CHAPTER 1

Introduction

Every cubic inch of space is a miracle.

Walt Whitman, *Leaves of Grass,* "Miracles"

WHAT THIS BOOK IS ABOUT

This book is intended as a guide in space planning rooms and spaces in a home. Related information regarding codes, mechanical and electrical systems, and a variety of additional factors that impact each type of room or space is also provided. In addition, this book includes information about accessible design in each chapter in order to provide a cohesive view of residential accessibility. This new edition includes updated 2021 International Residential Code information and additional updates.

Intended as a reference for use in the design process, this book can aid in teaching and understanding the planning of residential spaces. Most chapters follow a similar format, starting with an overview of the particular room or space and related issues of accessibility, followed by information about room-specific furnishings and appliances. Chapters continue with information about sizes and clearances, organizational flow, related codes and constraints, and issues regarding electrical, mechanical, plumbing, and basic lighting.

This book is meant to aid students and designers in understanding the amount of space that is minimally necessary in order for rooms to function usefully. Examples of larger spaces are also given, but at its heart, this book is intended to show students how to use space wisely and make good use of space throughout the dwelling. With clear knowledge about minimums, designers and students of design can learn when it is appropriate to exceed such standards for a variety of reasons that reflect specific project criteria based on client needs, budget, site, and other issues.

This book is intended as an introduction to the topics covered with the aim of familiarizing the reader with the basic concepts so that they might move forward in design education or on to additional research in certain areas. To that end, an annotated references section is provided at the end of each chapter. Thinking of the information provided in each chapter as basic building blocks that allow for the discovery of the issues involved is a helpful approach in using this book. (Figure 1.1)

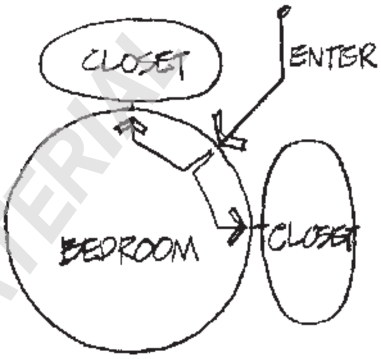

Figure 1.1 This book covers the design of houses using a basic room-by-room approach.

There is much that goes into the design of a dwelling that is not covered in this book; our intent is to focus on the use and design of individual rooms (again, a building-block approach) so that the reader will have the core information required to understand the design of these individual spaces. This basic informational approach may bring up questions about the role of the interior designer versus the role of the architect. Clearly, the design of the totality of the structure is the role of an architect, however, interior designers are taking an increasingly larger role in the design of rooms and spaces.

Interior designers engaged in renovation work can take a lead role in the design of the interior architecture of a space, with a significant hand in the design of a room or many rooms. This is in contrast to notions of the interior designer as the person tasked only with materials and furnishings selections.

The authors believe that interior designers and design students must be well versed in the aspects of residential design covered in this book. Readers will note that the detailed kitchen and bathroom information contained in this book is applicable to remodeling as well as to new construction.

AN OVERVIEW: QUALITY AND QUANTITY

The evolution of the use of rooms, room sizes, and changes related to American homes is mentioned throughout the book. It's worth noting that the authors have a bias toward careful consideration of the *quality* of design rather than the *quantity* of space in a given home. We hope to make clear that the successful design of space requires consideration of the real needs of clients measured against budgetary, code, climate, and site restrictions–all of which require careful development of a project program prior to the beginning of the actual design of the project.

The last hundred years have brought substantial changes to the public perception of the design, furnishing, and size of the American home. The overall size of new single-family homes followed a long-term trend of house size increasing from 1950 to 2015, with a brief decrease during the great recession. According to the National Association of Home Builders (NAHB), the average home built in 1950 was 983 square feet (91 m^2), with an average size of new single-family homes completed in early 2015 of 2,736 square feet (245 m^2).

The average (mean) square footage for new single-family homes has declined since 2015 and was down to 2,506 square feet in the first quarter of 2020. According to Robert Dietz, chief economist for NAHB, there is potential for the coronavirus and the recession of 2020 to reset those trends, "as evidence grows that households will seek more space for home offices, home gyms, and other purposes." (Figure 1.2)

The authors argue that a larger house is not necessarily a better house, and that designing a house that works well on a functional level is more important than mere size in creating a useful and pleasant environment. Additionally, large single-family homes are currently out of the financial reach of many citizens. Given issues of affordability and environmental sustainability, the future may require that space optimization is a worthy goal in designing dwellings.

Consideration of housing size and use of related resources is not unique to this publication. Architect Sarah Susanka's book *The Not So Big House* (1998) focused on quality over quantity of space and had an impact on the design of many homes. *A Pattern Language* by Christopher Alexander and colleagues (1977), an earlier book considered seminal by many, has at its core the notion that spaces should be designed for the way people really live and that good design can be accessible for all.

The notion of seeking quality of design rather than quantity of space is shared by many, and yet larger and larger houses continue to be built to house very small family groups. This dichotomy suggests that two opposing popular views of space exist. Although the architect Philip Johnson was once quoted as saying "architecture is the art of wasting space," clearly that was a bit tongue-in-cheek, and we concur more with Walt Whitman's notion that "every cubic inch of space is a miracle" – or should be.

The remainder of this chapter covers some general issues that relate to housing and serves as an introduction to the concepts that are covered in future chapters.

HUMAN BEHAVIOR, CULTURE, AND HOUSING

Environmental designers–including interior designers–benefit from gaining an understanding of human behavior as it relates to privacy, territoriality, culture, and additional issues related to the built environment. Privacy can be defined as the ability to control our interactions with others.

Understanding the human need for privacy and related issues can be helpful in designing spaces for human use. According to Jon Lang (1987, 148), "The ability of the layout of the environment to afford privacy through territorial control is important because it allows the fulfillment of some basic human needs." Lang goes on to say that the single-family detached home "provides a clear hierarchy of territories from public to private."

Lang (1987, 155) also states, "Differences in the need for privacy are partially attributable to social group attitudes." He continues, "Norms of privacy for any group represent adaptation to what they can afford within the socioeconomic system of which they are a part." From Lang's comments, we can learn that the need for privacy is consistent but that privacy norms vary based on culture and socioeconomic status.

The notion of territory is closely linked to privacy in terms of human behavior. There is a range of theoretical work concerning the name and number of territories within the home. One, developed by Clare Cooper (now Cooper Marcus) (1967),

Figure 1.2 The average new single-family home in the United States grew in size from 1950 to 2015 with brief interludes of reduction due to economic turmoil. Recent years have shown a decrease as noted here. Given housing costs, land availability, and environmental concerns, housing size may not continue to increase over time.

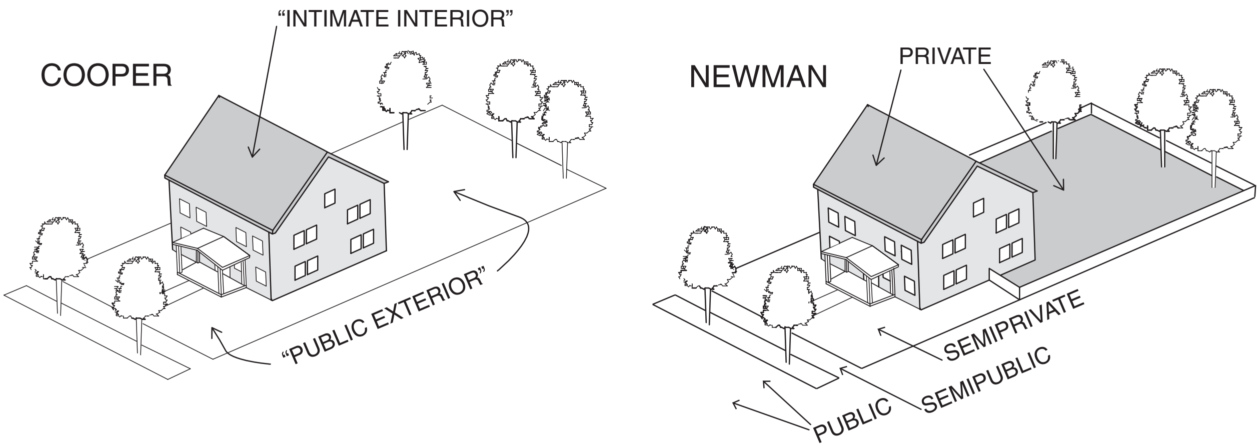

Figure 1.3 An illustration of territories identified by Cooper and Newman. Cooper identified a public exterior and an intimate interior. Newman identified public territories; semipublic territories such as sidewalks; semiprivate territories, and private territories, such as the private interior of a house or a fenced-in backyard.

describes the house as divided into two components: the intimate interior and the public exterior. Interestingly, Cooper later wrote *House as a Mirror of Self: Exploring the Deeper Meaning of Home* (1995), which traces the psychology of the relationship we have with the physical environment of our homes.

The term *defensible space* was coined by Oscar Newman in relation to his study of neighborhood safety and refers to "a range of mechanisms—real and symbolic barriers . . . that combine to bring an environment under the control of its residents." Defensible space, as described by Newman (1972, 9–23), includes *public*, *semipublic*, *semiprivate*, and *private territories*. Newman's work includes studies of various forms of housing (single-family attached, detached, high-rise, etc.) and the influence of the building type and design on territoriality and safety.

While there is variety based on housing type, Newman defined public spaces as streets, sidewalks, and those areas near or adjacent to the dwelling not possessed by any individual. Newman's semipublic spaces include those areas that may be publicly owned but are cared for by homeowners, such as planted parkways adjacent to sidewalks, whereas semiprivate spaces can include yards or spaces owned in association. (Some theoreticians include porches and foyers in this category.) According to Newman, private territory can include the interior of a home, fenced areas within a yard, or the interior of a student's dorm room. Private interiors are seen as distinct from private exteriors in Newman's work. In addition, Newman pointed to the need for some type of buffer between the public world and private interior.

In the years since Newman's original work defining defensible space and related territories, his theories have come under some criticism. However, his work continues to have implications for planners, architects, and interior designers because taking these concepts into account in designing homes can help to create spaces in which residents feel safe and have a sense of control over their immediate environment.

See Figure 1.3 for an illustration of territories as identified by theoreticians Cooper and Newman.

Rachel Sebba and Arza Churchman (1986, 7–24) studied the relationship between the home and territoriality, finding that viewing "the home as the individual's territory is related to viewing the family as a group and the dwelling unit as a socio-spatial system." Studying inhabitants of high-rise buildings in Israel, they identified the dwelling unit as a socio-spatial system and found that within apartments studied, there were three kinds of territorial areas: "those which belong to the whole family (public areas); those which belong to a sub-group within the family - parents or siblings (shared areas); and those which belong to individuals (individual areas)."

Sebba and Churchman also stated that the uniqueness of the home lies in it being the inhabitant's territory and that the home "can function as the individual's territory only if the individual has a defined area of space under his or her control." Finding that shared areas such as bedrooms could be divided into two individual areas by some type of boundary, they also noted that within shared areas particular pieces of furniture were identified as belonging to individuals. See Figure 1.4.

In *A Pattern Language*, Christopher Alexander and his colleagues described residential territories as falling along an "intimacy gradient" that involves a sequence of increasingly private spaces as shown in Figure 1.5. Alexander et al. (1977, 613) stated that spaces in a building should be laid out "so that they create a sequence which begins with the entrance and the most public parts of the building, then leads into the slightly more private areas and then the most private domains." Chapter 3 provides additional information about public and private spaces as related to entry spaces.

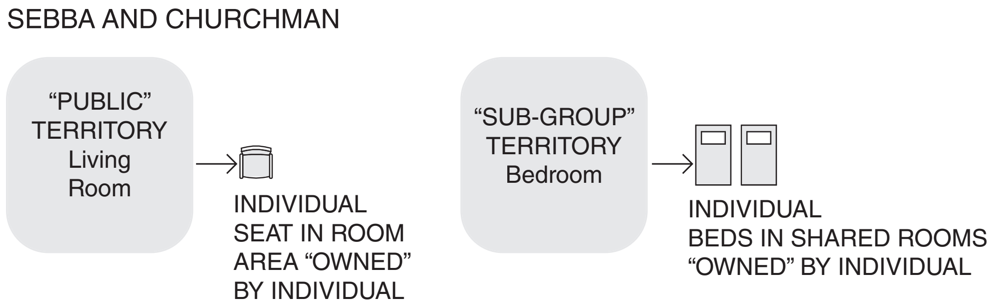

Figure 1.4 Sebba and Churchman described three areas within a home: "those belonging to the whole family (public areas); those belonging to a sub-group within the family - parents or siblings (shared areas); and those which belong to individuals (individual areas)." They also noted that within shared areas particular pieces of furniture were identified as belonging to individuals, for example, a chair within a shared living room can be seen as belonging to one member of the family.

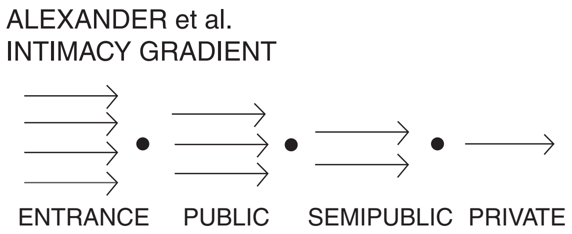

Figure 1.5 Alexander et al. describe an intimacy gradient that involves a sequence of increasingly private spaces moving from porch or entrance to bedrooms.

Personal space is a term introduced by Robert Sommer in the 1960s. According to Sommer (1969, 26), "personal space refers to an area with an invisible boundary surrounding the person's body into which intruders may not come." Sommer described personal space as being different from territory. Figure 1.6.

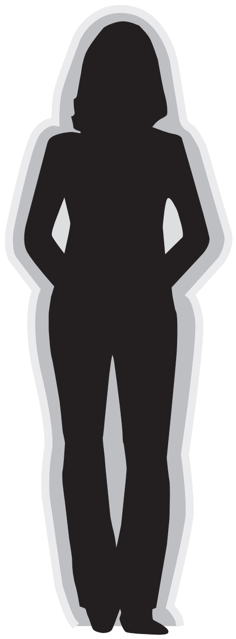

Figure 1.6 Robert Sommer's defined the term personal space, as referring "to an area with an invisible boundary surrounding the person's body into which intruders may not come." Sommer described this as aura-like rather than equally distant in all directions.

A similar-sounding term, *personal distance*, expresses a different concept and comes from work done by Edward Hall, an anthropologist who coined the term *proxemics*–for the "interrelated observations and theories of man's use of space as a specialized elaboration of culture" (1966, 1). While he noted these varied by culture, Hall (1966, 113–125) identified four distinct body distances or boundaries that people will maintain in varying social situations: *intimate, personal-casual, social-consultative,* and *public*. Each of the four types of boundaries has a close phase and a far phase, as described in Figure 1.7. Hall found that while spatial boundaries vary based on cultural differences, the concepts of intimate, personal, social, and public distances tend to be consistent cross-culturally.

Hall's term *personal distance* refers to the distance maintained between friends and family members for discussion and interaction, whereas Sommer's (1969, 26) term *personal space* refers to the invisible boundary around each person – which he also referred to as "breathing room." Similarly, Hall's *intimate space* is a "bubble" of space around a person that can be entered only by intimates, whereas *social-consultative spaces* are those in which people feel comfortable engaging in routine social interaction for business or in conversation with strangers. *Public space* is space with limited interaction where people are generally comfortable ignoring one another; this distance also allows one to flee when danger is sensed.

The emergence of COVID-19 led to widespread use of the term social distance or social distancing to indicate people spaced roughly 6 feet apart, which is within Hall's boundaries of social-consultative space and allows for social interaction.

Hall's spatial boundaries can be useful for designers in planning living spaces. For example, most casual social interaction in a residential setting takes place within personal distances. Later portions of this book focus on specific room-related dimensional information for encouraging interaction and creating privacy. It is also worth noting that in designing spaces that encourage interaction and help users attain privacy, it can be helpful to reference the work of social scientists such as Hall, Newman, Lang, and others.

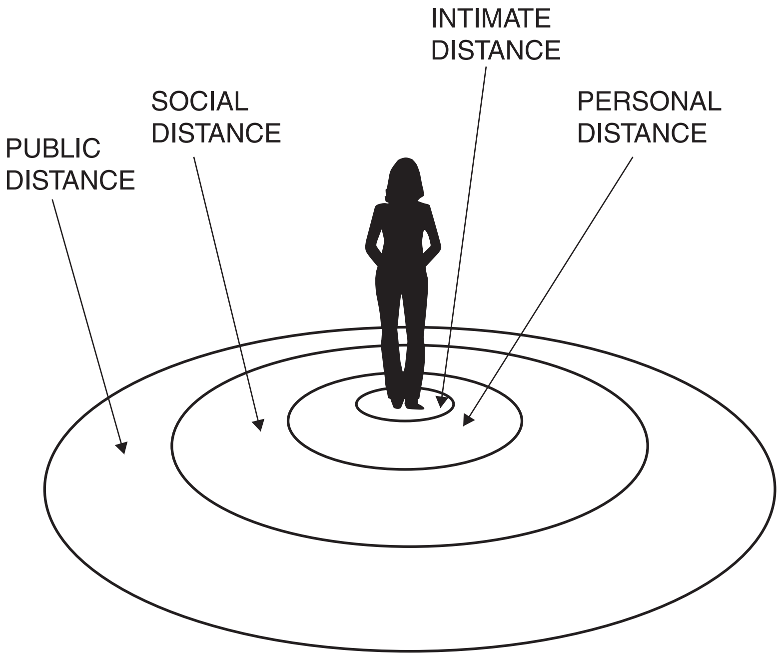

Figure 1.7 Edward Hall identified four distinct body distances or boundaries that people will maintain in varying social situations:

Intimate: 0 to 18 inches (0 to 0.5 m); *close phase* 0 to 6 inches (0 to 0.2 m), *far phase* 6 to 18 inches (0.2 to 0.5 m).
Personal-casual: 1½ to 4 feet (0.5 to 1.2 m); *close phase* 1½ to 2½ feet (0.5 to 0.8 m), *far phase* 2½ to 4 feet (0.8 to 1.2 m).
Social-consultative: 4 to 12 feet (1.2 to 3.7 m); *close phase* 4 to 7 feet (1.2 to 2.1 m), *far phase* 7 to 12 feet (2.1 to 3.7 m).
Public: 12 feet and beyond (3.7 m and beyond); *close phase* 12 to 25 feet (3.7 to 7.6 m), *far phase* 25 feet (7.6 m) and beyond.

It is important to keep in mind that there are cultural differences related to human behavior and housing. According to Delmar Jones and Joan Turner (1989, 27), "In most societies a house is more than a physical structure – it has social and cultural significance. Its very shape is often determined by cultural tradition, and it is saturated with cultural memories."

Many social scientists have studied housing and its relationship to culture. According to the Discover Anthropology website (2020), *Culture* can be described as "the sum total of a given people's beliefs, customs, knowledge and technology." Edward Hall (1973, 188) wrote that culture is "the link between human beings and the means they have of interacting with others."

Rapoport (1989, xii) stated that the variety of settings for housing is highly varied and that culture is what explains how similar needs for cooking, sleeping, and storing items lead to "many different solutions and settings." Rapoport (1990, 9) also wrote that culture and environmental design are "intimately related and that cultural differences must be considered in tracing environmental effects and in stating design requirements."

Writing about considering culture in the design process, Erve Chambers and Setha Low (1989, 4) noted there can be a difference in "cultural values, rules and perspectives of people who design and build housing and those who occupy housing." They describe this as "*cultural distance*" and state that "design failures can result from culturally inappropriate assumptions about the life-styles, needs and responses of the potential users." Low and Chambers (1989) also state that housing "design can be improved . . . when attention is paid to its cultural appropriateness."

Ethnography is one way to study culture and is used by designers and design theoreticians. Ethnography is a research methodology developed in the social sciences that involves personal observation in the study of a group or culture. Ethnographic studies can be a powerful design tool in that they allow insight into life experiences outside of one's own frame of reference.

Writing about North America, Galen Cranz stated, "Culture is not unified but rather, diverse. A 'normal house' in New Jersey is not the same in California or New Mexico–nor Florida or Minnesota" (2016, xv). Cranz continued by noting that in addition to regional differences there are class and cultural differences as well and "even within the same social class or culture there are age and gender differences." Making the case for the usefulness of ethnographic studies Cranz (2016) stated, "extrapolating from your own idea of a house to others' ideas might not be a surefire recipe for architectural success."

Designers can make use of previously conducted studies to inform design projects; additionally, design ethnographers can conduct studies that become central to the design process. According to Geke van Dijk (2011, 1), "Design ethnography is ethnographic qualitative research set within a design context. It delivers results that inform and inspire design processes."

In studying aspects of housing and culture, understanding the concept of *vernacular* housing can be helpful. Martha Henderson (1992, 15) observed, "vernacular architecture is an historical and geographical record of a culture group's relationship to physical and social environment." According to Allen Noble (2007, 7), the most precise definition of vernacular "refers to types of structures that occur in a limited area." The terms *traditional* dwelling or building and *folk* building are sometimes used interchangeably with vernacular (some social scientists argue that each of these terms has differing meanings).

Vernacular architecture is tied to the culture, physical characteristics, and resources of an area or region. Vernacular dwellings are often influenced by climate. Excessive heat, cold, flooding, tendency toward drought and high winds can all contribute to vernacular building form. Additionally, local materials and available resources have an influence on vernacular building design due to the fact that many of the building forms were in use prior to industrialization or globalization.

DEFINING HOUSING-RELATED TERMS

A variety of terms are used to describe housing, and understanding these can be helpful for designers. The terms house, home, and dwelling have been used and studied by social scientists, philosophers, and poets to convey different concepts related to the spaces in which we live. Additionally, some terms related to housing can relate to zoning, building codes, and legal issues. The following is a list of housing-related terms and definitions that may prove helpful to designers.

Housing-Related Terms

House

According to Coolen and Meesters (2011, 2), "in housing research, house is the word commonly used to describe the physical structure we live in." They also note that the term house "seems to be synonymous with the Western-type of single-family house." However, there is no general agreement about this. Chambers and Low (1989) identified three ways the term housing can be used. First, housing refers to those physical structures that shelter people. Second, the term is used within a design and environment context relating to shelter and the utility of the house. And third, they describe housing within an "environmental quality" profile, which adds an "evaluative dimension" to the study of housing." Importantly, Chambers and Low (1989, 5–6) state that there can be "no standard definition of the terms house or housing, and that in every instance these words must be understood as related to a particular cultural context and to the parameters defined for a specific research project."

Home

The term home can have a complex set of meanings associated with it. As Blunt and Dowling (2006, 3–4) wrote, "Home is hence a complex and multi-layered geographical concept. Put most simply, home is a place/site, a set of feelings/cultural meanings, and the relations between the two." The term home is often associated with attachment to a particular place and can be seen as describing our relationship to a physical structure and its surroundings and the meaning we relate to those things.

Janine Meesters (2006, 5) stated that dimensions of home include "home as a place that provides security and a place where people can be together with family and friends. It can also be a material structure reflecting personal status, identity, and the owner's ideas."

Within the social sciences, public policy, and design disciplines there is divergence in the meaning of the word home. According to Peter Somerville (1997, 228), sociological approaches focus "on issues of class, gender, tenure and age, while non-sociological approaches emphasize issues of territoriality, psychological needs and attachments and phenomenological connectedness."

Dwelling

Paul Oliver (1978, 7) states, "All houses are dwellings, but all dwellings are not houses. To dwell is to make one's abode, to live in, or at or on or about a place." He also states that *dwelling* is both "process and artifact" because it describes both the activity of residing in a place and the place or structure where the activity takes place.

Meesters (2006, 3) wrote that dwelling involves "two important elements: the place where the activities are performed (the residential environment and the actual dwelling) and the activities themselves." Stating also, "some everyday activities that are part of dwelling are cooking, sleeping, eating, and relaxing." She continues, "activities performed in and around the house and in the residential environment are an essential part of dwelling."

Residence/Residential

The term residence is also used to describe housing. This term can be used in the United States as a legal term to describe a place of domicile. Domicile can be defined as the place one establishes a home for legal purposes that may include voting, paying taxes, and area of governmental authority. Residential design is the term used to describe the design of living spaces. For legal purposes including zoning and building codes the term *residential* is used to describe areas where people live as distinct from areas intended for a business or commercial purpose.

Housing Studies

Housing studies is a term used to describe the study of a broad range of issues that impact housing. These issues include housing affordability, housing finance, homeownership, housing's role in the economy, housing policy, and housing's role within communities. Housing studies is interdisciplinary in nature involving those with expertise in fields such as political science, urban studies, history, social administration, sociology, geography, law, planning, and economics. Work done in housing studies can inform public policy by helping government and civic leaders make decisions.

AN OVERVIEW OF CHAPTER TOPICS

Generally, the remainder of this first chapter is organized in a manner that is similar to most of the following chapters covering individual rooms and spaces. The following sections introduce chapter focus areas, definitions, concepts, and organizing principles that will be used throughout this book.

INTRODUCTION TO ACCESSIBILITY NOTES

Throughout this book, content related to accessible design is noted separately yet included within each chapter in order to make it easy to reference.

Accessibility, Universal Design, Visitability, and Usability

The terms *accessible design* and *universal design* are sometimes used interchangeably; however, for the purposes of this book they are considered distinct. The nuances involved in using these terms are discussed below.

The term accessible was initially used to describe environments that do not present physical barriers for people with physical limitations, such as wheelchair users. The University of Washington, Center for Universal Design in Education offers the following definition:

> "Accessible Design is a design process in which the needs of people with disabilities are specifically considered. Accessibility sometimes refers to the characteristic that products, services, and facilities can be independently used by people with a variety of disabilities."

Generally, the design of private, single-family homes is not mandated by any current accessibility regulations except as noted later in this chapter. However, many homeowners seek residences that are accessible, either because they plan to "age in place" in the home (defined as growing older in one's home without having to relocate) or because they or a family member have current needs that warrant the design of accessible spaces. These two distinct scenarios present two distinct design criteria.

In cases where current physical or other limitations create the need for accessible spaces, the design should address the specific needs of the owner or family member. For example, designing a home for a specific person who uses a wheelchair requires meeting a set of appropriate criteria and guidelines, whereas designing a home for a person with a vision impairment requires considering a different set of standards and guidelines.

In contrast, designing a home for aging in place or for general accessibility requires making design decisions based on basic accessibility standards and guidelines. These are presented throughout this book as part of the body of each chapter, set apart and identified as an Accessibility Note. Incorporating accessibility information for each area is intended to provide readers with a comprehensive view of accessible design. Information about regulations and standards for accessibility is provided in the "Related Codes and Constraints" section of this chapter.

In cases where a home is intended to be wheelchair accessible, adequate clearance space must be provided for the chair as the user accesses items for daily activities; in addition, appropriate circulation space and turning space must be provided. Chapter 3 includes information about wheelchair-accessible circulation and clearance requirements. Additional detailed information is provided in each room-based chapter within these "Accessibility Note" sections.

The concept of universal design grew, in part, out of the accessible design movement, but is a broader concept. Ron Mace, an architect, product designer, and educator, is credited with coining the term. Ron Mace also established what is now the Center for Universal Design at North Carolina State University, which offers this insight into Universal Design:

> "The intent of universal design is to simplify life for everyone by making products, communications, and the built environment more usable by as many people as possible at little or no extra cost. Universal design benefits people of all ages and abilities."

Lever door handles are an example of universal design because these work well for people with limited hand mobility or strength, but also work well for many other people. The lever design does not limit use but extends it to the greatest possible number of people.

One approach to universal design in the home is to provide adaptable elements designed to offer greater flexibility for a range of occupants. For example, counters can be made so that they are adjustable to adapt for users of varying heights (including those using seats and wheelchairs). Adaptable cabinets can be designed with fronts and bases that can be removed to create a clear area underneath for use by someone in a wheelchair. Illustrations of both of these examples can be found in Chapter 5. Adaptable design is the umbrella term used to describe this approach, which involves creating design elements that can be easily adapted to become accessible.

To create a home that incorporates universal design principles, the features listed below can be included:

Residential Universal Design Features

- No stairs (at the entry or within the home).
- Wide doorways to allow for wheelchairs and general ease of movement.
- Wide hallways for wheelchairs and ease of movement.
- Extra floor space, especially in areas such as bathrooms and kitchens and around closets and utility areas, allowing for wheelchair use as well as extra space for movement.

Following the specific requirements for space for wheelchair movement included in the accessibility section of each chapter can aid in the creation of a home that meets universal design principles because it makes the home usable by a wide range of people.

Visitability is a concept that shares some commonalities with universal design concepts; it refers to creating homes that can be visited or accessed by people with physical disabilities and is sometimes called basic home access or inclusive home design. Visitable residences must meet three important criteria listed below:

Visitable Home Design Criteria

- At least one zero-step entrance approached by an accessible route on a firm surface no steeper than 1:12, proceeding from a driveway or public sidewalk.
- Wide passage doors: all main-floor interior doors, including the bathroom, must provide 32 inches (813 mm) of clear passage space.
- At least a half bath/powder room on the main floor (a full bath on the main floor is preferable).

Usability is a word that has meanings related to accessibility. The International Organization for Standardization (ISO) has defined usability as the "extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use."

Usability, also called usable design, can be tested and measured. While most often used in relation to electronics and communication, usability testing can be employed to test a range of products and environments. Although usability shares goals with accessibility and universal design, usability studies do not necessarily include testing of people with a range of abilities and are not necessarily conducted for the purpose of achieving universal design. According to the Center for Universal Design in Education's website, if "designers apply universal design principles, with a special focus on accessibility for people with disabilities, and if usability experts routinely include people with a variety of disabilities in usability tests, more products will be accessible to and usable by everyone." Table 1.1 is a side-by-side comparison of these accessibility-related concepts.

Federal Accessibility Regulations Governing Housing

In most cases federal accessibility regulations do not govern detached, private, and one- or two-family residential buildings. There are some federal regulations that may govern the design of multifamily dwellings as described in the following paragraphs.

The Fair Housing Act (FHA) was passed in 1968 as Title VIII of the Civil Rights Act of 1968, which prohibited discrimination in the sale and rental of housing as well as other housing-related transactions. The Act was amended with the Fair Housing Amendments Act of 1988 (FHAA), with requirements that new privately and publicly funded multifamily dwellings with four or more units provide basic accessibility to all units on the first floor and in all units in buildings with elevators.

Section 504 of the Rehabilitation Act of 1973 is a federal accessibility law that seeks to prevent discrimination based on disability, under any program or activity receiving financial

Table 1.1 Differences among Accessibility, Universal Design, Visitabiliy, and Usability

Term	Definition	Comment
Accessibility	The extent to which design specifically considers the needs of people with disabilities. Accessibility sometimes refers to characteristic of products, services, and facilities that can be independently used by people with a variety of disabilities.	Accessible and universal design both address the needs of users beyond those considered "average" or "typical." Accessibility can describe spaces that are accessible for a specific user's needs.
Universal design	The design of all products and environments to be as usable as possible by as many people as possible regardless of age, ability, or situation.	Accessible and universal design both address the needs of users beyond those considered "average" or "typical." However, universal design is a broader term meant to benefit users of all ages and abilities.
Adaptable Design	Adaptable dwelling units have accessible features that may be concealed or design elements that can easily be adapted to become accessible.	The term may also be used to describe buildings that are easily adaptable over a long life cycle.
Visitability	The extent to which new homes are designed so that they can be visited or accessed by people with physical disabilities.	Visitable homes incorporate concepts of universal design. Also known as basic home access or inclusive home design.
Usability	The extent to which products are easy and efficient to use.	While concerned with creating efficiency and ease of use, usability testing may not consider accessibility or the universal design of products because it may be focused on one specific type of user.

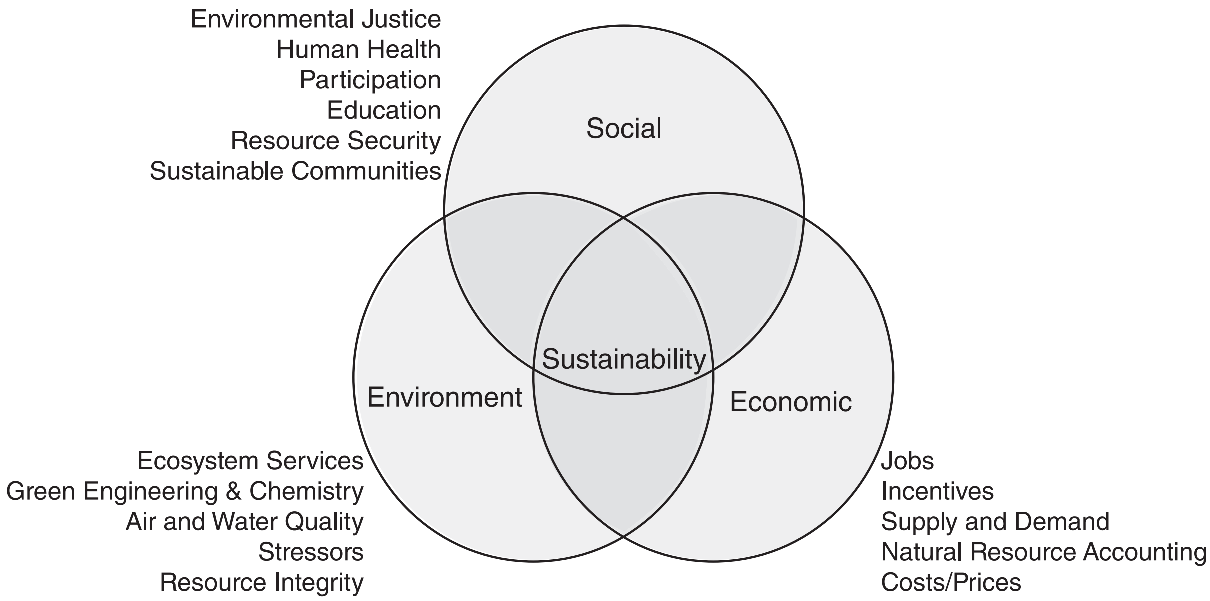

Figure 1.8a A Venn diagram illustrating the three interlinked sustainability systems. This version is adapted from the EPA's Sustainability Primer.

assistance from any federal agency, including the U.S. Department of Housing and Urban Development (HUD). Section 504 requires newly constructed multifamily dwellings with five or more units, and alterations of housing facilities in HUD-assisted programs, to meet the Uniform Federal Accessibility Standards (UFAS).

The American National Standards Institute standard ANSI A117.1 formed the basis for the first accessibility standards adopted by the federal government and many state governments. This standard continues to guide current accessibility standards. ANSI A117.1 provides standards for four types of dwelling units: Accessible, Type A, Type B, and Type C units. These standards relate directly to federal accessibility requirements; for example, Type B units are consistent with FHAA requirements, while Type A units are consistent with UFAS standards. A review of Type A and Type B standards will show that Type B standards are less strict; however, Type B standards are more broadly applied. Neither of these types is considered fully accessible for wheelchair users. Type C units incorporate visitability standards and are not currently mandated nationally but can provide a model for visitability.

Information about kitchen and bath layouts that meet ANSI standards for Type A and B units can be found in Appendix A.

The Americans with Disabilities Act (ADA) is civil rights legislation that includes federal accessibility design standards and guidelines. The ADA requires that public buildings (including those owned privately) be designed so that they accommodate people with disabilities. The ADA design standards, which were updated in 2010, share many similarities with ANSI standards.

While the ADA has significant implications for the interior design of public places and should be understood by the practicing designer, it does not directly impact the design of single-family homes – except in a small portion of housing built with public funding as well as some in lodging within hotels and some dormitories. The ADA has also had a direct impact on the availability of accessible plumbing fixtures, accessible cabinetry, and other items that can be used in residences. Additionally, the ADA Standards can be used as a starting point in the design of certain accessible residential features.

INTRODUCTION TO SUSTAINABILITY NOTES

Throughout this book, content related to sustainability is noted separately under this heading in order to make it easy to reference. This section provides an overview of current sustainable design practices and related background information.

Defining and Understanding Sustainability

Sustainable development was defined in the Brundtland Report in 1987 as: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

In 2015 the United Nations adopted a slate known as the 17 Sustainable Development Goals (SDGs), with a desire to achieve those goals by 2030. The 17 SDGs form a complex interconnected system that Barbier and Burgess (2017, 1–23) identified as three interlinked systems: social, economic, and environmental. This notion of three interlinked systems is commonly conceptualized in two ways: either as the "three pillars" of sustainability, or as illustrated by a Venn diagram with three intersecting circles with overall sustainably at the center as shown in Figure 1.8a. While now in common use, it is thought that this Venn diagram was first published by Edward B. Barbier.

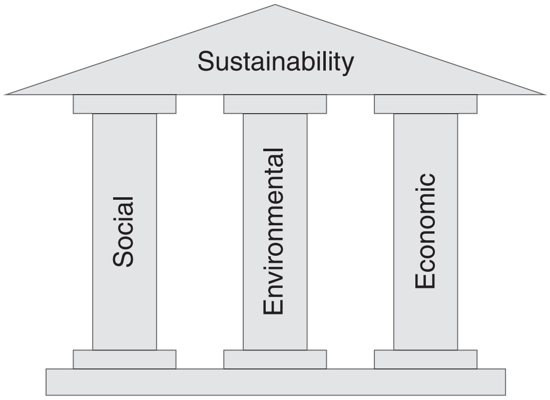

Figure 1.8b A diagram illustrating the three interlinked systems depicted as three pillars supporting sustainability.

The concept of three pillars of sustainability being social, economic, and environmental is widely recognized and is illustrated in Figure 1.8b.

According to the U.S. Environmental Protection Agency (EPA) Sustainability Primer, the goal of sustainability is to "create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations." The EPA (2015) also states that the three pillars approach allows us to "understand the interactions which exist among environmental, social, and economic pillars in an effort to better understand the consequences of our actions. Ideally, research that seeks sustainable solutions to protect the environment also strengthens our communities and fosters prosperity."

One can see the three pillars of sustainability as providing a broad, overarching systems approach that includes green design and green building. According to the World Green Building Council:

> "A 'green' building is a building that, in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on our climate and natural environment. Green buildings preserve precious natural resources and improve our quality of life."

Green Building Codes, Rating Systems, and Certification Programs

Several organizations have developed green building codes, rating systems, and certification programs; the following is a list of green building standards, rating systems, and certification programs within the United States.

Green Building Codes, Standards, and Certification Programs

ASHRAE 189.1 (short for ANSI/ASHRAE/USGBC/IES Standard 189.1) is a model code with requirements for increasing environmental health and performance of buildings. Where required it may be mandatory for all building types with the exception of single-family and multi-family homes of less than three stories as well as manufactured homes.

Building Research Establishment's Environmental Assessment Method (BREEAM) was the first green building rating system in the world and continues to be a global force in green building. BREEAM provides green building rating and certification through third-party verification (third-party assessment refers to those conducted by a party that has no financial interest in a product).

CALGreen is the name of the California Green Building Code, which was the first statewide mandatory green building code in the nation. Residential mandatory requirements include planning/design; water efficiency/conservation; material and resource efficiency; construction waste management; building maintenance and operation; environmental quality; detailed requirements for sealants, coatings (including paint), carpet (and carpet cushion), and other interior finishes and materials; interior moisture control; environmental comfort; interior air quality; and exhaust.

Green Globes Certification from the Green Building Initiative (GBI) is a rating assessment and certification program intended to encourage improved environmental and health performance for buildings. This program focuses on commercial and mixed-use buildings with only multi-family residential construction included (it is not oriented toward single-family residential).

The ICC-700 National Green Building Standard (NGBS) is a green building rating system for homes and multifamily buildings. NGBS grants project certification with six areas of high-performance building practices: lot design and development, resource efficiency, water efficiency, energy efficiency, indoor environmental quality, and building operation and maintenance. Home Innovation Research Labs™ is involved in NGBS certification; a link to their website can be found in chapter references.

The International Green Construction Code (IgCC) is a model code developed by the American Institute of Architects, ASTM International, and others in keeping with the American Institute of Architects 2030 Carbon Neutrality Goal.

The International Living Future Institute's Living Building Challenge is a certification system focused on transforming the design, construction, and operation of buildings. The Living Building Challenge encourages improved environmental and health performance and supports buildings that are a restorative, regenerative, and integrated component of the local ecology and culture. According to the website:

The Living Building Challenge consists of seven performance categories, or Petals: Place, Water, Energy, Health + Happiness, Materials, Equity, and Beauty. The equity refers to inclusion and universal access and beauty includes aesthetics and seeks incorporation of biophilic elements. The Materials category (petal) includes a "Red List" of materials containing toxins or harmful chemicals that has proven particularly helpful.

The International Living Future Institute also sponsors The ILFI Zero Energy Standard. The Institute certifies buildings as Zero Energy Building (ZEB) Certified through third-party verification. According to the website, certification "requires that one hundred percent of the building's energy needs on a net annual basis must be supplied by on-site renewable energy."

The International Well Building Standard is a performance-based standard and certification program that measures attributes of buildings that impact the health of occupants in ten areas: air, water, nourishment, light, movement, thermal comfort, sound, materials, mind, and community. The International WELL Building Institute (IWBI) delivers this standard.

Leadership in Energy and Environmental Design (LEED), the U.S. Green Building Council's (USGBC) green building certification system, is a set of green construction standards for certification that are widely recognized in the United States. There are also LEED standards for residential design and construction. According to the USGBC website: "LEED-certified homes are designed to provide clean indoor air and ample natural light and to use safe building materials to ensure our comfort and good health."

The Passive House Institute US (PHIUS) "Maintains the PHIUS+ climate-specific passive building standard, certifies and quality assures passive buildings, and conducts research to advance high-performance building. Buildings that meet the PHIUS+ standard use 40–60% less energy for space conditioning than conventional buildings" according to the Institute's website.

Note: In addition to providing certification of buildings and projects, many of the organizations listed here also provide accreditation/certification to professionals through testing and educational standards.

In addition to the green building codes, standards, and certification programs outlined in the previous list, a range of green product certification and standards programs exist. Green product certification can focus on a single attribute such as water, energy, or emissions. There are also multi-attribute programs that focus on life cycle parameters (life cycle assessment is described later in this chapter). Green product certification by third-party assessment tends to be the most reliable type of certification.

Table 1.2 lists some of the green product certification programs and services linked to the building industry.

Note: This is only a partial list and there are more industry specific certification organizations.

There are additional organizations involved in testing, certification, and writing standards. NSF is involved in testing and writing standards for a wide range of products including building products and furnishings. NSF's National Center for Sustainability Standards (NCSS) working in conjunction with ANSI created the following standards:

NSF/ANSI Standards Related to Interior Design Components

ANSI/BIFMA e3: Furniture Sustainability Standard (for commercial furnishings)

NSF/ANSI 140: Sustainability Assessment for Carpet

NSF/ANSI 332: Sustainability Assessment for Resilient Floor Coverings

ANSI/NSC 373: Sustainable Production of Natural Dimension Stone

ANSI/NSC 336: Sustainability Assessment for Commercial Furnishings Fabric

NSF/ANSI 342: Sustainability Assessment for Wallcovering Products

Life-cycle assessment

Life-cycle assessment (LCA) is a process that involves reviewing the total impact of a product's environmental cost over the *lifetime* of the product or building. A life-cycle assessment is an evaluation of the totality of the environmental consequences associated with a product or process.

The term *life-cycle* refers to the activities occurring in the course of the product's life span, including use of raw materials and their acquisition, production, shipping, installation, maintenance, and disposal. By evaluating all phases of a product's life span, this assessment can aid in avoiding shifting environmental impact to the future or to future generations. Many of the green building standards, regulations, standards, and certification assessment entities mentioned previously include consideration of life cycle assessment.

Increasingly, designers and the public are seeking full disclosure in review of building products within a life-cycle assessment approach. A number of labels and forms of environmental declaration are available and some of those can be found in the following list:

Environmental Declaration Information Systems and Labels

An EPD or Environmental Product Declaration is an independently verified and registered document that communicates transparent and comparable information

Table 1.2 Green Building Product Certification Programs and Services:

Certification	Product(s)	Agency/Sponsor	Description
Assure Certified	Rigid core luxury vinyl flooring	Resilient Floor Covering Institute (RFCI)	Third-party certification of indoor air quality (IAQ), product performance, and content.
Cradle to Cradle	Variety of products including textiles, fabrics, interior design–oriented items, and more.	Cradle to Cradle Products Innovation Institute	Provides third-party certification of products based on the Cradle to Cradle Design Framework.
Energy Star	Includes home appliances, heating and cooling equipment, lighting, home electronics, and more	Federal government (EPA and DOE) and partner organizations	Voluntary energy efficiency program. Includes Energy Star rating system for products as well as Energy Star certification for individual homes.
Floor Score IAQ Certification	Resilient flooring products	Resilient Floor Covering Institute (RFCI)	Third-party certification Items evaluated in relation to California Section 01350 (emissions criteria).
Forest Stewardship Council	Forests and forestry products (including wood building products)	Forest Stewardship Council (FSC)	Provides third-party certification of products.
Green Circle Certified	Products, building and operations, audits, compliancy, and more	GreenCircle Certified LLC	Multiple third-party certification and auditing services.
Green Label Plus	Carpet, flooring adhesive, and cushion products	The Carpet and Rug Institute	Independent laboratory testing. Items evaluated in relation to California Section 01350 (emissions criteria).
Green Seal	Variety of products including paints, adhesives, lamps, and more.	Green Seal	Provides third-party certification of products.
GREENGUARD	Indoor air quality, children's health, healthy schools.	UL Environment (a unit of UL Laboratories)	Provides third-party certification of products. GREENGUARD certified products are listed in the UL SPOT database.
GreenSquared	Tile and tile installation	Tile Council of North America (TCNA)	Third-party certification, tied to ANSI A138.1.
WaterSense	Showerheads, toilets, faucets, urinals, and valves.	Federal government (EPA)	WaterSense-labeled products meet EPA's specifications for water efficiency and performance.

about the life-cycle environmental impact of products. Available for free download on the International EPD System website.

Certified Environmental Facts (CEF) are labels generated by GreenCircle Certified focused on building products. These included information about recycled content, material sourcing, carbon, emissions, and LCA content. These labels also include information about whether product EPDs or HPDs are available. GreenCircle also offers Certified Sustainability Facts (CSF), which relate to food products.

Declare is a product declaration label from the International Living Future Institute (ILFI) with program alignment to the Living Building Challenge. Handprint is another tool from ILFI that certifies the positive impacts of products, tied to the Living Product Challenge.

An **HPD or Health Product Declaration** provides disclosure of product contents and associated health information for products used in the built environment. The Health Product Declaration (HPD) Open Standard is a defined specification standard format overseen by the Health Product Declaration Collaborative (HPDC).

Note: Many of the listed declarations are aligned with LEED or ILFI and summarize complex information within a simple label system modeled on the common nutrition labeling system.

Global Warming, Climate Change, Carbon, and the Built Environment

According to NASA (2021), the term global warming refers to the long-term warming of the planet. Whereas climate change "encompasses global warming but refers to the broader range of changes that are happening to our planet." NASA describes the greenhouse effect as "the way in which heat is trapped close to the surface of the Earth by 'greenhouse gases.' These heat-trapping gases can be thought of as a blanket wrapped around the Earth, which keeps it toastier than it would be without them. Greenhouse gases include carbon dioxide, methane, and nitrous oxides." The abbreviation GHG is sometimes used for greenhouse gases.

As stated by the EPA, "carbon dioxide (CO_2) is the primary greenhouse gas emitted through human activities." And, according to NASA, "Humans have increased atmospheric CO_2 concentration by more than a third since the Industrial Revolution began. This is the most important long-lived 'forcing' of climate change."

Given the impact of carbon dioxide on climate change, a careful look at the impact of carbon used in the building industry is required. The need to emit less carbon into the atmosphere is factored into life cycle assessments of construction and requires that we consider both embodied carbon and operational carbon defined in the following list along with additional related terms:

Terms and Concepts Related to Carbon Dioxide

Operational carbon refers to carbon dioxide emitted during the in-use or operational phase of a building. This includes all of the energy used to heat, power, and operate a building.

Embodied carbon refers to all of the carbon produced in the manufacture, transportation, and installation of construction materials. According to the Architecture 2030 website, "The embodied carbon emissions of building products and construction represent a significant portion of global emissions: concrete, iron, and steel alone produce ~9% of annual global GHG emissions; embodied carbon emissions from the building sector produce 11% of annual global GHG emissions."

Carbon Footprint refers to the total carbon emissions produced by an event, individual, or product.

Carbon Neutral refers to situations, settings, or products that make no net release of carbon dioxide to the atmosphere. This can be done with carbon offsets or by eliminating carbon emissions.

Carbon Negative describes a product, or entity with a carbon footprint that removes more CO_2 than it creates, making the carbon footprint less than neutral. Also called Carbon Positive.

Carbon Offset describes a reduction in the emission of CO_2 meant to compensate for an increase caused by a situation, setting, project, or product. Often this is done by the funding of projects that remove CO_2 from the environment to offset emissions created from another project or activity.

The Embodied Carbon in Construction Calculator (EC3) Tool is an open-source tool for building professionals and policymakers to use to compare and reduce embodied carbon emissions from construction materials.

Zero-energy building (ZEB), net-zero energy building (NZEB), zero-energy building (ZEB), zero net energy (ZNE) building, and net zero building are all terms used to describe buildings that produce enough renewable energy to meet their own annual energy consumption requirements.

Whole carbon refers to the sum of operational carbon added to embodied carbon. All carbon emissions related to building operation and construction is necessary to meet the goal of reducing all carbon emissions.

To learn more about embodied carbon, visit Architecture2030.org. For more information about the EC3 Tool, visit the Building Transparency website (buildingtransparency.org).

Issues mentioned thus far regarding sustainability, green building, and carbon emissions are not specific to the design of houses but are included to provide clarity and background for those beginning a study of design and green building. While there are not currently many mandatory green codes regulating private residential design outside of California, residences should not be overlooked in terms of environmental impact. Many homeowners have an interest in incorporating sustainability and limiting carbon emissions in the design of new and remodeled homes. Many of the green building codes, standards, and certification systems point the way to healthier indoor air quality and therefore can have a very positive impact on the interior of a home.

ERGONOMICS AND REQUIRED CLEARANCES

The field of study known as *anthropometrics* provides detailed information about the dimensions and functional capacity of the human body. According to authors Julius Panero and Martin Zelnik (1979, 23), anthropometry is "the science dealing specifically with the measurement of the human body to determine differences in individuals, groups, etc." *Ergonomics* is the application of human-factors data, including anthropometric data, to design. Specific ergonomic information and information related to clearance space required for furniture, fixtures, and equipment is included in each chapter.

Chapter 3 is devoted to circulation space; the focus of that chapter is movement from room to room. The discussion of room-specific circulation is covered within each chapter.

The introductory discussion of proxemics earlier in this chapter described Edward Hall's finding that human spatial boundaries vary from one culture to another; readers should note that the clearances and ergonomic information provided throughout this book represent North American norms rather than reflecting a worldview. This is particularly true of dining and leisure spaces.

Many chapters also provide furniture and appliance sizes; these, too, are based on items currently available in North America.

ORGANIZATIONAL FLOW

The authors use the term *organizational flow* to refer to the use of activity areas or elements within a room in relation to *traffic flow* or *circulation* and use. For example, in designing a kitchen, the designer must consider the various activity areas (such as cooking, cleanup, and preparation) and the ease of their use, as well as circulation within the room and to other areas within the residence. Each room or area in a home typically serves a distinct purpose, and the design of the room must support that purpose in order for the room to function well.

When considering organizational flow, the designer must review the range of uses of the room and make design decisions that support those purposes. For example, bedrooms are used for sleeping but also have other uses, such as clothing storage (in closets and dressers); the flow of the room should support both sleeping and accessing stored items as well as additional activities that occur within the room, such as watching television or working on a computer. Such issues of organizational flow are discussed in detail in the various chapters of this book.

RELATED CODES AND CONSTRAINTS

Building codes, zoning regulations, and fire, health, and safety codes all influence the design of buildings and their interior elements and provide constraints to the overall design. A basic understanding of the codes and regulations that affect residential design is required as projects are undertaken.

Previously in this chapter the term standard has been used and it is useful to define the meaning of the words code and standard. According to Stephen Quarles and Kelly Pohl (2018) writing for the Headwaters Economics research group:

> "*Codes* are model sets of rules recommended by experts and informed by research. Codes can be adopted by state or local jurisdictions as-is or customized for local conditions to become law. Codes explain *what* needs to be done."
>
> "*Standards* include definitions, procedures for testing materials, and technical guidelines. They are intended to provide standardization and a common reference, explaining how to meet minimum requirements referenced in a building code."

Building codes generally govern the construction of buildings based on the type of occupancy intended for the building. This means that residences are generally regulated by standards different from those regulating public spaces, and public spaces are regulated in varying ways based on intended use. Building codes are adopted by cities, states, and/or municipalities and, in rural areas, often by county agencies. In some cases, states adopt a statewide residential building code; however, codes adopted within states often can vary. Additionally, states and municipalities can add local requirements or amendments to generally adopted model codes to allow for incorporation of regional variation or geographic factors.

In 2000, various code entities came together to form the International Code Council (ICC) and to develop the International Building Code (IBC), which was written to serve as a consolidated model code for commercial and public buildings. Many states and municipalities have adopted the IBC, although it is not currently as consistently adopted as the name implies.

ICC also publishes related codes, including the International Residential Code (IRC), which is used in the regulation of one- and two-family homes, the International Mechanical Code, and the International Plumbing Code. See the "Electrical and Mechanical" section of this chapter for related information about electrical code requirements called for by the IRC, Section E. The IRC does not cover multifamily dwellings, dormitories, apartments, nursing homes, or assisted-living facilities; these are covered by the IBC.

Throughout this book, the International Residential Code (2021 edition) is the code that is referenced. Referencing this single code is useful for purposes of clarity; however, not all locales or code jurisdictions have currently adopted this code, and this code does not regulate multifamily housing. Therefore, prior to beginning any project, the designer must research local codes and all related regulations.

Zoning regulations control building size, height, location, setbacks, and use. These regulations are adopted by local municipalities and vary greatly throughout the United States. In some areas, there are very strict zoning codes that control many facets of a building's design; in others, there are few zoning restrictions. As with the building code, zoning regulations should be researched prior to beginning the design of any project.

Tiny Houses, Accessory Dwelling Units (AUDs), and Cohousing

A range of societal factors fuel a current interest in housing options that move beyond the traditional single-family or multi-family housing. Factors such as the lack of affordable housing, high land costs, and the need for social connection have led homeowners to seek innovative housing options. Because zoning regulations control building size, height, location, and use, these regulations can limit flexibility with less traditional forms of housing.

Prohibitive housing and land cost as well as limited available housing stock have led a number of cities to modify regulations to allow two or three units per residential lot in areas that were previously zoned single-family residential. There is not universal acceptance of these changes in zoning due to concerns area homeowners have about density and property values. However, given the lack of affordable housing in many areas, it may be that easing of zoning restrictions and acceptance of non-traditional housing options will continue. The following is a list of types of housing that are increasingly in use:

Accessory Dwelling Units/ADUs:

An accessory dwelling unit is a legal and regulatory term for a secondary dwelling unit that shares a lot with a primary (often larger) home; these are often referred to as ADUs. Tiny homes on foundations, living units over garages, basement and attic apartments are all considered ADUs. These go by various names such as granny flat, in-law units, and carriage houses.

Many areas are changing zoning policies to allow ADUs in residential areas and are issuing building and design standards for ADUs. While standards vary greatly, restrictions on ADUs may include building size, required parking areas, lot size, setbacks, and requirements for owners (or relatives) to occupy the units.

It is possible changes in zoning policy will continue in the future so that ADUs can provide affordable housing.

Tiny Houses:

Tiny houses are micro-homes that may be set on a foundation or on wheels. Interest in these has grown to the point that there is now content in the International Residential Code that governs tiny houses (Appendix AQ of the 2021 IRC), which defines a tiny house as 400 square feet (37 m^2) or less–excluding lofts. While regulations vary, tiny houses on foundations can be considered single dwelling units or ADUs. Various states and municipalities have regulations on room size, ceiling height, plumbing, egress, and other issues similar to those discussed in the code section of this chapter.

Tiny houses on wheels are classified as recreational vehicles and many communities have zoning regulations or laws prohibiting long-term occupation of recreational vehicles on residential lots. Additionally, some RV parks do not welcome tiny homes.

Cohousing:

Cohousing is community-based housing typically consisting of common spaces shared by community members surrounded by private homes. Shared community spaces often include a common house with a large kitchen and dining room, laundry, and entertainment areas with courtyards, outdoor walkways, gardens, and parking. According to the Cohousing Association of the United States' website, "The physical design of a cohousing community encourages both social connection and individual space. Private homes contain all the features of conventional homes; however, residents also have access to extensive common amenities such as open space, courtyards, and a common house with kitchen dining, entertainment and laundry facilities."

While cohousing typically includes private homes, those homes tend to be smaller than average, but share common spaces that may be designed to include a community kitchen, dining, laundry, and outdoor spaces. The first modern cohousing community was built in Denmark in 1972 and in the ensuing years cohousing has become a world-wide movement. Cohousing can be seen as environmentally sustainable due to sharing land and resources and is also increasing in popularity due to a desire for social connection and community cost savings.

Additional codes and regulations that govern the design of buildings include energy codes and fire and flammability standards. There are additional standards developed by testing agencies that are incorporated into model codes and federal regulations. Such testing agencies include the American National Standards Institute (ANSI) and ASTM International (formerly the American Society for Testing and Materials). The National Fire Protection Association (NFPA) publishes many fire-related codes and standards, including the National Electrical Code for One- and Two-Family Dwellings.

Current trends in housing development include rapidly increased building in wildland-urban interface (WUI) areas. These are areas where housing and burnable vegetation meet – often at the edges of wildlands. According to Headwaters Economics research group authors Quarles and Pohl, "Wildfires in the U.S. are bigger and burn longer than just a few decades ago, and danger to communities is increasing. Since the 1990s, the average acreage burned in U.S. wildfires has more than doubled." These wildfire risks have led to adoption of fire codes in at-risk communities.

In areas with wildfire risks and high fire hazard severity, residential buildings may be governed by fire codes, zoning regulation, or landscape ordinances. Such codes and ordinances govern vegetation location relative to the building (to create fire-safe landscaping) as well as exterior building materials including roofing, siding, eaves, soffits, decks, fencing, and patio covers. Additional concerns in areas with wildfire hazard severity are the design of vents, doors, windows, rain gutters, chimneys or stovepipes, water supply, and driveway design.

Three of the most widely used construction codes for wildfire prone areas are: the ICC's Wildland-Urban Interface Code (IWUIC), the National Fire Protection Association Standard for Reducing Structure Ignition Hazards from Wildland Fire (NFPA 1144), and Chapter 7A in the California Building Code (Materials and Construction Methods for Exterior Wildfire Exposure).

State and local codes may also regulate housing design and construction in areas subject to specific natural disasters beyond wildfire. Based on geographical zones the IRC includes provisions for hurricanes, termites, flooding, earthquakes (seismic regulations), and wind. Many code requirements related to flooding are based on zones developed by the Federal Emergency Management Agency (FEMA). These commonly use Base Flood Elevation (BFE) in identified zones to set requirements for elevating homes on piles. BFE is defined by FEMA as "The elevation of surface water resulting from a flood that has a 1% chance of equaling or exceeding that level in any given year."

MORE ABOUT THE INTERNATIONAL RESIDENTIAL CODE

As stated previously, the IRC regulates one- and two-family residences and is therefore referenced in this book. All notes about code requirements relate to new construction unless otherwise noted. In order to understand more about codes as they relate to each room within a house, it is worthwhile to cover some key concepts in advance.

For example, the IRC defines habitable space as "a space in a building for living, sleeping, eating or cooking," which means that the rooms within a home in which those activities are conducted must follow the guidelines as required throughout the code for habitable spaces. Note that the IRC does not include bathrooms, toilet rooms, closets, halls, and storage or utility spaces in the list of "habitable spaces"; therefore, those follow different guidelines.

In addition, the following sections specify other requirements.

Section R303 of the IRC covers light, ventilation, and heating:
It requires that all habitable rooms shall have a certain quantity of glazing areas (also known as windows) of "not less than 8 percent of the floor area." This means that the aggregate size and number of windows in rooms is controlled by the floor area and required by the IRC.

Natural ventilation is to be provided through windows, doors, louvers, or other approved openings, with a required minimum openable area to the outdoors of not less than 4 percent of the floor area. The 2021 IRC includes exceptions when specific mechanical ventilation systems are installed.

Section R304 of the IRC covers minimum room areas:
Each habitable room in every dwelling unit shall have a gross floor area not less than 70 square feet (6.5 m^2) and a minimum dimension not less than 7 feet (2,134 mm). Kitchens are the exception to this requirement.

Section R305 of the IRC covers ceiling height:
"Habitable space, hallways and portions of basements containing these spaces shall have a ceiling height of not less than 7 feet (2,134 mm)." Minimum listed ceiling height for toilet areas,

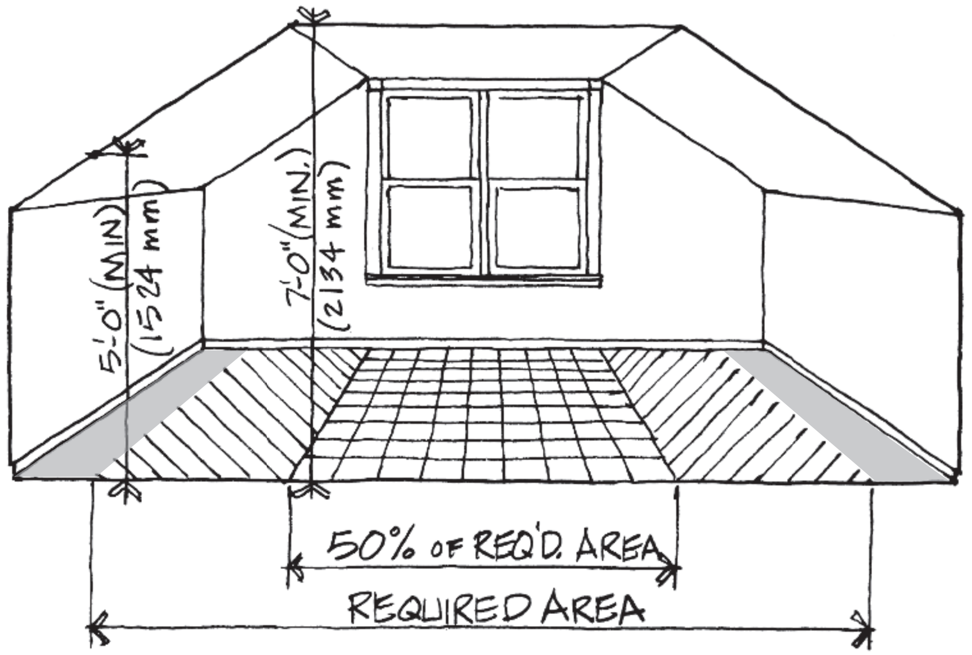

Figure 1.9 IRC-required floor area in sloped ceiling situations: R305 calls for hallways and habitable rooms to have a ceiling height of "not less than 7 feet (2,134 mm)." It also states that no more than 50 percent of the required floor area of spaces may have sloped ceilings less than 7 feet (2,134 mm) in height and requires that no portion of the required floor area be less than 5 feet (1,524 mm) in height. There are exceptions to this requirement related to exposed beams. Ceiling height also has an effect on room area; R304.3 requires that portions of a room with a sloping ceiling measuring less than 5 feet (1,524 mm) do not contribute the minimum required habitable area for that room (shaded here).

bathrooms, and laundry rooms is 6 feet, 8 inches (2,032 mm). There are exceptions for beams and girders in basements, where 6 feet, 4 inches (1,930 mm) is allowed. The 2021 IRC includes additional ceiling height exceptions for beams and girders based on spacing.

Another important exception to the ceiling height requirements states that for "rooms with sloped ceilings, the required floor area of the room shall have a ceiling height of not less than 5 feet (1,524 mm) and not less than 50 percent of the required floor area shall have a ceiling height of not less than 7 feet (2,134 mm)." This is illustrated in Figure 1.9.

Fire sprinklers and alarms are covered as follows:

Section R 313 of the IRC covers automatic fire sprinkler systems and requires that new residential townhouses and one- and two-family dwellings shall have fire sprinkler systems. However, as of this writing, only Maryland and California require residential fire sprinklers in *all* new one- or two-family homes.

Section R314 covers smoke alarms and states that the following rooms must have alarms: sleeping rooms, outside of sleep areas, on each additional story of the dwelling, not less than 3 feet (914 mm) from the door of a bathroom containing tub or shower and in open hallways.

Section R315.2.1 states that carbon monoxide alarms are required in dwelling units where there is a fuel-fired appliance and/or in cases where the dwelling unit has an attached garage with an opening that communicates with the dwelling unit.

The code issues mentioned to this point relate to single-family homes, which are governed by the IRC. Additional code requirements for specific rooms and locations will be given in each chapter.

ELECTRICAL AND MECHANICAL

Electrical and mechanical issues are covered in each chapter as they relate to individual rooms and spaces. With that said, there are some general rules for locating electrical switches and convenience outlets, with typical exceptions being in kitchens, bathrooms, and utility spaces. In most other locations, the on/off switches for overhead or general lights are best located close to the room entry door on the latch side of the doorway when possible. In larger rooms with more than one entrance, a second on/off switch can be employed in another convenient location; this is called a three-way switch. Where a number of light fixtures are used for general lighting, a single switch can be used to control several fixtures and outlets.

The IRC (Section E3903.2) requires that "At least one lighting outlet controlled by a *listed* wall-mounted control device shall be installed in every habitable room, kitchen and bathroom. The wall-mounted control device shall be located near an entrance to the room on a wall." One exception to this requirement is "in other than kitchens and bathrooms, one or more receptacles controlled by a listed wall mounted control device

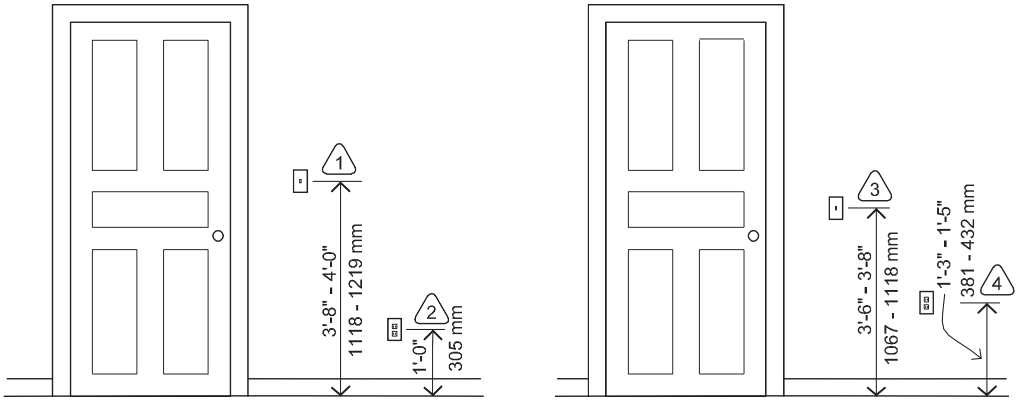

Figure 1.10 Switching and outlet locations for standing adult and seated (wheelchair) users.

1. Standard switch placement is convenient to the latch side of the door and centered at 4 feet (1219 mm) above the floor.
2. Standard wall outlet placement is one outlet for each 12 lineal feet (3,658 mm) of wall in general living spaces. Actual locations in individual rooms will vary based on room design and possible furniture arrangement.
3. For wheelchair users, switches are best located centered 3 feet, 6 inches to 3 feet, 8 inches (1,067 to 118 mm) above the floor and never higher than 4 feet (1,219 mm) above the floor.
4. For wheelchair users, wall outlets are best placed 1 foot, 3 inches to 1 foot, 5 inches (381 to 432 mm) above the floor and never lower than 1 foot, 3 inches (381 mm) above the floor.

Note that wheelchair users require a clear floor space that is 30 inches by 48 inches for chair access to outlets, switches, and environmental controls.

considered equivalent to the required lighting outlet." The term *listed* refers to equipment, materials, or services that meet identified standards.

The IRC (Section E3903.3) requires additional locations for a wall-switch-controlled lighting outlet in hallways, stairways, and attached and detached garages with electric power. This section of the code also requires that a wall-switch-controlled lighting outlet be installed on the exterior of egress doors with grade-level access.

The on/off switch should be mounted 44 to 48 inches (1,118 to 1,219 mm) above the floor. Because there are two receptacles, typical household electrical outlets are referred to as duplex outlets or duplex receptacles. These outlets are commonly placed about 12 inches (305 mm) above the floor, as shown in Figure 1.10.

A general rule of thumb for electrical outlet placement is one duplex receptacle per 12 feet (3,658 mm) of wall space in order to avoid the use of extension cords. (Standard appliance cords are often 6 feet [1,829 mm] long.) Following such rules can be a good starting point; however, the placement of outlets must be considered in relation to the design and layout of the room. It is important to consider the various possibilities for furniture placement so that the outlets can be designed in a way that is useful for a variety of scenarios. The IRC (Section E3901.2.1) requires that most rooms receptacles be installed so that "no point measured horizontally along the floor line is more than 6 feet (1,289 mm) from a receptacle outlet." Kitchens, laundry areas, and bathrooms have specific code requirements, and these are covered in those respective chapters. Outlet requirements for hallways and foyers are covered in Chapter 3.

Accessibility Note

Switching for Wheelchair Users

The standard placement of outlets (12 inches [305 mm] off the floor) is rather low for wheelchair and other users. For these users, outlets are best placed between 15 and 17 inches (381 and 432 mm) off the floor, and wall switches should be placed no higher than 48 inches (1,219 mm) off the floor, as shown in Figure 1.10. Wall outlets should be located no lower than 15 inches (381 mm) from the floor and frequently used controls should be within the 24- to 48-inch (610–1,219 mm) range. This is also true for environmental controls such as thermostats and alarm systems. It is worth noting that placing controls and receptacles at these heights meets universal design criteria and adds no extra expense, making it worth considering on many projects.

Note that wheelchair users require a clear floor space that is 30 inches by 48 inches for chair access to outlets, switches, and environmental controls. Additional information about this clear floor space requirement can be found in Chapter 3.

The term *mechanical* is an umbrella term used to describe the heating, ventilation, air-conditioning (known together as HVAC), and plumbing elements of a building. With very few exceptions, all residences in the United States are required by code to be heated; for example, the IRC (R303.10) calls for heating to a minimum of 68°F (20°C) when the winter temperature is below 60°F (15.5°C). Cooling may not be required by code, but in many parts of the country, most people consider it necessary.

The most common solution for providing heat is a furnace that burns a fossil fuel (such as natural gas, liquid propane, or heating oil) and less commonly wood, charcoal, or coal. Alternatively, some furnaces derive heat from electric resistance coils or a heat pump. In almost all cases, the furnace uses a fan that moves air, via ducts, to the various rooms where heat is required. This type of system can be equipped to clean the air, with the use of filters; humidify; and, with the addition of a compressor or condensing unit, to cool the air, which in the process dehumidifies the air.

Other heating systems are available, such as a boiler that heats water in tandem with a pump that moves the heated water to a baseboard convector unit; a similar result can be achieved with electric resistance baseboard units. Hot water can also be delivered to radiant heating pipes located in the floors of a residence, with similar results achieved with resistance heating in the floors. None of these methods accomplish the cooling, cleaning, and dehumidifying that forced-air systems allow; these must be achieved through the use of separate equipment.

Air-to-air heat pumps are commonly used in temperate climates; these remove heat from the inside air in warm weather and work in reverse to provide heat to the interior during colder weather. In these systems, air is delivered much like the forced-air systems described previously.

Increasingly, consumers are seeking alternative sources for heating and cooling homes. Geothermal heat pumps use the relatively constant temperature of the soil, the groundwater, or surface water as a heat source for a heat pump that can provide heating and cooling. These systems use tubing submerged in the soil or a nearby lake or pond. Many consumers find the initial higher cost of geothermal heat pumps offset by energy savings and special tax incentive programs.

While the systems described here most commonly rely on fossil fuel for heating and cooling, solar energy is increasingly used to heat and power homes. According to the Solar Energy Industry Association (2020) the "U.S. solar market installed 3.6 gigawatts (GW) of new solar photovoltaic (PV) capacity in Q1 2020, representing its largest first quarter ever in the United States" and "solar accounted for nearly 40% of all new electricity generating capacity added in the United States."

Another method of decreasing reliance on fossil fuels for heating and cooling is passive building also known as passive house principles. Passive building techniques employ a set of principles that can attain extremely high levels of energy efficiency through super insulation, airtight construction, high-performance windows, and other methods. These buildings are designed and constructed so as to require minimal energy for heating or cooling.

A great deal of information is available on designing solar energy, passive house design, as well as geothermal heating and cooling systems. These areas are clearly not the purview of this book, but designers are encouraged to seek additional information about these systems.

While interior designers are not responsible for the design of heating, ventilation, and air-conditioning systems, they should understand the various types of systems and their impact on the design of interior spaces. For example, knowing that hot water heat may require the use of baseboard convector units and that the location of such units will have a direct impact on the design and layout of interior spaces is useful.

Forced-air systems require the use of return-air grilles and supply-air registers/diffusers. These are available in a range of styles and in types such as baseboard, wall, floor, and ceiling units. Location of these items has an impact on the layout of a room and the level of comfort found there; for example, a favorite seating location that receives a constant blast of air will not remain a favorite for long. In addition, the visual qualities of grilles, diffusers, and registers should be in keeping with the overall design intent of the project. Placement of grilles, diffusers, and registers in relationship to trim and architectural details is also worth careful consideration.

With the ever-increasing use of connected devices within the home, the wiring of homes for data and communications is worth considering in the design of homes and individual rooms. For more information about data and communications wiring see the "Smart Homes and the Internet of Things" section of this chapter.

Lighting

Information about lighting specific rooms and spaces is provided in this book as a means of acquainting students with basic concepts related to planning and design. In no way is the information provided intended to be a significant source of a student's lighting design education. Instead, the information offered is introductory in nature and related to the overall design of rooms and spaces. So that the student can understand and work with the information provided in each chapter, an overview of terminology and basic lighting concepts is provided here. The references at the end of this chapter include lighting design publications helpful for more in-depth study.

Types of Lighting

Types of lighting discussed for various rooms include ambient, accent, task, and decorative lighting as described in the following list and illustrated in Figure 1.11.

Types of Lighting

Ambient Light

Provides general illumination that renders a uniform light level throughout the area or room. One option for creation of ambient light is indirect lighting, which describes light that arrives at a given surface after being reflected from one or more surfaces. This tends to cause less glare than downlights. Downlights are defined as lighting sources that direct light downward. These can be used to create ambient light; however, dark ceilings can make this type of lighting less ineffective. Indirect lighting tends to cause less glare than downlights.

Accent Lighting (Also referred to as Focal Lighting)

Illuminates features, objects, and/or specific areas. This type of lighting accents items or creates focal points and can add a level of interest to the general or ambient lighting. Well-planned accent lighting puts the focus on the desired objects rather than on the light source or fixture. Generally, using only accent lighting in a room without giving thought to ambient lighting creates clusters of darkness within rooms.

Task Lighting

Aids in performing work and specific tasks. In residences, many of these tasks are performed at table or counter height, requiring that the work surface be illuminated. Considering the types of tasks performed and the body positions required to complete them helps the designer make choices about task lighting. For example, at kitchen counters and worktables, the human body or head, creating shadows on the work surface rather than illumination, blocks light coming directly from the ceiling.

Decorative Lighting

Is ornamental in nature and provides interest based on its design and material qualities. Unlike accent lighting, decorative lighting functions to show itself off and make a visual statement. Decorative lighting can be used to accent elements and spaces or to add interest to ambient and in some cases task lighting, yet its function is typically secondary to the visual impact of the light source itself.

More Lighting Basics and Lighting Terminology

Understanding a variety of concepts and terms is helpful in developing an understanding of lighting basics. The following list includes lighting concepts and terminology.

Basic Lighting Concepts and Terms

Glare, which the Lighting Research Center at Rensselaer Polytechnic University defines as "loss of visibility and/or the sensation of discomfort associated with bright light within the field of view." There are two types of glare: direct glare, which results from bright light in the field of view, and reflected glare, which results from reflections in the field of view (including surfaces and reading material). Locating light sources out of the line of vision or shielding them in some manner can prevent direct glare. Reflected glare can be minimized by using less reflective surfaces and placing the light source so that it is not directly above but rather at an angle to the surface and/or viewer.

Lumen is a term used to describe the level of light (or brightness) gained from a lamp; it is a technical term measuring the luminous flux. Increasingly, a consideration of lumens produced is replacing a consideration of wattage; watts measure the energy consumed rather than the light

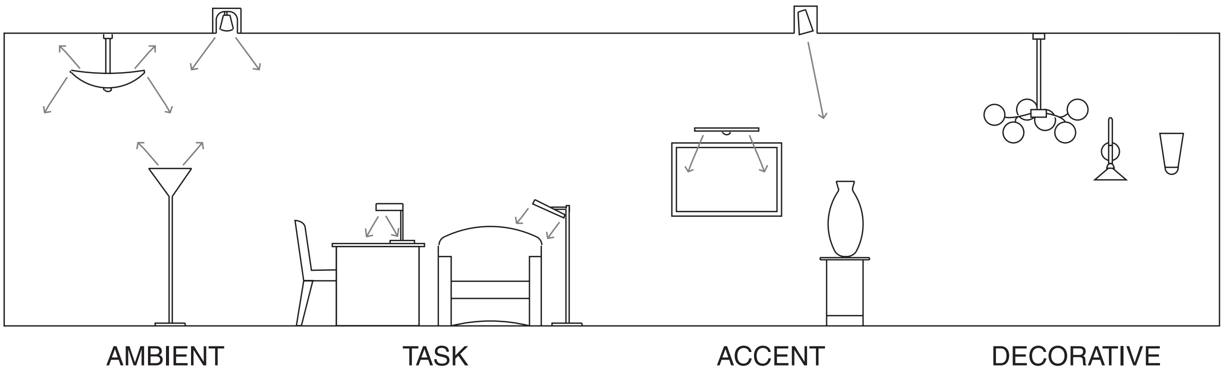

Figure 1.11 Types of lighting include the following: Ambient light is general illumination that provides a uniform light level. Task lighting aids in performing work such as reading or preparing food. Accent lighting functions to illuminate objects or special features. Decorative lighting tends to draw attention to itself in the form of a decorative element such as a chandelier or wall sconce. Note that decorative fixtures can add to a room's ambient lighting and offer task lighting.

produced. In the United States, packaging for lamps generally includes a lighting facts label that states the lumens produced as well as an estimated life of the lamp and the watts used.

Luminaire is a term used to describe the complete lighting unit, consisting of the following components:

1. A lamp or lamps (the general public calls these lightbulbs)
2. The parts (housing) necessary to distribute the light, position and protect the lamps, and connect the unit to the power supply.

Light fixtures are luminaires that are permanently affixed to the architecture of the building. Portable luminaires are, as the name implies, easily moved; these include what the general public calls table lamps, desk lamps, floor lamps, and so on. A range of luminaires and fixtures may be used to create ambient, accent, task, and decorative light; some of these are shown in Figure 1.12. Recessed luminaires are illustrated in Figure 1.13.

Daylight is a term that correctly refers to what most people call natural light; it is light produced by solar radiation and includes direct sunlight as well as reflected light. The term *daylighting* refers to the process of designing buildings to utilize daylight. True daylighting requires careful consideration of the totality of the architecture of the building, so that the orientation of the building to the site, the location and size of building openings, and adequate shading devices are incorporated into the building design. Daylighting is a useful component of sustainable design because it does not require electricity and when done properly can also save energy on building cooling. Currently, daylighting is a strategy employed more commonly for public buildings than for private homes. Regardless of how well daylighting is incorporated into a building design, electric light (referred to by the general public as artificial light) is required when it becomes dark outside.

Color Appearance is the appearance of electric light rated by the color rendering index (CRI), which, according to the Lighting Research Center at Rensselaer Polytechnic University, is a technique for describing the effect of a light source on the color appearance of objects being illuminated, with a CRI of 100 representing the reference condition (and thus the maximum CRI possible). In general, a lower CRI indicates that some colors may appear unnatural when illuminated by the lamp.

For residences, a CRI of 80 to 89 provides color rendering where color quality is important in residential applications, such as spaces where the visual quality of colors, materials, finishes, artwork, and accessories are an important part of the experience of the room. In some cases, such as utility and storage spaces, a CRI lower than 80 is acceptable.

Color Temperature or correlated color temperature (CCT), "describes the color appearance of the actual light produced in terms of its warmth or coolness," according to the Lighting Research Center. Color temperature is measured using the Kelvin (K) temperature scale, with lower temperatures (3000 K and lower) used to describe a warm source and higher temperatures (4000 K and above) used to describe a cool source. Typical incandescent lamps and warm fluorescent lamps are lower than 4000 K.

Efficacy, according to the California Lighting Technology Center, "refers to the ratio of luminous output produced by a light source to power consumed by that source (lm/W)."

This means: *Efficacy = Lumens/Watts*

Varying light sources provide different levels of efficacy; "for example, a 75 W A19 incandescent lamp, a 16 W A19 CFL lamp, and a 15 W A19 LED lamp use different amounts of power to produce the same amount of light (approximately 1100 lumens). Each type of lamp has a different rated efficacy." It is important to consider the lumens produced (and therefore the efficacy) as well as initial costs and overall lamp life when purchasing lamps.

Designers must understand the roles of lamps in lighting design (remember, these are called lightbulbs by the general public). Lamps are most often discussed as being divided into categories as follows: incandescent, fluorescent, light-emitting diode (LED), and high-intensity discharge. Within each category there is variety in how the lamps look and perform and the quality of light produced.

Incandescent lamps create light as electricity flows through a filament, heating it and making it glow. Incandescent lamps are popular because of the color quality of light that they create (remember the CRI and CCT). However, they use a great deal of energy to produce limited light and are therefore quite inefficient. Only 10–15% of the energy that goes into the filament is emitted as light; the remainder is generated as heat.

Incandescent lamps come in a range of shapes and sizes, with a letter designating shape and a number indicating the maximum diameter of the lamp (in eighths of an inch). For example, for a common A19 household lamp, the *A* refers to a standard bulb shape (*A* for "arbitrary"), and the *19* stands for 19 eighths of an inch, or 23/8 inches. Figure 1.14 illustrates the shapes of other incandescent lamps. Other terms referred to in lamp names have to do with the glass used in the lamp, such as clear or frosted types.

There are also reduced-wattage incandescent lamps, which are shaped similarly to other incandescent types but use a different gas inside the lamp that allows different wattages or, in some cases, a longer lamp life. As standard incandescent lamps

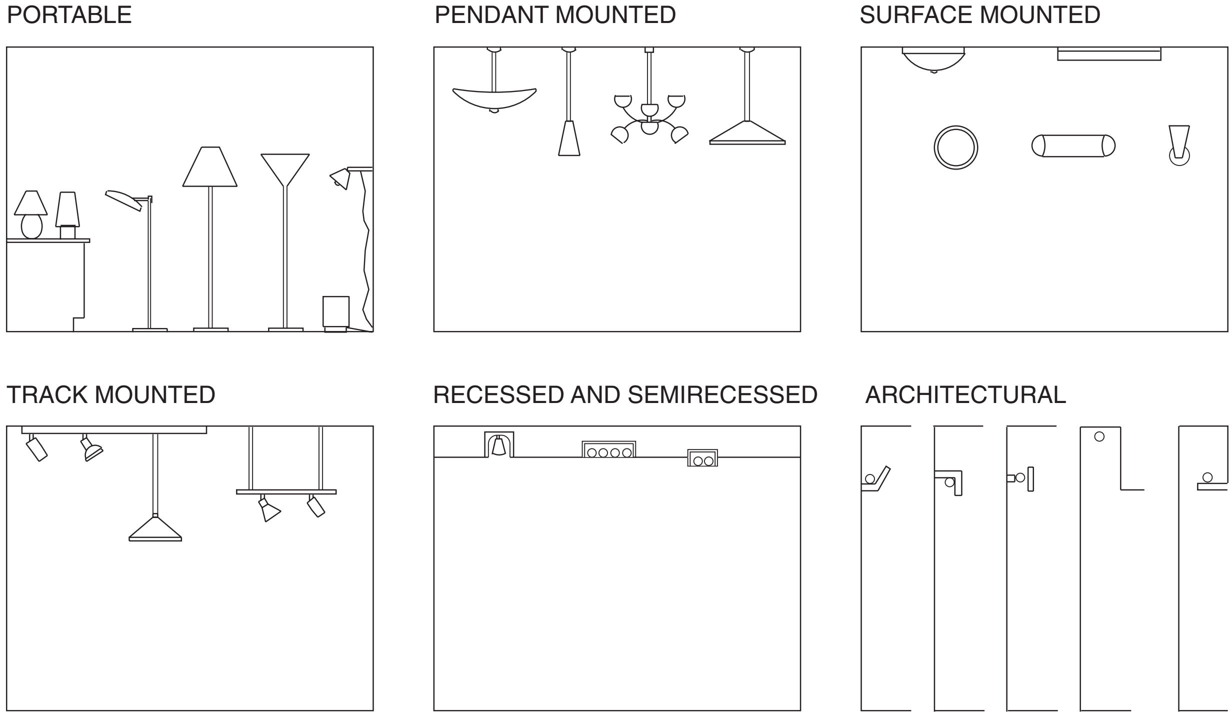

Figure 1.12 *Luminaire* is a term used to describe a complete lighting unit. Luminaires may be portable, pendant mounted (also known as suspended), surface mounted on walls or ceilings (decorative luminaires mounted on walls are often called sconces), or track mounted (the track can be mounted on the ceiling or suspended and can include track heads or pendants). Other options include recessed and semirecessed fixtures as well as other architectural lighting options (lighting permanently affixed to the architecture of the building), such as cove and valance lighting. More information on recessed luminaires can be found in Figure 1.13.

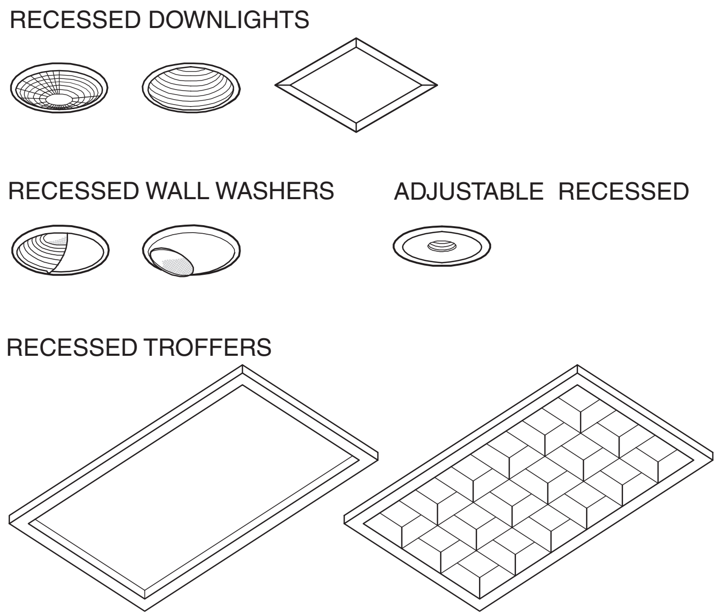

Figure 1.13 Recessed luminaires include recessed downlights (used for ambient lighting) and recessed adjustable downlights (also used for ambient lighting). Recessed wall washers direct light down at an angle and can be used for accent lighting. Recessed troffers are square or rectangular luminaires that house fluorescent lamps. These are available with diffusers or with louvers. Those with diffusers are used to provide ambient light, whereas louvers can direct light for tasks such as computer work. Surface-mounted versions are used more commonly in residential settings.

are being phased out, more energy-efficient incandescent lamps are under development. (See "Phasing Out Standard Incandescent Lamps.")

Halogen lamps (also called tungsten-halogen) are another type of incandescent lamp in which the filament is inside a halogen-filled capsule. The use of halogen gas allows lamps of a similar wattage to produce more light, making these lamps more energy efficient than standard incandescent varieties. Halogen lamps can become quite hot, requiring special care or lamp protection. Dimming these lamps changes the color dramatically and can shorten lamp life. Xenon lamps are similar to halogen but use only xenon gas (and electricity). Xenon lamps are brighter than halogen. They also burn cooler and last longer. Currently, xenon lamps for residential use are most commonly miniature types, often with pin or wedge bases, or those used in strip fixtures or puck fixtures.

Specialized incandescent reflector lamps have reflective coatings that create a directional light source and are available in a range of beam spreads from spot to flood. PAR lamps (for parabolic aluminized reflector), R lamps (for common reflector), and ER lamps (for ellipsoidal reflector) are all incandescent reflector types.

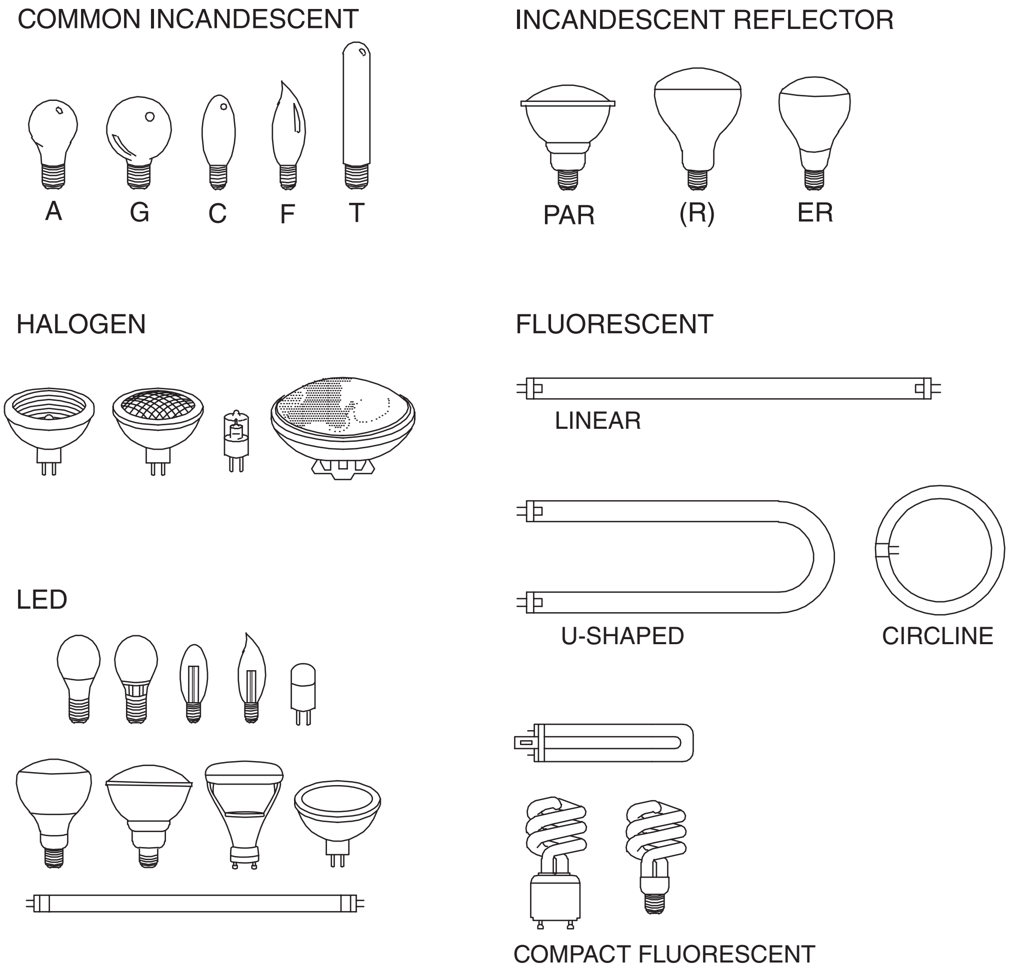

Figure 1.14 Lamps are divided into broad categories: incandescent, fluorescent, light-emitting diode (LED), and high-intensity discharge (not shown).

Incandescent lamp shapes and sizes vary, with a letter designation referring to shape (as shown) and a number indicating the maximum diameter of the lamp (in eighths of an inch). Halogen (and xenon) lamps are another type of incandescent lamp.
PAR, R, and ER lamps are incandescent reflector lamps.
Fluorescent lamp shapes and types include straight, tubular (or linear), U-shaped, twin-tube, and circular (properly called circline) lamps.
Compact fluorescent lamps (CFLs), which may have a single, double, or U-shaped tube as well as spiral types.
Light-emitting diodes (LEDs) are available in a range of lamp shapes and base types including those intended to look similar to incandescent and fluorescent lamps as well as strip and rope types (not shown). Integrated LEDs are luminaires with a light source integrated within the luminaire (not shown).

Incandescent lamps are also available in low-voltage versions, which require transformers to change the primary power (120 volts) to the required low voltage (often 12 volts). This type includes MR16 (the *MR* is for mirrored reflector; the *16* is for 16 eighths of an inch, or 2 inches) and PAR 36 lamps, which are often used for accent or display lighting. Figure 1.14 shows some halogen lamps.

Phasing Out Standard Incandescent Lamps

With the Energy Independence and Security Act of 2007, the United States legislated a gradual phase-out of incandescent lamps. This act required that as of 2014 the United States no longer manufacture or import standard tungsten-filament 40- and 60-watt lamps; however, existing lamps could be sold until supplies ran out. Rather than being a complete ban, however, this legislation requires only that many of the standard A-style lamps in inefficient wattages be phased out; more efficient incandescent lamps will continue to be available. Options for replacing high-wattage incandescent lamps include halogen, LEDs, and compact fluorescent (CFL). In 2019, under the Trump administration, the Energy Department reversed

the implementation of this standard. Despite changes in the standard, the lighting industry has moved forward with the development of energy efficient lighting. As of this writing five states have enacted standards identical to those of the Energy Independence act. Those are: California, Colorado, Nevada, Washington, and Vermont.

Fluorescent lamps are coated glass tubes filled with gas; light is produced when the gas reacts with electrical energy, producing ultraviolet light, which in turn is absorbed by the coating and produces visible light. Fluorescent lamps require ballasts within the luminaire or lamp. These provide the starting voltage and control the current when in use. Compared to standard incandescent lamps, fluorescent lamps produce minimal heat and are more energy efficient. Lamp color, such as "cool white" or "warm white," is created by the chemicals (called phosphors) used to coat the lamps and is controlled by the manufacturer.

A range of fluorescent lamp shapes and types are available, including straight tubular (or linear), U-shaped, twin-tube, and circular (properly called circline) lamps. In addition, there are compact fluorescent lamps (CFLs), which, as the name implies, are smaller in size (allowing them to fit in smaller locations). CFLs require the use of a ballast, which may be integral to the lamp or may be part of a separate module that can be replaced separately, and are available in single, double, U-shaped, and spiral tube types and with an adapter for use in incandescent lamp holders. Residential use of CFLs has grown rapidly because of their energy efficiency and long lamp life. Figure 1.14 includes illustrations of some fluorescent lamps.

Light-emitting diodes (LEDs), also known as solid-state lighting, have come to dominate the residential market. LEDs use solid-state technology to generate light, making them more like electronic equipment than incandescent lamps. LEDs are long lasting and extremely energy efficient. LEDs continue to improve in terms of light quality but they do have some limitations, particularly related to the highly directional nature of the light they generate. Several manufacturers have developed lamps that address this light dispersal problem, along with sensitivity to temperature, and color limitations creating more flexibility in the use of LEDs.

Advances in LEDs have evolved to include integrated LEDs. In these luminaires the LED light source is built directly into the fixture. This means integrated fixtures do not have a socket for placement of an LED lamp. This is true of panels or light strips along with decorative fixtures. There are pros and cons to using integrated LEDs. There are higher up-front costs, but good control and performance related to controls and dimming in integrated units. Fixtures with independent LED light sources offer ease of replacement and lower initial cost.

LEDs are also used in the creation of "smart lightbulbs," which allow for control via the Internet. These typically are placed in sockets that would accept standard LED lamps and then are controlled by an app or program. These can control brightness, color, schedule, and some include speaker and camera options. These can be seen as a simple way to create smart lighting but have some limitations, and some have had security issues. *Note that the term bulb is used by the general public to describe these and is therefore used here in quotes to indicate common popular usage*.

More information on smart lighting options can be found in the "Smart Homes and the Internet of Things" section.

Options should continue to improve in the future as an interest in saving energy has caused some incandescent lamps to be phased out. See "Phasing Out Standard Incandescent Lamps."

Another type of lamp, known as *high-intensity discharge* (HID), uses a current and gas or vapor under high pressure to produce light. HID lamps also require a ballast. While highly energy efficient, they are not widely used in residential interiors except for applications where lights are left on for extended periods of time, such as for security or in multifamily stairway applications.

It is worth noting that references to bulb shape are different from those used to describe the lamp base; for example, the screw base seen on standard lamps is referred to as a *standard base* or an *Edison base* (after Thomas Edison). Lamp bases come in a range of sizes and types and are referred to by name. For example, a standard *A lamp* with a screw-in base is referred to as a standard base, whereas a smaller, flame-tip-shaped lamp (for use in a chandelier, for example) may have a *medium* or *candelabra* base. Also, compact fluorescent lamps are widely available with an integral ballast and a standard screw-in base for use in a standard socket.

Controls for lighting include switches, dimmers, timers, sensors, central controls, and motion detectors. This large family of controls can be divided into two categories: manual controls and automatic controls. Note that for effective use, dimmers require the use of dimmable lamps and often CFLs and LEDs require compatible dimmers (consult the manufacturer's list for dimmer and lamp compatibility).

Commonly used manual controls include switches and dimmers, with switches used to turn lamps on and off and dimmers used to control the light output of some lamps. Timers are automatic controls that are intended to control lamps based on a designated time period. Controls vary a great deal in complexity and cost, with the more advanced and costly options used in some cases as part of a complete home security system.

The energy efficiency chapter of the IRC contains guidance regarding electrical power and lighting systems and building performance, and contains specific lighting requirements. Section N1104.1 requires that all "permanently installed lighting fixtures, excluding kitchen appliance lighting fixtures, shall contain only high-efficacy lighting sources." IRC N1104.2 requires that permanently "installed lighting fixtures shall be controlled with a dimmer, an occupant sensor control or another control that is installed or built into the fixture." Exceptions to this include bathrooms, hallways, exterior fixtures, and security lighting.

SMART HOMES AND THE INTERNET OF THINGS

Josh Fruhlinger (2020), writing for *Networkworld*, described the Internet of Things (IoT) as "a catch-all term for the growing number of electronics that aren't traditional computing devices, but are connected to the internet to send data, receive instructions or both." Fruhlinger continues, "For consumers, this means interacting with the global information network without the intermediary of a keyboard and screen; many of their everyday objects and appliances can take instructions from that network with minimal human intervention."

From smart appliances to security systems and temperature controls, smart devices and their connectivity have become part of our experience of home. The IoT remains in the early stages of development with issues of connectivity, security, and surveillance creating concerns; however, smart devices and IoT will likely continue to be a part of residential life moving forward.

The term smart appliance can be used to describe appliances that can be controlled via app, speaker, or display and is most commonly used to describe individual household appliances such as washers, dryers, dishwashers, refrigerators, and similar items. Where applicable these will be discussed in upcoming chapters pertaining to specific rooms where the appliances may commonly appear.

The following is a list of some of the available smart home products that can be found throughout the home.

Common Smart Home Products

Smart Lighting

Smart Bulbs are inserted into standard sockets and are therefore an easy entry into smart lighting. In addition to control via app, these can be used in conjunction with voice-activated speakers and displays.

Centralized Smart Lighting is a full-house system that can replace dimmers and switches with single keypads connected to a central panel. These are most often used in new construction and large-scale renovations and should be incorporated early in the design process. This type of system is appealing to those in search of a very clean, uncluttered wall appearance.

Local Lighting systems also offer whole-house systems but retain the use of traditional switches and dimmers, which are integrated into a single system and controlled with local keypads. This type of system uses wireless radio frequency communication and can be used in smaller-scale renovations as well as new construction.

Hybrid Lighting systems combine aspects of central and local controls with some rooms controlled via remote keypad and others through use of switches and dimmers. Additional wireless devices can be added to hybrid systems after construction if necessary.

Smart Plugs plug into standard home outlets and the devices plugged into smart plugs can be controlled via a home WiFi network including voice-controlled systems. These offer an inexpensive entry into smart home technology and offer great flexibility because they are easily moved.

Smart Switches and Dimmers are wired into the wall to replace standard or existing wall switches or dimmers. Older homes may need additional wiring to support these devices.

Smart Speakers and Smart Displays combine audio speaker functions with voice recognition technology and virtual assistant (software that performs tasks or services based on commands/questions). These can be seen as one part of a larger digital environment and can perform management of other smart devices. Sound quality of speakers varies but has improved. Smart display devices combine the functions of smart speakers with the functionality of a touch screen. Video, including that from security cameras, calendars, photos, and weather can all be made visible on a smart screen device.

Smart Outlets are wired into the wall to replace standard outlets. Smart outlets are larger than standard, which means they may not fit into an existing outlet box.

Smart Window Coverings include motorized window coverings that can be controlled with a remote device, wall control, or through smart technology via app, hub, voice assistant, or remote, and can include scheduling movement based on light levels.

Smart Security Components and Systems include a wide range of devices that secure and monitor points of entry as well as conditions on the interior (such as fire, flooding, and temperature fluctuations). Options include DIY and professionally installed systems. Two types of systems, monitored and unmonitored are available. Monitored systems are professionally monitored whereas unmonitored systems require the resident to be responsible for constant monitoring. Sensors attached to doors and windows, motion sensors, keypads, cameras, smoke alarms, glass break sensors, and panic buttons are all components that may connect to a base station device in smart home security systems.

Smart Locks offer remote and voice control of locks. Retrofit versions make use of an existing deadbolt lock.

Smart Doorbells have security cameras within a doorbell device. These can send alerts and videos to smart phones as well as provide two-way audio.

Smart Security Cameras are available as individual DIY options or as part of a more complex security system that also includes sensors and other monitors. These are available in interior and exterior options.

Smart Sprinklers control in-ground sprinkler systems via app or hub or scheduled settings, and many can adjust that schedule based on weather and soil conditions.

Smart Thermostats can automatically regulate room temperature and be scheduled or controlled via app or smart speaker/display. These can also factor in local and regional weather forecasts and user preferences and create a comfortable temperature without user input. It's worth noting that smart thermostats are not compatible with all individual HVAC systems or existing wiring and therefore careful examination of individual systems is required.

Smart Hubs connect to the home's network, receiving and sending coordinated communications to smart devices. Hubs configure groups of simultaneous controls for sophisticated home settings that may include audio, lighting, sensors, temperature control, etc. Until recently these were required to coordinate home systems; however, recent advances in smart speakers and smart displays allow them to perform some similar tasks albeit on a less sophisticated level.

Contactless technology, also known as touchless technology, describes automation of many items found in the home. Motion activated lighting and touchless plumbing fixtures are examples of this type of touchless residential product. Technically, many of the smart products described in this section can be considered touchless or contactless because they are controlled via phone app or hub.

While many of the smart devices mentioned are wireless, they do rely on Internet and cable connections brought into the home, and certain devices may benefit from ethernet connections. Additionally, some smart devices benefit from a nearby electrical outlet/receptacle. For example, an electrical outlet placed near windows can provide power to smart window coverings, and an ethernet port placed near a game console or media center is helpful.

Communications and data cabling enter a home through an external termination point (ETP). Within the house the services are housed in a distribution panel, from the distribution panel the various cables run to rooms and outlets where they are needed.

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