PDH Academy

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California NetZero Design

A Guide for Architects

AIAPDH733

5LU/HSW Hours

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Disclaimer Notice:

This course is intended to provide information as an educational benefit for architects and design professionals. The author and instructor have attempted to present a summation of the concepts and published data in a manner that intended to clarify these for architects. While the Information contained in this course has been reviewed and presented with all due care, the author does not warrant or represent that the Information is free from errors or omission. The author and instructor accept no liability whatsoever for, or in respect of any use or reliance upon this publication by any party. Author: Muhammad Siddiqui. Instructor: Sandy Stannard

ABOUT THE COURSE

This material is a sister course to the PDH Academy offering titled: *"Understanding Carbon Emissions for Building Design" by Ravi Srinivasan and Jaya Lakshmanan.* Various portions of this course rely on content from that course, especially when definitions, references or supporting research overlap.

The intent of this course is to address the complex topics that feed into the goals for achieving a NetZero built environment. One of the notations created for this material is the use of **nz0** as a shorthand for Net Zero (sometimes also written as NetZero). This is a creation of the author and not a globally recognized abbreviation (or a typo in the context of this course). Another acronym used often is NZE for Net Zero Emissions (favored by the World economic Forum). The discourse in this course is from the objective of Net Zero as it pertains to engaging architects, planners, engineers and designers for the purpose of understanding what is meant by Net Zero, what are the related topics, who are the involved stakeholders and how their work affects building designs and vice versa.

So, before starting the course content, let's define what is Net Zero. That way, the discussion that follows can be followed in its connection to the objectives of 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."[1]

It is not a design code, or an organization or even a design protocol. This is a target that is the cumulative culmination of the objectives of the many environmental, regulatory, professional and even social organizations. By its very nature, it is aspirational and absolute in its goal. In the course it will be examined how this translates for building design.

Because of the strong connection between the far-reaching nature of Net Zero aspirations and multiple environmental considerations such as climate change, carbon footprints and others, the course will examine these to provide context for comprehensive understanding of building designs for a Net Zero goal.

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

Learning Objectives

Learning Objective 1:

Define concepts such as Climate change, Sustainability, Green buildings, Net Zero Carbon, Carbon Neutrality, etc. and issues related to NetZero design in the context of buildings and materials used.

Learning Objective 2:

Describe various ways in which buildings affect the environment and are, in turn, affected by it.

Learning Objective 3:

Describe and review steps designers can take to advance their designs towards Net Zero objectives.

Learning Objective 4:

Examine the organized movements and future visions for the targets of achieving Net Zero.

Learning Objective 5:

Discuss the existing and evolving standards, regulations that will advance NetZero compliance and also look at the compliance of conscience – such as volunteer certification programs such as LEED, Green Globes, BREEAM, etc.

Course Outline

The course on NetZero Design is a five-part course broken down as follows:

PART 1 – Introduction to the History, Issues and Concepts Leading to the NetZero Aspiration

PART 2 – Background on How Buildings Impact and Interact with the Environment

PART 3 – Building Design Concepts for NetZero

PART 4 – Visions for the Future – Aspirations and Challenges

PART 5 – Standards, Regulations and Conscience

PART 1

PART 1 – INTRODUCTION TO Net Zero (nZ0)

1.1. Purpose of the Course:

Since about the 1980s and accelerating around the turn of the century, there has been what seems like a torrent of movements, regulations and debates around the need to contain the impacts of rapid urbanization and the built environment. This has been part of a broader environmental movement that is still gaining momentum. Regardless of one's personal opinions, the issues raised by this wave of activism, scientific study, media focus, political capital and regulatory ecosystem have now become an integral part of urban planning and building design discussion. Even when regulations are vague or do not exist, architects, designers and planners can no longer remain ignorant of the impact of the built environment on the planet's fragile ecosystems. It is the architect's role to balance a project's complexities, navigating through the potential doubts, cynicism, misinformation, misapplication, and simple misunderstandings about sustainable design through which design professionals have to navigate for clients on tight schedules and even tighter budgets. There are usually no added fees unless decisions are made to actually implement a tangible "sustainable" design such as the achievement of some type of LEED certification. Until such a decision is made, architects are expected to be intelligently conversant and knowledgeable about the subjects (there are multiple interrelated subjects that feed on each other to result in a "sustainable" design and even more so when the goal is Net Zero Energy or Net Zero Carbon).

Here is where the dilemma for many design professionals begins. Even if they understand the definitions, which many do not, there is often a struggle to express what sustainable design goals for a given project should be implemented and how best to provide a meaningful design response that the client can easily understand and buy into. This is not a simple proposition. In order to help make a design professional aware, knowledgeable and confident enough to have a comfortable and positive discussion, there are a series of interrelated concepts, issues, opinions and often competing and contradictory options that the designer must become familiar with and clearly understand.

To illustrate the point: Consider the following: Net Zero Energy, Net Zero Carbon, NZE, Sustainable Design, Green Buildings, Carbon Footprints, LEED, Cradle-to-Grave Design, Cradle-to-Cradle design, Environmental Responsibility, Environmental Sensitivity… and so on. Almost every architect has at least heard of all the preceding labels, and many may even know the differences between each one. However, for many, some of these terms get tangled and easily interchanged. Outside of the "industry", these terms are almost always misunderstood. For example, many companies (architects and clients) today have some sort of a mission statement to "work towards" sustainable design. Yet, most of their managers and staff will not be able to articulate what that means in tangible terms. As distressing as that may seem, it is not surprising since there are just too many variations on what this means to each organization. As a result, the mission statements become more aspirational, which makes them vague and subject to individual interpretation. This course will provide a definition for each of these and similar concepts, and how we might address them through design. In order to unravel the complexity of the issues and the many influences surrounding the topic, it requires the extensive breadth of coverage.

1.2. Background – How Did We Get Here?

To understand how the concern for a more environmentally focused building mindset went from a fringe movement to a global mainstream normality, we have to go back to about the 1970s for the genesis of the modern environmental movement. Prior to that, there was a nascent environmental awareness that remained peripheral for decades.

Environmentalism, or a "concern about and action aimed at protecting the environment[2]," started out in North America in the latter part of the 19th century. John Muir (1838-1914) is generally credited as being America's first environmentalist because of his activism in the preservation of Yellowstone National Park and the Yosemite and Sequoia valleys. He is often credited as the "Father of Our National Park System".[3] However, the movement he inspired was focused more accurately on conservation, especially in preserving the wilderness from human encroachment and development. And that remained the focus of much of the environmental movement until the post Second World War era.

During the 1950s and 1960s, amidst the economic boom, the growth of industry and the proliferation of automobiles, urban lifestyle changed, and sprawling suburbs came into being. Smog entered into the vocabulary and the browning of clear blue skies became a familiar backdrop of most large cities. Los Angeles became the poster child of smog, showing the stark impact of pollution in what had been a picturesque horizon. Groups of concerned citizens began to call for awareness, control and mitigation. But they were initially marginal voices that, when combined with the emerging Hippie culture, were dismissed and the rapid growth of cities across the globe continued. Ubiquitous availability of air conditioning and climate control equipment, cheap lighting fixtures and widespread, low cost, piped in running water through indoor plumbing meant design considerations for natural light, wind directions, solar patterns or water resources became were ignored.

The urban sprawl of the 1960s across the globe had become too visible and the effects on air quality were not only scientifically documented but obvious to the naked eye. This was also a general time of challenging "establishment norms" with protests against the Vietnam war, a generational shift in societal norms and the rise of the Civil Rights movement to upend centuries of racial inequality. In the midst of this social atmosphere, environmental issues found fertile ground and political opportunity. Rachel Carson wrote her seminal 1962 book, Silent Spring, questioning technological advances that ignored negative effects on both people and the planet, instigating the start of the modern environmental movement. On April 22, 1970, the first Earth Day was observed with millions of people attending events. It would become an annual commemoration that continues today. In July of 1970, the Environmental Protection Agency (EPA) was established by special executive order to regulate and enforce national pollution legislation.[4] Environmental awareness had come in from the cold and was no longer a shadow issue.

[2] Oxford Dictionary (online)
[3] John Muir, national park Service, NPS.gov
[4] EPA, History.com

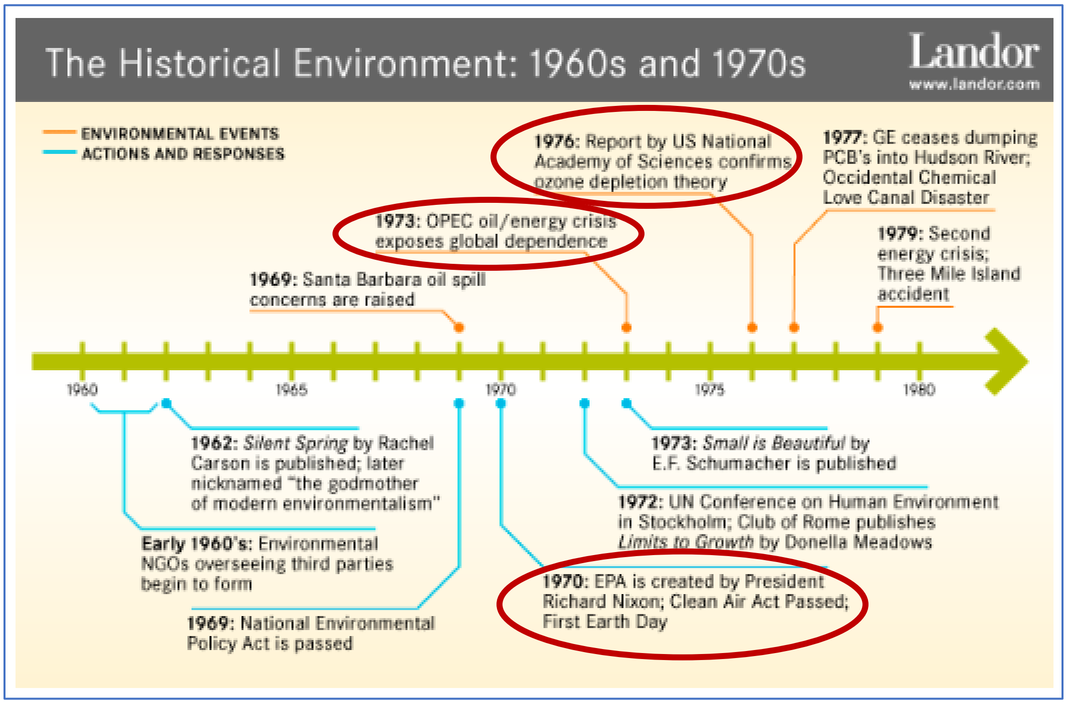


Figure 1.2

Source: www.fastcompany.com/1568686/a-history-of-green-brands-1960s-and-1970s-doing-the-groundwork

Recognition of an issue and even giving it formal credibility does not necessarily translate into cessation of harmful behavior, changes in future actions or reversal of damage already done. The EPA was a step that focused on air and water quality and limiting further pollution. In some cases, even mandating clean up. For building design and methodology, little changed.

There were architects coming out of the activism of the 1960s that had started to examine the impacts of buildings on the environment, but it was not until the Oil crisis of 1973 and beyond that energy costs became an issue of national importance. Everyone was impacted and energy conservation gained momentum and a "green architecture" [5]movement began to take shape. Energy conscious design through experiments with solar architecture began to appear in the 1970s. The EPA and the American Institute of Architects (AIA) began a collaboration in the 1980s and the AIA formed its Committee on the Environment in 1989. It was becoming increasingly clear that designers of the built environment had a role to play in a necessary environmental course correction.

In the 1990s, as awareness grew, and fueled by a new generation of architects seeking something beyond the design debates of post-modernism and deconstruction, a variety of groups, organizations, writers and thinkers entered into the arena of "green architecture" and "Green Buildings".

[5] The term "Green Buildings" is credited to John Elkington from his 1998 book Cannibals with Forks: The Triple Bottom Line of 21st Century Business. However, the term in loose combinations had been in use in design circles but not formalized until the book came out.

1.3. Net Zero – Why?

As discussed, concerns for the environment created an awakening for action and change. In the absence of any common standard or uniform agreement of what actions or objectives need to be achieved, initially several initiatives sprang up, from academic institution level conferences to more widely subscribed awareness events sponsored by organizations like the UN and several official or NGOs.

Many organizations emerged that focused on various aspects of addressing the broad issues covered by the notion of "The Environment". During the 2 decades from 1995 to 2015 the concern for planetary level consequences from "Global Warming", Climate Change", the exponential rise in "Greenhouse Gas emissions" and increases in the "Carbon Footprint" of human activity, all combined to create a level of urgency that caused the United Nations to sponsor a Climate Change Conference known as the Paris Climate Conference COP 21 that was held in December 2015 and resulted in an agreement and adoption by 196 countries, including the United States. *Note: In 2017, the USA unilaterally withdrew from the Agreement but then reapplied in 2021 and was readmitted into the Agreement.*

It was the Paris Agreement that created the provision now termed as Net Zero. Here are five of the agreement's key points.[6]

1. **Limit temperature rise 'well below' 2º C**.
   - The agreement includes a commitment to keep the rise in global temperatures "well below" 2º C compared to pre-industrial times, while striving to limit them even more, to 1.5 degrees.
   - Scientists consider 2º C the threshold to limit potentially catastrophic climate change.
   - In recent years, world leaders have stressed the need to limit global warming to 1.5 º C by the end of this century
2. **First universal climate agreement**.
   - It's the world's first comprehensive climate agreement, with all countries expected to pitch in.
   - Under the previous emissions treaty, the 1997 Kyoto Protocol, developing countries were not mandated to reduce their emissions.
3. **Helping poorer nations**.
   - The deal also calls on developed nations to provide financial assistance to developing countries to assist these poorer countries combat climate change and foster greener economies.
   - The agreement promotes universal access to sustainable energy in developing countries, particularly in Africa. It says this can be accomplished through greater use of renewable energy.
4. **Publishing greenhouse gas reduction targets**.

[6] key points in Paris Agreement on climate change | CBC Newshttps://www.cbc.ca › news › world › Paris-agreement

- Countries will be tasked with preparing, maintaining and publishing their own greenhouse gas reduction targets. The agreement says these targets should "reflect [the] highest possible ambition."
- The agreement currently state: “Starting in 2024, countries will report on actions taken and progress inclimate change mitigation, adaptation measures and support provided or received.”
- Since the agreement’s inception, more countries have established carbon neutrality targets

5. **Carbon neutral by 2050**?[7] (*This is the provision that created the Net Zero target*)
   - The deal sets the goal of a carbon-neutral world by 2050.
   - This means a commitment to limiting the amount of greenhouse gases emitted by human activity to the levels that trees, soil and oceans can absorb naturally.
   - Scientists believe the world will have to ***stop emitting greenhouse gases altogether*** in the next half-century in order to achieve this goal. This is also referred to as ***Net Zero Emissions (NZE)***

The Paris Agreement deals with greenhouse gas emissions mitigation, adaptation, and finance mechanisms. This Agreement, within the United National Framework Convention on Climate Change (UNFCCC), was signed by 196 countries globally.

The Paris Agreement was enforced on 4th November 2016 after at least 55 Parties to the Convention - accounting for at least an estimated 55% of the total global greenhouse gas emissions - deposited their instruments of ratification, acceptance, approval, or accession with the Depository.[8]

Although voluntary, the United States submitted a report titled, ‘Mid-Century Strategy for Deep Decarbonization’ in November 2016[9]. This report listed three major categories of action to achieve deep economy-wide net greenhouse gas emissions reduction:

- *“I. Transitioning to a low-carbon energy system, by cutting energy waste, decarbonizing the electricity system and deploying clean electricity and low carbon fuels in the transportation, buildings, and industrial sectors.*
- *II. Sequestering carbon through forests, soils, and CO_2 removal technologies, by bolstering the amount of carbon stored and sequestered in U.S. lands (“the land sink”) and deploying CO_2 removal technologies like carbon beneficial bioenergy with carbon capture and storage (BECCS), which can provide “negative emissions”; and*

[7] key points in Paris Agreement on climate change | CBC Newshttps://www.cbc.ca › news › world › Paris-agreement
[8] http://unfccc.int/focus/ndc_registry/items/9433.php
[9] https://unfccc.int/files/focus/long-term_strategies/application/pdf/mid_century_strategy_report-final_red.pdf

- *III. Reducing non-CO_2 emissions, such as methane, nitrous oxide, and fluorinated gases, which result mainly from fossil fuel production, agriculture, waste, and refrigerants."*

In the preceding discussion, several causes are mentioned that contribute to the state of current environmental concerns. All these phrases are familiar to most people as words, but it is important to understand what they really mean and how they relate to the quest for Net Zero Energy and Net Zero Carbon. We will examine the key ones below:

- <u>The Environment</u>

  There is no single definition of "the environment". It is relatable in terms of the situation it is used in. In the context of Net Zero Energy and Carbon and the concerns that have led up to it, there are two "types" of environments that are applicable:

  - Natural environment
  - Built or Human environment

  When we speak of "environmentalists", or concerns for the "environment", the context is of the natural environment and its stability. The underlying premise is that there is a balance, or equilibrium in the natural environment that sustains life on Earth as we know it and if that is disturbed beyond a threshold, a realignment of the natural environment can occur that may alter the resources, lifestyles, and survivability of many species of life on Earth, including human beings. Ironically, the other type of "environment", the "built environment" which is the result of human activity has a direct and increasingly decisive impact on the character of the natural environment. The entire issue of Net Zero is really about trying to restore the balance between the two types of environments.

  Central to the attainment of this goal is understanding how the Earth attempts to maintain an energy balance, i.e., a balance between the incoming and outgoing radiation from the sun. To elaborate, only 71% of sun's visible and Ultraviolet (UV) enters the atmosphere; 23% of this radiation is absorbed by water vapor, aerosols, and ozone, while the remaining 43% is absorbed by the Earth' surface and re-radiated as Infrared (IR) heat.

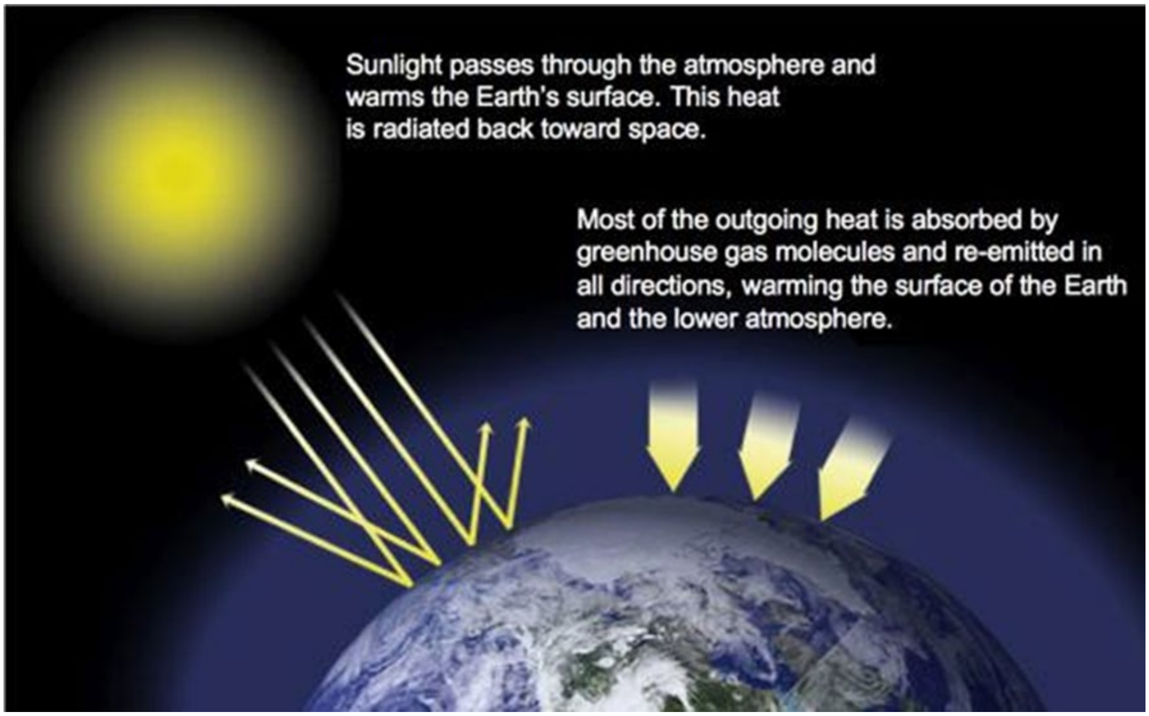


Figure 1.3.1

From NASA's Global Climate Change – Vital Signs of the Planet website

<https://climate.nasa.gov/causes >

"A layer of greenhouse gases – primarily water vapor, and including much smaller amounts of carbon dioxide, methane and nitrous oxide – acts as a thermal blanket for the Earth, absorbing heat and warming the surface to a life-supporting average of 59 degrees Fahrenheit (15 degrees Celsius)."

While the bulk of Earth's atmosphere namely Oxygen and Nitrogen absorb this outgoing reflected radiation, there are other gases in the atmosphere namely carbon dioxide (CO_2), methane (CH4), nitrous oxide (N2O) and other gases that trap this outgoing reflected energy and radiate in all directions impacting the energy balance. These gases are referred to as '*greenhouse gases*.'

When changes take place over extended time that affect the atmosphere, whether due to natural occurrences (e.g., volcanic eruptions, meteor impacts, solar flares) or due to man-made activity (e.g. fossil fuel emissions, re-routing natural flow of resources like water, deforestation, urbanization), an imbalance occurs in the cycle of greenhouse gasses. Some notable impacts of such energy imbalance results in an increase in the Earth's surface temperature; increase in sea level (also referred to as sea level rise which is due to the melting of the polar icebergs and an increase in ocean temperature expands sea water thereby resulting in sea level rise); changes to weather patterns and precipitation, etc. Many of the effects of global warming can now be seen in coastal cities inundated with constant flooding of seawater. Even some megacities such as Djakarta, Indonesia, are literally sinking at alarming rates. Some parts of the city have sunk 2.5m in 10 years and continuing to sink by as much as 25cm a [10]year, making it the fastest sinking city

[10] https://www.bbc.com/news/world-asia-44636934

on Earth. This is no minor issue for a city of over 10 million people. In this regard, Djakarta is not alone as many low-lying coastal cities across the globe are facing similar scenarios. Among those at risk are large metro areas like Dhaka, Bangladesh, Mumbai India, Miami, and New Orleans, to list a few. According to some projections, even some countries like the Maldives are at risk of disappearing entirely by 2100 [11]if the trends are not reversed.

Statistics such as these have prompted the formation of international collaborations, consortia, and conferences. One of the areas emerging as being of special concern is the building sector. Buildings and construction consume over 40% of all energy used globally and therefore reforms here are essential to affect any meaningful progress towards Net Zero.

Climate, Carbon and Global Warming

We have seen above how imbalance with greenhouse gasses can lead to potentially catastrophic consequences. One of the ways these impacts are realized is due to the changes in global weather patterns which, over time, create permanent shifts – what is referred to as Climate Change. While the science is irrefutable, the subject has, over time, become politicized and polarized as various interest groups vie to influence policies to ither maintain status quo or move to Net Zero targets.

The objective of this course is to present the data and regulatory positions on the subject so that architects and building designers understand the jargon, meanings, and underlying rationale for Net Zero implementation when the project requires it. As with codes, client requirements and preferences, it is not the opinion and agreement of the architect that defines the success of the project but the properly informed decision making of the designer to address and successfully execute the project program. What is obligatory upon the design professional is to be aware of the guidelines, regulations, and reasoning behind them so that decisions are informed and made within that logical framework.

As such spirit the focus here will be to present key definitions and descriptions of the key terminology so that the design professional has a working knowledge and can converse intelligently with clients and make effective design choices.

Below are some of the key definitions of terms as they relate to climate change and associated topics:

Table 1.3: Basic Terminologies Related to Climate

Terminology	Description / Explanation
Adaptation	*Adjustment or preparation of natural or human systems to a new or changing environment which moderates harm or exploits beneficial opportunities.*
Adaptive Capacity	*The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.*
Albedo	*The amount of solar radiation reflected from an object or surface, often expressed as a percentage.*

[11] https://www.cnbc.com/2021/05/19/maldives-calls-for-urgent-action-to-end-climate-change-sea-level-rise.html

Terminology	Description / Explanation
Anthropogenic	*Made by people or resulting from human activities. Usually used in the context of emissions that are produced as a result of human activities* [13]
Atmosphere	*The gaseous envelope surrounding the Earth. The dry atmosphere consists almost entirely of nitrogen (78.1% volume mixing ratio) and oxygen (20.9% volume mixing ratio), together with a number of trace gases, such as argon (0.93% volume mixing ratio), helium, radiatively active greenhouse gases such as carbon dioxide (0.035% volume mixing ratio), and ozone. In addition, the atmosphere contains water vapor, whose amount is highly variable but typically 1% volume mixing ratio. The atmosphere also contains clouds and aerosols.* [11]
Atmosphere (Layer)	***Stratosphere:*** *Region of the atmosphere between the troposphere and mesosphere, having a lower boundary of approximately 8 km at the poles to 15 km at the equator and an upper boundary of approximately 50 km. Depending upon latitude and season, the temperature in the lower stratosphere can increase, be isothermal, or even decrease with altitude, but the temperature in the upper stratosphere generally increases with height due to absorption of solar radiation by ozone.*
Atmosphere (Layer)	***Troposphere:*** *The lowest part of the atmosphere from the surface to about 10 km in altitude in mid-latitudes (ranging from 9 km in high latitudes to 16 km in the tropics on average) where clouds and "weather" phenomena occur. In the troposphere temperatures generally decrease with height.*
Atmospheric Lifetimes	*Atmospheric lifetime is the average time that a molecule resides in the atmosphere before it is removed by chemical reaction or deposition. This can also be thought of as the time that it takes after the human-caused emission of a gas for the concentrations of that gas in the atmosphere to return to natural levels. Greenhouse gas lifetimes can range from a few years to a few thousand years.*
Biosphere	*The part of the Earth system comprising all ecosystems and living organisms, in the atmosphere, on land (terrestrial biosphere) or in the oceans (marine biosphere), including derived dead organic matter, such as litter, soil organic matter and oceanic detritus.* [2]
Carbon Capture and Sequestration	*Carbon capture and sequestration (CCS) is a controversial set of technologies that alleges to greatly reduce carbon dioxide emissions from new and existing coal- and gas-fired power*

Terminology	Description / Explanation
	plants, industrial processes, and other stationary sources of carbon dioxide. It is a three-step process that includes capture of carbon dioxide from power plants or industrial sources; transport of the captured and compressed carbon dioxide (usually in pipelines); and underground injection and geologic sequestration, or permanent storage, of that carbon dioxide in rock formations that contain tiny openings or pores that trap and hold the carbon dioxide. It is controversial in that the method perpetuates the continued burning of fossil fuels.
Carbon Cycle	*All parts (reservoirs) and fluxes of carbon. The cycle is usually thought of as four main reservoirs of carbon interconnected by pathways of exchange.* *The reservoirs are the atmosphere, terrestrial biosphere (usually includes freshwater systems), oceans, and sediments (includes fossil fuels). The annual movements of carbon, the carbon exchanges between reservoirs, occur because of various chemical, physical, geological, and biological processes. The ocean contains the largest pool of carbon near the surface of the Earth, but most of that pool is not involved with rapid exchange with the atmosphere.*
Carbon Dioxide Equivalent	*A metric measure used to compare the emissions from various greenhouse gases based upon their global warming potential (GWP). Carbon dioxide equivalents are commonly expressed as "million metric tons of carbon dioxide equivalents ($MMTCO_2Eq$)." The carbon dioxide equivalent for a gas is derived by multiplying the tons of the gas by the associated GWP.* $MMTCO_2Eq$ = (million metric tons of a gas) * (GWP of the gas)
Carbon Dioxide	*A naturally occurring gas, and also a by-product of burning fossil fuels and biomass, as well as land-use changes and other industrial processes. It is the principal human caused greenhouse gas that affects the Earth's radiative balance. It is the reference gas against which other greenhouse gases are measured and therefore has a Global Warming Potential of 1.*
Carbon Dioxide Removal	*Technologies, practices and approaches that remove and durably store carbon dioxide from the atmosphere. (IPCC)*
Carbon Footprint	*The total amount of greenhouse gases that are emitted into the atmosphere each year by a person, family, building, organization, or company. A person's carbon footprint includes greenhouse gas emissions from fuel that an individual burns directly, such as by heating a home or riding in a car. It also includes greenhouse gases that come from*

Terminology	Description / Explanation
	producing the goods or services that the individual uses, including emissions from power plants that make electricity, factories that make products, and landfills where trash gets sent.
Carbon Sequestration	*Terrestrial, or biologic, carbon sequestration is the process by which trees and plants absorb carbon dioxide, release the oxygen, and store the carbon. Geologic sequestration is one step in the process of carbon capture and sequestration (CCS) and involves injecting carbon dioxide deep underground where it stays permanently.*
Climate	*Climate in a narrow sense is usually defined as the "average weather," or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands of years. The classical period is 3 decades, as defined by the World Meteorological Organization (WMO). These quantities are most often surface variables such as temperature, precipitation, and wind.* *A simpler definition is: Climate is the average of the weather patterns in a location over a longer period of time, usually 30 years or more.*[12]
Climate Change	*Climate change refers to any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among others, which occur over several decades or longer.*
Climate Feedback	*A process that acts to amplify or reduce direct warming or cooling effects.*
Climate Lag	*The delay that occurs in climate change as a result of some factor that changes only very slowly. For example, the effects of releasing more carbon dioxide into the atmosphere occur gradually over time because the ocean takes a long time to warm up in response to a change in radiation.*
Climate Sensitivity Model	*In Intergovernmental Panel on Climate Change (IPCC) reports, equilibrium climate sensitivity refers to the equilibrium change in global mean surface temperature following a doubling of the atmospheric (equivalent) CO_2 concentration. More generally, equilibrium climate sensitivity refers to the equilibrium change in surface air temperature following a unit change in radiative forcing (degrees Celsius, per watts per square meter, (C/Wm-2).*

[12] www.NOAA.gov

Terminology	Description / Explanation
Climate System	The five physical components (atmosphere, hydrosphere, cryosphere, lithosphere, and biosphere) that are responsible for the climate and its variations.
Concentration	*Amount of a chemical in a particular volume or weight of air, water, soil, or other medium.*
Cryosphere	*One of the interrelated components of the Earth's system, the cryosphere is frozen water in the form of snow, permanently frozen ground (permafrost), floating ice, and glaciers. Fluctuations in the volume of the cryosphere cause changes in ocean sea level, which directly impact the atmosphere and biosphere.*
Decarbonization	*Reduction or elimination of carbon dioxide from an energy source or production process.*
Embodied Carbon	*Carbon dioxide emissions related to building materials and construction, including the extraction, production, transport and manufacturing of materials. Sometimes referred to as embodied greenhouse gas (GHG) emissions (EPA)*
Emissions	*The release of a substance (usually a gas when referring to the subject of climate change) into the atmosphere.*
Emissions Factor	*A unique value for scaling emissions to activity data in terms of a standard rate of emissions per unit of activity (e.g., grams of carbon dioxide emitted per barrel of fossil fuel consumed, or per pound of product produced).*
Enhanced Greenhouse Effect	*The concept that the natural greenhouse effect has been enhanced by increased atmospheric concentrations of greenhouse gases (such as CO_2 and methane) emitted as a result of human activities. These added greenhouse gases cause the earth to warm.*
Forcing Mechanism	*A process that alters the energy balance of the climate system, i.e., changes the relative balance between incoming solar radiation and outgoing infrared radiation from Earth. Such mechanisms include changes in solar irradiance, volcanic eruptions, and enhancement of the natural greenhouse effect by emissions of greenhouse gases.*
Geosphere	*The soils, sediments, and rock layers of the Earth's crust, both continental and beneath the ocean floors.*
Global Average Temperature	*An estimate of Earth's mean surface air temperature averaged over the entire planet.*
Global Warming Potential	*A measure of the total energy that a gas absorbs over a particular period of time (usually 100 years), compared to carbon dioxide.*
Global Warming	*The recent and ongoing global average increase in temperature*

Terminology	Description / Explanation
	near the Earth's surface.
Greenhouse Effect	*Trapping and build-up of heat in the atmosphere (troposphere) near the Earth's surface. Some of the heat flowing back toward space from the Earth's surface is absorbed by water vapor, carbon dioxide, ozone, and several other gases in the atmosphere and then reradiated back toward the Earth's surface. If the atmospheric concentrations of these greenhouse gases rise, the average temperature of the lower atmosphere will gradually increase.*
Greenhouse Gas (GHG)	*Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include:* 1. *carbon dioxide* 2. *methane (note that natural gas is 70-90% methane)* 3. *nitrous oxide* 4. *fluorinated gases (F-Gases)* ○ *hydrofluorocarbons (HFCs)* ○ *perfluorocarbons (PFCs)* ○ *nitrogen trifluoride (NF_3)* ○ *sulfur hexafluoride (SF_6)*
Hydrosphere	*The component of the climate system comprising liquid surface and subterranean water, such as: oceans, seas, rivers, freshwater lakes, underground water etc.*
Indirect Emissions	*Indirect emissions from a building, home or business are those emissions of greenhouse gases that occur as a result of the generation of electricity used in that building. These emissions are called "indirect" because the actual emissions occur at the power plant which generates the electricity, not at the building using the electricity.*
Infrared Radiation	*Infrared radiation consists of light whose wavelength is longer than the red color in the visible part of the spectrum, but shorter than microwave radiation. Infrared radiation can be perceived as heat. The Earth's surface, the atmosphere, and clouds all emit infrared radiation, which is also known as terrestrial or long-wave radiation. In contrast, solar radiation is mainly short-wave radiation because of the temperature of the Sun.*
Longwave Radiation	*Radiation emitted in the spectral wavelength greater than about 4 micrometers, corresponding to the radiation emitted from the Earth and atmosphere. It is sometimes referred to as 'terrestrial radiation' or 'infrared radiation,' although somewhat imprecisely.*

Terminology	Description / Explanation
Metric Ton	*Common international measurement for the quantity of greenhouse gas emissions. A metric ton is equal to 2205 lbs. or 1.1 short tons.*
Mitigation	*A human intervention to reduce the human impact on the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks.*
Operational Carbon	*Carbon dioxide emissions related to building energy use [heating, cooling, ventilation, power, etc]*
Parts Per Billion (ppb)	*Number of parts of a chemical found in one billion parts of a particular gas, liquid, or solid mixture.*
Parts Per Million (ppm)	*Number of parts of a chemical found in one million parts of a particular gas, liquid, or solid.*
Parts Per Trillion (ppt)	*Number of parts of a chemical found in one trillion parts of a particular gas, liquid or solid.*
Radiation	*Energy transfer in the form of electromagnetic waves or particles that release energy when absorbed by an object.*
Radiative Forcing	*A measure of the influence of a particular factor (e.g., greenhouse gas (GHG), aerosol, or land use change) on the net change in the Earths energy balance.*
Short Ton	*Common measurement for a ton in the United States. A short ton is equal to 2,000 lbs. or 0.907 metric tons.*
***Sink* (or Removals)**	*Any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas or aerosol from the atmosphere.*
Solar Radiation	*Radiation emitted by the Sun. It is also referred to as short-wave radiation. Solar radiation has a distinctive range of wavelengths (spectrum) determined by the temperature of the Sun.*
Ultraviolet Radiation	*The energy range just beyond the violet end of the visible spectrum. Although ultraviolet radiation constitutes only about 5 percent of the total energy emitted from the sun, it is the major energy source for the stratosphere and mesosphere, playing a dominant role in both energy balance and chemical composition.* *Most ultraviolet radiation is blocked by Earth's atmosphere, but some solar ultraviolet penetrates and aids in plant photosynthesis and helps produce vitamin D in humans. Too much ultraviolet radiation can burn the skin, cause skin cancer and cataracts, and damage vegetation.*[12]
Vulnerability	*The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including*

Terminology	Description / Explanation
	climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed; its sensitivity; and its adaptive capacity.
Weather	*Weather is what you experience when you step outside on any given day. In other words, it is the state of the atmosphere at a particular location over the short-term.*[13]

1.4. Greenhouse Gases

Greenhouse gases have been found to be the most significant drivers of climate change. Among others, carbon dioxide is the major contributor of greenhouse gas emissions. A significant contributor of carbon dioxide is electricity generation and transportation.

The following four indicators are related to greenhouse gases.

- In 2022, US greenhouse gas emission totaled 5.489 million metric tons of carbon dioxide equivalents after accounting for sequestration from the land sector, increasing 1 percent fro m2021. This total represents a 1 percent increase since 2021 but a 12 percent decrease since 2005; the increase is largely due to fossil fuel combustion. (EPA) Carbon dioxide accounts for the majority of U.S emissions. Transportation in the U.S. is the major contributor of carbon dioxide followed by electrical power generation. U.S. greenhouse gas emissions data is made available by two EPA programs (a) Inventory of U.S. Greenhouse Gas Emissions and Sinks, and (b) the Greenhouse Gas Reporting Program. In the former Program, national energy data, data on national agricultural activities, and other national statistics are used to account for total greenhouse gas emissions for all man-made sources. In the latter Program, annual emissions data from industrial sources are collected.

- Global Greenhouse Gas Emissions - Between 1990 and 2015, global emissions of all major greenhouse gases increased by 43%. Emissions of carbon dioxide increased by 51 percent, over this period, which is particularly important because carbon dioxide accounts for nearly three-fourths of total global emissions. In the U.S., the majority of emissions results from electricity generation, transportation and other energy production-related use.

- Atmospheric Concentrations of Greenhouse Gases - Global atmospheric concentrations of carbon dioxide, methane, nitrous oxide, and certain manufactured greenhouse gases have all risen over the last few hundred years. Before the industrial era began in the late 1700s, carbon dioxide concentrations measured approximately 280 ppm. Concentrations

[13] www.NOAA .gov

have risen steadily since then, reaching an annual average of 419 ppm in 2023—a 49 percent increase. Almost all of this increase is due to human activities. (source: EPA)

- Climate Forcing – This refers to a change in the Earth's energy balance resulting in positive (warming effect) or negative climate forcing [14](cooling effect). Between 1990 and 2019, the total warming effect from anthropogenic greenhouse gases increased by 45 percent. At the same period, the warming effect owing to carbon dioxide alone is by far the largest share of radiative forcing. Carbon dioxide accounts for approximately 36 percent of the overall increase in radiative forcing since 1990.

1.5. International Agreements & Consortiums

IPCC

The Intergovernmental Panel on Climate Change (IPCC) was setup in 1988 by two United Nation (UN) organizations, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). IPCC is the foremost authoritative international body for assessing the science related to climate change, its impacts and future risks, and options for adaptation and mitigation.

> ***"If left unchecked, from 2000 and 2100, global average temperatures increases of 2 to 5 degree Celsius and sea level rise of 2 to 4 feet are likely, and much larger increases are possible."***
>
> \- IPCC 2013 Report

[14] For more on climate forcing, refer http://ossfoundation.us/projects/environment/global-warming/radiative-climate-forcing

Figure 1.5.1
From NASA's Global Climate Change – Vital Signs of the Planet website
https://climate.nasa.gov/climate_resources/26/

"The graphic above lists four highlights from the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report Summary for Policy Makers, released September 27, 2013, which more than 25 NASA scientists helped author and review. The report is the work of 209 lead authors and 50 review editors from 39 countries, and over 600 contributing authors from 32 countries."

Kyoto Protocol

The Kyoto Protocol is an international treaty that extends the 1992 UNFCCC's commitment to reduce greenhouse gas emissions. This protocol deals with reducing greenhouse gas concentrations in the atmosphere to a "level that would prevent dangerous anthropogenic interference with the climate system." [15]This Protocol was adopted in 1997, and as of December 2012, 192 parties have ratified this Protocol.

The central aim of Kyoto Protocol is:

> ***"To reduce greenhouse gas emissions, based on the fact that***
> ***(a) global warming exists and***
> ***(b) human-made CO_2 emissions have caused it."***

[15] http://unfccc.int/resource/docs/convkp/kpeng.pdf

There are seven Green House Gases (GHG)s listed in the Kyoto Protocol are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3).

It is to be noted that United States has not ratified this Protocol as of 2024 and so it has little consequence in the US. It is worth knowing about since it may have some relevance when dealing with international projects.

Montreal Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol)

The Montreal Protocol is an international treaty that deals with substances that deplete the stratospheric ozone layer by phasing out the production of ozone depleting substances. This Protocol was agreed in 1987 and enforced on 1st January 1989. This Protocol has been ratified by 197 countries making it the first international treaty of the United Nations that achieved a universal ratification and considered by many as the most successful global action on an environmental issue.

The central aim of Montreal Protocol is:

> ***"To protect the ozone layer by phasing out the production of numerous substances that are responsible for ozone depletion."***

This treaty focused on ozone depleting substances that contain either chlorine or bromine and implemented Phase-out Management Plans for (1) Chloro-Fluoro-Carbons (CFCs), (2) Hydro-Chloro-Fluoro-Carbons (HCFCs), and (3) Hydro-Fluoro-Carbons (HFCs). Studies have shown that since the treaty was signed in 1987, the atmospheric concentrations of ozone depleting substances that contain chlorine has decreased or levelled-off. In the U.S., it is estimated that over 280 million cases of skin cancer, 1.5 million skin cancer deaths, and 45 million cataracts were prevented thanks to the Montreal Protocol (US EPA 2015).[16]

[16] Updating Ozone Calculations and Emissions Profiles for Use in the Atmospheric and Health Effects Framework Model http://www.epa.gov/ozone/science/effects/AHEF_2015_Update_Report-FINAL_508.pdf

This concludes Part 1 of the course.

END – Part 1

Part 2 will focus on how buildings and interact with the environment and impact climate change and influence the Net Zero goal.

Review Questions

1) **Identify the Agreement that aims "to keep the global temperature rise this century well below 2 degrees Celsius above pre-industrial levels."**
   a. Kyoto Protocol
   b. Paris Agreement
   c. Montreal Protocol
   d. None of the above
2) **________________refers to the total amount of Greenhouse Gases that are emitted into the atmosphere each year by a person, family, building, organization, or company.**
   a. Carbon Footprint
   b. Carbon Sequestration
   c. Carbon Capture
   d. Carbon Cycle
3) **John Muir is:**
   a. The author of the Net Zero manifesto
   b. An American politician who promoted the U.S. withdrawal from the Paris Agreement
   c. A Canadian climate expert.
   d. credited as being America's first environmentalist.
4) **IPCC stands for:**
   a. International Protocol for Climate Change
   b. Intergovernmental Panel on Climate Change
   c. Interim Program for Concerned Citizens
   d. Intra-National Pact of Climate Concerns

PART 2

NetZer0 Design - A Primer for Architects

Disclaimer Notice:

This course is intended to provide information as an educational benefit for architects and design professionals. The author and instructor have attempted to present a summation of the concepts and published data in a manner that intended to clarify these for architects. While the Information contained in this course has been reviewed and presented with all due care, the author does not warrant or represent that the Information is free from errors or omission. The author and instructor accept no liability whatsoever for, or in respect of any use or reliance upon this publication by any party. Author: Muhammad Siddiqui. Instructor: Sandy Stannard

Course Outline

The course on NetZero Design is a five-part course broken down as follows:

PART 1 – Introduction to the Issues and Concepts Leading to the NetZero Aspiration

PART 2 – Background on How Buildings Impact and Interact with the Environment

PART 3 – Building Design Concepts for NetZero

PART 4 – Visions for the Future – Aspirations and Challenges

PART 5 – Standards, Regulations and Conscience

Part 1 of the course covered the historical background and context within which the environmental movements emerged and how mass urbanization and pollution focused attention on the need to address the situation. The concepts of global warming, climate change, greenhouse gases, carbon footprints and related topics were discussed. The section concluded with a review of some key international treaties, accords and protocols that have emerged as the sense of urgency around the need to halt and potentially reverse the damage that continues to be done. The discussion set the framework within which the idea of "Net Zero" has been adopted as a target for 2050.

To recap, ***"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."***[17]

In this section the focus will be on understanding how the building sector impacts the environment and contributes to the imbalance in greenhouse gas emissions. The section will also look at how climate and the natural environment in turn impact buildings and the built environment.

This course operates on the premise that an imbalance exists in the natural atmospheric environment and that this imbalance is causing climate change. This imbalance is due to emissions from human related (anthropogenic) activities causing increase in atmospheric concentrations of long- lived greenhouse gases (LLGHGs), thereby inducing radiative forcing on climate and resulting in "global warming".[18]

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

[18] *Understanding Carbon Emissions for Building Design*, Ravi Srinavasan and Jaya Lakshmanan, 2021.

PART 2 – How Buildings Impact & Interact with the Environment

2.1. The Role of Buildings

The building and related construction sectors comprise one of the major sources of greenhouse gas emissions contributing to climate change. The sector heavily uses raw materials, chemical processes, energy and equipment thereby contributing to greenhouse gas emissions. According to the International Energy Agency (IEA), the buildings and construction sector accounted for 30% of final energy use and 37% of energy and process-related carbon dioxide (CO_2) emissions in 2022. 2019 data indicates that eleven percent of these carbon dioxide emissions resulted from manufacturing building materials and products such as steel, cement and glass.[19] More specifically, cement manufacturing accounts for 7% of global carbon emissions, with steel contributing 7-9%, half of which can be attributed to buildings.[20]

There is a pressing need for the design sector to develop pathways to mitigate the impacts of climate change as well as adapt to the impacts of climate change on the built environment, because people spend much of their time inside buildings.

Given this context, change in relation to the natural and built environment will be discussed in the following structure:

a. Discuss buildings and their impact on climate change. The discussion will present interweaving system boundaries and scoping of emissions and removals, all with a common goal of mitigating climate change issues.

b. Examine the meaning of whole life and partial carbon footprint analysis of buildings.

c. Review the difference between carbon footprint analysis and life cycle assessment.

2.2. Buildings and Their Impact on Climate Change

A significant part of the natural earth environment has an overlay of man-made buildings and infrastructure among other things, the activities of which play a fundamental role in harnessing natural resources and providing energy, material and movement for the pursuit of human sustenance, experience and happiness. However, these activities propel a substantial amount of emissions to the atmosphere that gets to stay there anywhere from a few months to 50,000 years (or perhaps forever?) depending on the emission type. While in the atmosphere, this increased concentration of gases traps and radiates heat, forcing changes to the climate. This in turn threatens the sustenance, experience and happiness of humans. The impact is on a global scale affecting the entire ecosystem. As a result, it has become imperative even more than ever that humans become aware of the intensity of this problem and work collaboratively to alleviate the problem and achieve a state of resiliency.

Substantial groundwork has been done by organizations such as the *Intergovernmental Panel on Climate Change* (IPCC) by bringing together resources, researchers, and experts to a common unified ground to raise awareness and address issues of climate change. As mentioned in Part 1 of this course, International Protocols have begun to address the problems, albeit in targeted areas: the Montreal Protocol has successfully worked together with 179 countries which has

[19] https://www.iea.org/reports/global-status-report-for-buildings-and-construction-2019
[20] https://gbce.es/wp-content/uploads/2021/09/WorldGBC-NZCB-Commitment-Introduction-DG-Lite-2021.pdf

helped in alleviating the ozone depletion issue. The Kyoto Protocol initiated from Japan has played a key role in increasing the awareness and importance of curbing greenhouse gas emissions and led to the instituting of global environmental organizations, international standards and rating systems. And the Paris Agreement is so far the most comprehensive and action oriented with compact measurable targets including the all-encompassing Net Zero goals.

As has been noted, the building sector is one of the major contributors of greenhouse gas emissions. The operating energy use during the service life of the building has been the highest contributor and, therefore, the major focus of reduction in the past few decades. There has been a increasing movement towards low or zero energy and emissions buildings, surprisingly at competitive price tags in comparison to conventional buildings. This has been aided by regulatory requirements, policy instruments, incentive programs, technological advancements and, declining costs due to wider application.

Best practices as outlined by the IPCC Assessment Report 6 suggests over-arching design goals: (1) At the construction phase, the use of low-emission materials and a high performing envelope, (2) In the use phase, the specification of high efficiency appliances and equipment, an optimized use of the building itself and power provided with low emission energy sources and (3) at the disposal phase, the re-use and recycling of building materials and components.

The embodied energy and emissions of building materials and products is a major greenhouse gas contributor and has gained recent attention, especially with the advent of low energy buildings that lower life cycle operational energy use. Recent IPCC Assessment Report 5 Chapter 9 on Buildings [21]make the following important points about embodied energy and emissions of building materials and products.

1. *The total life cycle energy use of low-energy buildings is less than the conventional buildings, however the embodied energy of materials used in such buildings are generally higher.*[22]
2. *Wood-based wall systems require 10–20% less embodied energy than traditional concrete systems* [23] [24]*and that concrete-framed buildings require less embodied energy than steel- framed buildings.*[25]
3. *Insulation materials require a wide range of embodied energy per unit volume, and the time required to pay back the energy cost of successive increments insulation through heating energy savings increases as more insulation is added.*

[21] IPCC Assessment Report 5 - Chapter 9 - Buildings <https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_chapter9.pdf >
[22] Citherlet S., and T. Defaux (2007). Energy and environmental comparison of three variants of a family house during its whole life span. Building and Environment 42, 591–598. doi: 10.1016/j.buildenv.2005.09.025, ISSN: 03601323.
[23] Upton B., R. Miner, M. Spinney, and L. S. Heath (2008). The greenhouse gas and energy impacts of using wood instead of alternatives in residential construction in the United States. Biomass and Bioenergy 32, 1–10.
[24] Sathre R., and L. Gustavsson (2009). Using wood products to mitigate climate change: External costs and structural change. Applied Energy 86, 251–257.
[25] Xing S., Z. Xu, and G. Jun (2008). Inventory analysis of LCA on steel- and concrete-construction office buildings. Energy and Buildings 40, 1188–1193.

4. *The embodied energy of biomass-based insulation products is not lower than that of many non-biomass insulation products when the energy value of the biomass feedstock is accounted for but is less if an energy credit can be given for incineration with cogeneration of electricity and heat, assuming the insulation is extracted during demolition of the building at the end of its life.*[26]

With the spotlight on holistic environmental performance of buildings, an approach to a whole life assessment of buildings is gaining momentum. All the direct and indirect processes in the various stages of a building project that contribute to greenhouse gas emissions and removals are accounted for. Major sources of direct and indirect emissions and removals that occur over various stages of the life cycle of building projects can be categorized as follows:

Emissions from:	• energy use • material use • water use • land use • transportation use • chemical processes • construction processes • fugitive gas leakage • storage and distribution • waste processing • other sources
Removals from:	• sequestration, capture and utilization • other sinks

It is true that the building sector is one of the major contributors of these emissions, the good news is that the building sector can also substantially reduce the amount of these emissions through a combination of strategies i.e., by understanding the emission types and their global warming potential, accounting and reducing the greenhouse gas emissions, using methods to remove the uncalled-for greenhouse gases, using non-polluting renewable energy and fuels, using offsetting mechanisms, and last but not the least, building a resilient environment to adapt to the perils of an impending climate change.

In order to take all the necessary actions to reduce the amount of emissions and enhance removals, an understanding is required of all the processes associated with the building project that causes these emissions. This understanding lays the foundation of any environmental systems thinking and enables one to establish the system boundaries and scopes in order to develop meet mitigation goals.

System Boundary and Scope

[26] Ardente F., M. Beccali, M. Cellura, and M. Mistretta (2008). Building energy performance: A LCA case study of kenaf-fibres insulation board. Energy and Buildings 40, 1–10

The building project as a 'system' is a vast set of interacting or interdependent components and processes that coalesce into an intricate functioning whole during the course of its service life. What becomes more convoluted is the interminable progression of delineating the boundary of the 'system' for assessing environmental impacts. To illustrate: Does a building cease to have impact if it no longer in use and not consuming or emitting energy? What, then, about the degradation of and depletion effects of the residual materials?

A universally agreed upon procedure had long been absent until organizations like International Standards Organization (ISO), European Standards (EN) on the one hand and Greenhouse Gas Protocol on the other hand laid the foundations for system boundary conditions. The former group focused on a life-cycle stages approach specifically for buildings and the latter group focused on a control and ownership approach specifically from a reporting entity viewpoint.

I. <u>Based on Life-cycle Stages</u>[27]

There are five distinct life cycle stages for buildings namely: Product Stage, Construction Stage, Use Stage, End-of-Life Stage and Beyond Stage. Each life cycle stage consists of several attributes or elements that increase or decrease concentrations of heat trapping greenhouse gases in the atmosphere, thereby influencing climate change.

Stage	System Boundary
Product Stage	Includes processes from extraction / refinement of raw materials to manufacturing of construction products. Includes emissions from raw material supply, transport and manufacturing.
Construction Stage	Includes processes from factory gate of construction products to practical completion of construction works. Includes emissions from transport and construction - installation process.
Use Stage	Includes processes from the practical completion of construction works to the point of deconstruction or demolition of building. Includes emissions from use, maintenance, repair, replacement, refurbishment, operational energy and water use.
End-of-Life Stage	Begins when the building is decommissioned and not meant for further use. Includes emissions from deconstruction / demolition, transport, waste processing and disposal.
Beyond Stage	Potential resources for future use. Includes reuse, recovery and recycling potential.

For a new building, the system boundary includes the building life cycle stages indicated above.

[27] 7 EN 15804+A2 (2022) - Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products – provides detailed rules of assessment of construction products; and EN 15978:2011 – Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method – provides detailed rules for assessing the environmental performance of whole buildings.

For an existing building or part thereof, the system boundary includes all the stages representing the remaining service life and the end-of-life stage of the building.

Life Cycle Assessment (LCA) Stages	Scope Summary
Cradle-to-gate	Product stage (required)
Cradle-to-gate with Practical completion	Product stage (required) + Construction stage (required)
Cradle-to-grave	Product stage (required) + Construction stage (required) + Use stage (required) + End-of-Life stage (required)
Cradle-to-Cradle	Product stage (required) + Construction stage (required) + Use stage (required) + End-of-Life stage (required) + Beyond Stage (Recycle to Product stage)

The figures below help illustrate two of the most important of these concepts[28]:

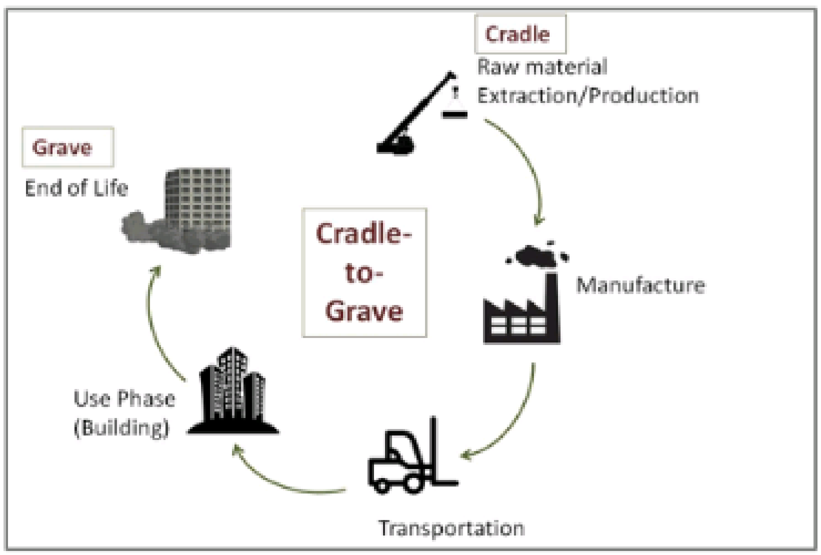


Figure 2.2.1
Cradle to Grave Life Cycle Assessment

[28] https://www.archecology.com/2017/05/31/life-cycle-assessment/

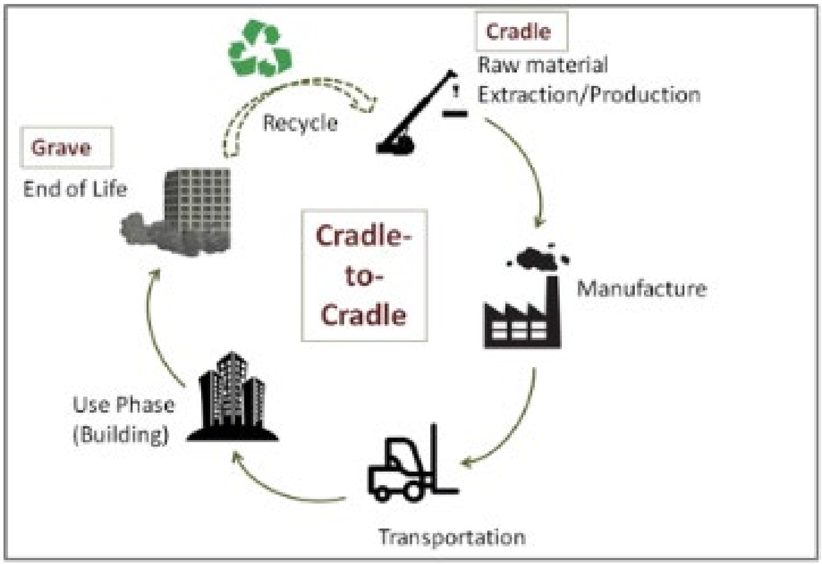


Figure 2.2.2
Cradle to Cradle Life Cycle Assessment

The use of LCA early in the design phase can help evaluate which design options would help to reduce the environmental impact of the building. It can influence design decisions regarding material selection (e.g., type of insulation, cladding material, etc.), structural system choice (e.g. wood frame structure v/s concrete or steel structure) and the quantity of materials required (e.g. number of columns or amount of insulation). LCA can help evaluate the trade-off between material selection, material quantity and energy performance (e.g., type and thickness of insulation v/s energy performance).[29]

Definitions from EN 15643-1:2010 - Sustainability of construction works. Sustainability assessment of buildings. General framework

System boundary *is the interface in the assessment between a building and its surroundings or other product systems.*

Service life or Working Life *is the period of time after installation during which a building or an assembled system (part of works) meets or exceeds the intended technical requirements and function*

Required Service Life *is the service life required by the client or regulations.*

[29] https://www.archecology.com/2017/05/31/life-cycle-assessment/

II. <u>Based on ownership and control of reporting entity</u>

Greenhouse Gas (GHG) emissions boundary conditions are set based on the ownership and control of the reporting entity. This approach provides a strong accounting approach of emissions across the board and is apt for existing residential and commercial reporting. This emissions accounting method has primarily been formulated by the Greenhouse Gas Protocol and has been widely accepted by business and government entities worldwide. The Greenhouse Gas Protocol (GHGP) provides standards, guidance, tools and training for business and government leaders to quantify and manage GHG emissions and become more efficient, resilient and prosperous.

According to GHGP, there are three distinct GHG accounting scopes namely: Scope 1 – Direct GHG Emissions, Scope 2 – Indirect GHG Emissions (Electricity) and Scope 3 – Other Indirect GHG Emissions, including both upstream and downstream emissions.

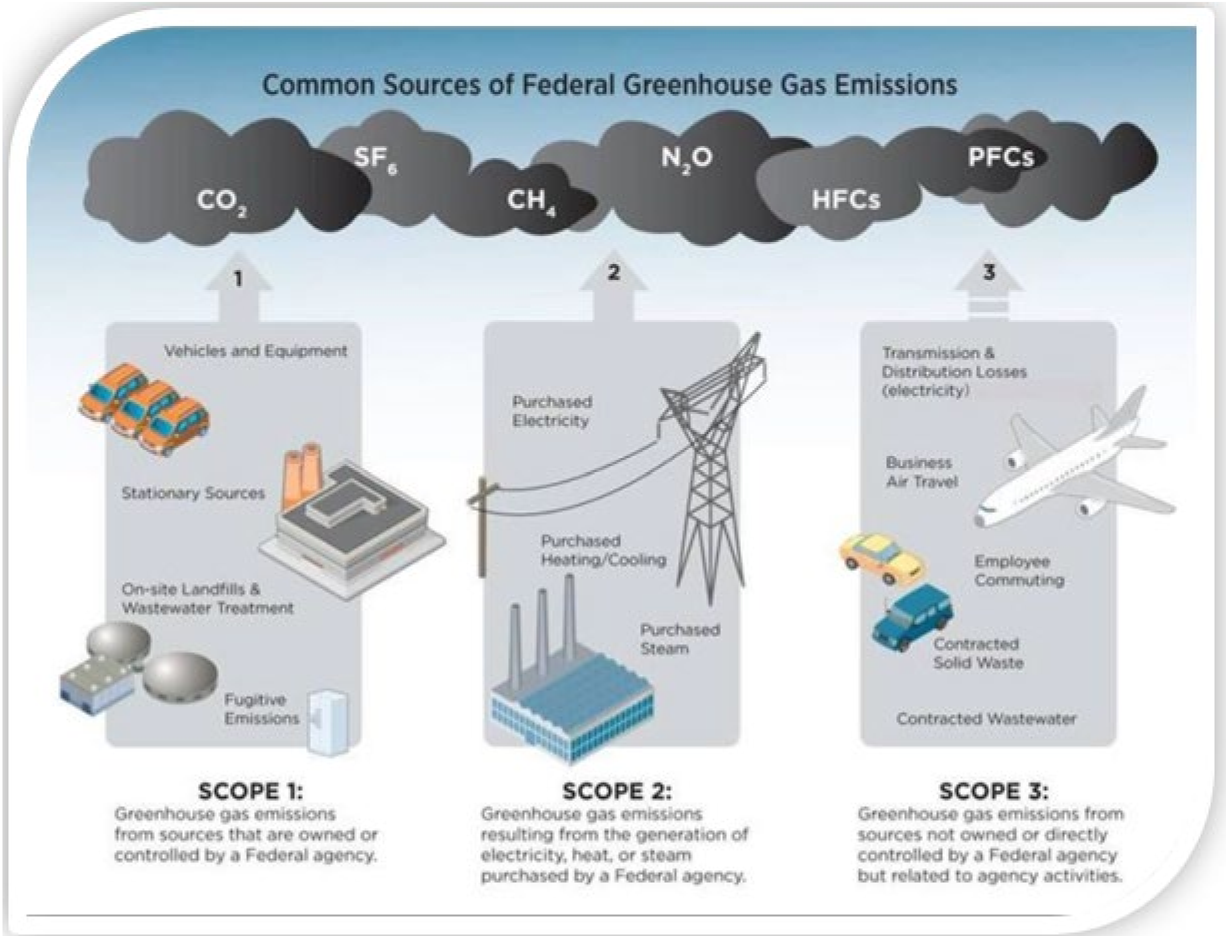


Figure 2.2.3
GHA Accounting at EPA[30]

The table below explicates with examples the three scope levels with the building in mind. It is not an exhaustive list and many elements and attributes related to other aspects of a reporting entity which is typically included such as downstream activities etc., of the reporting entity is not discussed.

[30] https://www.epa.gov/greeningepa/greenhouse-gases-epa

Scope and Boundary Condition		Examples
Scope 1: Direct greenhouse gas emissions or removals	Emissions or removals of GHGs from sources controlled or owned by the reporting entity, as a result of using a product system.	• Stationary Combustion of natural gas and petroleum for heating and cooking emits carbon dioxide, methane and nitrous oxide. • Combustion of fuels in facility vehicles can emit carbon dioxide and in small amounts methane and nitrous oxide. • Organic waste sent to landfill emits methane. • Wastewater treatment plants emit methane and nitrous oxide. • Fluorinated gas used in air conditioning and refrigeration may leak during service or due to leaking equipment.
Scope 2: Indirect greenhouse gas emissions or removals **– Purchased Energy**	Emissions and removals of GHGs from sources that are not directly controlled or owned by reporting entity, as a result of purchasing energy for consumption.	• Emissions associated with generation of purchased energy for consumption (such as natural gas, which is 70-90% methane).

Scope and Boundary Condition		Examples
Scope 3: Indirect greenhouse gas emissions or removals – Others	Emissions and removals of GHGs from sources that are not directly controlled or owned by reporting entity, as a result of using a product system other than purchased energy for consumption.	• Construction materials release various types of GHGs based on the energy type and chemical process used at the time of manufacture. • Construction processes release various types of GHGs based on the energy type and chemical process used at the time of construction. • Extraction, production and transportation of fuels used to generate electricity such as coal mining processes release methane, petroleum refining processes may emit carbon dioxide and methane, drilling and extraction of natural gas may leak methane, and production of hydrogen (if used as fuel) may release carbon dioxide. • Transmission and Distribution (T&D) emission losses of purchased electricity from systems and sources not owned by the business. • End-of-Life process such as demolition, transportation and combustion of materials in land-fill release GHGs.

2.3. The carbon Footprint of Buildings

Carbon Footprint Analysis [31]of Buildings is the total amount of greenhouse gases emitted and removed by the building project during either its entire life cycle, called the Whole Life Carbon Footprint Analysis or a relevant stage in the life cycle of the building namely Partial Carbon Footprint Analysis. Carbon Footprint Analysis of Buildings applies to both residential and non-residential sectors and can be used to assess all building types - existing, new or renovation buildings

<u>Whole Life Carbon Footprint Analysis of Buildings</u>

[31] ISO/TS 14067 Greenhouse gases -- Carbon footprint of products -- Requirements and guidelines for quantification and communication

A Whole Life Carbon Footprint Analysis of Buildings is the sum of greenhouse gas emissions and removals associated with a building project including both embodied and operational carbon, over its entire life cycle. Emissions and removals are focused on a single impact category i.e., climate change, measured in Carbon dioxide equivalent (CO_2e) and reported in pounds (lbs. CO_2e) or kilogram (kg. CO_2e) or Tonnes or Metric Tons (MT. CO_2e).

The system boundary for whole life accounting of carbon emissions and removals from buildings consists of five distinct life cycle stages:

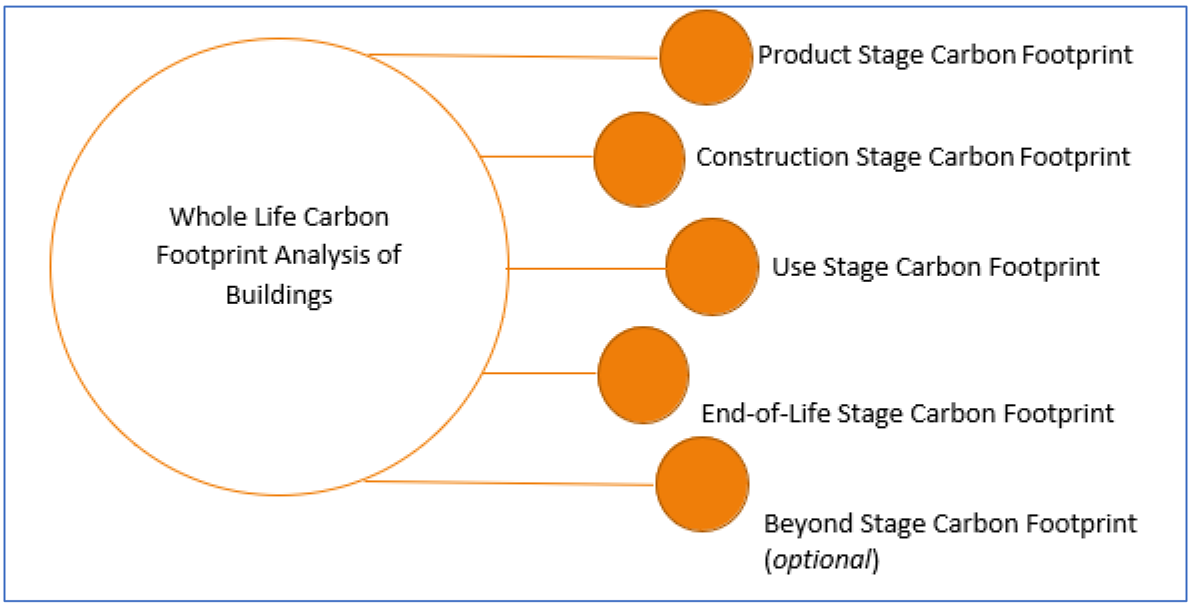


Figure 2.3.1

The sum of the five life cycle stages provides the ***whole life carbon footprint analysis for buildings***.

<u>Partial Carbon Footprint Analysis of Buildings</u>

Partial Carbon Footprint Analysis of Buildings is expressed the same way as Whole Life Carbon Footprint analysis of Buildings, except that only relevant stages of processes within a specified life cycle boundary are considered for analysis. Ideally, the aim of a carbon footprint analysis of buildings is to reduce the greenhouse gases associated with building activities that contribute to Global Warming and Climate Change. However, the processes analyzed in a partial carbon footprint analysis of buildings vary widely according to the goals and objectives of the assessment.

2.4. Differences Between Carbon Footprint and Life Cycle Assessment

In the era of environmental systems thinking, there are goals and objectives established by various visionary agencies or thought leaders in the industry. Most of these goals and objectives revolve around environmental impact categories. The spotlight maybe focused on either one or more categories depending on the acclimatizing mechanisms of the industry, presence of scientifically validated standards or guidelines and the rapidity at which a problem needs to be addressed. In this process two types of assessments evolved – on one hand, a comprehensive assessment of multiple environmental impact categories i.e., Life Cycle Assessment, and the other hand, a comprehensive assessment of a single environmental impact category, i.e., a subset of Life Cycle Assessment such as Carbon Footprint. While the life cycle thinking is the core of these two types of analysis, the difference is in the number of environmental impact categories that are included in each of the assessments, as shown below:

Difference Between Carbon Footprint & Life Cycle Assessment

Carbon Footprint of a Product (CFP)	Life Cycle Assessment (LCA)
International Standards Organization (ISO) 14067 defines Carbon Footprint of a Product (CFP) as *"the sum of greenhouse gas emissions and removals in a product system, expressed as CO_2 equivalents and based on a life cycle assessment using the single impact category of climate change*."	ISO 14040:2006 - Environmental management -- Life cycle assessment -- Principles and framework defines Life Cycle Assessment as "*compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle*."
Carbon Footprint Analysis is a **mono-criterion** approach to environmental analysis where it focuses only on one environmental impact category indicator i.e., the Global Warming Potential of Greenhouse Gas Emissions and its impact on Climate Change. Carbon Footprint of a Product is a **subset** of Life Cycle Assessment.	Life Cycle Assessment is a **multi-criteria** approach where it takes into consideration several environmental impact category indicators such as Global Warming Potential, Ozone Depletion Potential, Human Toxicity Potential, Eco-Toxicity Potential, Photochemical Ozone Creation Potential, Acidification Potential, and Nitrification Potential, to name a few.
Core Standards that govern Carbon Footprint of a Product are GHG Protocol, PAS 2050 and ISO 14067, 14064, 14065, 14066, 14069 and 16745.	Core Standards that govern Life Cycle Assessment are: ISO 14040, 14044, 14045, 14047, 14048, 14049, 14071 and 14072.
The above ISO Standards are discussed in Bibliography section of this Section. *GHG Protocol, PAS 2050 and other related Standards are discussed in later sections.*	

2.5. Importance of Carbon Footprint for Building Owners, Architects, Engineers and Contractors

So far there has been much discussion on how buildings play a major role in carbon emissions. This section focuses on the implications of Climate Change on buildings and its stakeholders.

According to the Intergovernmental Panel on Climate Change Sixth Assessment Report"[32] , the construction sector will be one of the sectors that is facing and will continue to face profound and direct impacts from Climate Change, even though the full extent of the impact cannot be currently estimated.

<u>Climate and Infrastructure in the U.S.</u>

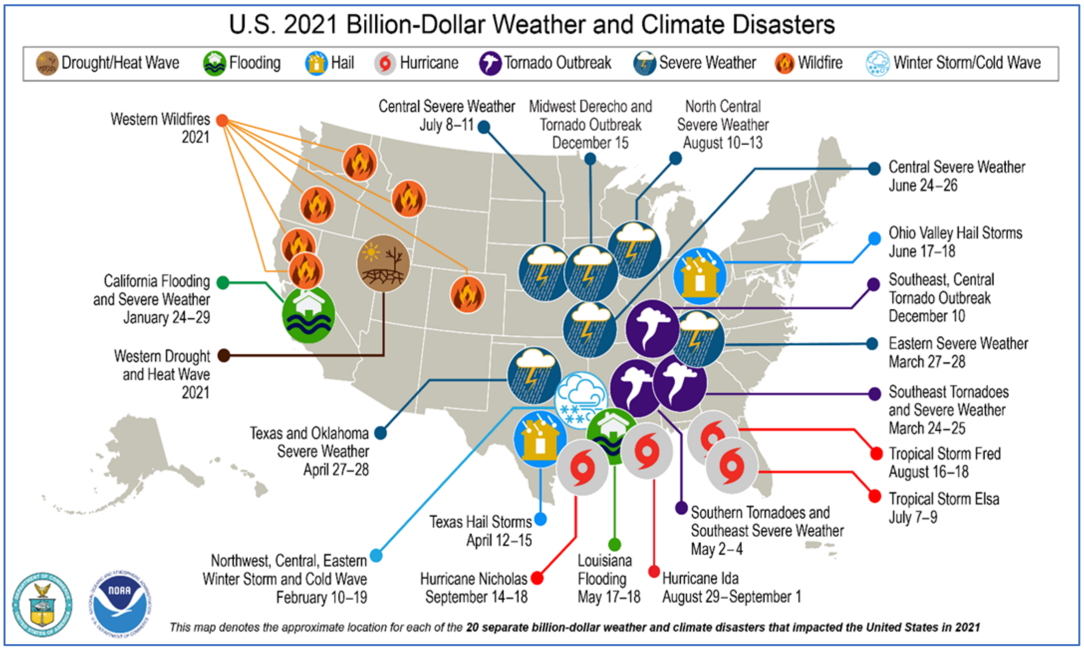
According to NOAA, since 1980, the U.S. has sustained 400 weather and climate disasters costing over $2.785 trillion[33].

More recently, in 2023, the U.S. sustained 28 weather and climate disaster with costs exceeding $1 billion each. These weather events are not evenly distributed across the U.S. with some states suffering more than others. However, the key points of the illustrations below are to show that the types, frequency, scale and distribution of the events is expanding and also encroaching into areas previously considered safe from threat. These disasters harm both the natural and the built environment. For example, depletion of forests or waterways reduces nature's ability to absorb GHGs even as disposal of damaged infrastructure and new construction add more GHGs. This further irritates the climate balance and so the cycle repeats and the accelerates.

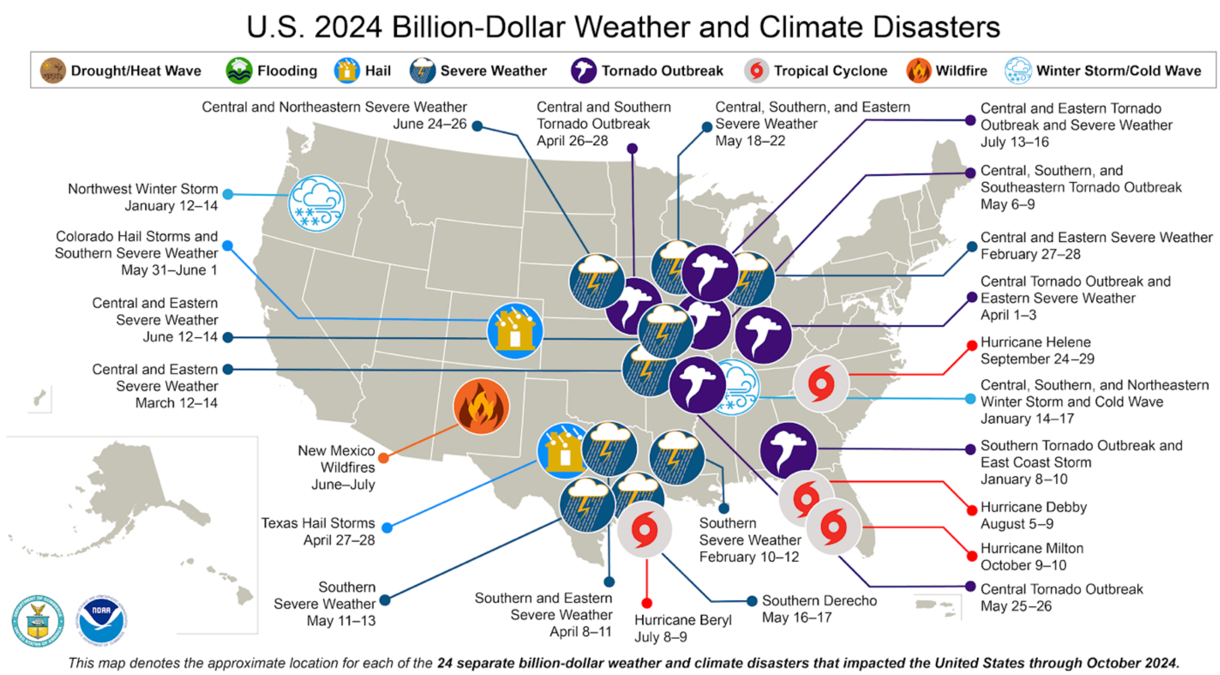
If, for no other reason than simple economic implications, the effects of climate change matter to any building owner, designer or builder. As the damages and risks increase, so does the cost of construction, the complexity of design responses, regulatory oversight and higher insurance rates and material costs.

To expand on this point, the following topics will highlight the risks and consequences of climate related events to the built environment.

[32] https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf
[33] NOAA (National Oceanic Atmospheric Administration) National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2024). < https://www.ncei.noaa.gov/access/billions/ >



Historically, the U.S. South, Central, and Southeast regions have experienced the highest frequency and highest cost from billion-dollar disaster events. Tropical cyclones have caused the most damage. Drought, severe storms, and inland have also caused considerable damage based on the list of billion-dollar events .In 2021, these events included 1 drought event, 2 flooding events, 11 severe storm events 4 tropical cyclone events, 1 wildfire event, and 1 winter storm event. These events resulted in 724 deaths of people and had significant economic effects on the areas impacted. The 1980-2021 annual average is 7.7 events; the annual average for the most recent 5 years (2017-2021) is 17.8 events.



So far, In 2024, these events included 17 severe storm events, 4 tropical cyclone events, 1 wildfire event, and 2 winter storm events. Overall, these events resulted in the deaths of 418 people and had significant economic effects on the areas impacted. The 1980–2023 annual average is 8.5 events (CPI-adjusted); the annual average for the most recent 5 years (2019–2023) is 20.4 events (CPI-adjusted).

Climate Related Impact on Buildings

Natural disasters cause multiple types of damage and consequential hardships. A certain number are expected over a span of time as part of a stable climate. However, when the frequency and intensity become abnormally severe or routine, building resiliency is required, inflating costs. When costs rise, partial solutions are often implemented and that can result in higher risks.

So, what kinds of damage do the various types of disasters cause to buildings?

For example, tornado outbreaks cause extensive damage to buildings including ripping off roofs. For example, the March 2017 Mideast Tornado Outbreak event caused, among other damage, substantial damage to a concrete building.

An unexpected freeze can cause building pipes to burst (freezing and thawing causes water pressure to increase and eventually leads to bursting pipes). In addition, freezing often results in high heating energy use. For example, the deep freeze in Texas in 2021, while lasting only 3 days, was unprecedented, causing billions of dollars of damage, multiple deaths and crashed the electricity grid.

Flooding damage may result from pressures leading to effects on buildings including wall failure, breaking of glass, collapsing of roofs, and loss of structural systems including foundations. To give an example, the August 2021 Hurricane Ida flooding event of near Port Fourchon, Louisiana was a $75 billion disaster. In Grand Isle, LA 100% of the homes had damage, and nearly 40% of those were completely destroyed. There was heavy damage to the energy infrastructure across southern Louisiana causing widespread, long-duration power outages to millions of people.

Below is a table listing just the billion-dollar disasters to affect the United States just in 2023. (Source: NOAA)[34]

Event	Summary
East Coast Storm and Flooding	December 2023: Powerful east coast storm from Florida to Maine produced widespread impacts from heavy rainfall, flooding, high winds and coastal erosion. The heavy rainfall and snowmelt were amplified by record-high temperatures in the Northeast.
Southern/Midwestern Drought and Heatwave	September 2023: Hail storms impact Texas, Oklahoma and Missouri. The most damaging impacts were in central Texas including Austin, Georgetown, Round Rock and Arlington on September 24. Towns north of Austin in particular were impacted by baseball sized hail causing damage to homes, vehicles and businesses.
Southern Hail Storms	September 2023: Hail storms impact Texas, Oklahoma and Missouri. The most damaging impacts were in central Texas including Austin, Georgetown, Round Rock and Arlington on September 24. Towns north of Austin in particular were

[34] 15 NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2024). < https://www.ncei.noaa.gov/access/billions/events/US/2023?disasters[]=all-disasters>

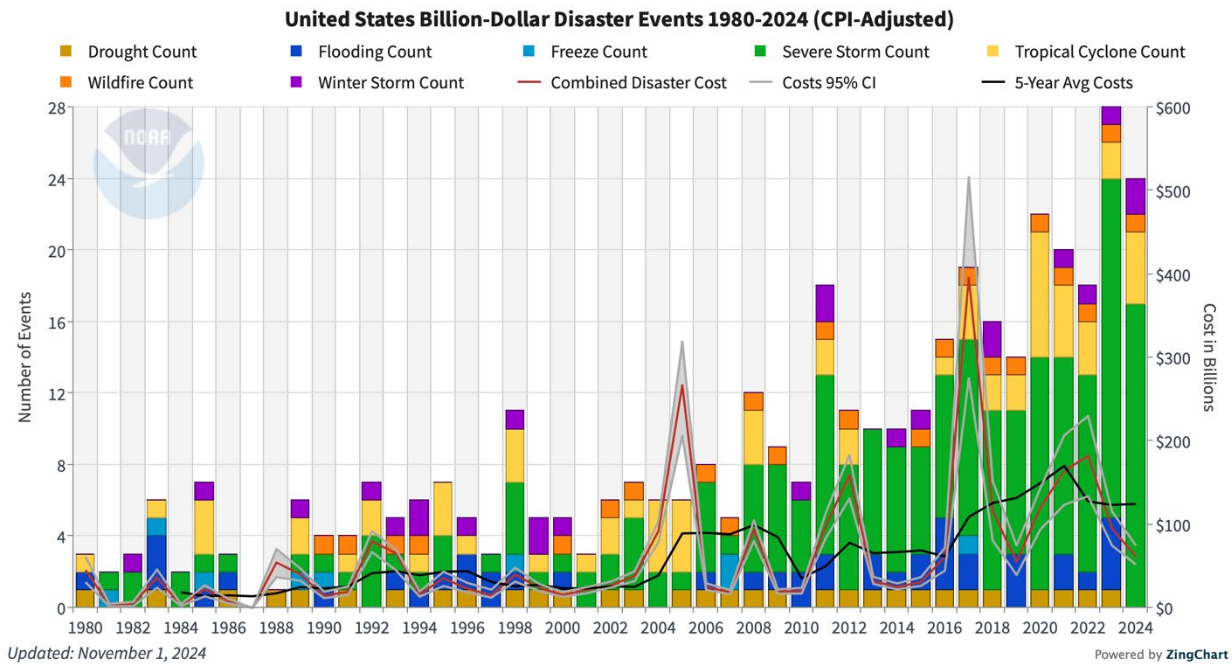
	impacted by baseball sized hail causing damage to homes, vehicles and businesses.
Hurricane Idalia	August 2023: Hurricane Idalia made landfall near Keaton Beach in the Big Bend region of Florida as a strong Category 3 hurricane with winds of 125 mph. Idalia was the strongest hurricane to hit the Big Bend region in more than 125 years. Storm surge was about 8 feet above ground at Cedar Key, which caused heavy damage to homes, businesses, vehicles and other infrastructure. Other Big Bend coastal communities were also inundated by storm surge. Idalia produced 5 to 10 inches of rainfall across the Big Bend region of Florida and southeastern portions of Georgia and the Carolinas. The relatively low population density of the Big Bend region helped to reduce the physical exposure and damage costs. Significant flooding was reported in downtown Charleston, SC and nearby Edisto Beach. There was also 2 to 4 feet of storm surge along the Carolina coastline, which was exacerbated by the full moon and high tide cycle.
Minnesota Hail Storms	August 2023: Numerous hail storms caused extensive damage across south-central Minnesota. Golf ball to baseball-sized hail caused damage to the windows, siding and roofs of many homes, vehicles and businesses.
Hawaii Firestorm	August 2023: Devastating wildfires destroyed the historic town of Lahaina on Maui Island of Hawaii. Winds were enhanced from the strength and position of a high-pressure system located northwest of Hawaii, which helped to exacerbate the wildfire as it spread on the island of Maui. Hurricane Dora was also positioned south of Hawaii. This was the deadliest wildfire in the U.S. in over a century. Thousands of homes, vehicles and businesses were destroyed.
Northeastern and Eastern Severe Weather	August 2023: More than one thousand reports of high wind, severe hail or tornadoes across many Northeastern and Eastern states. August 7 was a prolific day of severe weather with damage reports from Georgia to New York. These storms caused impacts to many homes, vehicles, businesses, agriculture and other infrastructure.
North Central and Eastern Severe Weather	July 2023: Severe storms caused damage across several North Central and Eastern states. The state most impacted were Nebraska, Missouri, Illinois, Indiana and Wisconsin. High wind, severe hail and tornadoes caused damage to many homes, vehicles, businesses and agriculture assets.

North Central and Southeastern Severe Weather	July 2023: Severe storms caused damage across several North Central and Southeastern states. The states most impacted were Michigan, Wisconsin, Ohio, Tennessee and Georgia. Ping pong to golf ball-sized hail and high winds damaged many homes, vehicles, businesses and other infrastructure.
Northeastern Flooding and North Central Severe Weather	July 2023: Severe storms brought devastation and flooding to portions of the Northeast, as areas reported up to eight inches of rain within a 24-hour period. Montpelier, Vermont received a record-breaking 5.28 inches of rain, flooding the city and damaging thousands of homes and businesses. The wide scale flooding in Vermont was similar to the flood impacts from Hurricane Irene in 2011. Early estimates put the flood damage in West Point, New York at more than $100 ($103.0) million. There was also considerable damage to roads, bridges and agriculture across the Northeast. Severe storms also caused high wind and hail impacts across Wisconsin, Minnesota and Illinois.
Central Severe Weather	June 2023: Severe storms caused damage across numerous Central states. The state most impacted were Missouri, Illinois and Indiana while there were also damage in many surrounding states. The damage to many homes, vehicles, businesses and agriculture assets was largely from high wind and damaging hail but there were also scattered tornado impacts.
Rockies Hail Storms and Central and Eastern Severe Weather	June 2023: Severe hail storms across Colorado damaged many homes, vehicles and injured approximately 100 people at a large outdoor concert. This multi-day outbreak of severe weather also produced more than 60 tornadoes across portions of Wyoming, Colorado, Minnesota, Indiana, Kentucky and Arkansas that caused damage to homes, businesses, vehicles, agriculture and other infrastructure.
Central and Southern Severe Weather	June 2023: Severe storms produce over one thousand reports of damaging weather across Oklahoma, Texas, Mississippi, Georgia, Florida, Arkansas and Ohio. Among these reports were over 70 preliminary tornadoes including an EF-3 tornado in Louin, Mississippi. This combination of high winds, hail and tornadoes caused damage to homes, businesses, vehicles, agriculture and other infrastructure. The damage was most focused in Oklahoma.
Southern Severe Weather	June 2023: Numerous southern states including Texas, Louisiana, Mississippi, Alabama, Georgia, Tennessee, Arkansas, South Carolina and Florida were impacted by hail, tornadoes and high winds. These storms caused damage to

	many homes, vehicles and businesses across several days of severe storm activity.
Typhoon Mawar	May 2023: A Category 4 Typhoon struck Guam on May 24 battering the island for 15 hours until the early morning of May 25. Typhoon Mawar's wind speeds of up to 145 mph damaged residential and commercial buildings, vehicles and infrastructure. Several U.S. military bases including Andersen Air Force Base sustained considerable damage. Guam's international airport also sustained flood damage.
Texas Hail Storms	May 2023: Texas hail storms impact numerous counties across north central Texas. Collin county in particular was impacted by golf ball to tennis ball sized hail causing damage to homes, vehicles and businesses.
Central and Eastern Tornadoes and Hail Storms	May 2023: Dozens of tornadoes and severe hail storms from the eastern Rockies and across several central states. The most costly severe hail impacts were focused in Colorado while numerous tornadoes also impacted western Kansas, central Oklahoma and eastern Nebraska. Texas and North Dakota were also impacted from combination of high winds, hail and isolated tornadoes with damage to homes, businesses, vehicles, farms and other infrastructure.
Central Severe Weather	May 2023: Severe weather across numerous central states including Missouri, Illinois, Iowa, and Indiana. There was additional damage in Kentucky, Tennessee, South Carolina and Texas. Large hail, high winds and tornadoes caused widespread impact to many homes, businesses, vehicles, farms and other infrastructure.
Southern Severe Weather	April 2023: Southern severe weather across Texas, Georgia and Florida. Considerable hail and wind damage to many homes, businesses, vehicles and other infrastructure.
Central Severe Weather	April 2023: Severe hail, scattered tornadoes and high winds caused damage across numerous central states. Central Oklahoma was impacted by a cluster of tornadoes. Texas, Missouri, Nebraska, Kansas, Iowa, Illinois and Wisconsin was impacted by hail and high wind damage from severe storms.
Central and Southern Severe Weather	April 2023: Several central and southern states including Missouri, Arkansas, Illinois, Texas, Louisiana and the Florida Panhandle were impacted by hail, tornadoes and high winds. These storms caused damage to many homes, vehicles and businesses.
Fort Lauderdale Flash Flood	April 2023: Historical rainfall and flash flooding inundated Fort Lauderdale and surrounding areas with over 25 inches

	of rainfall in less than 24 hours. This resulted in many flooded homes, vehicles and businesses. The Fort Lauderdale Airport also closed on April 13 due to the flooding.
Central and Eastern Severe Weather	April 2023: Severe storms produced large hail, high winds and more than 35 tornadoes across many central and southern states. The states most affected were Illinois, Kentucky, Iowa, Indiana, Ohio, Missouri and Michigan where there was considerable damage to homes, businesses, agriculture, vehicles and other infrastructure.
Central Tornado Outbreak and Eastern Severe Weather	March 2023: A historic tornado outbreak across numerous central states caused widespread damage from at least 145 tornadoes. States most impacted were Illinois, Indiana, Ohio, Missouri, Iowa, Arkansas, Tennessee and Pennsylvania where there was severe damage to homes, businesses, vehicles, agriculture and other infrastructure.
Southern and Eastern Severe Weather	April 2023: Southern and eastern severe storms including more than 40 tornadoes caused damage across Mississippi, Alabama, Georgia, Tennessee to many homes, businesses, vehicles and other infrastructure. Additional high wind damage occurred in parts of Ohio, West Virginia and Pennsylvania.
California Flooding	December 2022 – March 2023: Numerous atmospheric rivers in continuous succession caused severe flooding, record snowfall and copious rainfall that significantly reduced drought deficits across California, between late-December and March 2023. Flooding impacted many homes, businesses, levees, agriculture and other infrastructure particularly across central California.
Southern and Eastern Severe Weather	March 2023: Severe storms impact numerous southern and eastern states including Texas, Alabama, Mississippi, Tennessee, Kentucky, Indiana and Ohio. Impacts from high wind and tornadoes cause widespread damage to homes, vehicles, businesses, government buildings and infrastructure.
Northeastern Winter Storm/Cold Wave	February 2023: A strong winter storm produced snow, high winds and bitter cold across numerous Northeastern states. High winds caused widespread power outages in Massachusetts while Mount Washington, New Hampshire observed a wind chill temperature of -108 degrees Fahrenheit. This was one of the coldest wind chill temperatures ever recorded in the United States.

To see the long-term trend in billion-dollar disasters, the graphic below from NOAA shows the trend between 1980 and 2024. The values are CPI adjusted to account for inflation and normalize the value.



The International Institute of Sustainable Development (IISD), [35]an independent non-profit organization that provides practical solutions to the challenge of integrating environmental and social priorities with economic developments, provides a well-compiled list of implications and an IPCC based risk model of Climate Change on Building Infrastructure. The following contents have been reprinted with permission from Jessica Boyle the lead author of the report “Climate Change Adaptation and Canadian Infrastructure - A review of the literature”. This report summarizes current literature dealing with the challenge of adapting to climate change in Canada.

[35] See https://www.iisd.org/about/about-iisd

Climate Change and Infrastructure Impacts: Buildings[36]

CLIMATE HAZARD AND/OR WEATHERING PROCESS LIKELY AFFECTED BY A CHANGING CLIMATE	INFRASTRUCTURE IMPACTS
Permafrost degradation	▪ Soil subsidence and buckling can damage a property's foundation infrastructure ▪ Loss of strength in buildings, which can cause them to become uninhabitable ▪ Reduced strength and reliability of containment structures and other physical infrastructure
Hotter, drier summers and heat waves	▪ Building damage has sometimes been observed when clay soils dry out ▪ Forest fires can damage entire homes and businesses ▪ Premature weathering ▪ Increased indoor air temperature and reliance on cooling systems
Increased precipitation	▪ Reduced structural integrity of building components through mechanical, chemical and biological degradation ▪ Accelerated deterioration of building facades ▪ Premature weathering of input materials ▪ Increased fractures and spalling in building foundations ▪ Decreased durability of materials ▪ Increased efflorescence and surface leaching concerns ▪ Increased corrosion ▪ Increased mold growth
Increase rainfall, storm surges and higher tides	▪ Damaged or flooded structures ▪ Slope stability and integrity of engineered berms are also vulnerable to extreme precipitation ▪ Coastal infrastructure inducted ▪ Wharves to be rebuilt moved or raised to avoid inundation ▪ Increased risk of basement and localized flooding ▪ Increased corrosion in metals or deterioration in concrete
Hurricanes, tornadoes, hail, windstorms and ice storms	▪ Property destruction ▪ Damage building infrastructure ▪ Reduction of design safety margins ▪ Reduced service life and functionality of components and systems ▪ Increased risk of catastrophic failure ▪ Increased repair, maintenance, reserve fund contingencies and energy costs

[36] Reprinted from IISD. See page 13 Table 3 in http://www.iisd.org/pdf/2013/adaptation_can_infrastructure.pdf

2.6. Climate Risk

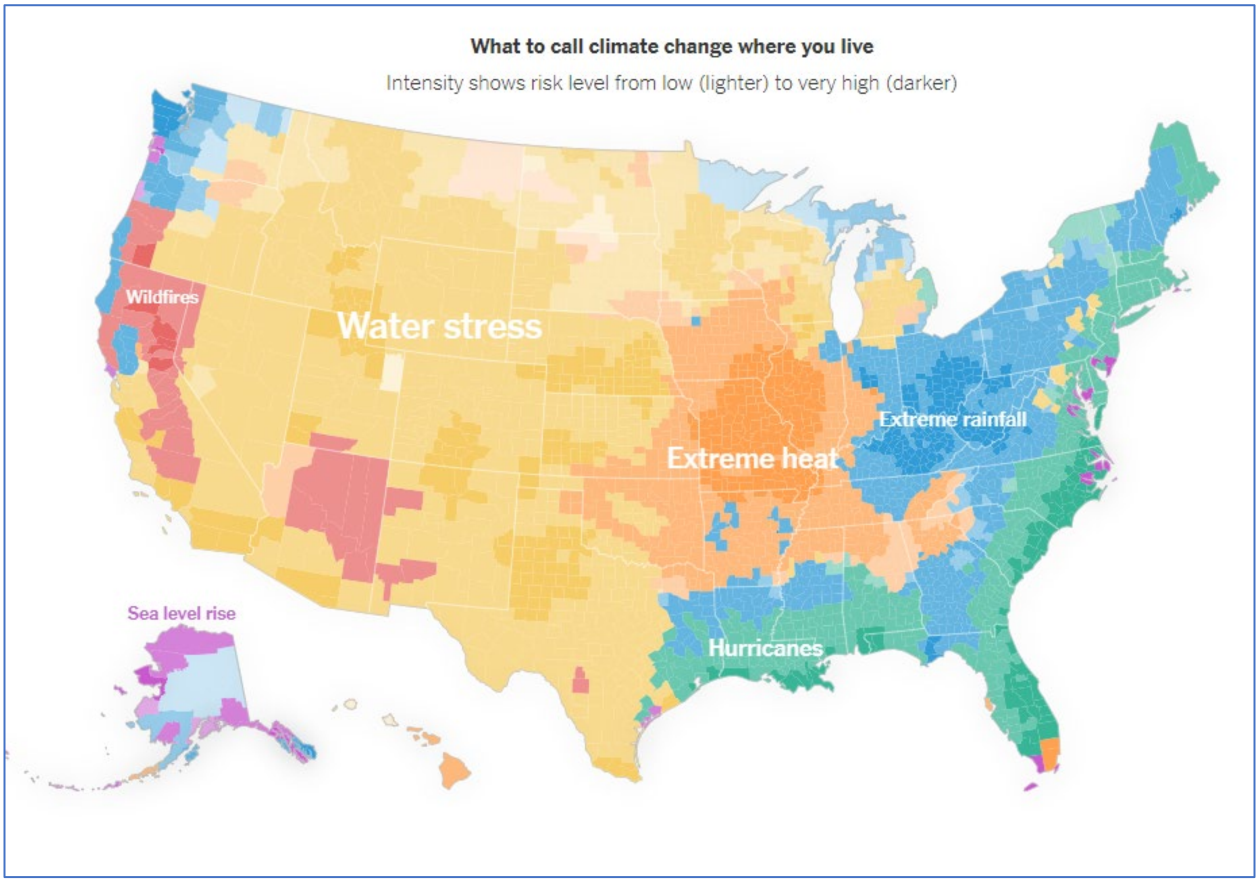
In a February 2022 publication, four partners at McKinsey & Company, a global management consulting firm, made the following assessment:

> *… These changes have brought a sense of urgency to the critical role of real-estate leaders in the climate transition, the period until 2050 during which the world will feel both the physical effects of climate change and the economic, social, and regulatory changes necessary to decarbonize. The climate transition not only creates new responsibilities for real-estate players to both revalue and future-proof their portfolios but also brings opportunities to create fresh sources of value.*
>
> *The combination of this economic transition and the physical risks of climate change has created a significant risk of mispricing real estate across markets and asset classes. For example, a major North American bank conducted analysis that found dozens of assets in its real-estate portfolio that would likely be exposed to significant devaluations within the next ten years due to factors including increased rates of flooding and job losses due to the climate transition. Additionally, a study of a diversified equity portfolio found that, absent mitigating actions, climate risks could reduce annual returns toward the end of the decade by as much as 40 percent.*[37]

To understand climate risks for a localized area in the United States, the New York Times has published a helpful tool [38]where subscribers can view an interactive climate risk map on their website and see county by county risks. A screen shot of the map is shown below with a link to their website.

[37] https://www.mckinsey.com/industries/real-estate/our-insights/climate-risk-and-the-opportunity-for-real-estate, Brodie Boland, Cindy levy, Rob palter and Daniel Stephens – February, 2022

[38] https://www.nytimes.com/interactive/2020/09/18/opinion/wildfire-hurricane-climate.html



https://www.nytimes.com/interactive/2020/09/18/opinion/wildfire-hurricane-climate.html

All things considered, Climate Change can significantly impact buildings and their stakeholders in many ways with some of the most important reasons being increase in: (1) premature or accelerated deterioration of building envelopes and enclosures, (2) construction delays and costs, (3) rebuilding, repair and maintenance work, (4) liability issues, (5) design requirements for buildings based on changing climatic patterns, (6) regulatory requirements, (7) energy demand, (8) health and safety risks for occupants, (9) indoor environment quality problems, (10) catastrophic failures, to name a few.

Therefore, there is a justifiable need to:

(1) Understand the vulnerability of the building sector to Climate Change by researching and identifying the impacts of Climate Change on the built environment,

(2) Establish mitigating pathways to reduce the impacts of Climate Change on the built environment, and…

(3) Revolutionize transformative pathways to building high performing and energy efficient as well as adaptable and resilient buildings and communities that can reinstate environmental balances, reinforce natural coexistence, and invigorate health, safety and well-being.

These needs have to be addressed together by all the stakeholders in the building sectors (policy makers, building owners, architects, engineers, contractors etc.) with much greater urgency and scale of action to not only avert the implications of Climate Change to the built environment, but also for the more altruistic objective of making the world a more habitable place for both humans as well as natural ecosystems.

2.7. What Now?

We started this section with the intent of exploring how buildings impact and interact with the environment. In the resulting discussion, we explored the interactive dynamic between buildings, their contributions to GHGs and the impact of climate change on the built environment. This has been a long developing situation with significant complexity. Designers of the built environment did not intend to harm the environment; but neither did many of them historically challenge the harmful side effects of their actions in any proactive or tangible manner – that is until this century when the alarm bells became loud enough to gain political and social attention. With the excuse of ignorance receding and clients no longer treating the subject of eco-friendly building design with disdain, the building industry, and particularly designers – Architects and engineers, are at the precipice of making decisions that will ultimately define the performance of their creations in relation to environmental sustainability. In some cases, regulations, codes and incentives will aid in this process; expanded knowledge may help further advance this effort. With increasing knowledge about Net Zero principles, with tangible targets and goals, leading design professionals are taking the legacy of the last 25 years of "green" architecture concepts, philosophies and ideas and increasingly incorporating them into new and adaptive re-use projects.

This concludes Part 2 of the course.

END – Part 2

The next part of the course (Part 3) will examine the many design concepts that have evolved and how they are being used to advance the changes that should reduce the building sector's contributions to GHGs. These in turn should make the target of Net Zero more achievable.

Part 2 Review Questions

5) **The key difference between Cradle-to-Grave and Cradle-to-Cradle is the added step for _______________**

a. Burial
b. New variations
c. Recycling
d. Clean manufacturing

6) **According to EN15643-1:2010, The period of time after installation during which a building or an assembled system (part of works) meets or exceeds the technical requirements and function is called:**

a. Working Life
b. System Boundary
c. Life Cycle
d. None of the above

7) **The long-term trend in billion dollar disasters between 1980 and 2024 has:**

a. Stayed remarkably stable
b. Dramatically decreased
c. Has increased
d. None of the above

PART 3

NetZer0 Design - A Primer for Architects

Disclaimer Notice:

This course is intended to provide information as an educational benefit for architects and design professionals. The author and instructor have attempted to present a summation of the concepts and published data in a manner that intended to clarify these for architects. While the Information contained in this course has been reviewed and presented with all due care, the author does not warrant or represent that the Information is free from errors or omission. The author and instructor accept no liability whatsoever for, or in respect of any use or reliance upon this publication by any party. Author: Muhammad Siddiqui. Instructor: Sandy Stannard

Course Outline

The course on NetZero Design is a five-part course broken down as follows:

PART 1 – Introduction to the Issues and Concepts Leading to the NetZero Aspiration

PART 2 – Background on How Buildings Impact and Interact with the Environment

PART 3 – Building Design Concepts for NetZero

PART 4 – Visions for the Future – Aspirations and Challenges

PART 5 – Standards, Regulations and Conscience

Part 2 of the course covered the topics of climate change and how the building sector contributes to Greenhouse Gasses. The section also examined the impact that the effects of climate change has on buildings.

In this part of the course, we will look at the concepts and techniques that building designers and builders can employ to help minimize, and eventually eliminate, the GHG contributions from buildings and reach the balance targeted by Net Zero.

To remind readers, ***"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."***[39]

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

PART 3 – Building Design Concepts for Net Zero

3.1 Search For Solutions

As populations have grown, buildings have followed suit. After all, shelter is one of the basic human necessities. However, with advances in technologies, abundant inexpensive energy, and the seemingly endless choices of materials and gadgets, the building boom has morphed from a necessity to a display of opulence and excess driven by short sighted consumerism rather than prudent functionality. It can be compared to an addiction. As such, in order to cure the ills brought on by this condition, it makes sense that the first step is the same for treating any addiction: acknowledging the problem! In this regard, it is reasonably accurate to say that the building design community has attained this state of consciousness. From here, the steps forward will determine whether building designers, master planners and builders can fulfil the promise offered by Net Zero design.

Before we look at concepts and evolving solutions, it should be recognized that the issue is very complex. The building design industry is continuously advancing, with new knowledge, materials, tools and processes not to mention changing regulatory environments, certifications and incentives. Architects and designers also need to evolve along with the industry.

Cities are facing unprecedented growth with an increase in population and urbanization. The United Nations estimates that the global population will increase to 9.8 billion by 2050, which is an increase of 2 billion people in the next 30 years. Also, over the same period, urban areas will grow faster and are anticipated to increase by 2.5 billion people[40]. This urbanization requires development of extensive infrastructure that imposes heavy loads on the environment in various forms, namely depletion of resources and contamination of air, water, and land. Furthermore, with an increase in migration of people from rural areas to cities and increases in energy consumption due to changing lifestyles, larger increases in greenhouse gas emissions will likely follow. These pressures are occurring at the same time there are efforts underway to contain, manage and mitigate the negative impacts of this growth. This dynamic situation is challenging for designers who are striving to attain the goals of Net Zero design. On the flip side, the constant need for new buildings and for updating older less efficient buildings offers an opportunity for improvement and an opportunity to incorporate the principles and concepts that will be discussed in this part of the course.

3.2 Concepts

As has been mentioned, Net Zero as a term owes its genesis to the Paris Agreement of 2015. However, the idea of reducing and even reversing GRG emissions has been around from much earlier. Many different terms and labels have been assigned over time to various efforts aimed towards similar objectives. The whole “zero” conversation began to take shape in the context of carbon footprints and emissions. Initially the narratives focused on attainment of zero carbon emissions (conceptually similar to Net Zero, only without a global agreement or a specific target date).

[40] Kolter, J. Z., and Ferreira, J. (2011). "A Large-Scale Study on Predicting and Contextualizing Building Energy Usage."

There are many zero carbon concepts or frameworks in the built environment that continue to evolve in the aftermath of increased awareness of issues related to climate change due to greenhouse gas emissions. These frameworks strive to provide building project participants with guidelines to mitigate, reduce or offset carbon emissions within certain system boundaries. They differ from each other in the scope of the parameters as applicable to their stakeholders. Their boundaries may be narrow or broad and span across portions of the life cycle of the building project. Most of these frameworks are not mandated or governed by a certification authority and is entirely voluntary to participate for building project stakeholders, at least for the time being.

Within the context of an originating ideation, in this chapter, the components of four conceptual carbon frameworks are discussed below, with a diverse set of terminologies used in the built environment.

- Zero Net Carbon Buildings
- Carbon Neutral Buildings
- Zero Carbon Buildings

The central dynamics prevalent in these concepts, in entirety or combinations, are:

- Measure and Reduce carbon emissions from or due to buildings (energy efficiency measures, on-site renewable energy generation, and/or off-site renewable energy purchase)
- Offset emissions from or due to buildings (certified renewable energy credits), and/or
- Export surplus on-site renewable energy to other off-site systems.

This part of the course will discuss the conceptual frameworks in the perspective of:

- Ideation and definition of concept,
- Applicable building sectors and types,
- Life cycle and spatial boundaries,
- Metric and timeline, and
- Pathways established by the frameworks and their integration in practice by involved stakeholders in the built environment.

We will also look at the concept of carbon offset and the role of some sample certification programs such as Green-e Climate, American Carbon Registry, Climate Action Reserve, Voluntary Gold Standard, Clean Development Mechanism and Joint Implementation, Verified Carbon Standard and the Living Futures Zero Carbon Certification programs are discussed.

3.3 Zero Net Carbon Buildings

In the wake of the Net Zero goals of the Paris Agreement, the concept of Zero Net Carbon (ZNC) [41] buildings originated from Architecture 2030, New Buildings Institute, and Rocky Mountain Institute (a group of US based Non-Profit organizations) in 2016 with an intention to establish a clear direction for new and existing buildings to advance toward zero-carbon built environments.

This group of organizations define a Zero Net Carbon building as:

"a highly energy efficient building that produces on-site, or procures, enough carbon-free renewable energy to meet building operations energy consumption annually."

Given that the California Architects Board is now requiring all California state architects to participate in "Zero Net Carbon Design" [ZNCD] training in order to maintain licensure in the state, it is useful to look at California's ZNCD definition:

"Zero net carbon design" means architectural designs including resilient designs of new construction and/or existing facilities that produce on-site, or equitably procure from offsite, enough carbon-free renewable energy to meet building operations energy consumption over the building project's life-cycle. 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.[42]

Applicable Building Sectors & Types

The Zero Net Carbon concept can be applied to all building sectors and types, residential and non- residential, new or existing, and also includes buildings in dense urban environments with limited on- site renewable energy capacity.

Life Cycle and Spatial Boundaries

The Zero Net Carbon concept focuses only on carbon emissions resulting from the operational stage of the building life cycle and the spatial boundary scale is set at the site level.

Metrics & Timeline

The annual metric established for ZNC buildings is site Energy Use Intensity (EUI) in KBtu/sq. ft-year and not source EUI. As a reminder, site EUI includes the energy consumed at the building site. Source EUI includes energy consumed in the extraction, processing and transport of off-site energy (including losses) PLUS the site EUI. The baseline for Zero Net Carbon Building is the national average energy consumption of existing U.S. commercial buildings as reported by the 2003 Commercial Building Energy Consumption Survey (CBECS).

Pathways and Applications in Practice

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[41] http://architecture2030.org/zero-net-carbon-a-new-definition/

[42] https://govt.westlaw.com/calregs/Document/I1BA4B660AA0211EE9219DDBB5599BB07?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default)

The proposed pathway for Zero Net Carbon is:

- First, measure and reduce emissions in comparison with the baseline building type through integrative building design strategies and energy efficiency measures.
- Second, reduce emissions by incorporating carbon-free on-site renewable energy systems; and/or purchasing of locally produced renewable energy to meet the balance of the project's energy needs.

Goal:
On an annual basis, On-site renewable energy generation + purchased off-site renewable energy meets site operational energy consumption.

Zero Net Carbon is a relatively recent concept. With diligence in the design process, all buildings should be able to achieve Zero Net Carbon status and many code structures (such as Title 24 in California) are mandating renewable energy sourcing, thus moving all projects toward Zero Net Carbon. The World Green Building Council (WGBC) has made considerable progress in this area, establishing a "Net Zero Carbon Buildings Commitment," which has a total of 176 signatories, including the state of California. This ambitious commitment requires the following by 2030:

- *Existing buildings reduce their energy consumption and eliminate emissions from energy and refrigerants removing fossil fuel use as fast as practicable (where applicable). Where necessary, compensate for residual emissions.*
- *New developments and major renovations are built to be highly efficient, powered by renewables, with a maximum reduction in embodied carbon and compensation of all residual upfront emissions*[43]

The Commitment includes a benchmark that all new projects globally must achieve at least 40% embodied carbon reductions by 2030, with a focus on upfront carbon (which they define as the total carbon emissions involved in the production and construction phases of the project). The Commitment further emphasizes a "whole life carbon" approach, with emphasis on both operational as well as embodied carbon.

Also in this area, an established agency for zero carbon buildings is the Building Research Establishment Environmental Assessment Method (BREEAM). Initiated in the UK, BREEAM also has US based certification systems. Key focuses of BREEAM include: "achieving whole life carbon reduction and net zero carbon in buildings, while addressing the increased demands throughout the supply chain."[44]

3.4 Carbon Neutral Buildings

[43] https://gbce.es/wp-content/uploads/2021/09/WorldGBC-NZCB-Commitment-Introduction-DG-Lite-2021.pdf
[44] https://www.bre.group/a-guide-to-breeam-for-net-zero-carbon-organisations/

The concept of Carbon Neutral building originated from an initiative by Architecture 2030[45] and was adopted by the American Institute of Architects (AIA) in 2006, which created the *2030 Commitment Program* aimed at transforming the practice of architecture to respond to the climate crisis in a way that is holistic, firm-wide, project-based, and data-driven. [46]

The 2030 Challenge organization defines a Carbon Neutral Building as:

> *"a building that uses no fossil fuel, greenhouse-gas-emitting energy to operate."*

Applicable Building Sectors & Types

The Architecture 2030 Challenge's Carbon Neutral building concept can be applied to all new buildings, developments and major renovations and is a voluntary commitment that can be made by individuals, firms and organizations, and governments.

Life Cycle and Spatial Boundaries

The Carbon Neutral building goal focuses only on carbon emissions resulting from the operational stage of the building life cycle and the spatial boundary scale is set at the building site level.

Metrics & Timeline

One of the key things to understand about a carbon neutral building is that it's not the same as a net zero building. A net zero building has broader goals and targets the reduction of ***all*** greenhouse gases [not just carbon]. In carbon neutral building, the operational energy sources use no carbon (without addressing other greenhouse gases).

A carbon neutral building may use the strategy of carbon offsetting, if it is not possible to produce enough carbon-free energy on site. Offsets are investments in projects that avoid and reduce carbon consumption. They often come in the form of carbon credits, with one carbon credit purchased equaling either the removal of one metric ton of carbon dioxide from the atmosphere, or the avoidance of producing that carbon dioxide.[47]

Pathways and Applications in Practice

The proposed pathway for Carbon Neutral buildings is:

- First, measure and reduce emissions in comparison with the baseline building type through integrative building design strategies and energy efficiency measures; see table below for specific percentages of targeted reductions over a baseline building type by year.

[45] http://architecture2030.org/2030_challenges/2030-challenge/
[46] https://architecture2030.org/2030_challenges/2030-challenge/
[47] https://nebldgsupply.com/what-is-a-carbon-neutral-building/

- Second, reduce emissions by incorporating carbon-free on-site renewable energy systems; and/or purchasing of locally produced renewable energy to meet the balance of its energy needs.
- Third, reduce emissions by purchasing locally produced renewable energy and/or offset emissions by purchasing certified renewable energy credits to meet the balance of its energy needs (20% maximum of targeted reduction).

An important aspect of Architecture 2030's Carbon Neutral goals is the percentage limit on locally produced renewable energy and/or renewable energy credits that a project can use to meet the Challenge. Architecture 2030 places a maximum limit of 20% of the required reduction from off-site strategies in order to challenge the projects to focus on reducing carbon emissions from operational energy. The required reduction from the baseline building type started at 50% and is presently at 80% and will progressively increase to 100% reduction in 2030.

Year	Required Reduction over Baseline
2010	50%
2010	60%
2015	70%
2020	80%
2025	90%
2030	100%

In June 2015, Architecture 2030 endorsed a prescriptive path developed by New Building Institute named the Advanced Buildings® New Construction Guide. This provides the building project team another tool to help in meeting the 2030 Challenge.

On an annual basis, On-site renewable energy + purchased off-site renewable energy and/or REC at a maximum of 20% required reduction) meets site operational energy consumption.

The Architecture 2030 Challenge has been widely adopted by individuals, firms and organizations, local governments, state governments (California, Illinois, Massachusetts, Minnesota, New Mexico, Ohio & Oregon, Washington and Vermont) and the Federal government.

A notable list of six Carbon Neutral Buildings in the west coast are:

1. Chartwell School in Seaside, CA
2. Orinda City Hall in Orinda, CA
3. Portland State Univ. Stephen Epler Hall in Portland, OR
4. Tillamook Forest Center in Tillamook, OR

5. The Gerding Theater in Portland, OR
6. East Portland Community Center in Portland, OR.

(Source: Case Studies of Carbon Neutrality by Alison Kwok).

Furthermore, Architecture 2030 has developed the following additional Challenges.

2030 Challenge for Embodied Carbon[48] - Annually, the embodied carbon of building structure, substructure, and enclosures are responsible for 11% of global GHG emissions and 28% of global building sector emissions. Eliminating these emissions is key to addressing climate change and meeting Paris Climate Agreement targets.

The Embodied Carbon Challenge is asking the global architecture and building community to adopt the following targets:

The embodied carbon emissions from all buildings, infrastructure, and associated materials shall immediately meet a maximum global warming potential (GWP) of **40% below the industry average today**. The GWP reduction shall be increased to:

- 45% or better in 2025
- 65% or better in 2030
- Zero GWP by 2040

The Challenge has been adopted by a number of manufacturers, design professionals and other professional supporters.

2030 Challenge for Planning [49]– Focuses on reducing GHG emitting fossil-fuel operating energy consumption, CO_2 equivalent emissions from transportation and water consumption. This challenge applies to both new and existing buildings and specifically targets new and renovated developments, neighborhoods, towns, cities and regions.

The targets for fossil fuel energy consumption reduction below the regional average or median is as follows:

Immediate – 80%; 2020 – 80%; 2025 – 90% or better.

2030 – Carbon Neutral – Using no fossil fuel GHG emitting energy to operate or construct.

The targets for CO_2 equivalent emissions from transportation and water consumption is set at 50% below regional average or median.

For all existing buildings within developments, neighborhoods, towns, cities and regions

The targets for reduction of fossil fuel energy consumption, CO_2 equivalent emissions from transportation and water consumption was set at 20% below regional average or median for 2020. It is increased to 35% for 2025 and 50% for 2030.

In addition to all the above 2030 challenges, Architecture 2030 has developed a 2030 Challenge for Districts – to reduce energy use, water use and transport emissions. Architecture 2030 has

[48] https://www.architecture2030.org/2030_challenges/embodied/
[49] http://architecture2030.org/2030_challenges/2030_challenge_planning/

also established the following educational tools and programs: 2030 Palette – an online tool to help in building in low carbon and adaptable buildings, and AIA + 2030 Online and Professional Series – to help design professionals create buildings that meet the 2030 energy reduction targets and a 2030 Curriculum to support sustainable design courses in U.S. Architecture and Planning schools.

Variants of Carbon Neutral Building Definitions

The Carbon Neutral Design (CND) project [50]was developed by a partnership of American Institute of Architecture (AIA), the AIA Committee on the Environment (COTE), and the Society of Building Science Educators (SBSE) in direct response to Imperative 2010, an Architecture 2030 ecological literacy initiative. The project's objectives were to develop pedagogics for Carbon Neutral Design to use in architectural design studios, improve students' ecological understanding, and provide integrative design solutions to university facilities and campuses to achieve Architecture 2030 Challenge.

The CND project group defined three variants of Carbon Neutral Buildings, by taking the base definition of Architecture 2030 and incorporating 3 scope types from Carbon Accounting Protocol developed by Professor Michael Utzinger while consulting on the design of the Aldo Leopold Legacy Center, a Carbon Neutral Building located in in Baraboo, Wisconsin.

- Scope 1 – Direct Emissions (Operational Energy) Example: Stationary Combustion (Boilers, Stoves), Organizational Vehicles
- Scope 2 – Indirection Emissions (Operational Energy) Example: Electricity Generation
- Scope 3 – Indirect Emissions (Organizational Energy) Example: Work Commute, Business Travel

1. Carbon Neutral Building - Operational Energy (Scope 1 & 2)

"The base definition for Carbon Neutral Design is taken from www.architecture2030.org. Carbon neutral with respect to Operating Energy means using no fossil fuel GHG emitting energy to operate the building. Building operation includes heating, cooling and lighting. These targets may be accomplished by implementing innovative sustainable design strategies, generating on- site renewable power and/or purchasing (20% maximum) renewable energy and/or certified renewable energy credits. According to the Carbon Neutral Design Protocol Tool developed for this project, this includes Scope 1 Carbon due to Direct Emissions as well as Scope 2 Carbon due to Indirect Emissions. It is felt that at the present time, Operating Energy accounts for approximately 70% of the Carbon Emissions associated with a building."[51]

On an annual basis, On-site renewable energy + purchased off-site renewable energy and/or REC [renewable energy credits] at a maximum of 20% required reduction meets operational energy consumption: Scope 1 & 2.

[50] http://www.tboake.com/carbon-aia/
[51] http://www.tboake.com/carbon-aia/carbon_definition.html

2. Carbon Neutral Building - Operational Energy (Scope 1 & 2) + Embodied Energy

   "This definition for Carbon Neutrality builds upon the definition above and also adds the Carbon that is a result of the Embodied Energy associated with the materials used to construct the building. This value is far more difficult to calculate.

   The initial embodied energy in buildings represents the non-renewable energy consumed in the acquisition of raw materials, their processing, manufacturing, transportation to site, and construction.

   This initial embodied energy has two components: Direct energy the energy used to transport building products to the site, and then to construct the building; and Indirect energy the energy used to acquire, process, and manufacture the building materials, including any transportation related to these activities.

   The recurring embodied energy in buildings represents the non-renewable energy consumed to maintain, repair, restore, refurbish or replace materials, components or systems during the life of the building.

   As buildings become more energy-efficient, the ratio of embodied energy to lifetime consumption increases. Clearly, for buildings claiming to be "zero-energy" or "autonomous", the energy used in construction and final disposal takes on a new significance."

   On an annual basis, On-site renewable energy + purchased off-site renewable energy and/or REC (renewable energy credits) at a maximum of 20% required reduction meets operational energy consumption: Scope 1 & 2 + Embodied Energy.

3. Carbon Neutral Building - Operational Energy (Scope 1 & 2) + Embodied Energy + Site Energy + Occupant Travel (Scope 3)

   "This definition of Carbon Neutrality builds upon the inclusion of Operating Energy and Embodied Energy, and also reflects the carbon costs associated with a building's location. This requires a calculation of the personal carbon emissions associated with the means and distance of travel of all employees and visitors to the building. This is referred to as Scope 3 Carbon due to Indirect Emissions (organizational travel)."

   On an annual basis, On-site renewable energy + purchased off-site renewable energy and/or REC at a maximum of 20% required reduction meets operational energy consumption: Scope 1 & 2 + Embodied Energy + Site Energy + Occupant Travel.

Along with the aims and desires of these standards, the objectives and ideals stated have been demonstrated to be achievable as in completed buildings.

Aldo Leopold Legacy Center in Baraboo, Wisconsin, designed by The Kubala Washatko Architects and completed in 2007 is the first LEED recognized Carbon Neutral, a zero net energy building and LEED c2.0 Platinum Building to be constructed in the world.

The one-story 11,900 sq. ft. building was completed in 2007. According to CND project website, this building was designed to use 70% less energy than a comparable conventional building. The building produces over 10% more energy than it annually consumes using 198-panel 39.6 kW rooftop photovoltaic array installation. "The project also had ambitious carbon accounting goals, with the goal of net zero carbon. A carbon balance based on WRI Greenhouse Gas Protocols indicates 13.63 Tons Carbon emitted per year, 6.24 Tons Carbon offset and 8.75 Tons Carbon sequestered in managed forests for a net offset/sequestration of 1.36 Tons of Carbon."[52] The building project won a 2008 AIA Committee on the Environment (COTE) Top Ten Award.

3.5 Zero Carbon Buildings

The concept of Zero Carbon buildings is widely prevalent in the built environment with no universally accepted definitions. Many institutions have recognized the need for an agreed upon definition and many researchers and governments investigated definitions for Zero Carbon buildings for consistent agreed upon application across the globe.

In 2011, On behalf of the Australian Sustainable Built Environment Council's (ASBEC's) Zero Emissions Residential Task Group (ZERTG), Sustainability Victoria commissioned the Institute for Sustainable Futures (ISF) to review all the existing definitions for low, zero and positive impact buildings and recommend a suitable definition that can be used in the country for communication, regulation and/or voluntary initiatives.

The group recommended the following standard definition for Zero Carbon buildings [53] that can be applied to all residential and non-residential buildings sectors and types:

"A zero-carbon building is one that has no net annual Scope 1 and 2 emissions from operation of building incorporated services.

- Building-incorporated services include all energy demands or sources that are part of the building fabric at the time of delivery, such as the thermal envelope (and associated heating and cooling demand), water heater, built-in cooking appliances, fixed lighting, shared infrastructure and installed renewable energy generation
- Zero carbon buildings must meet specified standards for energy efficiency and on-site generation
- Compliance is based on modelling and/or monitoring of greenhouse gas emissions in kg CO_2- e/m^2 /yr. "

On an annual basis, On-site renewable energy meets operational energy consumption: Scope 1 & 2.

[52] https://www.aiatopten.org/node/135
[53] http://www.asbec.asn.au/files/ASBEC_Zero_Carbon_Definitions_Final_Report_Release_Version_15112011_0.pdf

The group proposed terminology for Zero Carbon buildings variations, as outlined:

- Zero Carbon Buildings (base definition)
- Zero Carbon Occupied Buildings (includes occupant emissions)
- Zero Carbon Embodied Buildings (includes embodied emissions)
- Zero Carbon Life-Cycle Buildings (includes all emission sources in the building life cycle)
- Autonomous Zero Carbon Buildings (buildings that are not connected to the grid)
- Carbon Positive Buildings (achieves less than zero emissions)
- Carbon Positive Embodied Buildings (includes embodied emissions and achieves less than zero emissions)
- Carbon Positive Life-Cycle Buildings (includes all emission sources and achieves less than zero emissions)

There is no indication of whether the recommended definition and variants may have been universally or nationally accepted. However, they provide an informed understanding of what possibly maybe in the scope of these terminologies.

3.6 Zero Energy

In 2006, National Renewable Energy Laboratory (NREL), a US Department of Energy research laboratory, published a report titled, *'Zero Energy Buildings: A Critical Look at the Definition,'* [54] that introduced the Net Zero Energy definitions for buildings (commercial or residential).

The four net zero definitions are:

(1) Net Zero Site Energy

(2) Net Zero Source Energy

(3) Net Zero Energy Costs

(4) Net Zero Energy Emissions

This report was published to respond to the loosely used term 'zero energy' around that time which was found to be vague and needed more clarity. Essentially, the zero-energy status achieved by the building shows the rigor by which the designers and engineers have attempted to reduce energy consumption as well as promoting on-site energy generation.

In September 2024, the NZE definitions were updated by the US Department of Energy's report titled, '*National Definition of a Zero Emissions.'*[55] The primary purposes of this new report is to set forth standardized, consistent, and measurable minimum criteria for a zero-emissions building that users can achieve through multiple pathways. The definition is intended to provide guidance to help support the building sector moving

[54] http://www.nrel.gov/docs/fy06osti/39833.pdf

[55] https://www.energy.gov/eere/buildings/articles/national-definition-zero-emissions-building

toward zero emissions and thereby advance public- and private-sector climate goals. The new report notes that a definition is not a regulation; it also goes on to propose 3 basic criteria:

1. Energy efficient: The building is among the most efficient.
2. Free of on-site emissions from energy use: The building's direct GHG emissions from energy use equal zero.
3. Powered solely from clean energy: All the energy used by the building, both on-site and off-site, is from clean energy sources.

The new report calls for proposes minimum standards of performance in order for the building to qualify as a zero-emissions building for operational energy use:

- Energy Efficient: this criteria references Energy Star and EUI targets. This criteria also distinguishes between existing and new building performance criteria.
- Free of On-Site Emissions from Energy Use
- Powered Solely from Clean Energy [any combination of on and off site)

Renewable Energy Certificate – Zero Energy Building (REC-ZEB): An energy-efficient building where, on a ***source energy basis***, the actual ***annual delivered energy*** is less than or equal to the on-site renewable ***exported energy plus*** acquired ***Renewable Energy Certificates (RECs).***

The table below provides an understanding of how zero energy equations differ from zero carbon equations:

Concept	Measurement	Boundary Condition	Equations
Zero Net Carbon Building	Carbon Emissions	Site Energy	*On-site renewable energy generation + purchased off-site renewable energy meets operational energy consumption, on an annual basis.*
Carbon Neutral Building	Carbon Emissions	Site Energy	*On-site renewable energy + purchased off- site renewable energy and/or REC at a maximum of 20% required reduction) meets operational energy consumption, on an annual basis.*
Zero Carbon Building	Carbon Emissions	Site Energy	*On-site renewable energy meets operational energy consumption: Scope 1 & 2.*
Zero Energy Building	Energy	Source Energy	*Actual annual delivered energy ≤ on-site renewable exported energy*
Renewable Energy Credits – Zero Energy Building	Energy	Source Energy	*Actual annual delivered energy ≤ on-site renewable exported energy plus acquired Renewable Energy Certificates (RECs).*
Zero Energy Campus	Energy	Source Energy	*Actual annual delivered energy ≤ on-site renewable exported energy*
Zero Energy Portfolio	Energy	Source Energy	*Actual annual delivered energy ≤ on-site renewable exported energy.*
Zero Energy Community	Energy	Source Energy	*Actual annual delivered energy is ≤ on-site renewable exported energy."*

3.7 Carbon Offsets

A carbon offset is a mandatory or voluntary mechanism that allows individuals, companies and organizations to reduce their carbon dioxide equivalent on the atmosphere in one area by investing in projects that reduce carbon dioxide equivalent on the atmosphere in another area. One carbon offset represents the reduction or removal of one metric tonne of carbon dioxide equivalent from the atmosphere. The Environmental Protection Agency (EPA) defines a carbon offset as "a tradable, environmental commodity that represents the reduction of a specific amount of GHG emissions to the atmosphere and is measured in tons."

Carbon offsetting is a complicated topic and it has been a controversial method of carbon accounting in the decades since its inception. Carbon offsets exist in both mandatory and voluntary markets. While the mandatory market is aimed at heavy emitters and regulated by their respective authorities under international, national and regional requirements, there is no universally agreed upon international standards or frameworks for voluntary carbon offsets.

The International Organization of Standardizations (ISO)'s standards for greenhouse gas accounting and verification (ISO 14064 and ISO 14065) underpins the development of most of the independent third-party standards for voluntary carbon offsets. In addition, the Global Carbon Project (GCP) in its report on Carbon Reductions and Offsets [56]established underlying principles (or criteria) for carbon offset projects to ensure trading credibility and real atmospheric carbon reductions using the features of Clean Development Mechanism (CDM) as the benchmark. According to the GCP report,

"*A high-quality* carbon offset project should have at least the following three qualities. It must

(1) be counted only once

(2) be additional, transparent and verifiable; and

(3) avoid leakage."

Further, the report recommends carbon offset projects establish permanence, efficiency and consider projects with societal and economic benefits in addition to offsets – offset plus.

Carbon offset project types mostly consist of: Energy Efficiency (EE), Renewable Energy (RE), Reduced Emissions from Degradation and Deforestation (REDD+), Bio-Sequestration, Energy-from-Waste Capture, Mine Methane Capture (MMC), Livestock Methane Capture, Ozone Depleting Substances (ODS) Destruction, and Transport Emissions Reduction - to name a few.

Various standards have emerged in the voluntary carbon markets and can be characterized as either independent third-party project certification program or product certification programs.

Carbon credit accounting is not a simple process. As with many products whose quality is difficult for casual buyers to assess, standard-setting organizations have been established to provide quality assurance for carbon credits. These *carbon crediting programs*[1] range from international or governmental regulatory bodies – such as the UNFCCC Secretariat, which oversees an international carbon crediting program under Article 6.4 of the Paris Agreement – to independent non-governmental organizations (NGOs). Historically, governmental bodies certified carbon credits for regulatory purposes ("compliance programs"), while independent NGOs primarily served voluntary buyers ("independent programs"); more recently, both types of programs have begun to serve both types of markets (see Table, below) [57]

"Compliance" Carbon Credit Programs (run by governmental bodies)	**Geographic Coverage**	**Label Used for Carbon Credits**
Article 6.4 of the Paris Agreement[2]	Global	Article 6.4 Emission Reduction Units (A6.4ERs)

[56]http://www.globalcarbonproject.org/global/pdf/reports/GCP_Report_No.6.pdf

[57] https://offsetguide.org/understanding-carbon-offsets/carbon-offset-programs/

"Compliance" Carbon Credit Programs (run by governmental bodies)	Geographic Coverage	Label Used for Carbon Credits
California Compliance Offset Program	United States	Air Resources Board Offset Credit (ARBOC)
Korean Offsetting Program[3]	Global	Korean Offset Credit (KOC)
Regional Greenhouse Gas Initiative (RGGI)	Northeast United States	RGGI CO_2 Offset Allowance (ROA)
Australian Emission Reduction Fund (ERF)	Australia	Australian Carbon Credit Unit (ACCU)

"Independent" Carbon Crediting Programs (run by NGOs)	Geographic Coverage	Label Used for Carbon Credits
ACR	Multiple countries	Emission Reduction Tonne (ERT)
Climate Action Reserve (CAR)	Multiple countries	Climate Reserve Tonne (CRT)
The Gold Standard	International	Verified Emission Reduction (VER)
Plan Vivo	International	Plan Vivo Certificate (PVC)
Verra - Verified Carbon Standard	International	Verified Carbon Unit (VCU)

3.8 Green-e-Climate

Green-e Climate [58] is a global independent third-party product certification program. It is a consumer protection program that ensures credits sold by offset retailers are verified by eligible Green-e Climate endorsed project certification programs [59] such as American Carbon Registry, Climate Action Reserve, Gold Standard and Verified Carbon Standard. Green-e Climate further ensures the credits are sold as described and delivered correctly and exclusively to the buyer by the offset retailer.

Green-e Climate evaluates the projects are certified based on the principles of transparency, accountability and credibility using chain-of-custody certification for carbon offsets that requires project verification.

In 2022, Green-e Climate realized:[60]

• More than 147,600 residential customers purchased certified offsets

[58] https://www.green-e.org/
[59] https://www.green-e.org/programs/climate/endorsed-programs
[60] https://www.green-e.org/docs/Green-e%20Climate%201-pager.pdf

• Bundled natural gas-carbon offsets accounted for 37% of overall certified sales
• 23 countries sold certified offsets
• 38% of certified sales attributedto sales for LEED building certification

Company [61]	Product Name	Offset Mix
3Degrees Inc.	Green-e Climate Landfill Gas Carbon Offset	Landfill Methane Capture (100%)
3Phases Renewables	Offsets	Various
Callective Energy	Carbon Offset Green Gas	Various - Landfill Methane Capture, Renewable Energy (up to 100%)
Carbon Solutions Group (CSG)	CSG CleanBuild Offsets	Various - Renewable Energy, Landfill Methane Capture, Livestock Methane Capture, Energy Efficiency, Coal Mine Methane Capture, AFOLU, SF6 Destruction (Up to 100%)
Direct Energy Business, LLC	C-Neutral–Coal Mine Methane	Coal Mine Methane Capture (100%)
Direct Energy Business, LLC	C-Neutral–Landfill Methane Capture	Landfill Methane Capture (100%)
DTE Energy	CleanVision Natural Gas Balance	
Georgia Natural Gas	Greener Life	20% Improved Forest Management, 80% Landfill Methane Capture
Green Mountain Energy	Green Mountain Carbon Offsets	Landfill Methane Capture (100%)
Kratos Gas & Power	Carbon Offset Green Gas	Various - Landfill Methane Capture, Renewable Energy (up to 100%)

[61] https://www.green-e.org/certified-resources/carbon-offsets

Puget Sound Energy (PSE)	Carbon Balance	Improved Forest Management, Methane Capture
Schneider Electric	Green-e Climate Landfill Gas Carbon Offsets	Landfill Methane Capture (100%)
SouthStar Energy Services LLC	Greener Life® For Business	Landfill Methane Capture, Forestry
terrapass	terrapass Mix	Various - Landfill Methane Capture, Renewable Energy (up to 100%)
Uncle Frank Energy Services	Carbon Offset Green Gas	Various - Landfill Methane Capture, Renewable Energy (up to 100%)
United Energy Trading, LLC	Carbon Offset Green Gas	Various - Landfill Methane Capture, Renewable Energy (up to 100%)
United Energy Trading, LLC	Callective Energy Green Gas	Organic Waste Digestion (100%)
WGL Energy Services, Inc.	Carbon Offsets from WGL Energy	Landfill Methane Capture (100%)

3.9 Other Trends, Ideas and Philosophies

The preceding discussion has focused extensively on those programs and / or design protocols that have been established with a tangible structure and some form of measurable or quantifiable goals with mechanisms to recognize compliance. That is as it should be since the very objective of Net Zero is to achieve a real goal within a set time frame. To do this, success levels have to be measurable and documented so progress can be tracked.

However, there are also some design philosophies and movements that have been widely accepted and entered into everyday conversation. In this section, some of the most recognized of these concepts will be defined. It is important that design professionals understand the principles behind the terminologies. In the professional world, there can be confusion in the use of terms and overlaps in meaning.

Sustainable Design:

Sustainability is a word that is widely used in the design professions. It is virtually impossible to find any organization larger than a few employees that does not have some sort of "sustainability" statement in their company mission or vision statements. There is at least this clear perceived obligation to acknowledge that all segments of society have a role in advancing sustainability on multiple levels. However, agreeing on a common definition of the term "sustainability" can be difficult. The concept as it relates to the built environment is fairly straightforward:

a common industry term used to describe, in general, projects that incorporate design and construction practices that are intended to offer benefits to the environment, enhance the health and wellbeing of building occupants, or increase energy efficiency. [62]

Sustainability is a high level "umbrella" concept that establishes ambitious intentions. It does not have a tangible metrics targeting a specific outcome. However, all the measurable programs with targeted objectives, whether GHG reduction, carbon neutralization, LEED certification, the Living Building Challenge or other programs all fall under the "sustainable" umbrella. There are, however, some principles that help guide sustainable practices.

Sustainability has often been described as having three pillars (or the triple bottom line, as identified by John Elkington): the economy, society and the environment, also informally known as people, profit and planet. However, more nuanced definitions have advanced the dialog, such as that offered by the World Green Building Council. That organization's three pillars include:[63]

- Climate Action: total decarbonization of the built environment
- Health and Wellbeing: a built environment that delivers healthy, equitable and resilient buildings, communities and cities
- Resources and Circularity: a built environment that supports the regeneration of resources and natural systems, providing socio-economic benefit through a thriving circular economy.

From a governmental perspective, the US General Services Administration (GSA) defines sustainability in this way:[64]

Sustainable design optimizes building performance and minimizes negative impacts on building occupants and the environment. We incorporate sustainable design and energy efficiency principles into our construction and modernization projects, balancing cost, environmental, societal, and human benefits that help meet our tenant agencies' mission objectives and functional needs.

Sustainable design principles aim to:

[62] https://content.aia.org/sites/default/files/2018-12/D503-2013_120718.pdf
[63] https://worldgbc.org/what-is-a-sustainable-built-environment/
[64] https://www.gsa.gov/real-estate/design-and-construction/sustainability/sustainable-design

- *Optimize site potential.*
- *Minimize non-renewable energy consumption and waste.*
- *Use environmentally preferable products.*
- *Protect and conserve water.*
- *Improve indoor air quality.*
- *Enhance operational and maintenance practices.*
- *Create healthy and productive environments.*

Even though there is no universally recognized single definition of Sustainable Design, the intentions of improved building performance without harming the environment are generally shared. The main differences amongst the definitions often come down to how broadly the term is defined.

There are many opinions, preferences and recommendations from designers about how to achieve sustainable design in the built environment. An excellent holistic guide has been provided by the American Institute of Architects (AIA) through their Framework for Design Excellence, which has a goal of "setting the standard for sustainable, resilient and inclusive design." The ten principles outlined by the Framework include:[65] [*NOTE: the identified topics below will not be dealt with in detail in the context of this course as each topic is a detailed subject in its own right. It is relevant to point out that these are the levers of design that contribute toward sustainable design and ultimately towards Net zero attainment*]

Design for Integration
- Design for Equitable Communities
- Design for Ecosystems
- Design for Water
- Design for Economy
- Design for Energy
- Design for Well-being
- Design for Resources
- Design for Change
- Design for Discovery

Green Architecture / Buildings:

A fairly straightforward definition of green building is offered by Britannica:

philosophy of architecture that advocates sustainable energy sources, the conservation of energy, the reuse and safety of building materials, and the siting of a building with consideration of its impact on the environment.[66]

For comparison, consider the following definition of a "Green Building" from the US Green Building Council (USGBC):

[65] https://www.aia.org/design-excellence/aia-framework-design-excellence
[66] https://www.britannica.com/art/green-architecture

the term green building encompasses planning, design, construction, operations, and ultimately end-of-life recycling or renewal of structures. Green building pursues solutions that represent a healthy and dynamic balance between environmental, social, and economic benefits.[67]

At face value, these definitions are strikingly similar to those for sustainable design. The concepts have similarities and the terms are often used interchangeably. Given the general lack of universally accepted definitions of either term, that interchangeability is not surprising. But on closer inspection, there are differences in meaning between “sustainability” and “green building.” Consider this comparison:

Sustainability encompasses a set of principles and practices aimed at meeting the needs of the present without compromising the ability of future generations to meet their own needs. Green building practices, on the other hand, refer to the design, construction, and operation of buildings that are environmentally responsible and resource-efficient.[68]

With this understanding, “sustainable design” offers a broader, more holistic view while “green building” gets more specific about the application of sustainable principles as it relates to buildings.

So, what makes a building “green”? According to the EPA, the components of a green building are:[69]

- Thorough site analysis prior to selection and development
- Energy efficiency and renewable energy
- Water conservation
- Responsible stormwater management and landscaping
- Material reduction, recycling, composting and environmentally preferable building materials
- Improved indoor environmental quality
- Climate resiliency

Clearly, in the “energy efficiency” bullet point, architects have at their disposal significant tools to achieve the efficiency goal. This would include employing passive design principles (passive solar and natural ventilation), building envelope design, daylighting, energy efficient equipment and appliances as well as the use of renewable energy.

Design Methods Towards Achieving Carbon Neutral Design

Professor of Architecture Pablo LaRoche (Cal Poly Pomona) published a book entitled *Carbon-Neutral Architectural Design*. He outlines very clear, achievable processes toward achieving carbon neutral design. The issues that he proposes that designers consider include:[70]

[67] https://www.usgbc.org/articles/what-green-building-0
[68] https://green.org/2024/01/30/sustainability-and-green-building-practices/
[69] https://www.epa.gov/greeningepa/green-buildings-epa
[70] La Roche, Pablo, *Carbon-Neutral Architectural Design* (Routledge, 2024)

Operations
Thermal comfort
Climate responsive design
Site design
Reduce overheating and overcooling (through the thermal envelope)
Passive solar
Active solar
Design with daylight
Renewable energy
Plug and process loads

Construction
Shelter
Indoor air quality
Sustainable landscaping
Efficient material design
Material selection
Building construction

Water
Safe water
Rainwater harvesting

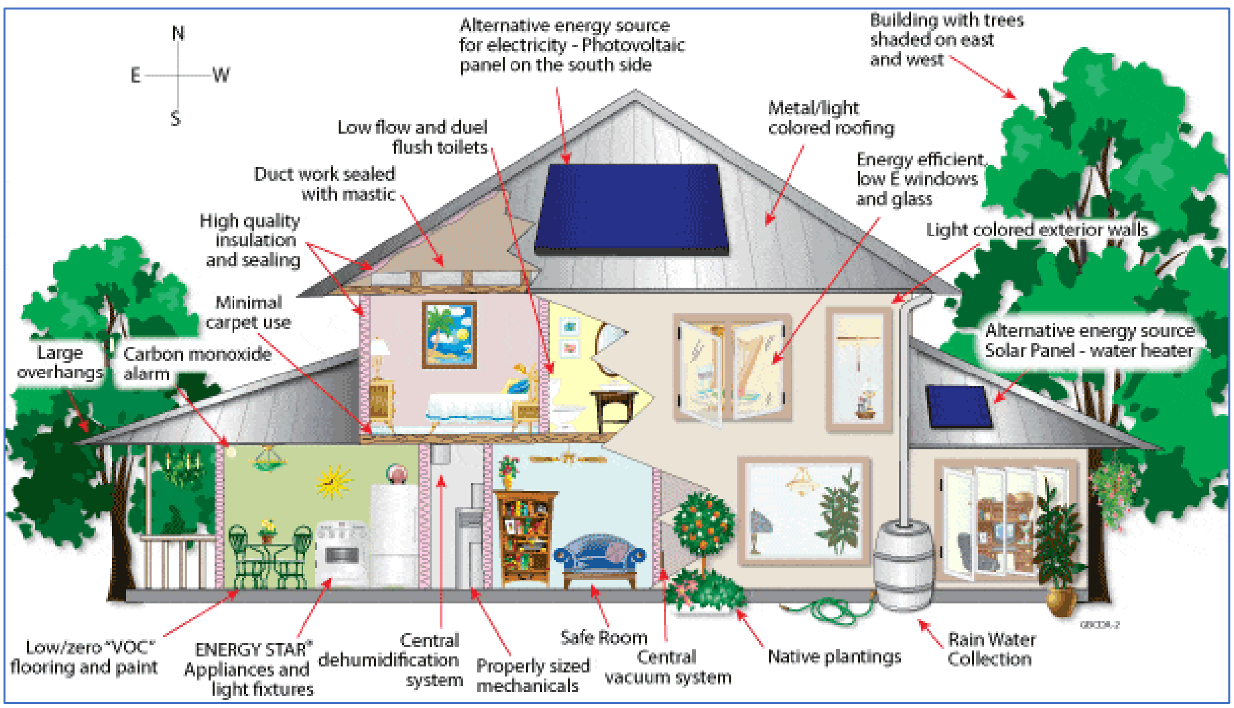
Waste
Energy generation from waste
Composting
Waste control

As La Roche notes in his book:

As designers of buildings and urban spaces, we are ethically obligated to design better environments. Buildings can be designed so that they work as natural air conditioners or heating systems, shaped by the natural forces of the sun, the wind, and the earth, until they are seamlessly integrated with the natural environment. We have the tools to do this and must act now.[71]

[71] La Roche, Pablo, *Carbon-Neutral Architectural Design* (Routledge, 2024), p. xv.

Source: World Green Building Council (www.worldgbc.org)



What Makes a Building Green: Green Building Concept *Source: The Constructor*[72]

High Performance Buildings

[72] https://theconstructor.org/building/buildings/what-makes-a-building-green-green-building-concept/7327/

As another term used to describe building performance under the umbrella of sustainability, high performing buildings are described by the GSA as follows:

high-performance buildings save energy, save water, cost less to operate, produce less waste, and have more satisfied occupants compared with typical buildings. In short, they deliver cost savings and tenant satisfaction. [73]

There are no specific metrics that lead to a building being classified as "high performing" and there is also common interchangeability between the terms "high performing" and "green" building. In general, a high performance buildings prioritize the optimization of building envelope and systems performance, and these buildings often exceed code performance requirements.

There is a perception that high performance building are more costly. However, this also depends on how costs are perceived and also over what timeframe, as noted by the AIA:[74]

While there is a perception that high-performance buildings are not cost-effective, many studies have found that high-performance buildings have many economic benefits such as an increased market value, lower operating and whole lifecycle costs, as well as indirect financial savings through improved health, lower absenteeism, higher productivity, and increased attraction and retention of employees.

With thoughtful design, high performance buildings can reduce operational costs over the long-term, can increase staff productivity and wellness, target carbon reduction, beat code minimums and be resilient in response to a changing climate.

Healthy Buildings:

The term "healthy buildings" encompasses a concept that has been around for some time. The notion that buildings can affect the health of their occupants' gained traction around the 1970s, along with the broader environmental awakening. This term evolved from the concerns about Indoor Air Quality (IAQ) and its effects on people. According to experts at the Harvard T.H. Chan School of Public Health, *"Good ventilation and air quality, a comfortable temperature, low noise levels, and natural light are all components of a "healthy" building."*[75]

The main focus of "healthy" building design is to positively impact elements of the building that can contribute to better physiological and psychological health of the public – those who inhabit the building and those who interact with it.

Many of the goals of healthy buildings are now also included in "green" or "sustainable" buildings, with the inclusion of targets focusing on human health and well-being. Additional benefits can include "reducing absenteeism and presenteeism, lowering health care costs, and improving individual and organizational performance."[76]

In 2017, Joseph G. Allen and Ari Bernstein of the Harvard T.H. Chan School of Public Health published the 9 Foundations of a Healthy Building[77]:

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[73] https://www.gsa.gov/governmentwide-initiatives/federal-highperformance-green-buildings/resource-library/integrative-strategies/the-impact-of-highperformance-buildings
[74] https://www.aia.org/resource-center/roi-high-performance-design
[75] https://www.hsph.harvard.edu/news/hsph-in-the-news/what-makes-a-building-healthy/
[76] "Buildings and Health". GSA Sustainable Facilities Tool.
[77] Allen, Joseph G; Bernstein, Ari (2020). "The 9 Foundations of a Healthy Building" (PDF). 9Foundations

1. Ventilation
2. Air quality,
3. Thermal health
4. Moisture [and humidity]
5. Dusts and pests
6. Safety and security
7. Water quality
8. Noise
9. Lighting and views

To the above list, the author would add that aesthetics of a building and its surroundings contribute to how occupants, visitors and the public at large "feels" about the building. This psychological aspect is very crucial but frequently overlooked (as in the Harvard study).

3.10 Connecting to Net Zero

As extensive as this section has been, there are many other movements, philosophies, programs and regulations around the world with similar objectives. All of these in some measure contribute to the overall target of Net Zero. Whereas Net zero can be narrowly viewed as simply a Greenhouse Gas / fossil fuel neutralization target, the broader view is that the objective of Net Zero is to achieve a better, cleaner and healthier built environment where the resources and consumption are balanced, and the polluting components of human activity reduced or eliminated. In this regard, whether the objective of a program or design philosophy is earmarked to something as specific as indoor air quality or whether it is as broad as a Sustainable Cradle-to-Cradle project, each moves society closer to Net Zero.

This concludes Part 3 of the course.

END – Part 3

Part 4 of the course will look beyond Zero Carbon Emissions Buildings and discuss future visions that are evolving in the built environment. Also examined will be the prognosis for achieving Net Zero.

Part 3 Review Questions

8) **The 2030 Commitment Program was created by**

a. Architecture 2030 Organization
b. American Institute of Architects
c. US Green Building Council
d. LEED

9) **Which of the following are qualities of a high-quality carbon offset project? It must**

a. be counted only once
b. be additional, transparent and verifiable
c. avoid leakage
d. All of the above

10) **Which of the following is not listed in this course as a Carbon Neutral building?**

a. Orinda City Hall in Orinda, CA
b. Stanford Historical Society Expansion, Paolo Alto, CA
c. Portland State Univ. Stephen Epler Hall in Portland, OR
d. Tillamook Forest Center in Tillamook, OR

PART 4

NetZer0 Design - A Primer for Architects

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Course Outline

The course on NetZero Design is a five-part course broken down as follows:

PART 1 – Introduction to the Issues and Concepts Leading to the NetZero Aspiration

PART 2 – Background on How Buildings Impact and Interact with the Environment

PART 3 – Building Design Concepts for NetZero

PART 4 – Visions for the Future – Aspirations and Challenges

PART 5 – Standards, Regulations and Conscience

Part 3 of the course examined several concepts applied to design and buildings towards t the goal of Net Zero design.
This part of the course will look at current efforts and trends towards achieving Net Zero by 2050. The section will also look at technologies, visions and applications being introduced or anticipated that will further stimulate and sustain Net Zero oriented design practices. Also reviewed will be the challenges and obstacles that affect and impede progress towards Net Zero.

To remind readers,

"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."[78]

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

PART 4 – Visions for The Future – Aspirations and Challenges

4.1. Is Net Zero Achievable?

So far, the course has investigated the issues that have led up to the climate related crises and the way those issues relate to buildings sector and the concepts developed to help mitigate and reverse the negative environmental conditions that are a result of poor design and over consumption. While there is a plethora of activity, formal and informal; local and global, there is still no coordinated universal mandate and path that denotes a collective path with clear milestones towards achieving Net Zero by 2050. While a deceptive simple goal on its face, quantifying Net Zero performance in building design is complex. In addition, the means and methods for achieving Net Zero are largely disjointed with levels of commitment differing widely from country to country and even locale to locale. The complexity of the quantification and the general lack of cohesion in tactical response begs the question about whether Net Zero is really achievable or simply an idealistic aspiration.

If the answer were to be based solely on the currently available science, the answer, according to the National Academies Organization, is a solid "Yes".

> *"Available technologies could allow the United States to achieve net-zero emissions by 2050. This would require rapid and widespread changes in policy and investment across many sectors of society and participation and commitment by government, industry, and individuals."*[79]

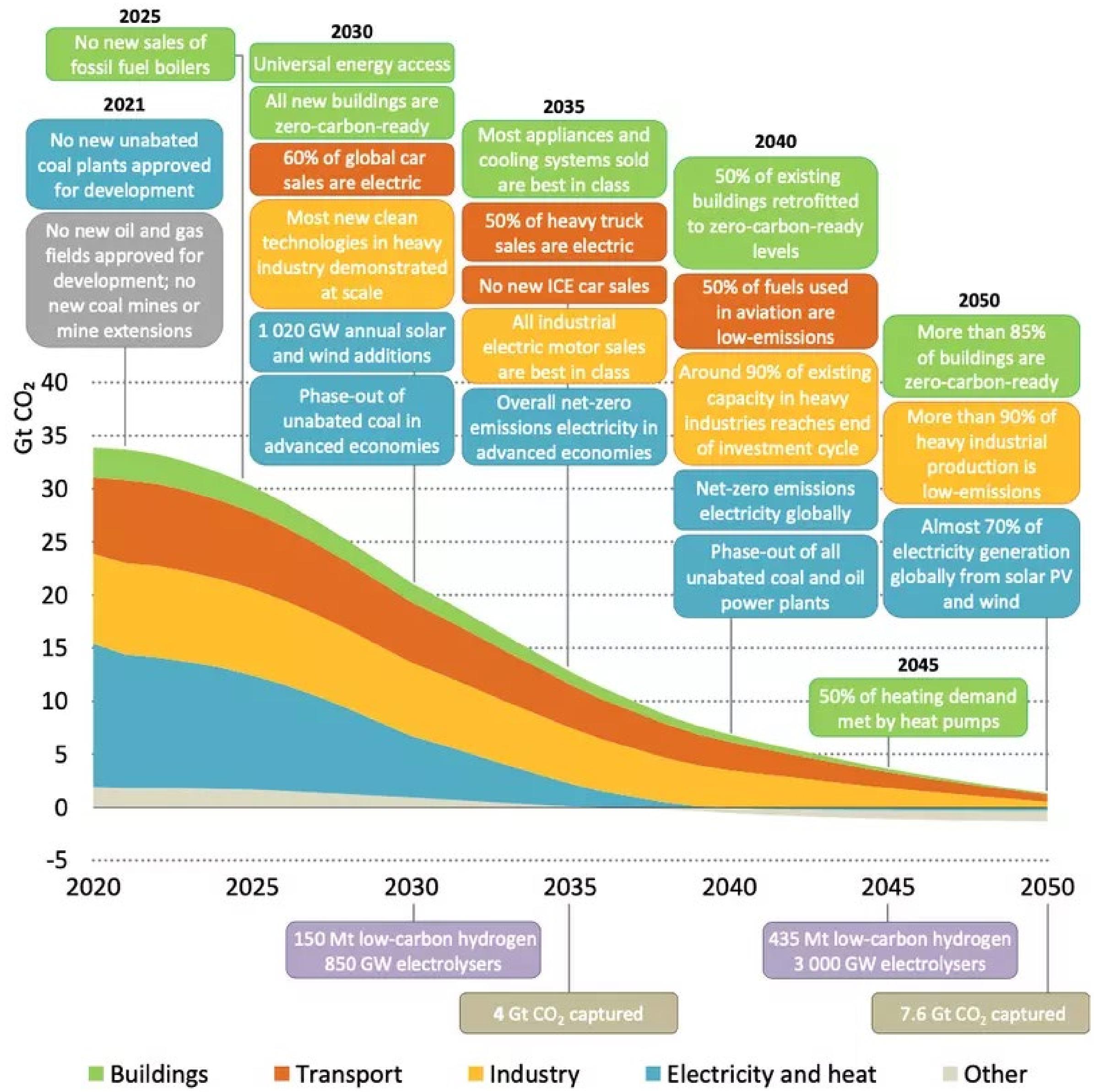
The International Energy Agency (IEA) echoed a similar finding published in May 2021 as part of the *Climate Breakthroughs: The Road to COP26 and Beyond* event for the World Economic Forum. [80]

Their findings state:

- The world can reach net zero emissions by 2050, but it will require some big changes, according to a new study.
- Our energy systems will need to be totally transformed; the International Energy Agency report Net Zero by 2050 says.
- Huge declines in the use of coal, oil and gas will be essential.
- The chart below shows global milestones for policies, infrastructure and technology deployment to achieve Net Zero emissions: these changes will have implications for the economy, citizens and governments.

[79] https://www.nationalacademies.org
[80] https://www.weforum.org/agenda/2021/05/net-zero-emissions-2050-iea/

Figure 4.1 ▹ Selected global milestones for policies, infrastructure and technology deployment in the NZE



Source: https://www.weforum.org/agenda/2021/05/net-zero-emissions-2050-iea/

It is possible to envision a more sustainable future for the built environment. According to UN Secretary General Antonio Guterres, "Three-quarters of the infrastructure that will exist in 2050 has yet to be built." [81] For architects and designers, this represents a significant opportunity to make positive change.

[81] https://news.un.org/en/story/2021/10/1101992

4.2. Obstacles and Challenges to Achieving Net Zero

The challenges and obstacles are identified in all the same studies and analyses that validate the feasibility affirming the possibility of achieving Net Zero.

Using the two citations used above, let's look at key wording. First, from the national Academies:

"…This would require rapid and widespread changes in policy and investment ***across many sectors…"***

If history is a guide, the notion that widespread policy changes across many sectors can be done rapidly would seem overly optimistic. It is not impossible but has only been achieved when the circumstances are dire like a war or national security threat. While the drumbeats around climate change and need for Net Zero have been gaining momentum, it is by no means agreed upon by all as an imminent threat overarching all others. The US vacillation over the Paris Agreement (on-off-on again) illustrates that the sense of urgency remains debatable in political circles despite the fact that two-thirds of Americans are in favor of changes such as a move away from fossil fuels in favor of renewable energy.[82]

Second, the milestones and radical transformations suggested by the IEA show the technical feasibility but require global synchronized effort. That is much easier said than done. Despite 196 countries signing on to the goals of the Paris Agreement, the reality is that national and local politics, economics and growth create unequal conditions around the world with many poorer countries lacking resources to make wholesale transformations to their energy systems and dated infrastructure. As climate and GHGs do not restrict themselves to neat national boundaries, transformation will require wealthy countries and those with disproportionally high GHG emissions need greater contributions to compensate for the poorer, less advanced countries. While logical, this idea has not been politically popular in most countries who would have to make the greater sacrifice or economic outlay. Recent events such as the war in Ukraine and conflict in the Middle East transfers focus and resources away from collaborative climate change mitigation efforts. These and other distractions inhibit the implementation of the collective policies needed to realize Net Zero on a global level.

Beyond the political issues, there are other challenges. As a US politician once remarked about a political issue: "It's the *economy*, stupid." And such is the case with achieving Net Zero. There may be initial costs in order to achieve Net Zero design, even though these costs may be recouped over time. Who pays and how much? remain subjects of unsettled debate. For buildings, "green" buildings or sustainable design is can be more expensive that conventional building techniques, though the gap is decreasing and thoughtful, strategic design can help mitigate these costs. In wealthier countries where there may be a higher degree of understanding of the necessity for environmental responsiveness, people may be willing to bear possible higher costs but in weaker economies, even if people acknowledge the benefits on an intellectual level, costs may present a barrier.

While the challenges may seem insurmountable, a more realistic way to examine the predicament is to recognize that economic disparity, conflict and disagreements have always

[82] https://www.pewresearch.org/short-reads/2023/08/09/what-the-data-says-about-americans-views-of-climate-change/

been part of human society. The response to contemporary environmental challenges will require phenomenal global collective action on an unprecedented scale. The good news is that over the past 30 years the awareness of impending environmental catastrophe is widely recognized and accepted. For building designers and professionals, this is an issue that transcends politics or nationalism. Efforts to clean up the emissions in country A is not only selfishly beneficial to country A but also improves the situation for its neighbors, friend or foe and vice versa. There is no upside for any country to deliberately pollute the atmosphere of its adversary since "what goes around will come around" – literally. In this context, architects, designers and builders can continue their march towards improving their practice, techniques and material selection.

4.3. Future Trends for Net Zero Building Design

As social awareness, regulatory requirements and a noticeable shift in the education and practice of architecture as these relate to sustainability issues has gained momentum, some new design trends are emerging that are building on the models currently in place and have been discussed previously.

While not an exhaustive list, some of these trends, captured succinctly by the website "Rethinking the Future" are presented below [83]:

1. GREEN BUILDING AND NET ZERO CONSTRUCTION

The energy efficiency of a building involves considering the energy used by the building before, during, and after construction, which includes building services such as air conditioning, lighting, etc. Net-zero energy refers to the annual amount of energy created on-site equal to the total energy consumed by the building. Various rating systems like LEED help provide a framework to build green buildings all over the world.

2. VERNACULAR ARCHITECTURE

Designing a building based on the native construction systems is beneficial beyond the preservation of the cultural aspect of the place. Vernacular architecture stresses on utilizing materials within reach from the site, which in turn cuts down on transportation cost and reduces the chance of shortage of materials.

3. PUBLIC SPACE INTUITIVE DESIGN

Being conscious of open spaces rather than filling up the site with the structure is crucial in bringing sustainability to the building. Public spaces act as a breathing space while utilizing the building. Providing a wide range of parks around built areas helps reduce the carbon footprint of the place, along with an enhanced lifestyle from the green landscape.

4. CIRCULAR ECONOMY FOR SUSTAINABILITY

Circular economy refers to Reduce-Reuse-Recycle. Architecture that involves this system aids in reducing wastage generated during construction or materials used on an everyday basis. Several architects also make use of plastic, glass bottles, etc. to cut down on wastage.

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[83] https://www.re-thinkingthefuture.com/rtf-fresh-perspectives/a1742-10-emerging-trends-in-sustainable-architecture-in-2020/

5. SMALL SCALE CONSTRUCTION

The significance of large mansions and structures are decreasing due to land shortage and high-density areas. A house has come down to its basic necessity with more importance given to its functionality and open spaces. With foldable and inbuilt furniture, an entire house can fit in one room area.

6. PASSIVE BUILDING DESIGN

Logically orienting the building on the site in such a way that wind flows through nature is an efficient way of ventilation with minimal or no air conditioning systems. With the help of architectural elements like sun shading devices and wing walls, passive design can open new possibilities to achieve low-cost construction.

7. UTILISING NATIVE VEGETATION

Designing organically with the site and utilizing the vegetation found within the area brings character and enhances the experience of the space while preserving nature at the same time. Planting trees and shrubs not native to the place just for its beauty is not a sustainable practice and requires unnecessary maintenance and is difficult to thrive in the new environment.

8. BIOPHILIC ARCHITECTURE

Biophilic architecture is a sustainable approach that incorporates nature into a structure. Such structures can act as a breathing lung in a metropolitan city or blend with the existing landscape of the place. Roof gardens and green walls are a few elements used that can incorporate vegetation with minimal space used.

9. PREFABRICATED CONSTRUCTION

With industrial manufacturing of building elements that can fit together on-site, prefabricated construction is an ingenious approach that saves time and money without compromising on the structural stability. Modular construction is a type of prefabricated housing built on repeated modules, which has become increasingly popular in present times.

10. ADAPTIVE REUSE

Adaptive reuse refers to modifying an existing building to present needs and remodeled with the addition of new functions. Reuse of several historic buildings is a great way to bring purpose in a building, which otherwise becomes deteriorated or left unused. It can even bring a new character to the existing structure and deliver an alternate meaning without compromising on its cultural significance.

4.4. Will Net Zero Emissions Really Clean the Air?

This was a question that was much debated even as the march for global emissions reductions continued. The scientific models and theoretical logic all supported the notion. However, detractors wondered how much of this was hype and whether the promise of cleaner air was even possible given the extent to which GHGs are already in the atmosphere.

In an ironic twist, the global COVID 19 pandemic provided the answer. With the world gripped in fear of the virus, an unprecedented lockdown of the entire planet occurred in 2020. While the halting of human activity and movement was a response to an epidemiological nightmare, it had an unintended consequence of providing a planetary scale testbed for observing the real time effects of reduction in carbon emissions. What emerged was even more unexpected than theories had projected. The change in air quality was noticeable within days as documented by the following news report from CBS in April 2020 (*Note that lockdowns started going into effect in March 2020*):

> *"...With billions of people quarantined and businesses closed, travel has all but come to a halt, significantly decreasing carbon dioxide emissions. In fact, 2020 is on track to see the largest yearly global decline ever in emissions, reports CBS News' Jeff Berardelli.*
>
> *Adding to the evidence, two weeks ago typically smoggy Los Angeles had the cleanest air of any major city on Earth, according to IQAir, a tech company that tracks global air quality.*
>
> *"About a year ago, Los Angeles was ranked the worst air quality in the entire country," CEO of IQAir Glory Dolphin Hammes told CBS News correspondent Jamie Yuccas. "Now, we're seeing some of the best air quality, not just in the country, but in the world."* [84]

Further, to see photographic evidence of before and after results of the COVID lockdown, there are many videos on YouTube and numerous articles that can be easily searched on the Internet. A few links are provided here. (*Note: The actual photographs cannot be reproduced here due to potential copyright restrictions*)

https://www.scmp.com/video/coronavirus/3087663/life-earth-breathing-cleaner-air-deadly-coronavirus-spreads-around-world

https://www.bbc.com/news/science-environment-57149747

https://www.cnbc.com/2020/04/23/coronavirus-photos-show-effect-of-air-pollution-drops-from-global-lockdown.html

https://www.q13fox.com/news/before-and-after-images-show-how-air-pollution-levels-have-dropped-around-the-world-amid-covid-19-lockdowns

Of course, a pandemic is not a solution to achieving clean air. The global reaction of quarantining entire populations served, albeit accidentally, to demonstrate that a dramatic reduction in some of the polluting human activities can in fact clean the environment rapidly. Naturally, this was an extreme measure for an extreme circumstance and real change for Net Zero needs to be through maintaining the trajectory of deliberate, planned strategies that not only allow human activity to continue but also to support healthier, less stressful, and sustainable lifestyles into the future.

[84] https://www.cbsnews.com/news/coronavirus-photos-decline-air-pollution-lockdown/

4.5. Aspirations for the Future

The future of architectural design has always been influenced, if not guided, by the famous and innovative practitioners (sometimes called Starchitects) of the age. Every generation of architects has been awed by and sought to emulate these masters of their time. From the Modernism of Mies Van Der Rohe, Le Corbusier to the organic architecture of Frank Lloyd Wright to the Post Modernism of Philip Johnson, Michael Graves and Robert Venturi and the Deconstructivism of Frank Gehry, Rem Koolhaas and Zaha Hadid (although Ms. Hadid decried being labeled to one style), architects have defined not only design styles but given fuel to design typologies and technologies of their given eras. In this regard, the built work examples authored by well-known architects can influence not only their professional peers but also public opinion. Seminal works can influence the precedents and design work that presented to clients and builders and eventually these trends may become mainstream. It is worth noting that some of the more prominent and influential architects of the 2010s and 2020s have expressed some very strong and definitive opinions about sustainable design and demonstrated these views in their designs. These contemporary visionary designers offer a refreshing shift from a previous generation of designers who often ignored (and sometimes disdained) sustainable building design building. Although there are many notable sustainable design architects, below are a few exemplary examples; their varying views highlight the breadth of approaches in the area of sustainable design:

William McDonough: Treat nature as a model

To many A&D professionals, William McDonough is synonymous with sustainable design. This sustainability trailblazer earned the first EPA Presidential Green Chemistry Challenge Award and a host of others, and he designed the acclaimed Ford Rouge plant, which still serves as a beacon of sustainability with an enormous living roof.
In 1992, McDonough created the Hannover Principles, a set of guidelines for sustainability. His eighth principle says: "***Understand the limitations of design. No human creation lasts forever, and design does not solve all problems. Those who create and plan should practice humility in the face of nature. Treat nature as a model and mentor, not as an inconvenience to be evaded or controlled***." [85]

Glenn Murcutt: Choose your materials mindfully

Glenn Murcutt is often called Australia's most famous architect. The only Australian winner of the Pritzker Architecture Prize, Murcutt is a vocal proponent of sustainability. A quick look at his projects reveals a studied balance between design and nature. (See the biophilic design of the Australian Islamic Centre.) His guiding ethos: to "touch the earth lightly."

Material selection is a large part of that ethos. ***As Murcutt puts it, "It's about: where did that material come from? What damage has been done to the land in the excavation of that material? How will it be returned to the Earth eventually, or can it be reused, can it be recycled, can it be put together in a way that can be pulled apart and changed and reused?"*** For Murcutt, touching the earth lightly means considering the environmental

[85] https://www.terramai.com/blog/6-famous-architects-share-their-top-sustainable-design

impact of every design choice, not the least of which is choosing the right building materials. [86]

Ken Yeang: An Ecologist Architect

Ken Yeang is an architect, ecologist and author known for his work in the field of ecological design. He is recognised as a pioneer in sustainable architecture. Yeang's approach involves integrating ecology-based principles into architectural structures as Applied Ecology, promoting environmentally sensitive, carbon neutral and energy-efficient solutions.

His innovative ideas focus on creating buildings that harmonise synergistically with nature while addressing contemporary environmental challenges.[87] Ken Yeang created his own experimental passive house in 1985 and he notes that it was only in the early 2000s that clients started asking for green buildings. As Yeang reflects: "*Ecological design has been consistently our primary focus and design agenda. We believe there are four sets of ecological infrastructures that need to be bio-integrated into a designed system: nature (the ecosystems and the biogeochemical cycles); human society (its socio-economic-political-institutional systems); the built environment (artifacts and technologies) and hydrology (water management and regimes). We need to synergistically bring all these systems together into a whole.*" [88]

Renzo Piano: Can Architecture and Nature Co-Exist?

In the present context, there is a constant debate about finding a balance between urban growth and environmental protection. Renzo Piano, on the other hand, stands out as a pioneer who firmly believes that built form and environment can coexist in harmony. He highlights the significance of comprehending the climate, geography, and ecosystem before developing any project. This mindful examination of the environment enables him to craft structures that not reconcile with their surroundings but also enhance them ("Renzo Piano, a visionary architect with a green heart"). Whether it's a museum, a building, or an office complex, Piano prioritizes elements such as light, ventilation, and passive cooling strategies in his designs. By integrating these aspects, he minimizes the reliance on lighting and air conditioning, resulting in a decrease in energy consumption and subsequently reducing the building's carbon footprint.[89]

As the statements above indicate, the drive to make sustainable design a permanent shift in mindset rather than a temporary design fad is beginning to take hold. In some ways, the four architects quoted above are stylistically very different but their shared commitment to sustainability in design thinking shows that "green" or sustainable or Net Zero design are concepts that can be embraced by all design styles and are not, in of themselves, a design style.

[86] https://www.terramai.com/blog/6-famous-architects-share-their-top-sustainable-design
[87] https://trhamzahyeang.com/ken-yeang/
[88] https://www.ribaj.com/culture/hindsight-ken-yeang-hamzah-yeang-climate-action-ecological-design
[89] https://www.re-thinkingthefuture.com/sustainable-architecture/a10888-architects-and-sustainability-renzo-piano/

As such, the aspiration is that the principles of sustainable design will be more enduring than a passing fad.

Many design professionals not only support the aims of Net Zero but they are determined to make fundamental transformative changes to the building design industry such that sustainable design is not voluntary but expected, to move beyond convincing clients that this is a "good" thing to do. To get to that point, some of the philosophies and principles of sustainable or Net Zero design will need to be codified or mandated to make them objective and acceptable across the industry. Some progress in this direction has already been made though this movement is more piecemeal rather than a universally accepted definitive charter. A main aspiration of design professionals is to have many of the primary performance components of sustainable design practices codified.

The next section of the course will provide a survey of the many regulations and standards that impact various aspects of the "green building," sustainable design, Net zero and carbon reduction arenas.

This concludes Part 4 of the course.

END – Part 4

Part 5 of the course will cover various standards, regulations and rating systems like ISO, Energy codes and LEED.

Part 4 Review Questions

11) **According to the IEA, is Net Zero achievable by 2050?**

a. No, there are too many political obstacles
b. Yes, easily achieved based on current trajectory
c. No, the technologies do not exist
d. Yes, but will require some big changes

12) **Which of the following is not an obstacle to achieving Net Zero?**

a. Politics
b. Technology
c. Economics
d. Wars

13) **Logically orienting the building on the site in such a way that wind flows through nature is an efficient way of ventilation with minimal or no air conditioning systems is an example of...**

a. Value engineering
b. Native architecture
c. Circular design
d. Passive building design

14) **Which famous architect said "Treat Nature as a Model":**

a. Walter Gropius
b. Renzo Piano
c. William McDonough
d. Zaha Hadid

PART 5

NetZer0 Design - A Primer for Architects

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The course on NetZero Design is a five-part course broken down as follows:

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PART 3 – Building Design Concepts for NetZero

PART 4 – Visions for the Future – Aspirations and Challenges

PART 5 – Standards, Regulations and Conscience

Part 4 of the course illustrated some of the emerging trends in sustainable and Net Zero design and how the some notable architects have adopted and are actively encouraging these practices. This final section of the course will document several existing regulatory guidelines and mandates that design professionals might expect to navigate depending on the location and type of project or the client's directives. Much of the content of this section is for reference and familiarity, it is useful for the building professionals to be aware of the evolving regulatory landscape and the many entities that are working to make Net Zero a reality.

One last time, to remind readers,

"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."[90]

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

PART 5 – Standards, Regulations and Conscience

5.1 Standards Related to Net Zero?

As has been shown so far, the recognition of a need to reduce and reverse the impacts of GHG emissions has garnered widespread support. However, most of the implementation is still dependent on well-intentioned sustainability-oriented voluntary compliance where designers and owners are asked to reevaluate the standard way of doing work and transform this work into sustainability pathways beneficial to the environment, society, and economy. As one notable shift, it should be noted that building codes such as Title 24 in California are pushing projects towards higher performance as well as renewable energy standards. In the process, a multitude of sustainability standards and rating systems have rapidly evolved to assist in meeting the end goals Net Zero ambitions. What has not yet emerged is an all-encompassing standard that enables the measurement, reduction and offset of the global environmental footprint, along with consideration of the societal and economic aspects of sustainability.

This part of the course will investigate some of the many standards, regulations and guidelines that exist and their applications. The first section will discuss the following ISO Standards related to sustainability of buildings:

- ISO 15392:2008 – Sustainability in building construction – General Principles
- ISO/TR 21932:2013 – Buildings and constructed assets — Sustainability in building construction — Terminology
- ISO 21929-1:2011 – Sustainability in building construction – Sustainability Indicators – Part 1: Framework for the development of indicators and a core set of indicators for buildings
- ISO 21930:2007 – Sustainability in building construction — Environmental declaration of building products
- ISO 21931- 1:2010 – Sustainability in building construction - Framework for methods of assessment of environmental performance of construction works – Part 1: Buildings.

The second section of this part will discuss the following standards related to carbon footprint:

- ISO/TS 14067:2013 - Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification and communication, Greenhouse Gas Protocol (GHGP) – Product life cycle accounting and reporting standard
- PAS 2060:2014 - Specification for the demonstration of carbon neutrality
- PAS 2060:2014 - Specification for the demonstration of carbon neutrality, International Energy Agency (IEA) Annex 57 - Evaluation of embodied energy and carbon dioxide emissions for building construction

- ISO 16745:2015 - Environmental performance of buildings – Carbon metric of a building – Use stage, and Common Carbon Metric for measuring energy use and reporting greenhouse gas emissions from building operations

The third section will discuss the multitudes of rating systems in today's global market and aspects of carbon footprint in sustainability rating systems such as LEED as an example.

The fourth section will discuss the need for a global environmental standard and provide a reference to the European Standard that leads the way in establishing a holistic life cycle-based standard encompassing the environmental, societal, and economic aspects of sustainability.

Finally, this part of the course will conclude by examining how much of the enforcement and execution is voluntary and comes down to conscience and what can be done to make the process more compulsory and whether that is warranted to achieve Net Zero.

5.2 Environmental Standards for Buildings

The International Organization of Standardization (ISO) [91], the leading authority of International Standards, has come out with a suite of standards for sustainability in building construction. These International Standards are qualitative in nature and provide general principles, terminologies, core indicator frameworks, assessment frameworks and environmental declaration frameworks, thus enabling assessing entities to formulate holistic life cycle based sustainability pathways in the building construction sector.

The International Standards specific to sustainability of buildings are briefly discussed below and their referencing standards are mentioned, yet it is recommended that the users of this course purchase these Standards to have a deeper understanding of the workings of the Standards. They are typically concise documents with an emphasis on qualitative processes and procedures.

- **ISO 15392:2019 – Sustainability in building construction – General Principles** [92]
  ISO 15392:2019

  This standard identifies and establishes general principles for the contribution of buildings, civil engineering works and other types of construction works (hereinafter referred to collectively as construction works) to sustainable development. It is based on the concept of sustainable development as it applies to the life cycle of construction works, from inception to the end-of-life.

  This standard is applicable to new and existing construction works, individually and collectively, as well as to the materials, products, services and processes related to their life cycle. This standard does not provide performance levels (benchmarks) that can serve as the basis for sustainability claims.

[91] ISO is an independent, non-governmental organization with a membership of 172 national standard bodies. http://www.iso.org/iso/home/about.htm
[92] https://www.iso.org/standard/69947.html

Per ISO 15392:2019, the following ISO Standards should also be referenced and used when applying the Standard.

ISO 6707-1, Buildings and civil engineering works — Vocabulary — Part 1: General terms

ISO 14050, Environmental management — Vocabulary

ISO/TR 21932, Sustainability in buildings and civil engineering works — A review of terminology.[93]

- **ISO/TR 21932:2013 – Sustainability in buildings and civil engineering works -- A review of terminology** [94]
  There are many frameworks for sustainability in the built environment all over the world. However, a universally accepted semantic is missing. ISO/TR 21932 establishes a standardized communication language that can be used across the globe for sustainability assessments. It provides a compilation of terms and concepts that can be commonly understood and applied in the building sustainability arena.
- **ISO 21929-1:2011 – Sustainability in building construction – Sustainability Indicators – Part 1: Framework for the development of indicators and a core set of indicators for buildings** [95]
  The essence of ISO 21929-1 is the establishment of a framework for developing sustainability indicators for buildings to use in the assessment of economic, environmental, and societal impacts of buildings. This Standard also establishes a set of fourteen (14) core indicators for sustainable buildings with respect to air, non-renewable resources, water, waste, land use, access to services, accessibility, indoor conditions and air quality, adaptability, costs, maintainability, safety, serviceability, and aesthetic quality. These indicators can be applied to both new and existing buildings. The Standard makers are aware that the core indicator list is not all inclusive and that additional indicators may need to be added according to the nature of the case. This is a pioneering first step in establishing an international standard for the development of unified sustainability core indicators that is applicable to all buildings across the globe.

  Per ISO 21929-1:2011, the following ISO Standards (latest editions including amendments) should be referenced and used when applying the Standard.

ISO 21929-1:2011 - Normative Reference	
ISO 6701-1	Building and civil engineering — Vocabulary — Part 1: General terms
ISO 14020	Environmental labels and declarations – General Principles
ISO 14021	Environmental labels and declarations – Self-declared environmental claims (Type II environmental labelling)

[93] https://cdn.standards.iteh.ai/samples/69947/14d7f4849cd645919f313f74ec4c20fd/ISO-15392-2019.pdf
[94] http://www.iso.org/iso/catalogue_detail.htm?csnumber=62888
[95] http://www.iso.org/iso/catalogue_detail.htm?csnumber=46599

ISO 21929-1:2011 - Normative Reference	
ISO 14024	Environmental labels and declarations – Type I environmental labelling – Principles and procedures
ISO 14025	Environmental labels and declarations — Type III environmental declarations — Principles and procedures
ISO 14040	Environmental management – Life cycle assessment – Principles and framework
ISO 14050	Environmental Management - Vocabulary
ISO 15392	Sustainability in building construction – General Principles
ISO 21930	Sustainability in building construction – Environmental declaration of building products
ISO 21931-1	Sustainability in building construction – Framework for methods of assessment of the environmental performance of constructions works – Part 1: Buildings

- **ISO 21930:2017 – Sustainability in building construction — Environmental declaration of building products** [96]
- ISO 21930:2017 provides the principles, specifications and requirements to develop an environmental product declaration (EPD) for construction products and services, construction elements and integrated technical systems used in any type of construction works.
- ISO 21930:2017 complements ISO 14025 by providing specific requirements for the EPD of construction products and services.
- ISO 21930:2017 establishes a core set of requirements to be considered as core product category rules (PCR) to develop an EPD for any construction product or service.
- In addition, this standard, as the core PCR document for construction products, construction elements and integrated technical systems:
- a) includes the rules for calculating the life cycle inventory analysis (LCI), the predetermined environmental indicators and the life cycle impact assessment (LCIA) results that are reported in the EPD;
- b) describes which life cycle stages are considered in a particular type of EPD, which processes are to be included in the life cycle stages and how the stages are subdivided into information modules;
- c) defines rules for the development of scenarios;
- d) includes the rules for reporting relevant environmental and technical information that are not covered by LCA;
- e) defines the core elements to be included in an EPD;
- f) establishes the structure of a project report;

[96] https://www.iso.org/standard/61694.html

- g) defines the conditions under which construction products can be compared, based on the information provided by an EPD;
- h) provides requirements and guidelines on PCR for sub-categories of construction products;
- i) includes mandatory and unalterable requirements for any PCR based on this document.

ISO 21930:2017 Normative References:[97]

- ISO 6707-1, Buildings and civil engineering works — Vocabulary — Part 1: General terms
- ISO 14020:2000, Environmental labels and declarations — General principles
- ISO 14025:2006, Environmental labels and declarations — Type III environmental declarations — Principles and procedures
- ISO 14044:2006, Environmental management — Life cycle assessment — Requirements and guidelines
- ISO 14046:2014, Environmental management — Water footprint — Principles, requirements and guidelines
- ISO 14050:2009, Environmental management — Vocabulary
- ISO 15392:2008, Sustainability in building construction — General principles
- ISO 15686-1:2011, Buildings and constructed assets — Service life planning — Part 1: General principles and framework
- ISO 15686-2, Buildings and constructed assets — Service life planning — Part 2: Service life prediction procedures
- ISO 15686-7, Buildings and constructed assets — Service life planning — Part 7: Performance evaluation for feedback of service life data from practice
- ISO 15686-8, Buildings and constructed assets — Service-life planning — Part 8: Reference service life and service-life estimation
- ISO 21931-1:2010, Sustainability in building construction — Framework for methods of assessment of the environmental performance of construction works — Part 1: Buildings
- ISO/TR 21932, Sustainability in buildings and civil engineering works — A review of terminology
- EN 15804, Sustainability of construction works — Environmental product declarations — Core rules for the product category of construction products

- **ISO 21931-1:2022 – Sustainability in buildings and civil engineering works — Framework for methods of assessment of the environmental, social and**

[97] https://www.iso.org/obp/ui/#iso:std:iso:21930:ed-2:v1:en

economic performance of construction works as a basis for sustainability assessment

Part 1: Buildings [98]

This standard provides a general framework for improving the quality and comparability of methods for assessing the environmental, social and economic performance of construction works, and their combination as a basis for the sustainability assessment of buildings.

It identifies and describes issues to be taken into account in the development and use of methods of assessment of the environmental, social and economic characteristics, aspects and impacts of new or existing buildings. These relate to the building's design, production of construction products, materials and components, construction, operation, maintenance and refurbishment and end-of-life processes.

This standard is applicable to the assessment of the building (or part thereof) and the external works within its site (curtilage).

NOTE The assessment of environmental, social and economic aspects related to the location of the building, such as those resulting from transportation of the users, can extend beyond the area of the building site.

This standard does not set benchmarks or levels of performance relative to environmental, social and economic impacts and aspects.

Per ISO 21931-1:2022, the following ISO Standards should also be referenced and used when applying the Standard.[99]

ISO 6707-1, Buildings and civil engineering works — Vocabulary — Part 1: General terms

ISO 6707-2, Buildings and civil engineering works — Vocabulary — Part 2: Contract and communication terms

ISO 14050, Environmental management — Vocabulary

ISO 15686-1, Buildings and constructed assets — Service life planning — Part 1: General principles and framework

ISO 15686-2, Buildings and constructed assets — Service life planning — Part 2: Service life prediction procedures

ISO 15686-5, Buildings and constructed assets — Service life planning — Part 5: Life-cycle costing

ISO 15686-7, Buildings and constructed assets — Service life planning — Part 7: Performance evaluation for feedback of service life data from practice

ISO 15686-8, Buildings and constructed assets — Service-life planning — Part 8: Reference service life and service-life estimation

[98] https://www.iso.org/standard/71183.html

[99] https://cdn.standards.iteh.ai/samples/71183/5584bc9b82254bde8a3068582f23cb7e/ISO-21931-1-2022.pdf

ISO 21678, Sustainability in buildings and civil engineering works — Indicators and benchmarks —

Principles, requirements and guidelines

ISO 21930:2017, Sustainability in buildings and civil engineering works — Core rules for environmental

product declarations of construction products and services

ISO/TR 21932, Sustainability in buildings and civil engineering works — A review of terminology

5.3 Standards Related to Carbon Footprint

There has been ongoing research by academic, industry, and other organizations to establish a whole life carbon footprint framework for buildings. However as of (2024), there are no generally accepted and validated frameworks available to quantify whole life carbon for buildings. As far as partial carbon footprint frameworks for buildings, there are a few general guidance or standards from organizations discussed below.

- <u>**Carbon Footprint of Products**</u>

  ISO/TS 14067:2018 - Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification and communication [100]

  This standard specifies principles, requirements and guidelines for the quantification and reporting of the carbon footprint of a product (CFP), in a manner consistent with International Standards on life cycle assessment (LCA) (ISO 14040 and ISO 14044).

  Requirements and guidelines for the quantification of a partial CFP are also specified.

  This standard addresses only a single impact category: climate change. Carbon offsetting and communication of CFP or partial CFP information are outside the scope of this standard.

  This standard does not assess any social or economic aspects or impacts, or any other environmental aspects and related impacts potentially arising from the life cycle of a product.

  Greenhouse Gas Protocol (GHGP) – Product life cycle accounting and reporting standard [101]; World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD)

  Greenhouse Gas Protocol's product life cycle accounting and reporting standard provides comprehensive guidelines to account, report and reduce greenhouse gas emissions and removals that occur during the life cycle of the product from material acquisition to final disposal (cradle-to-grave). The standard provides the principles and fundamentals of product life cycle accounting. The guidelines include defining

[100] https://www.iso.org/standard/71206.html
[101] https://ghgprotocol.org/sites/default/files/standards/Product-Life-Cycle-Accounting-Reporting-Standard_041613.pdf

goals, establishing scope, setting boundary, collecting data, assessing data quality, allocating emissions, assessing uncertainty, calculating inventory results, assuring quality, reporting, and setting reduction targets and tracking inventory changes. The standard also provides guidance on product comparison, land use change impacts and data management plans. The GHGP includes the seven GHGs listed in the Kyoto Protocol namely carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). The GHGP product standard encompasses all the three scopes defined below and includes all GHG emissions and removals from material acquisition to final disposal.

GHGP standard defines a scope system that is widely prevalent in today's carbon footprint world and important to know.

"*The GHG Protocol defines direct and indirect emissions as follows:*

- *Direct GHG emissions are emissions from sources that are owned or controlled by the reporting entity.*
- *Indirect GHG emissions are emissions that are a consequence of the activities of the reporting entity but occur at sources owned or controlled by another entity.*

The GHG Protocol further categorizes these direct and indirect emissions into three broad scopes:

- ***Scope 1:*** *All direct GHG emissions.*
- ***Scope 2:*** *Indirect GHG emissions from consumption of purchased electricity, heat or steam.*
- ***Scope 3:*** *Other indirect emissions, such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities (e.g., T&D losses) not covered in Scope 2, outsourced activities, waste disposal, etc*."

PAS 2050:2011 - Specification for the assessment of the life cycle greenhouse gas emissions of goods and services [102]; British Standards Institution (BSI)

PAS 2050:2011 specification for the assessment of the life cycle greenhouse gas emissions of goods and services is very similar to GHGP's product standard discussed above. The PAS 2050:2011 specification provides the requirements, principles and implementation procedures. The specification further explains the scope, system boundaries, data collection, emissions allocation and GHG calculation for products. The specification also provides guidelines for assessment of emissions arising from recycled or recyclable material inputs and delayed emissions due to use and final disposal phases of products.

[102] https://biolatina.com/wp-content/uploads/2018/08/PAS2050.pdf

PAS 2060:2014 - Specification for the demonstration of carbon neutrality; BSI [103]

The central principles of PAS 2060 specification are to demonstrate carbon neutrality through four stages: Measure, Reduce, Offset, and Document/Validate. This specification was introduced in 2010 to curtail carbon neutral claims that was prevalent during that time. The specification was updated in 2014 and provides consistent set of requirements and guidelines for all interested entities and individuals to demonstrate carbon neutral status for product, service, community, event or building.

- **<u>Carbon Footprint of Construction and Maintenance</u>**

  Annex 57 - Evaluation of embodied energy and carbon dioxide emissions for building construction [104]; International Energy Agency (IEA)

  Embodied energy and embodied GHG emissions (EEG) due to building construction and civil engineering account for 20% of the entire energy consumption and GHG emissions in the world. The figures are approximately 5 to 10% of the entire energy consumption in developed countries and 10 to 30% in developing countries. Though the figures greatly vary depending on the country and region, the reduction of embodied energy and GHG emissions may have a tremendous effect on the reduction of global energy consumption and GHG emissions.

  Annex 57 research reveals the actual situation of embodied energy and CO2 as well as discusses their calculation methods and theoretical background. The methods and effects of reducing embodied energy and CO2 are shown through case studies.

- **<u>Carbon Footprint of Use</u>**

  ISO 16745:2017 – Sustainability in buildings and civil engineering works – Carbon metric of an existing building – Use stage [105]

  ISO 16745-1:2017 provides requirements for determining and reporting a carbon metric of an existing building, associated with the operation of the building. It sets out methods for the calculation, reporting and communication of a set of carbon metrics for GHG emissions arising from the measured energy use during the operation of an existing building, the measured user-related energy use, and other relevant GHG emissions and removals. These carbon metrics are separated into three measures designated CM1, CM2, and CM3 (see 5.1.1).

[103] https://www.bsigroup.com/en-US/capabilities/environment/pas-2060-carbon-neutrality/
[104] https://www.iea-ebc.org/Data/publications/EBC_Annex_57_Results_Overview.pdf
[105] https://www.iso.org/standard/69969.html

ISO 16745-1:2017 follows the principles set out in ISO 15392 and those described in Clause 4. Where deviations from the principles in ISO 15392 occur, or where more specific principles are stated, this document takes precedence. The carbon metrics CM1 and CM2 are not quantified based on life cycle assessment (LCA) methodology. Carbon metric CM3 may include partial quantification based on the results of LCA.
ISO 16745-1:2017 does not include any method of modelling of the operational energy use of the building but follows the conventions provided by other International Standards, as given in relevant clauses.
ISO 16745-1:2017 is not an assessment method for evaluating the overall environmental performance of a building or a building-rating tool and does not include value-based interpretation of the carbon metric(s) through weightings or benchmarking.
ISO 16745-1:2017 deals with the application of the carbon metric(s) for an existing building, either residential or commercial, or a building complex. It does not include provisions for regional and/or national building stock.

Per ISO 16745: 2017, the following ISO Standards should also be referenced and used when applying the standard:

- ISO 6707-1:2004, Buildings and civil engineering works — Vocabulary — Part 1: General terms
- ISO 12655, Energy performance of buildings — Presentation of measured energy use of buildings
- ISO 14050, Environmental management — Vocabulary
- ISO 15392, Sustainability in building construction — General principles
- ISO/TR 16344:2012, Energy performance of buildings — Common terms, definitions and symbols for the overall energy performance rating and certification

- **<u>Waste Footprint</u>**
  Waste Framework Directive 2008/98/EC [106]; European Commission

  The Waste Framework Directive establishes basic principles, concepts and definitions related to waste management emphasizing minimal impact to environment and human health. The Waste Framework Directive introduces the concept of holistic life cycle thinking into waste policies thereby incorporating it in the broader aspects of sustainability and making it compatible with other environmental initiatives. The Directive also introduces concepts like "polluter pays principle" and the "extended producer responsibility" and updates its concept on waste hierarchy. The Directive tries to establish a streamline process to return

[106] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32008L0098

recoverable waste as a resource into the production system. Further, the Directive provides guidelines for waste to energy recovery process.

5.4 Standards Related to Carbon Footprint

There is no rating system assessing and certifying carbon footprint of buildings per se, however the major aspects of carbon footprint have been incorporated widely in prevalent multi-attribute rating systems such as:

- **LEED** from U.S. Green Building Council (USGBC)
- **Living Building Challenge** from Living Future, U.S.
- **Green Globes** from Green Building Initiative (GBI)
- **BREAM** from Building Research Establishment (BRE) U.K.
- **Green Star** form Green Building Council Australia (GBCA)
- **Passive House Institute U.S.** (PHIUS)

The above are just a few of the main examples. The aspects of reducing operational and embodied energy of products, increasing renewable energy generation and green power, and reducing fugitive emissions from refrigerants has been incorporated in the rating systems.

In the current scenario, there are many rating systems in the global market and the list keeps increasing day after day. Here is a list of rating systems from the above-mentioned organizations.

RATING SYSTEMS
United States Green Building Council (USGBC) [107] **LEED (Leadership in Energy and Environmental Design)**
LEED for Building Design and Construction (LEED BD+C)
LEED for Interior Design and Construction (LEED ID+C)
LEED for Building Operations and Maintenance (LEED O+M)
LEED for Neighborhood Development (LEED ND)
LEED for Homes Design and Construction
USGBC Partner Frameworks
WELL Building Standard [108] – for human health and well-being
Performance Excellence in Electricity Renewal (PEER) [109] – for power systems
Sustainable Sites Initiative (SITES) [110] – for sustainable landscapes
Global Real Estate Sustainability Benchmark (GRESB) [111] – for real assets

[107] http://www.usgbc.org/
[108] https://www.wellcertified.com/
[109] http://peer.gbci.org/
[110] http://www.sustainablesites.org/
[111] https://gresb.com/

RATING SYSTEMS	
Excellence in Design for Greater Efficiencies (EDGE) [112] – for energy and water	
Parksmart [113] – for parking garages	
Zero Waste Facility [114] - for zero waste business	
Living Future[115]	
Living Building Challenge (LBC)	
Net Zero Energy Buildings (NZEB)	
Green Building Initiative (GBI) [116]	
Green Globes New Construction	
Green Globes Existing Buildings	
Green Globes Sustainable Interiors	
Green + Product Workplace (sustainability and wellness for portfolios)	
Building Research Establishment (BRE) Group [117] Building Research Establishment Environmental Assessment Method –(BREEAM)	
BREEAM New Construction	
BREEAM International New Construction	
BREEAM In-Use	
BREEAM Refurbishment	
BREEAM Communities	
EcoHomes	
Green Building Council Australia (GBCA) [118]	
Green Star – Communities	
Green Star – Design and As-built	
Green Star – Interiors	
Green Star – Performance	
Passive House Institute US (PHIUS) [119]	
PHIUS+ 2015: Passive Building Standard	
PHIUS Verified Window Performance Data Program	
Other International Rating Systems or Approaches	

[112] https://www.edgebuildings.com/
[113] http://parksmart.gbci.org/
[114] http://www.gbci.org/gbci-administer-zero-waste-certification-and-credential
[115] https://living-future.org/
[116] http://www.greenglobes.com/home.asp
[117] https://www.bre.co.uk/page.jsp?id=829
[118] http://new.gbca.org.au/green-star/
[119] http://www.phius.org/about/mission-history

RATING SYSTEMS
Haute Qualite Environnementale (HQE), France [120]
Comprehensive Assessment System for Built Environment Efficiency (CASBEE) [121]
Building and Construction Authority (BCA) Green Mark Scheme, Singapore [122]
Building Environmental Assessment Method (BEAM) Assessment Tool, Hong Kong [123]
Pearl Rating System for Estidama [124]
ICC 700-2012: *2012 National Green Building Standard* (ICC 700)[125]

Model Codes[126]

International Code Council's *2012 International Green Construction Code* (IgCC)

A model code that contains minimum requirements for increasing the environmental and health performance of buildings, sites and structures. Generally, it applies to the design and construction of all types of buildings except single- and two-family residential structures, multi-family structures with three or fewer stories, and temporary structures.

ANSI/ASHRAE/USGBC/IES Standard 189.1-2011: *Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings* (ASHRAE 189.1)

A model code that contains minimum requirements for increasing the environmental and health performance of buildings, sites and structures. Generally, it applies to the design and construction of all types of buildings except single-family homes, multi-family homes with 3 or fewer stories, and modular and mobile homes.

As is evident from the above, there are a multitude of aspiring competitive rating systems and that is a source of encouragement for building designers. However, what is lacking is a single all-encompassing life-cycle based common measurement and benchmarking system that covers all aspects of sustainability in the built environment. To illustrate, here is a quick analysis of the line items that relate to carbon footprint in one of the leading rating systems in the world - LEED.

LEED v4 BD+C Rating System [127]				
Stage	**Assessment**		**Environmental Standards**	**Points**
Product Stage	Building	Historic Building Reuse (or)		5

[120] http://www.behqe.com/
[121] http://www.ibec.or.jp/CASBEE/english/
[122] https://www.bca.gov.sg/GreenMark/green_mark_buildings.html
[123] http://www.beamsociety.org.hk/en_beam_assessment_project_1.php
[124] http://estidama.upc.gov.ae/pearl-rating-system-v10.aspx?lang=en-US
[125] https://www.epa.gov/smartgrowth/icc-700-2012-2012-national-green-building-standard-icc-700
[126] https://www.epa.gov/smartgrowth/green-building-standards
[127] See rating system for additional details https://www.usgbc.org/credits?Version=%22v4%22&Rating+System=%22New+Construction%22&MinimumProgramRequirements=%5B%22Minimum+program+requirements%22%5D

LEED v4 BD+C Rating System [127]				
Stage	**Assessment**		**Environmental Standards**	**Points**
(Cradle-to-Grave)	Life Cycle Impact Reduction	Renovation of Abandoned or Blighted Building (or)		5
		Building and Material Reuse (or)		2-4
		Whole-Building Life-Cycle Assessment (structure and enclosure)	Data-sets compliant with ISO 14044	2
	Building Product Disclosure and Optimization - Environmental Product Declaration	Environmental Product Declaration (for 20 different permanently installed products from at least five different manufacturers)		1
		(a) Product-specific declaration (or)	ISO 14044 and have at least a cradle to gate scope	
		(b) Environmental Product Declarations (or)	ISO 14025, 14040, 14044, and EN 15804 or ISO 21930 and have at least a cradle to gate scope	
		Multi-attribute Optimization (for 50% by cost of permanently installed products)		1
		(a) Third party certified products (or)		
		(b) USGBC approved program		

LEED v4 BD+C Rating System [127]				
Stage	**Assessment**		**Environmental Standards**	**Points**
Construction and Demolition Stage	Construction and Demolition Waste Management Planning	Diversion (or) Reduction of Total Waste Material	For projects that cannot meet credit requirements using recycle and reuse methods, waste-to-energy systems considered if compliant with the following frameworks: - European Commission Waste Framework Directive 2008/98/EC and Waste Incineration Directive 2000/76/EC Waste to energy facilities meet CEN EN 303 Standards	Mandatory and additional 1-2 points
In-use Stage	Energy Performance	Minimum Energy Performance	ANSI/ASHRAE/IESNA Standard 90.1–2010	Mandatory
		Optimize Energy Performance		1 - 20
		Building Level Energy Metering		Mandatory
		Advanced Energy Metering		1
		Demand Response		1 - 2

LEED v4 BD+C Rating System [127]				
Stage	**Assessment**		**Environmental Standards**	**Points**
	Refrigerant Management	Fundamental Refrigerant Management (No CFC for new HVAC&R and phase- out for re-using existing HVAC&R)		Mandatory
		Enhanced Refrigerant Management	Montreal Protocol	1
	Water Use	Water Use Reduction	EPA's WaterSense EnergyStar	Mandatory
		Other water uses reduction credits including Water Metering		4 - 11
	Renewable Energy Production	Renewable energy up to 10% - 15% of the energy use		1 - 3
	Green Power and Carbon Offsets	Green power, carbon offsets, or renewable energy certificates (RECs) for 5 years – 50 or 100% of the project's energy use.	-Green-e Energy certified or the equivalent -Greenhouse Gas Protocol	1 - 2

Measurement/Prediction Tools

From the above analysis, it is evident that there is no measurement system for sustainability or whole life carbon footprint of buildings. While the rating systems add a remarkable value as market drivers, repositories of data and knowledge, and certifying experts, they still have not harnessed the tremendous opportunity to lead and establish a holistic life-cycle based sustainability measurement system in the field of building design, construction and management. Since each rating system has its own requirements, it is difficult to compare the performance of the building from one rating system to another, adding more complexity to benchmarking in the global environment.

There are many opportunities to leverage the data collected as part of the agreement with the rating system such as LEED. However, LEED's focus on measuring sustainability through a point based system stands in the way to becoming a systems based measurement entity, thereby limiting the opportunity of buildings to level play in the global market.

There is a clear benefit of rating systems as an amalgamation of expertise evolved over the past couple of decades, with a strong intention to reduce, avoid or offset impact, yet it is missing the mainstays of life cycle system thinking and measurement science, thereby depriving these rating systems of a holistic status. Essentially what this means is that while rating systems help classify individual projects as achieving a degree of sustainable design, they do not quantify the overall contribution towards reducing overall emissions and impact of a Net Zero target.

LEED has become very popular with Architects worldwide, in part due to its relative simplicity and numeric scale. In contrast, the other main competing system (BREEAM from the UK) is considered by many to be world's leading science-based suite of validation and certification systems for sustainable built environment.[128]

The difference between the two is that LEED's thresholds are based ***on percentages***, while BREEAM uses ***quantitative standards***. LEED is considered to be simpler in its approach, while BREEAM is more academic and rigorous.[129] For example, BREEAM supports solutions to reduce carbon emissions to net zero, improve whole life performance, manage health and social impacts, boost circularity, resilience and biodiversity, and support disclosures and reporting.[130]

As another globally recognized rating system, the **German Sustainable Building Certificate (DGNB)** [131] was established in 2009. DGNB includes the following six criteria [132]:

1. environmental quality
2. economic quality
3. sociocultural and functional quality
4. technical quality
5. process quality
6. site quality

With these criteria, the DGNB certification holistically considers the entire life cycle of a project. This method assesses the overall sustainability performance of the building in a holistic manner instead of focusing solely on individual measures. In fact, compared to LEED and BREEAM, DGNB offers the most holistic sustainability review of a project.

As a counterpoint, Living Future's Living Building Challenge is a rating system that is both rigorous and performance based. Achieving Living Building status requires one year of on site measured data of the completed building (rather than the intended performance as required of most other rating platforms). Once certified, Living Buildings are:

[128] https://bregroup.com
[129] https://www.prologis.com/what-we-do/resources/difference-breeam-leed
[130] https://breeam.com/
[131] http://www.dgnb-system.de/en/system/certification_system/
[132] https://www.dgnb.de/en/certification/buildings/new-construction

1) Regenerative buildings that connect occupants to light, air, food, nature, and community.
2) Self-sufficient and remain within the resource limits of their site.
3) Create a positive impact on the human and natural systems that interact with them.[133]

Currently, all of these rating systems remain predominantly voluntary and require additional expense to pay for the certification. Some jurisdictions require certification, such as the US GSA which mandates that all new construction of GSA buildings achieve a minimum of LEED Gold certification. In California, new buildings 10,000 s.f. and larger are required to achieve a minimum of LEED Silver.[134]

5.5 The Need to Account for Carbon in the Built Environment

How to account for carbon in the built environment is a significant challenge. Life cycle assessment (LCA) tools are currently the most effective prediction tools available for designers as they are challenged with net zero and net zero carbon design demands. It is difficult to list available tools as these instruments are in a constant state development. However, as of this writing, the following is a list of tools allowed by Living Futures as part of their Zero Carbon Certification which includes both whole building LCA tools as well as embodied carbon calculators: [135]

- Athena Impact Estimator
- BEAM Estimator
- BHoM LCA Toolkit
- Embodied Carbon in Construction Calculator (EC3)
- Environment Agency’s Carbon Planning Tool
- Cerclos (formerly eTool)
- Sphera GaBi
- One Click LCA
- One Click LCA Planetary
- OpenLCA
- Tally

5.6 The Need for a Global Environmental Standard for Buildings

International Standards are set up as top-down, methodical, and qualitative in nature, but these do not provide substantive subject matter knowledge of the building construction and management field itself from a bottom-up perspective (from the designer and builders viewpoint).

The rating systems, on the other hand, offer a bottom-up perspective and most are more directly related to actual building performance with some measurable metrics. However, the market is

[133] https://living-future.org/lbc/
[134] https://www.dgs.ca.gov/OS/Resources/Page-Content/Office-of-Sustainability-Resources-List-Folder/California-LEED-Certified-State-Buildings
[135] https://living-future.org/zero-carbon/

flooded with rating systems with no clear unifying and methodical leadership. So, in the absence of life-cycle based holistic systems thinking and measurement science, the value of the rating systems is diminished and risks making these more a public relations or tax motivated exercise rather than a verifiable solution to move society to Net Zero.

A paradigm shift from piecemeal systems to holistic streamlined systems with global metrics is needed. The good news is that there are many efforts by different entities working together to bring this task to fruition.

In this regard, the European Committee for Standardization CEN/TC 350 "Sustainability of Construction Works" has raised the bar by establishing a unifying framework for sustainability assessment of buildings – encompassing the three aspects of sustainability, providing detailed rules and methodologies for environmental product declarations, and establishing calculation methodologies for the environmental, social and economic performance of buildings – all this holistically interweaved based on life cycle thinking.[136] The goal of this ambitious endeavor is to bring all aspects of sustainability under one suite of standards with the ISO frameworks as the foundation. If all aspects of the performance knowledgebase is successfully integrated within the framework, this will be a major accomplishment.

The following is the suite of integrated building performance standards that has been established by the committee.

CEN/TC 350 Standards	
Framework Level	
EN 15643-1:2010	Sustainability of construction works – Sustainability assessment of buildings – Part 1: General Framework
EN 15643-2:2011	Sustainability of construction works – Assessment of buildings – Part 2: Framework for the assessment of **environmental** performance
EN 15643-3:2012	Sustainability of construction works – Assessment of buildings – Part 3: Framework for the assessment of **social** performance
EN 15643-4:2012	Sustainability of construction works – Assessment of buildings – Part 4: Framework for the assessment of **economic** performance
Product Level	
EN 15804:2012+A1:2013	Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products
CEN/TR 16970: 2016	Sustainability of construction works – Guidance for the implementation of EN 15804

[136] https://standards.iteh.ai/catalog/tc/cen/415e8b38-9bf9-455f-b531-96d83acf019d/cen-tc-350?srsltid=AfmBOorl-1wUMzF_PTovu4gmuELEMURzZCqzavtmmyXZvceOJMwH8c0f

CEN/TC 350 Standards	
Framework Level	
CEN/TR 15941:2010	Sustainability of construction works – Environmental product declarations – Methodology of selection and use of generic data
EN 15942:2011	Sustainability of construction works – Environmental product declarations – Communication format business to business
Building Level	
EN 15978:2011	Sustainability of construction works – Assessment of **environmental** performance of buildings – Calculation method
EN 16309:2014+A1:2014	Sustainability of construction works – Assessment of **social** performance of buildings – Calculation method
EN 16627:2015	Sustainability of construction works – Assessment of **economic** performance of buildings – Calculation methods
CEN/TR 17005:2016	Sustainability of construction works – Additional environmental impact categories and indicators – Background information and possibilities – Evaluation of the possibility of adding environmental impact categories and related indicators and calculation methods for the assessment of the environmental performance of buildings

In addition, the European Committee for Standardization (CEN) has initiated CEN/TC 474, a new Technical Committee on CO_2 capture, transportation, utilization, storage (CCUS) and carbon accounting. The committee's charge is to work toward standardization of the carbon capture market in Europe.[137]

Although the current suite of rating systems provide methods of evaluating intended sustainability performance, without more widespread adoption, uniform standards and actual measured performance, it will remain difficult to assess the actual environmental performance of building projects. Without a more uniform and rigorous approach, it will be difficult for society to achieve the goals necessary to slow the deleterious effects of climate change.

5.7 Net Zero is Still a Choice of Conscience

Net Zero remains an objective of many countries but current implementation plans are not ambitious enough to realistically achieve the target date of 2050 (despite technological feasibility). According to the United Nations Climate Action website:

[137] https://www.cencenelec.eu/news-and-events/news/2023/brief-news/2023-11-30-ccus/

"...commitments made by governments to date fall far short of what is required. Current national climate plans – for 195 Parties to the Paris Agreement taken together – would lead to a sizable increase of almost 9% in global greenhouse gas emissions by 2030, compared to 2010 levels. To keep global warming to no more than 1.5°C – as called for in the Paris Agreement – emissions need to be reduced by 45% by 2030 and reach net zero by 2050. Getting to net zero requires all governments – first and foremost the biggest emitters – to significantly strengthen their Nationally Determined Contributions (NDCs) and take bold, immediate steps towards reducing emissions now."[138]

The weak link in the quest toward achieving this goal is the same for buildings as for all sectors – lack of enforceable mandated codes or regulations.

As we have seen, there is no shortage of guidelines and standards, but adherence is almost entirely voluntary with no effective penalty for ignoring them. As a result, forward momentum often comes down to a choice of conscience for designers and builders and, most importantly, building owners, who ultimately pay for the design choices. The problem with choices of conscience is that when confronted with economic implications, "doing the right thing" often only prevails if it is backed up by significant economic incentives or by force of law.

Perhaps a similar but not exact analogy is the way in which Accessibility become a required component of any building design. Accessibility is no longer debated because the Americans with Disabilities Act (ADA) is mandated in the US and building codes have incorporated the requirements. This was not always so and regulations now require architects to do the "right thing" thus saving unnecessary debates with clients. Similarly, if Net Zero objectives were codified thus requiring legal compliance rather than a choice of conscience, the building sector's Net Zero goals would advance considerably. The next goal would be to transform this into a global movement, with Net Zero building performance required worldwide.

This concludes Part 5 of the course.

END – Part 5

[138] https://www.un.org/en/climatechange/net-zero-coalition

Part 5 Review Questions

15) **LEED is a ...**

a. Building rating system for environmental design
b. Draft building code
c. Universally accepted standard for Net Zero design
d. Subsidiary of BRE (UK)

16) **Which of the following is a building rating system based on actual measured building peformance?**

a. LEED
b. German Sustainable Building Certificate (DGNB)
c. BREEAM
d. Living Building Challenge

17) **What is the maximum points that can be earned in LEED rating for Optimizing Energy Performance?**

a. 1
b. 4
c. 20
d. 11

This concludes the course.

Review Question Answers:

Part 1

1) **Identify the Agreement that aims "to keep the global temperature rise this century well below 2 degrees Celsius above pre-industrial levels."**

a. Kyoto Protocol; incorrect, the 1997 Kyoto Protocol did not include this. Also, developing countries were not mandated to reduce their emissions.

b. Paris Agreement; correct, this agreement includes a commitment to keep the rise in global temperatures "well below" 2 degrees Celsius, as scientists consider 2 degrees C the threshold to limit potentially catastrophic climate change.

c. Montreal Protocol; incorrect, this is an international treaty that deals with substances that deplete the stratospheric ozone layer by phasing out the production of ozone depleting substances.

d. None of the above; incorrect, the Paris Agreement is the correct answer

2) **_______________refers to the total amount of Greenhouse Gases that are emitted into the atmosphere each year by a person, family, building, organization, or company.**

a. Carbon Footprint; correct

b. Carbon Sequestration; incorrect, this is the process by which trees and plants absorb carbon dioxide, release the oxygen, and store the carbon.

c. Carbon Capture; incorrect, Carbon capture and sequestration (CCS) is a set of technologies that can greatly reduce carbon dioxide emissions from new and existing coal- and gas-fired power plants, industrial processes, and other stationary sources of carbon dioxide.

d. Carbon Cycle; incorrect, All parts (reservoirs) and fluxes of carbon. The cycle is usually thought of as four main reservoirs of carbon interconnected by pathways of exchange.

3) John Muir is:

a. The author of the Net Zero manifesto; incorrect
b. An American politician who promoted the U.S. withdrawal from the Paris Agreement; incorrect
c. A Canadian climate expert; incorrect
d. credited as being America's first environmentalist; correct, because of his activism in the preservation of Yellowstone National Park and the Yosemite and Sequoia valleys.

4) IPCC stands for:

a. International Protocol for Climate Change; incorrect
b. Intergovernmental Panel on Climate Change; correct
c. Interim Program for Concerned Citizens; incorrect
d. Intra-National Pact of Climate Concerns; incorrect

Part 2

5) The key difference between Cradle-to-Grave and Cradle-to-Cradle is the added step for _______________

a. Burial; incorrect, both have End of Like (Grave) step
b. New variations; incorrect; not a step in this Life Cycle Assessment
c. Recycling; correct; Cradle-to-Cradle Life Cycle Assessment adds the Recycle step
d. Clean manufacturing; incorrect, manufacturing is in the Product Stage and in both Life Cycle assessments.

6) According to EN15643-1:2010, The period of time after installation during which a building or an assembled system (part of works) meets or exceeds the technical requirements and function is called:

a. Working Life, correct, this is the definition for Working Life from EN15643-1:2010
b. System Boundary; incorrect, System boundary is defined as the interface in the assessment between a building and its surroundings or other product systems
c. Life Cycle; incorrect; This is not the correct definition for life cycle
d. None of the above; incorrect, the answer is A

7) **The long-term trend in billion dollar disasters between 1980 and 2021 has:**

a. Stayed remarkably stable; incorrect, billion dollar disasters have increased
b. Dramatically decreased; incorrect, billion dollar disasters have increased
c. Has increased; correct just in 2016 there were 15, while in 2021 there were 20 billion dollar disaster events
d. None of the above; incorrect, they have increased as answer C states.

Part 3

8) **The 2030 Commitment Program was created by**

a. Architecture 2030 Organization; incorrect, the AIA created the program
b. American Institute of Architects; correct
c. US Green Building Council; incorrect, the AIA created the program
d. LEED; incorrect, the AIA created the program

9) **Which of the following are qualities of a high-quality carbon offset project? It must**

a. be counted only once; correct
b. be additional, transparent and verifiable; correct
c. avoid leakage; correct
d. All of the above; correct, A high-quality carbon offset project should have at least these 3 qualities.

10) **Which of the following is not listed in this course as a Carbon Neutral building?**

a. Orinda City Hall in Orinda, CA; incorrect, this building is listed in this course as a Carbon Neutral building
b. Stanford Historical Society Expansion, Paolo Alto, CA; correct, this building is NOT listed in this course
c. Portland State Univ. Stephen Epler Hall in Portland, OR; incorrect, this building is listed in this course as a Carbon Neutral building
d. Tillamook Forest Center in Tillamook, OR; incorrect, this building is listed in this course as a Carbon Neutral building

Part 4

11) **According to the IEA, is Net Zero achievable by 2050?**

a. No, there are too many political obstacles; incorrect, according to the IEA, this is achievable
b. Yes, easily achieved based on current trajectory; incorrect, it will not be easily achieved and will require some big changes.
c. No, the technologies do not exist; incorrect, according to the IEA, this is

achievable

d. Yes, but will require some big changes; correct, The IEA published their findings in May 2021 for the World Economic Forum that 2050 could be possible.

12) Which of the following is not an obstacle to achieving Net Zero?

a. Politics; incorrect, this is always an obstacle
b. Technology; correct, there are many available technologies that could allow the US to achieve net-zero emissions by 2050, therefore this is not one of the many obstacles
c. Economics; incorrect, this can be an obstacle
d. Wars; incorrect, this can be an obstacle

13) Logically orienting the building on the site in such a way that wind flows through nature is an efficient way of ventilation with minimal or no air conditioning systems is an example of...

a. Value engineering; incorrect
b. Native architecture; incorrect
c. Circular design; incorrect
d. Passive building design; correct, with the help of architectural elements like sun shading devices and wing walls, passive design can open new possibilities to achieve low-cost construction

14) Which famous architect said "Treat Nature as a Model":

a. Walter Gropius; incorrect, however he is a German-American architect
b. Renzo Piano; incorrect, however, he is one of our time's most impactful architects.
c. William McDonough; correct. William McDonough created the Hannover Principles, which is a set of guidelines for sustainability.
d. Zaha Hadid; incorrect, however she is a British-Iraqi architect

Part 5

15) LEED is a ...

a. Building rating system for environmental design; correct, it is from the US Green Building Council
b. Draft building code; incorrect
c. Universally accepted standard for Net Zero design; incorrect
d. Subsidiary of BRE (UK); Incorrect

16) Which of the following have been established based on European Standards?

a. LEED; incorrect
b. German Sustainable Building Certificate (DGNB); incorrect, it's holistic standard includes six criteria (environmental, economic, sociocultural and functional, technical, process and site)
c. BREEAM; incorrect, the concept of Carbon Negative building originated from

BREEAM

d. Living Building Challenge; correct, to achieve Living Building status requires one year of post construction measured data

17) What is the maximum points that can be earned in LEED rating for Optimizing Energy Performance?

a. 1; incorrect
b. 4; incorrect
c. 20; correct
d. 11; incorrect

Final Exam – California NetZero Design

1. The term Net Zero means:
    a. Free (Zero cost) energy
    b. Achieving a balance when the amount of carbon we add to the atmosphere is no more than the amount removed
    c. Buildings that rely only on natural ventilation and lighting
    d. Allowing new construction of buildings only if an older one is demolished – Zero new additions
2. Which of the following are referred to as “greenhouse gases”?
    a. CO_2
    b. CH_4
    c. N_2O
    d. All of the above
3. The state of the atmosphere at a particular location over the short term is:
    a. Atmospheric tension
    b. Climate change
    c. Climate
    d. Weather
4. Which one of the following is not included in the Greenhouse Gase (GHG) reporting under Kyoto Protocol?
    a. Carbon dioxide (CO_2)
    b. Methane (CH_4)
    c. Carbon Monoxide (CO)
    d. Nitrous Oxide (N_2O)
5. According to the International Energy Agency (IEA), in 2018 the buildings and construction sector accounted for ____ of energy and process-related carbon dioxide emissions.
    a. 32%
    b. 39%
    c. 57%
    d. 64%
6. According to the World Green Building Council, emissions due to cement manufacturing are responsible for:
    a. 7% of global carbon emissions
    b. 7% of US carbon emissions
    c. 7% of global pollution
    d. None of the above
7. How many distinct life-cycle stages are there for buildings according to EN:
    a. 5
    b. 4
    c. 2
    d. 3

8. _______ stage of building life-cycle includes processes from the practical completion of construction works to the point of deconstruction or demolition of buildings. Including emissions from use, maintenance, repair, replacement, refurbishment, operational energy and water use.
    a. Product
    b. Construction
    c. Use
    d. End-of-Life
9. The difference between Cradle-to-Grave and Cradle-to-Cradle is that the latter includes:
    a. Recycling of products
    b. Sensitive disposal of materials
    c. There is no difference, the terms are synonymous
    d. Locally procured materials at all stages of construction
10. According to GHG Protocol, there are three distinct Greenhouse Gas accounting scopes, namely: Scope 1, Scope 2 and Scope 3. _________ accounts direct Greenhouse Gas emissions or removals.
    a. Scope 1
    b. Scope 2
    c. Scope 3
    d. None of the above
11. Which of the following are impacts of increased precipitation?
    a. Decreased durability of materials
    b. Increased efflorescence and surface leaching concerns
    c. Increased corrosion
    d. All of the above
12. A highly energy efficient building that produces on-site, or procures, enough carbon-free renewable energy to meet building operations energy consumption annually is referred to as _______________________.
    a. Zero Net Carbon Building
    b. Carbon Neutral Building
    c. Carbon Negative Building
    d. Zero Carbon Building
13. In order to maintain licensure, ______________ is now requiring California architects to get training on zero net carbon design topics.
    a. The California Architects Board
    b. LEED
    c. Living Futures
    d. The AIA

14. The World Green Building Council (WGBC) established a "Net Zero Carbon Buildings Commitment" which has 176 signatories including the state of California. What are some of the goals of the Commitment?
    a. Phase out the use of concrete by 2030
    b. All new projects globally must achieve at least 40% of embodied carbon reductions by 2030
    c. Create a carbon accounting tool by 2030
    d. Develop a partnership with the other rating systems by 2030
15. A building that uses no fossil fuel, Greenhouse Gas emitting energy to operate is referred to as _____________________.
    a. Zero Net Carbon Building
    b. Carbon Neutral Building
    c. Carbon Negative Building
    d. Zero Carbon Building
16. Per the Architecture 2030 concept, what is the required % reduction over baseline building type by the year 2025?
    a. 50%
    b. 70%
    c. 90%
    d. 100%
17. Carbon Positive Buildings are those that:
    a. achieve less than zero emissions
    b. achieve more than zero emissions
    c. achieve zero emissions
    d. None of the above
18. According to the National Renewable Energy Laboratory (NREL) how many definitions are there of Net zero?
    a. 4
    b. 2
    c. 3
    d. 1
19. Green-e-Climate is...
    a. Part of the LEED certification process
    b. An EPA program to certify green products
    c. A global independent third-party product certification program
    d. A joint EU and US initiative to coordinate climate change response
20. According to the EPA, which of the following is not a component of a "Green Building"?
    a. Buildings only designed by LEED certified designers
    b. Water Conservation
    c. Resiliency
    d. Energy Efficiency and Renewable Energy

21. According to the author, which of the following is an overlooked component of a "Healthy building"?
    a. Its medical use
    b. Aesthetics
    c. Function
    d. No components were overlooked
22. According to the IEA, which of the following will be essential for achieving Net Zero by 2050?
    a. An increase tree planting
    b. Ending all new building construction
    c. Huge declines in the use of coal, oil and gas
    d. Replacing LEED with BREEAM
23. According to milestones for NZE published by the World Economic Forum and IEA, what is the target year for 50% of existing buildings to be retrofitted to zero-carbon-ready levels?
    a. 2025
    b. 2030
    c. 2040
    d. 2045
24. Vernacular Architecture has which of the following characteristics?
    a. Stresses on utilizing materials within reach from the site
    b. Applies only to developing countries
    c. Not designed by architects
    d. None of the above
25. A consequence of the lockdowns during the COVID 19 pandemic was ...
    a. A worsening of climate change
    b. New building techniques were developed
    c. A noticeable improvement in air quality
    d. All of the above
26. The Australian Islamic Center by Glenn Murcutt is an example of what kind of design?
    a. Biophilic
    b. Post Modern
    c. Deconstructivist
    d. Futuristic
27. LEED was developed by ...
    a. American Institute of Architects
    b. US Environmental Protection Agency (EPA)
    c. Building Research Establishment
    d. U.S. Green Building Council (USGBC)

28. Green Globes was developed by ...
    a. International Living Future Institute (ILFI) U.S.
    b. Green Building Initiative (GBI)
    c. Green Building Council Australia (GBCA)
    d. U.S. Green Building Council
29. GreenStar was developed by which organization?
    a. Passive House Institute US
    b. Green Building Initiative
    c. Green Building Council Australia
    d. MIT environmental lab
30. What is a choice of conscience?
    a. Something undesirable that is mandated by law
    b. A voluntary choice to “do the right thing”
    c. A choice that causes tax savings
    d. Something done out of getting caught