Chapter 1
Introduction

The building sector is the largest contributor to global greenhouse gas (GHG) emissions. Buildings use about 40 % of global energy, 25 % of global water, 40 % of global resources, and they emit approximately 30 % of GHG emissions. These emissions are set to double by 2050 if we carry on business as usual (UNEP 2014). The energy used by the building sector continues to increase, primarily because new buildings are constructed faster than old ones are retired. Electricity consumption in the commercial building sector doubled between 1980 and 2000, and is expected to increase another 50 % by 2025 (EIA 2005).

Other important facts:

- The building sector is estimated to be worth 10 % of global GDP (USD7.5 trillion) and employs 111 million people.
- Residential and commercial buildings consume approximately 60 % of the world's electricity.
- Energy consumption in buildings can be reduced by 30–80 % using proven and commercially available technologies.

Figure 1.1 shows that the buildings present the most impactful and also economical mitigation potential for GHG emissions globally.

Greenhouse gas emissions from buildings primarily arise from their consumption of fossil-fuel based energy, both through the direct use of fossil fuels and through the use of electricity which has been generated from fossil fuels. Significant greenhouse gas emissions are also generated through construction materials, in particular insulation materials, and refrigeration and cooling systems. Broadly speaking, energy is consumed during the following activities:

1. manufacturing of building materials ('embedded' or 'embodied' energy)
2. transport of these materials from production plants to building sites ('grey' energy);
3. construction of the building ('induced' energy);
4. operation of the building ('operational' energy); and
5. demolition of the building (and recycling of their parts, where this occurs).

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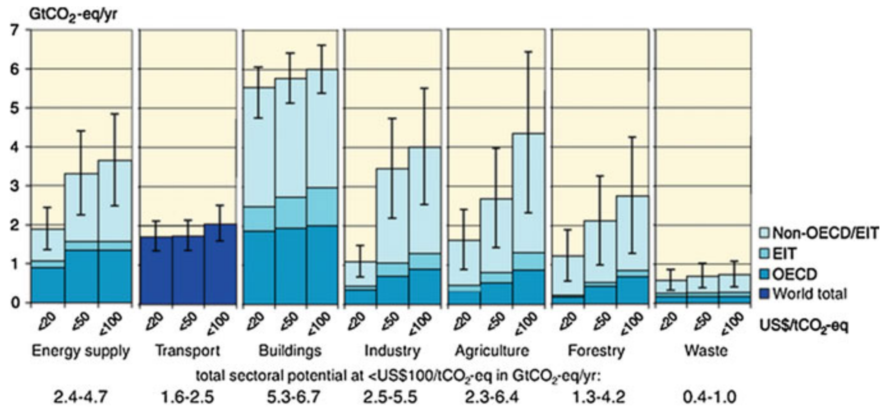

Fig. 1.1 Estimated economic mitigation potential by sector using technologies and practices expected to be available by 2030 (IPCC 2007)

Though figures vary from building to building, studies suggest that over 80 % of greenhouse gas emissions take place during the operational phase to meet various energy needs such as Heating, Ventilation, and Air Conditioning (HVAC), water heating, lighting, entertainment and telecommunications (Junnila 2004; Suzuki and Oka 1998; Adalberth et al. 2001). A smaller percentage, generally 10–20 %, of energy is consumed in materials manufacturing and transport, construction, maintenance and demolition.

Given these facts, it's imperative that significant actions be taken towards adoption and growth of green buildings, which can lead to significant reduction in GHG emissions especially during the operational phase of the building. Green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by:

- Efficiently using energy, water, and other resources
- Protecting occupant health and improving productivity
- Reducing waste, pollution and environmental degradation.

There are various definitions of a 'Green Building' and how it performs compared to any other building. One of the most comprehensive definition that I have come across and that will be used as a guideline for this book is as follows:

> 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. (US EPA 2014)

The design of building is an important factor affecting its eventual operational performance. Once designed and built, the potential for energy savings is locked and subsequent retrofits or refurbishments can be highly uneconomical. In this book, we look at several green building design technologies, including the design methodology itself (i.e. integrated design). Broadly speaking, green building design features can be divided into two main categories: passive and active design features.

The ‘passive design’ features impact the energy performance of the building in an indirect way, but at the same time can lead to major reduction in energy consumption of buildings in the operational phase. Passive design takes advantage of natural energy flows to maintain occupant comfort (thermal, ventilation and lighting) instead of overly relying on mechanical and electrical systems for the same. However, the passive design features are often not customisable to suit the dynamic operational conditions such as changes in weather and varying occupancy levels or heat sources. The elements of passive design are:

- Building orientation e.g. with respect to the sun-path
- Form factor of the building: massing, shape
- The building envelope viz. roof, facade, walls, windows, shading devices, etc.
- Insulation and exterior/interior finishes.

The passive design methodologies and technologies will be covered in details in Chap. 4.

The ‘active design’ features impact energy consumption in building directly and are often easy to customise (tune-up or tune-down) according to the operational requirements. They comprise of the mechanical and electrical provisions such as:

- Air-conditioning (heat/cooling)
- Mechanical ventilation
- Artificial lighting
- Elevators and escalators
- Pumps and compressors.

The active design technologies depend to a large extent on the equipment design and operating efficiency. As they need to be dynamically controlled, there are often moving parts or switching features that need to be maintained regularly in order to maintain high operating efficiencies and thermal comfort. We will review active design technologies for green buildings in Chap. 5.

As active and passive design features can both be impactful ways to reduce the overall energy consumption in buildings, there needs to be an optimal mix of the two considering the overall costs, utility, thermal comfort and reliability. This calls for an integrated design approach where various requirements, constraints and conditions are considered with the goal to design a green building. We will look at integrated design in details in Chap. 3.

Considering the fact that operational energy is the highest life-cycle contributor in buildings, it is important that building operations be cognizant to this fact. Building owners, facility managers and occupants should be aware and empowered to take actions necessary to reduce operational energy without sacrificing comfort and utility of the building. This brings us to the topic of 'Smart Buildings'.

A smart building can be defined as follows:

> Smart buildings use information technology during operation to connect a variety of subsystems, which typically operate independently, so that these systems can share information to optimize total building performance. Smart buildings look beyond the building equipment within their four walls. They are connected and responsive to the smart power grid, and they interact with building operators and occupants to empower them with new levels of visibility and actionable information. (Institute of Building Energy Efficiency 2011)

A basic but important element of a smart buildings is the Building Management System (BMS) or Building Automation System (BAS). There are many commercially available BMS and BAS systems for buildings and they consist of the following essential elements:

- Data acquisition: sensors, meters, etc.
- Database management
- Analytics
- Visualisation
- Controls.

Each of the above are relevant technology development areas with the goal to make the systems more powerful and cost-effective in operational energy savings. Such systems also ensure that the building is performing to its design standards at all times and trigger operation and maintenance activities to deal with deviations in performance. The Building Management and Automation technologies are covered in details in Chap. 6.

Apart from providing living and working spaces with good occupant comfort and operational functionality, buildings can be also looked upon as avenues for distributed energy generation especially using renewable energy technologies. These technologies include Solar Photovoltaic (PV)/Solar Thermal energy generation, Wind Energy and Geothermal Energy. Each of these technologies are, on their own, going through a lot of technological developments and often a challenge is to integrate them seamlessly in the building without compromising safety, comfort and functionality. We cover this topic in more details in Chap. 7.

Other than consuming energy in various forms (e.g. thermal and electric), buildings also consume water for several activities such as the provision of basic amenities like toilet and wash-rooms, cooking, landscaping, cleaning and also a significant amount of water can be consumed in the air-conditioning systems such as cooling towers. Buildings also produce waste such as paper, plastic, glass, food, cans, electronic waste and office equipment and furniture during its operational phase. Apart from this, there is construction waste during its construction and demolition phases. From recycling and reuse to purposeful at-source reduction, there are several strategies to reduce the water and waste in buildings. These strategies are covered in Chap. 8.

The business case for green and smart buildings is often fragmented and not strong due to the fact that the stakeholders viz. owner, developer, builder, operator and occupant, each have a role to play. Often, a well-designed green and smart building is not able to achieve its desired environmental performance due to misunderstanding or lack of understanding between the occupants or the users of the green features provided in the design. There are evolving techniques such as green-lease, green occupancy handbooks and incentive schemes that are useful to emphasise proper operations and sustainable utilisation of green and smart building features. We look at such occupant engagement techniques and tools in Chap. 9.

Green and Smart Building rating systems play an important role in benchmarking and assuring better performance. After all, how do we know if enough is being done to be able to classify a building as a green or smart building. There are now several green building rating systems throughout the world and each of them differ in how certain design and operational aspects are assigned weightage in the overall rating calculation. In Chap. 10 we look at various green and smart building performance assessment and rating systems and how they can impactfully shape the green building industry if used in an appropriate way.

Lastly, we look at two green and smart building case study examples in the concluding Chap. 11. There are now numerous such examples around the world and these examples prove that green and smart buildings should be aspired to as a norm and not as an exception or a high reaching ideal.

Thus a green and smart building is an interplay of various integrated design strategies such as passive and active design features, as well as water and waste reduction techniques, renewable energy integration, building management systems and controls, efficient operations and rating systems that allow effective benchmarking and performance analysis and guidelines for various stakeholders involved in the building industry. Figure 1.2 summarizes the essential elements of a green and smart building.

A green and smart building uses both technology and process to create a facility that is environmentally friendly, cost-effective and intelligence driven, while being safe, healthy and comfortable for its occupants. It provides its facility managers and owners with tools that allow for timely and intelligent decision making during its design, operations and maintenance phase. It enhances the user experience through logic and intelligence that caters for changing occupant requirements, climatic conditions and maintenance needs, while optimizing its performance throughout the life-cycle of the building.

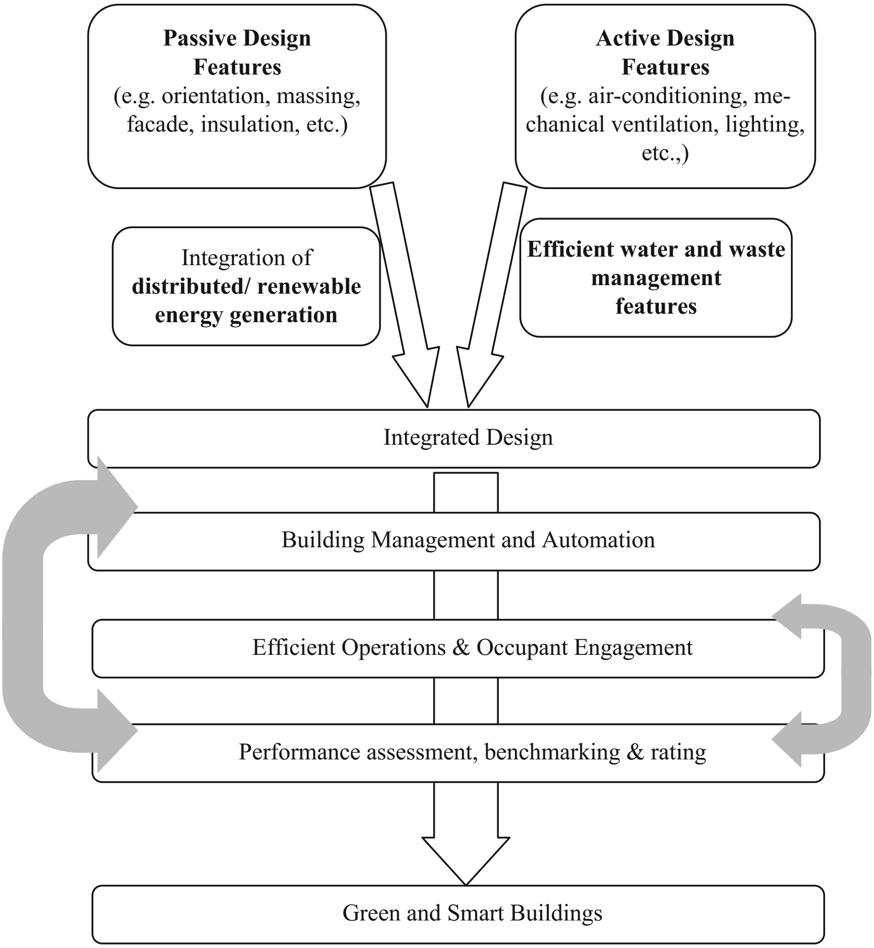

Fig. 1.2 Essential elements of a green and smart building

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