Chapter 11
Conclusion

Green and Smart Buildings technologies discussed and presented in this book are not necessarily all new and cutting edge technologies. Some of them have been available for decades. However, the adoption rates of these technologies are still very low. The list of the technologies discussed in this book, although not exhaustive, can offer a quick reference guide for building owners, designers, architects and facility managers to design and operate green and smart buildings. If the technologies discussed here can be adopted for new buildings and building retrofits, the energy, water and waste footprint of the built environment can be significantly reduced, while at the same time ensuring occupant comfort and safety with the appropriate choice of technologies.

The best time to plan and create green and smart buildings is during the early design stages of the building. It's important that various building stakeholders (building owner, architect, engineers, designers, operators, consultants and users) are involved in the design stage of the building in the integrated design process as discussed in Chap. 3. During this process it is very important to use the right modeling and simulation tools to assess building performance using different ideas and options that are discussed during the process. These tools such as Building Information Modeling (BIM), energy modeling and air-flow modeling using computational fluid dynamics (CFD) can go a long way in documenting the characteristics and performance of the building and provide transferable insights on the choice of technologies and their overall performance impacts.

A lot can be done with the 'passive' design elements of the building such as its orientation, layout and the choice of building envelope or the skin of the building. Passive design can have a major impact on the building performance by affecting its ventilation, lighting and heating and cooling needs. By leveraging the natural environmental factors, the passive design technologies discussed in Chap. 4 can help set up the building for its environmental performance and occupant comfort. It is highly recommended that the passive design of the building be thoroughly optimized first as once fixed, it is often not so easy to change the passive design elements and definitely not at low costs.

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After optimizing the building using passive design technologies, the active design provisions of the buildings should be appropriately chosen to ensure its high performance. The active design elements include the heating, cooling and ventilation, artificial lighting, building services such as elevators and the plug and process loads. In Chap. 5 we discussed energy efficient technologies in each of this areas and there is a lot of potential for energy and operational cost savings in the building by choosing the suitable technologies in this section. Active design technologies should also be investigated at the time of the building retrofit and refurbishment. They can offer good solutions for energy efficient retrofits and help the building achieve higher performance after retrofit and refurbishment.

The Building Management System (BMS) or Building Automation System (BAS) helps the building maintain its operational performance. Tools such as continuous monitoring, data analytics, dashboards, sensors and controls can help the facility managers, building owners and occupants to optimize its energy and water efficiency and reduce wastage. Several building provisions and their efficient operation can be automated by the BAS and use of advanced techniques such as automated fault detection and diagnosis can greatly help the facility managers to optimize the building for its highest overall performance at all times. The combination of Internet of Things (IoT) technologies in this area can offer low cost solutions to significantly enhance the 'smartness' of the building and drastically improve the overall occupant experience.

The integration of renewable energy generation options discussed in Chap. 7 as well as the water and waste reduction technologies discussed in Chap. 8, would enable buildings to holistically achieve its next level of sustainability performance. However, without engaging the occupant in the right way, the technologies may fail to deliver their intended purpose. Hence its crucial to focus on occupant engagement using some of the technologies discussed in Chap. 9. In Chap. 10 we looked at performance assessment and rating, which enables the building to benchmark itself against best practices and also motivates and guides the building stakeholders to critically think about the performance of their building and the alternative technologies available.

In a post-occupancy audit and survey conducted by the United States, General Services Administration (GSA), it was found that green buildings that incorporate sustainable practices and are rated as such using the green building rating system LEED, are indeed able to achieve the following compared to national average:

- significant reduction in energy consumption: 25 % less energy use and 58 % savings in energy costs in case of top performers.
- reduced water consumption: 11 % reduction on average.
- decrease carbon dioxide emissions: 36 %.
- higher occupant satisfaction: 27 % on average and 76 % higher in case of top performers.
- lower aggregate operational costs: 19 % lower on average and 43 % in case of top-performers.

- lower aggregate maintenance costs: 12 % lower on average and 47 % in case of top performers.

The survey was conducted on 22 representative green buildings from the GSA national portfolio and involved a comprehensive assessment, measuring environmental performance, financial metrics, and occupant satisfaction. Results were compared to both industry and GSA baselines. It also found that the Integrated Design approach (as discussed in Chap. 3 here) delivers higher performance and help meet the national climate change and sustainability goals (GSA 2011).

There are several examples of green and smart buildings in the world now that have achieved a very high energy and sustainability performance. As of last year (August 2015), there are more than 72,500 LEED certified green building projects located in over 150 countries and territories. A review of data from 195 LEED projects found that green buildings have a 57 % lower source Energy Use Intensity (EUI) than the national average (USGBC 2015).

One good example of a green and smart building in the **Bullitt Centre building** in Seattle, Washington in the United States of America (photo shown in Fig. 11.1). Touted as America's greenest office building by some (BuildingGreen 2016), this six-storey, 52,000 square-foot building completed in April 2013, can meet the Living Building Challenge, which is one of the most stringent challenges for green buildings as discussed in Chap. 10. It met the specific requirements of the challenge such as the net-zero-energy, net-zero-water and sustainable construction materials. Some of the features of this building include the following (WBDG 2016):

- *Integrated design approach* (see Chap. 3): The project made good use of a substantial pre-design phase, where building size and massing, architectural and MEP systems, and renewable energy production potential were proven, prior to the start of schematic design. It also made extensive use of Building Information Modeling (BIM) and energy modeling tools to support design decisions.
- *Passive Design* (see Chap. 4): Daylighting analysis drove not only the massing of the project, but the configuration of the curtain walls, skylights, and shading. Wherever possible, wood (timber) was used resulting in a hybrid structure consisting of concrete coming out of the earth, steel to resist lateral forces and timber for gravity loading conditions. It has a highly superior building envelope performance with use of triple-glazing windows, well insulated walls and effective massing and orientation for reducing solar heat gain and improve daylighting. It also incorporates automated exterior shading and operable windows that open and close automatically in response to conditions outside (a manual over-ride is included for occupant choice).
- *Active design* (see Chap. 5): It incorporates radiant floor heating and cooling coupled with a ground-source heat pump (GSHP) system. There is also a heat recovery system that system includes heat exchangers made of honeycombed rotating drums to extract heat from the warm air before it's vented outside. A very good lighting power density (LPD) of 0.4 W/ft^2 (or 4.3 W/m^2) is achieved with good daylight planning (2 % daylight factor) and use of LED

Fig. 11.1 Photo of the Bullitt Centre building (Alex Wilson, BuildGreen 2016)

lighting that has automatic sensor-based control for dimming and on/off features based on occupancy and daylight. The elevators used have a regenerative drives system that makes them much more energy efficient. Plug loads for office equipment, such as computers, monitors, servers, printers, and copiers are limited to a maximum of 0.8 W/ft^2 and further significantly reduced by using plug load occupancy sensors.

- *Building Management and Automation System* (see Chap. 6): The Bullitt Center's sophisticated Building Management System (BMS) includes sensors and actuators to monitor and control its heating, cooling, and ventilation systems. It also manipulates external louvers and the operable windows. In addition, the BMS monitors the greywater system and controls the composting system as well. The building employs an online dashboard that shows real-time energy usage and other building functions.

- *Renewable Energy Integration* (see Chap. 7): A 242 kilowatt peak (kWp) rooftop solar photovoltaic (PV) system is installed in the building to deliver 100 % of the building's electricity needs on an annual basis. To get a large enough PV array on the roof to supply electricity for six floors, the PV array cantilevers out over the walls (as can be seen in its photo above). The building also uses the geothermal heating and cooling system that consist of cross-linked polyethylene (PEX) tubes in the floors that carry a mixture of water and glycol throughout the building and 120 m (400 ft) underground.
- *Water and waste reduction* (see Chap. 8): The building has a 56,000 gallon (212 cubic meters) cistern for storage of rainwater that is harvested on the roof and meets 100 % of the water need in the building for drinking, sanitation and landscaping irrigation. The building has composting toilets, which divert the toilet waster directly to composting units located in the building basement. The toilets also use foam flushing system with natural soaps to reduce the water use per flush by a significant amount. The third floor terrace of the building serves as its greywater filtration system (1500 L or 400 gallons per day) that consists of a man-made wetland with horsetail plants that absorb organic material and purify the water.
- *Occupant engagement* (see Chap. 9): There is green lease in place that includes penalties if their energy budgets are exceeded by the tenants. There is an a unique, internal "cap-and-trade" system in which tenants have specific energy budgets and if they use less electricity than their budget, they can trade with other tenants in the building who may need more. Lease incentives for the tenants are used to ensure receptacle energy targets are met and to encourage tenants to employ the most efficient state-of-the-art equipment that meets their professional needs. Large interpretive and educational banners placed in the open reception area of the building show-off the green features of the building to occupants and visitors.
- *Overall performance* (see Chap. 10): The building was designed to achieve an overall energy utilization index (EUI) of 16 kBtu/ft^2/year (or 51 kWh/m^2/year). The onsite renewable energy generation (from the solar PV panels) of 257,800 kWh/year, meets slightly more than 100 % of the building's annual energy use (BuildingGreen 2016). The following chart in Fig. 11.2 shows the annual energy split by end use for the building.

Another green and smart building case worth mentioning is that of **The Edge building** in Amsterdam, the Netherlands (Photo shown in Fig. 11.3). This building is considered as the greenest and smartest building in the world (Bloomberg 2015). The Edge is a 40,000 m^2, 15 floors office building in Amsterdam that was designed

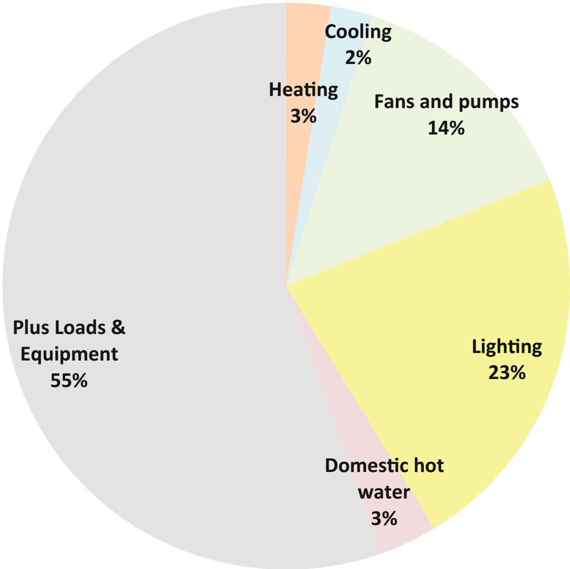

Fig. 11.2 Annual energy consumption split by end-use for the Bullitt Centre building

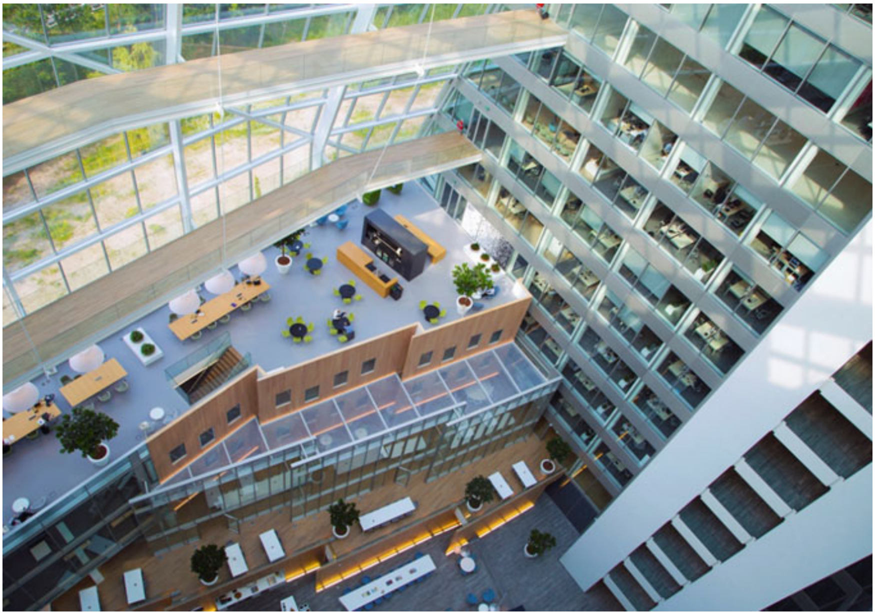

Fig. 11.3 Photo of the edge building

for the global financial firm and main tenant, Deloitte. In the year 2016, it was awarded the world's highest BREEAM rating awarded to an office building ('outstanding' rating with a score of 98.36 %) as it demonstrates that the pursuit of a vibrant and collaborative working environment can be combined successfully with achieving the highest levels of sustainability (BREEAM 2016). The building combines the following green and smart building features:

- *Passive design* (see Chap. 4): The building orientation is based on the path of the sun and harnesses northern daylight while there are solar panels installed on the south facade to harness sunlight for energy generation. Load bearing walls to the south, east and west have smaller openings to provide thermal mass and shading, and solid operable panels for ventilation. Louvers on the south facades are designed according to sun angles and provide additional shading for the office spaces, reducing solar heat gain. Every workspace is planned within 7 m (23 ft) of a window, allowing occupants to enjoy outside views as well as daylight.
- *Active design* (see Chap. 5): The spaces are heated and cooled using radiant cooling ceiling panels that are combined with a heat pump and an aquifer thermal energy storage system that provides all of the energy required for heating and cooling. During summer months, the building pumps warm water more than 400 ft deep in the aquifer beneath the building, where it sits, insulated, until winter, when it's sucked back out for heating. The atrium acts as a buffer between the workspace and the external environment. Excess ventilation air from the offices is used again to air condition the atrium space. The air is then ventilated back out through the top of the atrium where it passes through a heat exchanger to make use of any warmth. The building has an Ethernet-powered LED lighting system, whereby the lighting is powered using the same cables that carry data for the Internet.
- *Building Management and Automation System* (see Chap. 6): Almost all equipment and devices in the building, including the coffee machine and the towel rails in bathroom, are connected to the internet. The building has a newly developed lighting system called Light over Ethernet (LoE). The LED luminaries are not only powered by the Ethernet cables, but also fully internet connected. They have embedded sensors to continuously measure occupancy, movement, lighting levels, humidity and temperature, and then provide that data to the Building Management System (BMS). There are over 28,000 sensors in the building's smart ceiling and lighting system. There is a central dashboard that can process a massive amount of data collected in the building and is accessible to the facility managers and occupants. Heating, cooling, fresh air and lighting are fully IoT (Internet of Things) integrated and BMS controlled per 200 square feet based on occupancy to ensure that with zero occupancy there is next-to-zero energy use. On days when fewer employees are expected, an entire section might even be shut down, cutting the costs of heating, cooling, lighting, and cleaning.

- *Renewable Energy Integration* (see Chap. 7): 65,000 square feet of solar PV panels are located on the facades and roof, and remotely on the roofs of buildings of the University of Amsterdam, thereby making use of neighborhood level energy sourcing. This makes the building net-zero energy building and in fact positive energy as the solar panels produce much more energy than what is consume in the building.
- *Water and waste management* (see Chap. 8): Rain water is collected on the roof, stored in a concrete tank back of the parking garage, and used to flush toilets, and irrigate the green terraces in the atrium and other garden areas surrounding the building. The connected nature of its infrastructure also provides data to be able to reduce wastage in many areas. For example, the data from sensors is also used for predictions of occupancy at lunchtime based on real time historical data and traffic and weather information to avoid food-waste.
- *Occupant engagement* (see Chap. 9): This is an area where the building surpasses all expectations on a green and smart building. Every employee is connected to the building via an app on their smart phone. Using the app, they can find parking spaces, free desks and lockers (as no one has a pre-assigned desk) or other colleagues, report issues to the facilities team, or even navigate within the building. Employees can customize the temperature and light levels anywhere they choose to work in the building via the mobile app. The app checks the occupant's schedule, and the building recognizes their car when they arrive and directs them to a parking spot. The app also remembers how they like their coffee, and tracks their energy use so they're aware of it.

The case study of these two high performance buildings tells us that the technology necessary to create green and smart buildings is now available. There will always be further technological advancement, but with the use of existing technologies it's possible to design and operate buildings that can have a very low or even zero energy, water and waste footprint. The integrated design process used to bring together the several stakeholders in the building should also be used as a platform to generate new ideas and trigger research requirements to enhance building performance even further. Each building is unique based on its location, surrounding climatic conditions and its intended end-use. However, as is evident from the case studies, the creation of green and smart buildings of the future needs people who are aware of the benefits, technologies and processes to make them a reality.

It is a sincere hope that this book triggers interest of the building stakeholders to start championing green and smart buildings and accept nothing less. This book could be used a quick reference to understand, select and prioritize technologies that could be applied to new building designs and retrofits. The technologies described in this book could also be subject of future research and development in order to make them suitable for the local context and also make them cost-effective and readily adoptable by the building industry.

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