Chapter 30
Green Buildings to Approach Sustainable Buildings by Integrating Wind and Solar Systems with Smart Technologies

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Introduction

Sustainable clean energy is the key factor in the economic, environmental, and social growth. It is the core factor of a sustainable urban environment. Governments have therefore to take the initiative to develop and implement sustainable building policies and regulations to support the achievement of the United Nation Sustainable Development Goals (UNSDGs) [1]. These initiatives must be performed by those Governments in order to preserve natural resources and clean environmental strategy in their countries. This is to be achieved by constructing a framework of the vision to provide a sustainable built environment and a modern infrastructure for future sustainable energy-efficient buildings. The policies are to support the preparation of sustainable building legislation to transform conventional buildings' infrastructure to sustainable and environmentally healthy buildings and it will pave the way and encourage all buildings' developers to use in their practice in applying sustainability criteria, through the rationalization of water use and electricity consumption as well as reducing waste quantities and by monitoring air quality. Cities converting their buildings to sustainable buildings will become a coordinated center for advancing sustainable building by increasing general awareness, raising the bar for what is required, helping to engage the stakeholders to deliver high-performance energy-efficient buildings, and rewarding high performers. It will support integrating the sustainable energy-efficient building programs with what is happening in the neighboring communities. The policies define sustainable building vision for the Emirate and provide specific recommendations for improvements, resulting in a path toward a dynamic and coordinated active sustainable building plan. It is essential to have a sustainable source of energy for the selected building in order to consider that building to be sustainable. Energy demand for the residential building includes

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energy consumption for hot water, cooling, lighting, and other essential appliances. Natural gas has been used for urban buildings heating and electricity dependence is in increasing demand for the rest of the power need. Solar and wind technology has been proved efficient when integrated into the buildings [2, 3]. This paper is to present the main benefits and possible combinations for these renewable energy sources use for each building to support its conversion from a conventional building to sustainable [4]. In order to enhance buildings characteristics toward sustainability, key innovation issues are to be added for intelligent buildings include sustainability (energy, water, waste, and pollution), need to be considered [5]. This is to include the implementation of information and communication technology, robotics, embedded sensor technology, smart-materials technology including nanotechnology, health in the workplace, and social change. Technologies of smart buildings will provide large benefits in terms of more efficient energy use, on-site energy demand integration and generation with the grid. These automated green buildings represent a significant opportunity for energy efficiency and mass-scale renewable generation, as well as automated demand–response (DR) systems. Green buildings with smart integrated control systems result in a green-energy ecosystem [6].

Green-Sustainable Buildings

Green buildings encountered a way to build a comfortable lifestyle with beneficial developments for human and environmental health. In order to achieve sustainability for those buildings, green building practices methods to supplement healthier and more efficient materials and strategies throughout the construction process. EPA (Environmental Protection Agency) defined the green building as:

"Green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Green building is also known as a sustainable or high-performance building" [7]. Approaching the building sustainability will create economic stability generating an increased economic growth and contributes in different ways the unemployment.

Sustainable Building Objectives and Strategies

Three main objectives and strategies are to be initiated when working toward sustainable buildings. They are as follows [8, 9]:

- Resource conservation
  - Energy conservation
  - Material conservation

  - Water conservation
  - Land conservation
- Cost efficiency
  - Initial cost (purchase cost)
  - Cost in use
  - Recovery cost
- Design for human adaptation
  - Protecting human health and comfort
  - Protecting physical resources

Resource Conservation Strategies and Methods for Implementation

- **Energy conservation**
  - Choice of materials and construction methods.
  - Insulating building envelope.
  - Design for energy-efficient deconstruction and recycling.
  - Design for low energy intensive transportation.
  - Developing energy-efficient technological process.
  - Use of passive energy design.
- **Material conservation**
  - Design for waste.
  - Specify durable material.
  - Specify natural and local material.
  - Design for pollution prevention.
  - Specify nontoxic material.
- **Water conservation**
  - Using water efficient plumbing fixtures.
  - Design for dual plumbing.
  - Collecting rainwater.
  - Employ recirculating systems.
  - Designing low-demand landscaping.
  - Pressure reduction.
- **Land conservation**
  - Adaptive reuse of existing building.
  - Locate construction project close to existing infrastructure.
  - Development of nonarable lands for construction.

Sustainable Building-Integrated Wind and Solar Systems

Sustainable energy performances of green buildings design have respective impacts on sustainable developments. This requires identifying and developing efficient energy solutions associated with green buildings for addressing future energy demands. It has been highlighted that the sustainable energy performances associated with integrated technologies and renewable energy systems are still intertwined with significant challenges related to the fundamental parameters of cost, maintenance, and operation. Previous studies put forward a theory representing that the performance of green buildings is substantially related to the level of their environmental assessment [10].

Renewable energy sources including solar, winds, and waves, play a substantial role for sustainable developments [11]. Green buildings (including low energy, ultra-low energy, and zero-energy buildings) are associated with a reduction of the energy demand by implementing renewable energy sources. Wind and solar energy resources have always been a key factor toward the development of green buildings. In conclusion, buildings become an energy (thermal and/or electric) production unit for local needs. They can even contribute to global electricity production.

Building-Integrated Solar Photovoltaics Systems (BIPV)

Photovoltaics system is a stylish means of producing electricity on site, directly from the sun, without concern for energy supply or environmental harm. Distributed applications for implementing solar systems on and around buildings have recently drawn great interest for architects for integration. A building-integrated photovoltaics (BIPV) system consists of integrating photovoltaics modules into the building envelope. The following BIPV system is recognized whether integrated into the façade or in the roof [12].

- *Façade or roof systems added after built* (low powered up to 10 kW).
- *Façade-integrated photovoltaic along with an object* (several transparent module types such as crystalline and micro-perforated amorphous transparent modules. Part of natural light is transferred into the building through the modules), see Fig. 30.1.
- *Roof-integrated photovoltaic along with an object* (the roof is covered with transparent photovoltaic modules. Usually only if the building is small. It is possible to use tiles, which integrate solar cells), see Fig. 30.2.
- *Shadow-voltaic PV system* (shading) (photovoltaic modules serve as Venetian blinds).
- *Solar glazing* (low-iron tempered glass is usually used. Simple glass/glass laminate or as complex isolation glass/glass laminate), see Fig. 30.3.

Fig. 30.1 BIPV system powering Manchester College of Arts and Technology's library

Fig. 30.2 Roof-integrated photovoltaic along with an object [12, 13]

Fig. 30.3 Solar glazing

Fig. 30.4 The Francis Crick Institute in central London [16]

The main benefits are [14]:

- Simultaneously serving as building envelope material and power generator,
- Provide savings in materials and electricity costs.
- Reduce the use of fossil fuels and emission of ozone-depleting gases.
- Add architectural interest to the building.

Figure 30.4 shows BIPV system at the Manchester College of Arts and Technology's library at Harpurhey at sunset. It is a green building incorporating passive ventilation [15]. The system consists of 482, 80 W polycrystalline panels on the south facade and a further 178, 165 W panels on the roof.

Inspirational Examples for BIPVs

The BIPV systems are getting widely of interests with many available examples. One of which is the PV louver array is taking shape on the top of the Frances Crick Institute, next to St. Pancras Station in London, Fig. 30.4. The system is expected to generate around 204,200 kWh/year from a renewable energy source [16].

St. Pancras is Kings Cross Station, which has PV integrated into overhead glazing high up in one of the barrel-shaped halls. This new building-integrated PV is expected to produce 175,000 kWh of electricity each year, saving over 100 tonnes of CO_2 emissions per annum, see Fig. 30.5 [17, 18].

Blackfriars rail station secures half its power from 4400 roof-mounted solar panels, expected to generate 900,000 kWh of electricity every year and to cut the stations' carbon emissions by an estimated 511 tonnes a year, further reducing the carbon footprint of its train routes to the southeast of England, see Fig. 30.6 [19, 20].

Fig. 30.5 St. Pancras King Cross Station BIPV system [18]

Fig. 30.6 Solar panels on Blackfriars bridge in London [19, 20]

Fig. 30.7 Ziekenhuis (hospital) in Aalst, Belgium

Another example is the Ziekenhuis (hospital) Fig. 30.7, in Aalst, Belgium, an eye-shaped atrium is formed from sloping curtain walling system with glass-glass BIPV laminates forming the entire cladding. Cells are spaced further apart to create the desired light transmission [21]. The solar system is 46 kWp, generating 31,000 kWh/year (675 kWh/kWp).

Building-Integrated Wind Technology System

Another promising system that could enhance the energy efficiency and building sustainability transferring it from green aspects is the building-integrated wind turbine (BIWT) systems in addition to the BIPV system. This has been increasingly common as a green building icon to reach the self-powered building. The system has not achieved its optimum design criteria due to the absence of a framework for efficient integration. The main drivers for using this system are [22]:

- Meet targets of green building designers.
- Promote sustainability in the built environment.
- Minimum transmission/distribution losses.
- Accessing greater wind velocities at higher altitudes of 40% increase.
- Replace the existing buildings by self-sufficient energy buildings.
- Satisfy up to 20% of the building's energy needs.
- Ecological power generation in the future of the sustainable building.
- Can play a crucial role in unexpected situations delivering lacking energy.
- New wind turbines are developed quiet, no vibration and high-power output.
- Provide visible evidence to a building owner's commitment to the environment and increase the energy rating for the building performance.
- Wind will complement solar PV-integrated systems and can sustain the energy supply for a sustainable building and could together reach more than 40% of the building demand.

In this respect, it is believed that the proper stages for an efficient framework for the BIWT can be introduced as (see Fig. 30.8) [23]:

1. Determining site suitability
2. Determining suitable integration methods

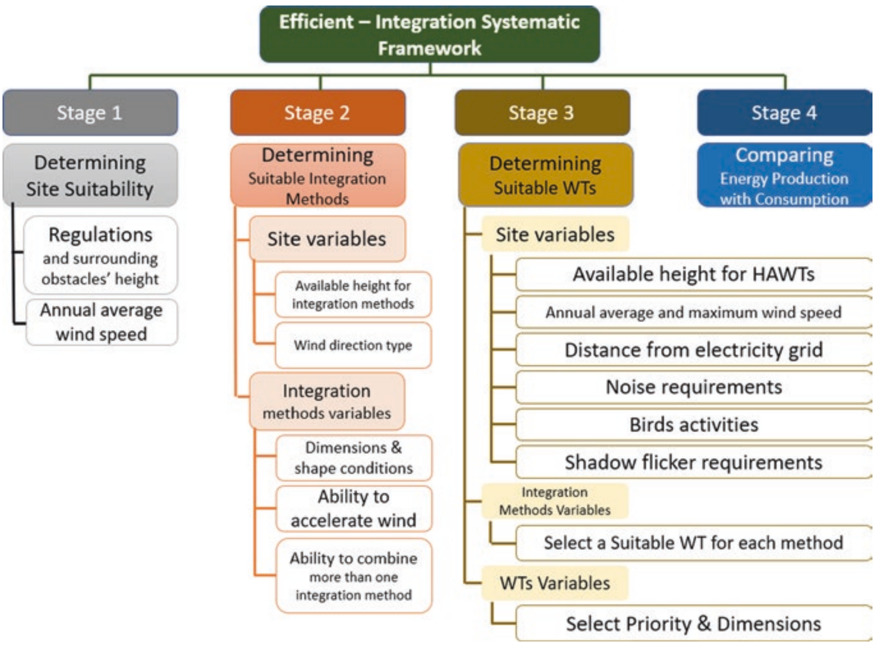

Fig. 30.8 Systematic framework for the efficient integration of WTs into buildings [23]

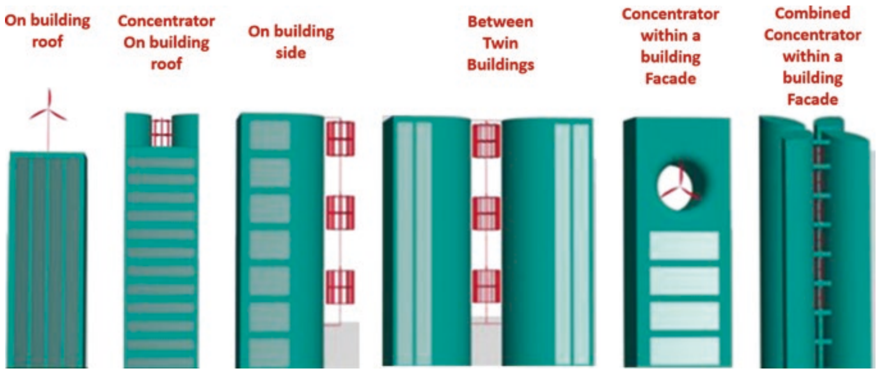

Fig. 30.9 Main methods of wind turbines integrated into buildings [23]

3. Determining suitable wind turbines
4. Comparing energy production with consumption

Main methods of wind turbines integrated into buildings vary depending on nature of the building design features, location, and the prevailing wind direction. Figure 30.9 shows different methods suggested by [23].

The improved system has also been introduced by [24], which consists of an assemblage of many unit modules filling an empty building skin area except for windows. It consists of a guide vane and a rotor as shown in Fig. 30.10, which flow around the building skin and are very complicated. The empty space behind the guide vanes plays the role as a passage for the wind passing through the rotor and creates a pressure difference between the back and forth of the guide vanes [25] around itself due to its form and arrangement with neighboring structures. This system was tested and verified experimentally and proved to be an efficient technique to be implemented.

Inspirational Examples for BIWTs

The first type of BIWTs is the *building mounted wind turbine with horizontal axis rotor type* as shown in Fig. 30.11 [26].

Another type is the building mounted wind turbine with vertical axis rotor type. Examples are shown in Fig. 30.12 [26].

Another example of the building-integrated vertical axis wind turbine is Honeywell Orion Campus—India (Fig. 30.13) [27]. The integrated system consists of 18 vertical axis wind turbines with total generated power of 137,304 kWh/year and 55 kW PV array with a total generated power 68,680 kWh/year.

The third type of BIWT is building-integrated wind turbine with a horizontal axis wind turbine. The practical example is the Strata SE1 residential tower in London (Fig. 30.14) at (57 kW), which was designed by the BFLS and completed

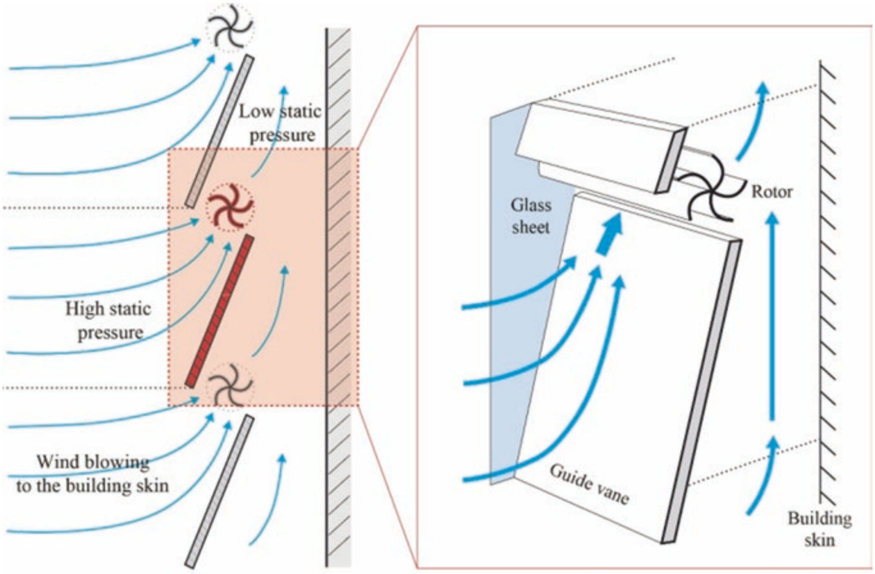

Fig. 30.10 Schematic diagram of the proposed system [24]

Fig. 30.11 Building mounted wind turbine with horizontal axis rotor [26]

Fig. 30.12 Vertical axis wind turbines, roof mounted [26]

Fig. 30.13 Honeywell Orion Campus—India [27]

Fig. 30.14 The Strata SE1 residential tower in London [28]

in 2010. It consists of three turbines (19 kW each) in its crown at 148 m off the ground. It is expected that it can produce up to 50 MWh/year, enough to power (8% of total consumption) [28].

Another type is the *building-integrated wind turbine with vertical axis wind turbine* shown in Fig. 30.15. The figure shows the public utility commission in HQ, San Francisco. Rooftop solar panels were integrated and building-integrated wind turbines. It has achieved LEED Platinum certification. The systems provide 7% of the building's entire energy use [29].

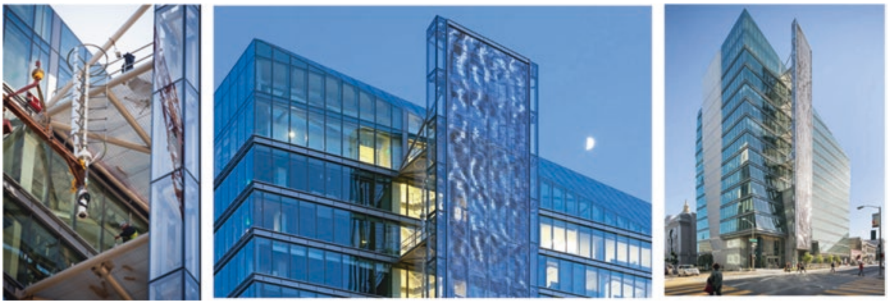

Fig. 30.15 Public utility commission HQ, San Francisco

Fig. 30.16 Building augmented wind turbine, horizontal axis (World Trade Center, Bahrain) [26]

The other type of BIWT is building-augmented wind turbine with horizontal axis rotor type. An example of this is the Bahrain World Trade Center (Fig. 30.16). The system consists of three horizontal axis wind turbines generates 225 kW each, totaling to 675 kW of wind power capacity equivalent to 15% of the total consumption [26].

Conclusion

Efforts have been put forward in order to help achieve the main goals for the United Nations for the sustainable development. It is believed that 70% of primary domestic energy usage being committed to buildings leads to energy and environmental challenges. Then the need for energy-efficient buildings is a prime aim. In order to approach building energy sustainability, sustainable energy resources are essential to be considered. Sustainable building objectives and strategies were discussed with the key successful design parameters. Types of building-integrated solar systems were discussed with practical examples. The main drivers for building-integrated wind technology were explained and systematic framework for the efficient integration of WTs into buildings was introduced with the main design methods. It is recommended that in order to achieve sustainable development goals in regards to the building sectors, building-integrated solar and wind technologies must be considered to support transforming the green building to buildings with energy self-sufficient buildings, which will have a great impact on the environment, economic, and social health and well-being.

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