NetZer0 Design – A Guide for Architects

AIAPDH266

5 LU/HSW Hours

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Final exam for NetZer0 Design

1) **Which one of the following is not included in the Greenhouse Gas (GHG) reporting under Kyoto Protocol?**
   a. Carbon dioxide (CO_2)
   b. Methane (CH_4)
   c. Carbon monoxide (CO)
   d. Nitrous oxide (N_2O)

2) **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.

3) **How many distinct Life-cycle stages are there for buildings according to EN:**
   a. 5
   b. 4
   c. 2
   d. 3

4) **_________stage of building life-cycle 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.**
   a. Product
   b. Construction
   c. Use
   d. End-of-Life

5) **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

6) 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

7) 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

8) 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%

9) 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

10) EPA's Green Chemistry program

a. supports the research and development of safer chemicals and safer chemical processes through education and incentives.
b. works to incorporate risk related concepts into chemical processes and products designed by academia and industry.
c. provides cost-efficient and environmentally friendly solutions for large-scale landscaping that are designed to help preserve natural resources and prevent waste and pollution.
d. helps schools with tools and resources to establish and maintain good indoor air quality.

11) The state of the atmosphere at a particular location over the short term course is:

a. Atmospheric tension.
b. Climate change
c. Climate
d. Weather

12) According to the International Energy Agency (IEA), in 2018 the buildings and construction sector accounted for ____ of energy and process-related carbon dioxide (CO_2) emissions.

a. 32%
b. 39%
c. 57%
d. 64%

13) 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

14) 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

15) 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 Efficiency
c. Environmentally Preferable Building Materials and Specifications
d. Waste Reduction

16) 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

17) 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

18) 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

19) The Australian Islamic Center y Glenn Murcutt is an example of what kind of design?

a. Biophilic
b. Post Modern
c. Deconstructivist
d. Futuristic

20) 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

21) Which of the following are common sources of Federal Greenhouse Gas emissions?

a. CO_2
b. CH_4
c. N_2O
d. All of the above

22) GreenStar was developed by which organization?

a. Passive House Institute US
b. Green Building Initiative
c. Green Building Council Australia
d. MIT environmental lab

23) 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

24) How are fugitive emissions and refrigerant use in buildings reported?

a. In alternate years
b. Cumulatively
c. Separately
d. Together in aggregate

25) 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

26) 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)

27) A building that is a net exporter of zero carbon energy is referred to as a ...

a. A carbon neutral building
b. Net Zero building
c. Green Star building
d. Carbon negative building

28) According to the National Renewable Energy Laboratory (NREL) how many definitions are there of Net zero?

a. 4
b. 2
c. 3
d. 1

29) Green-e-Climate is...

a. Part of the LEED certification process
b. An EPA program to certify green products
c. A primary independent third-party product certification program
d. A joint EU and US initiative to coordinate climate change response

30) 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

Disclaimer Notice:

This course is intended to provide information as an educational benefit for architects and design professionals. The author has 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 accepts no liability whatsoever for, or in respect of any use or reliance upon this publication by any party. Author: Muhammad Siddiqui.

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 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, 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 futurist 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 encroachment 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 meanings and implications of the concepts and approaches for redress that should at least be considered. Up to this point, the discussion is fairly benign. However, beyond this is where a spaghetti bowl of confusion, doubts, cynicism, misinformation, misapplication, and simple misunderstandings create a foggy mist of information 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).

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 causes and effects for the given project should be considered and how best to provide a meaningful design response that the client can easily understand and buy into. A simple proposition? Maybe. 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, 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 terns 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 just this example means to each organization. As a result, the mission statements are worded 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 address them. 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. Enter, Architects and the built environment.

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 irrelevant.

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. 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

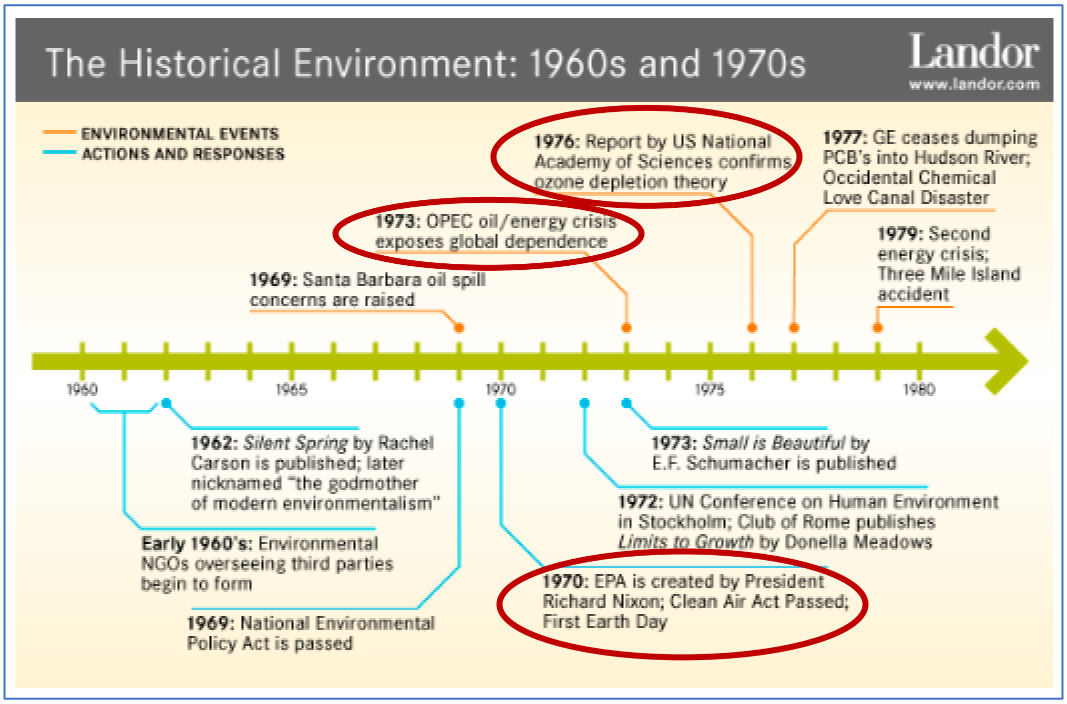


Figure 1.2

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. 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. An acknowledgement had occurred that buildings affect the environment and inefficient building tax resources disproportionally. It was also beginning to be observed that the solution would involve both short term corrections to retrofits but, more importantly, changes to fundamental design approaches to ensure lasting effects.

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 has been discussed above, 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' 2° C**.
   - The agreement includes a commitment to keep the rise in global temperatures "well below" 2° C compared to pre-industrial times, while striving to limit them even more, to 1.5 degrees.
   - Scientists consider 2° C the threshold to limit potentially catastrophic climate change.
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 give $100 billion annually to developing countries by 2020. This would help 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**.
   - Countries will be tasked with preparing, maintaining and publishing their own greenhouse gas reduction targets. The agreement says these targets should be greater than the current ones and "reflect [the] highest possible ambition."

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

- These targets will be reviewed and revised every five years starting in 2023.
- The agreement also says that each country should strive to drive down their carbon output "as soon as possible."

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 sometime after 2050 but before 2100.
    - 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. Although this Agreement, within the United National Framework Convention on Climate Change (UNFCCC), was signed by 196 countries globally, it was ratified (i.e., confirmed the agreement for adoption by 190 countries as of February 2021).

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 has 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*
- *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. We will examine the key ones below:

[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

- The Environment

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 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.

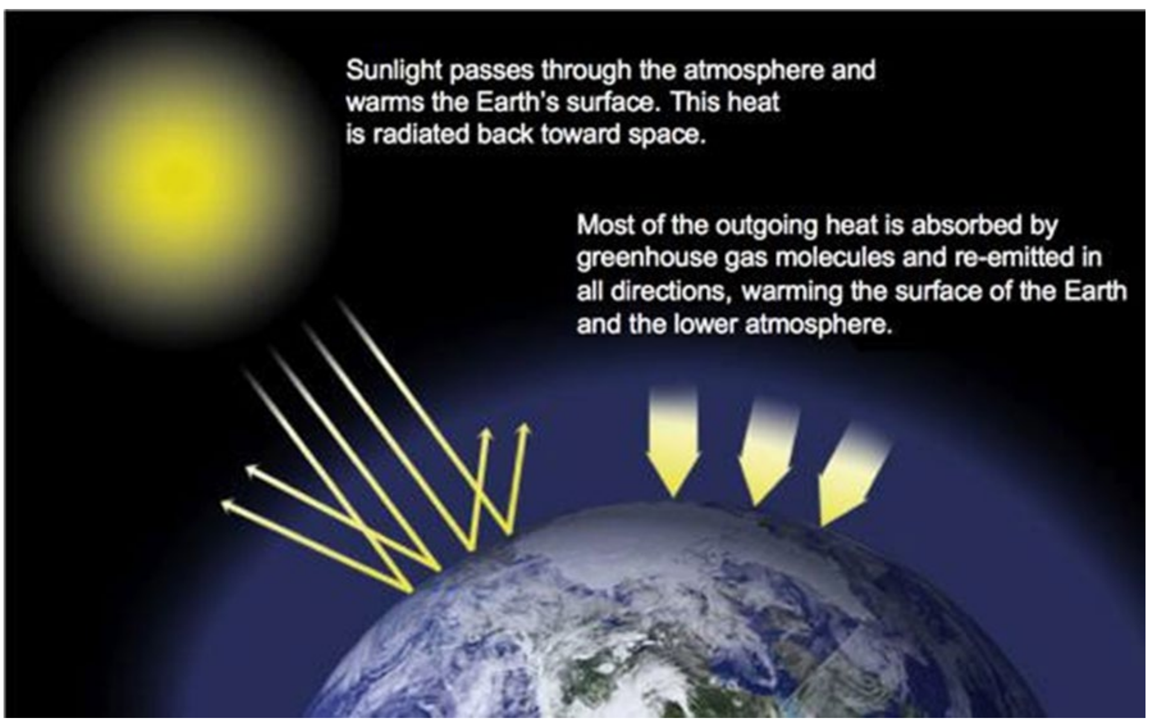


Figure 1.3.1

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 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 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 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 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, 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. 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.

It is not the intent of this course to debate or settle the issue of "climate change". Rather, the objective 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

[10] https://www.bbc.com/news/world-asia-44636934
[11] https://www.cnbc.com/2021/05/19/maldives-calls-for-urgent-action-to-end-climate-change-sea-level-rise.html

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.

In this spirit, rather than expand too much into the details and nuances of topics such as climate change, carbon footprints, and Global warming, the focus 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.*
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*

Terminology	Description / Explanation
	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 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. 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.*
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*

Terminology	Description / Explanation
	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 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 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*

[12] www.NOAA.gov

Terminology	Description / Explanation
	surface air temperature following a unit change in radiative forcing (degrees Celsius, per watts per square meter, (C/Wm-2).
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.*
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 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.*

Terminology	Description / Explanation
	Greenhouse gases include: 1. *carbon dioxide* 2. *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.*
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.*
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*

Terminology	Description / Explanation
	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 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.

- U.S. Greenhouse Gas Emissions – In 2019, U.S. greenhouse gas emissions totaled 6558 million metric tons of carbon dioxide equivalents. This total represents a 2 percent increase since 1990 but a 12 percent decrease since 2005. Carbon dioxide accounts for the majority of U.S emissions. Electricity generation in the U.S. is the major contributor of carbon dioxide followed by transportation. U.S. greenhouse gas emissions data is made available by two 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,

[13] www.NOAA .gov

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 have risen steadily since then, reaching an annual average of 410 ppm in 2015—a 46 percent increase. Almost all of this increase is due to human activities.
- Climate Forcing – This refers to a chance 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 2021 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 has 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 accepts no liability whatsoever for, or in respect of any use or reliance upon this publication by any party. Author: Muhammad Siddiqui.

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.

What we will not be presenting is a discussion of whether climate change is real or not, and whether it is caused by human or natural activities. That is best left to the scientific world of climate experts. Rather the course takes the supposition that an imbalance exists in the natural atmospheric environment and that is causing climate change. Further, it assumes that the 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. Buildings, Saviors or Villains?

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 36% of final energy use and 39% of energy and process-related carbon dioxide (CO_2) emissions in 2018. 11% of these resulted from manufacturing building materials and products such as steel, cement and glass.[19]

With such a stark indictment, one may rush to judge buildings as de-facto villains. But, as with most complex subjects, the reality is not binary. It is true that the building sector has a large share, but that is a result of its significant role in human habitation and urbanization. That said, there is no doubt that with such a significant proportionate responsibility, there is a pressing need for the 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.

With the above discourse in context the relationship of buildings, climate and the natural 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 or 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

[19] https://www.iea.org/reports/global-status-report-for-buildings-and-construction-2019

Protocol has successfully worked together with 179 countries which has 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 measurable targets including the all-encompassing Net Zero.

As has been noted, the building sector is one of the major causes or 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 relatively high proportion of attainment 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, technological advancements and, declining costs due to wider application.

The embodied energy and emissions of building materials and products is the second major 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 [20]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.*[21]
2. *Wood-based wall systems require 10–20% less embodied energy than traditional concrete systems* [22] [23]*and that concrete-framed buildings require less embodied energy than steel- framed buildings.*[24]
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.*
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.*[25]

[20] IPCC Assessment Report 5 - Chapter 9 - Buildings <https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_chapter9.pdf >
[21] 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.
[22] 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.
[23] Sathre R., and L. Gustavsson (2009). Using wood products to mitigate climate change: External costs and structural change. Applied Energy 86, 251–257.
[24] 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.
[25] 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

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 and 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

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 and an abandoned "zilch" or nothing at the end 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 reputed 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. Based on Life-cycle Stages[26]

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.

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 options	Product stage (required) + Construction stage (optional) + Use stage (optional) + End-of-Life stage (optional)

[26] 7 EN 15804:2012 - 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.

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[27]:

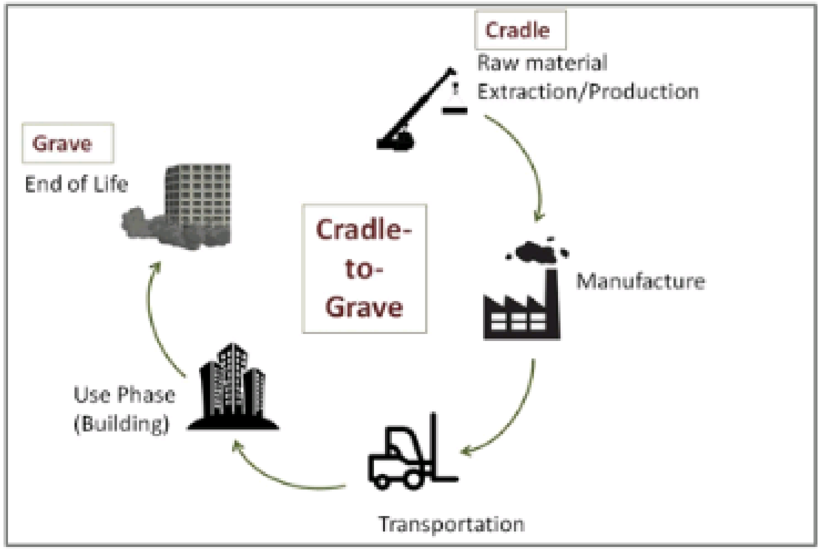


Figure 2.2.1

Cradle to Grave Life Cycle Assessment

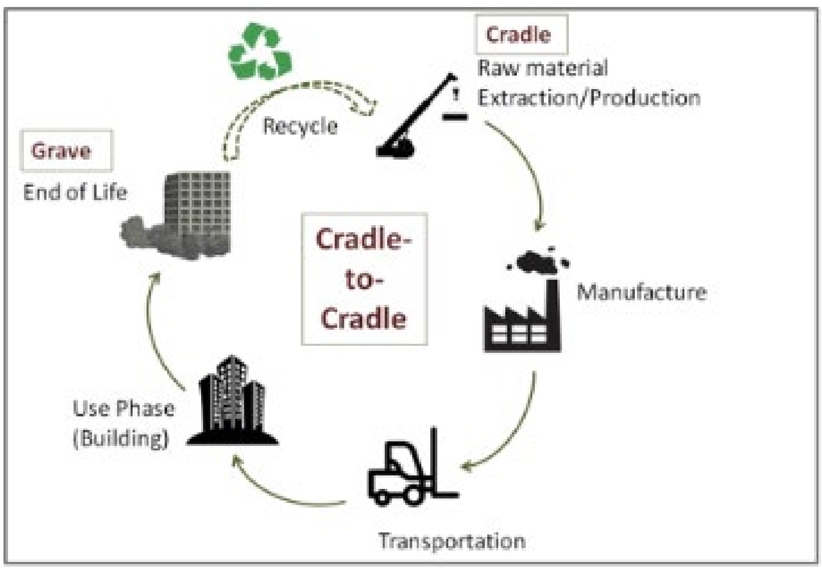


Figure 2.2.2

Cradle to Cradle Life Cycle Assessment

[27] https://www.archecology.com/2017/05/31/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).[28]

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 technical requirements and function*

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

II. Based on ownership and control of reporting entity

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 prosperous9.

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.

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

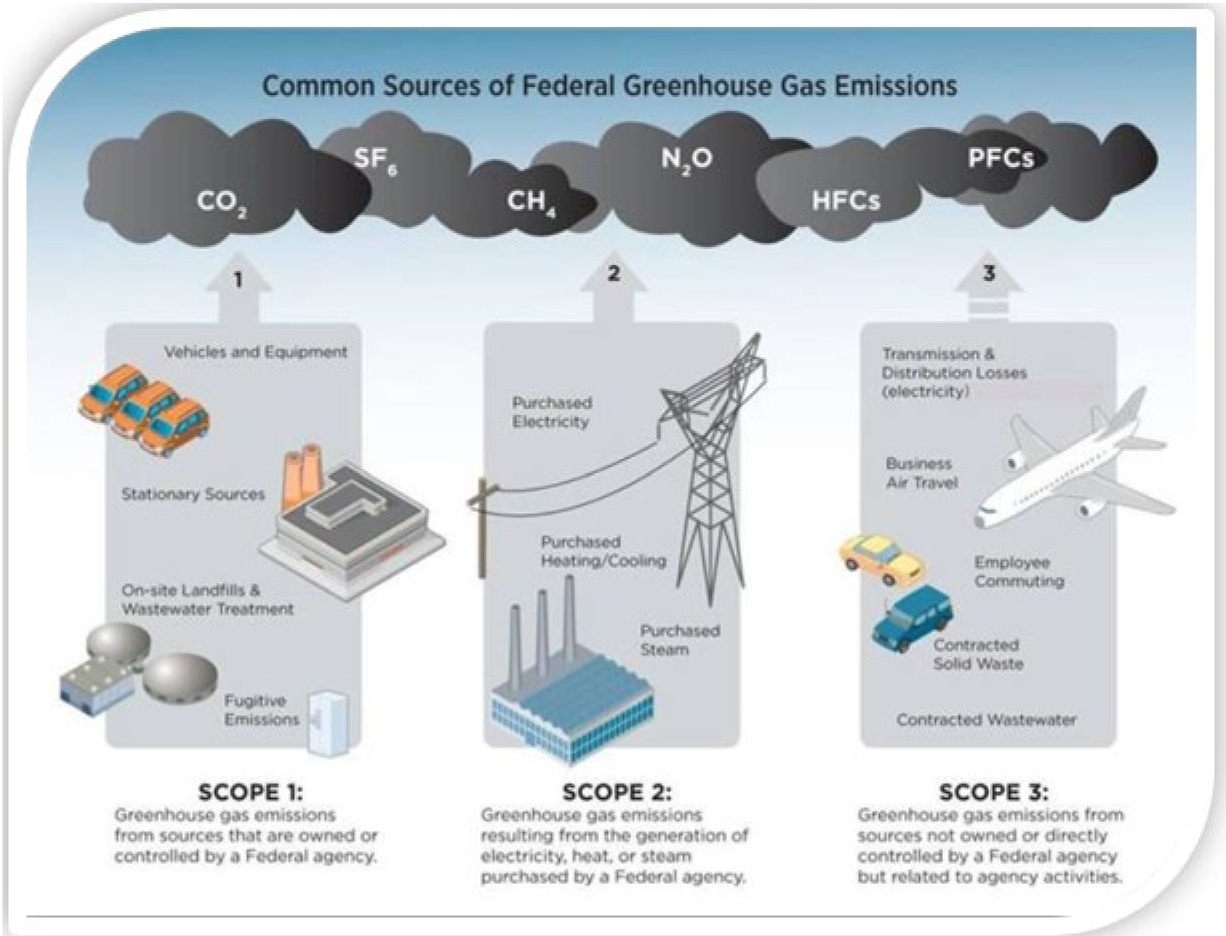


Figure 2.2.3

GHA Accounting at EPA[29]

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.

[29] 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.

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 [30]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>

A Whole Life Carbon Footprint Analysis of Buildings is the sum of greenhouse gas emissions and removals associated with a building project, over its entire life cycle. Emissions and removals are

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

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:

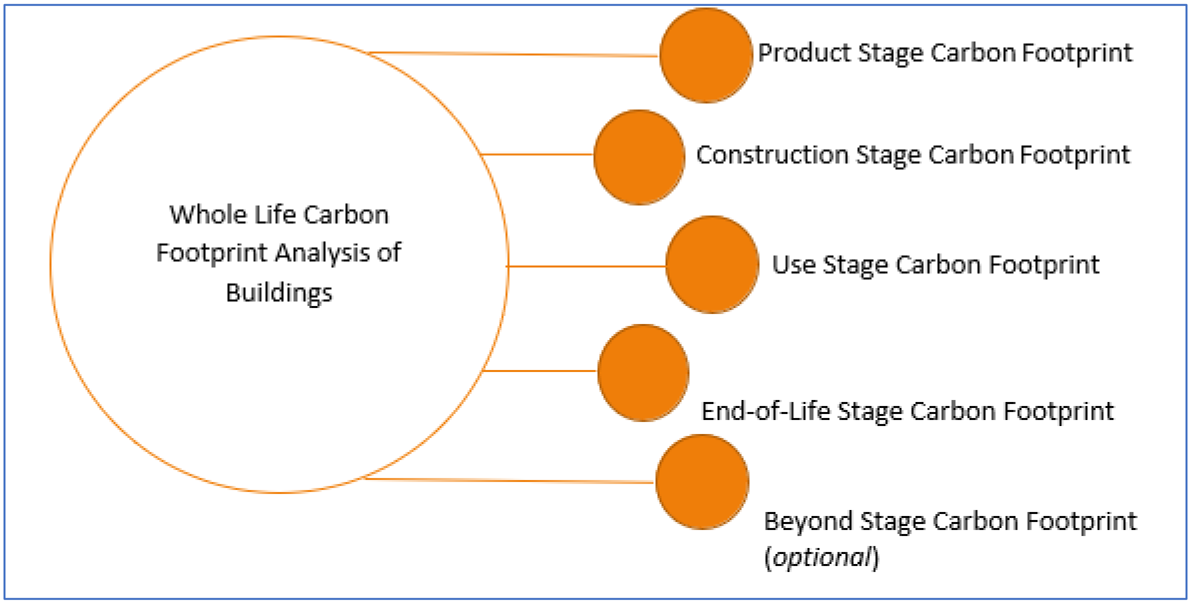


Figure 2.3.1

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 number of environmental impact category that is 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*." 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. Core Standards that govern Carbon Footprint of a Product are GHG Protocol, PAS 2050 and ISO 14067, 14064, 14065, 14066, 14069 and 16745.	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*." 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 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 "Key Findings from the Intergovernmental Panel on Climate Change Fifth Assessment Report"[31] , the construction sector will be one of the main 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.

Climate and Infrastructure in the U.S.

Since 1980, the U.S. has sustained 323 weather and climate disasters costing over $2.195 trillion[32].

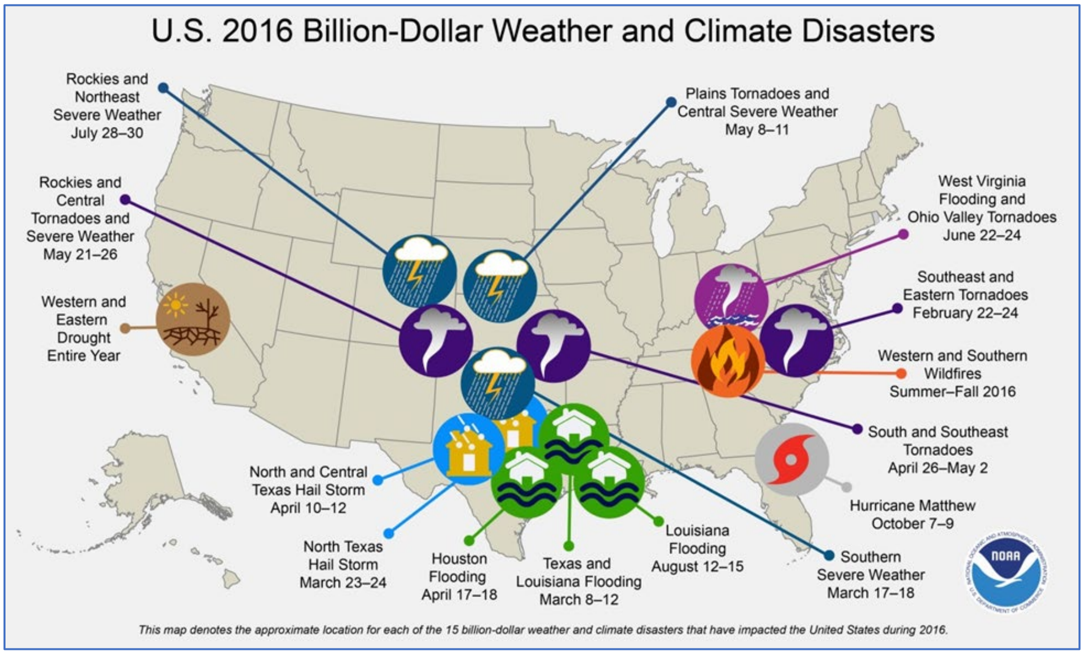
More recently, in 2021, the U.S. sustained 20 weather and climate disaster with costs exceeding $1 billion each, while in 2016, a total of 15 disaster events occurred in the U.S. (see figures below). These weather events are not evenly distributed across the U.S. with some states suffering more than 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 a certain 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 (read: more codes) and higher insurance rates and material costs.

To drive this point, the next few pages will highlight the risks and consequences of climate related events to the built environment.

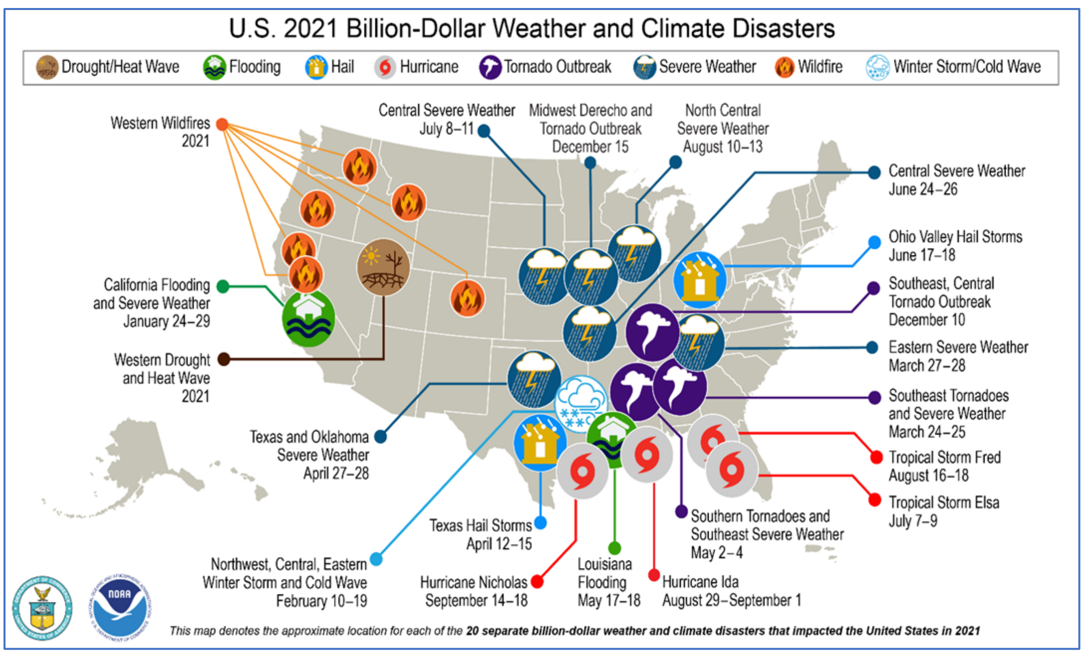
[31] Climate Change: Implications for Buildings - Key Findings from the Intergovernmental Panel on Climate Change Fifth Assessment Report < http://www.cisl.cam.ac.uk/business-action/low-carbon-transformation/ipcc-climate-science-business-briefings/pdfs/briefings/IPCC_AR5 Implications_for_Buildings Briefing WEB_EN.pdf >

[32] NOAA (National Oceanic Atmospheric Administration) National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2017). < https://www.ncdc.noaa.gov/billions/overview >



This map denotes the approximate location for each of the 15 billion-dollar weather and climate disasters that have impacted the United States during 2016.

In 2016, NOAA studies show that the U.S. South / Central and Southeast regions experience higher frequency of billion-dollar disasters. While Southeast regions are primarily due to wildfires, the Southern regions face drought. The weather disaster types include drought, flooding, freeze, severe storm, tropical cyclone, wildfire, winter storm, etc. Among these disaster types, tropical cyclone has the highest percent of total losses (at 47.3%) followed by drought (18.9%) and severe storm (15.7%).



This map denotes the approximate location for each of the **20 separate billion-dollar weather and climate disasters that impacted the United States in 2021**

In 2021, these events included 1 drought event, 2 flooding events, 11 sever 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.

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, buildings are forced to develop more resilience at a higher cost. When this is not affordable, partial solutions are implemented and that results 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 others, substantial damage to a concrete building.

An unexpected freeze causes building pipes to burst (freezing and thawing causes water pressure to increase and eventually leads to bursting pipes). Besides, freezing causes 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 foundations14. 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 2021. (Source: NOAA)[33]

Event	Begin Date	End Date	Summary
Western Wildfires	June 1, 2021	December 31,2021	Severe drought conditions and periods of extreme heat provided conditions favorable for another damaging western wildfire season most focused across California, Colorado, Oregon, Washington, Idaho, Montana and Arizona. Throughout the wildfire season air quality was also a concern across numerous states, as ash and fine particulates from wildfires obscured the skies and made outdoor activities more hazardous. Over 7.1 million acres burned nationally during the 2021 wildfire season.
Western Drought and Heat Wave	January 1, 2021	December 31, 2021	Wester drought conditions were persistent throughout 2021, as the drought expanded and intensified across many Western States. A historic heat wave also developed for many days across the Pacific Northwest shattering numerous all-time high temperature records across the region. This prolonged heat dome was maximized over

[33] 15 NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2017). < https://www.ncdc.noaa.gov/billions/ >

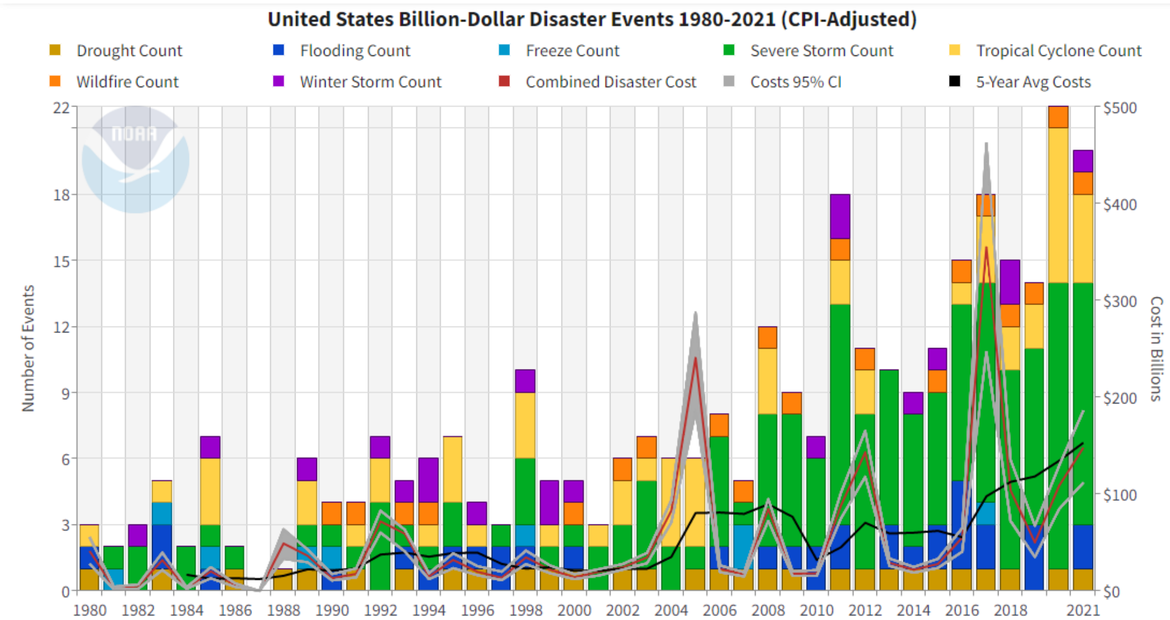
Event	Begin Date	End Date	Summary
			the states of Oregon and Washington and extended well into Canada. These extreme temperatures impacted several major cities and millions of people. This combined drought and heat rapidly dried out vegetation across the West, impacting agriculture. Low water levels also forced the hydroelectric power plant at Lake Oroville in California to shut down for the first time since it opened in 1967.
Midwest Derecho and Tornado Outbreak	December 15, 2021	December 15, 2021	A rare, record-breaking December derecho and tornado outbreak caused widespread damage that was focused across Kansas, Nebraska, Iowa, Minnesota and Wisconsin. There were many reports of hurricane-force thunderstorm wind gusts and more than 50 tornadoes causing widespread damage to homes, vehicles, businesses and infrastructure. This was the first December derecho on record to occur within the United States. This event also produced the first December tornado on record in Minnesota since 1950, with 17 tornadoes reported across southeast Minnesota.
Southeast Central Tornado Outbreak	December 10, 2021	December 10, 2021	Historic December tornado outbreak across several southeast and central states caused devastating damage across many towns and cities. This outbreak produced two long-tracked EF-4 tornadoes across Arkansas, Missouri, Tennessee and Kentucky. The longest tornado track was nearly 166 miles across Kentucky and a small portion of Tennessee. This was the longest-tracked tornado on record in Kentucky and was a U.S. record tornado track length for the month of December. There were over 800 total miles of tornado path length on December 10. The peak intensity from this outbreak was EF-4 rated wind speeds of 190 mph in Mayfield, Kentucky. This day was also the deadliest December tornado outbreak recorded in the United States surpassing the Vicksburg, Mississippi tornado of December 5, 1953, which caused 38 fatalities.
Hurricane Nicholas	September 14, 2021	September 18, 2021	Category 1 Hurricane Nicholas made landfall near Sargent Beach, Texas on September 14 and moved slowly toward Louisiana over the next several days. This slow progression helped to produce flooding rainfall across regions of the Gulf Coast that were already saturated from

Event	Begin Date	End Date	Summary
			Hurricane Ida.
Hurricane Ida	August 29, 2021	September 1, 2021	Category 4 Hurricane Ida made landfall near Port Fourchon, Louisiana with maximum sustained winds of 150 mph and a minimum central pressure of 930 mb. As the remnants of Ida moved into the Northeast it merged with a frontal system creating severe weather and flash flooding across a wide region from eastern Pennsylvania to New York. Flash flood emergencies were declared in New Jersey and New York for the first time, producing damage to homes, businesses, vehicles and infrastructure while also causing dozens of fatalities.
Tropical Storm Fred	August 16, 2021	August 18, 2021	Tropical Storm Fred made landfall near Panama City, Florida. As Fred progressed northward it caused torrential flooding across the southern Appalachian Mountains with more than a foot of rainfall reported in some locations of western North Carolina. This flash flooding caused damage to many homes, businesses, vehicles, roads and bridges, in additional to several fatalities. Fred also produced nearly a dozen tornadoes across the Northeast as it moved up the East Coast.
North Central Severe Weather	August 10, 2021	August 13 2021	Widespread high wind impacts across numerous North Central states including Illinois, Michigan, Wisconsin, Indiana, Ohio and Missouri. This multi-day event caused damage to infrastructure, homes, vehicles and businesses.
Central Severe Storms	July 8, 2021	July 11, 2021	Severe storms caused considerable hail damage across numerous Central states including Missouri, Nebraska, Iowa, South Dakota, North Dakota, New Mexico and Texas. There was also widespread high wind damage to homes, vehicles and businesses in many other surrounding states.
Tropical Storm Elsa	July 7, 2021	July 9, 2021	Tropical Storm Elsa made landfall in Taylor County, Florida producing heavy rain, wind, flooding and tornadoes in portions of Florida, Georgia and the Carolinas, as well as flooding across parts of the Northeast. Elsa was the earliest fifth-named storm on record.

Event	Begin Date	End Date	Summary
Central Severe Storms	June 24, 2021	June 26, 2021	A combination of thunderstorm high winds, hail and tornadoes affected numerous Central states. The states most affected included Michigan, Illinois, Indiana, Ohio, Missouri, Kansas and Texas with damage to homes, businesses, vehicles and agriculture.
Ohio Valley Hailstorms	June 17, 2021	June 18, 2021	Damaging hailstorm and high wind impacts across several states including Ohio, Illinois, Indiana, Michigan, Wisconsin, Minnesota, Iowa and Missouri.
Louisiana Flooding	May 17, 2021	May 18, 2021	Torrential rainfall from thunderstorms across Louisiana and coastal Texas caused widespread flooding and resulted in hundreds of water rescues. Baton Rouge and Lake Charles experienced flood damage to thousands of homes, vehicles and businesses, as more than 12 inches of rain fell.
Southern Tornadoes and Southeast Severe Weather	May 2, 2021	May 4, 2021	Tornadoes and severe storms with widespread high wind and large hail cause damage across many Southern and Southeastern states including Mississippi, Texas, Arkansas, Alabama, Georgia, South Carolina, North Caroline, and Tennessee.
Texas and Oklahoma Severe Weather	April 27, 2021	April 28, 2021	Severe weather including tornadoes, high wind, localized flooding and large hail cause widespread impacts across central Texas and Oklahoma. There was considerable damage across Texas and Oklahoma to many homes, vehicles and businesses particularly from hailstorms.
Texas Hailstorms	April 12, 2021	April 15, 2021	A series of hailstorms impacted central Texas causing damage to many homes, vehicles and businesses. There was considerable hail damage northeast of Austin, west of Georgetown and southwest of The Woodlands.

Event	Begin Date	End Date	Summary
Eastern Severe Weather	March 27, 2021	March 28, 2021	Severe weather producing hail, high wind and more than two dozen tornadoes impacted numerous states including Arkansas, Alabama, Georgia, Mississippi, South Carolina, North Carolina and Virginia. Tennessee was also affected with significant flooding in Nashville and surrounding areas that damaged businesses, homes and vehicles.
Southeast Tornadoes and Sever Weather	March 24, 2021	March 25, 2021	At least 41 tornadoes impact several states including Kentucky, Tennessee, Mississippi, Alabama and Georgia.
Northwest, Central, Eastern Winter Storm and cold Wave	February 10, 2021	February 19, 2021	Historic cold wave and winter storm impacts many northwest, central and eastern states. Temperature departures exceeding 40.0 degrees F (22.2 degrees C) below normal occurred from Nebraska southward to Texas. The prolonged arctic air caused widespread power outages in Texas, as well as other southern states, with multiple days of sustained below-freezing temperatures.
California Flooding and Severe Weather	January 24, 2021	January 29, 2021	California was impacted by an atmospheric river in late-January in which more than 7 inches of rain fell from southern California to the central California coast. Rainfall totals exceeded 15 inches in Monterey and San Luis Obispo counties. Cozens of slides and debris flows damaged homes, vehicles and businesses and infrastructure.

To see the long-term trend in billion-dollar disasters, the graphic below from NOAA shows the trend between 1980 and 2021. The values are CPI adjusted to account for inflation and normalize the value.



The International Institute of Sustainable Development (IISD), [34]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.

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

Climate Change and Infrastructure Impacts: Buildings[35]

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

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

2.6. Climate Risk

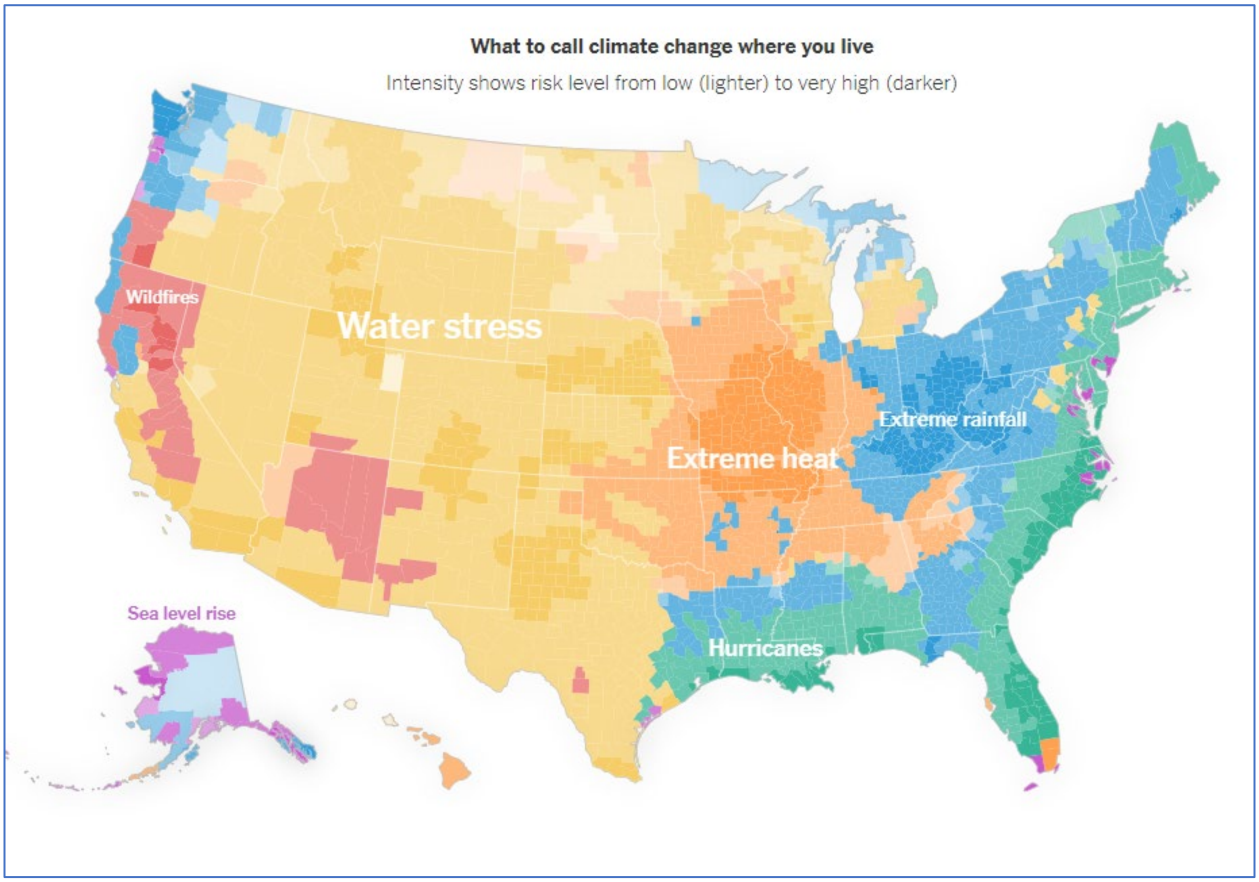
In a February 2022 publication, four partners at McKinsey & Company made the following assessment:

> *… 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.*[36]

To understand climate risks for a localized area in the United States, the New York Times has published a helpful tool [37]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.

[36] 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

[37] 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 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 better place to live for the current and future generations

2.7. What Now?

We started this section by asking whether buildings are villains or heroes in the quest for Net Zero? In the preceding discussion, sometimes admittedly dwelling excruciatingly deep into the realm of climate change and the many subjects and themes associated with it, it has been shown that there is an interactive dynamic between buildings and their contributions to GHGs and the impact of climate change (assuming its contribution at some level to the increased frequency of natural disasters and temperature extremes). This has been a long developing situation but as it reaches the proverbial “fever pitch”, a reckoning is approaching. So far, to the question of villain or hero, the situation is that buildings and their designers and builders have been more or less silent, maybe even “accidental” participants. They did not set out to willfully destroy the environment; but neither did they 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 specially the designers – Architects and engineers, are at the precipice of making decisions that will ultimately define whether they choose to make their creations heroes or villains. Thanks (or perhaps not) to the concept of Net Zero, where tangible targets and deadlines are in place, the design professionals are taking the legacy of the last 25 years of “green” architecture concepts, philosophies and ideas and increasingly incorporating them into new 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. That in turn will 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 2021 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 has 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 accepts no liability whatsoever for, or in respect of any use or reliance upon this publication by any party. Author: Muhammad Siddiqui.

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 have 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."***[38]

[38] 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 and abundant, cheap, energy, and the seemingly endless choices of materials and gadgets, the building boom has morphed from a necessity to a race for opulence and excess driven by short sighted consumerism rather than prudent functionality. It can be compared to an addition. As such, in order to cure the ills brought on by this condition, it would make sense for the first step would be that same as 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 of paving the way for the road to Net Zero.

Before we look at concepts and evolving solutions, it should be recognized that the issue is not being tackled from a static situation. The entire building cycle is very dynamic and intertwined with every other human activity.

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[39]. 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, levels of wealth, style of living conditions, and changes to household sizes, a larger increase in greenhouse gas emissions looms. This is happening at the same time there are efforts underway to contain, manage and mitigate the negative impacts of this growth. This dynamism compounds the challenges for designers who are trying to advance the improvements that will enable attainment of Net Zero. On the flip side, the constant need to build new and, facilitate replacement of older, more inefficient facilities, offers an opportunity to make the new better and 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)

[39] 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.

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

- Zero Net Carbon Buildings
- Carbon Neutral Buildings
- Carbon Negative 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 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 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) [40] 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."

Applicable Building Sectors & Types

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

Life Cycle and Spatial Boundaries

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. 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

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 its energy needs.

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

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

Zero Net Carbon is a concept very recent in origin, and detailed certification pathways are yet to be developed and incorporated in practice. The reasoning of this concept is that all buildings should be able to achieve Zero Net Carbon status, without the building project stakeholders of having to be swamped with constraints or limitations imposed by pathways. Since its origination in July 2016, there has been a workshop among the ten Green Buildings Councils (GBC) worldwide (Australia, Brazil, Canada, China, India, Germany, South Africa, Sweden, The Netherlands and the United State), along with the World Green Building Council (WBGC) and Architecture 2030 to adopt a ZNC definition and establish certification program to achieve Zero Net Carbon goals in their respective countries by 2017.

3.4 Carbon Neutral Buildings

The concept of Carbon Neutral building originated from an initiative by Architecture 2030 Challenge[41] 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. [42]

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

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

Carbon Neutral building 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 building site level.

Metrics & Timeline

One of the key things to understand about carbon neutral building is that it's not the same as net zero building. Net zero building means building structures that use zero net energy, thus they have no carbon emissions. In carbon neutral building, the buildings will still produce some carbon, even if their carbon footprints are drastically reduced.[43]

So, what about that remaining, if small, carbon footprint? That's where offsetting comes in. 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.[44]

[41] http://architecture2030.org/2030_challenges/2030-challenge/
[42] https://architecture2030.org/2030_challenges/2030-challenge/
[43] https://nebldgsupply.com/what-is-a-carbon-neutral-building/
[44] https://nebldgsupply.com/what-is-a-carbon-neutral-building/

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 required reductions over baseline building type by year.
- 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 required reduction).

An important aspect of Architecture 2030's Carbon Neutral building concept 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 70% 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 Products [45]– Focuses on reducing the embodied carbon equivalent of building products. This challenge applies to new buildings, developments and renovations. The proposed metric for this challenge is kilogram carbon dioxide equivalent (kg CO_2-Equivalent) per functional unit depending on whether a given assessment is cradle-to-grave or cradle-to-gate.

The targeted maximum carbon-equivalent footprint reduction over product category average is as follows:

2010 – 30% or better; 2015 – 35% or better; 2020 – 40% or better; 2025 – 45% or better; 2030 – 50% or better

However, product category benchmarks for comparisons have not been established and been long due since 2014. It is unclear if any alternative product benchmarks have been proposed. The Architecture 2030 Challenge for Products have been adopted by several manufactures, design professions and supporters.

2030 Challenge for Planning [46]– 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.

For 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 – 70%; 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.

[45] http://architecture2030.org/2030_challenges/products/
[46] http://architecture2030.org/2030_challenges/2030_challenge_planning/

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 is 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 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 [47]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 are 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 designing Aldo Leopold Legacy Center, a Carbon Neutral Building.

- 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. <u>Carbon Neutral Building - Operational Energy (Scope 1 & 2)</u>
"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."

[47] http://www.tboake.com/carbon-aia/

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.

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 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 buldings.

Aldo Leopold Legacy Center in Baraboo, WI, 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 building project won the 2008 AIA COTE Top Ten Green Projects Award.

3.5 Carbon Negative Buildings

The concept of Carbon Negative buildings originated from Building Research Establishment Environmental Assessment Method (BREEAM UK New Construction Rating System, Reduction of energy use and carbon emissions in the Energy section[48]) in 2011. BREEAM defines a Carbon Negative building as:

> *"a building/site that generates, surplus to its own energy demand, an excess of renewable or carbon neutral energy, and exports that surplus via the National Grid to meet other, off-site energy demands, i.e., the building is a net exporter of zero carbon energy."*

Applicable Building Sectors & Types

Carbon Negative building concept applies to all new construction and extension of non-domestic building types.

Life Cycle and Spatial Boundaries

Carbon Negative Building "focuses only on energy and carbon dioxide emissions resulting from the operational stage of the building life cycle (as this is the stated aim of this assessment issue). It does not take in to account the embodied carbon, in terms of carbon fixing or emissions resulting from the manufacture or disposal of building materials and components." The spatial boundary scale is set at the building level.

Metrics & Timeline

The annual metric established for Carbon Negative buildings is zero net regulated carbon emissions (kg CO_2 /m^2.yr.

Pathways and Applications in Practice

The pathway for Carbon Negative Building is:

[48] http://www.breeam.com/nondom_mobile/Advanced/content/06_energy/ene01.htm

- First, measure and reduce emissions through integrated building design strategies and energy efficiency measures.
- Second, reduce emissions by incorporating on-site and near-site renewable energy systems.
- Third, export of surplus on-site renewable energy through the National Grid to meet other off- site energy demands.

An example of a Carbon Negative Buildings is an educational facility for students called *Bramall Learning Center* at the Royal Horticultural Society's gardens. A 15kW wind turbine provides on-site energy generation. This building was designed by Eco Arc Architects. The building has won numerous awards owing to extraordinary performance in reducing greenhouse gas emissions by going above and beyond carbon neutral.

On-site and near-site renewable energy + purchased off-site renewable energy exceeds operational energy consumption.

3.6 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 [49] 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

[49] http://www.asbec.asn.au/files/ASBEC_Zero_Carbon_Definitions_Final_Report_Release_Version_15112011_0.pdf

- 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.*

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.

3.7 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,'* [50] 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

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

shows the rigor by which the designers and engineers have attempted to reduce energy consumption as well as promoted on-site energy generation.

In September 2015, the NZE definitions were updated by the US Department of Energy's report titled, '*A Common Definition for Zero Energy Buildings.'*[51] The primary purposes of this new report and common definitions are to create a standardized basis for identification for NZEs for use by industry and to influence the design and operation of buildings to substantially reduce building operational energy consumption. The four broad definitions introduced are:

(1) "***Zero Energy Building (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***.

(2) ***Zero Energy Campus***: An energy-efficient ***campus*** where, on a ***source energy*** basis, the actual ***annual delivered energy*** is less than or equal to the on-site renewable ***exported energy.***

(3) ***Zero Energy Portfolio:*** An energy-efficient ***portfolio*** where, on a ***source energy basis***, the actual ***annual delivered energy*** is less than or equal to the on-site renewable ***exported energy***.

(4) ***Zero Energy Community:*** An energy-efficient ***community*** where, on a ***source energy*** basis, the actual ***annual delivered energy*** is less than or equal to the on-site renewable ***exported energy***."

A Zero Energy Building variant that was introduced is:

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 <u>meets</u> 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) <u>meets</u> operational energy consumption, on an annual basis.*

[51] https://energy.gov/sites/prod/files/2015/09/f26/A%20Common%20Definition%20for%20Zero%20Energy%20Buildings.pdf

Concept	Measurement	Boundary Condition	Equations
Carbon Negative Building	Carbon Emissions	Site Energy	*On-site and near-site renewable energy + purchased off-site renewable energy exceeds operational energy consumption.*
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."*

3.8 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 offset is a complicated topic and have been subject to many controversies in the past few 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 [52]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

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

(2) be additional, transparent and verifiable; and

(3) avoid leakage."

Further, the report recommends carbon offset project 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 program.

- The independent third-party project certification programs develop their own standards and verify carbon offset project meet minimum standards. They may also verify the carbon reductions and issue credits that can traded by offset retailers.

The following is a list of independent third-party project certification programs for carbon offsets, along with the names of their carbon credit units and market coverage. Each project certification program has devised its own selection criteria and protocols for the types of projects eligible for registration under their authority.

Project Certification Programs[53]	Tradable Carbon Credit Units	Markets
American Carbon Registry (ACR)	Emission Reduction Tonne (ERT)	Global
Climate Action Reserve (CAR)	Climate Reserve Tonne (CRT)	North America
The Voluntary Gold Standard	Verified Emission Reduction (VER)	Global
United Nations Framework Convention on Climate Change Clean Development Mechanism (UNFCCC CDM)	Certified Emission Reduction (CER)	Global
United Nations Framework Convention on Climate Change Joint Implementation (UNFCCC JI)	Emission Reduction Unit (ERU)	Global
Verified Carbon Standard (VCS)	Verified Carbon Unit (VCU)	Global

- The independent third-party **product certification programs** develop standards and certify the final carbon offset product sold in the marketplace.

3.9 Green-e-Climate

Green-e Climate [54] is a primary 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

[53] http://apps3.eere.energy.gov/greenpower/markets/carbon.shtml?page=0
[54] https://www.green-e.org/

endorsed project certification programs [55] 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 additionality, permanence, transparency, balance and impartiality, environmental integrity of carbon emissions reduction, validity and verification of carbon emissions reductions, and disclosure and avoidance of double sales and double issuance.

Green-e Climate is required or recommended by programs such as Leadership in Energy and Environmental Design (LEED), Architecture 2030 Challenge, Sustainable Purchasing Leadership Council (SPLC), The Carbon Registry (TRC), B Corporation, and Cradle to Cradle. As of February 2017, the Green-e climate has about 11 participants offering one or more carbon offset products[56]

Green-e Climate Certified Carbon Offset Retailers	Product Name	Offset Project Type and Location	Project Certification
3Degrees0	Green-e Climate Landfill Gas Carbon Offset	Landfill Gas Carbon Offset (USA)	Climate Action Reserve
Blue Spruce Energy Services	BLUE SPRUCE Green Gas	Improved Forest Management (USA)	Climate Action Reserve
Bollinger Energy Corporation (Third party distributor for Terra Pass)	Net Zero Carbon Diesel and Net Zero Carbon Natural Gas	Landfill Methane Capture (USA)	Verified Carbon Standard
BEF	BEF Carbon Mix	Landfill Gas Capture (USA)	Climate Action Reserve
		Landfill Gas Capture (USA)	Verified Carbon Standard
		Renewable Energy (USA)	Verified Carbon Standard
		Organic Waste	Climate Action Reserve

[55] https://www.green-e.org/programs/climate/endorsed-programs
[56] https://www.green-e.org/certified-resources/carbon-offsets

Green-e Climate Certified Carbon Offset Retailers	Product Name	Offset Project Type and Location	Project Certification
		Composting (USA)	
		SF6 Reduction (Canada)	Verified Carbon Standard
Carbon Solutions Group	CSG Landfill Gas Carbon Offset	Landfill Gas Capture (USA)	Verified Carbon Standard
City of Palo Alto Utilities	PaloAltoGreen Gas	Livestock Methane Capture (USA)	Climate Action Reserve
Direct Energy	C-Neutral–Coal Mine Methane	Coal Mine Methane Capture (USA)	Verified Carbon Standard
	C-Neutral–Landfill Methane Capture	Landfill Methane Capture (USA)	Verified Carbon Standard
Renewable Choice Energy	Green-e Climate Landfill Gas Carbon Offsets	Landfill Methane Capture (USA)	Climate Action Reserve
Sterling Planet	Sterling Climate Premium	Landfill Gas Utilization (USA)	Verified Carbon Standard
TerraPass	Net Zero Carbon Diesel	Landfill Methane Capture (USA)	Verified Carbon Standard
	Net Zero Carbon Natural Gas	Landfill Methane Capture (USA)	Verified Carbon Standard
WGL Energy	Carbon Offsets from WGL Energy	Landfill Methane Capture (USA)	Verified Carbon

Green-e Climate Certified Carbon Offset Retailers	Product Name	Offset Project Type and Location	Project Certification
			Standard

3.10 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 win 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. On reason for the proliferation of these ideas into common language is precisely because they are broad in scope, catchy benign sounding phrases that create appeal without creating an intimidating aura of impending doom. In this section, some of the most popular of these concepts will be defined. It is important that design professionals understand what these philosophies really mean since so much of the popular usage conflates many of these with each other and with other, more specific terms.

Sustainable Design:

Sustainability is a word that has gained very wide traction over the past several years. 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 to advance sustainable behavior. On the other hand, what "sustainable" means is vaguely defined, if at all, by most groups. The concept, itself is really quite simple:

***Sustainability**: In the broadest sense, sustainability refers to **the ability to maintain or support a process continuously over time**. In business and policy contexts, sustainability seeks to prevent the depletion of natural or physical resources, so that they will remain available for the long term.*[57]

As can be gleaned from the definition, it can apply to many diverse sets of activities, behaviors, regulations, or techniques that in some way improve a process to make it less harmful towards natural resources, thereby maintaining a balanced supply. Sustainability is a high level, "umbrella" concept that establishes an ambition to achieve. It does not have a tangible target for a specific outcome. All the measurable programs with targeted objectives, whether GHG reduction, carbon neutralization, LEED certifications, or other programs all fall under the "sustainable" umbrella. The term is appealing because of the positive connotation and neutral tone. It is ***not*** a specific program with a measurable goal and schedule. There are, however, some principles that help guide sustainable practices.

[57] www.investopedia.com

"The principles of sustainability are the foundations of what this concept represents. Therefore, sustainability is made up of three pillars: **the economy, society, and the environment**. These principles are also informally used as profit, people and planet.

John Elkington, author of *Cannibals with forks* and co-founder of the sustainability consultancy firm *SustainAbility* and *Volans (a think tank to help solve the world's wicked problems),* was one of the first people to integrate these 3 principles. He argued companies should start considering this triple bottom line so that they could thrive in the long run (more info about the triple bottom line in our article: sustainable development).

Also known as the grandfather of sustainability, Elkington's most recent book (2020) *Greens Swans: Regenerative Capitalism* addresses precisely the need to re-design businesses and the economy, and the opportunities and risks the absence of such change might bring on the short run."[58]

In the context of building design, Sustainable Design is:

*Sustainable design **seeks to reduce negative impacts on the environment, and the health and comfort of building occupants, thereby improving building performance**. The basic objectives of sustainability are to reduce consumption of non-renewable resources, minimize waste, and create healthy, productive environments.*[59]

The above is the "official" US government definition (from GSA). Even though there is no universally recognized single definition of Sustainable Design, the definition above captures the intent and aspiration quite accurately.

There are many opinions, preferences and recommendations from designers about the techniques and thinking that building designers should employ to achieve Sustainable Buildings. However, almost all include variations of the following: [*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*]

- Energy efficiency over the building life cycle
    - HVAC system efficiency
    - Renewable energy generation and utilization – e.g., solar, wind, heat pumps.
- Building Material use: Recycled materials; lower volatile organic compounds.
- Design and Planning approaches: use of BIM to create integrated building models; follow performance-based rating systems like LEED; site analysis and building placement; use, recycling and preservation of water and waste management.
- Urban design that extends building design strategies into the broader community fabric.

[58] https://youmatter.world/en/definition/definitions-sustainability-definition-examples-principles/
[59] https://www.gsa.gov

Green Architecture / Buildings:

Consider the following definition of a "Green Building" as stated by the World Green Building Council:

A 'green' building is a building that, in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on our climate and natural environment. Green buildings preserve precious natural resources and improve our quality of life.[60]

Similarly, the term "Green Architecture" has been defined as follows:

Green architecture is a philosophy that advocates for building with the environment in mind by using sustainable sources of energy, designing efficiently to reduce energy use, and updating existing buildings with new technology.[61]

At face value, these definitions are strikingly similar to those for sustainable design. The concepts are apparent twins and hence often used interchangeably. In relation to building design, there is some merit to that interchangeability. But it is important to note that the terms have specific differences. Among the better explanations of the distinction is the following:

*The green building is the building that minimizes **the impact it has** on the environment while "sustainability" requires the **custodial operation to look at a product's entire life cycle**, from crib to grave.*[62]

Based on this assessment, it can be argued that "Green Buildings" are a subset of "sustainable" design with sustainable almost always being "green" but green is not always sustainable.

So, what makes abuilding "green"? According to the EPA, the components of a green building [63]are:

- Energy Efficiency and Renewable Energy
- Water Efficiency
- Environmentally Preferable Building Materials and Specifications
- Waste Reduction
- Toxics Reduction
- Indoor Air Quality
- Smart Growth and Sustainable Development

In support of the above, the Federal government, through the EPA has several programs and initiatives that are aimed to promote green building principles. The next few paragraphs, taken from EPA archives, outline some of the main ones:

- Energy Efficiency and Renewable Energy

EPA and U.S. Department of Energy's ENERGY STAR® program promotes partnerships with homebuilders, office building managers, product manufacturers, and many other organizations to improve the energy efficiency of homes, buildings, and various building components and appliances.

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[60] https://www.worldgbc.org/what-green-building
[61] https://learn.g2.com - *What Is Green Architecture? How It Informs Modern Sustainability.* Nicholas Van Antwerp, October 2019.
[62] https://eudl.eu *Similarities and differences between green, sustainable and healthy building concepts by* Huda Abdul Sahib Al Alwan and Ebtisam Sami M. Saleh June 2020
[63] https://archive.epa.gov/greenbuilding/web/html/components.html

- Water Efficiency

EPA's *WaterSense* program promotes and enhances the market for water-efficient products and services and educates homeowners, businesses, landscapers and others. *WaterSense* also develops performance criteria for water efficient products and services.

- Environmentally Preferable Building Materials and Specifications

EPA's *Industrial Materials Recycling Program* provides information on how industrial materials, such as coal combustion products, foundry sand, and construction and demolition debris, can be recycled to meet the material needs of our construction industry. Industrial materials can be recycled in construction applications because they have many of the same chemical and physical properties as the virgin materials they replace. In some cases, they can even improve the quality of a product.

- Waste Reduction

EPA's Office of Solid Waste supports projects to reduce, reuse, and recycle waste generated from building construction, renovation, deconstruction, and demolition.

EPA's *GreenScapes* program provides cost-efficient and environmentally friendly solutions for large-scale landscaping that are designed to help preserve natural resources and prevent waste and pollution.

EPA's *Industrial Materials Recycling Program* provides information on how industrial materials, such as coal combustion products, foundry sand, and construction and demolition debris, can be recycled to meet the material needs of our construction industry. Industrial materials can be recycled in construction applications because they have many of the same chemical and physical properties as the virgin materials they replace. In some cases, they can even improve the quality of a product.

The *Lifecycle Building Challenge* is a competition soliciting projects, designs and ideas that facilitate building disassembly and material reuse to minimize waste, energy consumption, and associated greenhouse gas emissions.

- Toxics Reduction

EPA's *Design for the Environment* (DfE) program works with stakeholders to provide EPA's chemical assessment tools and expertise to inform substitution to safer chemistries and to develop best practices. For example, DfE Furniture Flame Retardancy Partnership is helping industry factor environmental and human health considerations into their decision-making as they choose chemical flame retardants for fire safe furniture foam. Another example is the health, safety, and use information on spray polyurethane foam (SPF) posted on the DfE Web site to help educate and ensure that best practices are used when SPF is applied.

EPA's *Green Chemistry* program supports the research and development of safer chemicals and safer chemical processes through education and incentives.

EPA's *Green Engineering* program works to incorporate risk related concepts into chemical processes and products designed by academia and industry.

EPA provides information for consumers about products containing mercury that may be found in the home and information about mercury in schools.

EPA's *OPPT Lead Web site* provides information about lead, lead hazards, and provides some simple steps to protect your family.

EPA's *OPPT Asbestos Web site* provides various paths for the public to access information about asbestos including general information about asbestos and its health effects, a list of commonly used Asbestos acronyms, and information about what to do if you suspect asbestos in your home or your school.

EPA's *Pesticide Environmental Stewardship Program (PESP)* forms partnerships with pesticide users to reduce the potential health and environmental risks associated with pesticide use and implement pollution prevention strategies.

- Indoor Air Quality

Indoor Air Quality (IAQ) (sometimes also referred to as Indoor *Environmental Quality or (IEQ)* is a critical component of constructing "green" homes and buildings. EPA's Indoor Environments Program offers several IAQ tools and programs designed to protect occupant health, promote comfort and productivity, and enhance the durability of structures.

  - IAQ Home Label for ENERGY STAR qualified new homes that also meet EPA construction specifications designed to reduce IAQ problems.
  - Radon Resistant New Construction provides information and resources for new home builders.
  - *IAQ Design Tools* for Schools helps schools with tools and resources to establish and maintain good indoor air quality.
  - *IAQ Building Education and Assessment Model (I-BEAM)* helps building professionals establish and maintain good indoor air quality.

- Smart Growth and Sustainable Development

Community Action for a Renewed Environment (CARE) is a competitive grant program that offers an innovative way for a community to organize and take action to reduce toxic pollution in its local environment.

EPA's *Green Infrastructure program* promotes a new approach to stormwater management that is cost-effective, sustainable, and environmentally friendly.

EPA's *GreenScapes* program provides cost-efficient and environmentally friendly solutions for large-scale landscaping that are designed to help preserve natural resources and prevent waste and pollution.

EPA's *Sustainability Program* offers individuals, communities and institutions the ability to develop and implement sustainable practices.

EPA's *Smart Growth Program* provides tools to develop healthy communities, promote economic development, build strong neighborhoods and helps to make smart transportation choices.

  - EPA's Location page highlights location-efficient siting or locating a building within or near an existing community. This smart growth strategy connects particularly well with green building practices, as how people and goods get to and from a site affects the environmental performance of its buildings and occupants.

EPA's *Urban Non Point Source Pollution Program* provides information on how to reduce the run-off of pollutants from urban environments into our waters, including low-impact development strategies.

EPA's *Brownfields* Initiative works with public, private and non-profit partners to sustainably reuse sites whose redevelopment may be complicated by the real or perceived presence of contaminants.

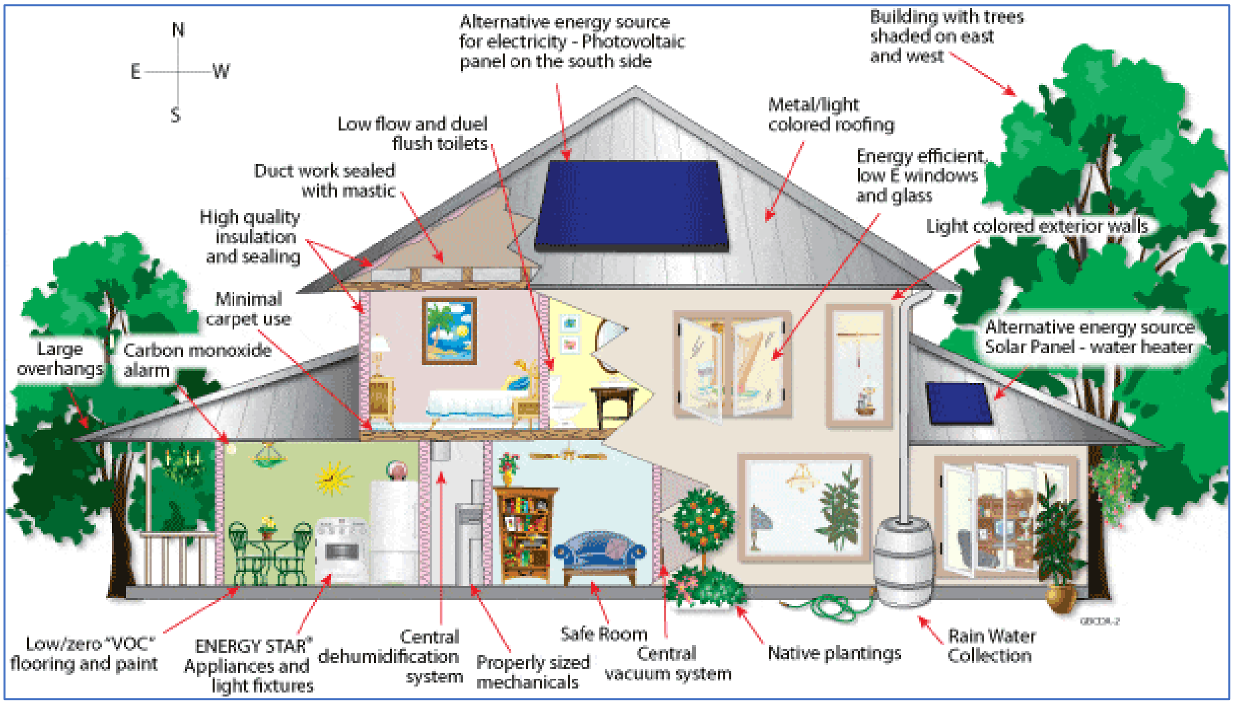
- EPA's Environmentally Responsible Redevelopment and Reuse (ER3) Initiative uses enforcement and other Agency-wide incentives to promote sustainable redevelopment of contaminated sites.

EPA's *Heat Island Reduction Initiative* works with communities and other partners to reduce the heat island effect caused by urban patterns of development.

- Cool Roofs provides information about energy saving roofs.
- Green Roofs provides information about water and energy saving vegetated roofs.

The above listing and descriptions are again very similar to the types of initiatives for Sustainability. The extent of focus is the main differentiator.

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



What Makes a Building Green: Green Building Concept *Source: The Constructor*[64]

Healthy Buildings:

This is a concept that has been around for some time and is worth understanding in terms of what it is. 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."*[65]

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.

Healthy buildings can be seen as the next generation of green buildings that not only include environmentally responsible and resource-efficient building concepts, but also integrate human well-being and performance.[66] These benefits can include "reducing absenteeism and presenteeism, lowering health care costs, and improving individual and organizational performance."[67]

[64] https://theconstructor.org/building/buildings/what-makes-a-building-green-green-building-concept/7327/
[65] https://www.hsph.harvard.edu/news/hsph-in-the-news/what-makes-a-building-healthy/
[66] Ramanujam, Mahesh (2014-03-28). "Healthy buildings and healthy people: The next generation of green building". US Green Building Council.
[67] "Buildings and Health". GSA Sustainable Facilities Tool.

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[68]:

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).

3.11 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 environment for the planet where the resources and consumption are balanced, and the polluting components of human activity 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 life cycle sensitive 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 futuristic visions evolving in the built environment. Also examined will be the prognosis for achieving Net Zero and whether it is a practical goal or something that is only an idealized aspiration.

[68] Allen, Joseph G; Bernstein, Ari (2020). "The 9 Foundations of a Healthy Building" (PDF). 9Foundations

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

Disclaimer Notice:

This course is intended to provide information as an educational benefit for architects and design professionals. The author has 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 accepts no liability whatsoever for, or in respect of any use or reliance upon this publication by any party. Author: Muhammad Siddiqui.

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 that contribute towards that seek to support the goals of Net Zero.

This part of the course will look at whether the current efforts and trends are on pace to achieve 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."***[69]

[69] 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 revers the conditions that can then get things back in a Net zero balance. While there is a plethora of activity, formal and informal; local and global, there is still no coordinated universal mandate and path that denotes the way to achieving Net Zero by 2050 with clear milestones along the way. Despite the quantifiable target of Net Zero, the means and methods for achievement are largely disjointed with level of commitment differing widely from country to country and even locale to locate. This lack of cohesion in tactical response begs the question 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."*[70]

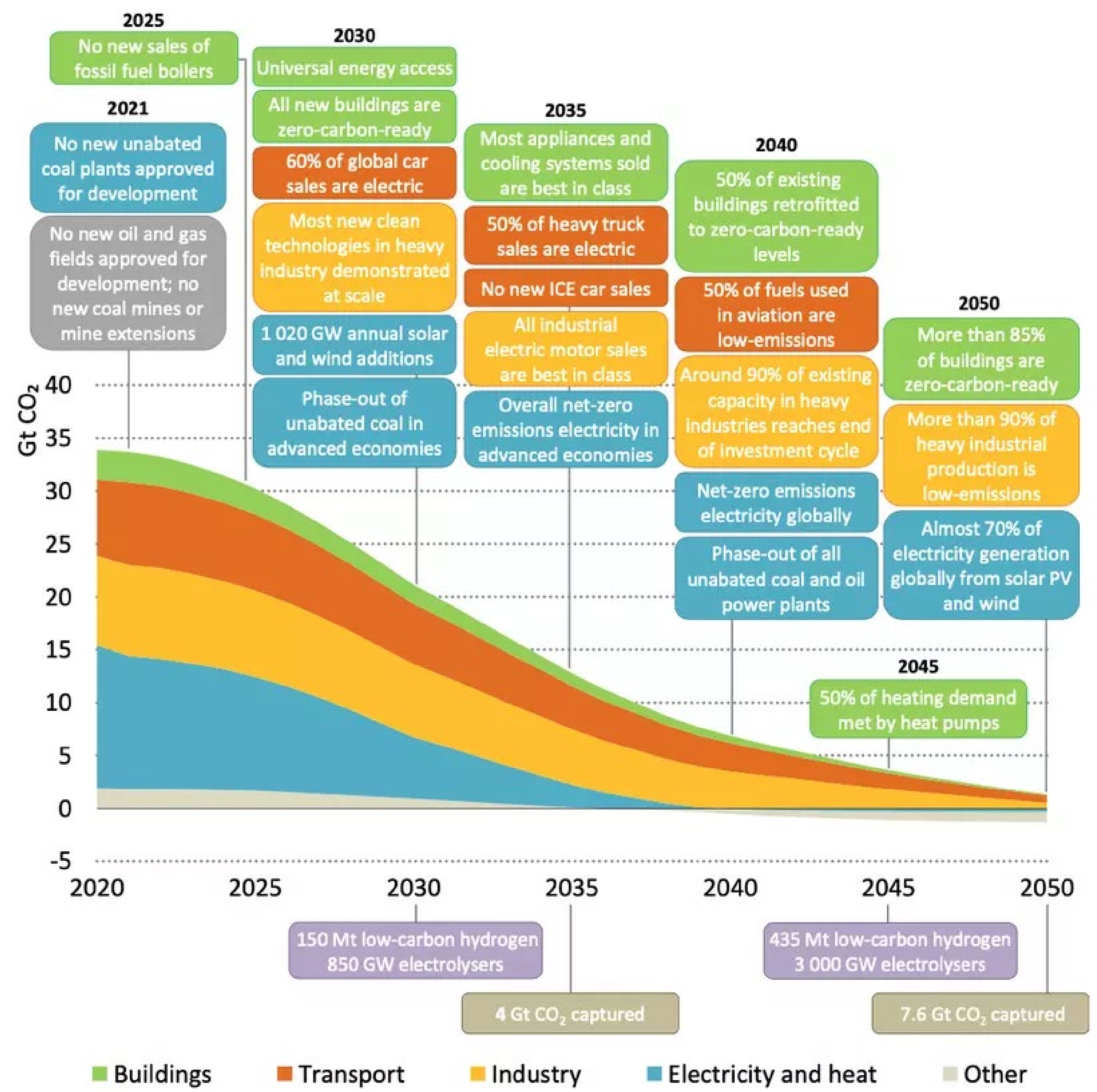
The International Energy Agency (IEA) echoed a similar finding published in May 2021 as part of the *Climate Breakthroughs: The Road to COP26 and Beyond* event for the World Economic Forum. [71]

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 blow 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.

[70] https://www.nationalacademies.org
[71] 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/

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, lets 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 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.

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 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. This requires that for a global balance (climate and GHGs do not restrict themselves to neat national boundaries), rich countries and those with disproportionally high GHG emissions would need to contribute greater commitment to compensate for the poorer, less advanced countries. This idea, while seemingly logical, has not been politically popular in most countries who would have to make the greater sacrifice or economic outlay. Recent events in Europe with the war in Ukraine and simmering tensions around the world, multiple wars are not out of the realm of possibility. These developments do not bode well for implementation of the type of policies needed to realize Net Zero.

Beyond the political issues, there is another major bump in the road. As a US politician once remarked about political issue: "It's the *economy*, stupid." And such is the case with achieving Net Zero. There is a significant economic price tag associated with the policies and even design changes that will be needed. Who pays and how much? remain subjects of unsettled debate. For buildings, "green" buildings or sustainable design is generally still more expensive that conventional unmitigated building techniques, though the gap is decreasing. In countries where there is a higher degree of social acceptance of the need, people are willing to bear the higher costs but in many weaker economies, even if people acknowledge the benefits at an intellectual level, the price is simply not affordable.

While the above may sound a note of despair and foreboding, the more realistic way to examine the challenges is to recognize that economic disparity, conflict and disagreements have always been part of human nature and will always remain so. The good news is that over the past 30 years the awareness of an impending environmental catastrophe is quite 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 popularity, social awareness, regulatory requirements and noticeable shift in the education and practice of architecture has gained tempo, some new design trends are emerging that are building on the models currently in place and have been discussed previously.

Some of these trends, captured succinctly by the website “Rethinking the Future” are presented below [72]:

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.

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

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

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 went on. 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."* [73]

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 normally but make it healthier, less stressful, and sustainable into the future.

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 and 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 technologies and the role of the design professionals of their era. In this regard, the opinion of these masters of their trade carries huge influence on how their peers and portages practice their profession. This informs the options that are presented to clients and builders and eventually these trends become the norm. 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. This validation by the design nobility in a profession where elites usually are rebels and “buck the trend” is a significant boost to the cause of Net Zero design. Some of the comments are worth noting[74]:

[73] https://www.cbsnews.com/news/coronavirus-photos-decline-air-pollution-lockdown/
[74] https://www.terramai.com/blog/6-famous-architects-share-their-top-sustainable-design

Jean Nouvel: Think into the future

Jean Nouvel is unquestionably one of our time's most impactful sustainable architects. The Pritzker Architecture Prize-winning architect behind the Louvre Abu Dhabi and Philharmonie de Paris is widely renowned for his groundbreaking work in sustainable design. Projects like the futuristic One Central Park and the National Museum of Qatar showcase Nouvel's knack for blending eco-friendliness with beautiful design.

In a 2017 interview, Nouvel encouraged sustainable architects to think about how their design might adapt to long-term changes: "More than ever, sustainability is at stake…We live in a world of constant and profound transformation, ***so architects have to radically rethink the way we build***. New expressions need to reflect new paradigms and the rise of technology. ***We have to project our ideas far into the future, they need to stand the test of time***."

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***."

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

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 three architects quoted above are stylistically very different but their shared commitment to sustainability in design thinking shows that "green" or sustainable or Net Zero are concepts that can be embraced but all design styles and are not, in of themselves, a design style. That would, by definition, be a passing phase like any fashion.

The consensus that sems to be emerging is that there is strong desire among design professionals to not only support the aims of Net Zero but to go beyond and make fundamental transformative changes to the way building designs approached in future where the effort to design and build sustainable buildings is focused on the building creation and construction rather than in convincing clients that this is a "good" thing to do. To get to that point the philosophies and principles that need to be employed will have to be codified or mandated in some way to make them objective and acceptable across the industry. Some progress in this direction has already been made though it is more like regulatory Swiss cheese rather than a universally accepted definitive charter. A main aspiration of design professionals is to have 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 "Think into the future":

a. Walter Gropius
b. Jean Nouvel
c. William McDonough
d. Zaha Hadid

PART 5

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 has 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 accepts no liability whatsoever for, or in respect of any use or reliance upon this publication by any party. Author: Muhammad Siddiqui.

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 4 of the course illustrated some of the emerging trends in Net Zero design and how the mainstream elite in the building design fields 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 must 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 know the evolving regulator landscape and the many entities that have taken a stake in their efforts 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."***[75]

[75] 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 them into sustainability pathways beneficial to the environment, society, and economy. 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 then enables the measurement, reduction and offset of the global environmental footprint, along with consideration of societal and economic aspects of sustainability.

This part of the course will investigate 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 system 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

International Organization of Standardization (ISO) [76], 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 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 15392:2008 – Sustainability in building construction – General Principles** [77]
  ISO 15392:2008 is a general introductory Standard that establishes a tone for sustainability of buildings and infrastructure. The standard gives the meaning of sustainability as a state that requires humans to "carry out their activities in a way that protects the functions of the earth's ecosystem as a whole". Next, the Standard accentuates that addressing sustainability of buildings and other construction works should interpret and consider economic, environmental, and societal goals as the primary aspects of sustainability. Further, the Standard emphasizes the importance of considering objectives and principles in its entirety and provides detailed guidelines for the same. The Standard explains the concept of product and clarifies meanings of terms such as material, components, assembly, elements, construction that are commonly used interchangeably in the industry.

  Per ISO 15392:2008, the following ISO Standards should also be referenced and used when applying the Standard.

ISO 15392:2008 - Normative Reference	
ISO 6701-1:2004	Building and civil engineering — Vocabulary — Part 1: General terms

[76] ISO is an independent, non-governmental organization with a membership of 163 national standard bodies. http://www.iso.org/iso/home/about.htm
[77] http://www.iso.org/iso/catalogue_detail?csnumber=40432

ISO 15392:2008 - Normative Reference	
ISO 14050 (latest edition including amendments)	Environmental Management - Vocabulary
ISO/TS 21929-1 (latest edition including amendments)	Sustainability in building construction – Sustainability indicators – Part 1: Framework for development for indicators for buildings

- **ISO/TR 21932:2013 – Sustainability in buildings and civil engineering works -- A review of terminology** [78]
  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** [79]
  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)
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

[78] http://www.iso.org/iso/catalogue_detail.htm?csnumber=62888
[79] http://www.iso.org/iso/catalogue_detail.htm?csnumber=46599

ISO 21929-1:2011 - Normative Reference	
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 21930:2007 – Sustainability in building construction — Environmental declaration of building products** [80]

A major lacuna exists for building stakeholders when it comes to selecting building products that has low environmental impacts over the life cycle of the building. A lack of a proper environmental labelling system has been prevailing for a long time despite a high need. ISO 21930 tries to fill the gap by establishing a process for developing environmental product declarations (EPD) for building products, thereby enabling enthused environmental standard setting authorities to jumpstart and streamline the EPD process in their respective countries. This Standard establishes a framework for providing quantified environmental data using predetermined parameters based on ISO 14040 and ISO 14044, and where applicable providing additional quantitative and qualitative environmental information for the product. Further, this Standard aims at providing a consistent, transparent, reliable, and verifiable environmental accounting methodology for products. This Standard points out that the manufacturers are the sole owners of their data and are liable and responsible for the environmental product declaration. The Standard provides system boundary guidance (cradle-to-gate, cradle-to-grave etc.), methodologies for product category rules (PCR), reporting requirements, EPD content requirements, and review and verification procedures. Environmental product declarations enable architects, planners, and other building stakeholders to compare and select products that have a low impact on the environment assuming certain uniform conditions.

Per ISO 21930, the following ISO Standards should also be referenced and used when applying the Standard.

ISO 21930:2007 - Normative Reference	
ISO 6701-1 (latest edition including amendments)	Building and civil engineering — Vocabulary — Part 1: General terms
ISO 14001 (latest edition including amendments)	Environmental management systems — Requirements with guidance for use
ISO 14020:2000	Environmental labels and declarations — General principles
ISO 14025:2006	Environmental labels and declarations — Type III environmental declarations — Principles and procedures

[80] http://www.iso.org/iso/catalogue_detail.htm?csnumber=40435

ISO 21930:2007 - Normative Reference	
ISO 14040 (latest edition including amendments)	Environmental management — Life cycle assessment — Principles and framework
ISO 14044:2006	Environmental management — Life cycle assessment — Requirements and guidelines

ISO 21930 was used as a basis to build the European Standard EN 15804+A1 Sustainability of construction works -Environmental product declarations - Core rules for the product category of construction products. However, EN 15804+A1 has been updated since its inception and includes more product category rules and EPD content. ISO 21930 has not been updated since 2007 and it is time to review the Standard and ensure it is up to date with EN 15804+A1

- **ISO 21931-1:2010 – Sustainability in building construction - Framework for methods of assessment of environmental performance of construction works – Part 1: Buildings** [81]
At this point in time, there are many organizations developing, assessing, and certifying environmental performance of buildings all over the world. However, there is not much uniformity, transparency or seamless integration of their assessment methods. This has caused a huge cost burden and frustrating experiences for building stakeholders and end users. A unifying standard has been very

much needed to provide certifying entities a streamlined process in the development, implementation, and certification of the environmental performance of buildings and ISO/TS 21931-1 has been a crucial preliminary step in this direction.

The importance of ISO/TS 21931-1 is the establishment of a framework for formulating methods of assessment of environmental performance of both new and existing buildings during its entire life cycle. The Standard consist of documentation requirements for an organization establishing the framework and assessing the environmental performance of buildings. The documentation should identify the responsible body that develops and maintains the assessment method, details of stakeholders who have been involved in the development and validation of the method, details of recognitions or accreditations of the assessment method at the national or regional or organization levels, and details of the processes and procedures for the delivery of the assessment. The documentation should also include the purpose of the assessment method, system boundary, list of issues that are assesses, assumptions and scenarios, life cycle stages covered, quantification methods, information sources, evaluation, and reporting of results.

In addition to providing the general requirements of the process owners of assessment methods, the Standard also provides the extent and application of the assessment method, a high-level modular structure for the life-cycle stages of a building, a schematic matrix structure to assess cause and effect relationships between the characteristics of the

[81] http://www.iso.org/iso/catalogue_detail?csnumber=45559

building/site and its resulting environmental aspects, and to categorize them as environmental and societal impacts, and a mapping of relevant environmental issues during the different life cycle stages of a building and indicates whether it is mandatory or voluntary to assess and report each issue. This helps in clarifying the system boundary of an assessment method and provides consistency and transparency in accounting and reporting the environmental issues.

Per ISO 21931-1:2010, the following ISO Standards should also be referenced and used when applying the Standard.

ISO 21931-1:2010 - Normative Reference	
ISO 6701-1 (latest edition including amendments)	Building and civil engineering — Vocabulary — Part 1: General terms
ISO 14025 (latest edition including amendments)	Environmental labels and declarations — Type III environmental declarations — Principles and procedures
ISO 14040:2006	Environmental management – Life cycle assessment – Principles and procedures
ISO 14050 (latest edition including amendments)	Environmental Management – Vocabulary
ISO 15392:2008	Sustainability in building construction – General Principles
ISO 15686-1	Buildings and constructed assets – Service life planning – Part 1: General Principles and Framework
ISO 21930:2007	Sustainability in building construction – Environmental declaration of building products

5.3 Standards Related to Carbon Footprint

There has been ongoing research by academia, industry, and organizations to establish a whole life carbon footprint framework for buildings. However as of a date (2022), 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 14067:2013 - Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification and communication [82]

  ISO/TS 14067 provides a technical specification that explains the principles, requirements and guidelines for quantifying and communicating carbon footprint of products (CFP). This technical specification is based on International Standards on life cycle assessment (ISO 14040 and ISO 14044) for quantification, and environmental labels and declarations (ISO 14020, ISO 14024 and ISO 14025) for communication. The technical specification provides definition, terminologies, and principles for carbon footprint of products. It provides a methodology for quantification and includes product category rules (PCR), goals and scope, and life cycle assessment processes. It establishes comprehensive reporting and

[82] http://www.iso.org/iso/catalogue_detail?csnumber=59521

communication protocols for carbon footprint of products. Offsetting is not within the scope of this technical specification.

Per ISO 14067:2013, the following ISO Standards should also be referenced and used when applying the Standard.

ISO 14067:2013 - Normative Reference	
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 14050 (latest edition including amendments)	Environmental management - Vocabulary

Greenhouse Gas Protocol (GHGP) – Product life cycle accounting and reporting standard [83]; 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 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:

[83] http://www.ghgprotocol.org/standards/product-standard

- ***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 [84]; 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.

PAS 2060:2014 - Specification for the demonstration of carbon neutrality; BSI [85]

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 [86]; International Energy Agency (IEA)

  IEA Annex 57 has been established to provide a framework to evaluate embodied energy and embodied greenhouse gas emissions for building construction and provide guidelines for low embodied energy and low carbon design. The team has been working on the framework for about six years and are in the stage of publishing detailed reports and guidelines. There will be detailed case studies from many countries included in the report.

[84] http://shop.bsigroup.com/upload/shop/download/pas/pas2050.pdf
[85] http://shop.bsigroup.com/ProductDetail/?pid=000000000030286698
[86] http://www.ecbcs.org/annexes/annex57.htm

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

  ISO 16745:2015 - Environmental performance of buildings – Carbon metric of a building – Use stage [87]

  Carbon emissions and removals of a building in 'Use' stage comprises of various sources and has not been clearly defined by standard setting or certifying authorities. ISO 16745 has taken the initial step in defining the carbon metric of a building in-use stage. The Standard provides a protocol for measuring the carbon metric of a building in the 'use' stage which includes system boundary, metric and calculation methodology (for energy related sources).

  According to ISO 16745, a carbon metric is measured by the amount of direct and indirect emissions and removals associated with a building in-use state and defines three types of carbon metrics of a building in 'Use' stage, all of them expressed in CO_2 equivalents.

  - The first type called Carbon metric 1 (CM1) is the sum of annual GHG emissions from <u>building-related energy-use</u>. Quantification not based on LCA.
  - The second type called Carbon metric 2 (CM2) is the sum of annual GHG emissions from <u>building-related **and** user-related energy-use</u>. Quantification not based on LCA.
  - The third type called Carbon metric 3 (CM3) is the sum of annual GHG emissions and removals from <u>building-related and user-related energy-use **plus** other building-related sources of GHG emissions and removals</u>. Quantification based on partial LCA.

The Standard further provides the reporting and communication and verification requirements.

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

ISO Standard 16745:2015 - Normative Reference	
ISO 6701-1:2014	Building and civil engineering — Vocabulary — Part 1: General terms
ISO 12655 (latest edition including amendments)	Energy performance of buildings – Presentation of measured energy use of buildings
ISO 14050 (latest edition including amendments)	Environmental Management – Vocabulary

[87] http://www.iso.org/iso/catalogue_detail.htm?csnumber=57576

ISO Standard 16745:2015 - Normative Reference	
ISO 15392 (latest edition including amendments)	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

Common Carbon Metric for measuring energy use and reporting greenhouse gas emissions from building operations; UNEP SBCI – Sustainable Buildings and Climate Initiative [88]

United Nations Environment Program - Sustainable Buildings and Climate Initiative (UNEP-SBCI) is the first initiative to propose a global Common Carbon Metric for buildings with the help of a wide range of worldwide contributors from the field of sustainability. UNEP-SBCI describes Common Carbon Metric as the "*calculation used to define measurement, reporting, and verification for GHG emissions associated with the operation of building types of particular climate regions*." It further states that Common Carbon Metric is consistent with GHG Protocol and ISO 14040/44:2006 Standard and considers the six Kyoto Protocol Greenhouse Gases in the accounting of carbon emissions.

UNEP-SBCI defines two metrics: Energy Intensity and Carbon Intensity to provide for a globally harmonized basis for energy use and GHG emissions. These two metrics are based only on operating energy i.e., on-site generated power and purchased energy. Fugitive emissions and refrigerant use in buildings are reported separately.

Energy Intensity = kWh/m^2/year and kWh/o/year (if occupancy data is available)

Carbon Intensity = kgCO$_2$e/m^2/year and kgCO$_2$e/o/year (if occupancy data is available)

These metrics help in establishing baselines, enhancing benchmarks, and targeting improvements.

This in turn helps policy and decision makers to understand energy use, improve performance and mitigate carbon emissions in their respective authority ranging from building, campus, cities up until national levels.

UNEP SBCI considers the total emissions of the building arise from the following three life cycle phases:

- Before-Use Phase Emissions (Stage 1): Extraction of raw materials, agriculture or forestry, manufacturing of building products and equipment and construction.

[88] http://www.unep.org/sbci/pdfs/UNEPSBCICarbonMetric.pdf

- Use-Phase Emissions (Stage 3): Operations, maintenance and retrofits of buildings during the useful service life of the building.
- After-Use Phase Emissions (Stage 3): Demolition, re-use and recycling of material components or energy content, and waste processing.

All the three phases involve transportation of goods, services and people.

The Common Carbon Metric established by UNEP-SBCI only considers emissions from operational energy in Stage 2, since this is the source of the highest emission during the life cycle of buildings and data is easily available, measurable, reportable and verifiable. UNEP-SBCI ensures that the Common Carbon Metric uses a modular approach that allows changes in future to include greater scope across life cycle stages.

Further, UNEP-SBCI establishes the following scope of emissions for buildings. The Common Carbon metric takes into consideration only Scope 1 and Scope 2 Emissions (operational energy).

Scope 1: Direct, on-building site or on-building-stocks, GHG Emissions

- Stationary combustion emissions
- Process emissions
- Fugitive emissions

Scope 2: Indirect on-building-site GHG Emissions

- Purchased energy emissions

Scope 3: Other Indirect GHG Emissions

- Upstream and Downstream emissions related to Before-use phase of the buildings
- Transport emissions related to all stages of the building life cycle
- Re-use, Recycling, Thermal recycling and Waste disposal processes emissions related to After- Use phase of the buildings.

UNEP-SBCI also provides emission data sources to be used for purchased electricity, purchased chilled water/steam/heat, power generation, refrigerants, refrigeration and air-conditioning equipment.

- **Waste Footprint**
  Waste Framework Directive 2008/98/EC [89]; 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

[89] http://ec.europa.eu/environment/waste/framework/
http://ec.europa.eu/environment/waste/framework/pdf/guidance_doc.pdf

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 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 International Living Future Institute (ILFI) 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) [90] **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 [91] – for human health and well-being

[90] http://www.usgbc.org/
[91] https://www.wellcertified.com/

RATING SYSTEMS	
Performance Excellence in Electricity Renewal (PEER) [92] – for power systems	
Sustainable Sites Initiative (SITES) [93] – for sustainable landscapes	
Global Real Estate Sustainability Benchmark (GRESB) [94] – for real assets	
Excellence in Design for Greater Efficiencies (EDGE) [95] – for energy and water	
Parksmart [96] – for parking garages	
Zero Waste Facility [97] - for zero waste business	
The International Living Future Institute (ILFI) [98]	
Living Building Challenge (LBC)	
Net Zero Energy Buildings (NZEB)	
Green Building Initiative (GBI) [99]	
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 [100] **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) [101]	
Green Star – Communities	
Green Star – Design and As-built	
Green Star – Interiors	
Green Star – Performance	
Passive House Institute US (PHIUS) [102]	
PHIUS+ 2015: Passive Building Standard	

[92] http://peer.gbci.org/
[93] http://www.sustainablesites.org/
[94] https://gresb.com/
[95] https://www.edgebuildings.com/
[96] http://parksmart.gbci.org/
[97] http://www.gbci.org/gbci-administer-zero-waste-certification-and-credential
[98] https://living-future.org/
[99] http://www.greenglobes.com/home.asp
[100] https://www.bre.co.uk/page.jsp?id=829
[101] http://new.gbca.org.au/green-star/
[102] http://www.phius.org/about/mission-history

RATING SYSTEMS
PHIUS Verified Window Performance Data Program
Other International Rating Systems or Approaches
Haute Qualite Environnementale (HQE), France [103]
Comprehensive Assessment System for Built Environment Efficiency (CASBEE) [104]
Building and Construction Authority (BCA) Green Mark Scheme, Singapore [105]
Building Environmental Assessment Method (BEAM) Assessment Tool, Hong Kong [106]
Pearl Rating System for Estidama [107]

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 [108]				
Stage	**Assessment**		**Environmental Standards**	**Points**
Product Stage (Cradle-to-Grave)	Building Life Cycle Impact Reduction	Historic Building Reuse (or)		5
		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	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	

[103] http://www.behqe.com/
[104] http://www.ibec.or.jp/CASBEE/english/
[105] https://www.bca.gov.sg/GreenMark/green_mark_buildings.html
[106] http://www.beamsociety.org.hk/en_beam_assessment_project_1.php
[107] http://estidama.upc.gov.ae/pearl-rating-system-v10.aspx?lang=en-US
[108] See rating system for additional details
http://www.usgbc.org/sites/default/files/LEED%20v4%20BDC_01.27.17_current.pdf

LEED v4 BD+C Rating System [108]				
Stage	**Assessment**		**Environmental Standards**	**Points**
	Declaration		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		
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	Minimum Energy Performance	ANSI/ASHRAE/IES NA	Mandatory

LEED v4 BD+C Rating System [108]				
Stage	**Assessment**		**Environmental Standards**	**Points**
	Performance		Standard 90.1–2010	
		Optimize Energy Performance		1 - 20
		Building Level Energy Metering		Mandatory
		Advanced Energy Metering		1
		Demand Response		1 - 2
	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

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 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, their growth in their own accord, market position as sustainability leaders, and compulsion to look at sustainability as a point based system stands in their 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 the rating systems as an amalgamation of experiential knowledge expertise evolved over the past couple of decades, with a strong intention to reduce or avoid or offset impact, yet it is missing the mainstays of life cycle system thinking and measurement science, thereby depriving them 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 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.[109]

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.[110]

5.5 The Need for a Global Environmental Standard for Buildings

The International Standards are set up as a 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, have a strong grip of the bottom-up perspective and expertise in the field of built environment. However, the market is flooded with multitudes of rating systems with no clear underlying methodical and qualitative leadership. So, in the absence of a life-cycle based holistic systems thinking and measurement science, the value of the rating systems diminishes over time 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 the need of the hour. The good news is that there are many efforts by the different entities to working together to bring this task to fruition.

In this regard, the European Committee for Standardization CEN/TC 35034 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. All aspects of sustainability covered under one suite of standards with the ISO frameworks as the foundation, which is impressive, and a head start in the right direction. If the tacit and explicit knowledgebase is integrated within the framework, then it becomes complete in major aspects.

[109] https://bregroup.com
[110] https://www.prologis.com/what-we-do/resources/difference-breeam-leed

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
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

These standards enable the member European countries move in the direction of a consistent method of measuring and reporting environmental, societal, and economic performance data, all evaluated uniformly to a substratum of underlying holistic standards. The **German Sustainable Building Certificate (DGNB)** [111] has been established based on the European Standards. DGNB includes the following six criteria [112]:

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

All of the above are over the entire life cycle of the building. The DGNB assesses the overall sustainability performance of the building not the individual measures, thus establishing a benchmarking process for comparing building performance.

Such a suite of standards along with strategic knowledge repositories and upkeep of standards in the form of rating systems is an immediate and inevitable need for the global community to level play in the arena of responsible participation in the ecosystem goods and services.

5.6 Net Zero is Still a Choice of Conscience

Net Zero remains a committed objective of many countries but implementation plans put forth are not ambitious enough to realistically achieve the date of 20250 (despite technological feasibility). According to the United Nations Climate Action website:

"...commitments made by governments to date fall far short of what is required. Current national climate plans – for all 193 Parties to the Paris Agreement taken together – would lead to a sizable increase of almost 14% in global greenhouse gas emissions by 2030, compared to 2010 levels. 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. The Glasgow Climate Pact called on all countries to revisit and strengthen the 2030 targets in their NDCs by the end of 2022, to align with the Paris Agreement temperature goal."[113]

The weak link in the goal is the same for buildings and it is in the aggregate for all sectors – lack of enforceable mandated codes or regulations.

As we have seen, there is no shortage f guidelines and standards, but adherence is almost entirely voluntary with no effective penalty for ignoring them. As a result, the forward movement comes down to a choice of conscience for the designers and builders and, most importantly, building owners, who ultimately make the call to pay for the design choices. The problem with choices of conscience is that

[111] http://www.dgnb-system.de/en/system/certification_system/
[112] http://www.dgnb-system.de/en/system/criteria/core14/
[113] https://www.un.org/en/climatechange/net-zero-coalition

when confronted with economic implications, “doing the right thing” often only prevails if it is backed up by force of law.

Perhaps a similar but not exact analogy is the way in which Accessibility came to become a required component of any building design. It is now no longer debated because the Americans with Disabilities Act (ADA) mandates it in the US and building codes have incorporated the requirements. This was not always so and regulations were aggressively pushed by Architects to enable them to do the “right thing” without having to debate clients. Similarly, if Net Zero objectives were codified and made a choice of legal compliance rather than a choice of conscience, the likelihood of buildings achieving their targets on the road to Net Zero will have a very high probability. And the designers will become heroes of the movement.

This concludes Part 5 of the course.

END – Part 5

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 have been established based on European Standards?

a. ARGDF
b. German Sustainable Building Certificate (DGNB)
c. BREEAM
d. PHIUS

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

<u>Part 4</u>

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 “Think into the future”:

a. Walter Gropius; incorrect, however he is a German-American architect
b. Jean Nouvel; correct, he is one of our time’s most impactful sustainable architects.
c. William McDonough; incorrect, however, William McDonough did create 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. ARGDF; incorrect
    b. German Sustainable Building Certificate (DGNB); correct, this is based off of European Standards and 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. PHIUS; incorrect, this stands for Passive House Institute U.S. and is a rating system

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

PDH Academy

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	Poor		⟷		Excellent
1. Overall satisfaction with this course	1	2	3	4	5
2. Course learning objectives clearly stated and met:	1	2	3	4	5
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How could these courses be improved?

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What other topics would be of interest?

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Additional Comments:

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