Resilient Design

AIAPDH261

5 LU/HSW Hours

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Resilient Design Final Exam

1. **Resilient Design is based on which of the following?**
    a. A concept introduced by the AIA
    b. The theory of Resilience
    c. The iCodes formulated by the International Code Council
    d. Fire Codes developed in California
2. **The 2021 changes to the California regulations require what additional type of continuing education for Architects?**
    a. Resilient Design specific training courses
    b. Sustainability and LEED continuing education
    c. Zero Net Carbon Design continuing education
    d. No new regulations have been implemented.
3. **A definition of resilience, as articulated by the Resilient Design Institute, states that resilience is …**
    a. The capacity to adapt to changing conditions and to maintain or regain functionality and vitality in the face of stress or disturbance.
    b. The capacity to bounce back after a disturbance or interruption.
    c. Ability to maintain livable conditions in the event of natural disasters, loss of power, or other interruptions
    d. All of the above.
4. **Which of the following materials were banned for use in the downtown area of Chicago after the great fire?**
    a. Wood
    b. Terra cotta
    c. Limestone
    d. None of the above
5. **Which of the following is not one of the principles of Resilient Design?**
    a. Transcending scale
    b. Durability
    c. Building style
    d. Anticipation of interruptions
6. **Which of the following government agencies have resilience programs:**
    a. The Environmental Protection Agency (EPA)
    b. FEMA
    c. HUD
    d. All of the above
7. **The Resilient Building Codes Toolkit is published by which of the following**
    a. LISC Division of HUD
    b. IBC
    c. FEMA
    d. UN commission on Resilient design

8. **The Better Buildings ® program addresses which of the following?**
    a. Transportation networks
    b. Building design awards
    c. Water & Waste
    d. All of the above
9. **A set of rules that specify the standards for construction of objects such as buildings and non-building structures is called a _____?**
    a. code
    b. guideline
    c. practice
    d. statute
10. **Chapter 9 of the IBC supports which resilience strategy?**
    a. Inclusive communities
    b. Fire Resistance
    c. IAQ
    d. Mold, mildew, rot
11. **The first state to adopt an energy code was?**
    a. Oregon
    b. Colorado
    c. California
    d. Minnesota
12. **The Global Principles for Resilient Infrastructure were developed by :**
    a. COP 27 in Sharm Al Sheikh, Egypt
    b. National Research Council Canada
    c. UN office for Disaster Risk Reduction
    d. AIA Resilient Design Committee
13. **An example of a building that uses sustainable materials and has climate responsive features, as presented in this course, is:**
    a. Fallingwater in Pennsylvania, USA
    b. Coppenhill, Copenhagen, Denmark
    c. The Al Wasl Dome, Dubai
    d. The Museum of Tomorrow in Rio de Janeiro, Brazil
14. **The ___________ of natural disasters refers to how often they occur while _______ refers to the severity of a single event.**
    a. frequency, magnitude
    b. frequency, intensity
    c. cycle, intensity
    d. likelihood, damage
15. **According to Novogradac, (average) property insurance rates between 2020 and 2021 changed in which way?**
    a. Increased by $514
    b. Increased by 13.0%
    c. Decreased by 13.3%
    d. Increased by 33.5%

16. **In the United States, most damage has been done by which form of natural disaster?**

    a. Wildfires
    b. Earthquakes
    c. Floods
    d. Tropical storms and cyclones (hurricanes)

17. **According to the National centers for Environmental Information, the state that has suffered the highest cost of natural disasters since 1980 is:**

    a. Texas
    b. California
    c. Florida
    d. Louisiana

18. **Use of impact resistant roofing materials addresses which climate change impact?**

    a. Shrapnel in a war zone
    b. Wildfire risk
    c. Flooding
    d. Hail events

19. **What does DfD stand for?**

    a. Department for Design.
    b. Design for Deconstruction
    c. Department for De-forestation
    d. Design for Development.

20. **SHERPA is:**

    a. An online assessment tool for evaluating sustainable housing
    b. A study by the European Union to analyze the impact of resilient design in Nepal
    c. A DoD program for promoting resilient design in military facilities
    d. A report on Resilience published by the International Center for Science and High Technology

21. **Which of the following is / are published by the American Institute of Architects?**

    a. Climate Change Adaptation Design Resources
    b. Guidelines and Solutions for Architects on Climate Resiliency
    c. Disasters and the Built Environment
    d. b & c

22. **Which of the following is / are true of the wildfires around the Los Angeles, California area in January 2025:**

    a. The Eaton and Hurst fires were cumulatively the worst fires
    b. Only 18,000 people were evacuated at the peak
    c. There were multiple fires with the Palisades fire being the largest, consuming over 24,000 acres
    d. a & b

23. Some of the structures that escaped damage while others around them perished in the 2025 Los Angeles wildfires are credited to have survived due to which of the following factors?

   a. Luck
   b. Use of resilient design strategies
   c. Removal of debris and loose landscaping from around the home(s)
   d. All of the above

24. Achieving zero or negative carbon emissions over the life of a building is a goal of which type of design approach?

   a. Net Zero design
   b. Zero Net Carbon (ZNC) design
   c. Biophilic design
   d. Negative carbon design

25. Architect Onah Jung has argued that we need to think beyond Net Zero to tackle climate change and sustainability. The approach that is proposed as a more effective approach is:

   a. Minimalist design
   b. More strict code enforcement
   c. Resilient design
   d. Universal design

26. What is the ASCE risk category for buildings designated as essential facilities?
   a. IV
   b. III
   c. II
   d. I

27. A key recognition about the Resilient design principle of not being absolute is:
   a. Unless all aspects align, resilient design options cannot be implemented
   b. All solutions will inherently be partial
   c. A phased approach is not recommended
   d. All risks have to be treated equally

28. "Economic Darwinism" refers to:
   a. An economic practice which establishes that competition leads to lowest prices and maximum profits.
   b. An economic theory which suggests that businesses that can adapt to change will survive will success, while those that cannot, will fail.
   c. An unofficial measure for building life-cycle cost.
   d. That notion that a population's survivability is based on economic well-being.

29. Building strong foundations is a resilient design tactic that contributes to which of the following:

   a. Improved operational efficiency
   b. Cost savings
   c. Earthquake resistance
   d. None of the above

30. Which of the following is not a means of achieving resilience in landscaping?

a. Use of artificial plants
b. Using native plants
c. Water efficient irrigation systems
d. Using diverse plant species

Resilient Design

What Is It and What it Means for Architects

By: Muhammad A. Siddiqui, AIA.

Course Summary

"Resilient design is the process of designing buildings, landscapes, and entire communities to mitigate the impact of extreme weather and other external threats. Resilient design focuses on practical and realistic solutions." – Nearby Engineers.

This concept of Resilient Design, which traces its origins in the theory of Resilience, has been introduced into architecture since the 1970s to proactively design buildings in a way that they can withstand and "recover" from the impact of nature, whether disasters or climate change. While there is no real fixed definition, the concept has endured and recently gained much traction as the push towards NetZero and sustainability become mainstream in architecture. Resilient Design is, in many settings, an umbrella type of concept that can apply to many design approaches with the common denominator being the ability of structures to be adaptable to changing conditions and remain functional. Implicit in this is the objective to sustain the building's use during and after natural (or even human-caused) events within the design parameters.

This course is intended to discuss the origins of the concept of Resilience and how it has come to become relevant in building design. The course will address the overlap and differences between sustainability and resilient design. This will be followed by examining how architecture is embracing resilient design and how these influences and inform building design and urban planning. The increasing role of regulatory bodies in adopting sustainability and resilient design principles will be explored and the current and future trends in resilient design will be presented with a concluding discussion on the long-term impact of resilient design concepts on other parallel design trends.

Objectives

There are five main objectives of the course:

1. Review and understand the history of the theory of Resilience and its adoption in design and architecture.
2. Provide an overview of the influence of governmental and legislative actions on promotion of Resilient design.
3. Examine the principles of Resilient design as applied to buildings.
4. Examine how Resilient design can contribute towards climate sustainability and the Net Zero aspirations of COP21.
5. Discuss the emerging trends in Resilient design and evaluate the impact of these on architectural practice and the practical ways these can influence the wider fields of urban planning.

Learning Objectives

- Understand the characteristics of climate sustainability and Resilient design.
- Filter through the gumbo of green building and sustainable design concepts to learn how Resilient design objectives intersect with building design and urban planning.
- Understand how architects can use Resilient design principles in their work to support sustainability and Green building objectives.
- Be familiar with how climate sustainability and Resilient design can contribute towards the Net Zero aspirations of COP21.

PART 1 - Resilient Design, its Origins, Evolution, and Contemporaries

1.1. Resilience Theory

Resilience is an English word derived from the Latin "*resiliens*," meaning to rebound or recoil – to jump back up. This trait of the word made it the descriptor of what is known as Resilience Theory. Resilience theory is the conceptual framework for understanding how some individuals can bounce back after experiencing an adverse situation in a strength-focused approach.[1]

Resilience theory has its roots going back to the 1970s in psychology when psychologists studied the outcomes of children at high risk for psychopathology[2]. The development of the formal theory itself is credited to Norman Garmezy, who was a professor at the University of Minnesota, and his contribution was so notable that he was called the "grandfather of resilience theory" by the New York Times magazine[3]. Dr. Garmezy argued that resilience is "not necessarily impervious to stress, rather, resilience is designed to reflect the capacity of recovery and maintained adaptive behavior that may follow initial retreat or incapacity upon initiating a stressful event"[4].

OK, so what has this psychological theory got to do with Architecture or building design and construction? After all, the study and origins of the theory and the concept of resilience were focused on children and the adaptability of children to overcome stressful situations. It may not be the immediate results of the original psychological studies that directly produced Resilient Design, but the notions and implications postulated by Resilience theory in a broader context offered a framework that could be applied to fields beyond just understanding childhood development. In this vein, when applied to design of the human built environment, the Resilient Design Institute (RDI) defines Resilience as "the capacity to adapt to changing conditions and to maintain or regain functionality and vitality in the face of stress or disturbance. It is the capacity to bounce back after a disturbance or interruption."[5] It further goes on to expand on where this can be applied: At various levels —individuals, households, communities, and regions — through resilience we can maintain livable conditions in the event of natural disasters, loss of power, or other interruptions in normally available services.[6]

[1] parentingforbrain.com/resilience-theory/ - Pamela Li; Sept 21, 2024
[2] Ibid
[3] PsychReel.com/Resilience Theory – Nov 12, 2020
[4] optimistminds.com/resilience-theory/ - 27/08/2022
[5] https://www.resilientdesign.org/resilient-design/
[6] Ibid

Based on this line of thinking the RDI defined Resilient Design as "the intentional design of buildings, landscapes, communities, and regions in order to respond to natural and manmade disasters and disturbances—as well as long-term changes resulting from climate change—including sea level rise, increased frequency of heat waves, and regional drought."[7]

The above definition, which is largely focused on disaster and climate change impacts, can be broadened somewhat to include other external threats that would consider economic and social disruptions. When you amalgamate all these, a slightly more comprehensive definition would read: *"Resilient design is the process of designing buildings, landscapes, and communities to mitigate the impact of extreme weather and other external threats"*.[8]

1.2. Background of Resilient Design

The specific term "Resilient Design" does not seem to have a singular creator but appears to have organically evolved and made popular in the fields of architecture, urban planning, environmental design, and sustainable building design – primarily by way of writings and organizations that emphasize creating communities and buildings that can respond to disasters and disturbances. One of the organizations that pioneered and is leading the efforts to promote Resilient Design is the previously mentioned Resilient Design Institute (RDI) formed in 2012 as a nonprofit venture launched by Alex Wilson who is also the founder of BuildingGreen, Inc. in 1985, pre dating the USGBC with a focus on sustainability and a stated aim to "transform the building industry into a force for positive change".[9] Additionally, the American Institute of Architects (AIA) has also played a significant role in advancing the concept with the California chapter of the AIA being the most active. AIA CA uses the following definition to guide its efforts: *Resilient Design is planning and designing our built environment to sustain probable impact from progressive climate change and episodic natural disasters.*[10]

In 2021, the California Architect's Board (CAB) proposed regulatory action to require Zero Net Carbon Design Continuing Education for Architects under the DEPARTMENT OF CONSUMER AFFAIRS; TITLE 16. PROFESSIONAL AND VOCATIONAL REGULATIONS. As part of this requirement, the CAB sought modification of the Business and Professions Code (BPC) section 5600.05 (a)(2)(B), to consider adopting section 166 in article 10 of division 2 of title 16 of the California Code of Regulations (CCR). This was presented in the state legislature as Assembly Bill (AB) 1010 (Chapter 176, Statutes of 2021) that added BPC section 5600.05 subsection (a), paragraph (2), subparagraph (B), which requires architects to complete five hours of continuing education (CE) coursework on zero net carbon design (ZNCD). The statute requires the Board to develop regulations to implement a requirement for architects to complete five hours of coursework regarding ZNCD as a condition of license renewals occurring on or after January 1, 2023. While the title and focus are on Zero Net carbon Design, the language of the requirements place significant emphasis on Resilient design as being a key feature of what would define "Zero Net Carbon Design." For example, *Subsection (a), paragraph (2) would define "zero net carbon design requirement" to mean architectural designs including* ***resilient designs*** *of new construction and/or existing facilities that produce on-site, or equitably procures from offsite, enough carbon-free renewable energy to meet the building's operations energy consumption*

[7] Ibid
[8] Microsoft AI summary
[9] USGBC
[10] Aiacalifornia.org/byline – William Melby, FAIA; January 19, 2022

over the building project's lifecycle. This also includes architectural design responsive to embodied carbon reduction and ***resilient*** *performance of a facility that results in reduced embodied carbon or minimized carbon.*[11] It goes on to specifically address Resilient Design: *Subsection (a)(2)(A) would define resilient performance as the capacity of a system, for example: a community, society, or ecosystem, to withstand physical calamities and continue to function. Resilient building design as described in this subparagraph fosters resilient performance.*[12]

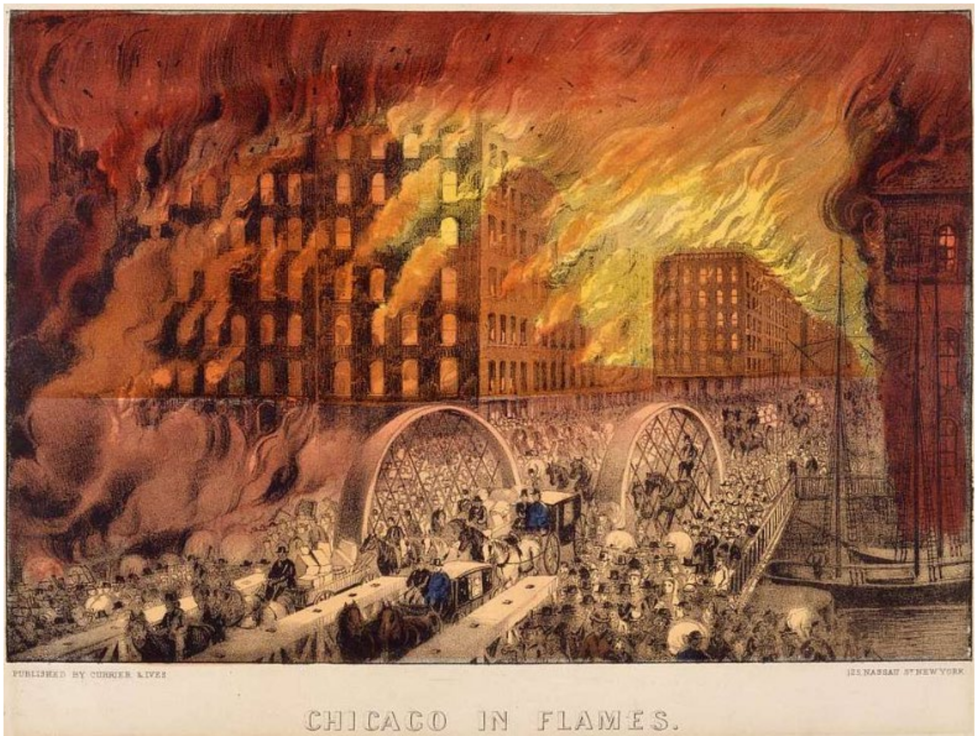
Based on this relative importance given to Resilient Design, it is a bit surprising that until recently, the topic was not one of the "hot" trends or much talked about in professional discussions – certainly not as prominently as "sustainability", "green buildings", or even "biophilic design" and "renewable buildings". A plausible reason for this is that many of the principles and concepts inherent with Resilient design have been around for a long time and in varying degrees were always part of the design process. What has changed is that only within the past few years these have been formalized and expressed as a structured way of approaching building design. Due to the ongoing confluence of many design philosophies emanating from the NetZero targets and the focus placed on buildings and construction, Resilient design is emerging as a strategic platform to help guide and shape building construction. It is not a design "style" *per se* but a design approach. This makes it qualitatively different in architecture as it is not an aesthetically recognizable genre but a framework that can be applied to any style or typology. In this way, resilient design shares many of the same characteristics as "sustainable" design in that both provide guiding frameworks to achieve measurable outcomes in terms of building performance rather than appearance. While both design approaches have much in common, they are not synonymous. Reducing the environmental footprint of buildings with sustainable architecture is important as the building sector contributes 40% of greenhouse gas (GHG) emissions. However, a LEED certification for green buildings becomes irrelevant if the building becomes uninhabitable due to natural disasters or emergency situations. Thus, resilient design and sustainability complement each other.
The concept of sustainability has evolved over time, the basic principle is the same which is protecting the environment from the impacts of human society. On the other hand, a resilient design is meant to protect human society from the natural calamities to prevent disruption of normal life.[13]

1.3. How Resilient Design Concepts Have Evolved in Architecture and Planning

The awareness for resilience in architecture, in its very primal sense, is as old as the building profession itself. Inherent in the creation of a building is the notion of providing shelter – protection from the elements and sufficient structural strength to withstand basic natural elements of the surrounding environment. However, Resilient design, as it has evolved in the contemporary sense, goes beyond just making a building structurally viable and able to shield from water and wind. It is a more comprehensive approach that goes beyond just addressing individual buildings – it integrates architecture, infrastructure, landscape and urban planning to create systems and communities that can prepare for, handle, and then effectively recover from problems – whether they be natural disasters or human created events. One of the earliest

[11] cab.ca.gov/docs/regulation_changes/2022-23/ccr166notice.pdf
[12] Ibid
[13] https://constructionreviewonline.com/knowhow/home-and-office/sustainable-and-resilient-design/

examples of bringing resilience into widespread building design came after the great fire of Chicago that devastated the city in 1871, destroying some 17,450 buildings covering almost 3.5 square miles (9 square km), and caused $200 million in damage. Roughly one-third of the city lay in ruins, and an equal proportion of the population—nearly 100,000 people—was homeless.[14]



Chicago In Flames by Currier & Ives, 1871. Source: public domain (http://commons.wikimedia.org/)

After the fire, laws were passed to prevent the same thing from happening again. Materials like brick, limestone, marble and Terracotta tile became the preferred building materials and wood was banned as a material in the downtown area.[15] These laws evolved into some of the earliest Fire Codes that continue to exist and mandate safety for buildings till this day (of course, with continuous modifications as risks, technologies and solutions evolve). This development of making buildings able to withstand fires and recover to functionality is consistent with the definition of resilient design, albeit focused on fire. As more threats to buildings gained recognition and mitigations were developed, many requirements were introduced into mandatory building codes. In this way, many aspects of building codes already incorporate elements of resilience, without consciously using the term. However, the purpose and intent of most building codes is to establish minimum requirements to protect the health, Safety and “general welfare” human occupants and public at large in buildings.[16] Codes typically are not concerned with the reusability post event functionality of a building or structure after a disaster (natural or human caused) has struck. In a building built “per code,” it is reasonable to expect that occupants and, in some cases, assets survive the event for which the building was designed based on the code criteria. However, the ability of the building itself to recover rapidly and

[14] https://www.britannica.com/event/Chicago-fire-of-1871; Dec 4, 2024
[15] Moss architecture design build; “The Great Chicago Fire Changed Building Code Forever” 10.12.2017
[16] International Code Council, “Building Codes 101, PART 1: Introduction to Building Codes”

effectively from the event is not an explicit expectation based on adherence to traditional building codes. Similarly, building codes typically address individual buildings or projects and are not generally designed to encroach on adjacent properties or the broader urban fabric and community. While some jurisdictions do consider a given project's impact on the community, this is done through planning, zoning and urban management regulations that are exclusive to the locality.

As the population shift towards urbanism spread across the globe throughout the 20th century, the complexities and permutations of challenges posed by this hasty amalgamation of buildings, people, transportation infrastructure, social centers and commercial requirements created a fertile environment for rapid, often unchecked, growth with very few safeguards or enforced mandates for addressing the risks posed by various natural or potential human generated threats. As it tends to be the historical trend with human nature, we tend to approach everything with an abundance of optimism. Only when a disaster strikes and that only if it is measurably large in human and /or material costs, do we acknowledge the problem as real and take measures to find solutions from preventing harm the next time around. The 20th century provided ample lessons to keep regulators, engineers and planners on their toes and continually update codes, regulations, and design guidelines. These ranged from wind load designs to protect from hurricanes to seismic solutions for withstanding earthquakes and a plethora of natural incidents in between. If nature was not enough of a challenge, the dark side of human activity, sometimes deliberate and sometimes unintended, added to threats and risks that required design and planning attention. These ranged from the dramatic and overt effects of war and terrorism to the more subtle and silent but just as deadly effects of pollution (of all kinds) resulting from careless and wasteful human activities. By the 21st century, the global nature of the damage caused by unrestrained human activity was not only harmful in of itself but it was also affecting the natural balance of the planet to the point of potentially redefining the norms of temperature and climate patterns that allow various life forms to exist on Earth. This ushered in a period of activism and awareness that culminated in the Paris Agreement of 2015 (COP21) that created the targets for NetZero. Even though the focus of Net Zero is targeted on neutralizing carbon emissions, there has emerged a broad and heightened recognition of a need for tangible actions to take a more comprehensive approach to managing and developing the built environment and even take corrective actions where feasible.

It is in this atmosphere of culpability and obligation that design professionals globally are advocating for better design guidelines and regulatory mandates to ensure compliance with tactics that can achieve tangible and comprehensive results. It is here that abstract terms like sustainability, carbon neutrality, resilience, among others begin to generate specific design strategies and concepts. Resilient Design compliments the concept of designing for carbon neutrality and energy efficiency by layering on the need for buildings and the broader urban fabric to be not just "sustainable" in terms of carbon utilization but be durable and able to sustain itself through its natural geographic threats as well as incorporating contingencies for human based threats, deliberate or accidental. This has made the Resilient Design framework attractive for organizations like the AIA and code development bodies because it is aimed at merging safety and welfare with disaster response, sustainable design and long-term economic benefits for the building and community at large. This will become more evident as we discuss the principles of resilient design in the next sections.

1.4. The Overlaps Between Resilient Design and Other Analogous Design Philosophies and Approaches

As mentioned already, terms like “sustainability”, “environment”, and “green buildings”, among others, do not have universally agreed upon definitions and different organizations, companies and “experts” use variant descriptions based on the context, area of focus, and application. Some are very narrow while others can be overly broad to the point of being generic. The same holds true for Resilience and Resilient Design. In this regard, the RDI has done a commendable job of laying out a working framework and defining a set of principles that are useful to help navigate implementation of Resilient Design. These are listed below:

The Resilient Design Principles[17] ***[bolded emphases by author]***

1. ***Resilience transcends scales.*** Strategies to address resilience apply at scales of individual buildings, communities, and larger regional and ecosystem scales; they also apply at different time scales—from immediate to long-term.

2. ***Resilient systems provide for basic human needs.*** These include potable water, sanitation, energy, livable conditions (temperature and humidity), lighting, safe air, occupant health, and food; these should be equitably distributed.

3. ***Diverse and redundant systems are inherently more resilient.*** More diverse communities, ecosystems, economies, and social systems are better able to respond to interruptions or change, making them inherently more resilient. While sometimes in conflict with efficiency and green building priorities, redundant systems for such needs as electricity, water, and transportation, improve resilience.

4. ***Simple, passive, and flexible systems are more resilient.*** Passive or manual-override systems are more resilient than complex solutions that can break down and require ongoing maintenance. Flexible solutions can adapt to changing conditions both in the short- and long-term.

5. ***Durability strengthens resilience.*** Strategies that increase durability enhance resilience. Durability involves not only building practices but also building design (beautiful buildings will be maintained and last longer), infrastructure, and ecosystems.

6. ***Locally available, renewable, or reclaimed resources are more resilient.*** Reliance on abundant local resources, such as solar energy, annually replenished groundwater, and local food provides greater resilience than dependence on nonrenewable resources or resources from far away.

7. ***Resilience anticipates interruptions and a dynamic future.*** Adaptation to a changing climate with higher temperatures, more intense storms, sea level rise, flooding, drought, and wildfire is a growing necessity, while non-climate-related natural disasters, such as earthquakes and solar flares, and anthropogenic actions like terrorism and cyberterrorism, also call for resilient design. Responding to change is an opportunity for a wide range of system improvements.

[17] www.resilientdesign.org/the-resilient-design-principles/

8. ***Find and promote resilience in nature.*** Natural systems have evolved to achieve resilience; we can enhance resilience by relying on and applying lessons from nature. Strategies that protect the natural environment enhance resilience for all living systems.

9. ***Social equity and community contribute to resilience.*** Strong, culturally diverse communities in which people know, respect, and care for each other will fare better during times of stress or disturbance. Social aspects of resilience can be as important as physical responses.

10. ***Resilience is not absolute.*** Recognize that incremental steps can be taken and that total resilience in the face of all situations is not possible. Implement what is feasible in the short term and work to achieve greater resilience in stages.

As is quite clear from the above principles, there are many compliments and overlaps with other design strategies like use of renewable materials, redundancy in design, adapting lessons from nature, use of passive systems and designing to respond to threats and failures. But it also goes on to incorporate broader human needs and cultural considerations that are not always directly a consideration in building design. However, it is the first and last of the principles that really provides the differentiation, flexibility, and practicality for Resilient Design implementation. It seeks to influence on a regional scale but can be modified to just a single building if that is all that is achievable in each situation. What makes this possible is the acknowledgement of incremental implementation since the principles are guidelines and not an absolute step by step methodology.

At this point let us examine the relationship between Resilient Design and some of the other design philosophies that are in the popular public and professional design discourse:

Resilience vs. Sustainability[18]

Resilience and sustainability are closely related concepts, but some distinct differences should be highlighted.

> *Sustainability is aimed primarily at reducing the environmental impacts of buildings and structures. It focuses on using resources more efficiently to reduce air pollution, conserve water, improve energy efficiency, and reduce carbon dioxide emissions.*
>
> *Resilience is aimed predominantly at preparing for future hazards associated with climate change. It focuses on employing strategies such as better construction practices, robust planning measures, and wiser decision-making processes to create buildings to withstand extreme weather events and other natural catastrophes.*

For more context, consider this example: a sustainable building would use solar power and energy-efficient appliances to reduce emissions, while a resilient building in the same location might be designed with higher storm resistance or stronger foundations to better withstand flooding. Together, these approaches make up a comprehensive

[18] KREO.net: "Why Resilient Design Is a Key Part of Sustainability"; blog by Andrew; February 24, 2023

strategy for creating resilient and sustainable buildings that are more durable against natural disasters and climate change impacts.

Resilience vs. Green Buildings

The United States Green Building Council (USGBC) has actively promoted the concept of resilience and gone so far as to make a case for the terms "green buildings" and "resilience" to be considered synonymous. While that may be debatable since there are some key "mission" differences between the two. A "green building" primarily addresses minimizing environmental impact by using energy-efficient practices and sustainable materials, while a "resilient building" is designed to withstand natural and human caused disasters with rapid recovery. However, in practical terms, there is indeed great overlap between the two and the USGBC makes some valid arguments for the practical synonymity of the two.

> In 2015, USGBC introduced a series of resilient design pilot credits in an effort to bring this topic to the forefront of project design. In 2018, the credits were revised to improve effectiveness, reflect feedback and harmonize them with RELi. The credits are available to all new construction projects looking to certify through LEED v4 or LEED v4.1 and include:[19]
>
> > *Assessment and Planning for Resilience: To earn the credit, teams must identify risks and potential vulnerabilities related to the effects of climate change. Risks that must be considered include sea level rise, extreme heat and more intense winter storms.*
> >
> > *Designing for Enhanced Resilience: This ensures that risk-related information collected from the above credit is taken into account through mitigation measures. Project teams must address either one or two of the top hazards.*
> >
> > *Passive Survivability and Back-Up Power During Disruptions: This centers around the concept that buildings should be able to safely shelter occupants during a power outage, as well as be able to provide backup power.*
> >
> > *LEED advocates for resilience-enhancing strategies that include durable materials, thoughtful site selection, rainwater collection, demand response, grid islanding, energy efficiency and more. Communicating the impact of that work is also a vital part of ensuring people are ready in the face of a serious event. USGBC recently released a Living Standard Action Toolkit to help guide companies and individuals and engage them in talking more about the impact this work has on human beings.*

Resilience vs. NetZero Design

Both NetZero design buildings and Resilient buildings are designed to reduce their environmental impact. But as with other similar philosophies, there are differences in the primary focus of each approach: NetZero design buildings focus on generating clean

[19] USGBC.org; "Why green building is synonymous with resilience"; Sarah Stanley; Sep 16, 2019

energy on site to meet their needs to reduce (and eventually eliminate) their dependence on fossil fuels and carbon emissions. Resilient design buildings are more focused on resisting effects of climate change and disasters while balancing that with utilization of affordable and clean energy.

Later in the course there will be a more detailed discussion on how Resilient Design compliments the NetZero goals and supports Zero Net Carbon Design (ZNCD).

In almost every aspect of sustainable or environmental related design concept, there are significant overlaps. While the extent of commonality may vary, there is no one strategy that is all-encompassing. The ultimate higher objectives are the same, but each philosophy, framework, or strategy follows a slightly different tactical path and methodology. None are redundant but all are complimentary and are useful for various applications and tastes with some focusing more on design aesthetics while others deal with energy consumption and others yet deal with safety, longevity, and economics. Some are targeted to individual buildings or even systems within buildings while others look at the communal or even regional scale. In this way each approach creates a benefit that is not unique but rather complementary to others. Implemented collectively, they are more likely to have a meaningful and measurable impact.

This concludes Part 1 of the course.

In Part 2 the course will address:

Resilient design and legislative engagement

- The engagement of governmental agencies to promote Resilient Design
- EPA, FEMA, NIAC and other adoptions of Resilient deign principles
- California Mandates for Resilient design – a preview for other jurisdictions

Part 1 Review Questions

1. What does RDI stand for?
    a. Resilient Design Institute
    b. Resilient Design Infrastructure
    c. Rapid Deployment Infrastructure
    d. Resilient Development Installation
2. Which of the following is not a design "style" per se?
    a. Biophilic Design
    b. Post Modern Design
    c. Resilient Design
    d. Minimalist Design
3. Which of the following are true about the 1871 great fire of Chicago?
    a. Over 17,000 buildings were destroyed
    b. Over $200 million in damage
    c. Nearly 100,000 people were left homeless
    d. All of the above
4. The focus of Net Zero is?
    a. To ensure human habitats recover rapidly after climate events
    b. To neutralize carbon emissions
    c. Aimed at political action rather than any impact on physical infrastructure
    d. Limited to environmental changes made until 2050
5. Is Resilience the same as Sustainability?
    a. No. They are closely related but have some differences.
    b. Yes. They are interchangeable phrases.
    c. No. Resilience deals with codes while sustainability deals with non-safety related items.
    d. Yes. Both were introduced at COP 21 Paris accord.

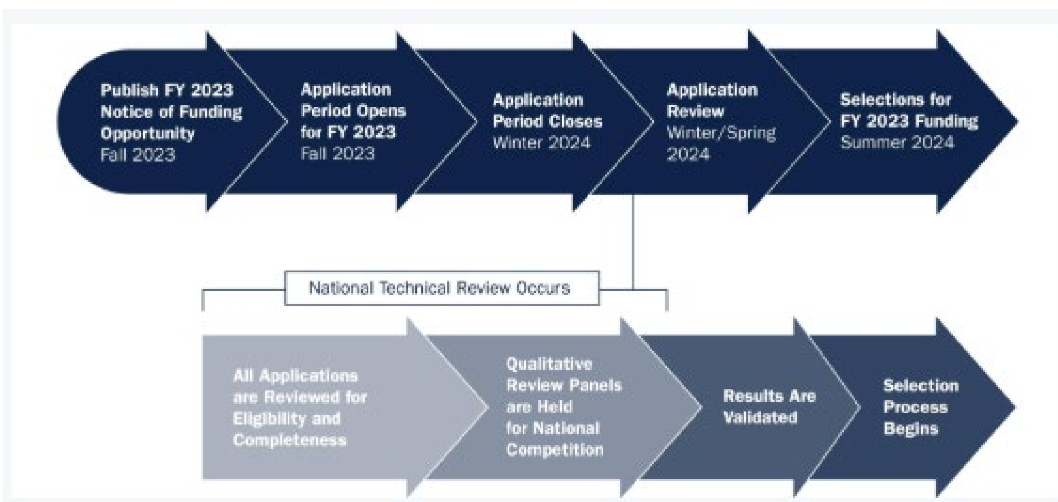
PART 2 - Resilient Design – Regulatory & Legislative Engagement

2.1. Governmental and Regulatory Agencies Promote Resilient Design

It is now common to see Sustainability and "Sustainable" design referenced in institutional, corporate, large commercial and almost all levels of governmental and municipal projects. What is less known is that Resilient design and resiliency as a guiding program has been an operational part of many significant governmental agencies, especially at the Federal level in the United States. Among the agencies of the government that have active design resilience programs are the following with the trend moving towards greater adoption:

- **The Environmental Protection Agency (EPA)**: The EPA has a Resilient Infrastructure Subgroup on Climate that helps the agency invest in climate-resilient projects. The EPA also has a Resilience Directory that includes programs like Climate Ready Estuaries Program and Coastal Wetlands Initiative.

- **Federal Emergency Management Agency (FEMA)**: FEMA's Building Resilient Infrastructure and Communities (BRIC) program helps states, local governments, tribes, and territories reduce their hazard risk. Through BRIC, FEMA continues to invest in a variety of mitigation activities with an added focus on infrastructure projects benefitting disadvantaged communities, nature-based solutions, climate resilience and adaption and adopting hazard resistant building codes.[20]



BRIC Program Annual Cycle Timeline. *Source: FEMA.gov*

- **U.S. Department of Housing and Urban Development (HUD)**: HUD is part of the National Integrated Heat Health Information System (NIHHIS), which aims to reduce the negative impacts of extreme heat on communities. HUD has several programs and resources to help make buildings more resilient, including:

[20] FEMA.gov; "About BRIC: Reducing Risk through Hazard Mitigation"; 11 Sept. 2024

Designing for Natural Hazards Series

A five-volume guide that provides technical guidance for builders and developers to design buildings and neighborhoods that are more resilient to natural hazards. The guides cover hazards such as wind, water, fire, earth, and other hazards.

Green and Resilient Retrofit Program (GRRP)

A program that prioritizes both energy efficiency and climate resilience. GRRP evaluates Multifamily Rental Assisted properties based on a combined energy and climate risk score.

Community Resilience Toolkit

A toolkit that includes recommendations for building and rehabilitating housing and public facilities with more resilient materials. Recommendations include using cool pavement, installing green roofs, and incorporating natural vegetation.

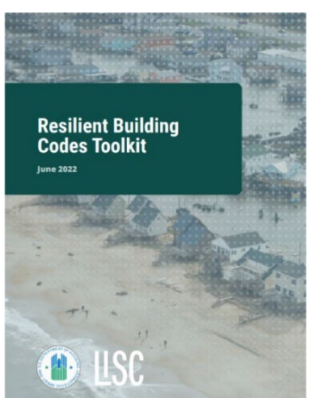
Minimum Energy Standards

Updated standards that improve the resilience of homes, reduce carbon emissions, and improve resident health and comfort.

Disaster response

HUD provides resources and flexibility to disaster-stricken communities to help them respond quickly and recover equitably. This includes technical assistance, capacity building support, and HUD-Certified Housing Counselor assistance.[21]

HUD has also developed an excellent resource publication called the "Resilient Building Codes Toolkit", that provides data-based information to guide the development of resilient design elements into building codes. The intent of this guide is to bring transparency and clarity to building codes, especially with respect to resilience.[22] Some of the data and information published in the toolkit will be used throughout this course.



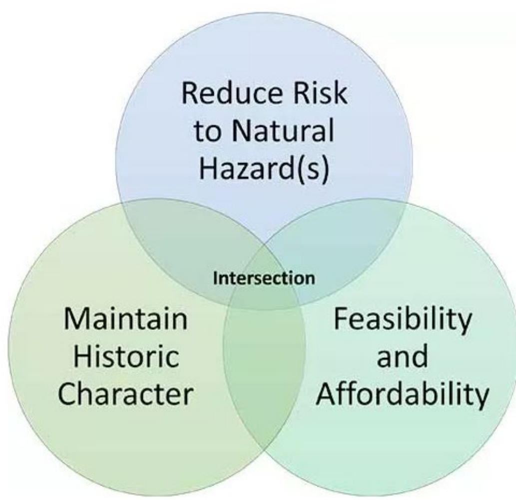
US Department of Housing and Urban Development publication cover; *Source: HUD Exchange*

[21] HUD.gov

[22] "Resilient Building Codes Toolkit"; HUD; June 2022

- **National Park Service (NPS)**

  The National Park Service protects natural and cultural resources in coastal areas and parks that are vulnerable to climate change. The National Park Service (NPS) maintains some of the most iconic buildings and monuments in the United States, many of which are in areas vulnerable to the effects of climate change. To preserve these historically and culturally significant assets for future generations, the NPS is working to foster climate change resiliency in its facilities across the country.[23] Pursuant to these objectives, the NPS has been actively incorporating resilient design concepts from the perspective of climate and natural disaster resiliency. In 2021 the NPS published "*The Guidelines on Flood Adaptation for Rehabilitating Historic Buildings*". While this guideline was developed specifically in response to flood risk, it provides a framework that can be adapted for use in the planning, assessment, and evaluation of risks for other types of natural hazards as well as recommended and not recommended actions.[24]



Resilience Factors Diagram. *Source: National Park Service, Technical Preservation Services.*

- **Department of Energy**

  Through the DOE Climate Adaptation and Resilience Plan (CARP), DOE takes a risk-based resiliency approach to its operations to identify and minimize climate-related and other vulnerabilities across all DOE policies, programs and activities. Site-specific Vulnerability Assessment Resilience Plans (VARP) compel DOE sites to assess vulnerabilities using the

23 www.nps.gov/subjects/sustainability/resiliency.htm; Apr 23, 2021
24 nps.gov/orgs/1739/resilience-to-natural-hazards-historic-buildings.htm; Apr 12, 2024.

best available science, to strengthen the agency's planning, operations, and investment activities.[25]

Specific to resilient design applications for The Department of Energy (DOE) has a Resilience and Security Integration program for buildings called *Better Buildings®*. This program addresses the following areas and provides useful information, public programs and implementation toolkits:

- Decarbonatization
  - Emissions Reduction Planning
  - Energy Efficiency
  - Renewable Energy and Low Carbon fuels
  - Electrification
  - Carbon Capture, Utilization and Storage
- Funding
  - Financial Navigator
  - Funding Incentives Resource Hub
- Water & Waste
- **Resilience**
- Workforce Development
- Better Buildings Challenge
- Better Plants
- Better Climate Challenge

- **Department of Defense**

The Department of Defense (DOD) has several initiatives to make its installations and communities more resilient, the main one relevant to buildings being:

Resilient and Healthy Defense Communities (RHDC) Strategy

Announced on Feb 15, 2024, this strategy aims to improve the quality of life for service members, their families, and the civilian workforce. The RHDC Implementation Plan outlines actions to make installations and communities safer, more appealing, and supportive. The DOD has 280,000 buildings across 538 installations and approximately 26 million acres of land that support the Department's more than two million military and civilian personnel and their families. At this sheer scale, the DOD acknowledges "that improving the Department's vast infrastructure footprint is a significant undertaking, it recognizes the opportunity to reduce the gap that persists between installation conditions today and the quality standards Service members and their families deserve."[26]

[25] energy.gov/ehss/resilience

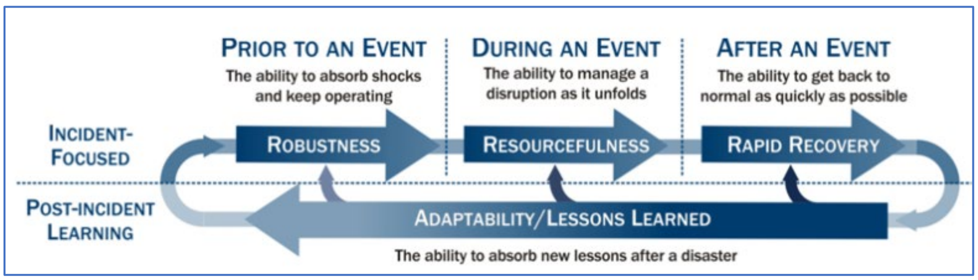
[26] DOD.gov; "DOD Releases Resilient and Healthy Defense Communities Strategy"; Feb 15, 2024.

- **The National Infrastructure Advisory Council**

  The National Infrastructure Advisory Council (NIAC), which operates as part of the Cybersecurity & Infrastructure Security Agency (CISA), has the task of advising the White House on physical and cyber threats to critical infrastructure, breaks resilience down into Four Rs:

  - Robustness
  - Resourcefulness
  - Rapid Recovery
  - Redundancy

  The Resilience Planning Program works with federal, state, local, tribal, and territorial government officials and infrastructure owners and operators to plan, design, and implement solutions that enhance the security and resilience of critical infrastructure against a variety of threats.



NIAC model for continuous infrastructure resilience improvement. Source: Public Domain image

The above are some of the main practical government programs at the Federal level. The list of departments that have or are in the process of adopting a resilience program or specific resilient building design guidelines continue to grow, often as an appendage to existing sustainable design initiatives. Beyond the Federal level, most States and many local municipalities, institutions and school districts are also formally adopting Resilient Design requirements for future projects. Detailed discussion on these programs is beyond the scope of this course but the general flavor is noted in the examples cited above. *[NOTE: Resilient Design, like Sustainability, is not limited to US borders in its appeal or implementation but has varying degrees of acceptance and focus across the globe.]*

As can be inferred from the preceding discussion, Resilient Design implementation takes on multiple dimensions and is interpreted differently for different applications. The underlying principles and drivers, however, are fairly consistent.

In the next section the inclusion of Resilient design requirements relative to building codes and ordinances will be examined since it is most likely that will be the formal mechanism for broad implementation of Resilient design for buildings. Guidelines, toolkits and the weight of technical support as mentioned above can be effective only to a point in promoting Resilient practices. A lesson being learned from the Sustainability and Net Zero efforts is that plain real-world economics are a significant hinderance to widespread adoption even though most long-term economic analyses favor these practices. Commercial (including the mass residential market) building design and construction is much more informed by short-term costs and returns. The only effective way to move the direction on a substantial scale is through regulatory mandates such as building codes or planning ordinances.

2.2. Resilient Design and How Regulatory Bodies and Codes are Incorporating these Principles.

The construction of new buildings or retrofit and modification of existing buildings and structures is typically governed by laws and regulations developed locally, regionally, or nationally. These can be in the form of building codes, planning ordinances or design mandates. The most effective and common means of regulating the practice of building design and construction standards is through Building Codes.

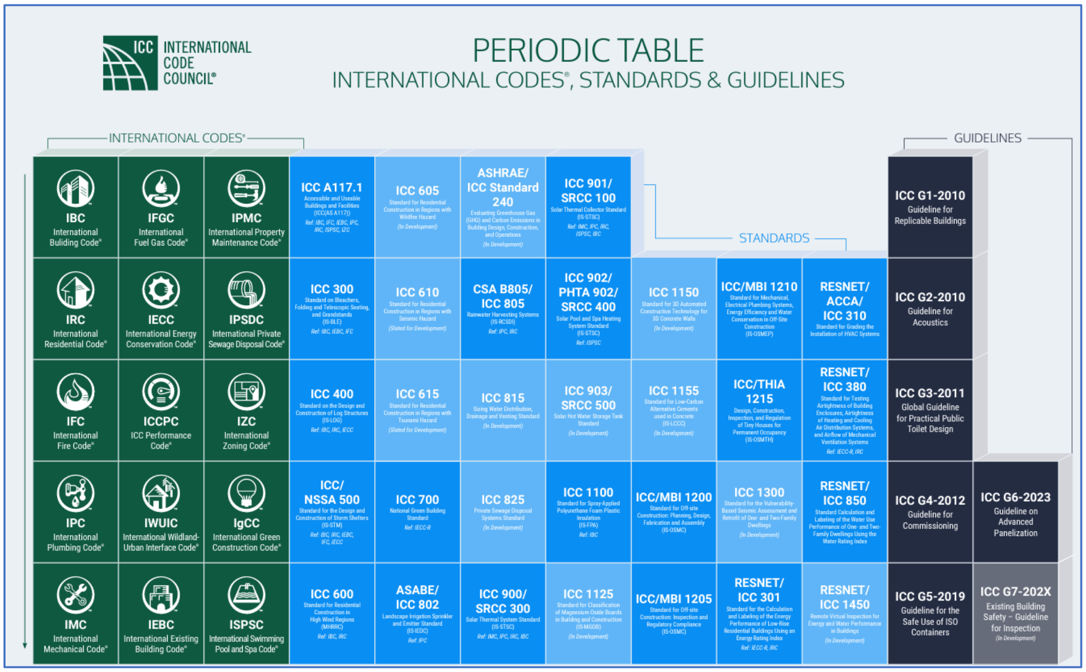
- **Building Codes**

  A **building code** (also building control or building regulations) is a set of rules that specifies the standards for construction of objects such as buildings and non-building structures. Buildings must conform to the code to obtain planning permission, usually from a local council. The main purpose of building codes is to protect public health, safety and general welfare as they relate to the construction and occupancy of buildings and structures…. The building code becomes law of a particular jurisdiction when formally enacted by the appropriate governmental or private authority.[27] Building codes establish minimal life safety requirements for the construction of new buildings and retrofits to existing buildings. They underpin how we design and construct housing and other building types. While ubiquitous, the details of their requirements, governance, and overall application may vary from state to state and, within states, from locality to locality.[28] While the intent of building codes originally focused on life safety, there has been a shift to think more broadly, incorporating aspects of both sustainability and resilience. The recent increase in the frequency and intensity of extreme weather events has made these concepts even more relevant.[29]

  In the United States model building codes (see illustration below) aim to safeguard occupants from dangerous conditions by specifying fire safety and evacuation requirements as well as the level of wind, rain, hail, or other hazards that buildings should withstand. These codes, produced primarily by the nonprofit **International Code Council (ICC)**, incorporate existing consensus building standards developed by professional organizations with expertise in a particular relevant field.
  The standards specify design practices associated with a diverse array of building elements including sprinklers, exit signage, structural steel and concrete, windows and many more. ASTM International, the National Fire Protection Association (NFPA) and the American Society of Civil Engineers (ASCE) are just some of the many standards organizations commonly referenced in the model codes. As gaps or errors are identified and as pertinent information about engineering, natural hazards or human behavior

[27] en.wikipedia.org/wiki/Building_code
[28] HUD Exchange; "Resilient Building Codes Toolkit"; June 2022
[29] Ibid

comes to light, standards organizations and the ICC can upgrade standards and model codes through a process that normally takes many years.[30]



This illustration shows the variety of codes that make up the family of just the codes, Standards and Guidelines published by the ICC. (*For more about the Code Council's codes and standards development process, go here: iccsafe.org/codes-standards*)

Because of the pace at which building codes evolve (see graphic below), it is difficult to inject the sense of urgency that is required to meet the challenges of climate change. So, designers, planners and municipalities must achieve greater resilience within the current codes while, in parallel, continuing efforts to enhance and modify codes for the longer term.

Source: new buildings institute [31]

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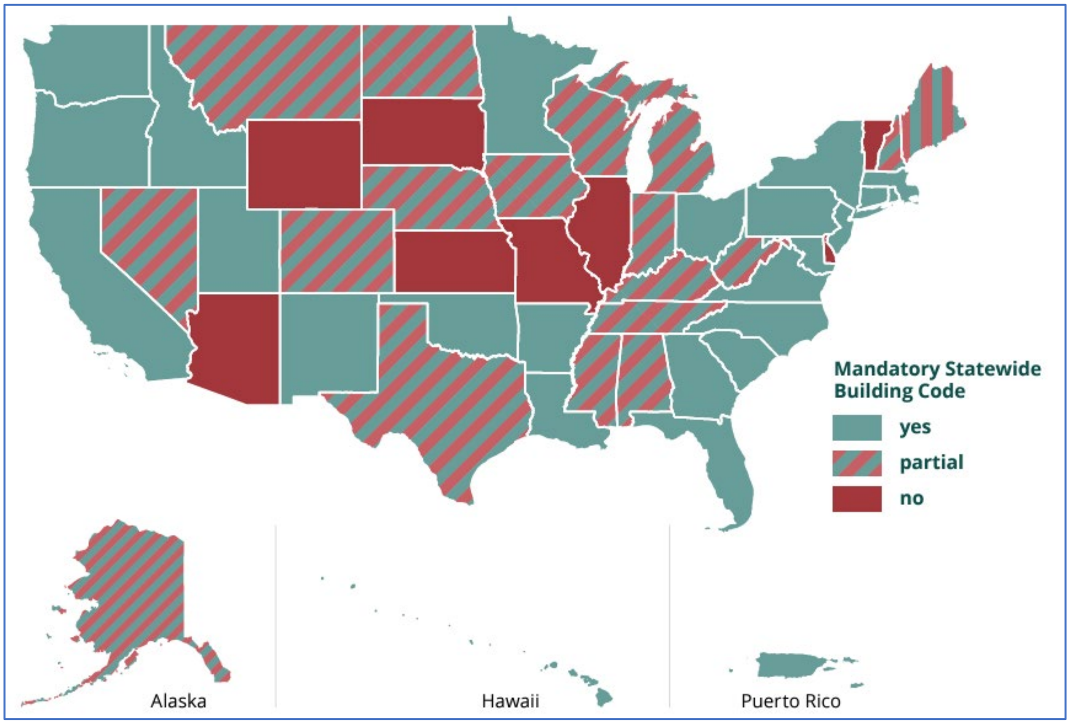
[30] US Department of Commerce, National Institute of Standards and Technology (NIST); "Understanding Building Codes"; June 21, 2022

[31] ICC document: "19-16743_CORP_Code_Dev_Process_FINAL"

Later in this section we will explore other regulatory mechanisms and the elements of existing codes that already address resilient design or that can be used to incorporate resiliency with interpretive modifications. Before that, it is important to recognize that Model Building Codes as developed by the ICC are not universally used across the United Staes even though they are the basis for many locally adopted codes across the US and even in various other countries. The graphic below shows which States within the US have mandatory statewide building codes. ***Yes**, **partial**, and **no** refer to whether statewide code mandates apply for all building types; some mandates for some building types (partial); or no state-level code requirements*.



Mandatory Building Codes by State. *Source: HUD "Resilient Building Codes Toolkit"*

While building codes are not universal and modifications occur at a glacial pace, the good news is that over time many of the ICC codes have already captured significant aspects of resiliency within current (reference year 2018) versions of the codes. Below is a Table that summarizes these:[32]

Aspects of resilience already captured in IBC

Selected Code Topic	Relevant Sections (2018 IBC)	Supported Resilience Strategy	Relevant Hazards
Critical facilities identification	307	• Emergency planning • Community operations • Response and recovery	• Flooding • Hurricanes • Tornadoes • Blizzards • Terrorism

[32] HUD Exchange; "Resilient Building Codes Toolkit", Exhibit 18 "Aspects of resiliency captured in IBC"; June 2022

Selected Code Topic	Relevant Sections (2018 IBC)	Supported Resilience Strategy	Relevant Hazards
			• Wildfire
Hazardous or combustible materials	413, 414	• Isolating risks	• Terrorism • Fire • Flooding • Hurricanes • Tornadoes
Storm shelters / areas of refuge	423, 1009, 1026	• Shelter in place / refuge • Robustness • Community protection	• Tornadoes • Terrorism • Fire
Flammability of materials	Chapters 6, 7, 8	• Fire resistance • Egress • Indoor air quality • Smoke exposure	• Fire • Secondary to other hazards
Protection of openings	Chapter 7, 1069.2	• Structural integrity • Debris impacts	• Hurricanes • Tornadoes
Fire suppression / protection, smoke control	Chapter 9	• Fire resistance • Egress • Property protection	• Fire • Secondary to other hazards
Communication	907, 908, 917	• Public safety • Evacuation	• Fire • Terrorism • Earthquake • Tsunami • Tornadoes
Means of egress	Chapter 10	• Evacuation • Fire protection • Accessibility	• Flooding • Hurricanes • Tornadoes • Blizzards • Terrorism
Accessibility	Chapter 11	• Inclusive communities • Community cohesion • Evacuation	• Public Welfare • Secondary to other hazards
Occupant health	Chapter 12	• Indoor environmental quality • Indoor air quality • Access to sanitation	• Public health • Fire • Extreme heat / cold
Exterior envelope protection	Chapter 14	• Property protection • Debris impact • Hazard spreading	• Fire • Flooding • Hurricanes • Tornadoes
Roof assemblies	Chapter 15	• Fire resistance • Debris impacts • Sealing	• Fire • Hurricanes • Tornadoes • Extreme heat / cold
Moisture protection	1209, 1402, 1503	• Durability • Mold, mildew, rot, • Property protection	• Blizzards • Hurricanes • Flooding • Thunderstorms
Hazard maps	1608, 1609, 1611, 1613, 2603	• Identifying risk	• Tornado • Hurricanes • Seismic • Pests

Selected Code Topic	Relevant Sections (2018 IBC)	Supported Resilience Strategy	Relevant Hazards
			• Snow • Rain
Continuous load paths	Chapter 16	• Structural Integrity • Anchorage and bracing	• Earthquake • Tornadoes • Hurricanes
Identification of risk	1604.5	• Public Safety • Emergency planning	• Earthquakes • Tornadoes • Hurricanes • Blizzards
Elevation of structure	1612	• Flood mitigation • Property protection	• Flooding • Hurricanes • Sea level rise
Tsunami	1615, Appendix M	• Identifying risk • Elevation above inundation • Minimum design loads • Evacuation / refuge	• Tsunami
Special inspections	Chapter 17	• Verification of performance • Structural integrity	• Earthquake • Fire
Soils and foundations	Chapter 18	• Load support • Subsidence	• Earthquake • Sea level rise • Drought • Flooding
Materials performance	Chapter 19 - 26	• Fire resistance • Structural integrity • Product safety	• Flooding • Hurricanes • Tornadoes • Blizzards • Terrorism • Wildfire
Safety during construction	Chapter 33	• Public safety • Fire safety • Means of egress	• Fire • Civil unrest
Fire Districts	Appendix D	• Fire safety	• Fire
Flood resistance	Appendix G	• Flood mitigation • Property protection	• Flooding • Hurricanes • Sea level rise

Source: https://www.iccsafe.org/wp-content/uploads/19-17804_IBC_Resilience_WhitePaper_FINAL_HIRES.pdf

Other aspects not covered in the IBC are addressed in the International Energy Conservation Code (IECC) as summarized below:[33]

Aspects of resilience captured in energy efficiency portions of the International Energy Conservation Code

Selected Code Topic	Relevant Sections (2018 IECC)	Supported Resilience Strategy	Relevant Hazards
Insulation	C402.2, R402.2	• Passive survivability • Reduced energy burden	• Extreme heat / cold • Snow storms

[33] HUD Exchange; "Resilient Building Codes Toolkit", Exhibit 19 "Aspects of resilience captured in energy efficiency portions of the International Energy Conservation Code"; June 2022

Selected Code Topic	Relevant Sections (2018 IECC)	Supported Resilience Strategy	Relevant Hazards
		• Reduced grid impact • Reduced ice-dams • Reduced condensation, limiting mold and mildew	• Social resilience • Secondary impacts to all hazards
Walk-in coolers and freezers	C403.10	• Food safety / preservation	• Extreme heat • Secondary impacts to all hazards
Daylighting	C402.4.1	• Passive survivability • Reduced grid impact	• Extreme heat • Secondary impacts to all hazards
Window-to-wall ratios	C402.4.1, R402.3	• Passive survivability • Reduced grid impacts	• Extreme heat / cold • Hurricanes • Tornadoes
Solar heat gain coefficient	C402.4.3, R402.3.2	• Contaminants (secondary to wildfire, earthquake, etc.) • Mold and Mildew (secondary to flooding, hurricane, extreme cold, etc.)	• Secondary impacts to all hazards
Solar reflectance of roof	C402.3	• Urban heat island • Passive survivability	• Extreme heat • Secondary impacts to all hazards
Air Leakage	C402.5, R402.4	• Contaminants (secondary to wildfire, earthquake, etc.) • Mold and Mildew (secondary to flooding, hurricane, extreme cold, etc.)	• Secondary impacts to all hazards
Pipe insulation	C404.4, R403.4	• Passive survivability • Reduced energy burden	• Extreme cold • Drought • Social resilience
On-site renewable energy	C406.5, Appendix CA, Appendix RA	• Contribute to distributed generation • Facilities islandability	• Secondary impacts to all hazards

Source: https://www.iccsafe.org/wp-content/uploads/19-17804_IBC_Resilience_WhitePaper_FINAL_HIRES.pdf

- **Legislative Action**

In addition to the direct and indirect ways in which building codes adopt, enforce and encourage resilient design, there are several legislative actions enacted or recommended at all levels of government that incorporate resilient design into requirements for buildings that are developed or funded (in whole or sometimes even in part) using resources within the purview of the legislation. A recent example of this is the **DE-FOA-0003225**, referred to as the “Bipartisan Infrastructure Law (BIL)”. In January 2024 The U.S. Department of Energy’s (DOE) Office of Energy Efficiency and Renewable Energy (EERE) Building Technologies Office (BTO) announced a $90 million funding opportunity announcement (FOA) titled Bipartisan Infrastructure Law (BIL): Resilient and

Efficient Codes Implementation (RECI). The current FOA represents the second installment in the RECI initiative, which maintains the same broad format, flexibility, and crosscutting areas of interest, while emphasizing and prioritizing specific gaps, needs, and opportunities to support building energy codes identified as focal points through the first RECI FOA and continued stakeholder engagement.[34]

The activities to be funded under the FOA support the BIL, as well as a broader government-wide approach to advance building codes and support their successful implementation. The primary focus centers around updating to more efficient building energy codes that save money for American homes and businesses, reduce greenhouse gas (GHG) emissions, and encourage more resilient buildings.[35]

An even more targeted bill specifically promoting Resilient buildings was re-introduced in congress by US Congressman Chuck Edwards (Republican; North Carolina 11th district) and Dina Titus (Democrat; Nevada 1st district) in January 2025 to update the original bill – H.R. 5473, of 2023. The ***Promoting Resilient Buildings Act*** provides greater flexibility to state and local governments, thereby increasing adherence to codes and preserving and promoting more resilient buildings in communities to make sure that they are prepared for disaster if it ever strikes. The bill is also expected to stabilize building costs by reducing the frequency that the trade industry must adapt their techniques to meet new codes. Lastly, the Promoting Resilient Buildings Act will create a pilot program as part of the Federal Emergency Management Agency's (FEMA) Building Resilient Infrastructure and Communities program to allow families to safety proof their homes using grant money.[36] However, as of the writing of this course, the bill has yet to be passed in the senate and get presidential approval before it becomes law.

The point of the above examples is to illustrate the emerging recognition and consequent tangible actions being taken by elected officials to bring resilient design into public discourse and even law. While getting legislation passed inti law is always a lengthy and politically influenced process, the recognition of the need is a major step. Eventually, it is likely that some form of this proposed legislation will take on the force of law especially considering the continued recurrence of natural disasters and the increasing magnitude of damage in terms of human and material costs. What is unclear is whether this will come as a federal level mandate or whether it will evolve within each state (in the case of the United States). For example, Resilient Design has been a very high-profile topic in California, spurred very vigorously by the architectural and design community in the state.

- **California Mandates for Resilient Design.**

An architect once remarked that California creates all our building codes. While that may be a simplified, perhaps flippant, exaggeration, there is some truth that many building design control initiatives that start in California do, over time, tend to either

[34] energy.gov/eere: Bipartisan Infrastructure Law (BIL): Resilient and Efficient Codes Implementation (RECI)
[35] Ibid
[36] Edwards.house.gov/media: Edwards re-introduces bill to reduce red tape for WNC homebuilders, municipalities; January 22, 2025.

directly become part of national codes or strongly influence the evolution of those codes and controls. In this regard, the State has certainly been at the forefront of enacting significant building codes that had a national and even international impact. Among these are three notable examples:

1. **Seismic Codes:** California was the first state to introduce seismic design requirements in building. This occurred first after the 1925 Santa Barbara earthquake when California introduced earthquake provisions in its building codes. Then, following the 1933 Long Beach led to the adoption of the "Field Act" for school buildings and the "Riley Act" for all buildings, mandating earthquake-resistant design. Ever since, California has been the standard bearer for seismic design standards across the United States and even foreign countries like New Zealand and Japan, both with very active seismic zones.

2. **Accessibility Codes:** The first accessibility building code was developed by the California Building Code (CBC) and became enforceable in 1982. This went on to form the blueprint for the accessibility (or "handicap design" codes as they were called in the early stages) requirements in other states, culminating with the passage of the ADA accessibility codes, also known as the "ADA Standards for Accessible Design," which were first passed on July 26, 1991 when the Department of Justice adopted them, following the signing of the Americans with Disabilities Act (ADA) into law on July 26, 1990.[37] This mandated the accessibility for public accommodation across the whole country whereas previously it was only mandated for federal buildings under the Architectural Barriers Act (ABA) of 1968.

3. **Energy Building Codes:** While not the first, California was the second and arguably the most prominent and influential state in the promotion and adoption of energy codes into its "Title 24" building standards in 1978. (Oregon was the first state to adopt an energy code in 1974). These codes have now become ubiquitous across most building codes around the world.

4. **Sustainability "Code":** In 2011, California became the first state in the US to develop a sustainability code, known as "CALGreen" (California Green Building Standards Code), which is a state-mandated green building code. This is now being used as a model influencer for similar codes in states like Massachusetts, New Jersy and Washington State.

5. **California Wildfire Building Code, Chapter 7A:** This code went into effect in 2008, and it mandates fire-resistant siding, tempered glass, vegetation management, and vents for attics and crawlspaces designed to resist embers and flames. The code is the "most robust" in the nation [according to] Lisa Dale, a lecturer at the Columbia Climate School and a former environmental policy advisor for the State of Colorado.

[37] Access-board.gov

It applies to nearly any newly built structure in one of the zones mapped out by state and local officials as especially prone to fire hazard.[38]

[Author's Note: Later in the course there will be a discussion of the devastating Los Angeles fires of January 2025 and how resiliency, or lack thereof, played a part in the level of damage and protection experienced during this event]

When it comes to Resilient Design, all the examples above, except perhaps the accessibility requirements, emphasize resilient design principles. So, it is unsurprising that California would champion making Resilient design a component subject of mandatory education for architects. The American Institute of Architects California (AIACA) sponsored AB1010, the California state legislative bill passed into law that requires 5 hours of Zero Net Carbon Design mandatory continuing education.[39] This requirement, which has been discussed earlier in the course, specifically cites Resilient design and its principles as critical areas of learning and implementation for architects.

- **Global Impact**

While the focus of the course and much of the discussion has been relative to Resilient Design and its impact on American, specifically US, building design and construction practice, it is worth noting that the principles of Resilient design and its codification and promotion extend well beyond US borders. Just as the iCodes have been used to model many building codes globally, the principles of Resilient design are likely to influence design and construction practices worldwide, especially as the frequency and severity of natural disasters and human induced events become more intertwined. To highlight this point, a couple of initiatives are indicative of the evolving international scope of Resilient Design for buildings:

1. **Global Resiliency Dialogue**: Building code developers/researchers from Australia, Canada, New Zealand and the United States launched the Global Resiliency Dialogue, a joint initiative to inform the development of building codes that draw on both building science and climate science to improve the resilience of buildings and communities to intensifying risks from weather-related natural hazards. In November 2021, representatives from the Global Resiliency Dialogue (GRD) announced the release of the new publication, *Delivering Climate Resilient Building Codes and Standards* in a hybrid presentation during COP26 in Glasgow.[40] The following year the GRD announced the publication of the *Global Building Resilience Guidelines* at the 27th UN Conference of the Parties (COP27) in Sharm El Sheik, Egypt. The Guidelines are based on the findings of two prior surveys conducted by the GRD and provide a framework for jurisdictions around the world to consider as they work to effectively integrate future-focused climate science into building codes and standards.[41]

[38] HEATMAP.News: California Has America's Strictest Wildfire Code; Matthew Zeitlin; January 16, 2025
[39] AIAcalifornia.org
[40] ICCSAFE.org: Global resiliency diaogue
[41] Ibid

2. **Global Principles for Resilient Infrastructure:** Under the auspices of the United Nations Office for Disaster Risk Reduction (UNDRR), in March 2022, Representatives from over 100 countries moved closer towards finalizing the Principles for Resilient Infrastructure, which set a new global standard for strengthening infrastructure systems and critical services such as energy, digital, transport, water, waste and others.[42] As a follow up, the UNDRR hosted The ARISE Symposium on Climate and Disaster Resilient Infrastructure, in partnership with the *ARISE Private Sector Alliance for Disaster Resilient Societies*, which convened over 120 leaders from the public and private sectors, international organizations, and academia in Dubai to accelerate efforts towards building resilient infrastructure in the face of growing climate and disaster risks.[43]

While no universal Resilient Design regulations have yet emerged in a binding or enforceable manner, the pace of dialog and the converging objectives indicate a potential for some consensus agreement like the one that was achieved by the Paris Agreement of 2015. However, international accords and aspirations are always subject to broader, sometimes unrelated, political, social, and economic pressures that complicate practical enforcement. Nevertheless, the research and science that emerges continue to nudge the process forward and any resulting changes to building codes that are approved become a more lasting legacy of these efforts.

This concludes Part 2 of the course.

In Part 3 the course will address:

[42] UNDRR: "Countries move forward on new global principles for resilient infrastructure"; 30 March 2022
[43] UNDRR: "ARISE symposium advances global agenda on climate and disaster resilient infrastructure"; 10 December, 2024

Resilient Design, Sustainability, Climate Impacts and NetZero

- Resilient Design and Sustainability
- Resilient Design and Climate Impact
- Resilient Design, Net Zero and Zero Net Carbon

Part 2 Review Questions

6. The Green and Resilient Retrofit Program (GRRP) is a program within which of the following?
    a. FEMA
    b. HUD
    c. OSHA
    d. EPA
7. The Climate Adaptation and Resilience Plan (CARP) of the DOE takes a ___________ resilience approach.
    a. Solution oriented
    b. Cost factored
    c. Energy focused
    d. Risk-based
8. Which of the following is not one of the "R"s of the National Infrastructure Advisory Council?
    a. Robustness
    b. Rapid Recovery
    c. Resource loading
    d. Redundancy
9. ICC 825 and ICC 815 are ______________ published by the International Code Council (ICC).
    a. International codes
    b. Guidelines
    c. Commentaries
    d. Standards
10. Which of the following sections of the 2018 IECC (International Energy Conservation Code) supports the Resilience strategy of dealing with urban heat islands?
    a. C404.6
    b. C402.3
    c. C403.10
    d. R401.2
11. Researches from four countries participated in the Global Resiliency Dialogue. Which of the following was not one of the countries that participated?
    a. United States
    b. New Zealand
    c. Canada
    d. United Kingdom

PART 3 - Resilient Design, Sustainability, Climate Impacts and NetZero

As the California bill AB1010 alludes, Resilient design is seen as an essential part of the wider Zero Net Carbon Design objective. In section 1.4 a brief comparison of Resilient Design and Sustainability, Green Buildings and Net Zero was presented. In this section the discussion will look more closely at the overlaps and contrasts between Resilient design and the three main issues that have emerged as the core of the environmental challenges that define the current building design era – Sustainability, Climate Impact and Net Zero (or Zero Net Carbon).

3.1. Resilient Design and Sustainability

Resilience and sustainability go hand in hand. Resilient design and sustainability both focus on energy and water independence, renewable resources, local materials, resource storage, community support, and preventing environmental effects.[44] While the overlaps are many and the principles have significant synergies, they are not always equivalent. The table below[45] compares many of the priorities of resilience and sustainability:

RESILIENCE	SUSTAINABILITY
Using multiple energy sources, especially renewable energy	*Energy savings*
Using multiple water source	*Production of renewable energy*
Passive systems with manual overruns	*Implementing recycled water systems*
Building designs that withstand disasters	*Local materials*
Floodplain evaluation for building locations	*Indoor environmental quality*
Preventing environmental threats	*Brownfield restoration*

When incorporating practical resilient elements that also support sustainability, the following are some common design principles to note:[46]

- Creating structures maintained by relying on renewable energy sources.
- Specifying materials that won't emit hazardous substances in case of flood or fire.
- Reducing dependency on complex systems and using locally available products and skill sets.

The above can be translated into some broad building strategies that support both Resilience and Sustainability:[47] *[Information below is summarized from the source referenced in the footnote]*

[44].ny-engineers.com/blog: "Resilient Design: Is Resilience the New Sustainability?"; Michael Tobias; 2024
[45] Ibid
[46]KREAO.net: "Why Resilient Design Is a Key Part of Sustainability"; Blog by Andrew; February 24, 2023
[47] ny-engineers.com/blog: "Resilient Design: Is Resilience the New Sustainability?"; Michael Tobias; 2024

- **Low carbon-input materials:** Construction materials like wood, bamboo and eco-friendly masonry are preferred over materials with a high energy footprint, or materials that come from the fossil fuel industry.

- **Design buildings that operate with a low energy input from external sources:** Building designs should be energy efficient, using measures like highly insulated envelopes, triple glazing and passive solar heating. Lighting costs can be reduced with a combination of LED lighting and daylighting. Natural ventilation should be used whenever possible, to reduce the energy consumption of mechanical systems.

- **Optimize daylighting:** Maximize the use of daylight, using it as the primary lighting source when possible. Internal courtyards and atrium spaces are useful to provide daylight for large indoor areas.

- **Modular construction:** Modularity provides an opportunity for spaces to have multiple uses during their lifespan, reducing the cost of renovations and retrofitting.

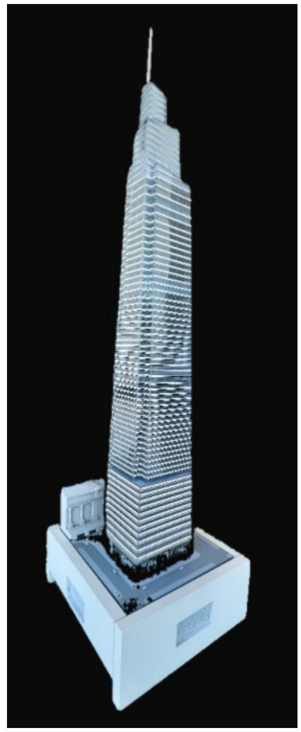
- **Durability and robustness:** Durability should be considered an aspect for any project. The objective is to create durable structures that withstand weather events while keeping suitable indoor conditions, providing shelter for occupants.

- **Local materials and products:** Using local materials and products helps achieve resilience. Local materials are more abundant, transportation costs are lower, and local business benefit.

- **Low energy input during construction:** Design using low-energy construction techniques that minimize the use of heavy equipment. Promote energy efficiency and consider alternative fuels with lower carbon footprints.

Examples of buildings that are considered Resilient and are also generally recognized to be sustainable include the following:

- The One Vanderbilt in New York City (with its energy-efficient design, rainwater harvesting, sustainable façade design and LEED Gold certification)

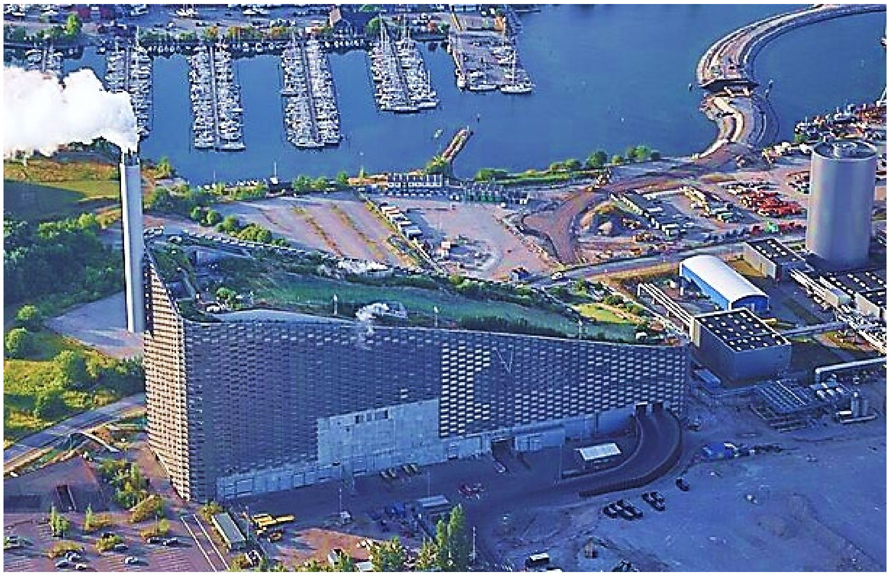


One Vanderbilt, New York, NY; Architect: Kohn Pedersen Fox; *(Image source: Muhammad a Siddiqui; February 2023)*

- *Bosco Verticale* in Italy (incorporating vertical greenery for natural cooling and air purification)

Bosco Verticale, Milan Italy; Architect: Stefano Boeri Studio; *(Image source: Lêer:2329px-Bosco Verticale, Milano.jpg – Wikipedia, common license)*

- CopenHill in Denmark (a waste-to-energy plant with a ski slope on its roof)



CopenHill, Copenhagen, Denmark; Architect: Bjarke Ingles Group; *(Image source: Wikimedia Commons; Amager Bakke (aerial view).jpg; 2022)*

- The Museum of Tomorrow in Brazil (designed with sustainable materials and climate-responsive features)

Museu do Amanha, Rio de Janiero, Brazil; Architect: Santiago Calatrava *(Image source: Wikimedia Commons; Museu do Amanhã I - Rio.jpg; 2016)*

Key features used in the examples above include: (*Note: Not all features are in each building)*

- Energy efficiency:
  Utilizing passive solar design, high-performance insulation, and renewable energy sources like solar panels to minimize energy consumption.

- Water conservation:
  Implementing rainwater harvesting systems, low-flow fixtures, and efficient irrigation to reduce water usage.

- Adaptive design:
  Incorporating features that can withstand extreme weather events – like flood protection, elevated foundations, and storm-resistant building materials.

- Sustainable materials:
  Using recycled materials, locally sourced timber, and low-carbon concrete to reduce environmental impact throughout the building lifecycle.

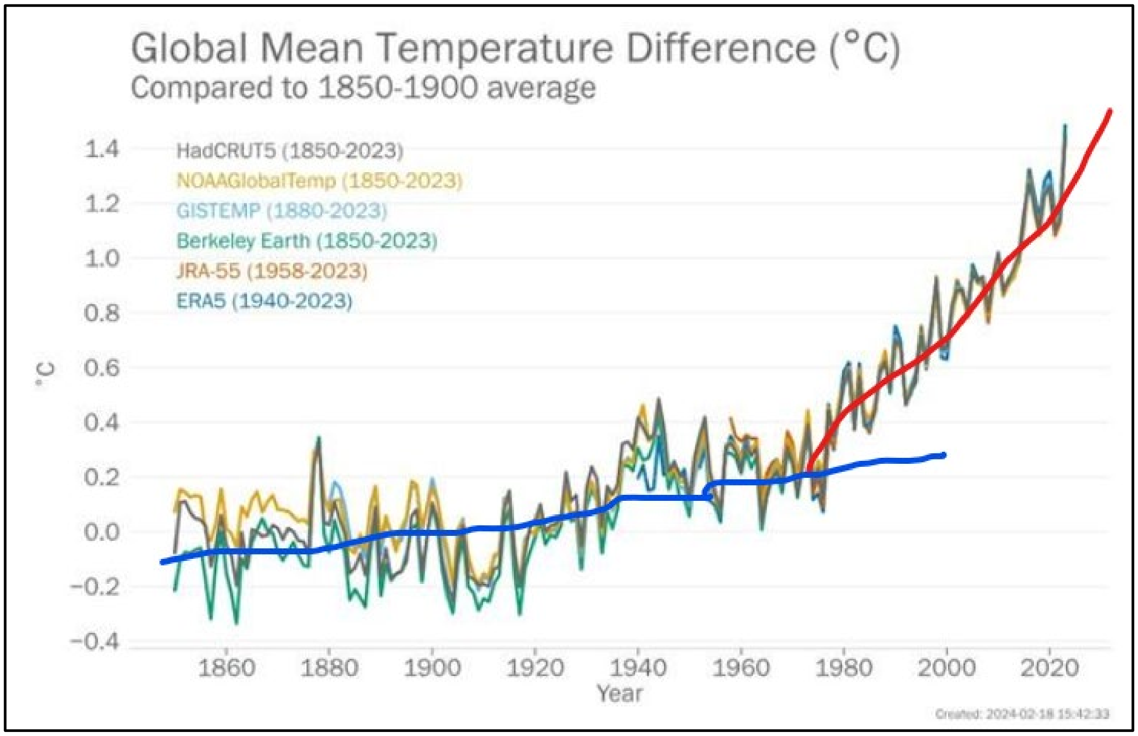
- Green roofs:
  Vegetation on rooftops to manage stormwater runoff, provide insulation, and enhance biodiversity.

3.2. Resilient Design and Climate Impact

The genesis of Resilient design with respect to buildings has its roots in response to natural disasters that are related to climate patterns and evolution. As has been mentioned in this course and documented over the past several decades, the intensity, frequency and severity of these disasters has been increasing at what is being seen as an alarming rate. This, coupled with the rising average global temperatures has brought on the notion of "Global Warming" that threatens to continue to affect climate and further disrupt the cycles of natural disasters. It is this long-term shifting of temperatures and weather patterns that is referred to as "Climate Change". The term, along with "Global Warming" have also become highly politicized in recent years with public opinion often questioning the credibility of the scientific community. For the purposes of this course and in terms that are of practical benefit to architects, the discussion will address factual climate related considerations that are and will continue to impact design and the responses that are needed. These are:

1. **Average temperatures globally are rising at an increasing rate**

   According to the World Meteorological Organization in its 2021 State of Climate report, the previous seven years were the warmest on record, leading United Nations Secretary-General Antonio Guterres to state "…the latest scientific evidence [shows] how our planet is changing before our eyes. From the ocean depths to mountain tops, from melting glaciers to relentless extreme weather events, ecosystems and communities around the globe are being devastated." The global annual mean temperature difference from pre-industrial conditions (1850-1900) for six global data sets are captured in the graph below, which not only shows the stark acceleration in temperature rise, but a high level of consistency in the data captured.[48]



(Image source: World Meteorological Organization; 2024-02-18)

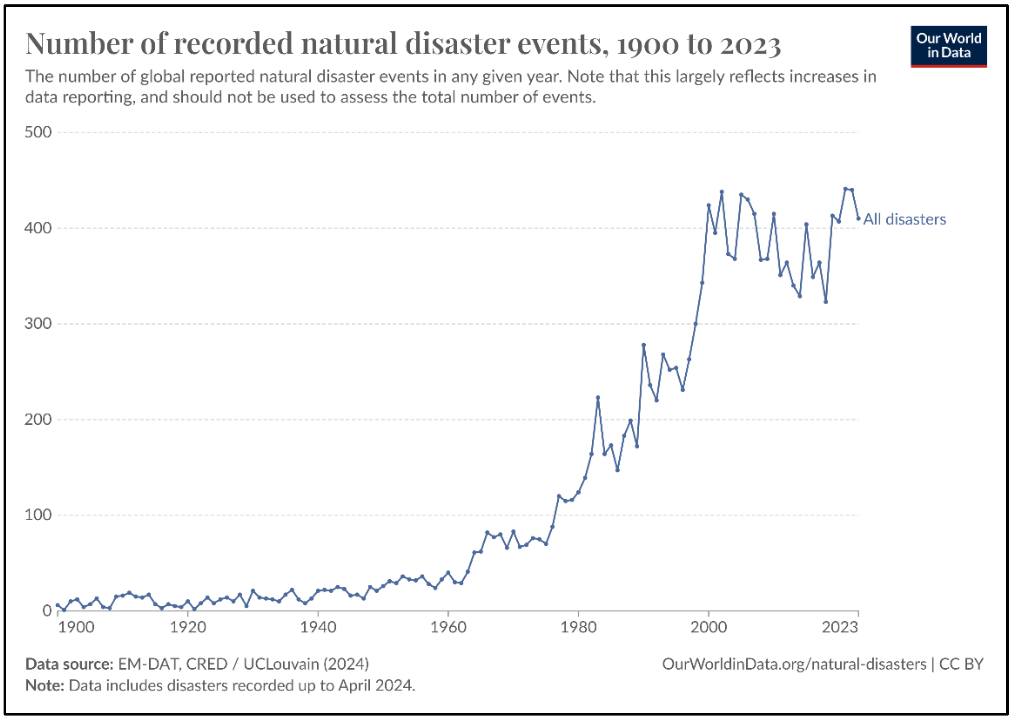
Trend line 1860 - 1980 (superimposed by author)

Trend line 1980 - 2023 (superimposed by author)

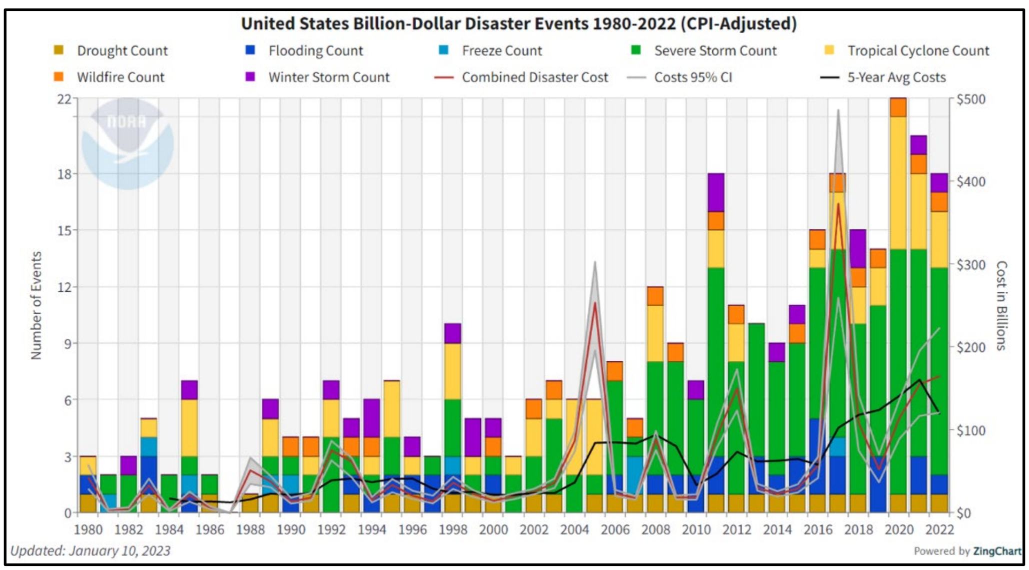
2. The frequency and intensity of natural disasters is increasing

The "frequency" of natural disasters refers to how often they occur in a given area, while "intensity" refers to the severity of a single disaster event, like the wind speed of a hurricane or the magnitude of an earthquake. Another measure of “severity” is the cost (in monetary terms) of natural disasters. While this primarily influenced by population increase and greater urban development, it further magnifies the impact of a disaster and strengthens the case for Resilient structures and communities. According to prevailing research, the frequency and intensity of natural disasters are considered to be increasing, largely attributed to climate change, leading to more extreme weather events happening more often. The series of graphs below illustrate the trends and impacts.

[48] World Meteorological Organization, 2021



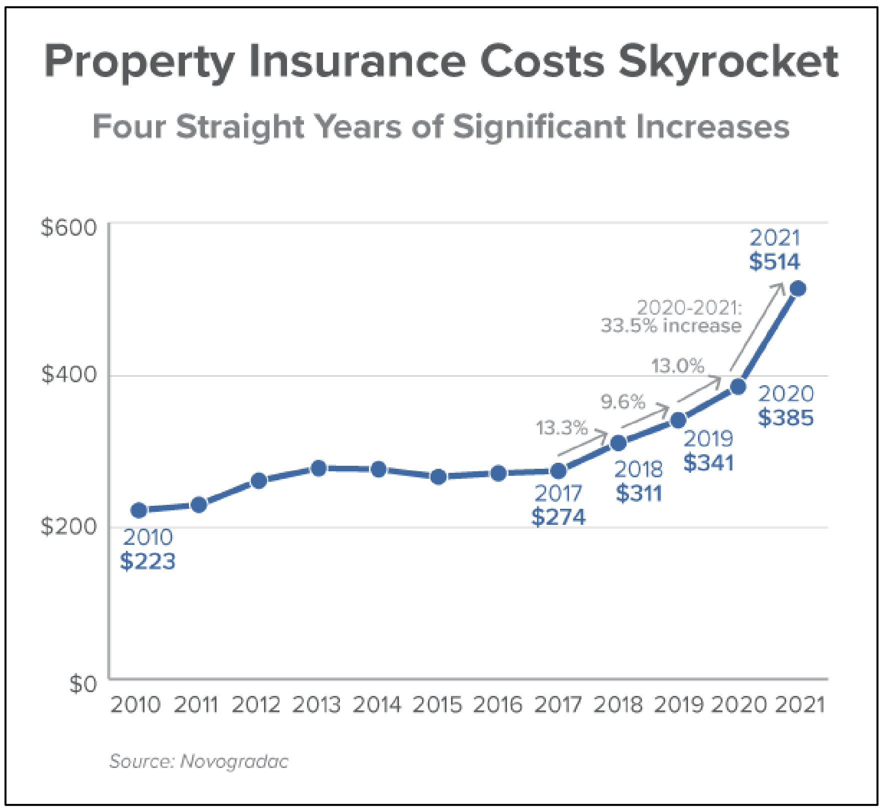
Many organizations, such as the United Nations and World Meteorological Organization, have reported on this as a dramatic rise in actual disaster events.



Source: NOAA NCEL

The history of billion-dollar disasters in the United States each year from 1980 to 2022, showing event type (colors), frequency (left-hand vertical axis), and cost (right-hand vertical axis.) The number and cost of weather and climate disasters is rising due to a combination of population growth and development along with the influence of human-caused climate change on some types of extreme events that lead to billion-dollar disasters.

The preceding graphs clearly lay out the case for the need for Resilient building design as the costs of disasters become untenable if conventional construction remains the norm. So, regardless of one's views on climate change, the impact of climate driven natural disasters is having tangible, measurable and severely consequential impacts on human habitats, infrastructure and ultimately the community fabric. In response, architects, urban planners and city planners have to respond in a meaningful way to not only address the aftermath of the challenges posed by the disasters but to proactively design buildings and plan communities and cities in a way that they can absorb these disasters and emerge with minimal damage after the event. It is a paradigm shift to invest in robust structures, infrastructure and maintenance that produces little to no visible outward enhancement but is in effect an insurance for an event that may or may not occur. Interestingly, the insurance analogy is more relevant than ever as the costs of insuring homes and buildings is increasing rapidly (see graph below). If more resilient buildings and communities are built and they can demonstrably survive disaster events, the investment in fortifying the buildings can help stabilize (if not reduce) insurance costs among other costs.



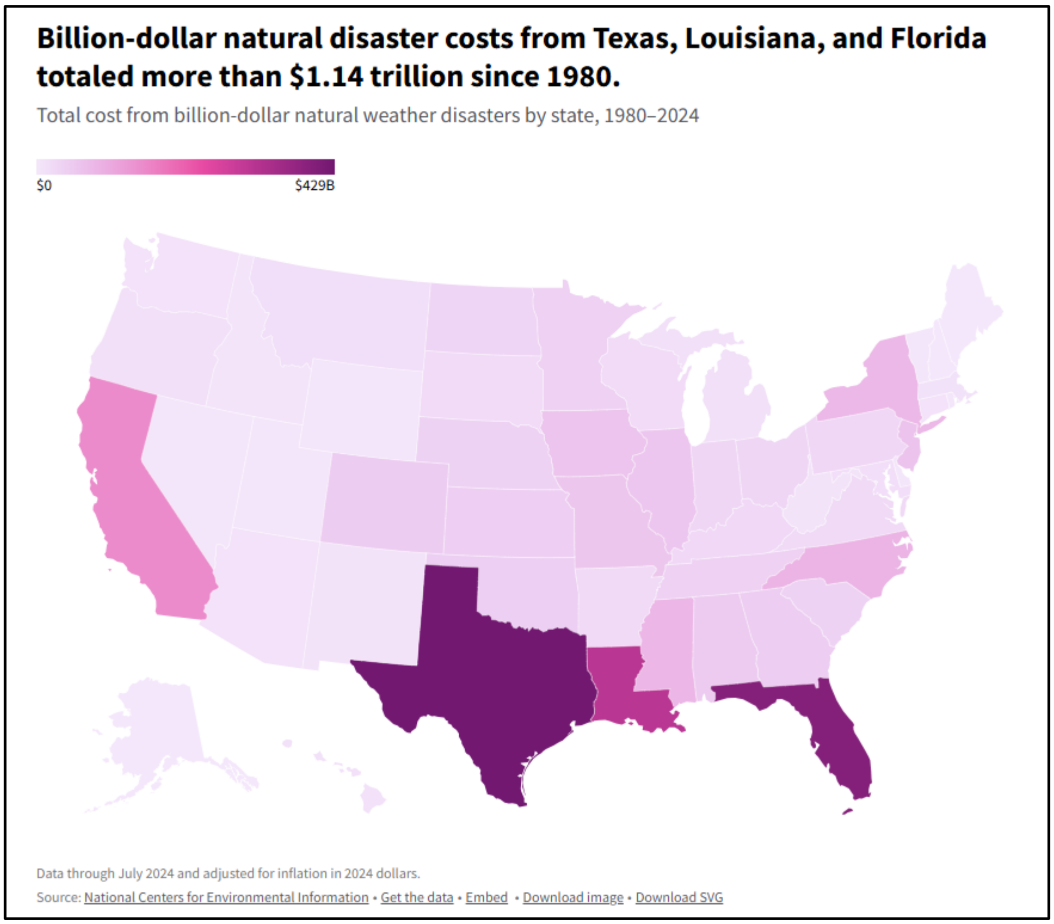
Source: NOVOGRADAC; November 2022

Given that the impact of climate-induced disasters does indeed appear substantial, the types of resilient responses that are needed must be assessed. These vary depending on the type(s) of disasters that are likely in each location.

The most common climate related natural disasters include the following:

- Tropical Cyclones (Hurricanes, Typhoons)
- Earthquakes
- Tornadoes
- Floods
- Wildfires
- Extended Droughts

In the United States, major tropical cyclones, including hurricanes, have done the most damage in terms of both total costs and loss of life.[49] Unsurprisingly, the southern Gulf coast states have cumulatively suffered the highest costs from natural disasters, with Texas bearing the brunt of those.*



**[NOTE: The wildfires that consumed parts of greater Los Angeles, CA in January 2025 are being estimated as potentially taking the dubious tile of most expensive disaster with economic loss exceeding $250 billion by some estimates. However, not all data is available as of this course preparation and there is still much speculative assessment that needs validation]*

[49] USAFACTS.org: "Are major natural disasters increasing?"; September 6, 2024

As climate-induced disasters and human development have clashed, numerous cycles of building code modifications and local regulatory mandates have been enacted to make designers and planners build structures that can address nature's challenges. Historically the emphasis was on making buildings strong and safe enough to allow the human occupants to survive the event or have enough time to safely evacuate. The thrust of codes typically does not focus on the functional survivability of the building, structure or community infrastructure. However, as the economic tolls of the disasters mount as has been noted above, there is growing support for Resilient design to be incorporated to directly address climate induced disasters. The term used for these specific strategies is *Climate Resilience*. Climate resilience refers to the ability of buildings and infrastructure to withstand and recover from climate-related hazards. Understanding these concepts is crucial for developing strategies that can address the challenges posed by climate change and ensure the long-term functionality of buildings.[50]

The ways in which Resilient design can support these goals are many, flexible and diverse depending on the nature of threats that need to be addressed. Among the resilient options are the following, depending on the scale on which they need to be applied:[51]

(Notes below are adapted from a Policy Brief by C40 Knowledge HUB[52], based on the World Green Building Council publication "CLIMATE CHANGE RESILIENCE IN THE BUILT ENVIRONMENT - Principles for adapting to a changing climate")

City Scale

- Adopt land use policies and regulations to reduce/prevent development in high-risk areas and incentivize development in lower risk ones.
- Assess most vulnerable locations to focus priority interventions – pay close attention to vulnerable locations, particularly informal settlements, and aspire to transform slums into healthy, clean, and safe communities.
- Assess the risk of climate change on physical assets and infrastructure and system stressors through future scenario modelling and risk assessments that consider the lifespan of an asset, including risk of stranded assets.
- Set building regulations or guidelines to target specific climate risk, e.g. guidelines for better buildings can reduce storm damage. New building standards should be able to be resilient to changing extreme weather conditions.

[50] Green.org: "Enhancing Building Resilience in the Face of Climate Change"; 1/30/2024
[51] C40KnowledgeHub.org: "Climate change resilience in the built environment: Principles for adapting to a changing climate"; Policy Brief; November 2022
[52] Ibid

Community and Neighborhood Scale

- Protect and invest in natural resources, such as protecting ponds, lakes, and rivers nearby from over-extraction and pollution, and investing in water storage for emergency situations. Sustainable drainage solutions and green infrastructure techniques, such as planting moisture-loving plants and trees and installing permeable hard surfacing to absorb excess water that can support resource management, for example by allowing infiltration to support groundwater levels.

- Consider community scale-built asset upgrades and retrofit to improve resilience of community assets in case of severe climate events, such as community level master-planning to implement passive shading techniques, including narrow streets to create shade, expanding urban tree cover to combat urban heat island impacts and fire breaks to act as a buffer between natural and residential zones.

- Plan community emergency hubs that will provide access to safe space and services during extreme weather events and prioritize establishing community protocols and maintaining evacuation pathways.

Building Scale

- Implement passive design and retrofit techniques – to mitigate extreme heat – northerly orientations, building or adding semi-permanent shading devices, deciduous tree shading, shutters, light color roofs, overhangs and utilizing thermal mass, and avoid large volumes of glazing (on south or north-facing aspects and facades depending on the global north or south regions), or to mitigate extreme cold – capture residual heat with thermoelectric generators and heat exchangers, install passive systems including roof lights and reflective surfaces to increase solar gain, or increase air tightness or wall cladding and glazing insulation and quality to reduce heat loss.

- Adopt backup strategies at building scale in case of extreme weather events such as off-grid, decentralized and resilient energy supply.

- Design for durability, disassembly and maintenance, such as planning for climate appropriate structures and urban layouts to prevent damage, considering techniques in which the building can withstand floods, fire, storms, heat waves, and other climate change events.

To implement adaptive approaches for climate resilient construction, the table below is summarized from the UN environment programme report “A Practical Guide to Climate-resilient Buildings & Communities”; published 2021:

Summary of adaptive approaches by climate impact and sphere of construction *(Adapted from: L. Amitrano et al., 2007; Gupta & Gregg, 2011)*[53] [54]

Climate Change Impact	Building Design	Planning / External Factors
Increased temperature averages and extremes (e.g. heatwaves)	ALL CLIMATES: • Control solar gain through site or building changes: green roofs, white roofs, ventilated roofs, integrated green cover on walls, internal and external manufactured shading devices. • Provide adequate insulation and ventilation (natural ventilation, ceiling fans, raised structure where appropriate). • Decrease lighting and equipment loads.	ALL CLIMATES: • Consider orientation of building (longer walls facing north and south) and placement of surrounding geographic features, trees, and structures to capture and direct wind flow and control solar gain. • Implement efforts to strengthen social connectivity, community capacity, skills and networks.
	HOT CLIMATES: • Maximize external wall areas (plans with one room depth are ideal) to encourage movement of breezes through the building (cross-ventilation). • Ventilate roof spaces. • Include high ceilings and other design features for natural ventilation. • Arrange multiple buildings to benefit from mutual shading. - Shade whole building summer and winter (consider using a fly roof or other roof shading strategy). Minimize east and west openings. • Consider lightly coloured roof, walls, and surrounding paving (high albedo). • Provide screened, shaded outdoor living areas to provide additional relief from heat.	HOT CLIMATES: • Increase green space for microclimate cooling, including landscape (green infrastructure). • Use garden ponds and water features to provide evaporative cooling (blue infrastructure). • Provide access to external shaded space for overheating relief (also important in cold climates, as buildings designed for the cold climate can be most ill-equipped to cope with high temperature extremes). • Install rainwater collection systems.

[53] Amitrano, L., et al., An assessment of the need to adapt buildings for the unavoidable consequences of climate change. Report for Victorian Department of Sustainability and the Environment, 2007.

[54] Gupta, R. and M. Gregg, Adapting UK suburban neighbourhoods and dwellings for a changing climate. Advances in building energy research, 2011. 5(1): p. 81-108.

Climate Change Impact	Building Design	Planning / External Factors
	HOT – HUMID • Use materials which reduce heat gain, provide fast heat loss, and minimizes humidity. • Limit the number of large, glazed windows. • Fewer windows can be helpful in humid climates. • Openings to buildings should avoid direct sun. HOT-DRY: • Use thermal massing with natural ventilation, such as: • Install convective (stack) ventilation, which vents rising hot air while drawing in cooler air. • Use materials which minimize heat gain and capture solar radiation where diurnal temperature ranges are high. • Use wind towers or earth air tunnels • Arrange multiple buildings to benefit from mutual shading. • Use thermal mass, i.e. use lightweight construction where diurnal (day/ night) temperature range is low and include thermal mass where diurnal range is significant. • Provide insulation with a proficient vapor barrier. • Use window shading (louvres) to minimize heat-gain. • Consider using Trombe or water walls and solar chimneys.	
	COLD: • Manage shading to allow solar gains in winter. • Where heat gain is desirable, locate buildings on southern slopes (northern hemisphere), exposure to cold winds can be minimized by placing buildings on the leeward side.	COLD CLIMATES: • Make streets wide enough to prevent shading.

Climate Change Impact	Building Design	Planning / External Factors
	Consider ventilation and solutions to prevent heat-loss at exit points. • Provide insulation with a proficient vapor barrier. • Place windows to facilitate heat gain. • Consider using Trombe or water walls and solar chimneys.	
Increased water stress/ wildfire risk	ALL CLIMATES: • Use fire-resistant building materials. • Install building fire suppression systems (sprinklers) in high-risk zones. • Provide for emergency irrigation of surrounding landscaping to reduce fire risk (link with rainwater collection system).	ALL CLIMATES: • Plan drought resistant ground shading plants to retain ground moisture. • Install rainwater collection systems. • Balance the need to plant vegetation for cooling and shading with the need to clear at-risk vegetation. (Potentially problematic for shading and reduction of UHI • Consider alternative building elements to replace lost site shading, e.g. traditional fabric courtyard coverings or a raised PV system that remains open underneath)
More intense storms with high speed winds and driving rain, e.g. cyclones (hurricanes) and tornadoes	ALL CLIMATES: • Consider frangible architecture options. • Apply a “triage” approach to building design and construction and consider Design for Deconstruction (DfD). • Raise the house above flooding levels. • Use rectangular or square roofs with multiple slopes (hip roof) and sufficient gradient. • Build circular or geodesic-shaped houses, e.g., domes. • Upgrade fasteners in roof structures and in sub-floor. • Ensure weathertightness (sealing corners, holes, unintended entry	ALL CLIMATES: • Avoid cyclonic areas. • Consider orientation of building and placement of surrounding geographic features, trees and structures to capture and direct wind flow. • Install warning systems. • Promote efforts to strengthen social connectivity, community capacity, skills and networks.

Climate Change Impact	Building Design	Planning / External Factors
	points for wind or rain) and drainage detailing (routing water away from the building as quickly as possible through sloped drainage pipes). • Limit overhangs on roofs. • Use water-resistant materials.	
Hail events	ALL CLIMATES: • Use impact-resistant roofing materials. • Design more appropriate window protection. • Install protection of externally fitted services and fixtures, such as PV.	
Flooding and increased concentration of rain events	ALL CLIMATES: • Consider frangible architecture options. • Increase repair drainage capacity with or without integrated green infrastructure. Consider flood barriers / raised entry threshold. • Plan for higher placement of electrical, ventilation and heating systems. • Use moisture-resistant materials. • Design for de-/ re-construction. • Elevate building so finished floor is above flood plain. • Implement systems for rainwater collection and use, consider stormwater control through green roofs. • Use sloped roofs instead of flat roofs.	ALL CLIMATES: • Avoid flood-prone areas. • Improve land-use and site management. Plant trees to improve soil stabilization. • Improve permeation of water into the ground - reduce hard surfaces and increase provision of pervious and/or semi-pervious surfaces such as vegetation, pebble beds and porous pavements/ reduction of hard surfaces. • Use nature-based solutions (NbS), such as the planting of trees, to improve soil stability. • Consider including flood gates. • Consider including green infrastructure such as sustainable drainage systems. • Develop early warning systems and prepare evacuation plans. • Promote efforts to strengthen social connectivity, community capacity, skills, and networks.

Climate Change Impact	Building Design	Planning / External Factors
Sea-level rise	ALL CLIMATES: • Design for de-/ re-construction. • Construct buildings above ground. • Use wet-dry architectural approaches, including selection of water and salt resistant materials	ALL CLIMATES: • Avoid coastal areas. • Use nature-based solutions to reduce storm surge, such as mangroves.

In addition to the above, there are several useful resources the offer guidance and solutions depending on the geographic area, type of concern and economic viability. Among these are the following that designers and planners should acquaint themselves with:[55]

TITLE	SOURCE	DESCRIPTION
Building Regulation for Resilience Managing Risks for Safer Cities	World Bank	Low- and middle-income countries will experience a doubling of their building stocks in the next 15- 20 years, and it is crucial to ensure that this new construction does not recreate and expand the disaster vulnerability of the present. Priority must be placed on the production of safe and resilient cities, communities, and homes. While safer, codecompliant construction may add to initial construction costs, these investments can be balanced against the reduced loss of life and property in future disasters.
A Review Of Climate Change Implications for Built Environment: Impacts, Mitigation Measures and Associated Challenges in Developed and Developing Countries	Hamad Bin Khalifa University	This interdisciplinary review organizes, summarizes, and critically analyses the literature regarding the nexus between climate change and the built environment, its associated impacts, and the proposed mitigation measures and challenges for their implementation. While global warming-driven changes of ecosystems could have multiple impacts on the built environment (most prominently on building energy demand and related urban energy systems), the building sector presents significant potential for climate change mitigation.

[55] UN Environmental Programme; "A Practical Guide to Climate-resilient Buildings & Communities"; 2021

TITLE	SOURCE	DESCRIPTION
Key Findings from The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) on Buildings	IPCC	It is now corroborated that the world's buildings account for a large share of the global final energy use and greenhouse gas (GHG) emissions. This overview of the key findings stresses the major role of buildings in effectively addressing climate change and shows the need for stronger building codes. There is major potential for energy savings of up to 50%–90% in existing and new buildings.
Resilience and Resource Efficiency in Cities	UN Environment Programme	This report looks at the relationship between building the resilience of cities in the face of global environmental change and increasing the resource efficiency of cities to reduce their harmful impacts on the environment. It provides examples of effective ways to address these agendas, as well as the potential and challenges for integration.
Sheltering from a Gathering Storm: Flood Resilience in India	Institute for Social and Environmental TransitionInternational	This report focuses on key issues related to housing in Gorakhpur, India, and provides insights into the economic and non-financial returns of adaptive, resilient shelter designs that take into consideration hazards such as flooding and temperature increases.
SHERPA for Sustainable Housing Projects	UN Habitat and One Planet Network	SHERPA is a free-to-use online assessment tool for evaluating sustainable housing. It can be used in support of the design, construction, and planning of housing projects.
Available Technologies for Local Building Materials	International Centre for Science and High Technology	This report provides a broad survey of available technologies for the development and implementation of local building materials. It covers low-cost, LCA, as well as a number of case studies.
Nature-based Solutions for Building Resilience in Towns and Cities: Case	Asian Development Bank	"This publication summarizes the rich seven-volume "Resource Kit on Building Resilience and Sustainability in Mekong Towns." It includes the principles of green

TITLE	SOURCE	DESCRIPTION
Studies from the Greater Mekong Subregion		infrastructure and measures for building resilience; nature-based solutions of special relevance to Mekong towns, grouped into four categories of water and flood management, slope stabilization, and pollution management; the urban planning and management framework required for mainstreaming of green infrastructure, in particular, the role of town master planning and zoning schemes; the process for conducting vulnerability assessment; and includes case studies”
MaS-SHIP Mainstreaming Sustainable Social Housing in India Project	One Planet Network	Online resource for improving the environmental performance of social housing in India. Contains case studies, resources, reports, and recommendations.
Disasters and the Built Environment	CIB	The roadmap has been largely drawn from the series of webinars that shared knowledge and expertise between CIB, UNISDR, and cities that are involved in the ‘Making Cities Resilient’ Campaign.
Bioclimatic Architecture in Warm Climates: A Guide for Best Practices in Africa	Springer and Associates	“This book provides a comprehensive approach to building design. Bioclimatic design is key to urban sustainability and a critical issue in Africa where many building types were ‘imported.’”
Energy Efficient Building Design: Nigeria	GIZ-Nigeria Energy Support Programme	The report provides an overview of building physics for architects and engineers. It focuses on the building envelope and thermal balance; thermal flow; properties of materials and how to identify and select appropriate materials and components.
Tracking Buildings 2020	IEA	Report outlining Climate Change Impacts on Buildings
Policy Database	IEA	Policy and Building Code Database

TITLE	SOURCE	DESCRIPTION
Climate Change Adaptation Design Resources	American Institute of Architects (AIA)	Collection of resources to help prepare buildings to manage climate changes. Includes examples, resources, simulation tools to assist with the visualization of environmental impacts on buildings, and case studies.

Before concluding the discussion on climate impact on buildings and Resilient design, it is worthwhile to offer a brief opinion on the massive wildfires that devastated parts of Southern California and Los Angeles in January 2025.

Special NOTE on Resilient Design and the Los Angeles Fires of January 2025.

The basic facts (as of February 2025)

- The Palisades fire broke out on Tuesday, January 7, near Los Angeles. It burned more than 24,000 acres, including homes and businesses in Pacific Palisades and along the Pacific Coast Highway.
- The Eaton fire also began January 7 and burned more than 14,000 acres.
- The Hurst fire also began January 7 and burned nearly 800 acres.
- The Lidia fire broke out on January 8 and burned 395 acres.
- The Kenneth fire began on January 9 and burned 1,052 acres.
- The Sunset fire broke out on January 8 and became fully contained January 9. It burned 43 acres.
- The Auto fire started on January 13 and burned more than 60 acres.
- Twenty-nine people have died, and more than a dozen people were still reported missing as of late January 2025.
- During the worst of the fires, 180,000 people were under evacuation orders.
- Crews from California and nine other states and Mexico engaged in fighting the flames with 1,400 fire engines and 84 aircraft.
- At the end of January 2025, the official cause(s) for the fires remained under investigation.

These fires, likely to become the most expensive natural disaster to affect the United States this century, highlighted many issues related to climate impact, construction techniques, firefighting infrastructure, and the magnified risks when human development overwhelms an area without fully considering the changing natural risks created by the altering the ecosystem balance that existed prior to the encroachment. Until the final analyses are done and objective findings made public, there is growing anecdotal data which suggests that buildings with resilient features like fire-resistant design and those situated with "defensible space" around them generally fared better, with some homes remaining largely intact while others in the same area were destroyed, highlighting the importance of proper construction and landscaping to withstand wildfire conditions.

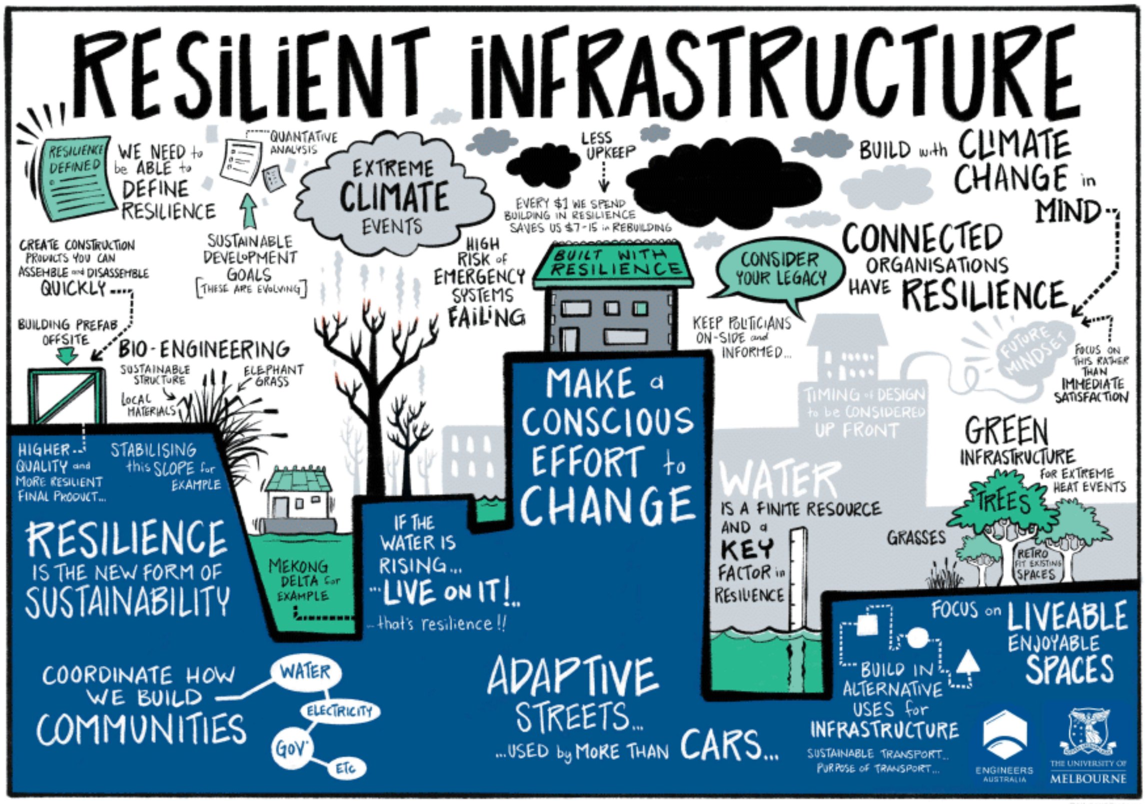
Source: commons.wikimedia; public domain; Homes destroyed in the Palisades fire (54272193113).jpg

While luck, sudden changes in wind direction, availability of combustible materials and spread of embers play a role in how fires spread, it is also highly likely that some structures that were built with resilience in mind escaped the onslaught of the fire due to their design. One example that received significant notice was a 'brand-new house in Pacific Palisades designed and built by architect Greg Chasen in summer 2024 … None of the other homes around it survived, and a car parked out front by a neighbor was the perfect vector to spread the flames. Yet on Jan. 9, after a night of devastation, Chasen found the house intact, barely touched by the fire. Luck was the [possibly] biggest factor, Chasen concedes, but it wasn't providence alone. If it weren't for several fire-resilient design strategies, the home would have been destroyed…

'Some of the fire-proofing decisions made by Chasen stand out in the picture. The yard is a protected area free of vegetation, fenced off by cast-in-place concrete garden walls, with landscaping in a sparse Mediterranean desert style. The home's owner has been through fires before, so he was prepared: He removed trash cans and other loose items from around the house and even left the side gates open, knowing that a fire can spread along a fence to a house.'[56]

In the forensics that will follow the aftermath of the wildfires, many lessons will be learned and likely affirm that designing with resilient strategies should be a driver in the rebuilding that is to come.

[56] Bloomberg: "These Homes Withstood the LA Fires. Architects Explain Why"; by Kriston Capps; January 13, 2025



Source: GREEN.org; "Enhancing Building Resilience in the Face of Climate Change"; 01/30/2024.

3.3. Resilient Design, NetZero and Zero Net Carbon

The world reached a monumental consensus in December 2015 under the Paris Agreement – to limit global average temperature increase to "well below 2°C and to drive efforts to limit the temperature increase even further to 1.5°C above pre-industrial levels."[57] Out of this conference agreement a significant mandate was to achieve carbon neutrality by 2050. That target became known as Net Zero. The term ***Net Zero means achieving a balance between the carbon emitted into the atmosphere, and the carbon removed from it. This balance – or net zero – will happen when the amount of carbon we add to the atmosphere is no more than the amount removed***.[58] While realistic in terms of technology and implementable time frame, the charge is only practical if there is cooperation on a global scale with realistic economic and developmental initiatives and subsidies for poorer nations who have to forego traditional polluting, but cheaper technologies. That global cooperation continues to remain politically charged and has been elusive to date. For example, the United States, undoubtedly the most important industrial power in the world, did sign on to the agreement in 2015, but withdrew in 2017, only to rejoin in 2021 and withdraw again in 2025. This vacillation by the most important signatory is likely to

[57] Architecture 2030: "Zero-Net-Carbon: A New Definition"; July 2016

[58] Energy savings Trust.org (UK). The definition is consistent with other sources, with slight verbiage syntax difference but not in substance.

dampen the resolve of many other countries, thereby putting the achievement of the 2050 target in jeopardy. Nevertheless, so far most of the other signatories continue to move forward with regulatory mandates to limit carbon emissions. Furthermore, at a non-governmental level, most of the leading American corporations, municipal agencies and the design community remain committed to pursuing carbon reduction initiatives.

A related term, Zero Net Carbon (ZNC), often gets equated and interchanged with Net Zero. While both address reduction in carbon emissions, there are some key differences that should be noted in the context of applicability to design. Net Zero design is a strategy to **reduce and offset** greenhouse gas emissions, while Zero Net Carbon Design is a strategy to **achieve zero or negative** carbon emissions.

Net Zero design

- Goal: Reduce emissions as much as possible and offset the remaining emissions.
- Strategies: Use renewable energy sources, reduce energy demand, and absorb carbon dioxide from the atmosphere.
- Examples: Net-zero energy buildings generate as much energy as they consume.

Zero Net Carbon (ZNC) design

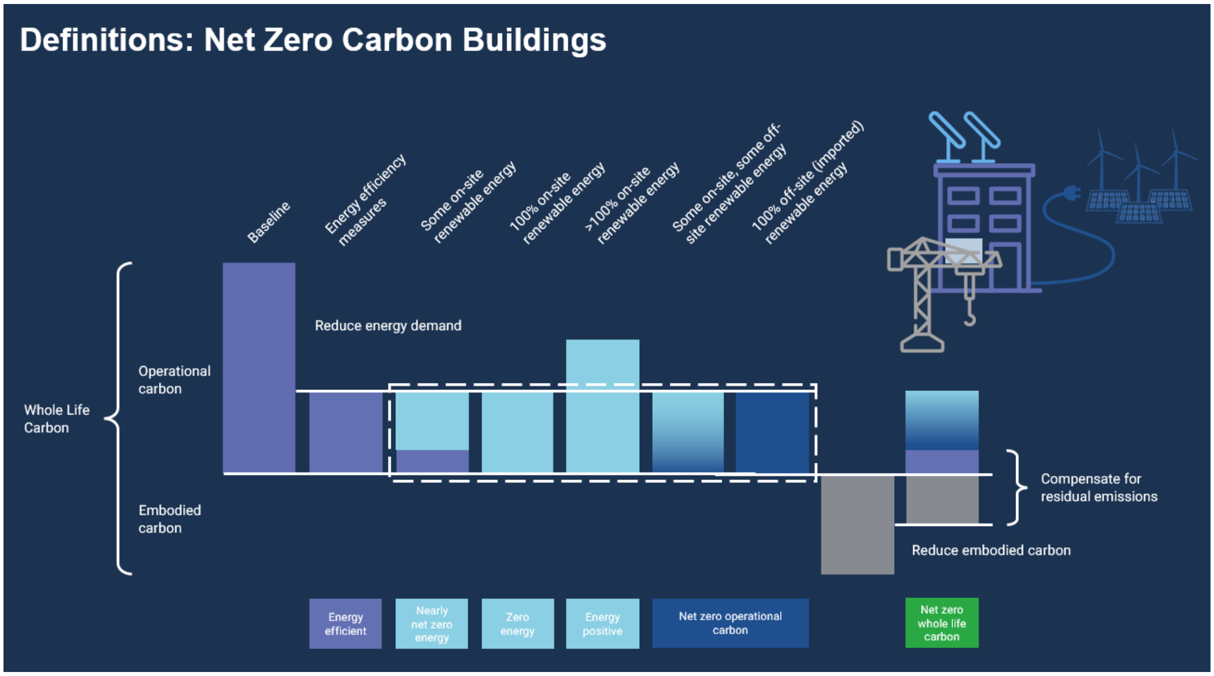
- Goal: Achieve zero or negative carbon emissions over the life of a building.
- Strategies: Reduce emissions during construction, operation, and disposal.
- Examples: Net-zero carbon buildings can be constructed with zero or negative carbon emissions during construction, operation, and disposal.

In addition, there are other definitions that closely align with and qualify as supporting Net Zero. Among these are:

- Net Zero Site Energy Building (Site ZEB)
- Net Zero Source Energy Building (Source ZEB)
- Zero Emissions Building (ZEB)
- Zero Energy Building (ZEB)
- Zero Net Energy (ZNE) Building

Each of these definitions is compatible with ZNC because they offset carbon-based energy consumption with energy efficiency and new renewable energy capacity. In fact, these definitions represent a narrower path for achieving zero net carbon, specifically for locations that have the on-site renewable energy production capability to meet annual energy demands. However, this limits their application to mostly low-density, low-rise, suburban, or rural building applications. A standard that is more closely aligned to ZNC is the European definition of a Nearly-Zero Energy Building (NZEB) as it also allows for accessing nearby off-site generated renewable energy. While all energy and greenhouse gas emissions reduction targets are important, as we move to a carbon emissions-free built environment by 2050, all strategies and definitions will converge to meet the ZNC definition.[59]

The chart below illustrates Net Zero Carbon Buildings as envisioned by the World Green Building Council (WGBC):



Source: worldgbc.org: "Advancing Net Zero".

As Net Zero and ZNC continue to impose ongoing pressure on architects and the building industry, many question why so much emphasis on buildings, creating what may seem to be a disproportionate burden on architects without matching adjustments to their design fees? The first part is relatively easy to answer:

> Buildings are responsible for 38% of global energy-related carbon emissions and 50% of all extracted materials. Four billion people are vulnerable to climate risks and 91% of people worldwide live in areas with air pollution. By 2050, the world's building stock will double, increasing the impact of our sector significantly. Its demand on natural resources accelerates climate change, and inefficient, unhealthy buildings are affecting our livelihoods.[60]

Since the consequences of buildings and the built environment are singularly so significant, it is logical to see why the source of building design and specifications – the architects and their consulting engineers would be the essential to any solution.

[59] Architecture 2030 / New Buildings Institute; "Zero Net Carbon (ZNC) Building

[60] Worldgbc.org: "How sustainable buildings are #BuildingResilience and driving the Sustainable Development Goals";

As to the complaint that the added effort to calibrate designs to meet ZNC/NZ goals, designers are not adequately compensated, there is some merit to the contention. The reality is that until the requirements are codified or mandated, clients see these as optional, and in some cases, economic drains, and so are not inclined to pay for the added design effort. However, as shifts occur in societal expectations, codes, regulations, and recognition of the need for such designs, fee adjustments will inevitably follow either directly or indirectly with evolving Artificial Intelligence (AI) tools, reducing time for other design tasks.

Having examined NetZero design and Zero net Carbon Design, the relationship with Resilient design can be explored. While all these notions are important for the overall umbrella concept of "Sustainability", Resilient design focuses on the ability of cities to withstand and adapt to severe weather and other shocks and considers the long-term durability and adaptability of buildings. Whereas NetZero design focuses on reducing emissions by using renewable energy sources and other strategies. NetZero design aims to create buildings that use as much energy as they generate.

So, while there is some divergence or difference in core focus, there are some overlaps between Net Zero related design and Resilient design:

- Integrated approach: An integrated approach to both resilient design and net zero design can help cities transition to net zero while also improving resilience.
- Building energy modeling: Building energy modeling can help optimize a building's shell and integrate renewable energy generation.
- Natural ventilation: Natural ventilation can help reduce energy consumption and cooling needs.
- Exterior shading: Exterior shading can help reduce reliance on cooling systems.
- Daylight design: Daylight design can help reduce the need for electric illumination.

The overlaps here are remarkably like many that occur in all aspects of design approaches that are aiming to ultimately achieve a sustainable built environment. However, Net Zero is quite narrow and specific in its goals while Resilient design is quite broad and much more holistic. This has led to a recent debate in academic circles and in design literature about why Resilient design may deserve more attention because it encompasses many of the other environmental challenges, albeit, by definition, Resilient design will vary wildly from one geography and economic area to another.

In an October 17, 2024, blog post, architect Onah Jung posited a question: "if the effects are already at our doorstep, is aiming for net-zero carbon emissions really enough? Or do we need to think beyond emissions reduction to prepare for a reality that's already shifting?"[61] Jung went on to argue that just focusing on NetZero is not enough. The argument: "To be fair, Net-Zero goals have their place. They aim to balance energy use by reducing greenhouse gas emissions, making the built environment less harmful. But if we focus solely on net-zero, we're missing the point—because it's not just about energy. What happens when the power goes out during a

[61] Onahjung.com: "Net Zero Isn't Enough: Why Resilient Design is the Real Answer to Climate Change"; by Onah Jung; October 17, 2024

heatwave, or a storm surge floods a downtown core? Net-zero doesn't address how a building, or a city for that matter, will survive when nature pushes back harder than anticipated. It is an unpredictable, evolving challenge that demands more than just reducing our carbon output. And that's where resilient design comes into play—it is about making our structures capable of adapting, evolving, and thriving amid instability."[62]

As a solution to the problem posed, Architect Jung made a case for why Resilient design is a better approach to tackle the challenges of climate change and sustainability. He argued that "At its core, Resilient Design goes beyond reducing energy use to address the bigger picture: it is about creating spaces that can handle environmental shocks and keep functioning. Whether it is extreme weather, rising temperatures, or energy shortages, resilient design means building with flexibility and preparedness in mind. The goal is not just to meet today's environmental standards but to be ready for tomorrow's unknowns. It is the difference between a building that conserves energy and one that can withstand a flood. Between reducing a carbon footprint and ensuring a neighborhood can recover quickly from a power outage.

"Resilient design is proactive, not reactive, integrating adaptability into every aspect of a building. Think modular construction, flood-resistant materials, passive heating, and cooling systems—these elements don't just save energy, they protect lives and property."[63]

He concludes his argument by stating: "While net-zero targets might seem like the holy grail of sustainability, they do not guarantee long-term survivability. What good is hitting zero emissions if the buildings we construct cannot withstand increasingly severe weather? Resilient design pushes us to think beyond energy conservation to consider the long-term durability and adaptability of the built environment. It's about making sure our cities can endure and function in more volatile conditions—because the future we're designing for is already here. As climate challenges grow more intense, retreating to a cave might seem like the ultimate resilient design choice: temperature control, natural shelter, low energy consumption—it is practically net-zero! But since we are not ready to revert to cave dwelling just yet, it's time to rethink how we build for the realities of today and tomorrow. Net-zero might be a good start, but resilient design is where true sustainability lies. Because if we cannot weather the storms ahead, all those zeroes won't mean much."[64]

While Architect Jung's conclusion may seem a bit tongue in cheek, the points made are a glaring reflection of reality and that is apparent in the simple fact that of all the design trends to emerge from the sustainability movement, Resilient design is fast becoming the one that regulators, code officials and urban planners are gravitating to. In part this is because it is not a rigid, formula-based approach, nor is it a stylistic design philosophy. It is a fundamental paradigm shift that puts building, infrastructure and community fabric survivability and functionality on the same plane as human survivability following a major disruptive event. Done right, it encapsulates the major elements of Net Zero and offers long term economic advantages and potentially lower costs of ownership of buildings and community places.

[62] Ibid
[63] Ibid
[64] Ibid

This concludes Part 3 of the course.

In Part 4 the course will address:

Resilient Design Principles, Applications and Practical Examples in Architecture, Planning & Landscape Design

- Resilient design principles
- Application of Resilient design principles to building design, landscaping, and urban planning
    - Building better foundations.
    - Developing strategies to reduce energy consumption.
    - Using materials able to withstand extreme weather conditions.
    - Considering alternative power sources, such as solar or wind power.
    - Incorporating green infrastructure elements (e.g., rainwater catchment systems);
    - Improving the thermal efficiency of buildings, which helps them withstand extreme temperatures.
    - Resilient design also involves social components such as increasing community awareness about climate-related risks and creating strong networks for collaboration between stakeholders.
- Practical examples of Resilient design in buildings

<u>Part 3 Review Questions</u>

12. Resilience and Sustainability both focus on all of the following except:
    a. Building aesthetics
    b. Energy and water independence
    c. Local materials
    d. Renewable resources
13. The *Bosco Verticale* is presented in the course as an example of a building that addresses which of the following Resilient design strategies?
    a. Incorporating recreational elements in the design
    b. Incorporating vertical greenery for natural cooling and air purification
    c. Community engagement
    d. All of the above
14. A characteristic of adaptive design is:
    a. Vegetation on rooftops
    b. Implementing rainwater harvesting systems
    c. Incorporating features that can withstand extreme weather events
    d. Including low-flow fixtures
15. The number of billion-dollar disaster events in the US have ____________ between 2008 and 2022.
    a. Risen sharply
    b. Risen only slightly
    c. Stayed the same

    d. Declined when adjusted for temperature

16. According to the course material, one way to help stabilize property insurance costs is by:
    a. Opting out of insuring properties
    b. Increasing regulations
    c. Investing in resilient buildings and communities
    d. Using a single payer government funded insurance scheme
17. According to a policy brief by C40 Knowledge HUB, the scales of applying Resilient design options are:
    a. City, Community, Building
    b. Neighborhood, Town, Community
    c. Micro, Macro
    d. None of the above
18. Designing for durability, disassembly and maintenance is a strategy for which scale of resilient design?
    a. Neighborhood
    b. Building
    c. Regional
    d. It is not a viable strategy at any scale
19. Planning drought resistant ground shading plants to retain ground moisture as a response to water stress / wildfire risk is applicable to which climates?
    a. Dry desert climates only
    b. Cold dry climates
    c. All climates
    d. Hot and humid climates in the northern hemisphere
20. Who developed the Building Regulation for Resilience Managing Risks for Safer Cities?
    a. United Nations Development Program
    b. USAID
    c. World Bank
    d. Australian Sustainability Council
21. Which of the following is / are true of the wildfires around the Los Angeles, California area in January 2025:
    a. The Eaton and Hurst fires were cumulatively the worst fires
    b. Only 18,000 people were evacuated at the peak
    c. There were multiple fires with the Palisades fire being the largest, consuming over 24,000 acres
    d. a & b
22. Which of the following is not an aspect of resilient infrastructure according to GREEN.org?
    a. Build with climate change in mind
    b. Ignore politicians
    c. Focus on livable, enjoyable spaces
    d. Build with resilience

PART 4 - Resilient Design Principles, Applications & Practical Examples

Given that building codes are generally focused on achieving goals of life safety, amenity (comfort) and sustainability, there is a need to ensure that building resilience is placed in the right context to deliver better and achievable building outcomes. In failing to achieve an agreed definition of resilience in a building context, resources may be allocated inefficiently, regulatory tools may prove ineffective, unintended outcomes or consequences may be generated and a loss of public confidence may arise through the raising of unrealistic expectations, such as an asset not needing to be insured.[65]

Some common elements of existing definitions that have been used for the resilience of buildings include:[66]

Resilience…	Applied to buildings
Of what	Buildings or parts of buildings and the contribution this makes to the broader community.
To what	Future extreme weather events, which are anticipated to change in frequency, duration, intensity and/or distribution.
For how long	Before (i.e., adapt), during (i.e., durability) and after (i.e., recovery), short and longer term.
For whom	Health and safety of the following: 1. the intended occupants of the building, and 2. those who rely on essential systems, services, or infrastructure provided by or from the building

As with many design and sustainability concepts and philosophies, there are seldom definitive, universally accepted definitions. The organizations, agencies and design studios tend to evolve their own takes on the broadly accepted parameters and these become "definitions" that are similar but not identical. Take the following examples for Resilient Design:

Definition adopted by the Global Resiliency Dialog:

"Building resilience: The ability of a building and its component parts to withstand current and future climatic conditions (including wildfires/bushfires, extreme wind, extreme precipitation and extreme temperature), to minimize the loss of functionality and recovery while sustaining damage proportionate to the intensity of the events experienced, and preserving the intended level of performance at the time of construction over the proposed design life of the building."[67]

Definition articulated by the Resilient Design Institute:

[65] Global Resilience Dialog: "Global Building Resilience Guidelines; Guidelines for Resilient Buildings to Extreme Weather; November 2022

[66] Ibid

[67] Ibid

> Resilient design is the intentional design of buildings, landscapes, communities, and regions in order to respond to natural and manmade disasters and disturbances—as well as long-term changes resulting from climate change—including sea level rise, increased frequency of heat waves, and regional drought.[68]

The definitions are similar but vary in level of specificity and breadth of application. In application and a preference for the course, the RDI definition is more desirable as it extends beyond the envelope of the building to account for landscape and community. These links are, in the opinion of the author, essential to achieving the base objective of resiliency – functional survivability of the building and its occupants. The operative word being functional. It is difficult for a building to be singularly useful or for its inhabitants to remain functional if the infrastructure around them and the community places are also not functional and usable.

This link between building and community is a key differentiator, and possibly the catalyst that makes a Resilient design approach appealing at the design, planning and political levels.

Before delving into a detailed discussion about Resilient design principles and applications, it is important to reiterate that resilient design applications are not a one size-fit all approach. It varies depending on location and the hazards that are prevalent. Sometimes a single hazard is the driving basis while in other locations, multiple hazards and/or events have to be accounted for. Once the hazard event(s) are identified, buildings can be designed to respond to a level of performance commensurate with the risk level that a community or building owner wants to address.

The *expected performance* of buildings following a hazard event depends on the design criteria based on Risk Category and occupancy. Some buildings need to be functional immediately following a hazard event, while other buildings maintain life safety objectives. Buildings consist of an integrated set of systems (e.g., structural, architectural, mechanical, electrical, plumbing, communications) that perform together to serve the intended functions within the building. In general, buildings are highly dependent on external or ancillary infrastructure systems such as electric power, water, and communication systems. For community resilience planning, buildings can also be characterized as part of a building cluster. The term "cluster" refers to a set of buildings that serve a common function, such as housing, healthcare, or retail, and may be distributed throughout a community (NIST 2016).[69]

Buildings are classified in model building codes by occupancy type and use. The term "occupancy" in model building codes refers to the nature of the activities that occur inside the buildings, which influences fire and life safety provisions, types of construction, mechanical systems, electric power systems, plumbing systems, and structural systems. Occupancy classifications include assembly, business, educational, factory and industrial, high hazard, institutional, mercantile, residential, utility and miscellaneous, and storage.[70]

Model building codes also classify buildings into Risk Categories, which correlate the criteria for environmental design loads specified in the code to the consequence of the loads being exceeded for a building and its occupants (ASCE 2021a). The Risk Category as defined by IBC

[68] Resilient Design Institute: "Resilient Design"

[69] National Institute of Standards and Technology: NIST Technical Note 2209 "Assessment of Resilience in Codes, Standards, Regulations, and Best Practices for Buildings and Infrastructure Systems"; Editors: Theresa P. McAllister; Richard F., Walker; Amy Baker. April 2022

[70] Ibid

(2021) is "a categorization of buildings and other structures for determination of flood, wind, snow, ice and earthquake loads based on the risk associated with unacceptable performance." The building codes include prescriptive lists for Risk Category based on occupancy, which can be altered by a community when it adopts local codes based on the model building code. As shown in Table below, the classification of Risk Category progresses with an increase in the seriousness of the consequence of failure from Risk Category I for buildings with the lowest risk to human life to Risk Category IV for the highest risk (ASCE 2021a).[71]

ASCE 7-22 Table 1.5-1 – Risk Category of Buildings and Other Structures for Flood,Wind, Snow, Earthquake, and Ice Loads (Source: ASCE 2021a)

Use or Occupancy of Buildings and Structures	Risk Category
Buildings and other structures that represent low risk to human life in the event of failure	**I**
All buildings and other structures except those listed in Risk Categories I, III, and IV	**II**
Buildings and other structures, the failure of which could pose a substantial risk to human life.	**II**
Buildings and other structures, not included in Risk Category IV, with potential to cause a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure.	**I**
Buildings and other structures not included in Risk Category IV (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, hazardous waste, or explosives) containing toxic or explosive substances where the quantity of the material exceeds a threshold quantity established by the Authority Having Jurisdiction and is sufficient to pose a threat to the public if released.[a]	
Buildings and other structures designated as essential facilities	**IV**
Buildings and other structures, the failure of which could pose a substantial hazard to the community Buildings and other structures (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, or hazardous waste) containing sufficient quantities of highly toxic substances where the quantity of the material exceeds a threshold quantity established by the Authority Having Jurisdiction and is sufficient to pose a threat to the public if released. [a]	
Buildings and other structures required to maintain the functionality of other Risk Category IV structures	

[a] Buildings and other structures containing toxic, highly toxic, or explosive substances shall be eligible for classification to a lower Risk Category if it can be demonstrated to the satisfaction of

[71] Ibid

the Authority Having Jurisdiction by a hazard assessment as described in Section 1.5.3 that a release of the substances is commensurate with the risk associated with that Risk Category.

Based on the above risk categories, the most used building types are the following:[72]

- **Residential** – Structures designed following the IRC (2021). One- and two- family dwellings, such as single-family homes, two-family houses (duplexes), and townhouse units.

- **Commercial** – Structures classified as Risk Category I, II, and III and designed following the IBC (2021). Commercial buildings include those that support services, manufacturing, and assembly. Buildings classified in Risk Category III include those that house a large number of persons in one place. Risk Category II includes buildings not listed in the other Risk Categories, and Risk Category I includes buildings that are normally unoccupied and have the lowest risk to human life.

- **Critical** – Structures classified as Risk Category III and IV and designed following the IBC (2021).

When considering building or civic infrastructure performance from a resilience perspective, there are some core terms that have to be understood:[73]

- ***Absorption capacity*** is the ability of a system to withstand a shock without experiencing significant functional decline.

- ***Time to recovery of function*** (sometimes referred to as Rapidity) is a measure of how long it takes before a building or infrastructure system is functioning after a natural hazard event.

- ***Re-occupancy*** is a post-event performance state in which a building is maintained, or restored, to allow safe re-entry for the purposes of providing shelter or protecting building contents. (For a *re-occupancy* performance state, basic functions are provided at less than pre-event functionality levels but meet minimums sufficient for buildings).

- ***Functional recovery*** is a post-event performance state in which a building or infrastructure system is maintained, or restored, to safely and adequately support the basic intended functions associated with the pre-event use or occupancy of a building, or the pre-event service level of an infrastructure system.

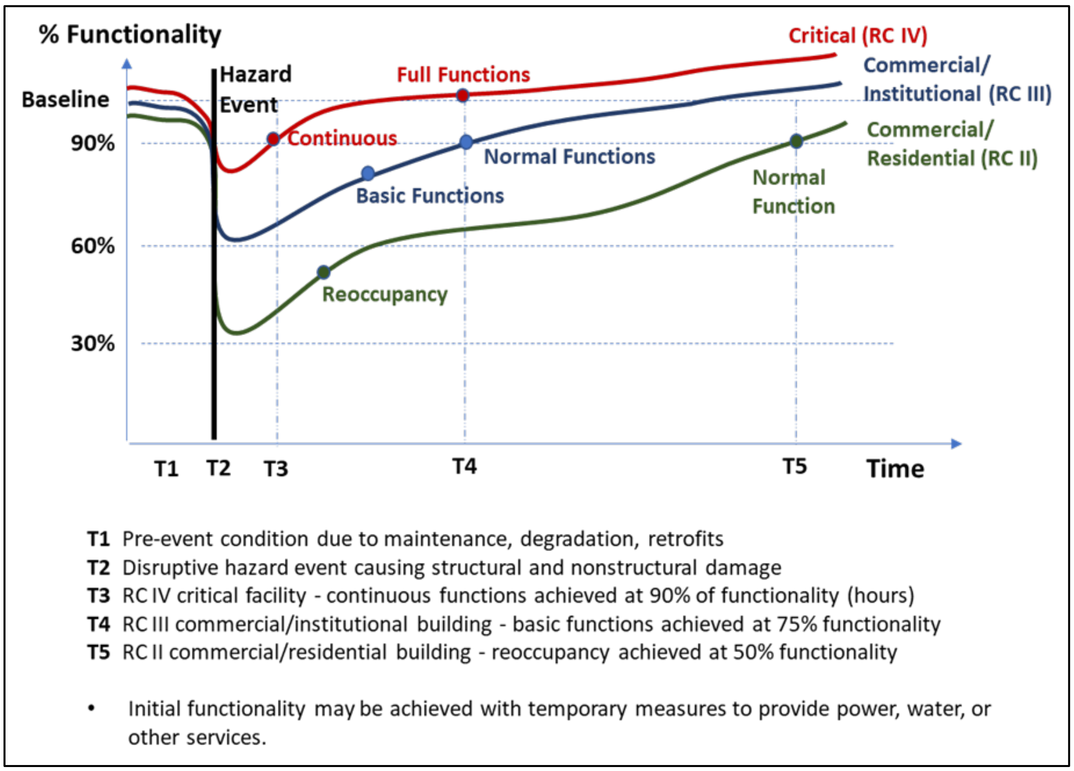
- ***Operability*** is the ability of an infrastructure system to provide near-normal services to a customer, sufficient for supporting a significant measure of pre-event functionality.

- ***Functionality*** is a measure of an infrastructure system working normally to provide its regular pre-event services, even if temporary solutions are and the system may not be as reliable or resistant to service interruptions.

[72] Ibid
[73] Ibid

- ***Full functionality*** (i.e., full recovery) is achieved when the entire system is functioning and repaired (e.g., restoration of all services and repair/replacement of infrastructure system to full capacity).

The United States Department of Commerce's National Institute of Standards and Technology, founded in 1901 with a mission to "promote measurement science, standards, and technology", has produced useful research and reference data that helps in understanding and developing appropriate resilient design responses. Many of their resources are cited in this course. Below is a graph that depicts how % functionality and recovery time measures can help specify performance states for buildings and infrastructure.[74]



Functionality Versus Recovery Time with Example Performance States.

Conceptually, the objective of a resilient design approach to individual buildings and / infrastructure has the goal of minimizing the dip in the graph at the point of Hazard Event and then helping reduce the duration of time intervals T1 through T5. In order to place some practical, measurable (or noticeable) performance, it is useful to state what recovery impacts are expected for given hazards.

The design hazards summary table below illustrates, by comparison, resilience principles of hazard design levels, and recovery considerations in current codes and standards (as of 2022). It

[74] Ibid

illustrates the adjustments needed to achieve a common performance for design within and across sectors.

Key Resilience Provision Comparison of Codes and Standards by Sector and Hazard

Sector	Commonality of Design Hazards (Baseline Event MRI, yr)*			Recovery Performance Provisions (Risk Category IV or Highest)		
	Flood	Wind**	Seismic	Function Loss	Recovery Time	Damage Cost***
Buildings (ASCE 7)	100/500	100/1700	500/2475	Continued operation	Days to weeks	<10%
Water	500	ASCE 7	ASCE 7	Continue operation	Days to weeks (per AWWA J100)	No criteria
Electric Power	100/500	ASCE 7	ASCE 7	Emergency backup	No criteria, relies upon operational guidance docs	No criteria
Transportation**	<100/100	ASCE 7	1000/2500	Continued operation, no collapse	Days to weeks	No criteria

*Routine / Design event levels. ASCE 7 alignment is shaded green
**Additional MRI used are based on design categories, code versions, and between modes
*** Percent of facility/system replacement cost

Having considered that Resilient design seeks to achieve desired performance results when applied to buildings, infrastructure and other areas of urban planning, the various responses that can be applied will be presented in the next section.

4.1. Resilient Design Principles

In Part 1 we examined a very brief overview of the ten principles of Resilient Design, as articulated by the RDI. This section will explore a more in-depth account of each of the principles.

To recap, the ten principles are:

1. ***Resilience transcends scales.***
2. ***Resilient systems provide for basic human needs.***
3. ***Diverse and redundant systems are inherently more resilient.***
4. ***Simple, passive, and flexible systems are more resilient.***
5. ***Durability strengthens resilience.***

6. ***Locally available, renewable, or reclaimed resources are more resilient.***
7. ***Resilience anticipates interruptions and a dynamic future.***
8. ***Find and promote resilience in nature.***
9. ***Social equity and community contribute to resilience.***
10. ***Resilience is not absolute.***

Elaborating on each:

1. **Transcending Scales:** Resilient design transcends scales by applying strategies across various levels, from individual buildings and sites to entire communities and regional ecosystems, considering both immediate and long-term impacts. In this way it ensures that solutions address needs at each level while also taking into consideration those solutions interact and influence one another to build a more robust overall system. Principally, it is not just about designing resilient buildings, but also designing resilient landscapes, infrastructure networks, and social systems that work together to adapt to changing conditions and recover from disruptions. Some of the ways in which this is accomplished are:

    - **Building level**: Elevating buildings in flood-prone areas, using flood-resistant materials, designing for passive cooling to reduce energy demand during heat waves.
    - **Neighborhood level**: Creating walkable communities with diverse housing types, implementing green infrastructure to manage stormwater runoff, establishing community resilience hubs.
    - **Regional level:** Developing regional flood protection plans, coordinating land use planning to protect natural habitats, investing in infrastructure upgrades to address climate change impacts.

2. **Providing Basic Human Needs:** Resilient design endeavors to provide basic human needs by addressing the needs for food, water, energy, air, and shelter. Resilient design also aims to make these needs accessible to all people, regardless of their social status or location. Among the features of Resilient design that achieve these objectives are:

    - **Water**: Resilient design includes systems that provide clean drinking water and sanitation.
    - **Energy**: Resilient design includes systems that provide energy, such as renewable energy sources, and backup power sources.
    - **Safe Air**: Resilient design includes systems that provide clean air. Indoor Air Quality (IAQ) is an important design objective that often gets overlooked. In

areas prone to wildfires and, generally, in light of the Coved pandemic, IAQ is fast rising to the top of HVAC considerations.[75]

- **Shelter**: Resilient design includes systems that provide protection from the elements, such as flooding and extreme weather.
- **Food**: Resilient design includes systems that provide access to food, such as non-perishable food supplies.

3. **Diverse and Redundant Systems:** Resilient design promotes this by encouraging intentional incorporation of multiple, varied components within a system, ensuring that if one part fails, other parts can take over and maintain functionality, effectively eliminating single points of failure and promoting adaptability to changing conditions or disruptions. This principle has historically been standard practice in critical infrastructure facilities like nuclear plants, petrochemical plants, airports, as some examples. Redundancy includes utilizing backup systems, geographically dispersed locations, and different operational methods to enhance overall resilience. Examples of properties of resilient design in diverse and redundant systems include:

- **Redundancy**: Implementing duplicate or backup systems, like having multiple power sources, data centers in different locations, or redundant communication channels, to ensure critical functions continue even if one system fails.
- **Diversity**: Incorporating different types of systems or components with varying vulnerabilities to mitigate the impact of a single threat or failure mode. For example, using different communication protocols or energy sources.
- **Modular design:** Breaking down systems into smaller, independent modules that can be easily isolated and replaced in case of failure, allowing for localized repairs without affecting the entire system.
- **Scalability**: Designing systems that can be easily expanded or contracted based on changing demands, providing flexibility to handle unexpected surges or drops in usage.
- **Fault tolerance:** Incorporating mechanisms to detect and automatically recover from errors or failures, minimizing downtime and disruption.
- **Building design:** Utilizing multiple power grids, backup generators, flood-resistant features, and diverse ventilation systems to maintain functionality during extreme weather events.

[75] IKIGAIconsulting: "Design Strategies for Resilient Buildings"; 31 August, 2023

- **IT infrastructure:** Deploying geographically dispersed data centers with redundant servers and network connections to ensure data availability even if one location is compromised.
- **Transportation systems:** Designing public transport networks with multiple routes and alternative modes of transportation to minimize disruption during disruptions like road closures.

A point to consider this principle is that it can often conflict with the efficiency aims and green building priorities while also imposing added costs. Nevertheless, redundant systems for such needs as electricity, water, and transportation improve resilience for critical buildings and infrastructure. Given the recent consequences of a succession of natural disasters, the benefits of redundancy in post disaster scenarios have become self-evident.

4. **Use of Simple, Passive and Flexible Systems:** These traits of a design are inherently less prone to failure, require minimal maintenance, and can easily adapt to changing conditions, making them more capable of withstanding disruptions and recovering quickly. Some fundamental points about using simple, passive, and flexible systems in Resilient design are:

- **Simplicity**: Complex systems with many interconnected parts are more likely to fail at a single point, while simpler designs with fewer components are easier to maintain and repair.
- **Passive design**: Utilizing natural forces like sunlight and wind for ventilation and heating reduces reliance on mechanical systems that could fail during power outages, making the building more resilient.
- **Flexibility**: Flexible design allows for adaptations to changing conditions, including potential future needs or unexpected events, by incorporating features that can be easily modified or repurposed.

Examples of how resilient design incorporates these principles:

- **Natural ventilation**: Designing buildings with strategically placed openings to utilize natural air flow for cooling instead of relying solely on air conditioning.
- **Daylighting**: Maximizing natural light through windows and skylights to reduce the need for artificial lighting
- **Solar thermal panels**: Using solar energy to heat water, reducing reliance on grid electricity.
- **Flood-resistant construction:** Elevating buildings above flood levels, using flood-proof materials, and incorporating flood vents.
- **Modular design**: Building components that can be easily disassembled, relocated, or replaced to adapt to changing needs.

- **Redundant systems:** Having backup systems for essential functions like power generation or water supply to ensure functionality even during disruptions.

5. **Durability**: This is achieved by prioritizing the use of materials and construction methods that can withstand prolonged exposure to environmental stressors. This allows a structure to maintain its functionality even after experiencing natural disasters or other challenging conditions, allowing it to "bounce back" and recover from damage over time. In this way durability is a principal component of resilient design, enabling a building or system to resist degradation and remain functional for a long period. Some main ways about how resilient design uses durability are:

    - **Material selection**: Choosing quality, weather-resistant materials that can withstand wear and tear, like reinforced concrete, specialized coatings, and corrosion-resistant metals, is crucial for achieving durability in resilient design.

    - **Structural integrity**: Designing structures with robust load-bearing elements and proper redundancy in critical systems can ensure stability even during extreme events, enhancing overall resilience.

    - **Maintenance considerations**: Incorporating easily repairable components and accessible design features allows for efficient maintenance and repairs after damage occurs, contributing to long-term resilience.

    - **Adaptability**: Beyond just resisting damage, resilient design can also incorporate features that allow for adaptation to changing conditions, like flood-resistant elevations or flexible building layouts, further enhancing long-term functionality.

    Example scenarios where durability is employed:

    - **Coastal development:** Using elevated foundations and flood-resistant materials for buildings in flood-prone areas to minimize damage from storm surges.

    - **Seismic design**: Incorporating flexible building elements and earthquake-resistant construction techniques to withstand seismic activity.

    - **Renewable energy systems:** Integrating solar panels and battery storage to maintain power supply during outages caused by natural disasters.

6. **Locally Available, Renewable, or Reclaimed Resources:** Resilient design incorporates locally available, renewable, or reclaimed resources by prioritizing the use of materials and energy sources that are readily accessible within a region, can be replenished naturally, or are salvaged from existing structures. This allows for a reduction on reliance on non-renewable resources from farther distances, augmenting the ability of a community to recover from disruptions like natural

disasters or supply chain issues. The benefits achieved by using local, renewable, and reclaimed resources in resilient design include the following:

- **Reduced transportation needs**: Sourcing materials locally minimizes the need for long-distance transport, reducing carbon footprint and potential disruptions to supply chains during disasters.
- **Adaptability to local conditions**: Utilizing locally available materials often means they are better suited to the region's climate and environmental challenges.
- **Community resilience**: Supporting local industries and knowledge bases by using locally sourced materials can strengthen community resilience.
- **Renewable energy integration**: Incorporating renewable energy sources like solar or wind power, which are readily available in many locations, provides backup energy during power outages.
- **Reclaimed materials**: Reusing salvaged materials from demolished buildings reduces waste and provides a readily available resource for construction.

Some examples of resilient design using local, renewable, and reclaimed resources:

- Using locally sourced timber for construction in forested regions.
- Implementing solar panels to harness abundant sunlight in sunny climates.
- Utilizing rainwater harvesting systems to collect and store rainwater for irrigation.
- Employing recycled bricks or concrete from demolished buildings.
- Incorporating natural ventilation strategies that leverage local wind patterns.

7. **Anticipation of Disruptions and Dynamic Futures:** In the context of resilient design, anticipation of disruptions involves recognizing and planning for changes, hazards, and climate-related events. The anticipatory response is the result of a risk analysis that establishes scenarios and probabilities. This facilitates the development of prioritized responses. The architects and planners design features to mitigate the risk and vulnerability to enable capability of withstanding disruptions. Dynamic future is a recognition that climate events, human development and human induced events like terrorism, war, mass riots, arson, and such potentially destructive behaviors, are all unpredictable and evolve over time. By acknowledging this dynamism, a resilient approach opts for anticipation of likely events and allowing for a flexible (or dynamic) capability to respond. A term used to describe this aspect of resilient design is "future-proofing". Future-proofing (also futureproofing) is the

process of anticipating the future and developing methods of minimizing the effects of shocks and stresses of future events.[76] An understanding of resilient design applications for future-proofing or anticipatory mitigation of dynamic futures comes from understanding some real estate concepts.

> In the valuation of real estate, there are three traditional forms of obsolescence which affect property values: physical, functional, and aesthetic. Physical obsolescence occurs when the physical material of the property deteriorates to the point where it needs to be replaced or renovated. Functional obsolescence occurs when the property is no longer capable of serving the intended use or function. Aesthetic obsolescence occurs when fashions change or when something is no longer in style. A potential fourth form has emerged as well: sustainable obsolescence. Sustainable obsolescence proposes to be a combination of the above forms in many ways. Sustainable obsolescence occurs when a property no longer meets one or more sustainable design goal.[77]

> One reasonable approach to future-proof sustainable cities is an integrated multi-disciplinary combination of mitigation and adaptation to raise the level of resilience of the city. In the context of urban environments, resilience is less dependent on an exact understanding of the future than on tolerance of uncertainty and broad programs to absorb the stresses that this environment might face. The scale of the context is important in this view: events are viewed as regional stresses rather than local. The intent for a resilient urban environment is to keep many options open, emphasize diversity in the environment, and perform long-range planning that accounts for external systemic shocks.[78]

8. **Finding and Promoting Resilience in Nature:** Resilient design in nature is the practice of designing to withstand natural disasters and climate change by observing and learning from nature's resilience. This principle promotes identifying the natural mechanisms that allow ecosystems to recover from disturbances, such as fires, floods, or climate change, and actively working to maintain or enhance those abilities through conservation, restoration, and sustainable practices, essentially helping nature "bounce back" from challenges and adapt to changing conditions. By recognizing and promoting resilience lessons from natural design can help to protect the natural environment and not only enhance the natural ecosystem but also apply strategies to help all living systems. This can sound a bit fluffy and vague

[76] Rich, Brian. "The Principles of Future-Proofing: A Broader Understanding of Resiliency in the Historic Built Environment." Journal of Preservation Education and Research, vol. 7 (2014)
[77] Is Sustainability the 4th Form of Obsolescence? PRRES 2010: Proceedings of the Pacific Rim Real Estate Society 16th Annual Conference. 2012. Pacific Rim Real Estate Society (PPRES)
[78] Thornbush, M., O. Golubchikov, and S. Bouzarovski. "Sustainable Cities Targeted by Combined Mitigation-Adaptation Efforts for Future-Proofing." Sustainable Cities and Society 9 (2013)

but there are many valuable design strategies that can be learned by understanding how nature has evolved resilience over time. Here are some examples:

- **Forest regeneration after fire**: Many tree species have adapted to fire by producing fire-resistant seeds that germinate after a fire, allowing for rapid forest regrowth.
- **Coral reef recovery**: Corals can slowly regenerate after bleaching events through the process of coral larvae settling and growing into new colonies.
- **Migratory patterns of animals:** Animals adjusting their migration routes to adapt to changing climate conditions.
- **Floodplain ecosystems:** Wetlands and floodplains naturally absorb floodwaters, acting as a buffer against flooding.

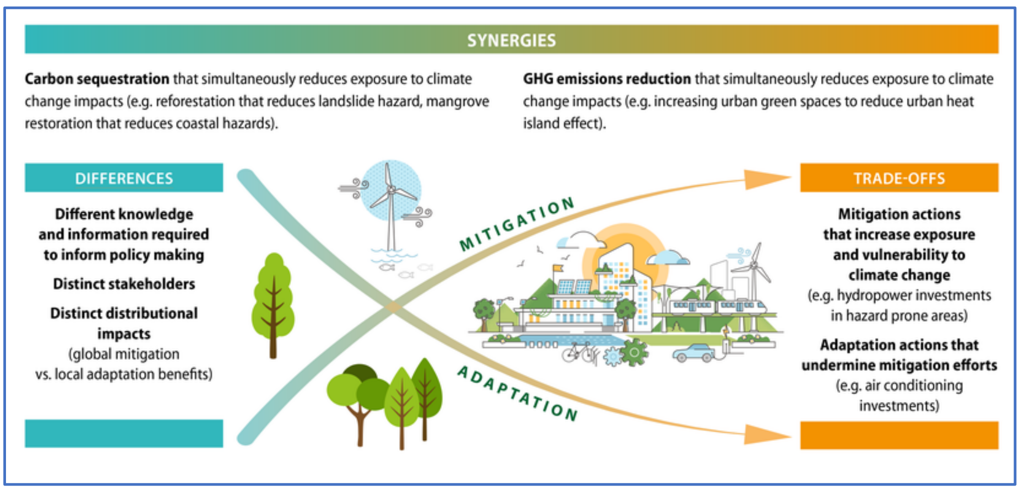
If it is recognized that nature develops resiliency and that human activity and encroachment into natural habitats, if unmitigated, can cause problems for both, here are some ways in which resilient design thinking can promote resilience in nature:

- **Protected areas:** Establishing and managing protected areas to preserve natural ecosystems and their resilience.
- **Sustainable land management:** Implementing practices like rotational grazing, agroforestry, and responsible logging to minimize disruption to ecosystems.
- Climate change mitigation: Reducing greenhouse gas emissions to lessen the impacts of climate change on natural ecosystems.
- **Community engagement:** Educating local communities about the importance of nature conservation and engaging them in restoration efforts.

In addition to ways in which humans can help maintain or even enhance resilience in nature, there are many ways in which engaging with nature can foster resilience for human communities:

- Healthy ecosystems can play a key role in strengthening resilience to a changing climate. Nature-based solutions, such as wetland restoration and forest conservation, have been recognized for their potential to provide effective natural protection against climate risks and address the threats posed by climate change. Coastal wetland protection is estimated to have helped prevent over USD 500 million in direct property damage during Hurricane Sandy in 2012. Nature-based solutions can be used as a substitute or complement to grey infrastructure, and provide a wide range of co-benefits for biodiversity, human well-being and communities. OECD work supports countries in enabling nature-based solutions to increase their use to build socio-economic resilience to climate change.[79]

- **Nature-based solutions can foster synergies between adaptation and mitigation:** Climate change adaptation and mitigation policies have often been addressed separately in the past, and there are good reasons for distinct policies. The type of knowledge needed to inform adaptation and mitigation policies is different. As a result, distinct stakeholders have been involved in the implementation of adaptation and mitigation policies. Yet, there are synergies between adaptation and mitigation efforts that can help to achieve climate resilience more effectively. For example, nature-based solutions create an opportunity to increase carbon storage capacity, while also contributing to reduce weather-related risks. Identifying these opportunities can help avoid trade-offs and develop mutually reinforcing policies.[80]



Source: OECD "Nature-based solutions and climate-resilient infrastructure"; accessed 2024.

9. **Social Equity and Community Contribute to Resilience:** Social equity and community play a critical role in building resilience and resilient design by fostering strong social networks, ensuring access to resources for all members of a community, and enabling coordinated responses to disruptions or disasters. This makes communities better equipped to rebound from challenges and adapt to change. This principle of Resilient design is especially relevant when considering marginalized groups who might be (and often are) disproportionately affected by

[79] Organisation for Economic Co-operation and Development (OECD): "Nature-based solutions and climate-resilient infrastructure"; accessed 2024.
[80] Ibid

adversity. Some points on how social equity and community contribute to resilience are noted below:

- Access to resources: When a community prioritizes social equity, everyone has access to essential services like healthcare, food, housing, and education, which are crucial for individuals and families to withstand shocks and recover effectively.
- Strong social networks: Strong community bonds and trust between neighbors facilitate information sharing, mutual support, and collective action during crises, enhancing the community's ability to respond effectively.
- Community engagement: Inclusive decision-making processes where diverse voices are heard in planning and design processes lead to solutions that better address the needs of all community members, enhancing resilience.
- Reduced vulnerability: By identifying and addressing existing inequities within a community, resilience efforts can target the most vulnerable populations and mitigate the disproportionate impact of disasters.
- Cultural awareness: Incorporating cultural understanding and community traditions into resilient design can create solutions that are more relevant and adaptable to the specific needs of a population.

Some examples of how social equity and community are incorporated into resilient design:

- Community-based planning: Engaging residents in the planning process for disaster preparedness and recovery to ensure their needs are considered.
- Green infrastructure in underserved areas: Prioritizing green infrastructure projects in communities with limited access to parks and open spaces to improve environmental quality and resilience.
- Community resilience hubs: Establishing designated locations within a community that can serve as gathering points and provide essential services during emergencies.

As an example of why such practices and strategies mare helpful, it is important to note one obvious factor: Extreme weather or natural disasters do not discriminate on any human societal factor. However, across the globe, a long history of discriminatory policies and practices have resulted in disproportionate burdens of extreme weather on economically marginalized communities with weak communal and infrastructure development. Consider the following from an October 2016 report from the Center for American Progress, which bills itself as “an independent nonpartisan policy institute that is dedicated to improving the lives of all Americans through bold, progressive ideas, as well as strong leadership and concerted action."[81]

> Environmental hazards — whether from power plants, toxic waste, or landfill sites—are often built alongside low-income neighborhoods and communities of color. This creates additional risks for such communities during and after extreme storms and flooding. After an extreme weather event, financial insecurity in the form of lost wages and other financial hardships can push already struggling families into poverty. The largest job losses after extreme weather events are often in service-related industries, which have median hourly wages between $9 and $15. After Hurricane Sandy, for example, the New York City metropolitan area lost 32,000 jobs two weeks after the superstorm. Including climate equity as a key component in climate resilience efforts can offset these added risks and help people move beyond surviving an extreme weather event to thrive afterward.[82]
>
> The costs of extreme weather do not just affect households struggling to recover; all taxpayers, and the federal government, are paying for this new normal. Between 2005 and 2015, the Federal Emergency Management Agency, or FEMA, issued more than $67 billion in grants to assist communities and individuals devastated by extreme weather and wildfires, which amounted to approximately $200 per U.S. resident for disaster assistance during that time period. Investing in climate resilience, particularly in communities that are most vulnerable to more extreme weather and other climate change effects, can help reduce the devastation wrought by disasters, scale back government funding for disaster relief, and free resources to help communities strengthen their climate resilience. It is estimated that every $1 spent on resilience efforts yields $4 in economic benefits, not including the thousands of prevented injuries and hundreds of saved lives.[83]

Overall, integrating social equity and community engagement into resilient design strategies is essential for creating truly resilient communities that can withstand future challenges and ensure equitable recovery for all members of a community, and, by extension, a region and /or country.

10. **Resilience is Not Absolute:** This principle, while not exactly a design strategy, is quite important in that it highlights the recognition that all solutions will inherently be partial, and that very fact encourages implementation of whatever can be implemented to move forward. In an absolute setting, the inability, whether due to social, technical, political, or economic factors, to implement some aspects of a plan

[81] Center for American Progress (CAP): "3 Strategies for Building Equitable and Resilient Communities." By Danielle Baussan and Cathleen Kelly; Oct 17, 2017.
[82] Ibid
[83] Ibid

would derail the plan. However, "Resilience is not absolute" means that when designing for resilience, it's not possible to completely protect against every potential disaster or disruption; instead, the focus should be on creating systems that can adapt, recover, and maintain functionality to a reasonable degree even when facing significant challenges, acknowledging that some level of impact is inevitable and prioritizing practical solutions to mitigate the most likely risks. The practical points to these concepts include the following:

- **No perfect solution:** No single design can completely prevent damage from all possible scenarios, so the goal is to minimize impact and facilitate recovery.
- **Prioritizing risks:** Identify the most likely and impactful threats to a system and focus design efforts on mitigating those risks first.
- **Phased approach:** Implement resilience strategies in stages, addressing the most critical needs first and gradually improving resilience over time.
- **Adaptability is key:** Designing systems with flexibility to adapt to changing conditions and unforeseen events is crucial.

Some applications of the above points are:

- **Building design:** Instead of trying to make a building completely hurricane-proof, focus on features like elevated electrical systems, flood-resistant materials, and adaptable ventilation to minimize damage and enable faster recovery.
- **Community planning:** Rather than aiming for complete self-sufficiency, prioritize establishing local support networks, emergency response plans, and access to critical resources to help communities bounce back after a disaster.

From the preceding discussion of the principles of Resilient Design there is a case for why making buildings, infrastructure and communities resilient not only makes sense but is increasingly becoming a priority as the clash between human expansion and natural disasters spirals upwards and the consequences get more severe in physical, social and economic terms. If the “WHY” makes sense, the next logical area of focus is “HOW” – a look at practical ways in which architects and planners can apply resilient design in their work. *[Note: resilient design principles are applicable to almost all areas of human activity, but the focus of this course is on aspects that have relevance for architects, planners and designers].*

<u>The Economic Case for Resilient Design</u>

However, before proceeding to the topic of the application of resilient design principles, it is worthwhile to address the economic case for resilient design. Most philosophies and ideas aiming to address "Sustainability" and environmental balance through either design concepts or planning techniques require some measure of economic price, at least at the front end of a project. If they were cheaper or even cost neutral, there would be no resistance and adoption would become universal. Human development, infrastructure and expansion is, as it always has been, fundamentally economic in nature. Generally, the most cost-effective option tends to win out, regardless of their long term impacts – environmental, social or any other metric. Even when it can be demonstrated that over a life span of a building or community, there would be significant cost advantages and savings in return for a slightly increased upfront investment in quality, materials and planning considerations, most land developers tend to minimize upfront capital expenditure regardless of increased overall operating costs. Those are borne by later buyers of the property, and the initial developer would have maximized their profit since that is only tied to initial costs. From a business perspective that makes perfect sense and even buyers prefer lower purchase prices rather than some abstract long-term cost savings. Sometimes, this aspect of a capitalist structure is called "Economic Darwinism", implying that the common denominator of competition leads to lowest costs and most profits and so only decisions that result on lowest competitive price and maximum profits will lead to long term success. However, this is a rather twisted interpretation. "Economic Darwinism," actually is an economic theory that uses Darwin's theory of evolution to explain how businesses compete and adapt to economic change. It suggests that **businesses that can adapt to change will survive**, while those that cannot, will fail.[84] Without going into the economic models and the various academic opinions, the basic theory emphasizes that adaptability is the key to survival and success. It is on this basis that the economic case for Resilient design can be argued. As the likelihood and severity of harmful events increases, the economic costs are also getting higher and more probable to affect a greater segment of the population. This makes investment is resilient design cost effective as the benefits are more likely than not to be realized. Statistically, since most of the world's population lives near or on coastal areas, climate impact will, with a high degree of certainty affect them and the less resilient a building or community is, the greater the expected disruption and recovery cost. In November 2023, the American Institute of Architects (AIA) published a white paper outlining some key talking points for making an economic case for resilient design. Below are the key take-aways from that publication which serves as a good stepping point for architects and offers some additional resources.

- **Resilient design economics:** When thinking about the economic case for resilient design it is important to acknowledge the various scales of systems that

[84] Homework.study.com

architects and building owners are working within. Taking a systems-thinking approach, there are nested scales of the hazard impacts that are interlinked—from global to federal, regional, state, local, and individual—all impacting the value chain in which building owners, businesses, and architects are acting. [85]

- **Establishing economic resilience:** The resilience of the built environment underpins the economic resilience of all organizations and communities; establishing economic resilience can buffer both from the worst economic outcomes when disasters strike. Architects can assist their clients in increasing the resilience of their built environment by helping them understand their vulnerabilities to shocks and stresses. This includes helping them increase their ability to avoid, withstand, or recover from the shock quickly.[86]

- **Direct economic benefits:** Architects can provide both direct clients and greater social value with more resilient strategies and projects. Economic benefits can be calculated for each by looking at the direct benefit of the action, as well as associated benefits which are more difficult to quantify. Adaptive, or resilient design, encompasses approaches that span from nature and site-based, to building and infrastructure-focused, to management and operations interventions.[87] Direct benefits can be easily given a direct monetary value as an avoided loss, including reduced insurance premiums, based on the extent of property and assets that are protected by an action.[88]

- **Indirect economic benefits:** The collateral, ancillary, or co-benefits that may result from the direct effect of protecting specific features from loss can be considered indirect benefits. These benefits are more qualitative since assigning a monetary value to them can be a complex process. Actions such as building pedestrian and bike paths around wetlands can provide benefits including positive community and public relations, as well as added ecosystem services. Infrastructure Systems are interrelated and integrated. Essential infrastructure systems—such as water, energy supply, and transportation—will be increasingly compromised by interrelated climate change impacts. In urban settings, climate-related disruptions of services in one infrastructure system will almost always result in disruptions in one or more other infrastructure systems, compounding the impacts.[89]

- **Benefits of business continuity:** Keeping essential facilities and businesses open is the first priority in mitigating disasters. Avoiding disruptions among

[85] AIA: "ROI: The economic case for resilient design"; November 30, 2023
[86] Ibid
[87] Ibid
[88] Ibid
[89] Ibid

> businesses has a positive economic impact including maintaining business continuity, avoiding loss of productivity, and attracting future economic investment. Disruptions to businesses can be devastating; direct negative impacts on business operations are cited as one of the top environmental sustainability and climate change issues that are already impacting organizations. Forward-looking resilient design contributes to positive economic resilience for communities, including the ability to avoid shocks, withstand shocks, or recover from shocks quickly. Economic benefits for resilience can consist of avoided interruptions to businesses (both asset destruction and lost income flows) and avoided lost productivity. Economic benefits can consist of avoided disruptions to jobs, incomes, and tax revenues both directly and indirectly linked through supply chains. The term economic revitalization is also used to show how some action alternatives provide resilience benefits that can restore and enhance an economy that would otherwise be disrupted and increase its ability to withstand future adverse events.[90]

The American Institute of Architects California chapter has noted that the benefits of Resilient Design risk reduction can be economic, such as reduced insurance premiums or maintenance costs, and can also include intangible benefits such as personal safety, business continuity, peace of mind, and the protection of irreplaceable personal belongings.[91]

Similarly, the National Institute of Building Science (NIBS) has shown that additional mitigation, above code requirements, can result in significant safety and financial rewards. The NIBS study shows that building to standards above Building Code can result in savings of up to $11 for every $1 spent on mitigation measures.[92]

4.2. Application of Resilient Design Principles to Buildings, Landscaping and Urban Planning

Having looked at why resilient design is gaining support and becoming integrated into many existing aspects of building design, planning approaches and regulatory codes, this section will look at some practical applications where resilient design is gaining importance for architects and planners.

Building better foundations

Building better foundations is crucial for resilient design because a strong foundation acts as the anchor for the entire structure, allowing it to withstand the forces of natural disasters like earthquakes, floods, and high winds. This can minimize damage and ensure the building's

[90] Ibid
[91] AIA California: "Resilient Design: Why It's Important to Architects"; William Melby, FAIA; January 19, 2022
[92] National Institute of Building Science (NIBS) Study full report Natural Hazard Mitigation Saves 2019 Report (nibs.org)

integrity during extreme events. Basically, a solid foundation provides the stability necessary for a resilient building.

Below are some ways in which strong foundations contribute to resilient design:

- **Structural stability:** A well-designed foundation can distribute forces evenly throughout the building, preventing localized stress points that could lead to cracks or collapses during extreme weather.
- **Flood resistance:** Deeper foundations can help elevate a building above floodwaters, minimizing damage from inundation.
- **Earthquake resistance:** Properly engineered foundations with reinforced concrete can better withstand the lateral forces of earthquakes.
- **Soil stability:** Considering soil conditions and using appropriate foundation types (e.g., piles, raft foundations) helps prevent foundation settlement and movement, which can lead to structural damage.

Developing strategies to reduce energy consumption

Developing strategies to reduce energy consumption directly contributes to resilient design by minimizing a building's reliance on external energy sources. The objective is to make it more adaptable to disruptions like power outages or extreme weather events, while also ensuring its functionality even when energy is limited. This boosts its overall resilience to climate impacts.

Practices by which reducing energy consumption supports resilient design:

- **Reduced dependence on grid electricity:** By designing buildings to use less energy, they become less vulnerable to power grid failures or fluctuations, which can occur during extreme weather events.
- **Passive design strategies:** Incorporating passive design elements like proper insulation, optimal window placement, and natural ventilation can significantly reduce energy needs, making a building more resilient to external temperature changes.
- **On-site renewable energy generation:** Integrating renewable energy sources like solar panels can provide backup power during outages, further enhancing resilience.
- **Improved operational efficiency:** Efficient building systems and appliances not only reduce energy consumption but also minimize potential disruptions due to equipment malfunctions.
- **Cost savings:** Lower energy usage translates to reduced operational costs, allowing for better preparedness to manage potential disruptions and recovery efforts.

- **High-performance insulation:** Properly installed insulation minimizes heat loss and gain, maintaining comfortable indoor temperatures with less energy usage.

- **Energy-efficient lighting:** Utilizing LED lighting systems with high efficiency and long lifespans

- **Smart building controls:** Automated systems that optimize heating, cooling, and lighting based on occupancy and weather conditions

- **Optimized HVAC systems:** Selecting efficient HVAC equipment with variable speed drives to match cooling/heating needs

Using materials able to withstand extreme weather conditions

Using materials that can withstand extreme weather conditions helps resilient design by ensuring that structures remain functional with minimal damage during severe events like hurricanes, floods, earthquakes, or extreme heat. The goal is to foster long-term durability and reduce the need for repairs or replacements after a disaster. The areas where there is a heightened focus for such materials include:

- **Coastal areas:** Stainless steel, polymer coatings, laminated glass, and tropical woods that resist salt corrosion and humidity.

- **High-wind areas:** High-performance roofing membranes, reinforced concrete walls, and wind-resistant windows.

- **Flood-prone areas:** Elevated foundations, waterproof materials, and flood-resistant building components.

The characteristics for materials used in resilient design include weather resistance as a primary trait and some of the following:

- **Structural integrity:** Materials like reinforced concrete, high-strength steel, and specialized roofing systems can withstand strong winds, heavy rain, and seismic activity, preventing structural failure during extreme weather.

- **Reduced damage:** By choosing materials that resist weathering, such as corrosion-resistant metals, moisture-resistant wood treatments, and UV-resistant coatings, the risk of damage from elements like water, sun, and salt spray is significantly reduced.

- **Cost-effectiveness:** Preventing damage from extreme weather events through resilient materials can lead to lower repair costs over time, making the design more economically sustainable.

- **Improved safety:** By ensuring buildings remain intact during severe weather, resilient materials contribute to the safety of occupants and surrounding communities.

Considering alternative power sources, such as solar or wind power

Considering alternative power sources like solar or wind power enables resilient design by providing a diversified energy supply. This means that if one source is disrupted due to a natural disaster or other event, the alternative source can still provide power. In this way, the resilience of the system can be strengthened against outages and disruptions. This also reduces reliance on a single energy source, making the system more stable and less vulnerable to fluctuations in supply or price. The approaches for achieving this include:

- **Diversification:** By incorporating multiple renewable sources, you can mitigate risks associated with weather-dependent fluctuations in power generation from a single source.
- **Local generation:** Solar and wind power can be generated on-site or within a community, reducing reliance on long-distance power transmission lines that could be damaged during disasters.
- **Backup power:** When paired with energy storage systems, solar and wind can provide backup power during grid outages, ensuring critical functions can continue.
- **Reduced environmental impact:** Switching to renewable energy sources can lessen the strain on traditional energy infrastructure, potentially reducing the impact of disruptions caused by extreme weather events.

Incorporating green infrastructure elements

Incorporating green infrastructure elements is a feature of resilient design that alleviates the impacts of climate change through natural processes like rainwater absorption, reducing urban heat islands, improving air quality, and providing habitat for wildlife. These allow communities to be better equipped to handle extreme weather events like floods and droughts while improving overall environmental quality and sustainability. Elements of green infrastructure that contribute to resilient design include the following:

- **Stormwater management:** Green infrastructure like rain gardens, bioswales, and permeable pavements can capture and filter stormwater runoff, reducing flooding risks during heavy rain events.
- **Urban heat island mitigation:** Trees and vegetation in green spaces help cool urban areas by providing shade and evapotranspiration, reducing the urban heat island effect.
- **Floodplain protection:** By slowing down water flow, green infrastructure can help protect floodplains and reduce flood damage.
- **Drought resilience:** Strategic planting of drought-tolerant vegetation can help conserve water during dry periods.

- **Improved air quality:** Trees absorb pollutants from the air, contributing to better air quality.
- **Biodiversity enhancement:** Green spaces provide habitats for various plant and animal species, supporting biodiversity within urban areas.

Some examples of green infrastructure elements are trees and urban forests, green roofs, rain gardens, bioswales, permeable pavements, wetlands restoration, and living shorelines.

Improving the thermal efficiency of buildings

Improving the thermal efficiency of buildings supports resilient design by minimizing the energy required to maintain comfortable indoor temperatures. This in turn reduces reliance on heating and cooling systems that can be heavily impacted by extreme weather events. This makes the buildings more adaptable to climate change and its associated challenges like heatwaves and cold snaps. In principle, a more energy-efficient building is better equipped to withstand climate fluctuations and remain functional during extreme weather conditions. Some of the strategies employed to achieve these goals for resilient design are:

- **Proper insulation:** Adding insulation to walls, roofs, and floors to minimize heat loss or gain.
- **High-performance glazing:** Using windows with low-emissivity coatings to control solar heat gain and heat loss.
- **Shading systems:** Implementing shading devices like awnings or overhangs to reduce direct sunlight exposure during hot weather.
- **Air sealing:** Sealing air leaks to prevent drafts and maintain consistent temperatures
- **Natural ventilation:** Utilizing natural ventilation strategies to cool buildings during mild weather.

Utilizing strategies like those mentioned above promotes resilient design in the following ways:

- **Reduced energy consumption:** By better insulating walls, roofs, and windows, a building loses less heat in cold weather and gains less heat in hot weather, thereby decreasing the need for excessive heating or cooling, which can be crucial during extreme weather events when energy grids might be strained.
- **Minimized impact of power outages:** When energy consumption is lower due to improved thermal efficiency, the impact of power outages is lessened as the building can maintain a more stable temperature for longer periods.
- **Improved occupant comfort:** Maintaining comfortable indoor temperatures during extreme weather events enhances occupant well-being and productivity, which is critical for resilience.

- **Mitigation of heat island effect:** By reducing energy usage for cooling, buildings with high thermal efficiency can contribute to reducing the urban heat island effect, which is a significant climate change concern in cities.

Involving social components and creating collaboration between stakeholders

Involving social components like community awareness and collaborative networks in the design process encourages resilient design by promoting a deeper understanding of local needs and vulnerabilities, leading to more effective solutions that are better equipped to handle future disruptions. Furthermore, this also helps to increase a sense of ownership and buy-in from the community to implement and, more importantly, maintain those solutions. Some of the practices that are used include the following:

- Local Knowledge and Context: By engaging with the community, designers gain valuable insights into specific risks, existing coping mechanisms, and cultural considerations that might not be apparent through solely technical analysis, allowing for more tailored solutions.

- Community Ownership and Participation: When communities are actively involved in the design process, they are more likely to support and participate in implementation, leading to greater resilience in the long run.

- Collaboration and Shared Responsibility: Creating networks between stakeholders, including government agencies, community leaders, and experts, enables better coordination, resource sharing, and problem-solving across different sectors.

- Capacity Building: Raising community awareness about potential hazards and resilience strategies empowers individuals to take proactive measures to protect themselves and their communities.

- Social Equity: Engaging diverse community members ensures that the design process considers the needs of vulnerable populations and addresses potential inequalities.

- Community workshops: Facilitating discussions with residents to identify local risks and priorities for adaptation strategies.

- Public education campaigns: Raising awareness about climate change impacts and resilience measures through outreach programs.

- Stakeholder engagement meetings: Bringing together diverse groups to discuss and collaborate on design solutions.

- Participatory mapping: Using community input to identify vulnerable areas and potential mitigation strategies.

Overall, incorporating social components into resilient design promotes a more holistic method that considers the physical infrastructure and the social fabric of a community. This leads to more sustainable and effective solutions for dealing with future challenges.

The strategies, tactics and concepts discussed above, with some being duplicated across categories, have applications for buildings and broader infrastructure. It is important to note here that there are two related and integral fields of design where Resilient design principles are prominently utilized. These are the fields of Urban planning / design and Landscaping (or Landscape Architecture).

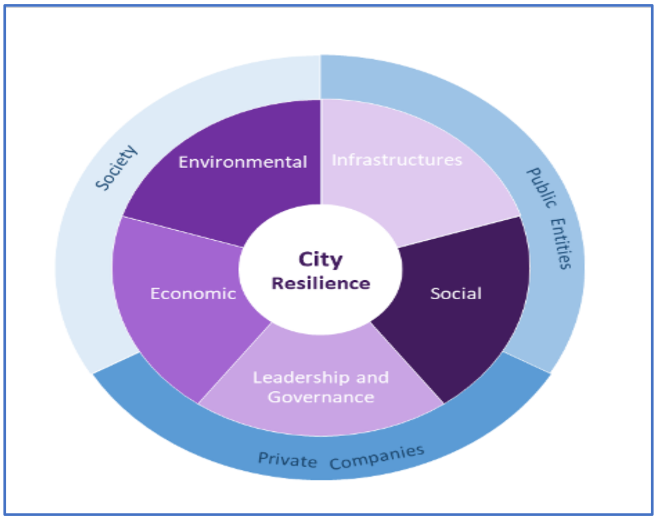
Urban Planning and Resilient Design

Resilient design, when integrated into urban planning, aims to create cities that can effectively adapt to and recover from natural disasters, climate change impacts, and other disruptions by incorporating many of the strategies that have been mentioned previously - like green infrastructure, adaptable building designs, community engagement, and infrastructure redundancy. All these are intended to ensure that the city can rebound quickly and maintain essential functions even during extreme events. In urban planning these principles help prioritize adaptability, sustainability, and inclusivity in urban settings to build more resilient communities. The philosophy that has emerged at the urban or city scale is one that is called Urban Resilience.

Urban resilience is the capacity of a city's systems, businesses, institutions, communities, and individuals to survive, adapt, and thrive, no matter what chronic stresses and acute shocks they experience. Urban resilience demands that cities look holistically at their capacities and their risks, including through meaningful engagement with the most vulnerable members of a community. This is not easy work. Urban governance is often siloed, with separate teams designing disaster recovery plans, exploring sustainability issues, focusing on livelihoods and well-being, and examining land-use planning and infrastructure. This approach cannot meet the demands of today's interconnected world. Cities are systems – not silos. Cities are made up of people and places, often experiencing rapid change.[93]

Planning for a resilient urban future requires tackling challenges and creating solutions in a place-based, integrated, inclusive, risk-aware, and forward-looking manner. In this way, solutions developed through resilience approaches will allow cities to enjoy resilience dividends – helping to prevent and reduce the impact of shocks and stresses on the city's people, economy, infrastructure and natural environment.[94]

[93] Resilient Cities Network: "What is Urban Resilience?"; Accessed 2024
[94] Ibid



Source: Resilience Engineering Association[95]

Landscaping and Resilient Design

Resilient design in landscaping refers to creating outdoor spaces that can withstand and adapt to environmental challenges of the types that have been discussed. However, before looking at means of achieving resilient landscapes, it would be helpful to define resiliency in the context of landscape architecture.

According to the American Society of Landscape Architects, resilient design means working with nature and allowing communities to bounce back stronger and more quickly than with previous "one-size-fits-all" approaches. Resilient design includes well-known measures like man-made reefs, urban forests and green infrastructure, which controls flooding. Resilient design also entails using locally sourced materials, creating systems and places for people to connect with flora and fauna, and designing spaces that are easily adaptable as time, usage and the ephemeral qualities of a place shift.[96]

Some of the common means of achieving resiliency in landscaping is by using native plants, diverse plant species, water-efficient irrigation systems, and features that manage stormwater runoff, like rain gardens and permeable pavements. The aim is to design landscapes that are more resistant to disturbances and can recover quickly. Below are some of the main elements of resilient landscape design:

- Native plants: Utilizing plants naturally found in the region which are well-suited to local climate conditions, requiring less water and maintenance while supporting native wildlife.

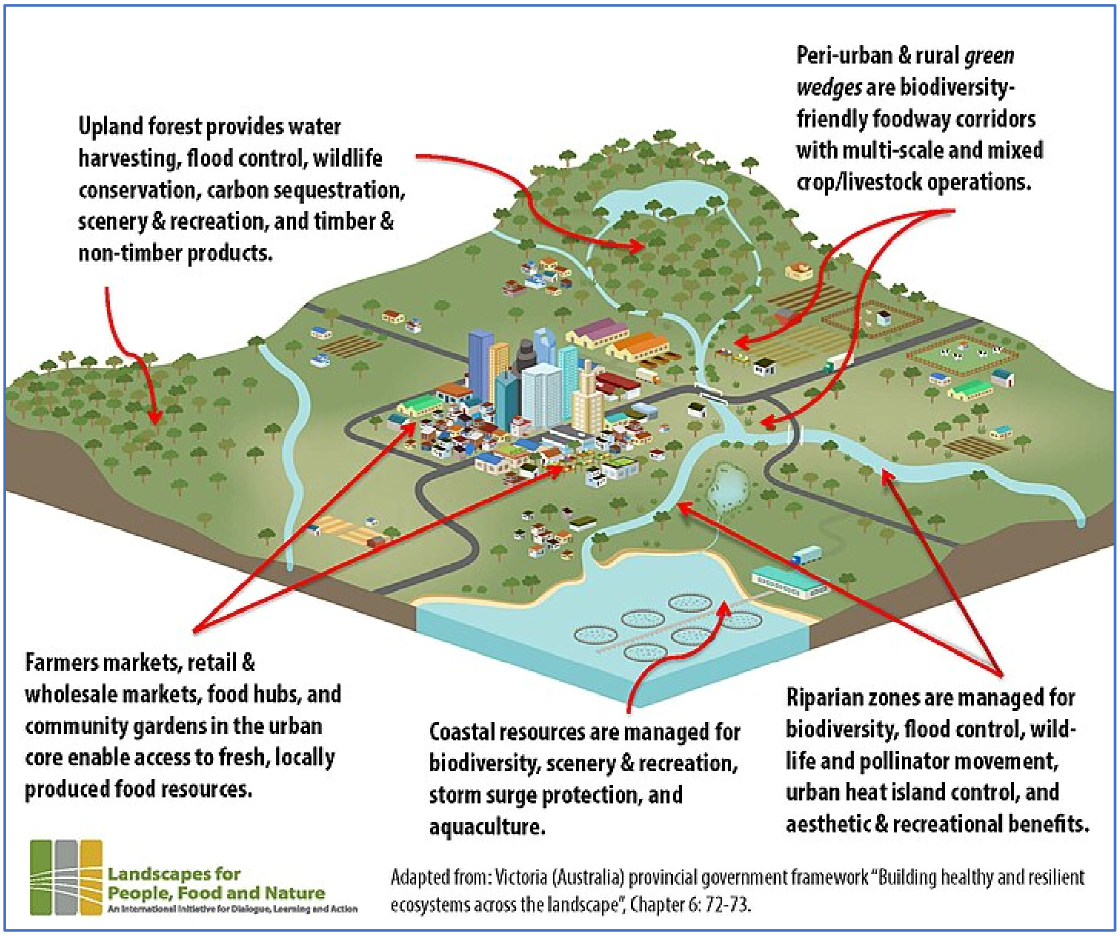
[95] Resilience Engineering Association: "How Can We Build Resilient Cities?"; Sudeep Hegde; 6 April 2020 by Leire Labaka, TECNUN, University of Navarra, Spain

[96] Woolpert.com; Blog: "Landscape Architecture: Strolling Through Resilient Design in Leisurely Spaces"; Jason Thomas; Accessed 2024

- Plant diversity: Incorporating a variety of plant species with different growth habits and drought tolerances to create a more resilient ecosystem, reducing the impact of pest outbreaks or disease.
- Rainwater harvesting: Implementing features like rain gardens, bioswales, and permeable pavements to capture and filter stormwater runoff, reducing strain on drainage systems.
- Water-efficient irrigation: Using smart irrigation systems that monitor soil moisture levels to optimize water usage.
- Shade trees: Planting trees to provide shade and cool urban areas, mitigating the heat island effect.
- Green roofs: Installing vegetation on rooftops to manage stormwater runoff and improve building energy efficiency.

Using the features listed above, there are tangible benefits that can be gained from resilient landscaping:

- Reduced environmental impact: Less water usage, improved water quality, and decreased stormwater runoff.
- Increased biodiversity: Supporting native wildlife populations by providing food and shelter.
- Improved aesthetics: Creating visually appealing landscapes that are adapted to the local environment.
- Climate change adaptation: Building resilience to extreme weather events like droughts and floods.



Source: Wikimedia Commons: File:City-Region-Landscape withsource.jpg

4.3. Practical Examples of Resilient Design

There are many examples of projects and applications of resilient design across all scales and geographic locations. For this section, some select samples will be presented in three categories, in descending scale: City / Urban Resilience; Landscape Resilience and Building Resiliency.

Urban Resilience Examples at a City Scale [97]

Numerous cities around the world have embarked on urban resilience projects to create sustainable and future-proof urban environments. Here are some inspiring examples:

- **Rotterdam, Netherlands:** Rotterdam is known for its innovative approaches to urban resilience. The city has implemented a multifaceted strategy, including water

[97] Zigurat Institute of Technology: Blog: "Urban Resilience: Building Sustainable and Future-Proof Cities"; 18/07/2023

management solutions, climate adaptation measures, and sustainable infrastructure development. They have transformed their vulnerability to flooding into an opportunity for economic growth and sustainable development.

Rotterdam. *Source: Wikimedia Commons; "Haringvliet - Rotterdam.jpg"*

- **Singapore:** Singapore is widely recognized for its commitment to urban resilience and sustainability. The city-state has integrated smart technologies, green infrastructure, and efficient public transportation systems to enhance resilience. Singapore's efforts have resulted in a highly livable and environmentally sustainable city.

Singapore. *Source: Wikimedia Commons; "Singapore (SG), Gardens By The Bay -- 2019 -- 4759.jpg"*

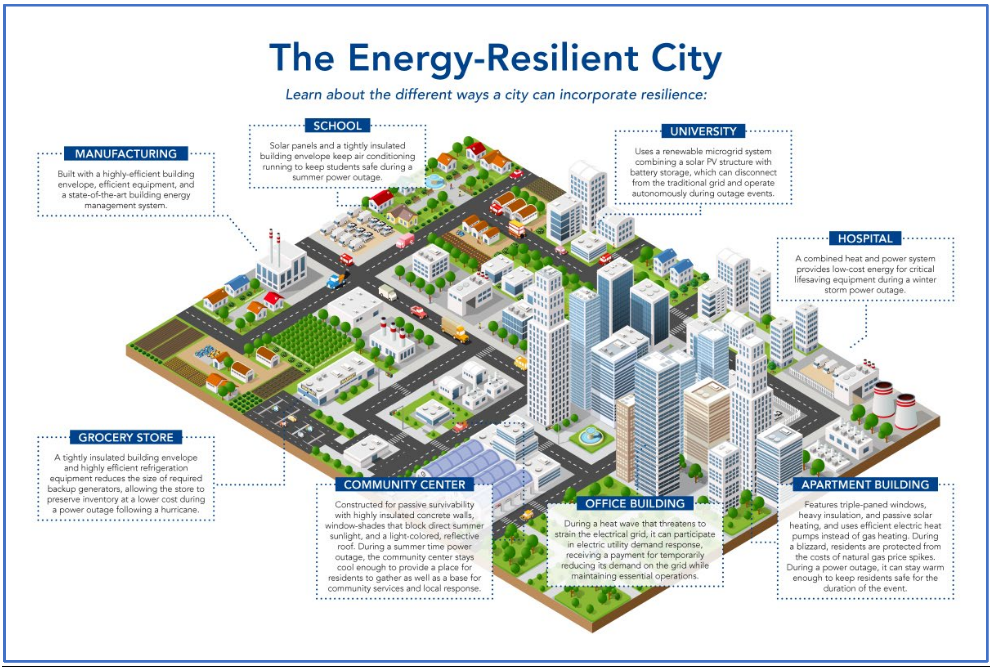
- **Portland, United States:** Portland has prioritized urban resilience by focusing on sustainable land use planning, transportation options, and renewable energy. The city has also engaged its community in resilience-building initiatives, including neighborhood-level resilience hubs and emergency preparedness programs.

Portland, Oregon, USA.

Source: Wikimedia Commons; "Portland and Mt. Hood from Pittock Mansion.jpg"

- **Rio de Janeiro, Brazil:** Rio de Janeiro proposes to use 3D laser scanning technology, to analyze urban conditions in the favelas, and create a digital map that can help quantify public health risks and generate data for future policy decision-making. Rio's idea is compelling because, without this critical data, the city cannot implement sustainable solutions for the 1.5 million people who live in favelas, which are communities that have been hit particularly hard disasters and crisis.

Rio de Janeiro, Brazil. *Source: Wikimedia Commons; "Cidade Maravilhosa.jpg"*



Source: Better Buildings Solutions Center – US Dept. of Energy [98]

<u>Landscape Design Resilience Examples</u>

Numerous cities around the world have embarked on urban resilience projects to create sustainable and future-proof urban environments. Here are some inspiring examples:

- **Central Park, Manhattan, New York:** This New York City park, conceived as "the lungs of the city" by famed Landscape Architect, Frederick law Olmsted[99] uses trees to clean the air, buffer gardens to slow runoff, and locally sourced materials**.**

[98] Better Buildings – US DOE: "Building Resilience: Preparing for an Unpredictable Future"; Better Buildings Beat Team; Aug 02, 2021

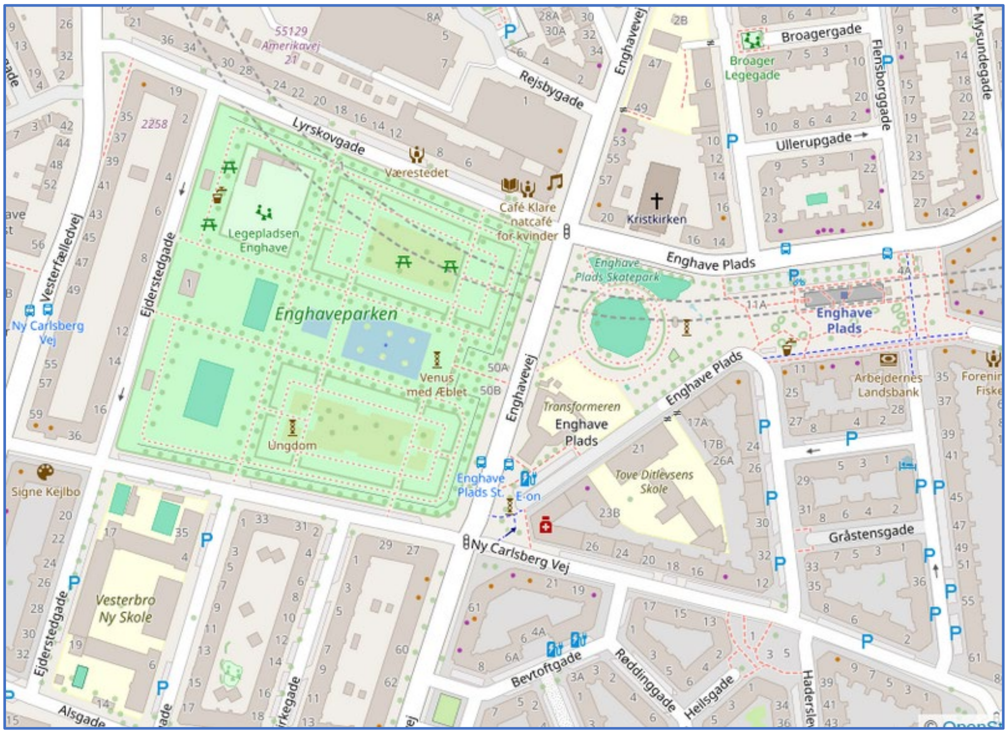
[99] Gotham center for New York History: ""The Lungs of the City": Frederick Law Olmsted, Public Health, and the Creation of Central Park"; July 30, 202; Lucie levine.

Central Park, New York City. *Source: Wikimedia Commons; "NYC - Manhattan - Central-Park.jpg"*

- **Houston Arboretum and Nature Center, Houston, Texas:** This landscape restores the original prairie, savannah, and woodland ecosystems.

Arboretum and Nature Center, Houston, Texas. *Source: Author*

- **Enghaveparken, Climate Park, Denmark:** This park stores rainwater in a retention basin for use during dry spells.

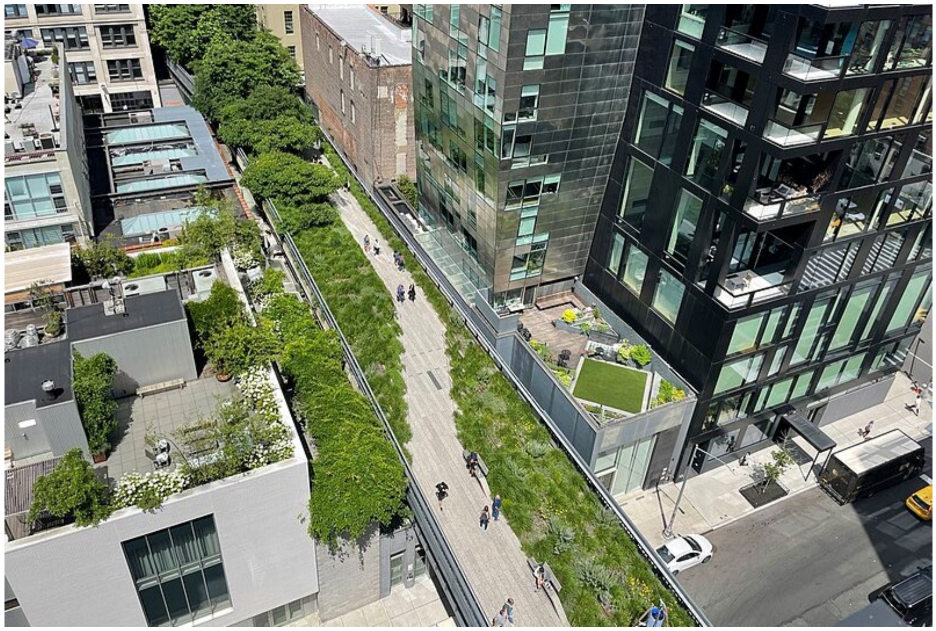


Enghaveparken.

Source: Wikimedia Commons; "File:OSM Enghaveparken Copenhagen 2024-09-01.png"

- **Urban forests:** These forests clean the air and reduce the urban heat island effect**.** One transformative example of this is the High Line in New York City near Hudson yards. It is a 1.45-mile-long elevated linear park created on a former New York Central Railroad spur on the west side of Manhattan2. The High Line has become a cultural and recreational hub and is viewed as a model for urban renewal worldwide.[100]

[100] Architizer: "An Urban Masterstroke: The Complete History of the High Line"; Paul Keskeys



High Line - Panorama. *Source: Wikimedia Commons; "File:Highline 02.jpg"*

- **Green infrastructure:** This includes green roofs, walls, and streets that can cool the air, insulate buildings, and manage stormwater. There are many examples among which the POST in Houston and the Living Roof at the California Academy of Sciences (CAS) are green roofs that have become active community spaces.

CAS Living Roof San Francisco. The POST Houston Rooftop Park

Source: Wikimedia Commons; "File:CAS Living Roof-2-Sarah Stierch.jpg"; Source: Author

<u>Resilient Design Building Examples</u>

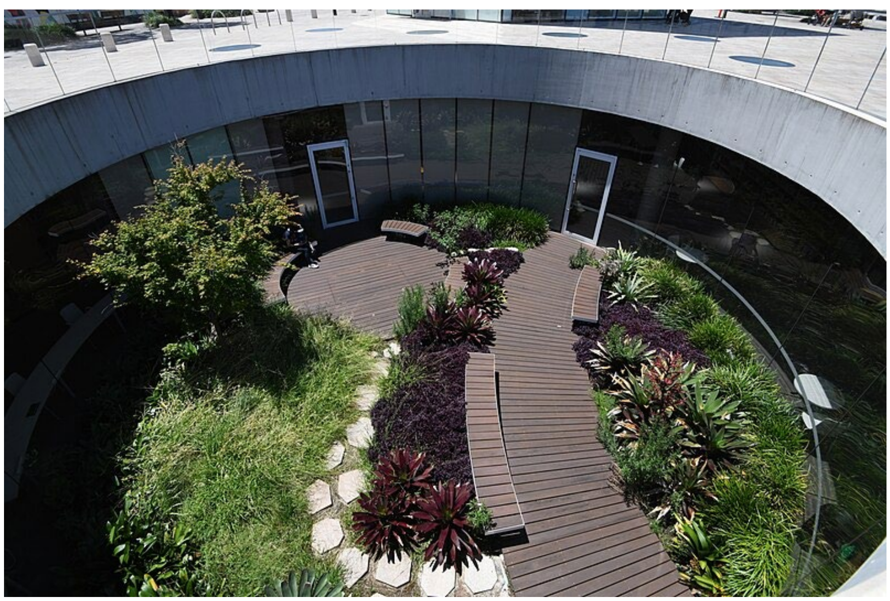
The bulk of focus on resilient design has been focused on buildings as these are the building blocks of any community where people work, live and congregate. Some examples were presented earlier in Part 3 of the course. Here are some additional examples from around the world:

Christchurch Art Gallery: A building in New Zealand that uses base isolation technology and flexible joints to absorb seismic energy.

Christchurch Art gallery, New Zealand.

Source: Wikimedia Commons; "File:Christchurch Art Gallery, Christchurch, New Zealand.jpg"

Green Square Library: A library in Sydney that uses sustainable materials, a green roof, and rainwater harvesting system.



Green Square Library, Sydney, Australia. *Source: Wikimedia Commons; "File:Green Square Library 008.jpg"*

The Aga Khan University Hospital: Located in Karachi Pakistan, the complex responds to local climate, culture and harsh urban conditions by using durable materials, passive design techniques and elaborate biophilic elements.

Aga Khan University Hospital, Karachi, Pakistan. *Source: Author*

This concludes Part 4 of the course.

In Part 5 the course will address:

Resilient design, current trends and future prospects

- Is Resilient design another flavor of “green” design or a durable concept?
- The future of Resilient design – band wagon or a new normal?

<u>Part 4 Review Questions</u>

23. According to the National Institute of Standards and Technology, what term refers to a set of buildings that serve a common function?
    a. Functional grouping
    b. Operationally common
    c. Syngiocast
    d. Cluster

24. From a resilience perspective, what is the term to describe a post-event performance state of a building that can adequately support the basic intended functions intended in the pre-event state?
    a. Re-occupancy
    b. Functional recovery
    c. Full recovery
    d. Operability
25. Which of the following is /are basic human needs that Resilient design endeavors to provide:
    a. Water
    b. Food
    c. a & b
    d. Diversity
26. Modular design is a feature that supports which of the principles of Resilient design?
    a. Diverse and redundant systems
    b. Locally available materials
    c. Promoting resilience in nature
    d. Durability
27. What is a direct economic benefit that can be achieved through resilient design?
    a. Providing pedestrian and bike paths around wetlands
    b. There are no measurable direct economic benefits; all are qualitative
    c. Psychological peace of mind resulting from resilient design reduces stress and so can reduce mental health related costs
    d. Monetary values as an avoided loss, including reduced insurance premiums
28. Which of the following are features of incorporating green elements in resilient design?
    a. Urban heat island mitigation
    b. Biodiversity enhancement
    c. Stormwater management
    d. All of the above
29. A US location that was presented in this course as an example of a city that prioritizes urban resilience is:
    a. Dallas, Texas
    b. Portland, Oregon
    c. San Jose, California
    d. Seattle, Washington

PART 5 - Resilient Design Trends and Future Prospects

In this final section of the course two main issues will be examined: Is Resilient Design a fad or is it a resilient concept (no pun intended) and what are the future prospects.

5.1. Is Resilient Design Another Flavor of "Green" Design?

Since the eve of the 21st century, there have been many design concepts that have swirled under the umbrella of "sustainability" and "Green building design". These have ranged from Net Zero, biophilic design to minimalism, energy efficiency and a host of others in between. Each of the concepts has merit and an area of focus which supports targeted objectives of the broader "sustainable" or carbon reduction goals. Some of the concepts are more rigorous than others and some are simply design styles, or even "fads". Of course, a fad, while immensely popular at its inception, is short-lived and quickly fades, either due to loss of aesthetic appeal or lack of practicality for long term adoption. So, naturally it is a fair question to wonder whether the recent surge of the term "Resilient Design" simply another flavor of design that will fade away, become a niche "style" or take root as a permanent guiding principle for sustainable and green design?

Predictions about styles is a risky prospect but an informed assessment can be a reliable determinant about the viability and practicality of a theory or concept. In the preceding sections of the course, a significant amount of information and supporting evidence has been presented to make a case that Resilient design is not a mere passing buzz phrase but is a deeply embedded concept that has been omnipresent in guiding design and planning. What makes it seem new or a "Johnny come lately" idea is that the term "Resilient Design" accompanied with a structured set of principles and strategies have only relatively recently been organized and infused into practical implementation. Most of these are ideas and tactics that have been followed in some way for a long time – such as fire codes or wind load designs for coastal areas, seismic design codes, flood controls, landscape ordinances, to mention a few. All of these are core resilient design concepts but were not necessarily called such. The recognition of protecting and strengthening the survival of buildings and need for effective infrastructure has been a core basis of design for as long as building construction and towns have been around. The learnings from these do not go away over time; they only improve and get more refined as new knowledge is obtained.

What has happened in the past two decades is that the clash of urban development and the increase of natural disasters and threats of human acts have made the risks more ubiquitous, and the consequent economic costs have started to swing the focus from just surviving an event to the need to recover rapidly and economically. This paradigm shift was the catalyst to create a design framework that channeled a consistent and holistic way of approaching buildings in disaster prone and climate sensitive areas. In this way Resilient Design has emerged as that guiding philosophy. It also lends itself easily to all scales of development from a single-family home to entire city scale planning as has been discussed at some length in the previous sections. These characteristics set Resilient Design apart from any architectural "style" or urban planning formula. Resilient design fits as a value-added component within any style, culture, or community since adaptation to local conditions and environment is a fundamental defining trait of Resilient Design. For these reasons, it is relatively safe to accept that Resilient Design, in varying degrees, will become a permanent overlay for urban development, architecture and construction. As has been presented in this course, there is widespread acknowledgement of resiliency as a sustaining concept in many areas of development to influence a change in approach and execution of future development(s) and re-adaptation of existing environments where feasible.

If it can be reasonably concluded that a structured Resilient Design framework is here to stay, its continued relevance will depend on meaningful ways to measure how the "resilient" features perform. The need for tangible evaluation and documenting the performance of the "Resilient Design" is essential to long term credibility and continued advancement. For this reason, Resilient design rating systems are important because they provide a standardized structure to assess and incentivize the incorporation of features. Below are some of the current rating systems that are in use (NOTE: There is no universal standard rating or measuring system in place as of 2024):

Rating System (Sample List)	**Developed by**	**Description** (Taken from system developer website public statements)
FORTIFIED ® Home and Commercial	Insurance Institute for Business & Home Safety	FORTIFIED is a voluntary construction and re-roofing Program designed to strengthen homes and commercial buildings against specific types of severe weather such as high winds, hail, hurricanes and even tornadoes.
LEED ® Pilot Credits	{LEED} Resilient Design Pilot Credit Core Committee	There are three credits in the new LEED pilot credits on resilient design. These fall into the Integrative Process category of LEED (thus the IP in the credit identities), and they are pilot credits (pc in the identities). In the LEED Rating System, they are applicable to all Building Design and Construction (BD+C) rating systems, along with Homes and Mid-Rise Residential rating systems. • **Credit IPpc98** – Assessment and Planning for Resilience • **Credit IPpc99** – Design for Enhanced Resilience • **Credit IPpc100** – Passive Survivability and Functionality During Emergencies

Rating System (Sample List)	**Developed by**	**Description** (Taken from system developer website public statements)
REDi	Arup	REDI provides Engineering design services for buildings that allows for designs that are resistant to seismic activity. REDi is a set of prescriptive guidelines for owners, engineers, and architects to implement resilience-based design to achieve beyond-code resilience objectives. It is not an index.
RELi Rating System	C3 Living Design (adopted in 2017 by USGBC)	RELi takes a holistic approach to resilient design. With more than 50 requirements and credits spread throughout eight categories, including panoramic design, hazard mitigation, materials used in construction and community vitality, RELi encompasses a wide variety of strategies and techniques. RELi also overlaps with other rating systems, particularly LEED.
USRC Earthquake Building Rating System	U.S. Resiliency Council (USRC)	The USRC Rating System provides information that is useful in designing a building for greater resilience by predicting a building's performance during an earthquake. USRC's Rating System builds on the model of the popular USGBC LEED® ratings but addresses aspects of building performance that are of critical importance for the resilience of businesses and the communities where people live and work, including: the supporting structure, MEP systems, and the architectural components such as cladding, windows, partitions, and ceilings.

5.2. Resilient Design – Impact for Architects

The impacts of Resilient design for architects are quite obvious as has been discussed in all the preceding sections. Some of this summation may seem repetitive but Resilient design significantly impacts architects by requiring them to proactively plan and design buildings and communities that can withstand and recover quickly from natural disasters, climate change impacts, and other disruptions, ultimately leading to safer, more sustainable, and adaptable built environments for occupants while improving the quality of life in the community at large. The following are some direct actions that Architects can start with to address Resilient design:[101]

1. Consider what you can do to avoid risk to your project (site selection, building location or orientation)
2. Consider how your design can be adapted to reduce risk for your project (material choices, equipment selection)
3. Consider how your design choices can lower the costs of risk transfer options like insurance. (Incentive programs, discounts)
4. Consider how building and land use choices impact community resilience goals.
5. Discuss setting beyond code minimum performance goals with your clients.
6. Visit the AIA "Hazard mitigation design resources" web page for simple targeted mitigation measures you can take for specific kinds of potential disasters; you'll also find with many links to more advanced information.
7. Visit the AIA "Climate Change adaptation design resources" web page for concise information and simple projection tools you can use to plan for future climate and sea level conditions.
8. Recognize the contribution an individual project can make to the community-at-large.

At some point soon Resilient design will become codified beyond the elements that are already mandated in codes, albeit under different names. Architects will benefit from being engaged at the inception of these discussions to influence the decisions and ensure that the appropriate elements are incorporated in a meaningful and practical way, with responsibilities /accountability assigned fairly.

5.3. The Future of Resilient Design

The preceding section stated the position Resilient design as a framework that will stabilize as a permanent feature in building and infrastructure design with varying emphases depending on location and disruption concerns. It is more likely a new normal rather than a band wagon effect that will subside.

[101] AIA California: "Resilient Design: Why It's Important to Architects"; William Melby, FAIA; January 19, 2022

A recent article in Brick & Bolt Home Construction magazine offered a succinct account of what the future looks like for Resilient design:[102]

> With new trends and technology providing creative answers to industry problems, the future of resilient building design is bright. Among the most important developments and technologies are:
>
> **Climate-responsive design:** Buildings can be designed more resilient to natural disasters and climate change by using design principles that are sensitive to the local climate and weather conditions.
>
> **Smart materials:** Buildings can be designed to be more resilient and long-lasting by utilizing smart materials like shape-memory alloys and self-healing concrete.
>
> **Digital technologies:** Building design, construction, and maintenance may all be made better by integrating digital technologies like the Internet of Things (IoT) and Building Information Modelling (BIM).
>
> **Renewable energy:** Buildings can be made more resilient to disruptions and power outages by utilizing renewable energy sources like solar and wind power.
>
> **Green infrastructure:** Building resilience can be increased, and the effects of natural disasters can be lessened by utilizing green infrastructure, such as rain gardens and green roofs.

Of the areas mentioned above, emerging technologies are likely to have a significant impact on the spread of resilient design as they provide both real-time monitoring and fine-tuning techniques and the ability to produce more efficient materials at lower costs. The latest technologies can assist throughout the design, estimating, manufacturing, construction, and all phases of a project to optimize sustainability and resilience.

In conclusion, the Resilient Design framework is approaching a stage of maturity where guidelines, metrics to gauge performance and broad-based support are converging to make this one of the crucial supporting legs for sustainability and better communities. The impact of climate, urban sprawl and the economic costs of natural disasters and human-caused disruptions have combined to force the design and development professionals to take action to strengthen our buildings, communities and infrastructure in ways that can sustain the impact. There is a demonstrable collective cost for not making resilience a cornerstone of future development. For existing buildings, infrastructure and communities, pre-emptive retrofit strengthening is likely to face strong economic opposition but if and when any of these fall victims to a natural disaster or some other disruptive event, the rebuilding efforts should use resilience as a

[102] Brick & Bolt Home Construction: “Resilient Design: Principles, Architecture, and the Future of Sustainable Building”; Apoorva H P Achar; September 17, 2024

foundational criterion so the next time the damage can be minimized or mitigated altogether.

Thinking in terms of resilient design should not be an optional consideration or afterthought for architects and planners; it should be a basic design criterion that morphs based on location, scale and economics.

> *Resilience has become non-negotiable in a world of ever-increasing disruptions. Now is the time for action: we must move from "talking the talk" to "walking the walk". The present time must be recognized as an opportunity to build a different muscle group for resilience and a new leadership model for the future. To do so, organizations need to recognize where they stand on their resilience journey and leaders need opportunities to share experiences, learn from best practices and build partnerships to develop joint solutions.* [103]
>
> *– World Economic Forum 2025*

Part 5 Review Question

1. Which of the following resilient design rating systems was adopted by the USGBC?
    a. REDi
    b. FORTIFIED
    c. LEED Pilot Credits
    d. RELi

This concludes the course

[103] World Economic Forum: "The Resilience consortium: Building a robust future" – Website: February 2025

Review Question Answers

Part 1 Review Questions

1. What does RDI stand for?
    a. **Resilient Design Institute; Correct. In section 1.1 of the course, the Resilient Design Institute is abbreviated as "RDI".**
    b. Resilient Design Infrastructure; Incorrect
    c. Rapid Deployment Infrastructure; Incorrect
    d. Resilient Development Installation; Incorrect
2. Which of the following is not a design "style" per se?
    a. Biophilic Design; Incorrect
    b. Post Modern Design; Incorrect
    c. **Resilient Design; Correct. Resilient design is emerging as a strategic platform to help guide and shape building construction. It is not a design "style" per se, but a design approach.**
    d. Minimalist Design; Incorrect
3. Which of the following are true about the 1871 great fire of Chicago?
    a. Over 17,000 buildings were destroyed; Incorrect
    b. Over $200 million in damage; Incorrect
    c. Nearly 100,000 people were left homeless; Incorrect
    d. **All of the above; Correct. Section 1.3 of the course describes one of the earliest examples of bringing resilience into widespread building design is after the great fire of Chicago in 1871. This fire destroyed some 17,450 buildings covering almost 3.5 square miles, caused $200 million in damage, and left nearly 100,000 people homeless.**
4. The focus of Net Zero is?
    a. To ensure human habitats recover rapidly after climate events; Incorrect
    b. **To neutralize carbon emissions; Correct. The Paris Agreement of 2015 created the targets for NetZero. Even though the focus of Net Zero is targeted on neutralizing carbon emissions, there has emerged a broad and heightened recognition of a need for tangible actions.**
    c. Aimed at political action rather than any impact on physical infrastructure; Incorrect
    d. Limited to environmental changes made until 2050; Incorrect
5. Is Resilience the same as Sustainability?
    a. **No. They are closely related but have some differences; Correct. Section 1.4 of the course states that Resilience and Sustainability are closely related concepts, but some distinct differences should be highlighted.**
    b. Yes. They are interchangeable phrases; Incorrect
    c. No. Resilience deals with codes while sustainability deals with non-safety related items; Incorrect
    d. Yes. Both were introduced at COP 21 Paris accord; Incorrect

Part 2 Review Questions

6. The Green and Resilient Retrofit Program (GRRP) is a program within which of the following?
    a. FEMA; Incorrect
    b. **HUD; Correct. The Green and Resilient Retrofit Program (GRRP) is a program within the U.S. Department of Housing and Urban Development (HUD).**
    c. OSHA; Incorrect
    d. EPA; Incorrect
7. The Climate Adaptation and Resilience Plan (CARP) of the DOE takes a ___________ resilience approach.
    a. Solution oriented; Incorrect
    b. Cost factored; Incorrect
    c. Energy focused; Incorrect
    d. Risk-based; Correct. Through the DOE Climate Adaptation and Resilience Plan (CARP), DOE takes a risk-based resiliency approach to its operations to identify and minimize climate-related and other vulnerabilities across all DOE policies, programs, and activities.
8. Which of the following is not one of the "R"s of the National Infrastructure Advisory Council?
    a. Robustness; Incorrect
    b. Rapid Recovery; Incorrect
    c. Resource loading; Correct. The NIAC breaks resilience down into the four Rs: Robustness, Resourcefulness, Rapid Recovery, and Redundancy
    d. Redundancy; Incorrect
9. ICC 825 and ICC 815 are ______________ published by the International Code Council (ICC).
    a. International codes; Incorrect
    b. Guidelines; Incorrect
    c. Commentaries; Incorrect
    d. Standards; Correct. The ICC Periodic Table in section 2.2 of this course shows ICC 825 and ICC 815 as being in the "Standards" part of the table.
10. Which of the following sections of the 2018 IECC (International Energy Conservation Code) supports the Resilience strategy of dealing with urban heat islands?
    a. C404.6; Incorrect
    b. C402.3; Correct. In the table summarizing the aspects of resilience captured in energy efficiency portions of the IECC, C402.3 deals with urban heat islands.
    c. C403.10; Incorrect
    d. R401.2; Incorrect
11. Researchers from four countries participated in the Global Resiliency Dialogue. Which of the following was not one of the countries that participated?
    a. United States; Incorrect
    b. New Zealand; Incorrect
    c. Canada; Incorrect
    d. United Kingdom; Correct. Building code developers/researchers from Australia, Canada, New Zealand, and the United States launched the Global Resiliency Dialogue.

Part 3 Review Questions

12. Resilience and Sustainability both focus on all of the following except:
    a. **Building aesthetics; Correct. Resilient design and sustainability both focus on energy and water independence, renewable resources, local materials, resource storage, community support, and preventing environmental effects.**
    b. Energy and water independence; Incorrect
    c. Local materials; Incorrect
    d. Renewable resources; Incorrect
13. The *Bosco Verticale* is presented in the course as an example of a building that addresses which of the following Resilient design strategies?
    a. Incorporating recreational elements in the design; Incorrect
    b. **Incorporating vertical greenery for natural cooling and air purification; Correct. *Bosco Verticale* in Italy is shown as an example of incorporating vertical greenery for natural cooling and air purification.**
    c. Community engagement; Incorrect
    d. All of the above; Incorrect
14. A characteristic of adaptive design is:
    a. Vegetation on rooftops; Incorrect
    b. Implementing rainwater harvesting systems; Incorrect
    c. **Incorporating features that can withstand extreme weather events; Correct. Adaptive design is incorporating features that can withstand extreme weather events – like flood protection, elevated foundations, and storm-resistant building materials.**
    d. Including low-flow fixtures; Incorrect
15. The number of billion-dollar disaster events in the US have ____________ between 2008 and 2022.
    a. **Risen sharply; Correct. The graph from NOAA NCEL showing the history of billion-dollar disasters shows a sharp rise in the number of billion-dollar disasters.**
    b. Risen only slightly; Incorrect
    c. Stayed the same; Incorrect
    d. Declined when adjusted for temperature; Incorrect
16. According to the course material, one way to help stabilize property insurance costs is by:
    a. Opting out of insuring properties; Incorrect
    b. Increasing regulations; Incorrect
    c. **Investing in resilient buildings and communities; Correct. According to the course, if more resilient buildings and communities are built and they can demonstrably survive disaster events, the investment in fortifying the buildings can help stabilize (if not reduce) insurance costs among other costs.**
    d. Using a single payer government funded insurance scheme; Incorrect
17. According to a policy brief by C40 Knowledge HUB, the scales of applying Resilient design options are:
    a. **City, Community, Building; Correct. The policy brief by C40 Knowledge HUB breaks resilient design into the following scale options: City, Community, and Building.**
    b. Neighborhood, Town, Community; Incorrect
    c. Micro, Macro; Incorrect
    d. None of the above; Incorrect

18. Designing for durability, disassembly and maintenance is a strategy for which scale of resilient design?
    a. Neighborhood; Incorrect
    b. Building; Correct. Designing for durability, disassembly and maintenance, such as planning for climate appropriate structures and urban layouts to prevent damage is included on the Building Scale of Resilient Design.
    c. Regional; Incorrect
    d. It is not a viable strategy at any scale; Incorrect
19. Planning drought resistant ground shading plants to retain ground moisture as a response to water stress / wildfire risk is applicable to which climates?
    a. Dry desert climates only; Incorrect
    b. Cold dry climates; Incorrect
    c. All climates; Correct. According to the chart summarizing adaptive approaches by climate impact and sphere of construction, planning drought resistant ground shading plants to retain ground moisture is applicable to all climates.
    d. Hot and humid climates in the northern hemisphere; Incorrect
20. Who developed the Building Regulation for Resilience Managing Risks for Safer Cities?
    a. United Nations Development Program; Incorrect
    b. USAID; Incorrect
    c. World Bank; Correct. The World Bank developed the Building Regulation for Resilience Managing Risks for Safer Cities
    d. Australian Sustainability Council; Incorrect
21. Which of the following is / are true of the wildfires around the Los Angeles, California area in January 2025:
    a. The Eaton and Hurst fires were cumulatively the worst fires; Incorrect
    b. Only 18,000 people were evacuated at the peak; Incorrect
    c. There were multiple fires with the Palisades fire being the largest, consuming over 24,000 acres; Correct. In the Special NOTE on Resilient Design and the Los Angeles Fires of January 2025, there were multiple fires with the Palisades fire (breaking out on January 7) being the worst, burning more than 24,000 acres including homes and businesses in Pacific Palisades and along the Pacific Coast Highway.
    d. a & b; Incorrect
22. Which of the following is not an aspect of resilient infrastructure according to GREEN.org?
    a. Build with climate change in mind; Incorrect
    b. Ignore politicians; Correct. The “Resilient Infrastructure” graphic from GREEN.org does not show “Ignore Politicians” as one of their aspects of resilient infrastructure.
    c. Focus on livable, enjoyable spaces; Incorrect
    d. Build with resilience; Incorrect

Part 4 Review Questions

23. According to the National Institute of Standards and Technology, what term refers to a set of buildings that serve a common function?
    a. Functional grouping; Incorrect
    b. Operationally common; Incorrect
    c. Syngiocast; Incorrect
    d. Cluster; According to the NIST, the term "cluster" refers to a set of buildings who serve a common function, such as housing, healthcare, or retail, and maybe distributed throughout a community.
24. From a resilience perspective, what is the term to describe a post-event performance state of a building that can adequately support the basic intended functions intended in the pre-event state?
    a. Re-occupancy; Incorrect
    b. Functional recovery; Functional recovery is a post-event performance state in which a building or infrastructure system is maintained, or restored, to safely and adequately support the basic intended functions associated with the pre-event use or occupancy of a building, or the pre-event service level of an infrastructure system.
    c. Full recovery; Incorrect
    d. Operability; Incorrect
25. Which of the following is /are basic human needs that Resilient design endeavors to provide:
    a. Water; Incorrect
    b. Food; Incorrect
    c. a & b; Correct. Resilient design endeavors to provide for basic human needs by addressing the needs for food, water, energy, air, and shelter.
    d. Diversity; Incorrect
26. Modular design is a feature that supports which of the principles of Resilient design?
    a. Diverse and redundant systems; Correct. Modular design is a property of diverse and redundant systems. Modular design is breaking down systems into smaller, independent modules, that can be easily isolated and replaced in case of failure.
    b. Locally available materials; Incorrect
    c. Promoting resilience in nature; Incorrect
    d. Durability; Incorrect
27. What is a direct economic benefit that can be achieved through resilient design?
    a. Providing pedestrian and bike paths around wetlands; Incorrect
    b. There are no measurable direct economic benefits; all are qualitative; Incorrect
    c. Psychological peace of mind resulting from resilient design reduces stress and so can reduce mental health related costs; Incorrect
    d. Monetary values as an avoided loss, including reduced insurance premiums; Correct. Direct benefits can be easily given monetary value as an avoided loss, including reduced insurance premiums, based on the extend of property and assets that are protected by an action.

28. Which of the following are features of incorporating green elements in resilient design?
    a. Urban heat island mitigation; Incorrect
    b. Biodiversity enhancement; Incorrect
    c. Stormwater management; Incorrect
    d. All of the above; Correct. The list of elements of green infrastructure includes stormwater management, urban heat island mitigation, floodplain protection, drought resilience, improved air quality, and biodiversity enhancement.
29. A US location that was presented in this course as an example of a city that prioritizes urban resilience is:
    a. Dallas, Texas; Incorrect
    b. Portland, Oregon; Correct. Portland has prioritized urban resilience by focusing on sustainable land planning, transportation options, and renewable energy.
    c. San Jose, California; Incorrect
    d. Seattle, Washington; Incorrect

<u>Part 5 Review Question</u>

30. Which of the following resilient design rating systems was adopted by the USGBC?
    a. REDi; Incorrect
    b. FORTIFIED; Incorrect
    c. LEED Pilot Credits; Incorrect
    d. RELi; Correct. In the table showing some of the current rating systems, RELi was developed by C3 Living Design and adopted in 2017 by the USGBC).