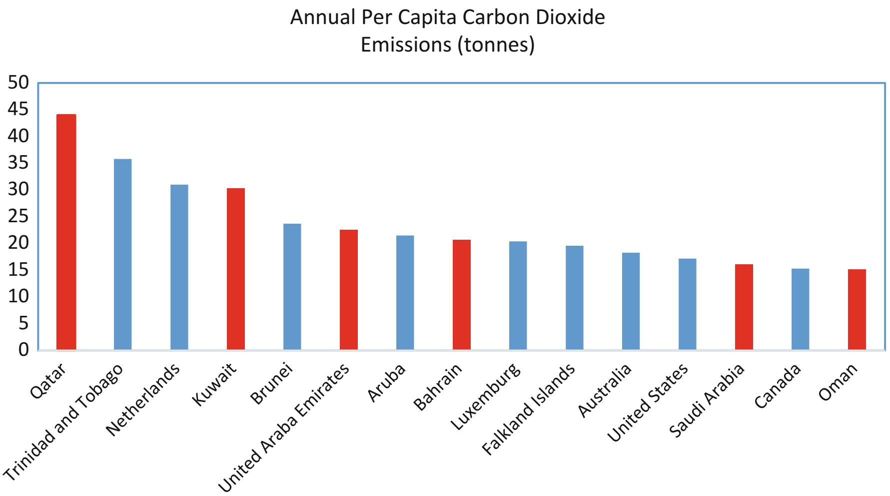

Fig. 55.2 Annual per capita carbon dioxide emissions (tons)

countries have among the highest rates of energy consumption in the world. High energy consumption means high carbon dioxide levels, and so GCC countries also have among the highest levels of CO_2 emissions. Figure 55.2 shows [7] annual per capita carbon dioxide emissions (tons). Qatar, Kuwait, and the United Arab Emirates (UAE) are among the top six countries in the world for CO_2 emissions; Qatar is the global leader.

It is clear that the environmental impact of CO_2 emissions is significant and a grave matter that could lead to future environmental disaster.

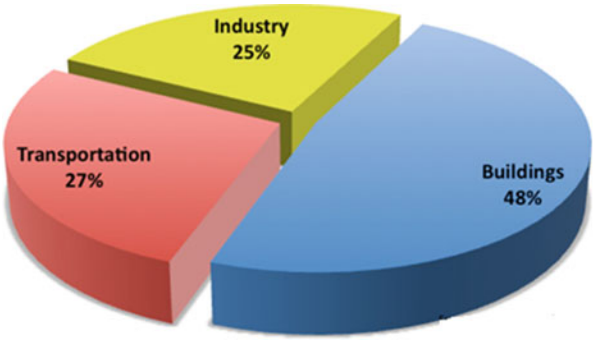

Fig. 55.3 Energy consumption sectors

Energy consumed for cooling and heating in buildings is becoming an increasingly serious cause of global warming. Buildings are responsible for 48 % of energy consumption and 45 % of CO_2 emissions within the region. Urbanization has increased the demand for cooling energy and is accelerating the formation of smog. Figure 55.3 shows sectors of energy consumption and illustrates that buildings generate the highest amount of energy consumption [8].

3 Sustainable Buildings: The Right Solution

The benefits of sustainable buildings are as follows:

- Lower life-cycle costs
- Lower insurance fees
- Higher property values
- Higher productivity
- Improved image
- Reduced risks
- Healthier for residents and visitors
- Reduced effects on infrastructure
- Better for the environment and local economy.

The best and most effective way to protect the environment is to use sustainable methods during building construction [9, 10]. It is important that all new construction strike a careful balance between economic, social, and environmental considerations.

Sustainable building innovation creates economic stability, which in turn generates high rates of economic growth and employment. These factors improve project delivery and increase profitability and productivity. Environmental sustainability protects the environment by avoiding pollution, enhancing biodiversity, and developing an eco-friendly transportation system. It also facilitates the management of natural resources by employing technology, education, and forecasting to

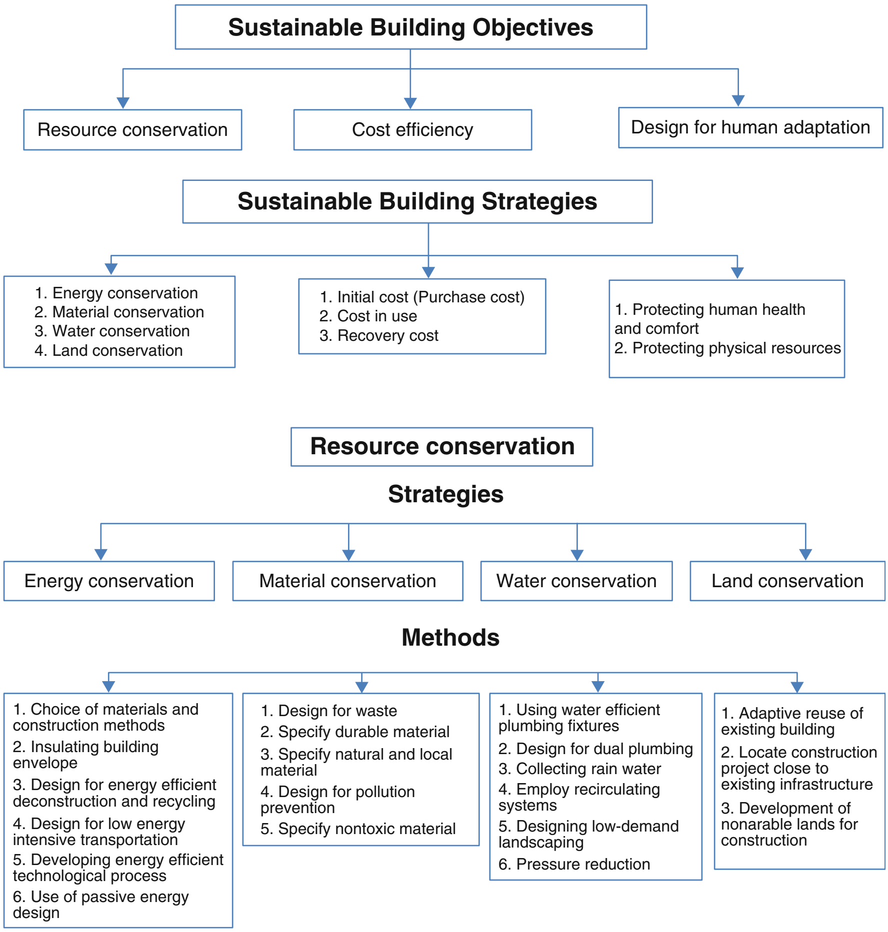

Fig. 55.4 Practical framework for sustainability implementation in building construction, strategies, and methods to achieve resource conservation [11]

improve energy efficiency and ensure the proper utilization of resources. This sustainability is achieved through a social process that recognizes the needs of everyone and creates a partnership with local communities to ensure that everyone's needs are satisfied [11] (Fig. 55.4).

4 Strategic Energy Technology Plan

A strategic energy technology plan represent the principal decision-making support tool for many countries' energy policies. It encourages the development and use of low-carbon technologies through the wide dissemination of education and information technology. It is characterized by specific targets that will be met in a set period of time or by a certain deadline [12].

Countries, both in general and particularly within the GCC area, will need to implement their strategic energy technology plans through the following initiatives:

- Wind initiative
- Solar initiative (i.e., photovoltaic and concentrated solar power)
- Electricity grid initiative
- Carbon capture initiative
- Industrial geothermal initiative
- Transport and storage initiative
- Smart cities and communities initiatives
- Fuel cells and hydrogen initiative
- Wave and tidal initiative.

5 Smart Sustainable Buildings

Smart buildings incorporate all of the latest technological instrumentation and inventions in order to achieve energy efficiency goals and long-term social sustainability. Mapping out a smart building's design requires strategic planning and depends on the actualization of multiple factors. To achieve a perfect combination, smart building construction should not only be smart but also green and intelligent in various design and operation aspects. There are three different approaches to defining intelligent buildings [13].

- Performance-based approach
- Service-based approach
- System-based approach.

The performance-based approach reflects the ways in which the building is performing according to its users' environment and demands and emphasizes the efficient use of resources in a cost-effective manner and in accordance with international standards and measures. The service-based approach considers the quality of services the buildings provide, such as, for example, intelligent functions, communications, or automation. The system-based approach refers to all of the available high-end technology that is embedded within the building's design and construction.

By implementing the right combination and management of these three approaches, an optimal composition of structure, system, service, and management will result in high-efficiency building automation, office automation, communication network systems, safety, and comfort. This combination will satisfy all regulations to fulfill the smart building philosophy (Fig. 55.5) [13].

High-performance building systems and services include the following:

- Heating, ventilation, and air conditioning (HVAC) control

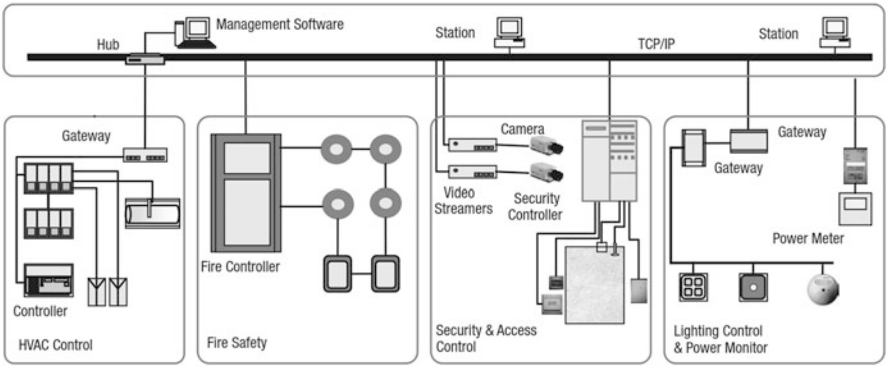

Fig. 55.5 An integrated intelligent building system [14]

- Electrical lighting
- Vertical transport control
- TV and image communications
- Voice and data communications
- Security and access control
- Data and video communications
- Fire alarm control systems
- Integrated building automation systems
- Computerized integrated systems
- Enterprise network integrated systems.

Additionally, smart buildings will need to be capable of integrating into the innovative electrical grid of smart cities so as to be able to fully utilize all potential renewable energy options. This capacity will require computerized power delivery services using the latest two-way communication and control systems for the smart grid, as well as so-called smart meters for commercial and residential buildings.

6 Energy Certification for Smart and Green Buildings

Energy performance evaluations and certifications will positively benefit from so-called intelligent technologies and facilities incorporated into the smart building [11].

- Optimize Energy Performance
  Using the building simulation package Energy Cost Budget Method, energy performance is well presented, and therefore points for assessment are earned accordingly.
- Additional Commissioning

This involves an independent commission agent; since a smart building includes the integration of all of the building's systems, the additional commissioning will meet a certification requirement.

- Measurement and Verification
  Smart metering systems and management system tools that can track actual usage and cost will provide verifications requirements for the monitoring of energy consumption and storage.
- Carbon Dioxide (CO_2) Monitoring
  Using a smart technology monitoring system, HVAC systems will be adjusted to improve indoor air quality and comfort. Zones and individual spaces will be controlled by integrated monitoring systems.
- Controllability of Systems: Perimeter and Nonperimeter Spaces
  Lighting, temperature, and ventilation of building spaces are smartly controlled, allowing credits to be awarded for perimeter and nonperimeter spaces.
- Thermal Comfort: Permanent Monitoring System
  Integrating the temperature and humidity measurement systems into HVAC control systems will automatically provide the desired comfort level. Smart technology will facilitate data collection for systems and occupants. These data will then be used for performance optimization throughout the smart building.
- Innovation in Design
  As the smart building system introduces many innovative ideas not covered by green building ratings systems, extra rating points are added and granted by the rating system [15].

7 Smart Grid's Impact on Intelligent Buildings and Connected Cities

Reasons to Incorporate a Smart Grid:

1. It is a more reliable type of grid, with fairer pricing and optimum energy use. These qualities make certain locations more attractive places in which to invest.
2. These investments will in turn bring new businesses and consumers to the locations. (This will spur economic growth and create additional customers for utilities.)
3. A generational change is under way; young graduates are very information technology (IT) literate and very aware of the benefits of IT. Their involvement will drive change.
4. A Smart grid reduces power usage at peak hours.
5. It increases grid stability and reliability.
6. It can improve efficiency for energy consumption and data management.
7. It decreases energy costs.
8. It optimizes prices.
9. It empowers customers.

8 Elements of a Smart Energy Building

- Smart lighting system
- Increased daylight appearance
- Onsite electricity generation
- DC grid for DC loads
- Load/generation balancing
- Energy management system
- Electrical and thermal energy storage/buffering
- Energy efficient practices.
  - Active/passive techniques for heating and cooling:
  - Glazing
  - Insulation
  - Shading
  - Construction materials
  - Pricing incentives
  - Low-temperature heating/high-temperature cooling systems
  - High-efficiency heat-recovery ventilation
  - Flexible workspaces (Table 55.1).

9 Building Rating System

The nature of the Middle East's extreme climate, combined with its continuous population growth, has a profound effect on its levels of energy, water, and materials consumption. The concept of smart cities has raised alternatives to traditional building methods. Coupled with green building rating systems, smart cities will lead this building evolution in a sustainable direction. The most important factors for such a rating system are that its implementation must be obligatory and that it must conform with the American LEED and British BREEAM rating systems, though be adaptable to local cultural, environmental, social, historical, and economic contexts.

Countries within the GCC region have used their own modified versions of these systems. For instance, Abu Dhabi of the UAE introduced the Estidama and Pearl Building Rating System in 2007 [16], Qatar introduced the Sustainability Assessment System in 2010 [13], Egypt introduced the Green Pyramid system in 2011, Jordan introduced the Idama system in 2009, and Lebanon introduced the ARZ Building Rating System in 2008 [17].

Table 55.1 The main control and communication systems of a smart building [14]

Control and communication systems	Technology and application
Digital controllers	• Computers
	• Microcomputers
	• Processors
	• Digital controllers
	• Actuators
Building automation systems	• Programming and monitoring
	• Building management functions with automatic processing
Local area networks (LANs)	• Wireless technology
	• LAN technologies
Building automation system communication standards	• Integration and interoperability of building automation systems (BAS)
	• Communication standards for BAS networks
	• (BACnet) building automation and control networks
	• (LonWorks) Local operating network
	• (Modbus) Serial communication protocol
	• PROFIBUS (process field bus), defined as a standard for field bus communication in automation technology
	• European installation bus (EIB), defined as a field bus designed to improve electrical installations in homes
Internet technologies	• Internet protocols
	• Internet LAN vs. wide area network (WAN)
	• Internet technologies at automation level
	• Internet technologies at management level

10 An Ongoing Case Study in the UAE

A commercial building was considered in Ajman in the UAE taking into account the climate and energy resources in the area. The aim was to create an energy self-sufficient and carbon-neutral green, sustainable, smart building with an extraordinary photovoltaic wall with vertical axis wind turbines and a zero-energy footprint with no grid support. Energy is to be generated using solar and wind technologies that are designed specifically to match the climate and weather conditions over the course of a year. A solar thermal cooling system was selected with an efficient innovative system that matches the building's air-conditioning requirements, with all old conventional systems having been removed. All principles and ideas presented in this chapter were implemented, and an integrated smart control system was designed to fulfill all green building rating requirements. More details will be published in a later report.

11 Conclusion

The Middle East, and specifically the GCC countries, faces considerable energy and environmental challenges that result from its huge energy demands. As GCC countries are able to fund projects and get involved in developing and maintaining better building designs and construction, these countries will reduce their carbon footprints while simultaneously maintaining high rates of economic growth and modernization. Combining smart technology with green buildings results in smart, sustainable, green buildings that can be integrated into smart cities.

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