32

The Social Contexts of Resilient Architecture

Terri Peters

Introduction

This chapter explores the social contexts of resilience in architectural design focusing on strategies for high-performing buildings that promote happiness and health among building users. Resilience is often generally defined as the ability to become strong, healthy, or successful again after a mishap or to return to an original shape after being pulled, stretched, pressured, or bent by external forces. Depending on context, this term could relate to a person's resilience, or an object's or a material's resilience, in relation to its respective contexts. Researchers have traced a recent history of this term as it applies to the design disciplines and found that its interdisciplinary focus emerged from different fields, including psychology, engineering, and ecology (Trogal, Bauman, Lawrence, & Petrescu, 2019). The work of ecological scientist C. S. Holling is particularly relevant as it frames the concept of resilience as "a measure of the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables" (Holling, 1973, p. 14). Holling's definition is often cited in texts on resilient design due to his focus on the impacts of human activity on ecosystems. Academic and professional disciplines relating to the built environment have explored more specific interpretations of resilience, for example, urban ecological resilience (Alberti & Marzluff, 2004), urban resilience (100 Resilient Cities, 2019), security and risk reduction in cities (Coaffee, 2008), and promotion of resilience through urban governance and institutions (Leichenko, 2011).

In architecture, the term *resilience* tends to be used narrowly describe a building's structural and environmental performance in quantitative terms, but can a building be called resilient if it fails to make inspiring spaces for people, promote well-being, or improve people's experience? This is the focal question to be addressed in this chapter. The chapter brings an architectural perspective to the concept of resilience and begins by exploring how the

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term is currently evaluated in and around buildings, through discussion of related concepts such as sustainability, passive survivability, and performance gaps. Promising new design approaches that better consider occupant comfort and well-being are introduced, in particular the behavioral design practice of 3XN, which focuses on how buildings can positively impact people's social interactions. The chapter traces the emergence of a new generation of building evaluation metrics and certification systems that are focused not solely on environmental performance but that also consider synergies between people's experience and our natural resources, such as the WELL Building Standard and Active House. Examples from the multifunctional, process-based strategies used in a series of new climate adaptation renovations in Copenhagen, Denmark, are discussed as exemplary resilient design projects that address neighborhood flooding by simultaneously improving the qualities of public spaces and better connecting people to nature. The chapter concludes with a discussion of how locally specific and socially focused designs can support more resilient environments for people.

From Resilient Buildings to Resilient Occupants

According to the U.S. National Infrastructure Advisory Council and included as guidance to building designers in the Whole Building Design Guide, resilient buildings should address four main considerations: *robustness*, both at the building scale in terms of soundness and functionality and in terms of infrastructure that allows building operations like power and thermal comfort during a crisis; *resourcefulness*, for example, prioritizing actions to control and mitigate damage and keep communications and supply chain going; *rapid recovery*, to resume normal operations and conditions as soon as possible after a crisis; and *redundancy*, which means having access to back up resources in case of a failure in normal operations (National Institute of Building Sciences, 2018). By this definition, resilient buildings are not about people and our specific emotional and cultural needs but rather about the responsibility of buildings to continually provide the bare necessities of functionality and shelter.

The social roles of buildings and how they influence our well-being are entirely overlooked—although these aspects would be particularly important in the event of a crisis. People spend more than 90% of our time indoors (Klepeis et al., 2001), and the qualities of buildings and landscapes impact our moods, well-being, social experiences, and how we behave. The American Association of Architects (AIA) brought together a working group to develop design priorities for the creation of built environments that promote health and well-being to inform design. According to their findings, the main points that designers must focus on are *environmental quality*, for example, by reduce chemicals and pollutants; *natural systems*, for example, by promoting healthy eating and social behavior; *physical activity*, by considering how the environment encourages daily movement; *safety*, by reducing changes of accidental injury and considering ways to lessen stress and anxiety; *sensory environments* that are varied and include diversity in sounds, light, smells; and *social connectedness*, by designing spaces where people like to be, to help strengthen professional and social relationships (AIA, n.d.). However, the AIA's design priorities are general and do not include spatial suggestions, nor are there any examples of best practices. These also do not include design guidelines or drawings, which limits how much practical use they can be to the profession.

One reason for the lack of prescriptive information and quantitative description could be that important concepts such as safety and sensory environments are difficult to apply in the same way to different projects. Much of the designer's role is to interpret what strategies are most needed in a specific scenario and to consider how to balance client requirements with the needs of the future building users. Due to people's cultural backgrounds, ages, and interests, and personal expectations of a space, as well as numerous other factors, people respond differently to qualities in their environments.

There are some environmental features and qualities that nearly everyone would have a positive reaction to, like daylight and connection to outdoors. Adopting principles of *biophilia*, a term coined by E. O. Wilson in 1984 referring to people's natural affinity to nature, is one way that designers can attempt to design spaces that have universal appeal (Kellert & Wilson, 1984). Studies show that biophilic design strategies, using specific spatial and sensory strategies to connect people to the natural environment, reduces people's stress and promotes well-being (Kellert, Heerwagen, & Mador, 2008). Foregrounding biophilic design strategies could also be an effective way of boosting resilience in assisting people in our adjustment to the realities of a changing climate. Currently mainstream notions of occupant comfort in buildings is based on how well the indoors seems to defy seasonal variations in temperature and humidity and assumes that people want a steady state of "comfort" indoors. Globally, people are experiencing more extreme weather and a changing climate, and our buildings could help us better understand our local context. Biophilic design strategies such as limiting floorplan depth and thereby increasing chances for daylight and natural ventilation, using effective building orientation to achieve daylighting in main spaces, as well as designing windows to give views of the sky could help people be more connected to the natural world, can be ways of encouraging people to acknowledge rather than conceal seasonal variabilities. This could lead to different expectations of comfort inside buildings. As outlined in this chapter, the current state of building performance evaluation, and how buildings are considered high performing or not, is often quantitative and removed from our social contexts. This is starting to change, as designers and clients become aware that often the strategies for positive environmental performance and benefits to human well-being are compatible or even the same (Peters, 2017).

Climate change and extreme weather are a main focus in resilient design, but largely from the perspective that minimizing a building's environmental impact will achieve better building performance and therefore require fewer scarce resources (National Institute of Building Sciences, 2018). In design, resilience is often considered alongside *passive survivability*, a term coined by Resilient Building Institute founder Alex Wilson, which he defined after studying how uncomfortable and vulnerable buildings were without power after Hurricane Katrina in New Orleans (Wilson, 2005). Over the past 100 years, people have become heavily reliant on "active" systems in buildings for their comfort, those systems that require fossil fuels to function, like typical heating, ventilation, and air conditioning systems. Given these technological advances, the ability of our buildings to serve our needs in the event of a loss of power has been tremendously compromised. Resilient design addresses these shortcomings. It is "the intentional design of buildings, landscapes, communities, and regions in response to vulnerabilities to disaster and disruption of normal life" (Resilient

Design Institute, n.d.). Passive survivability is a desirable condition where due to effective resilient design strategies, buildings maintain livable conditions in the event of extended loss of power or interruptions in heating fuel. The terms *sustainability* and *sustainable design* in buildings are also widely used, largely relating to a building's performance. In design, the term *sustainability* is borrowed from the concepts of sustainable development, relating to the goals of balancing and maintaining a relationship between built and natural environments and has within it the notion of social, environmental, and economic parameters (World Commission on Environment and Development, 1987). While sustainability seeks balance, resilience focuses on restoring the balance while accommodating future challenges.

In architectural design and urban design research and practice, there is an emerging interest in expanding the concept of resilience to better consider people and our experience inside buildings. Boone (2013) argues that any efforts to design resilient or sustainable cities must therefore take into account the "social contexts" of urbanism. This could be applied to architectural design as well. Recently, design researchers have been incorporating concepts of social justice and urban community resilience (De Carli, 2019), which explicitly considers people and our relationships to one another in the spaces we build. However, there is a missing link between this forward-thinking design research and current design practice. For example, there are few if any published examples that illustrates these principles in practice, nor are there design guidelines for social justice and architecture. Some progress is being made in terms of considering buildings and people, in particular new research is aimed at gaining a better understanding of the significant role that building users play in how a building performs compared to design intentions. The difference between user expectations and design intentions and buildings in use are known as "performance gaps" (Coleman, Touchie, Robinson, & Peters, 2018). Understanding the reasons behind the gaps, has been an area of research for the last five or so years in academia. A number of special issues of journals have picked up on this topic including a special issue of Building Research and Information journal titled, *Energy Performance Gaps: Promises, People, Practices*, in 2017. This has been reflected in the building industry with a number of building standards and metrics that seek to quantify the ways buildings impact people's health and well-being. For example, the WELL Building Standard, established in 2014 and slowly gaining momentum, is the first building standard that is exclusively concerned with people—there are no points for low energy use (International WELL Building Institute, n.d.). It is focused on quantifying how people feel in buildings and considers how a building promotes mental health, healthy nutrition, air quality, water quality, and exercise, along with other human-centered criteria. Such standards signal a noticeable shift in the building industry toward new ways of certifying green or sustainable buildings and defining and measuring building performance and resilient design. There remains, however, a lack of coordination and few built examples of how to reconcile the seemingly conflicting needs of people and our natural environment.

Design features for resilient buildings and human resilience are often the same and are most effective when considered together. People know, and numerous studies support the idea, that how we experience buildings shapes our well-being and behavior. It makes sense to focus on the building performance impacts that people can experience and care about. For example, people using a building care about how a space or room makes them feel in

the moment, not necessarily the cost savings over time or environmental benefits of putting extra insulation in the walls. The concepts of resilience and sustainability in buildings needs to be reframed as offering benefits to people, promoting social sustainability and human well-being rather than focusing solely on environmental sustainability.

Two built examples are discussed in detail in this chapter, a Canadian example of an Active House that is part of the VELUX Model Homes program, and two neighborhood scale climate adaptation projects in Denmark. These examples highlight how resilient design can be an opportunity to rethink current building typologies, rather than a constraint. For example, suburban homes could be health-promoting with better environmental performance, as evidenced by several of the VELUX Model Homes projects, which focus on designing for a higher than typical quality and quantity of natural light and its impact on people's sense of well-being in the home (VELUX, n.d.). These pilot projects in this program address the issues that in and around buildings, experiential aspects such as daylight, thermal comfort, sound, privacy, comfort, and spaciousness are harder to measure than, for example, energy performance or light levels, but they impact quality of life and offer valuable benefits to people. Experiential parameters of light and air are invisible and not drawn on floorplans. For this reason, it is challenging to have a vocabulary for these experiential aspects of a building, and although people spend so much time in their homes, these aspects are often not well considered. The Active House building rating system is part of a new generation of voluntary building certification standards that have emerged in the last few years that consider well-being and experience in everyday buildings like housing, or offices, not just hospitals and care environments (Active House Alliance, n.d.). Pairing this with examples from a citywide initiative in Copenhagen that aims to address flooding and public space shows how resilient design strategies can be adapted at varied scales. Rather than individual buildings, the initiatives in Copenhagen impacts streetscapes, roads, sidewalks, parking areas, and pedestrian links in neighborhoods. These initiatives began with an overall plan and looked to identify and maximize the positive co-benefits for both the environment and for local residents as a way to increase public support for these urban renovations, which are costly and cause short-term disruptions.

New Forms of Practice: How Design Shapes Behavior

Architects believe that when they design buildings, their decisions directly and indirectly impact how people use the spaces, their health and well-being, and their interactions with others (U.S. Green Building Council, n.d.). Architects have been known to agonize over the dimensions of a window seat or the quality of the view, or the qualities of a cladding material on a building and how it will weather over the course of time and how its color will appear in different weather and seasons. Research from numerous disciplines supports the belief that people act differently depending on environmental qualities (Huisman, Morales, van Hoof, & Kort, 2012). For example, in behavioral economics researchers have measured the impacts of lighting quality on consumer spending (Summers & Hebert, 2001) and in public health

researchers have studied hospital ward design and room layouts and the spread of infectious disease (Stiller, Salm, Bischoff, & Gastmeier, 2016). In architectural design, researchers have examined the impacts of various floorplan arrangements and environmental cues on people living with dementia to see how it impacts their ability to find their way around their nursing homes (Marquardt, 2011), and in environmental psychology researchers have examined the restorative benefit of nature (Kaplan, 1995). The discipline of environmental psychology is relatively new, becoming popular in the 1970s by focusing on the relationships between human behavior and the natural and built environments. Research organizations like Environmental Design Research Association, which holds international conferences on this topic and publishes proceedings, remains a leader in research into how people's environment impacts their behavior.

Environmental psychology has not greatly impacted mainstream architectural design or engineering research or practice and is not taught in the North American professional architecture curriculum. However, over the last decade, there has been a growing interest in understanding aspects of environmental psychology in the workplace, starting with questions about occupant productivity and now including occupant well-being and mental health. Over the last decade, three architectural research journals, *Health Environment Research Design*, *World Health Design*, and *Environment and Behaviour*, have been leaders in promoting evidence-based design (Lundin, 2015) to study the impacts of buildings and on occupant health and well-being beyond healthcare settings. For example, researchers have found links between people's well-being in buildings and the outdoor context and walkability, due to the opportunities for social contact and sense of community that being out in public brings (French et al., 2013). The quality of our surroundings has been shown to impact our neurological functioning as well. For example, a series of studies led by researchers at Harvard show a measurable link between fresh air and enhanced mechanical ventilation and better cognitive performance at work (Allen et al., 2016; MacNaughton et al., 2017). A sense of control over one's immediate surroundings and freedom to move around a space has been positively linked to a person's well-being and health (Ulrich, 1991).

Designing spaces that are customizable with aspects that can be personalized with color or furnishings, with local environmental controls such as operable windows, are ways that design can influence well-being. In particular the design of a person's home impacts mental health and well-being and sense of self. Housing can have a major impact on our social interactions and mental health. Among other considerations, at a minimum a home must be safe, large enough for people to have privacy and social connections, and thermally comfortable. Recent studies such as a pilot project in the United Kingdom called "Boiler on Prescription" tested assumptions about thermal performance in buildings and people's perception of their health (Burns & Coxon, 2016). This initiative found that installing new energy efficient heating systems in people's homes did more than improve their thermal comfort, people had 60% less interactions with their general practitioner doctor. This study showed a link between thermal comfort, mental well-being, and physical health (Burns & Coxon, 2016). This particular study also had economic impacts, as the new boilers were higher efficiency and cheaper to run in the long term. Given this accumulating evidence, there has been a number

of design offices formally researching how and in which ways building design shapes behavior of the inhabitants they design for, then using this information as feedback in their design processes (Peters, 2018). One example, 3XN Architects in Denmark, follows.

3XN Architects

3XN is a globally successful architecture firm focused on designing buildings to encourage social connectedness, effective communication and community (GXN, n.d.). They have an in-house research office, GXN, which investigates digital design, circular design, and behavioral design. GXN's research practice informs every 3XN project, and the team carries out experiments, develops prototypes and designs research to better understand the social impacts of buildings. Their methods are interdisciplinary, drawing from environmental psychology, social sciences, humanities, and architecture. Their research team responds to changing design practice, as the architecture profession faces new challenges and professional expectations relating to sustainability, including the social aspects of how buildings make people feel. These challenges have led the team to develop and adopt new workflows, methods, and ways of representing their work. For example, they integrate PhD researchers into their team. A recent social psychology doctoral student worked on documenting and analyzing how people used some of the buildings the office designed, creating a number of postoccupancy evaluations relating to social interactions in everyday spaces (Sylvest, 2018). In these studies (Figures 32.1 and 32.2), the firm's finished buildings were compared with their design intentions. Findings focused on the social interactions that take place within buildings. For example, the 3XN is known for designing grand staircases; they have dubbed these "lazy staircases" and they are normally daylit, in an atrium, wider than usual, and encourage people to climb up (rather than take a faster elevator) to be social and have views up and through the building (3XN, 2010). For example, in their Ørestad College project, the main staircase encourages students to chat together and becomes important for social mixing, and it is designed so that people can gather around the atrium on various floors and see people walking up and down between floors. After it was built, GXN conducted formal evaluations and observations of this (see Figures 32.1 and 32.2) to understand how they worked and then used their findings as feedback for future designs.

This work draws on the history of socially focused Danish design, including the work of urban designer and researcher Jan Gehl who runs a research driven practice that focuses on people and how we respond to design (Gehl Architects, n.d; Gehl & Svarre, 2013). Gehl Architects uses methods from environmental psychology like behavioral mapping and other observational techniques to quantify people's behavior in urban spaces. Both Gehl Architects and GXN are exploring architectural resilience without using the term, and developing their designs based on research they carry out to gain an enhanced understanding of the specific social contexts of the resilient architecture they are producing. Their work is part of a new approach to sustainable and resilient design that 3XN calls "informed design" meaning that they use data and observation to lead their work, in addition to their intuition and experience in the process of building design (GXN, 2019).

(a)

(b)

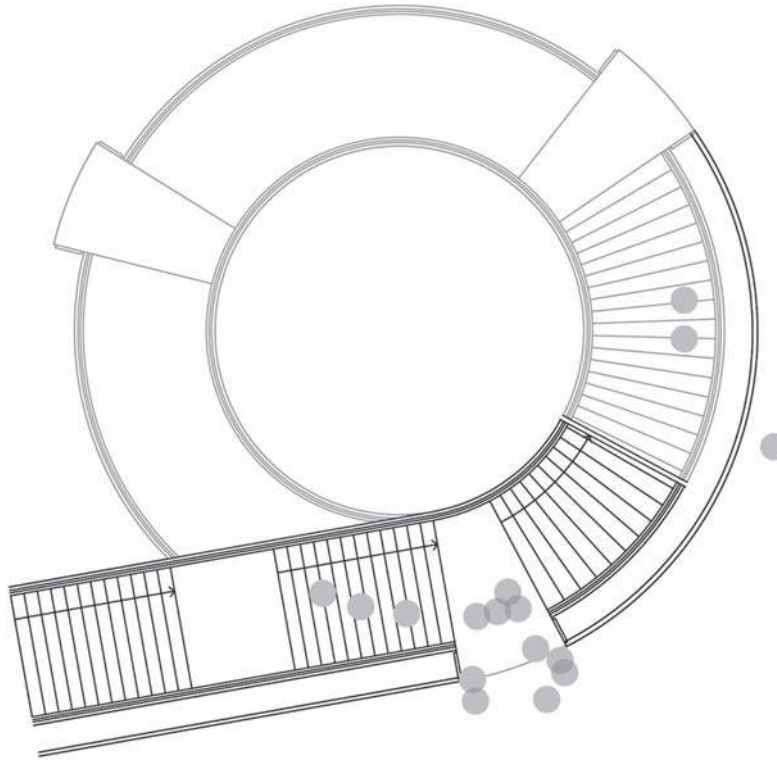

FIGURE 32.1 Behavioral Analysis of Social Uses of Staircases, Ørestad College, Copenhagen Denmark 2007 (a). GXN's behavioral design research group analyzed Ørestad College after it was built considering how people used the building (b). This diagram by researcher Mille Sylvest was part of her PhD research about the social use of spaces. She mapped people's movement around the open plan design and how the sightlines of the staircases and landings promoted social connectedness and facilitated wayfinding. Images by Mille Sylvest and GXN.

(a)

(b)

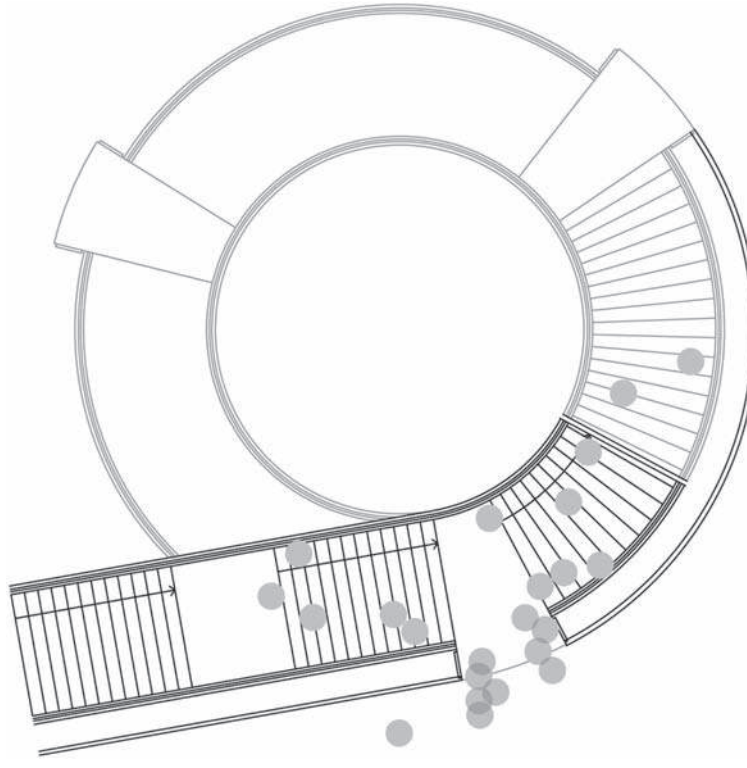

FIGURE 32.2 Behavioral Analysis of Greetings on the Staircase, Ørestad College, Copenhagen Denmark 2007 (a). This diagram (b) by GXN researcher Mille Sylvest was part of her PhD research about the social use of spaces. She mapped people's movement around the open plan design in particular she studied the nature of meetings and greetings in or around the staircase landings which she termed "social junctions." Images by Mille Sylvest and GXN.

Process-Based, Multiscale Architecture

The resilient design approaches used by 3XN are process-based. To be successful, they must function on multiple scales. For example, in the Ørestad College project, the building was arranged on the site to maximize the potential for a positive interaction with the natural environment: it is oriented toward sunlight and shade and social conditions such as proximity to amenities, views, and privacy (Poulsgaard, 2019). The relation to neighboring buildings, availability of local materials, and building systems that can use local skills and labor were all considered in the building's design and fabrication. In this sense, the building's resilience is a result of multiple decisions at multiple scales across multiple systems. Even at the scale of the building's component parts such as the classrooms and entry areas, views from each space, daylight, and electric lighting were considered for optimal learning conditions, accessibility and indoor-outdoor connectivity of students and staff. Specifically, at the scale of the classroom, designers focused on maximizing light and air, positioning and size of windows for daylight and views, thermal comfort, and privacy. The larger scale of the building required design of passive and active heating and ventilating systems as well as effective circulation between rooms and considerations of adjacencies and experiential qualities of views, sound, privacy, and smells. The design aimed to disrupt typical hierarchies of student and teachers and to make an open and inclusive environment that would prepare students for life after high school. The ground floor and entry of the building are quite public, creating an interface with the community that shows the students that they are part of a larger community rather than sealed off from the outside world. This project illustrates how the practice of architecture is concerned not only with inhabitant well-being but also interpreting and meeting a client's or institution's needs. It illustrates how a building's design can take into consideration the broader cultural impact of the building and the part it plays in our shared material culture.

Evaluating the Social Contexts in Sustainable Architecture

In this process-based approach to building architecture that promotes material and psychological resilience, there is a need to develop new ways of evaluating sustainable design and resilient architecture. The current methods of evaluating the multidisciplinary concepts of sustainability in design remains bound by the three-pillar model (environment, economy, and society). The social pillar has been largely neglected as the wider debate has prioritized environmental criteria, such as climate change, and economic concerns within the context of industrial capitalism (Davidson, 2009; Littig & Griessler, 2005). In architecture, "social sustainability" is often mentioned but has no clear definition, although human value and needs are the foundation for what the phrase means in the built environment. In architecture, practitioners and theorists work on the assumption that the design of spaces explicitly shapes the well-being and even the behaviors of people that use them (Peters, 2013). This is not necessarily easy to prove outside of the discipline, but it is nevertheless a guiding principle in theory and in practice. For example, architects do not typically require evidence that cluttered or unhygienic environments make us uncomfortable or that spacious, sunlit, varied environments put us at ease. Architects assume that we are able to impact the moods, desires, and

experiences of people that inhabit the spaces we design. This is well studied in the theoretical framework of phenomenology in the classic works of Norberg-Schulz (1966) and Bachelard (1964). Since architectural design cannot take into consideration the desires of every inhabitant personally, architects intuitively assume there are certain universal needs that all people have and design for those. Culturally and professionally, however, there is little agreement about what these needs are and therefore social sustainability in architecture remains a major challenge.

Globally, the most used green building certification system is the Leadership in Energy and Environmental Design (LEED) designation. This program has been at the forefront of granting recognition for "green" buildings designed with energy conservation in mind since its development in 1993 (U.S. Green Building Council, n.d.). LEED is a points-based system whereby a candidate building or neighborhood is assessed based on its merits across a series of broad categories with points assigned based on a structure's performance in seven distinct sustainable parameters relating to:

1. *Sustainable sites*: focusing on site selection and site attributes and associated infrastructure.
2. *Water efficiency*: centered on retention and conservation measures.
3. *Energy and atmosphere*: rewarding minimization of energy consumption and on building commissioning protocols.
4. *Materials and resources*: focused on ecologic construction materiality practices and building longevity.
5. *Indoor environmental quality*: centered on air quality monitoring and non-toxic material palettes, thermal comfort and daylighting/view amenity
6. *Innovation and design process*: addressing ecologically attuned design strategies
7. *Regional priority*: relating to the building's location and context.

Scores for the lowest certification (certified) are often criticized as supporting initiatives that are easy to achieve and not very impactful, such as adding bike racks or educational displays (Frangos, 2005). This is in contrast to the highest certification (platinum), which demands that a building score extremely well in all categories. Additionally, since LEED certification is based on a design's expected energy use before it is built, rather than actual measured building performance, there have been many cases where LEED buildings do not perform any better than noncertified buildings (Newsham, Mancini, & Birt, 2009).

The first building certification system to focus on human well-being and experience was introduced in 2013. As previously mentioned, the WELL Building standard aims to measure "how design, operations and behaviors within the places where we live, work, learn and play can be optimized to advance human health and well-being" (International WELL Building Institute, n.d.). WELL is the only building certification system that does not measure energy use. It too awards points in seven categories though these differ significantly from those assessed by the LEED system and are more human-centered. They include:

1. *Air*: requiring buildings to promote clean air and reduce sources of air pollution.
2. *Water*: promoting safe and clean water through the implementation of proper filtration techniques and regular testing.

3. *Nutrition:* making available fresh, wholesome foods, limiting unhealthy ingredients and designs that encourage better eating habits and food culture.
4. *Light:* design thresholds that minimize disruption to the body's circadian system, enhance productivity, support good sleep, and provide appropriate visual acuity.
5. *Fitness:* integrating physical activity into everyday life by providing opportunities and support for an active lifestyle and discouraging sedentary behaviors.
6. *Comfort:* rewarding designs that are distraction-free, productive, and comfortable indoor environments.
7. *Mind:* designs that optimize cognitive and emotional health through technology, design strategies, and assistance programs to employees.

Rating systems like LEED have raised awareness of green buildings among clients and professionals, and now WELL is starting to shift the focus to people and how buildings can make people feel more productive and happier. Unlike LEED, WELL certified buildings must be evaluated after they are built and occupied for a period of time so they use actual performance data for aspects such as energy use, lighting levels, and air quality, and performance data must be submitted to the International WELL Building Institute to maintain their WELL certification. However, like all rating systems, on their own certification systems like these cannot create more ecological buildings. Designers, clients, and the wider community need to keep a focus on harder to measure priorities such as integrating renewable energy, improving design quality, and creating inspiring buildings and places that people want to maintain and keep over time. Not only the measurement tools but also the language and cultural aspects of nature and culture need to shift in response to architectural design imperatives.

Representative of this shift, *superarchitecture* is a term describing designs that do more than minimize harm (Peters, 2017). These designs form a special category of regenerative buildings that offer measurable and integrated positive co-benefits for environmental sustainability and human health and well-being. Superarchitecture describes building strategies that work at multiple scales, using multifunctional strategies for our physical environment and improving health. A related term is *net zero building*, defined by the World Green Building Council as a high performance building that is entirely powered by renewable energy either from the site or near it (World Green Building Council, n.d.). The even more ambitious concept, *net positive building*, is also beginning to be used although there are very few if any built examples (Cole, 2015). Net positive, like superarchitecture, is focused on improving the existing environment and doing more than minimizing harm and actually adding value to the environment (Cole & Fedoruk, 2015). Certification programs generally lag behind the new concepts and theories and LEED overwhelmingly remains the most well used building certification standard. Newer initiatives such as Passive House, which focuses on ultra-low energy strategies that minimize the need for heating and cooling (Passive House Institute, n.d.), Living Building Challenge, the most rigorous environmentally focused building performance metric that evaluates the regenerative potential of a building and site to restore its environment (International Living Future Institute, n.d.), and Active House, a building standard that focuses on measurable design strategies for occupant comfort, daylight and air strategies (Active House Alliance, n.d.). This latter program is the focus on the following detailed case study.

Active House

The Active House standard (Active House Alliance, n.d.) evaluates buildings in three main categories:

1. *Energy*: measuring how a building integrates renewable energy to positively contribute to the energy balance of the building.
2. *Indoor climate*: measuring how the building creates a healthier and more comfortable life for occupants.
3. *Environment*: measuring the positive impact on the environment

There have been several educational and housing projects built in the VELUX Model Homes initiative as prototypes for highly performing buildings (VELUX, n.d.). This program, led by VELUX, a Danish window and skylight manufacturer with an in-house research team, has seen the design and construction of a several single-family houses designed to connect environmental design and wellness in specific architectural ways. The design of these buildings has included the use of digital simulation tools to predict aspects of environmental performance including energy and daylight. A recent example in this program, is a suburban home in Toronto, Canada designed by local architects Superkul. The Active House Centennial Park became Canada's first certified Active House and used environmental simulation tools to be able to predict qualities of light and energy use in the building during design stage. The design focuses on natural daylight and ventilation for optimal indoor quality in ways that promotes sustainability and the well-being of inhabitants (Figure 32.3

FIGURE 32.3 The benefits of extra daylight in the home. Active House Centennial Park, Toronto Canada, 2016. Photograph: Eyecapture—Igor Yu.

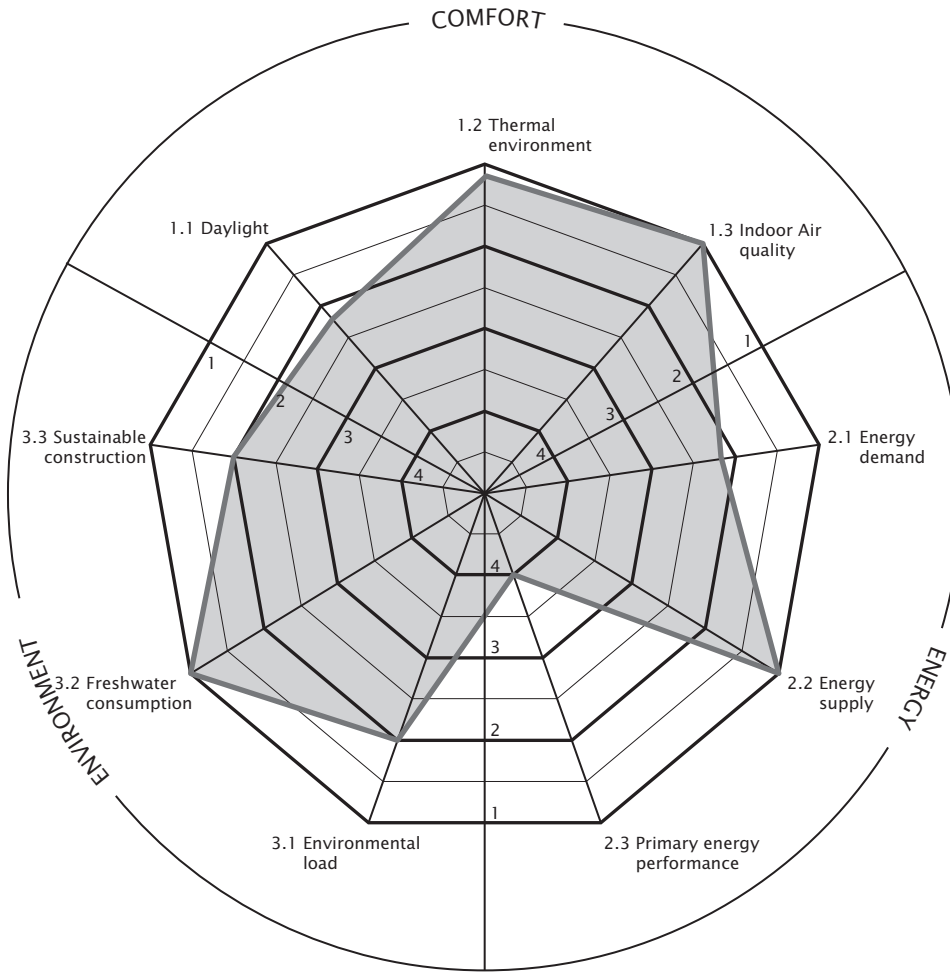

FIGURE 32.4 Active House Metric, Centennial Park Active House, 2016. The Active House metric focuses on comfort, environment, and energy, producing a score for how the building performs. This diagram shows the relationships and tradeoffs between the different parameters such as thermal comfort and energy use. Image courtesy Velux.

and 32.4). The large house has operable triple-paned windows and programmable skylights, as well as a Tesla Powerwall rechargeable lithium-ion battery system for the home that pulls electricity from its energy provider (in this case a provider whose grid is 100% renewable) during off-peak hours. From the outside, it has a similar size and shape as its neighbors, but on the inside, it is surprisingly bright with 11 skylights and the living room is two stories high, not like a typical suburban home (Active House Centennial Park, building visit, April 25, 2017; Great Gulf, n.d.a). Superkul incorporated details like an articulated side wall with windows to bring daylight into the house's middle spaces and to give the living room a sense of having a small courtyard facing the neighbor's blank side wall. After it was completed in 2016, a VELUX employee and his family moved into the house to document their experiences and blog about how it feels to live in the house and its psychological impact on their

comfort and well-being as well as how easy the technologies that operate the house are to use (Great Gulf, n.d.b).

The Social Benefits of Climate-Adapted Neighborhoods

The intersections between the social and ecological aspects of resilient design have been explored at a neighborhood scale in a series of climate adaptations in Denmark. These are a series of road and public space renovations that address rising sea levels and urban flooding and are designed to encourage social and nature-based interactions among residents. The projects began in response to a serious flood event that occurred in July 2011, when more than 150 mm of rain fell in Copenhagen in only two hours causing some areas of the city to be up to a meter under water (Strickland & Divall, 2015). Many residents experienced serious flooding in their homes and damage to roads and parks, as the water overwhelmed the sewer system. Causing more than €800 million in insurance claims, with a total socio-economic loss estimated to be more than double this figure (Strickland & Divall, 2015), this particular flooding event became a catalyst for political and economic support for the development of an ambitious climate adaptation strategy for the city. Shortly after, Copenhagen adopted the Climate Adaptation Plan (City of Copenhagen, 2011) and then a Cloudburst Management Plan (City of Copenhagen, 2012), which outlined specific urban renovation projects. Over the next 10 to 20 years, 300 neighborhood design transformations will be implemented around the city to respond to local needs and current and projected flood events (City of Copenhagen, 2012; Saaby & Bauman, 2019). The mandate of the program is to improve resident quality of life using these renovations and to better connect people to each other and to nature, not solely to stop buildings and streets from flooding. The plan details that Copenhageners must be able to deal with a one-meter sea level rise over the next 100 years, and these urban design changes should help people emotionally and practically cope with the future reality of a climate changed city.

Danish office Tredje Natur was part of the team that designed the one square kilometer neighborhood masterplan for the first Climate Neighborhood in 2012 (Tredje Natur, 2015). Among its key principles, the masterplan reclaims 20% of the current road area for pedestrians, bikes, and parks, by optimizing the road infrastructure and parking lots (SLA & Ramboll, 2016). The masterplan introduces bicycle paths that act as storm water channels, water towers, green roofs, urban gardens, green houses, and canals that carry water out from the neighborhood to the harbor. These strategies were designed to simultaneously give rise to greater biological diversity in the city. Tredje Natur is known for their multiscale approach to resilience, and their ideas extended beyond neighborhood regeneration. For example, their "Climate Tile" is a rainwater management strategy but also a tactile and modular material system that improves the sidewalks in the city (Tredje Natur, 2014). The tile is designed to be used when sidewalks are demolished for infrastructure works or to widen the sidewalk. The tiles are permeable, modular, sidewalk pavers that can be installed in such a way that they drain excess rainwater to street trees and to the soil beneath for absorption.

FIGURE 32.5 Rendering of the climate adaptation of Sankt Kjelds Square and Bryggervangen in rainy weather, Copenhagen, Denmark, 2017. The climate adaptation by SLA completed in 2019 and is designed to improve people's connection to nature and address the storm water and rising sea levels in Copenhagen. This image shows the vision of the project in rainy weather. Rendering courtesy SLA.

Climate Adapted Renovation of Sankt Kjelds Square and Bryggervangen Road by SLA Architects

The first completed climate adapted neighborhood in Copenhagen focused on the redevelopment of a public square and main road by SLA architects. Finished in early 2019, the design integrated trees, plants, walking paths, and green space into this streetscape, previously dominated by hard, nonporous surfaces and a very wide circular roundabout (City of Copenhagen, 2012). The paved roads for cars was narrowed and reduced in size, and the area now has a variety of pedestrian spaces and planted areas. There 586 new trees, shrubs, and plants providing a surface for absorbing rainwater, reducing flooding, and greatly enhancing the area's natural environment. The design encourages residents to spend more time outside and to engage with nature with areas for outdoor dining, benches between the trees, and large tree trunks that children can play on and climb. During an extreme cloudburst, rainwater will be directed to the permeable areas called "rain beds" where it will slowly be absorbed and sink or drain further away to the Copenhagen harbor via a cloudburst line (Figure 32.5). The renovation is specifically designed to offer neighborhood amenities during sunny weather as well (Figure 32.6). Studies of neighborhood greenspace show that initiatives incorporating trees not only promote biodiversity, but they also positively impact people's sense of health and well-being, and quality of life for residents (Kardan et al., 2015).

Climate Adapted Renovation of Hans Tavsens Park and Korsgade, SLA Architects

The newest climate adaptation neighborhood by SLA Architects incorporates a public park and street renovation and will start construction in late 2021. The designers worked closely

FIGURE 32.6 Rendering of the climate adaptation of Sankt Kjelds Square and Bryggervangen in sunny weather, Copenhagen, Denmark, 2017. The climate adaptation by SLA completed in 2019 reduces the area of paved roads for cars and provides more shared space for neighbors. This image shows the vision of the project in dry weather. Rendering courtesy SLA.

with local residents to understand specific local needs to maximize the social and ecological improvements (SLA & Ramboll, 2016.). There will be an improvement to the dimensions and materials of the sidewalks and pedestrian areas along Korsgade street while making the built environment more resilient to sudden weather events. As with the earlier project, the redesigned street has been narrowed to reduce space for cars and has been redesigned with permeable paving materials and patterns. The street will have vegetation to absorb excess rainwater, and channels of irrigation to force the water away from the local site and into the lake. With fewer hard impermeable surfaces, city noise will be dampened, the new greenery improves biophilia, and bird and pollinators will be attracted to the site (SLA & City of Copenhagen, 2016). Combined with environmental and ecological benefits, there are a number of social sustainability features that incorporate active design principles, including new bike lanes and multifunctional minigardens to get people outside playing, tending to nature, and walking along the new streetscape (Peters, 2017). The new Hans Tavsens Park will function as a large rainwater catchment basin during storm events creating a sculptural circular pool. The pool will become a local landmark and symbol for the park and a way of making water a part of the city.

Locally Specific Approaches to Resilient Design

In each of the climate adaptation projects in Copenhagen, the focus has been on multifunctional design features that have many benefits. These projects illustrate how resilient architecture can be a process that is influenced by people's expectations and how people use buildings, not an end goal with clear boundary conditions. For example, in the areas of Copenhagen that were just described, the context of climate change and extreme weather is a focus but

the designers have taken into account that water imposes varied environmental challenges (and opportunities) throughout the year. Not just flash flooding but a number of unusual weather events are impacting Copenhagen, including storm surges, blizzards, and summer dry spells. A strong feature of the urban interventions is that rather than a singular climate change vision for the city, there has been a neighborhood scale approach that has been carefully planned by Tredje Natur, with numerous designs created by different design teams (the two examples discussed here are by SLA Architects, but future design competitions have been won by different designers). Although the process of arriving at climate adaptation initiatives can and should be repeated elsewhere, the specific design solutions employed are not resilience promoting strategies that should necessarily be replicated around the world in other social or ecological contexts. The nature-based urban interventions proposed for a number of resilient neighborhoods in Copenhagen are examples of how some design studios are rethinking resilient design to maximize the social impacts of resilient design strategies.

Conclusion

Since the qualities of buildings play such an important role in how we live, there is potential to better relate to, and incorporate, concepts of resilience. As shown, terms like *resilience* and *sustainability* are often used interchangeably in architecture but in the push for new buildings to reduce their impact on the natural world, the human and social dimensions, and potential benefits of buildings are often neglected. While reducing negative impact is critical, given that buildings and their operations contribute nearly half of all harmful greenhouse gas emissions and that buildings are intensive users of nonrenewable energy and resources especially during their operational phases (International Energy Agency, n.d.), research has shown that overwhelmingly it is the operation of buildings—how, when, in which ways they are used, and by whom—that most affects the environmental performance and impacts of buildings on people and natural environments (Janda, 2011). The culture of how we use buildings and what we expect from them needs to shift to make real progress if we are to make our cities, and ourselves, more resilient. Multifunctional resilience initiatives that focus on positive co-benefits for the environment and people can lead to better collaboration from stakeholders and increased public support. The example of the Copenhagen Cloudburst program, and others, illustrate some of these challenges. There is an urgent need for deeper studies and analysis of built examples of resilient architecture. By better connecting the term *resilience* to concepts in other fields and better aligning the priorities of people to buildings, the term *resilience* will be made more relevant and adaptable to architectural design.

Key Messages

1. The social roles of buildings and how they influence our well-being are largely overlooked—although these potentially resiliency-promoting aspects would be particularly important to people in the event of a crisis. People spend more than 90% of our time indoors and the qualities of buildings and landscapes impact our moods, well-being, social experiences, and how we behave.

2. Designers have the potential to better relate to, and incorporate, concepts of resilience. This means finding better ways of evaluating the success of buildings, and challenging the narrow existing metrics of building performance. New metrics such as Active House and WELL are focusing on people and our experiences.
3. Design features for resilient buildings and human resilience are often the same, and are most effective when considered together. Multifunctional resilient design initiatives that focus on positive co-benefits for the environment and people can lead to better collaboration from stakeholders and increased public support.
4. There are some examples of forward thinking architects that are incorporating behavioral design in their work. Multidisciplinary researchers at GXN in Denmark have a behavioral design research cluster in their office that studies how people use buildings and how to design environments that promote social interactions and well-being.
5. A series of climate adaptation renovations in neighborhoods in Copenhagen Denmark offer a multifunctional approach to resilient design, addressing neighborhood flooding by simultaneously improving the qualities of public spaces and better connecting people to nature.

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