Zero Architecture Design

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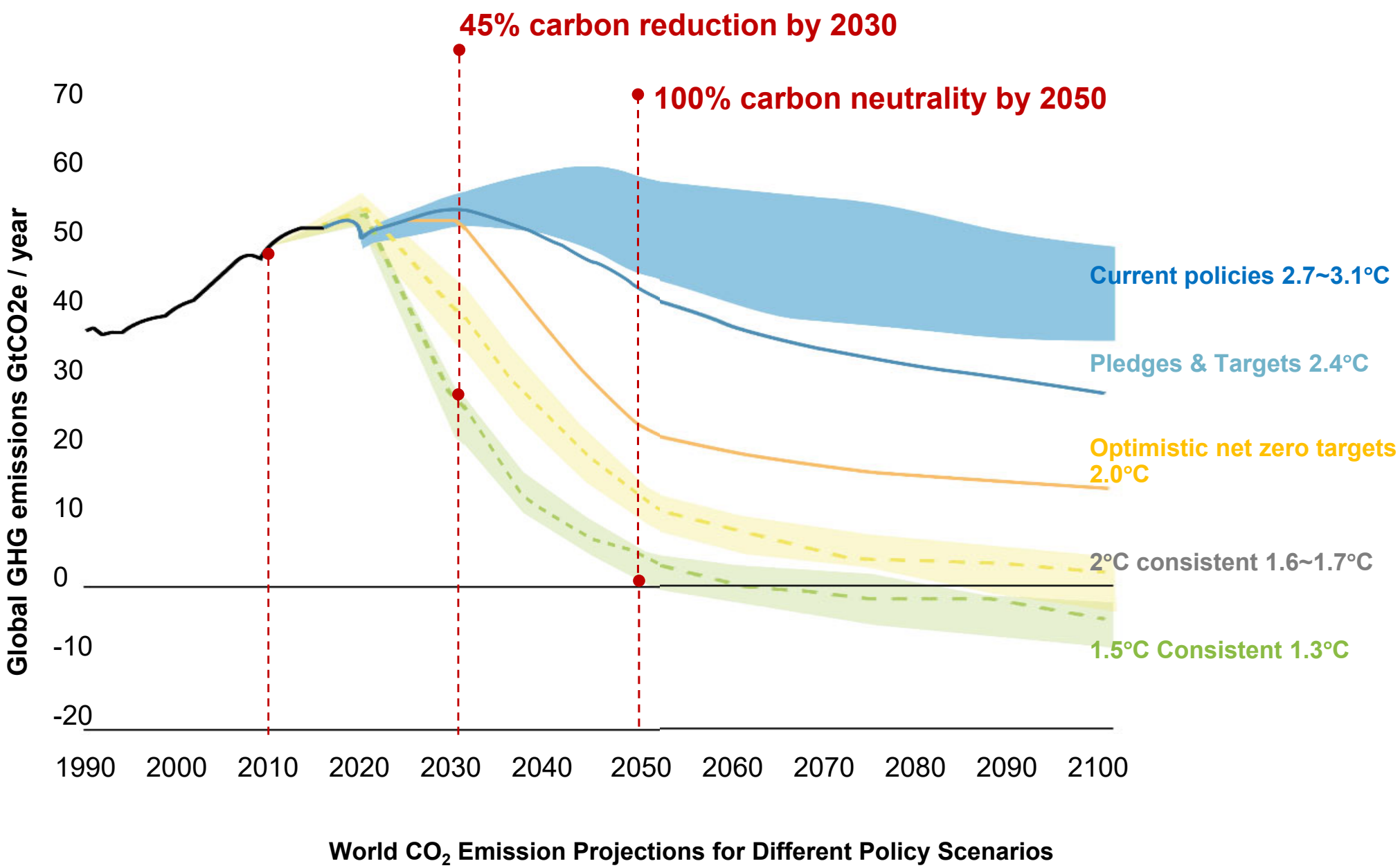
Director of Integrated Design Research Lab
Ravin School of Architecture
UNC Charlotte

In this module

- **Why zero architecture is important?**

- **What are the key design framework, focusing on:**
  - **Zero energy**
  - **Zero carbon**
  - **Zero water**
  - **Zero waste**

- **What are design strategies to meet the zero design goals?**



World CO_2 Emission Projections for Different Policy Scenarios

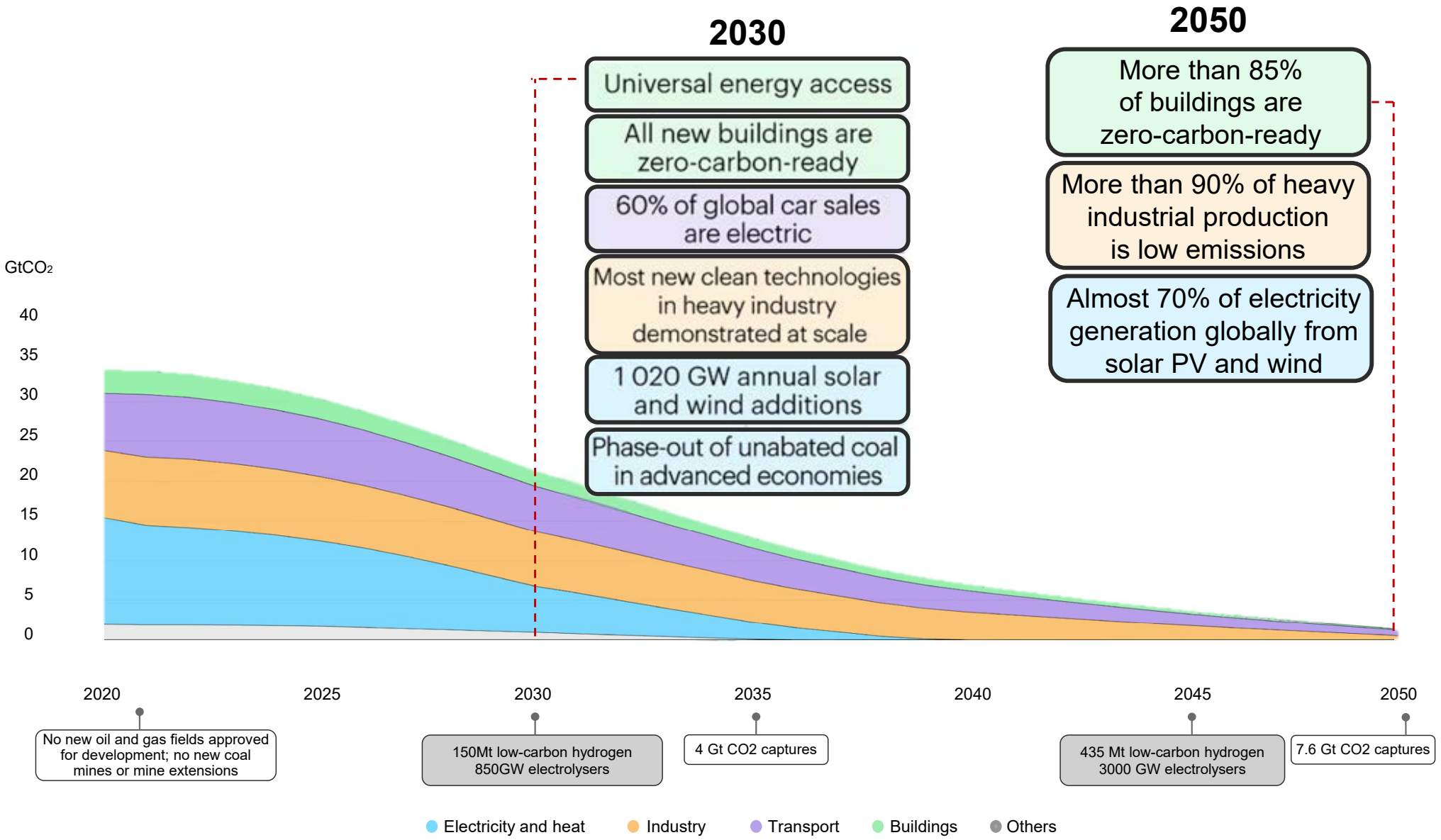
2018 IPCC Special Report on Global Warming of 1.5 °C

$$I = f\,(P, A, T)$$

I: Environment Impact
P: Population
A: Affluence or consumption per person.
T: Technology or Resource utilization


2.2 billion population increase by 2050
2 trillion sq.ft of new construction By 2050
NYC every month for 35 years
Source: The New Carbon Architecture, King

Zero Carbon Roadmap



2021 IEA's Net Zero by 2050 A Roadmap for the Global Energy Sector

Zero Carbon Goal in Major Countries

- In law – 29 countries
- In policy document – 52 countries
- Pledge – 15 countries
- In discussion – 46 counties

Countries	Carbon neutrality target year	Implementation Progress as of 2023	Carbon footprint per country in 2021	Carbon footprint per capita in 2020
China	2060	In policy document	11.5Gton	7ton
USA	2050	In policy document	5Gton	15.5ton
EU	2050	In law	3.1Gton	9.5ton
India	2070	In policy document	2.7Gton	1.6ton
Japan	2050	In law	1.1Gton	9.5Gton
Indonesia	2060	Pledge	619Mton	2.3ton
South Korea	2050	In law	616Mton	12.7ton
Vietnam	2050	In policy document	326Mton	2.1ton
Thailand	2065	In policy document	278Mton	3.8ton

1. Net Zero Scorecard by Energy & Climate Intelligence Unit
2. Our World in Data, 2021


$1.1 trillion from 152 climate related events
(2013-2022)
NOAA Climate. Gov
Image source: The Guardian

Four Net Zero Goals

- Zero Energy
- Zero Carbon
- Zero Water
- Zero Waste

Zero Energy Design

Zero Energy Design Framework

Reduce

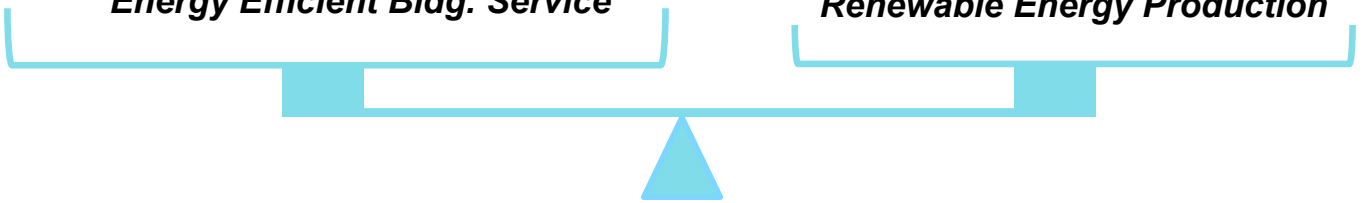
Bioclimatic Design

- Building orientation
- Window areas and orientation
- Nature ventilation
- Natural cooling
- Daylighting
- Passive heating

Energy Efficient Bldg. Service

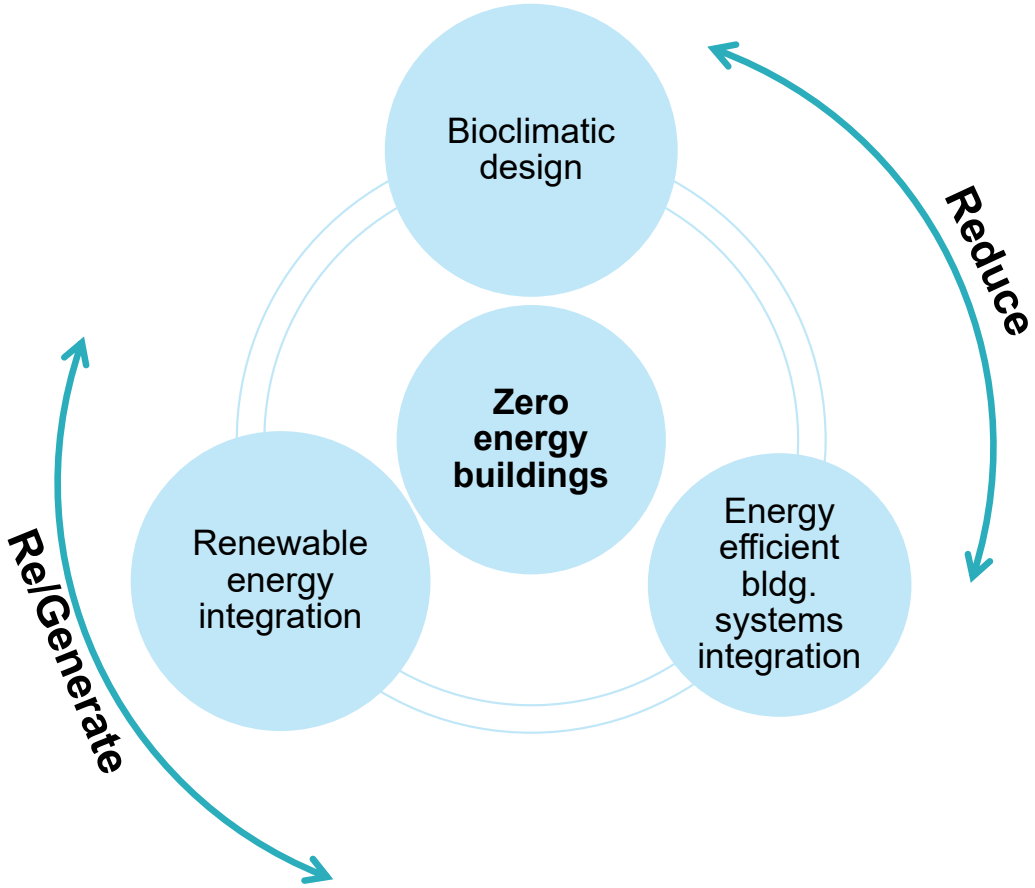
Re/Generate

Renewable Energy Production



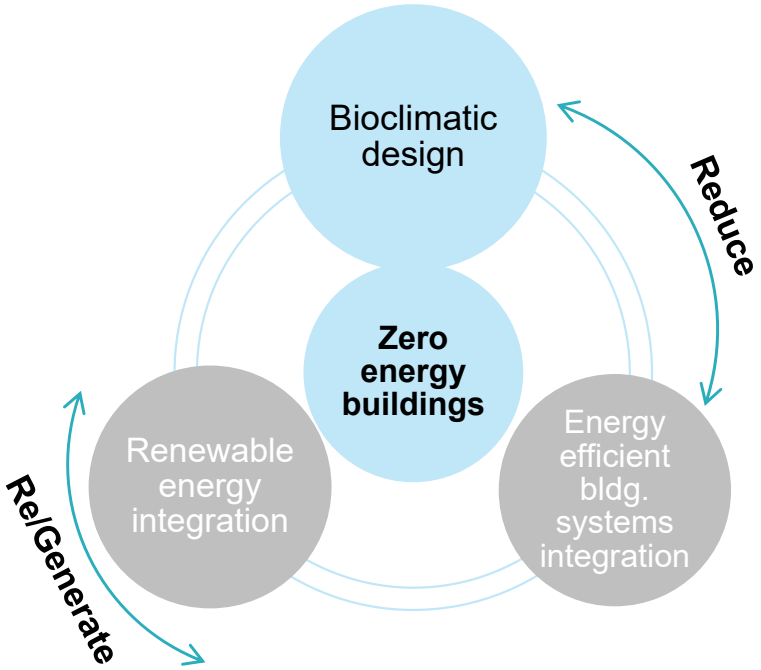
Zero Energy Design Framework

Zero Energy Design Strategies



Interconnected Elements Explaining Zero Energy Design Strategy

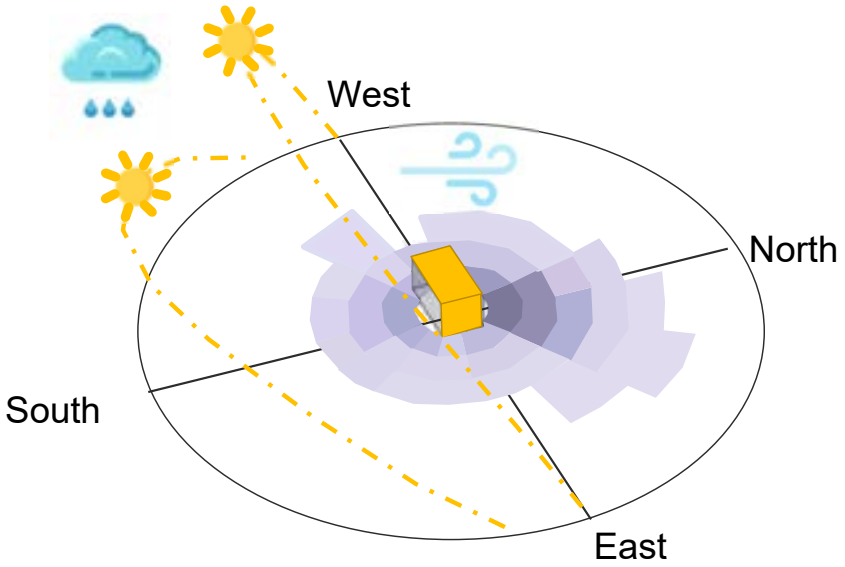
Zero Energy Design Strategy: Bioclimatic Design



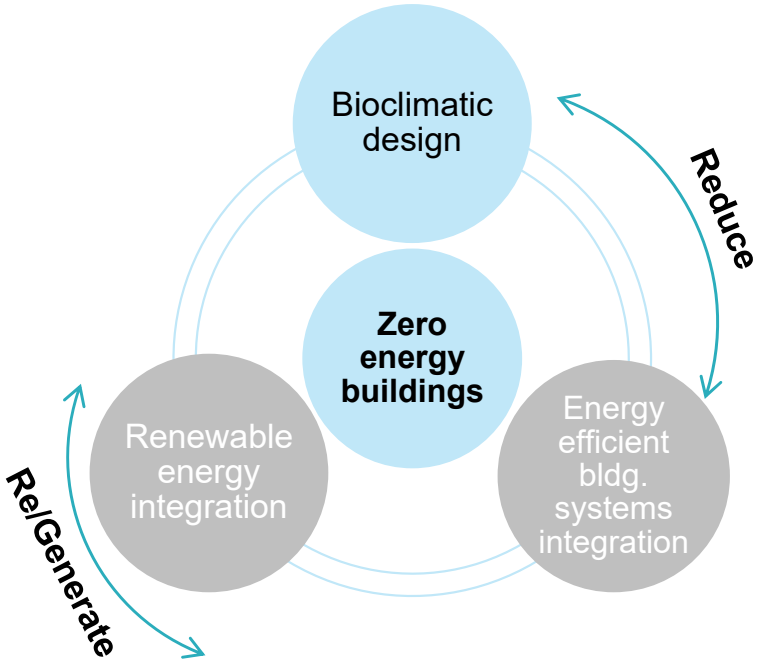
Zero Energy Design Strategy

Bioclimatic Design

- Building orientation
- Window areas and orientation
- Nature ventilation
- Natural cooling
- Daylighting
- Passive heating

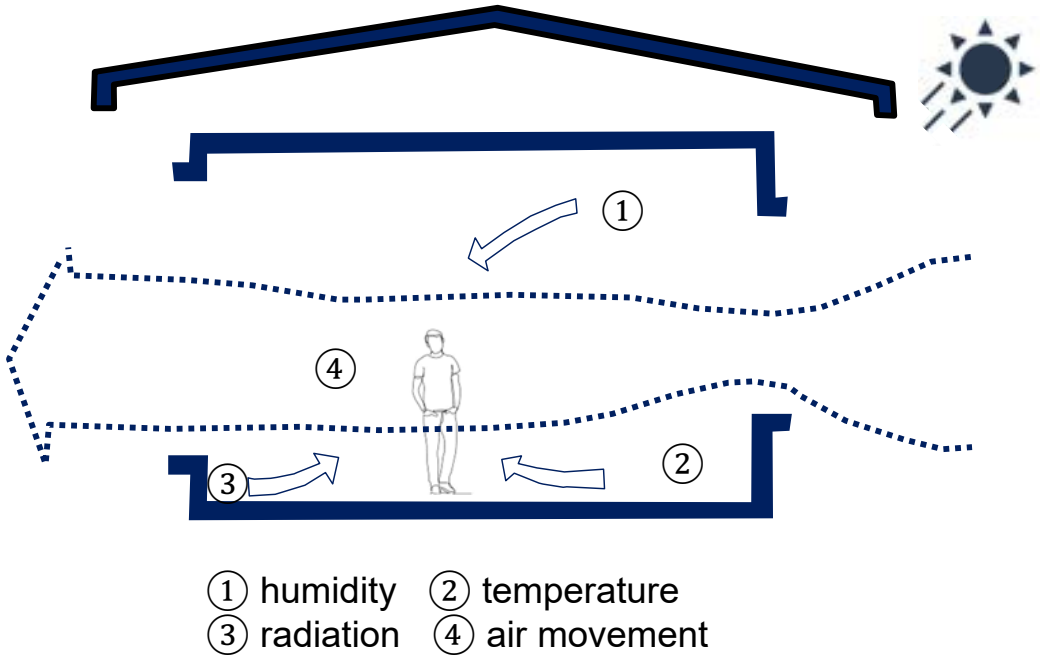


Net Zero Energy Design Strategy: Bioclimatic Design



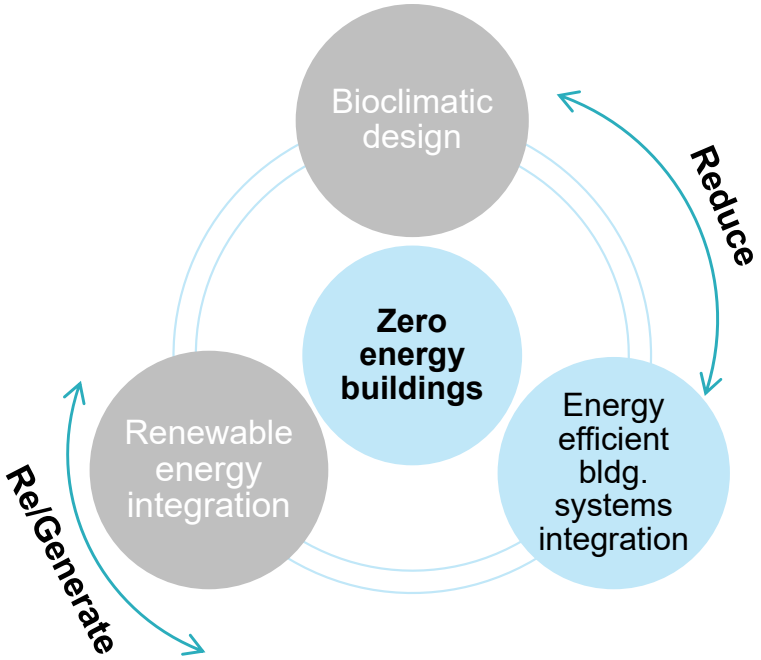
Zero Energy Design Strategy

Bioclimatic Design



Antonin Raymond, diagram of tropical design principles, from Fry and Drew, Village Housing in the Tropics, 1947. Modern Architecture and Climate, Baber, 2020.

Zero Energy Design Strategy: Energy Efficient System and Building Management System



Zero Energy Design Strategy

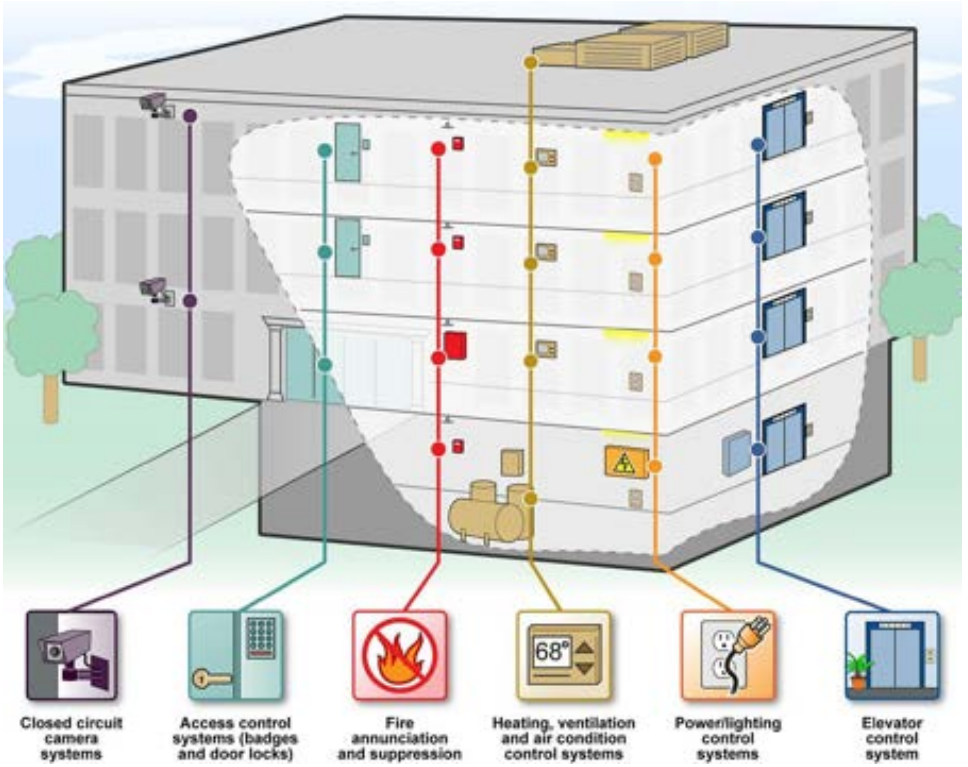
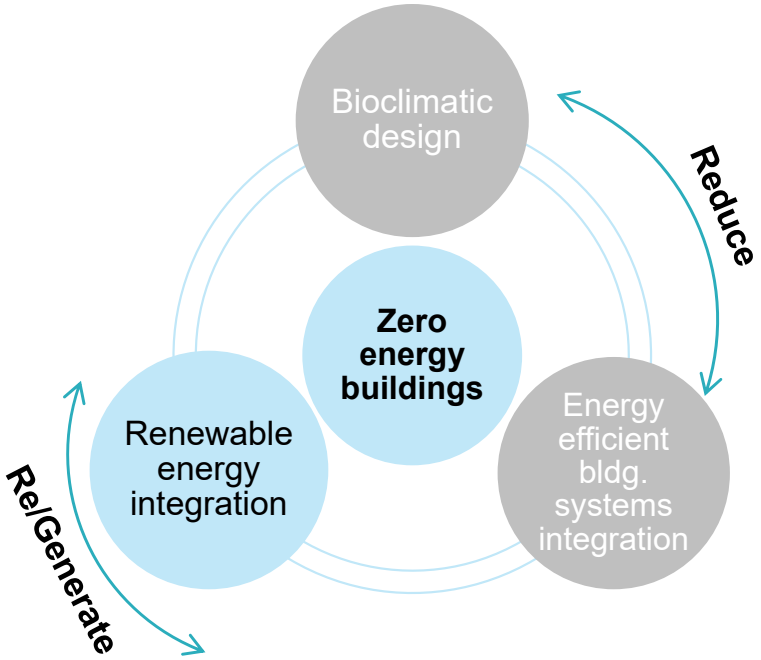


Image source: All Perfect Stories

Zero Design Strategy: Renewable Energy Integration



Zero Energy Design Strategy

Infrastructure

Floatovoltaics, China

Solar desalination, Netherlands

Solar farm, USA

Solar canal, India

Urban

Solar lamp, Abu Dabi

Fluid Cube, Hungary

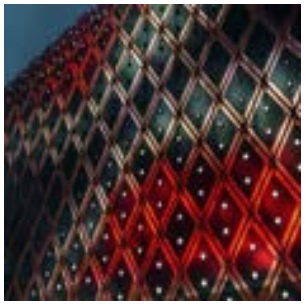
Solar acoustic barrier, Canada

Solar parking deck, Sweden

Buildings

Blauhaus, Germany

Apple HQ, USA



Novartis Pavilion, Switzerland

FKI, Korea

Zero Carbon Design

Zero Design Framework: Net Zero Carbon

Reduce

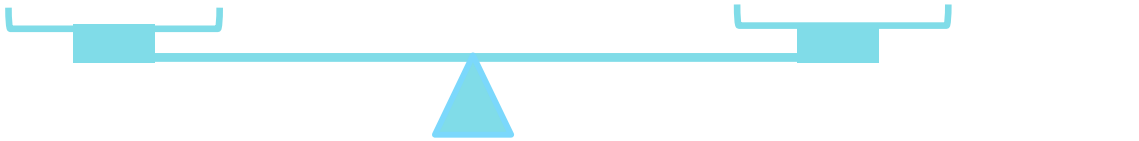
Bioclimatic Design
•Nature ventilation
•Natural cooling
•Daylighting
•Passive heating

Energy Efficient Bldg. Service

Re/Generate

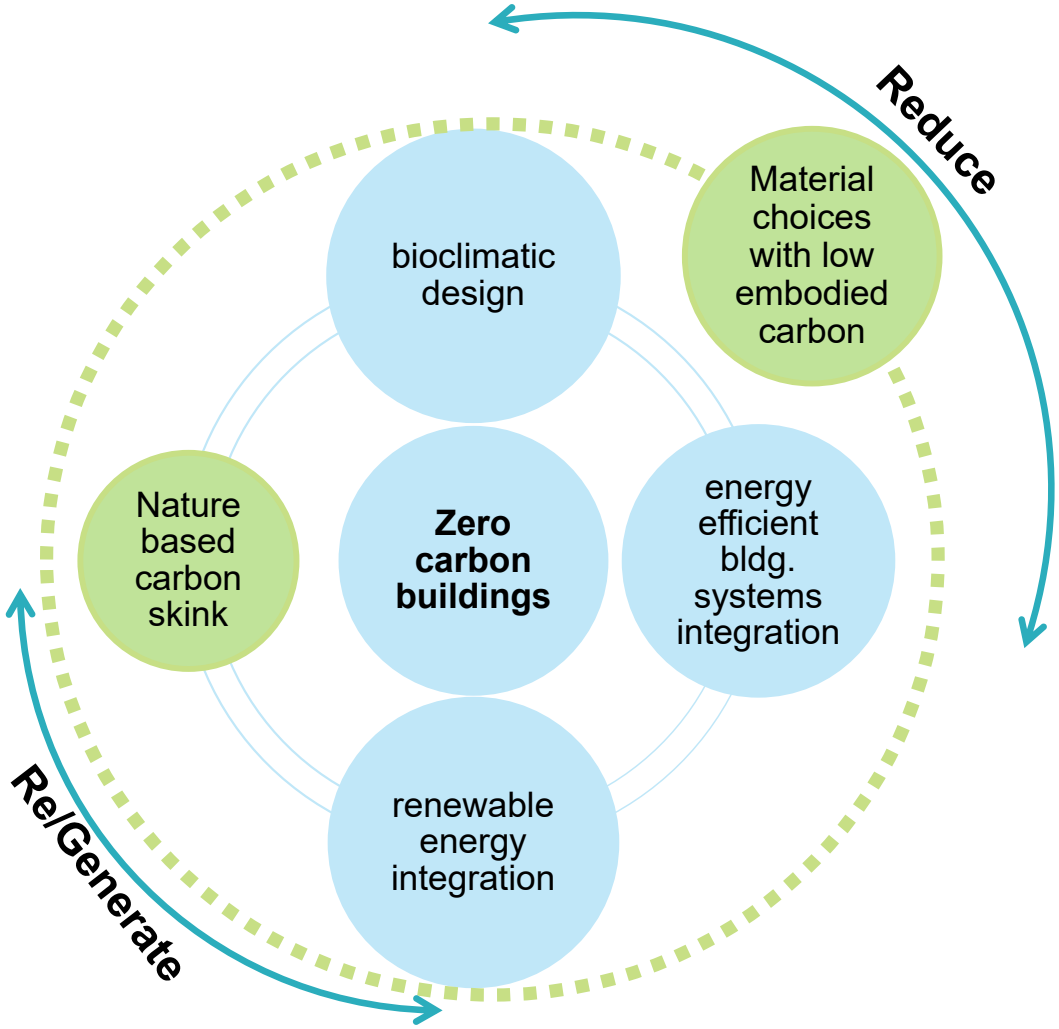
Nature-Bldg. Integration
Nature-Site Integration

Renewable Energy Production



Zero Carbon Design Strategy

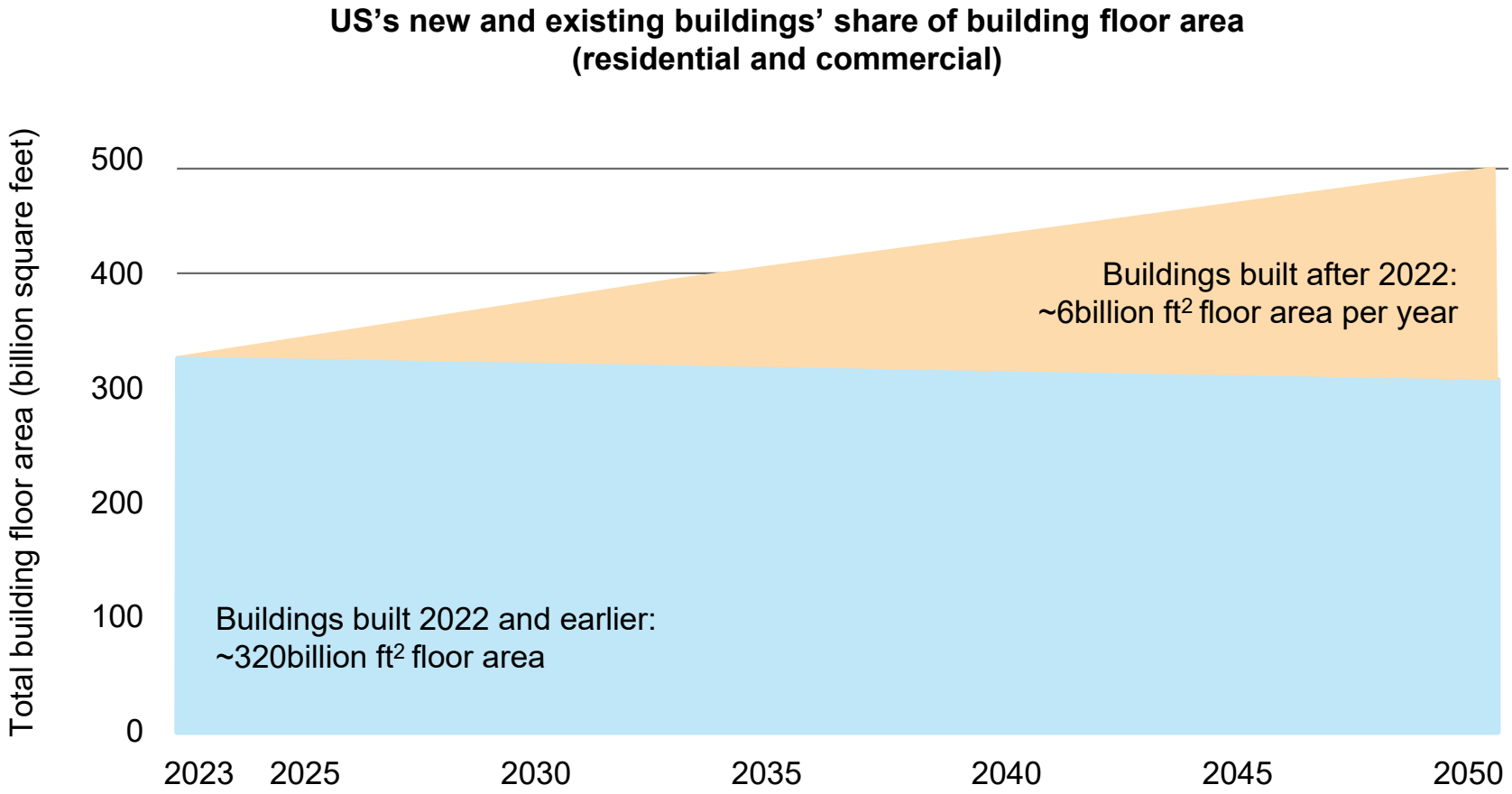
Zero Design Framework: Net Zero Carbon



Interconnected Elements Explaining Zero Carbon Design Strategy

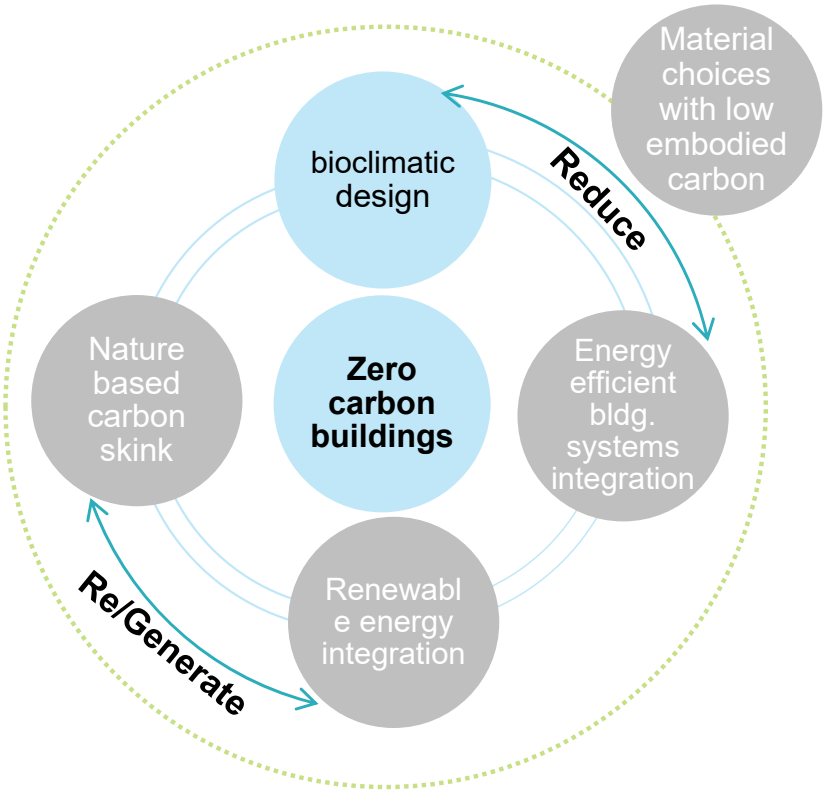
US New Construction Prediction

- ~320 Billion ft^2 in 2022
- ~170 Billion ft^2 of additional area by 2050



ACEEE calculations based on data in EIA AEO 2023

Zero Energy Design Strategy: Bioclimatic Design



Zero Carbon Design Strategy

Bioclimatic Design

- Building orientation
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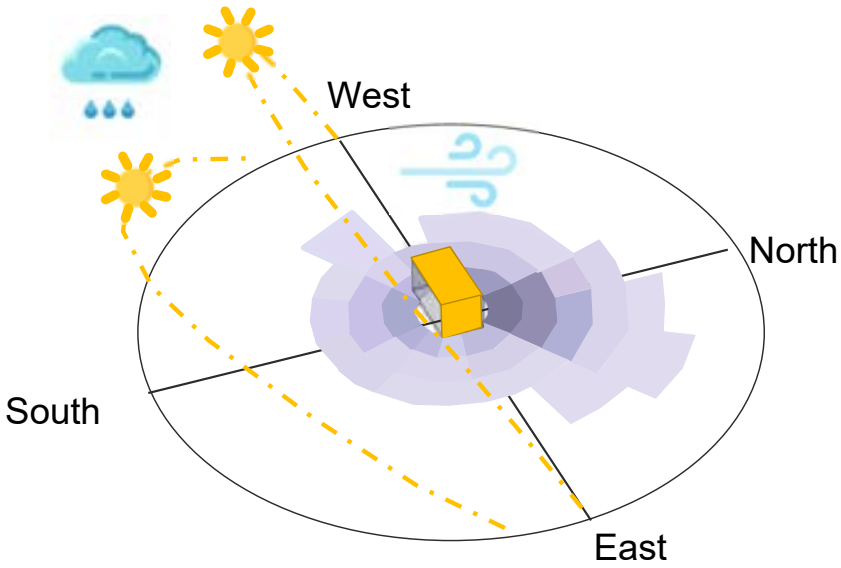
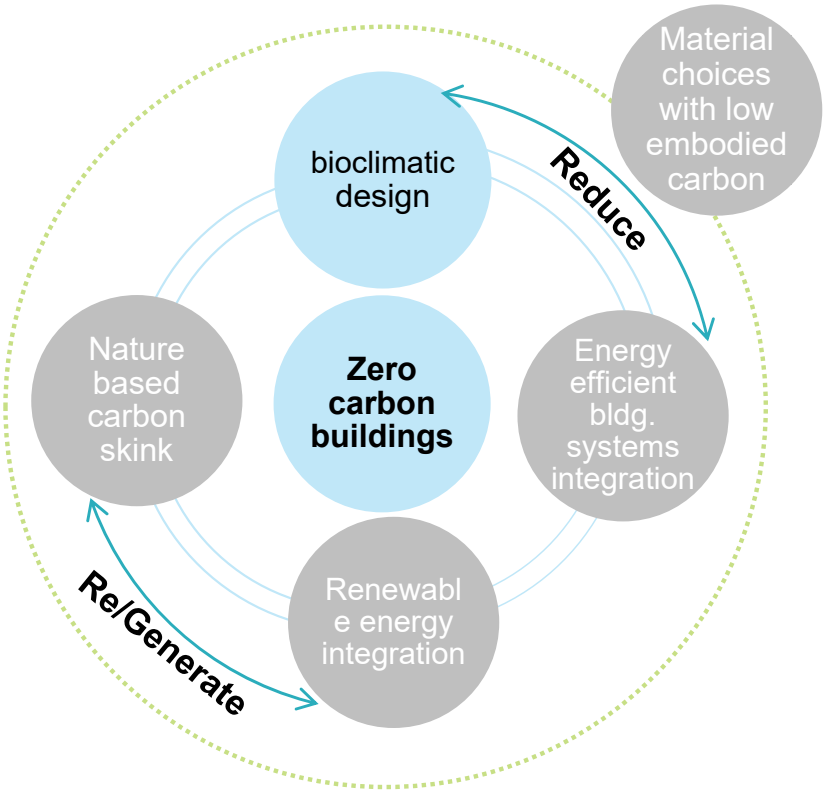
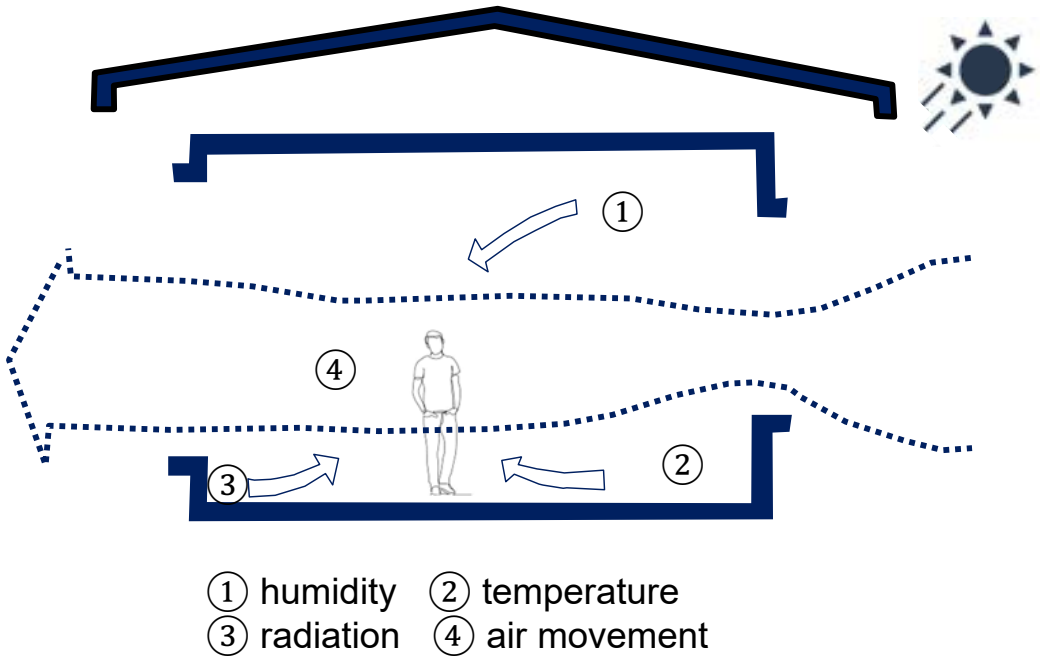


Net Zero Energy Design Strategy: Bioclimatic Design



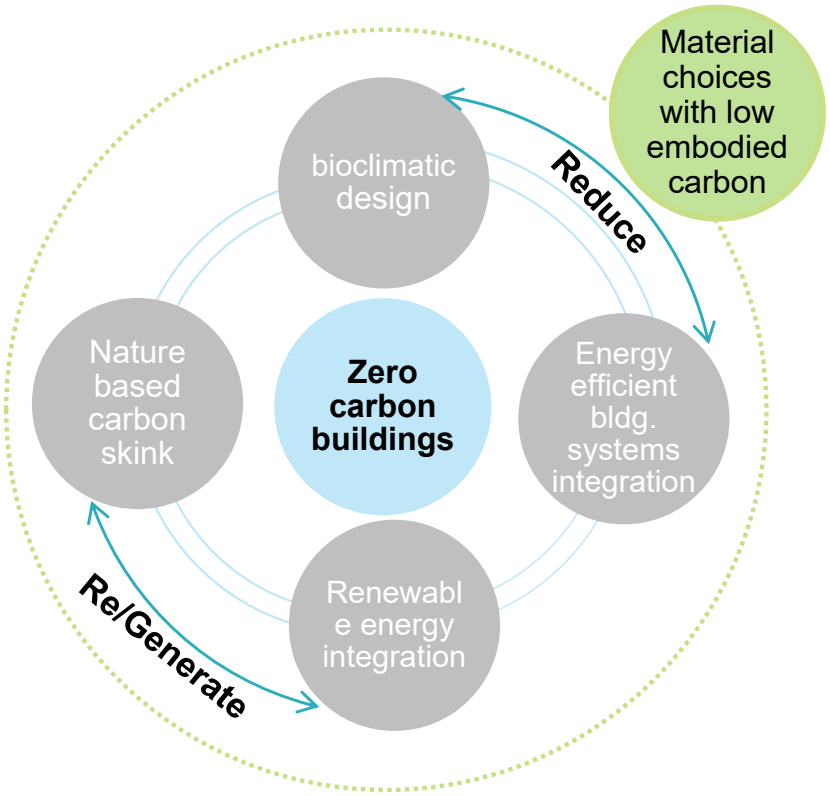
Zero Carbon Design Strategy

Bioclimatic Design

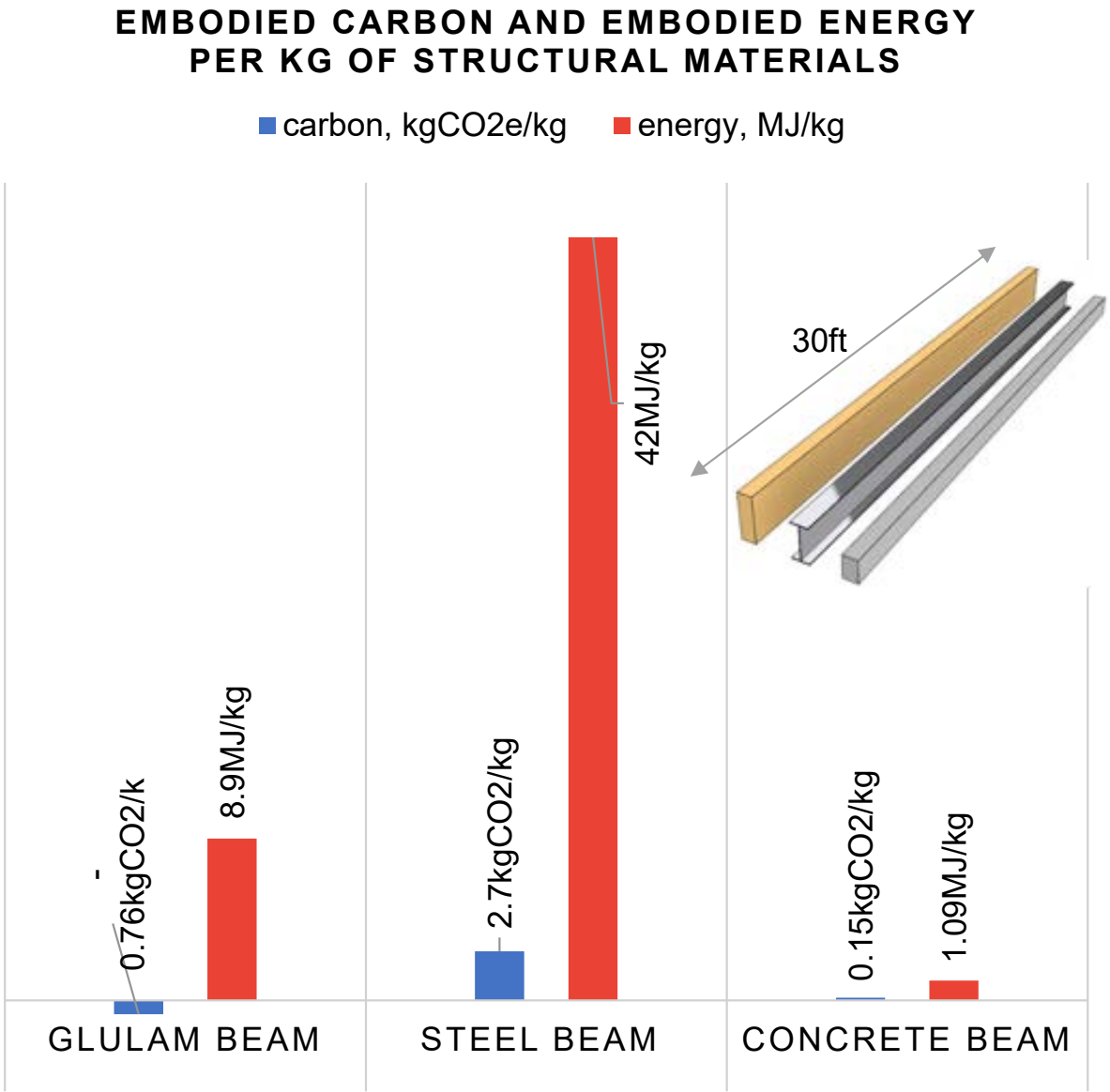


Antonin Raymond, diagram of tropical design principles, from Fry and Drew, Village Housing in the Tropics, 1947. Modern Architecture and Climate, Baber, 2020.

Net Zero Design: Low- Impact Materials



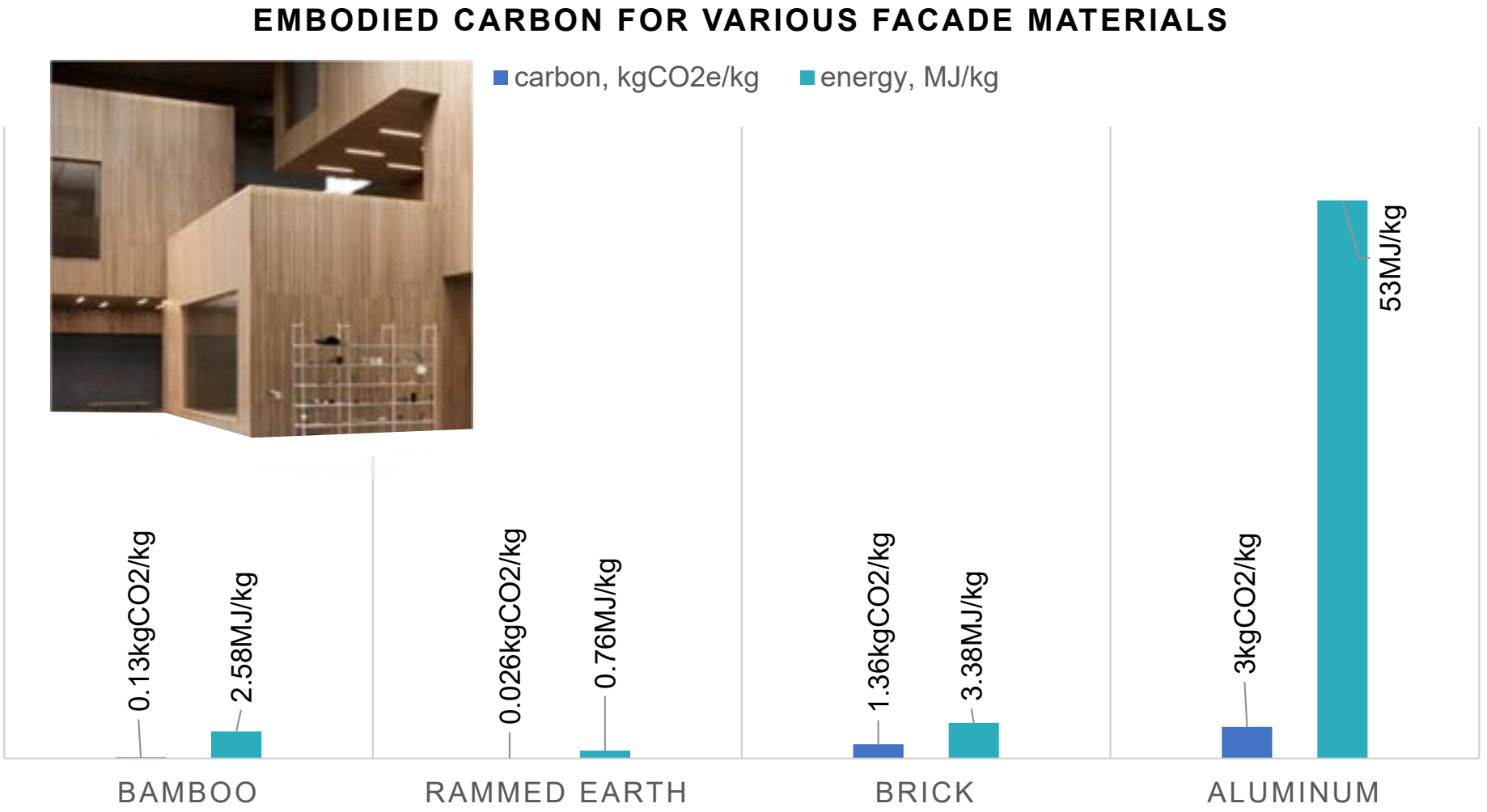
Zero Carbon Design Strategy



- Glulam: -0.76kgCO2/kg | STL: 2.7kgCO2/kg | Concrete: 0.15kgCO2/kg

IPCC Sixth Assessment Report Chapter 9, 2022

Zero Design: Low- Impact Materials



IPCC Sixth Assessment Report Chapter 9, 2022

Embodied Carbon vs. Embodied Energy

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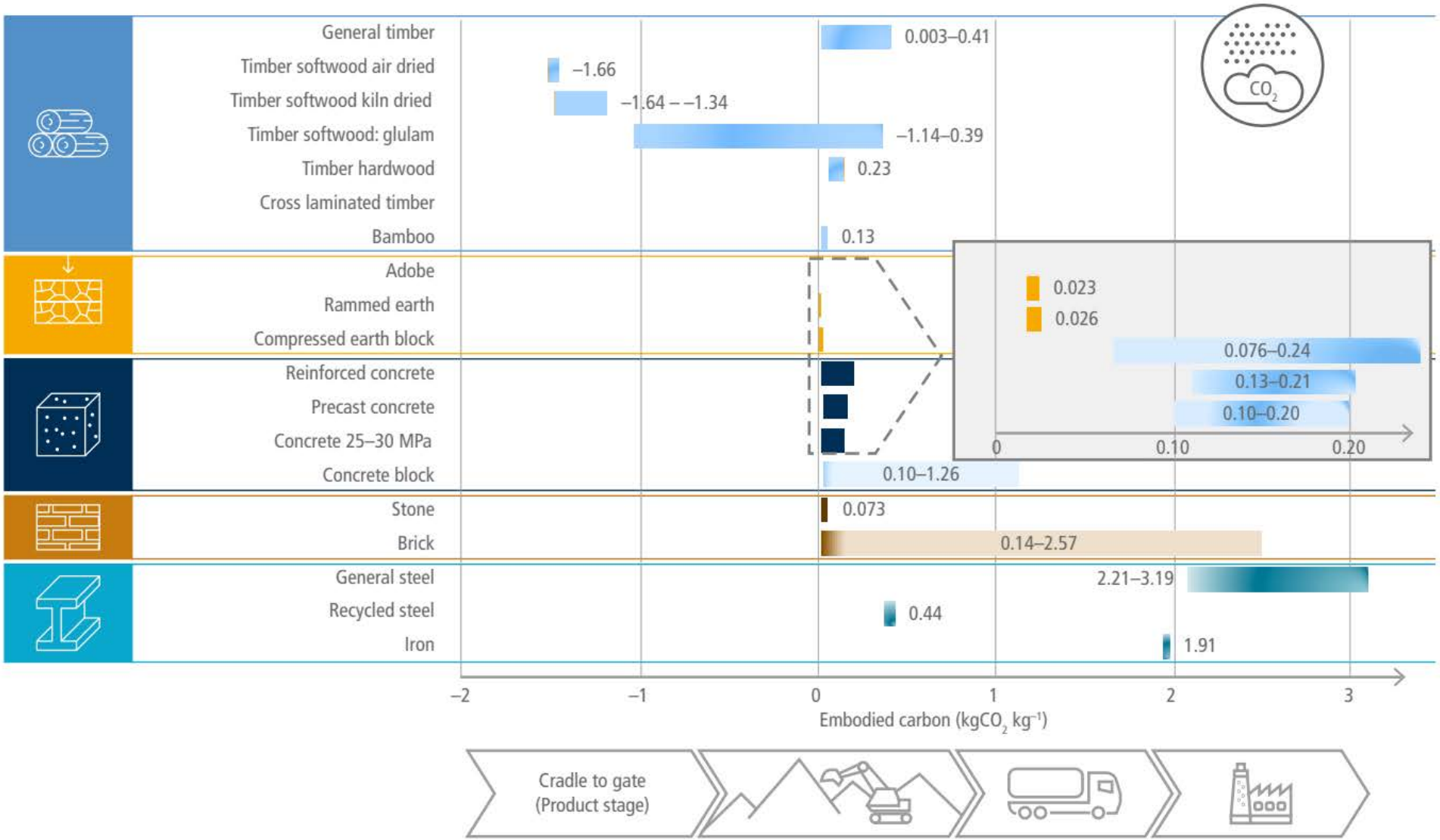
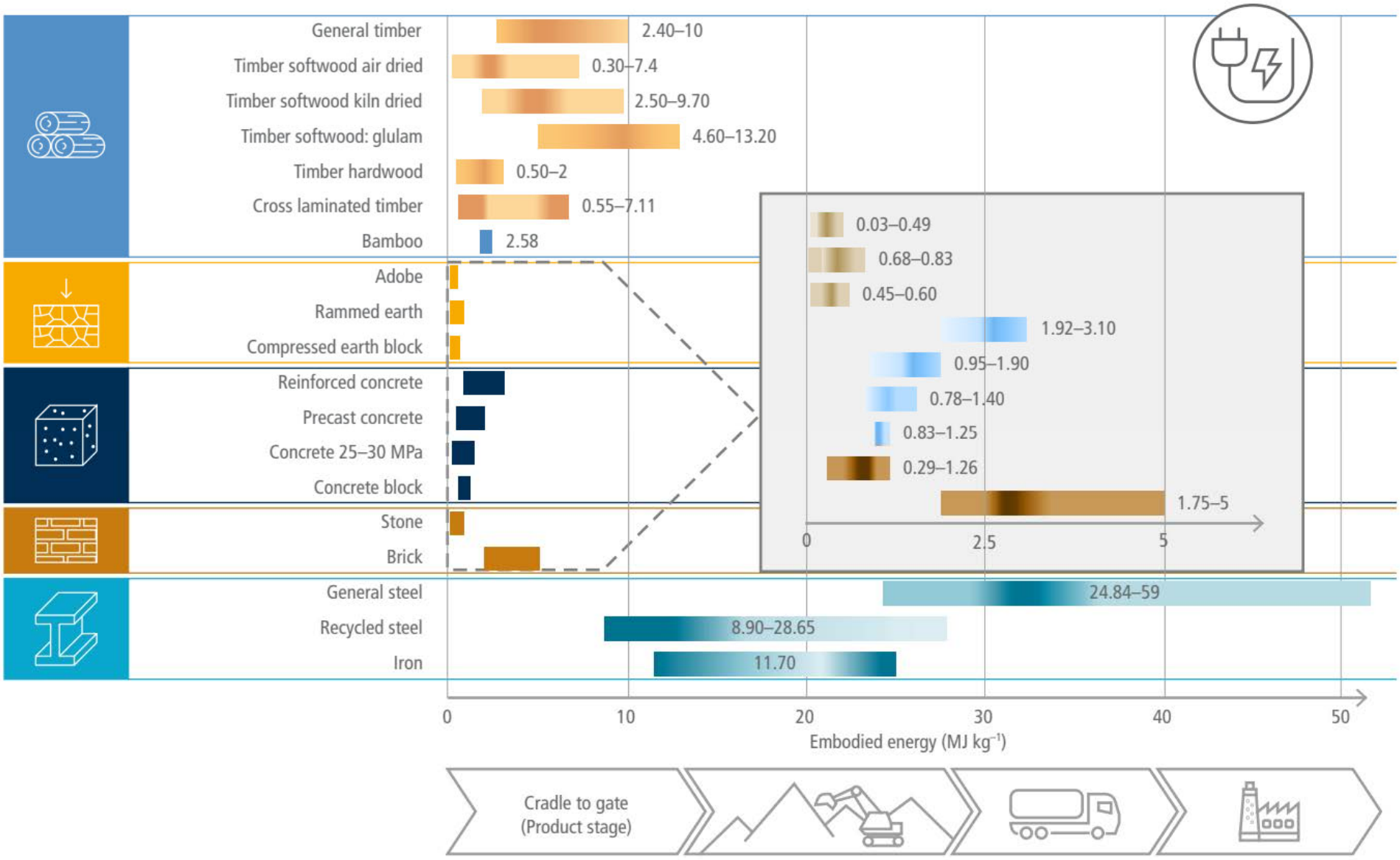


IPCC Sixth Assessment Report Chapter 9, 2022

Embodied Carbon vs. Embodied Energy

- Glulam: 8.9MJ/kg | STL: 42MJ/kg | Concrete: 1.09MJ/kg



IPCC Sixth Assessment Report Chapter 9, 2022

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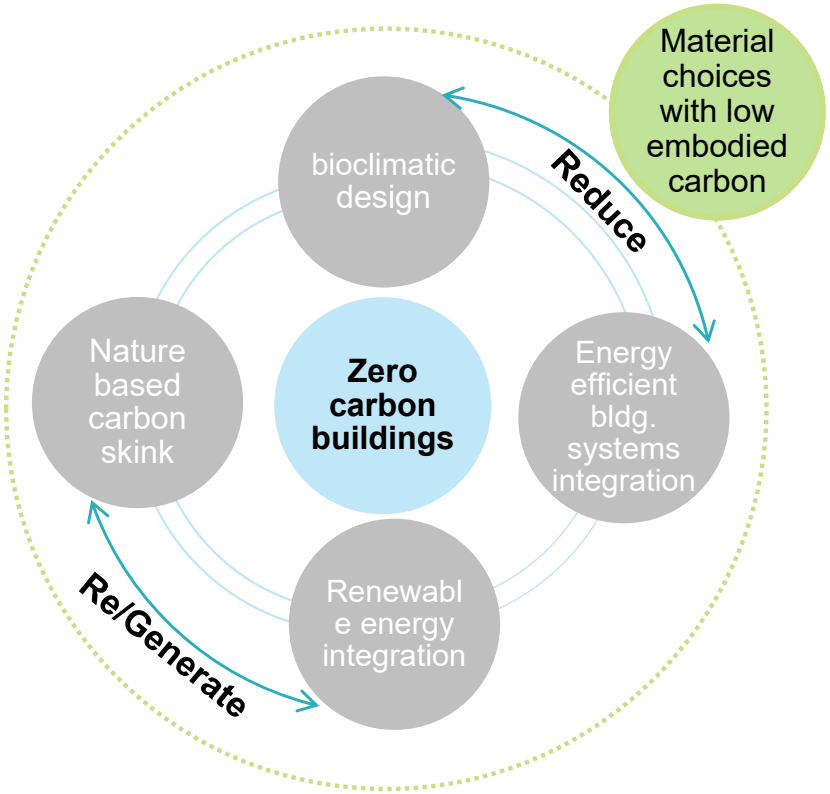


Net Zero Carbon Design Strategy

CLT board

Cellulose GreenFiber

Plyboo® Bamboo

Mycelium structure

Prometheus bioconrete

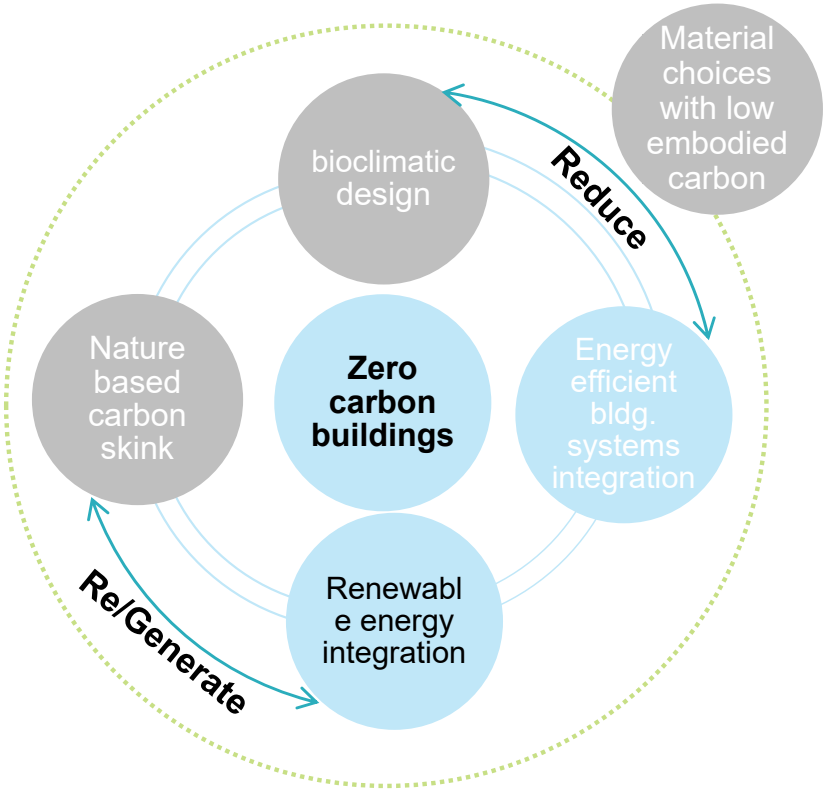
Hempcrete

Recycled rubber roofing

UltraTouch™ Denim Insulation

Recycled rubber flooring

Zero Design Strategy: Renewable Energy Integration



Net Zero Carbon Design Strategy

Infrastructure

Floatovoltaics, China

Solar desalination, Netherlands

Solar farm, USA

Solar canal, India

Urban

Solar lamp, Abu Dabi

Fluid Cube, Hungary

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Solar parking deck, Sweden

Buildings

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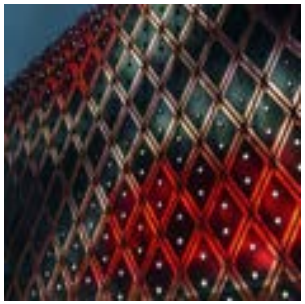
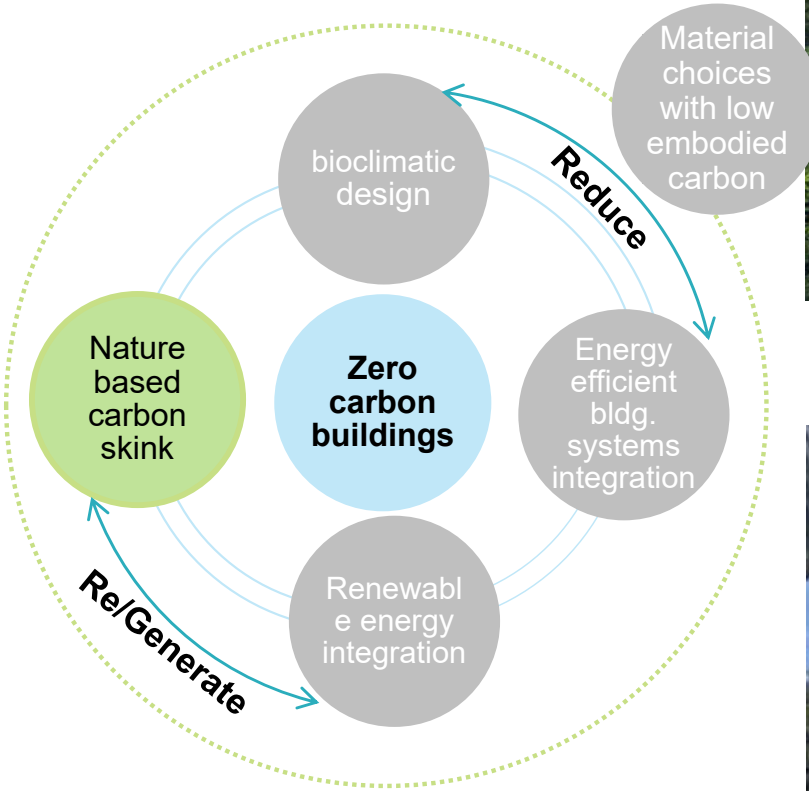


Novartis Pavilion, Switzerland

FKI, Korea

Zero Design: Nature-based Carbon Sink



Net Zero Carbon Design Strategy

Park Royal Pickering
Singapore | WOHA

Wisma Dharmala Tower
Jakarta, Indonesia | Paul Rudolph

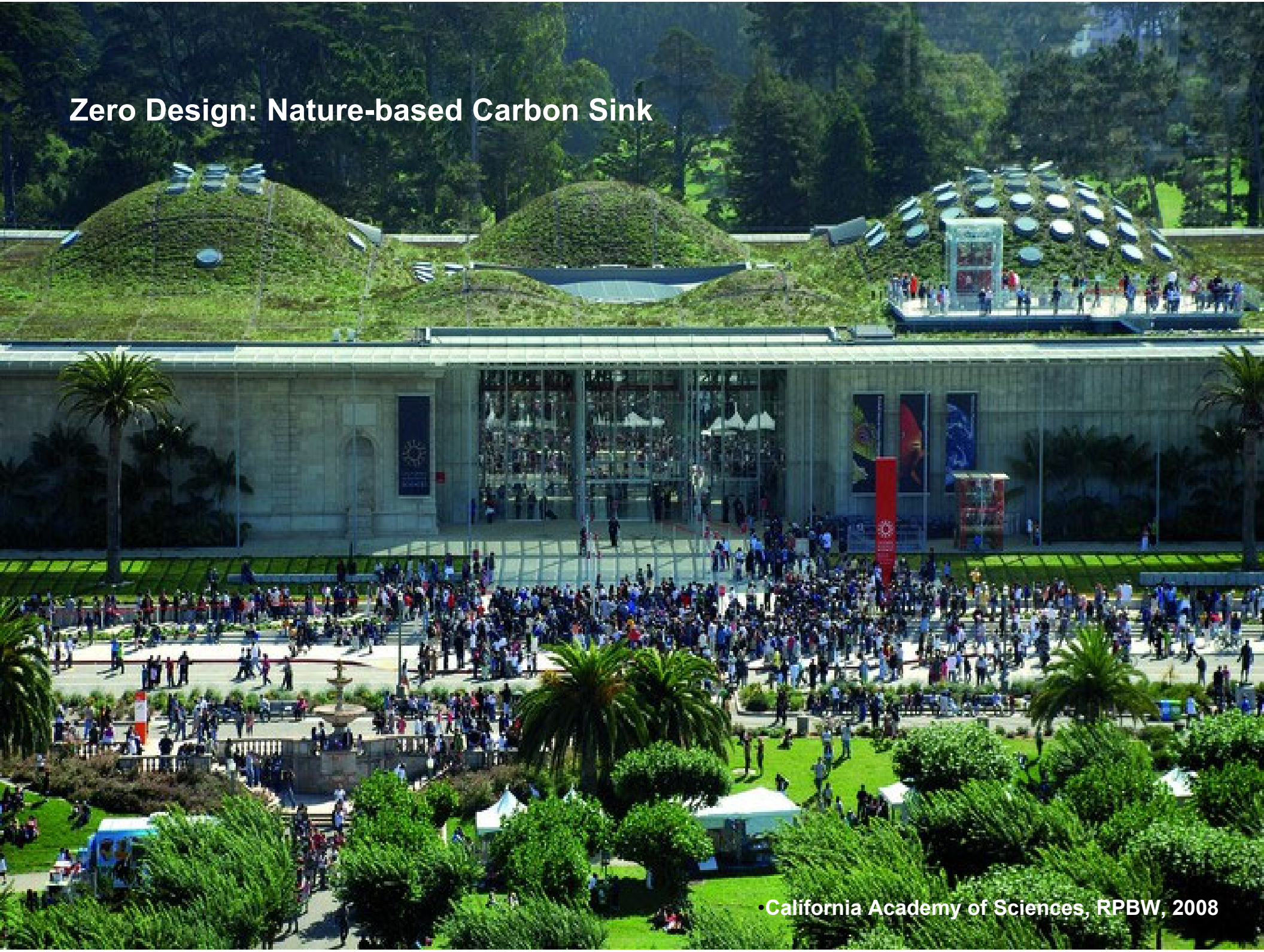
Vertical Forest
Milan | Stefano Boeri

Le Nouvel Tower
KL, Malaysia | JNA

Haus E
Zurich | MSA

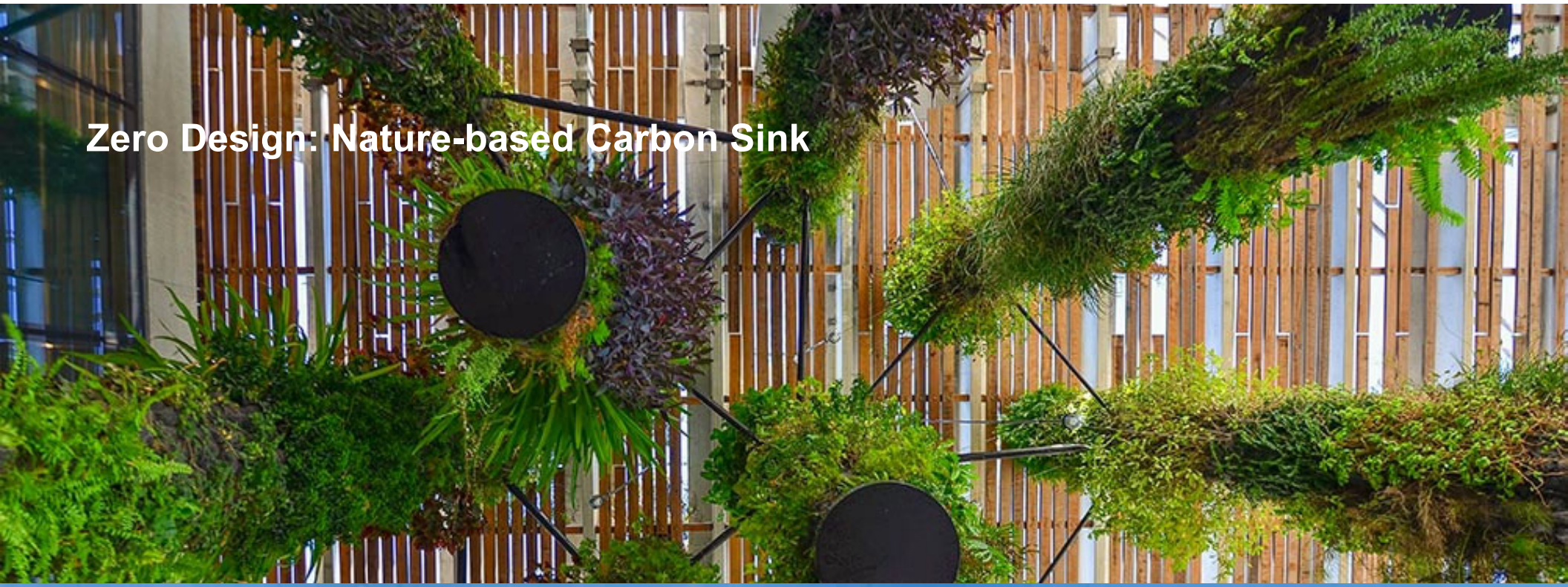
Landscape rift
Denver USA| MAD Architects

Zero Design: Nature-based Carbon Sink



- California Academy of Sciences, RPBW, 2008

Zero Design: Nature-based Carbon Sink

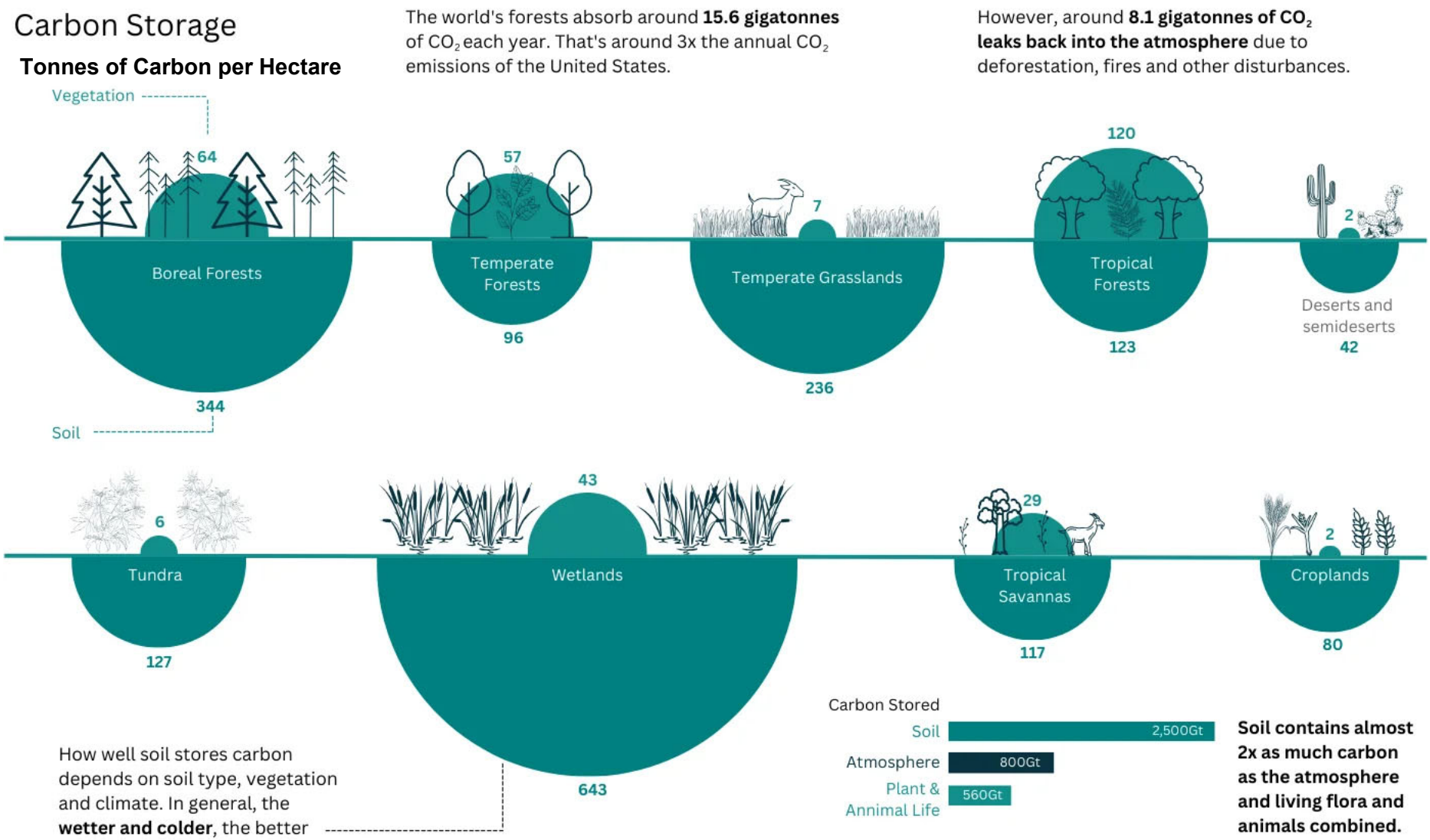


•The Perot Museum of Nature and Science , **HdM, 2013**

Zero Design: Nature-based Carbon Sink

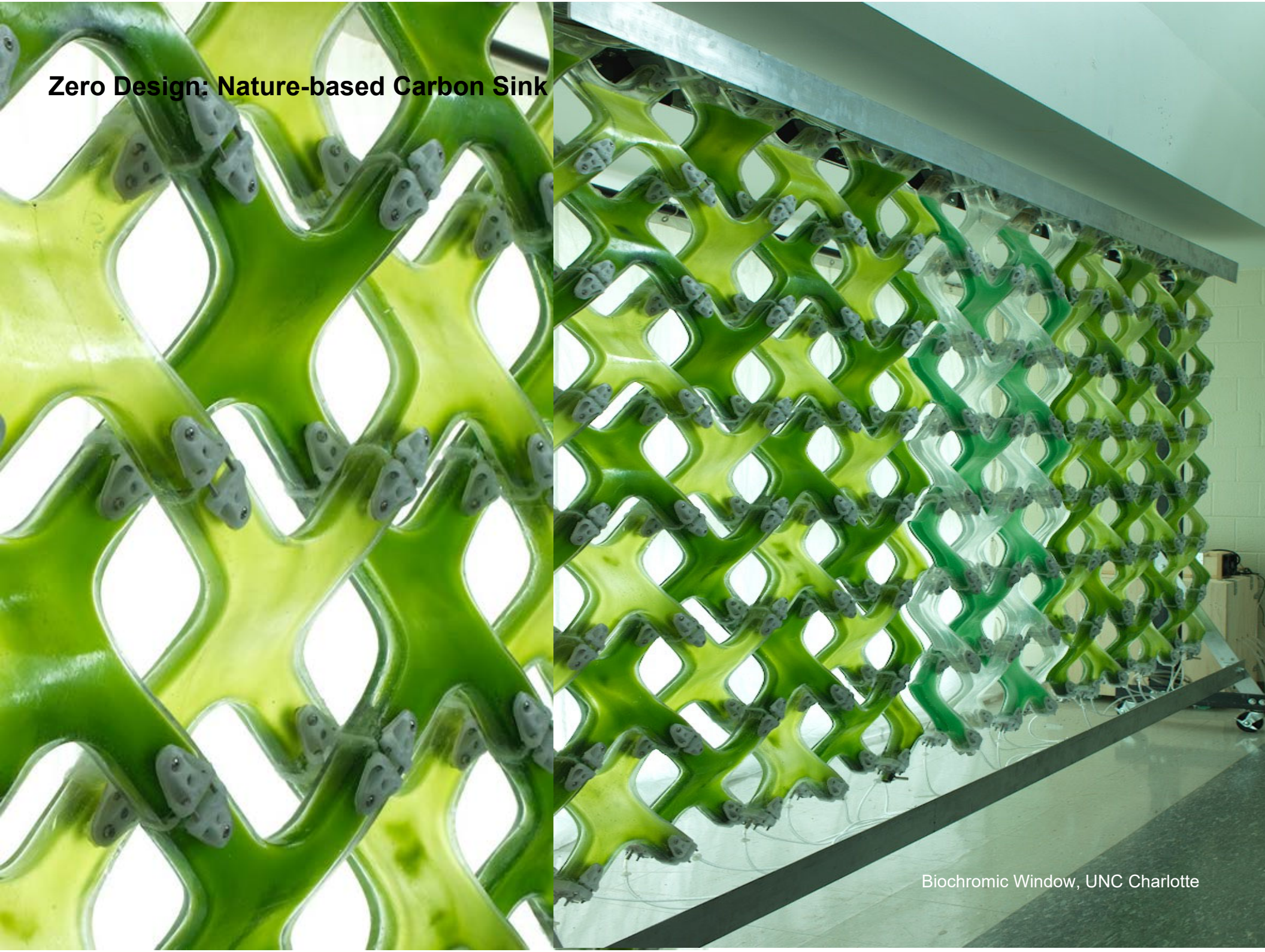
Southwest Montgomery Green Street, Oregon. Nevue Ngan Associates

Zero Design: Nature-based Carbon Sink



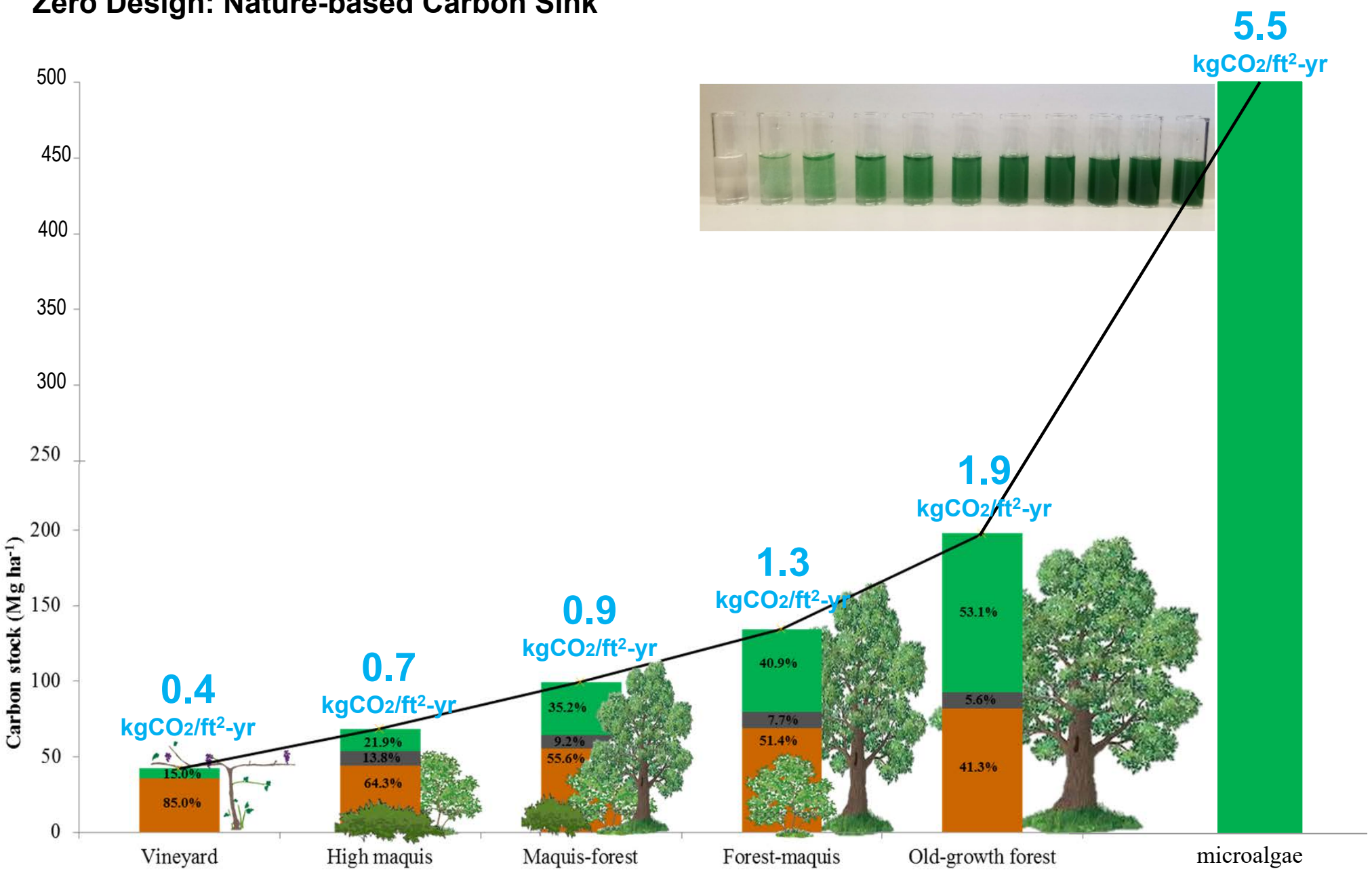
Data Source: IPCC
Data visualization: Visualizing Carbon Storage in Earth's Ecosystems

Zero Design: Nature-based Carbon Sink



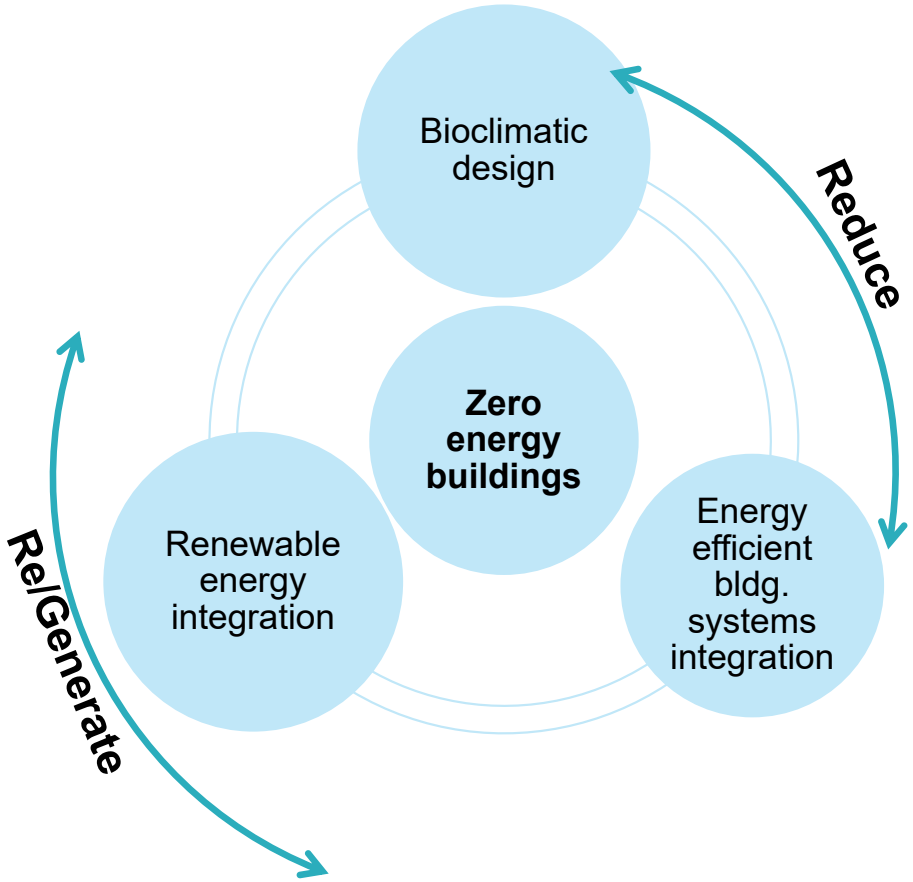
Biochromic Window, UNC Charlotte

Zero Design: Nature-based Carbon Sink

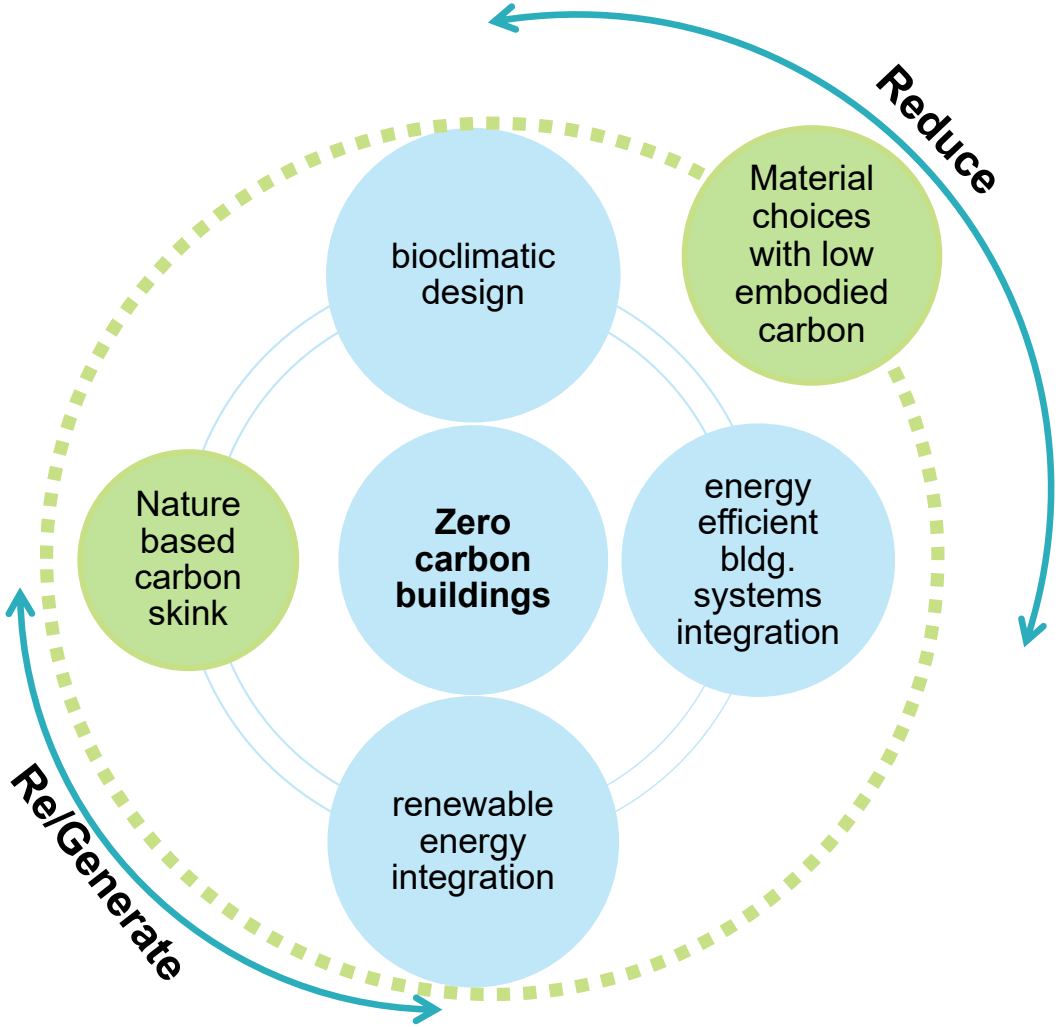


doi: https://doi.org/10.1371/journal.pone.0220194.g002

Zero Energy and Net Zero Carbon Strategies Comparisons



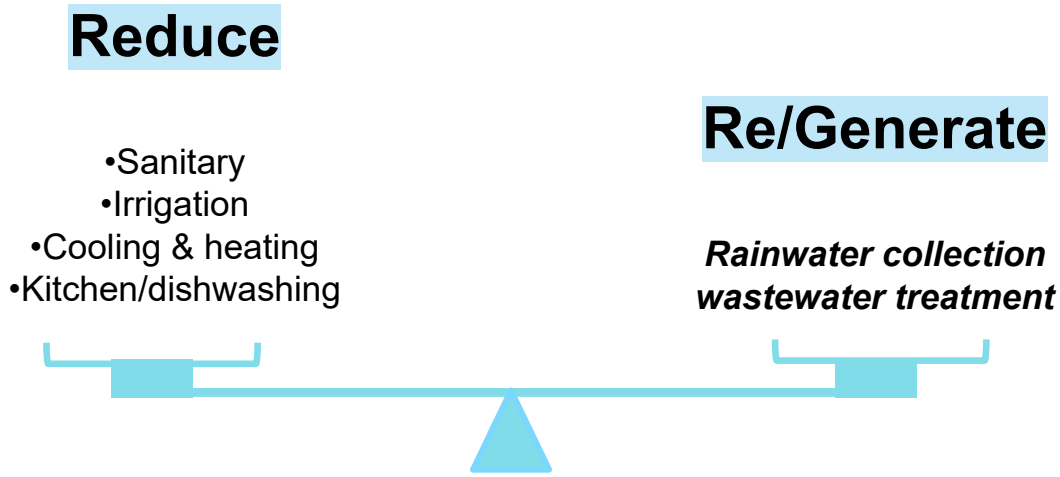
Net Zero Energy Design Strategy



Net Zero Carbon Design Strategy

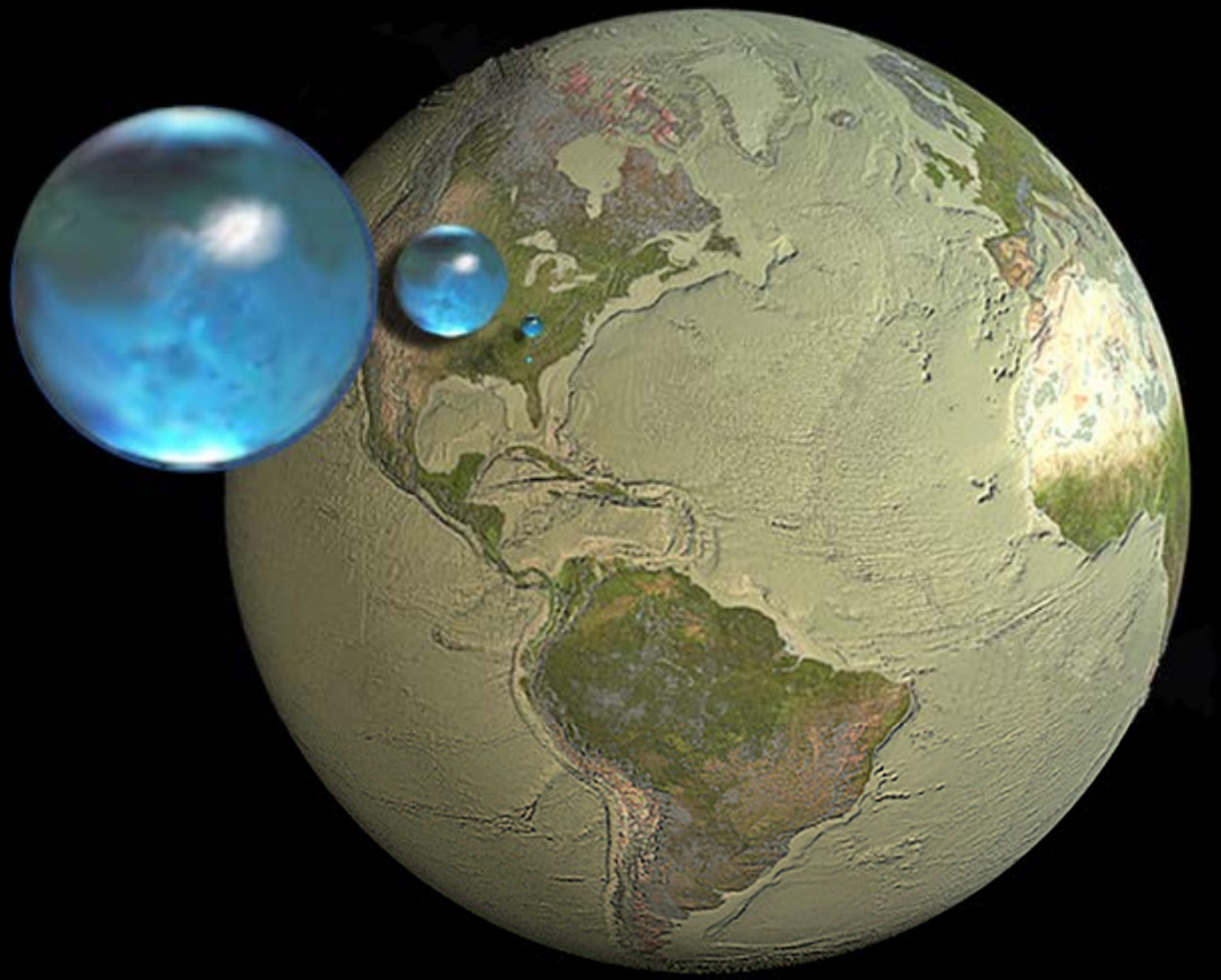
Zero Water Design

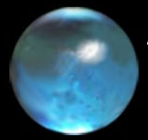
Zero Water Framework



Zero Water Strategy

The World's Water





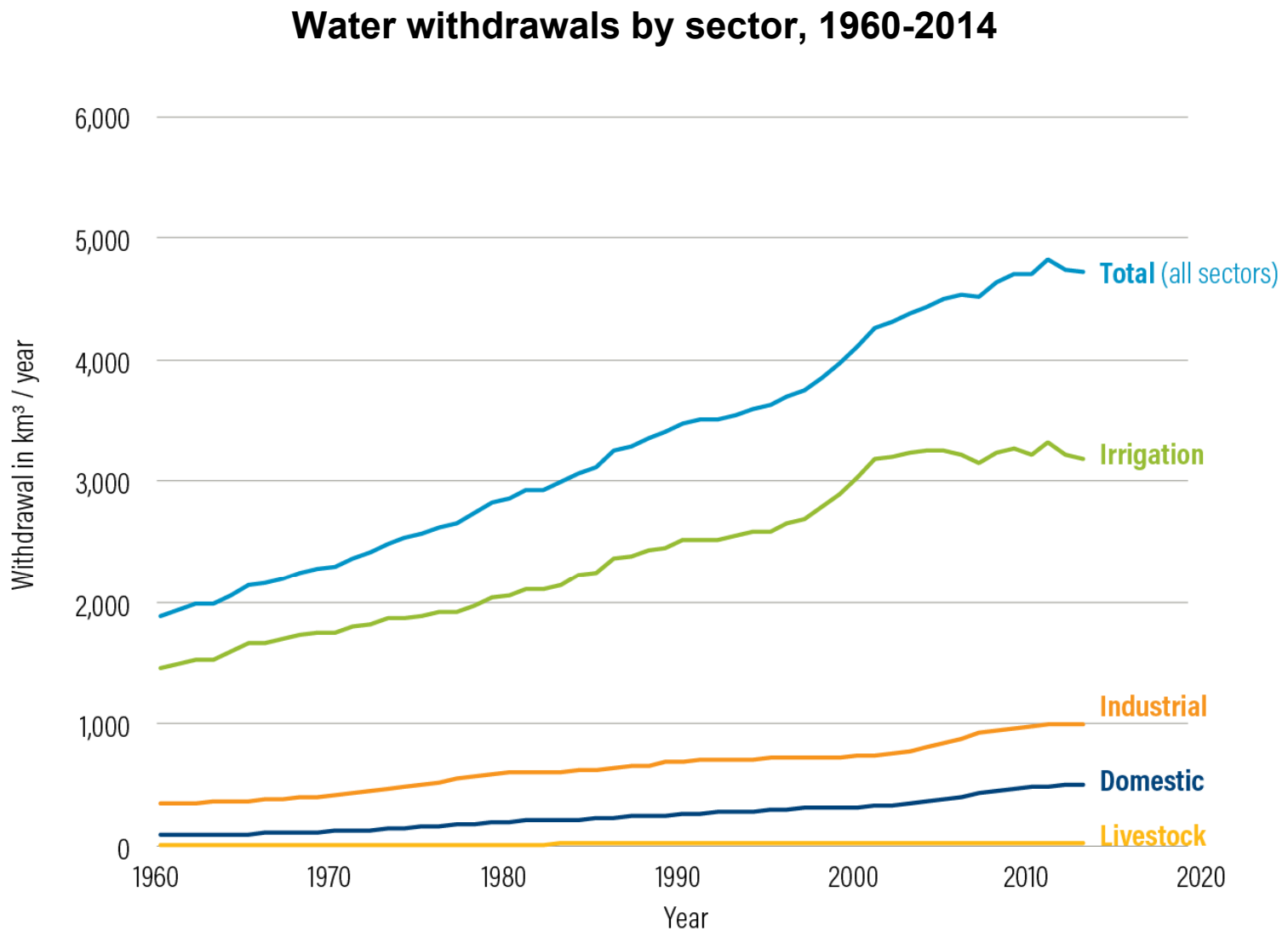
All water on, in, and above the Earth

- **Liquid fresh water**
- **Fresh-water lakes and rivers**

Howard Perlman, USGS,
Jack Cook, Woods Hole Oceanographic Institution,
Adam Nieman
Data source: Igor Shiklomanov
http://ga.water.usgs.gov/edu/earthhowmuch.html

US Geological Survey

Global Water Use



Source: Authors.

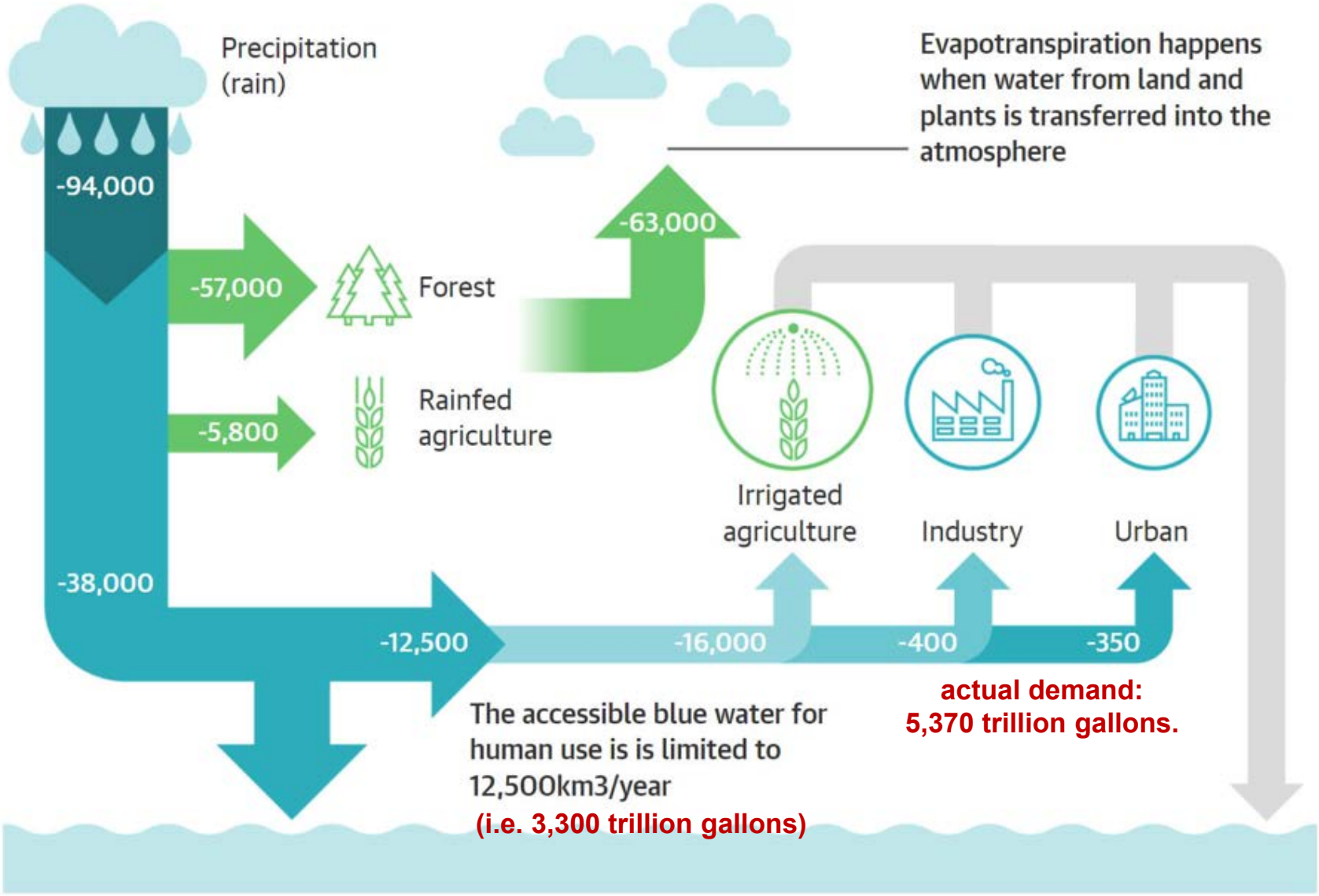
20.2.10

AQUEDUCT

WORLD RESOURCES INSTITUTE

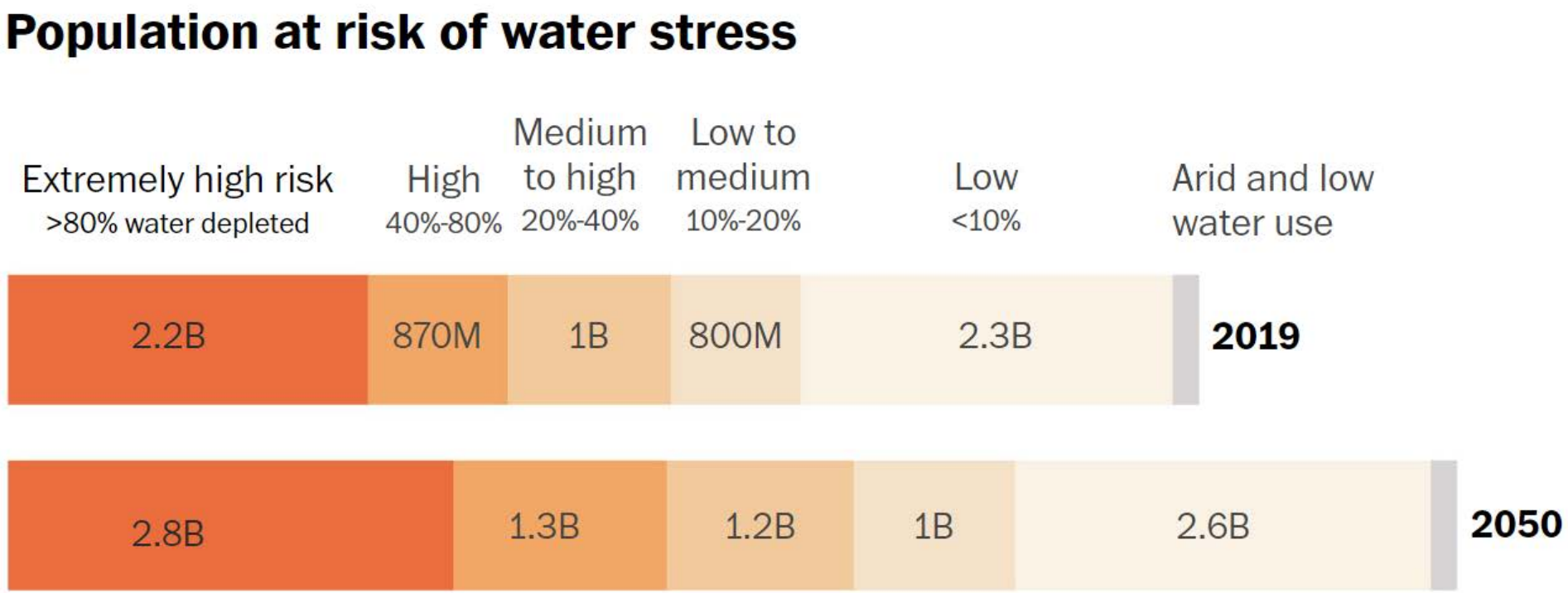
Betsy Otto and Leah Schleifer, World Resources Institute (WRI)

Global Available Water vs. Actual Water Use



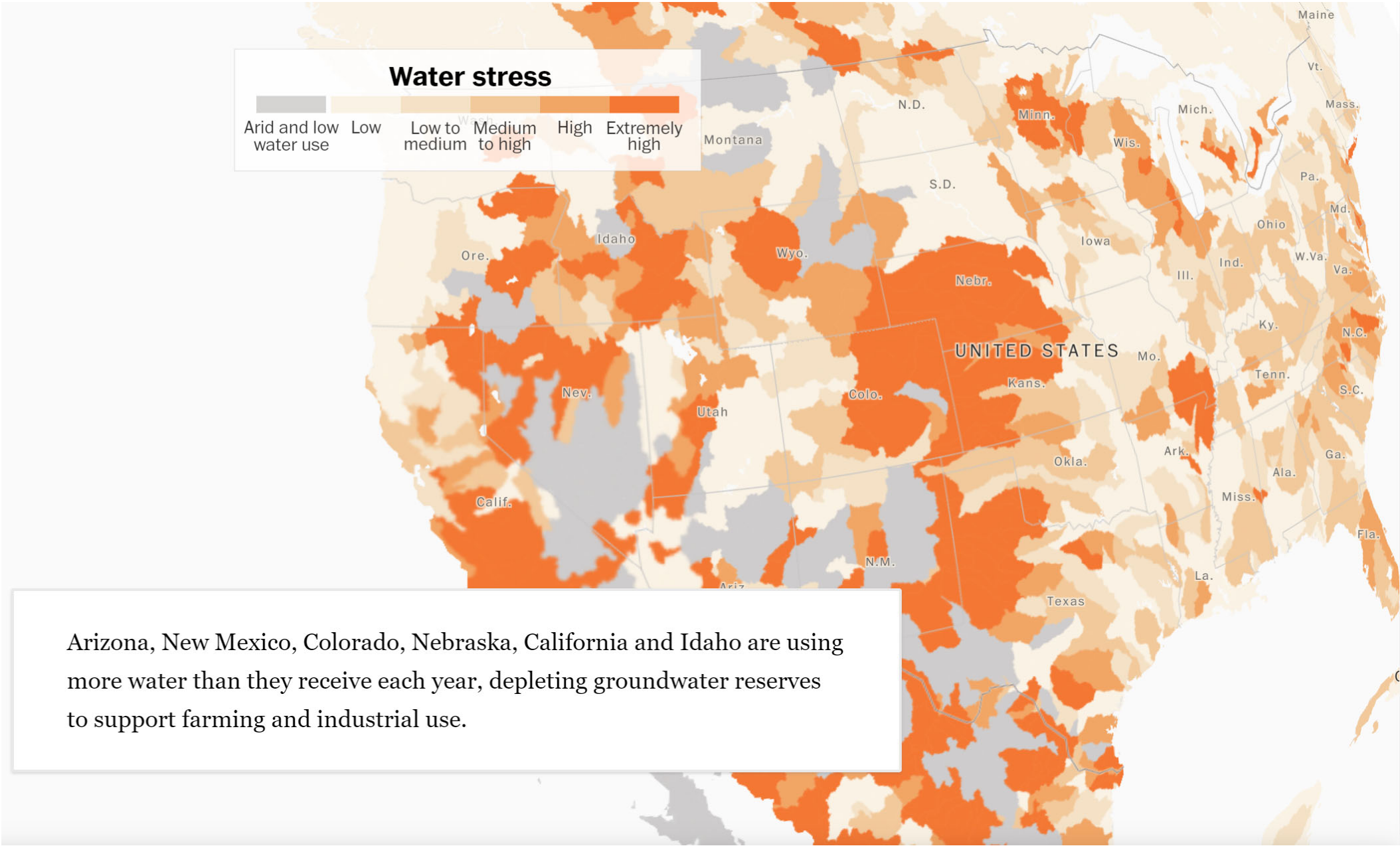
Guardian graphic. Source: Global Commission on the Economics of Water

Water Stress: Global Available Water Greater than Actual Water Use



The Washington Post

Water Stress: Global Available Water Greater than Actual Water Use

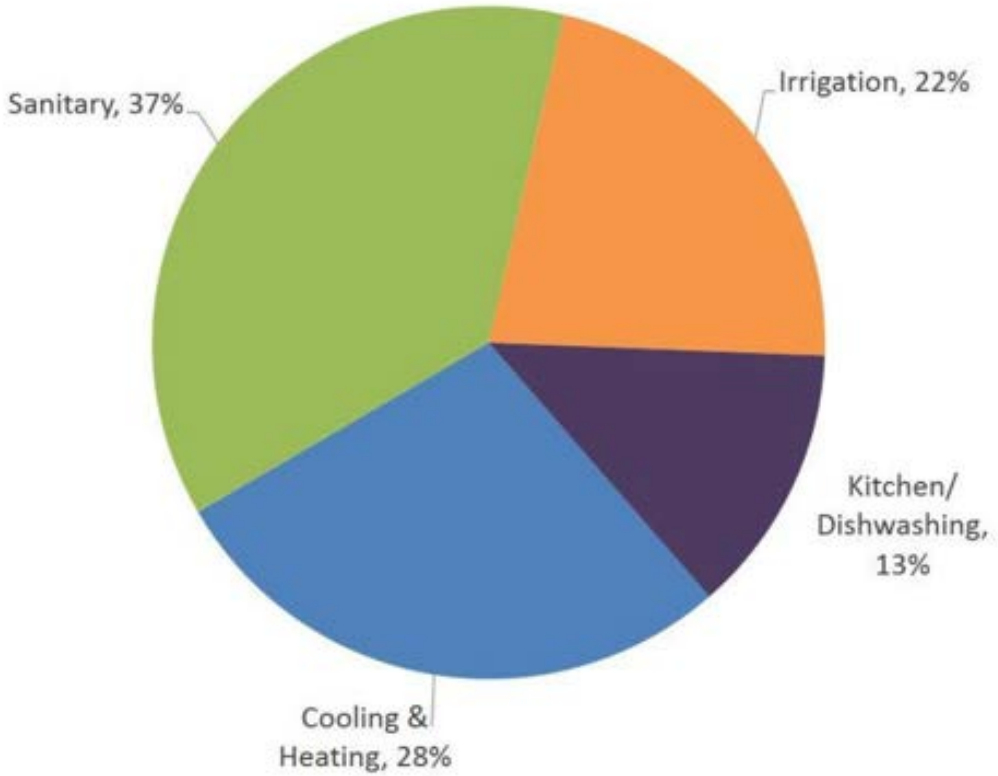


Arizona, New Mexico, Colorado, Nebraska, California and Idaho are using more water than they receive each year, depleting groundwater reserves to support farming and industrial use.

The Washington Post

Water End Users in Buildings

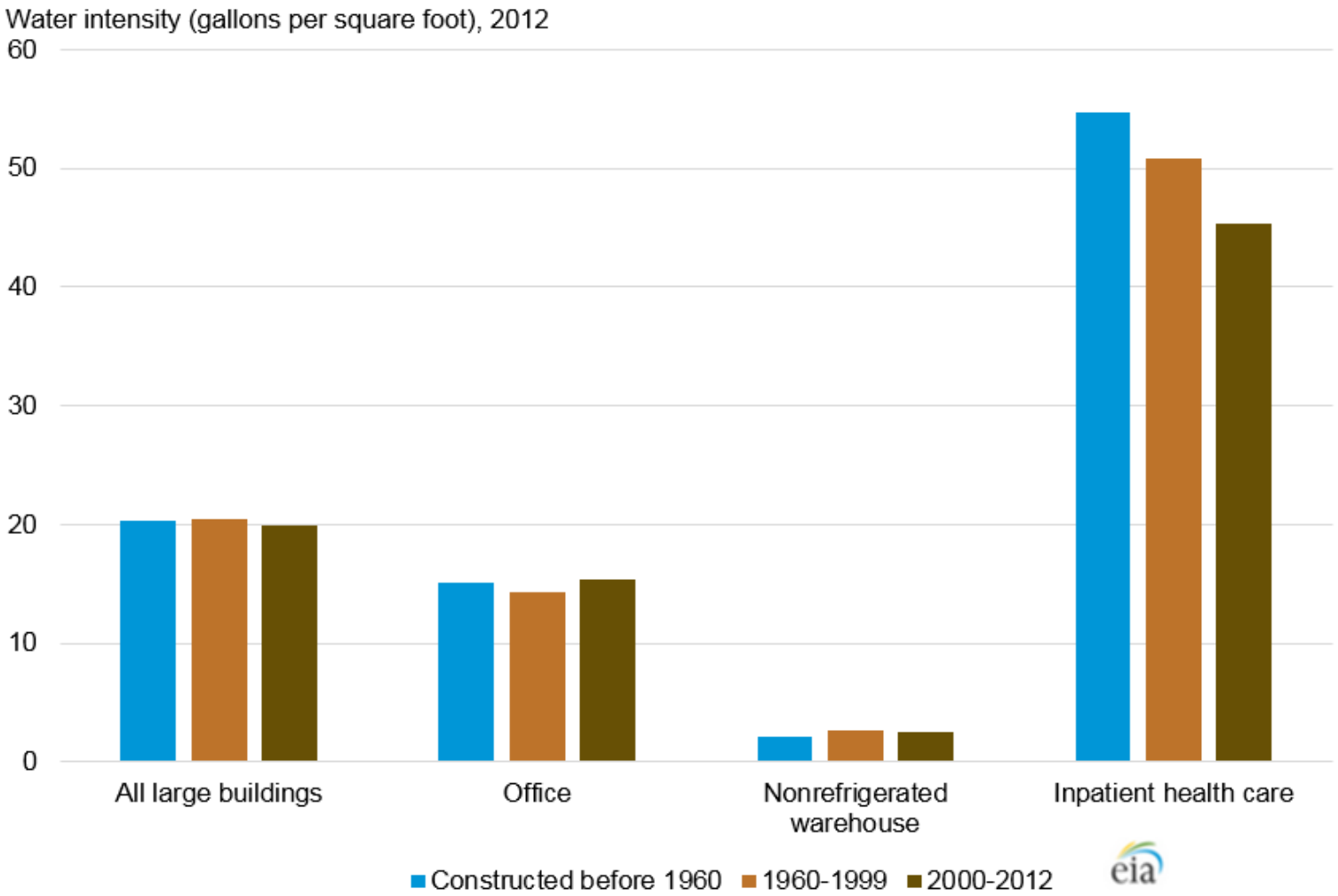
Typical office building energy uses of water: ~17 gallons/sq.ft (2012)



US EPA

Water Footprint in Buildings

Typical office building energy uses of water: ~17 gallons/sq.ft (2012)
Water intensity varies little by year of construction except in inpatient heath care buidlings



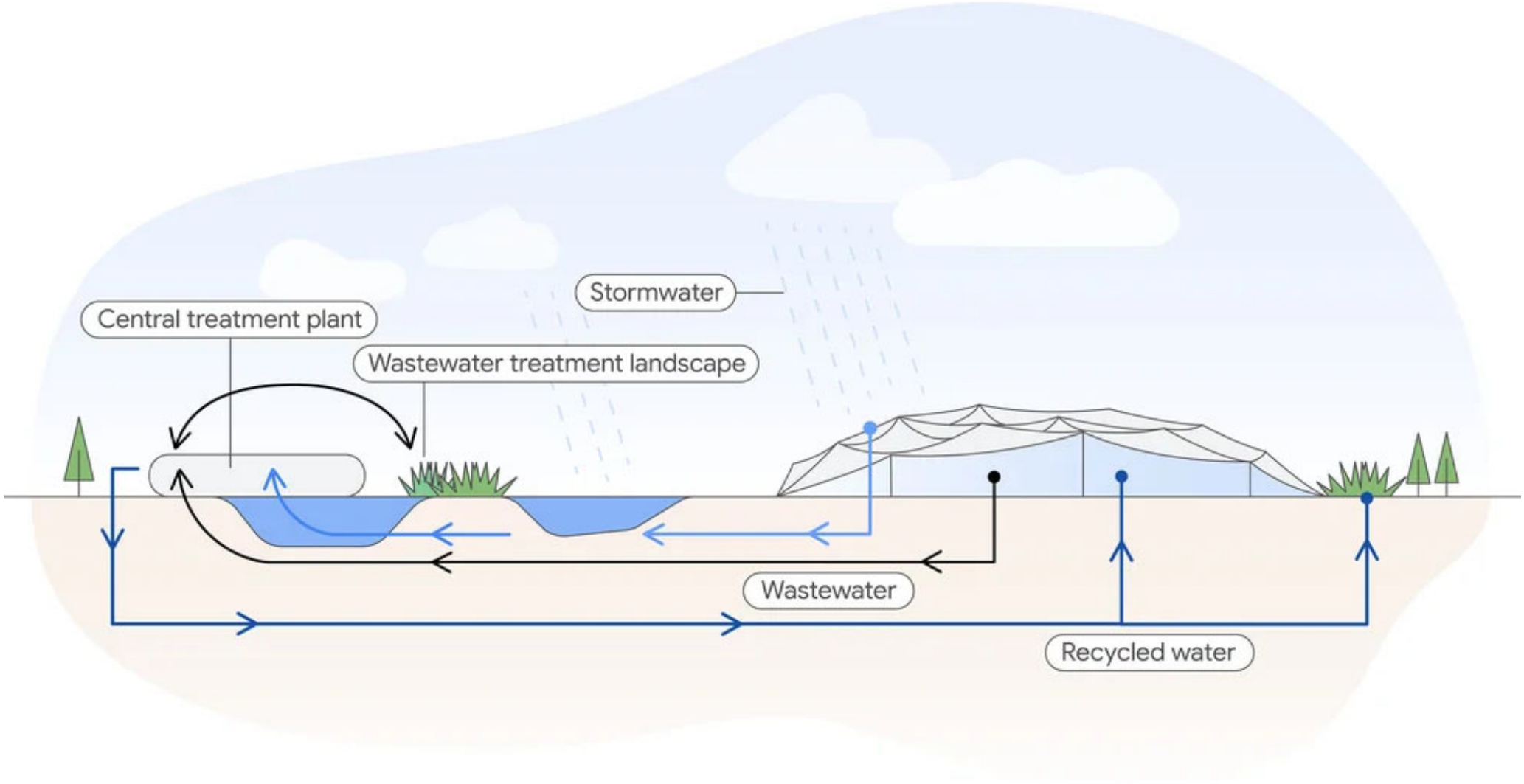
Zero Water Design:

- Reduce: Water Fixtures/Geothermal Pile
- Re/Generate: Rainwater Collection/Greywater Treatment

Google HQ, CA, 2022

Zero Water Design:

- Reduce: Water Fixtures/Geothermal Pile
- Re/Generate: Rainwater Collection/Greywater Treatment



Google HQ, CA, 2022

Zero Water Design:

- Reduce: Water fixtures/Compost Toilet
- Re/Generate: Rainwater Collection/Greywater Treatment/Cooling Tower Water Collection

Kendeda Building, GeorgiaTech, 2019

NET POSITIVE WATER CYCLE – LIVING BUILDING CHALLENGE STRATEGY

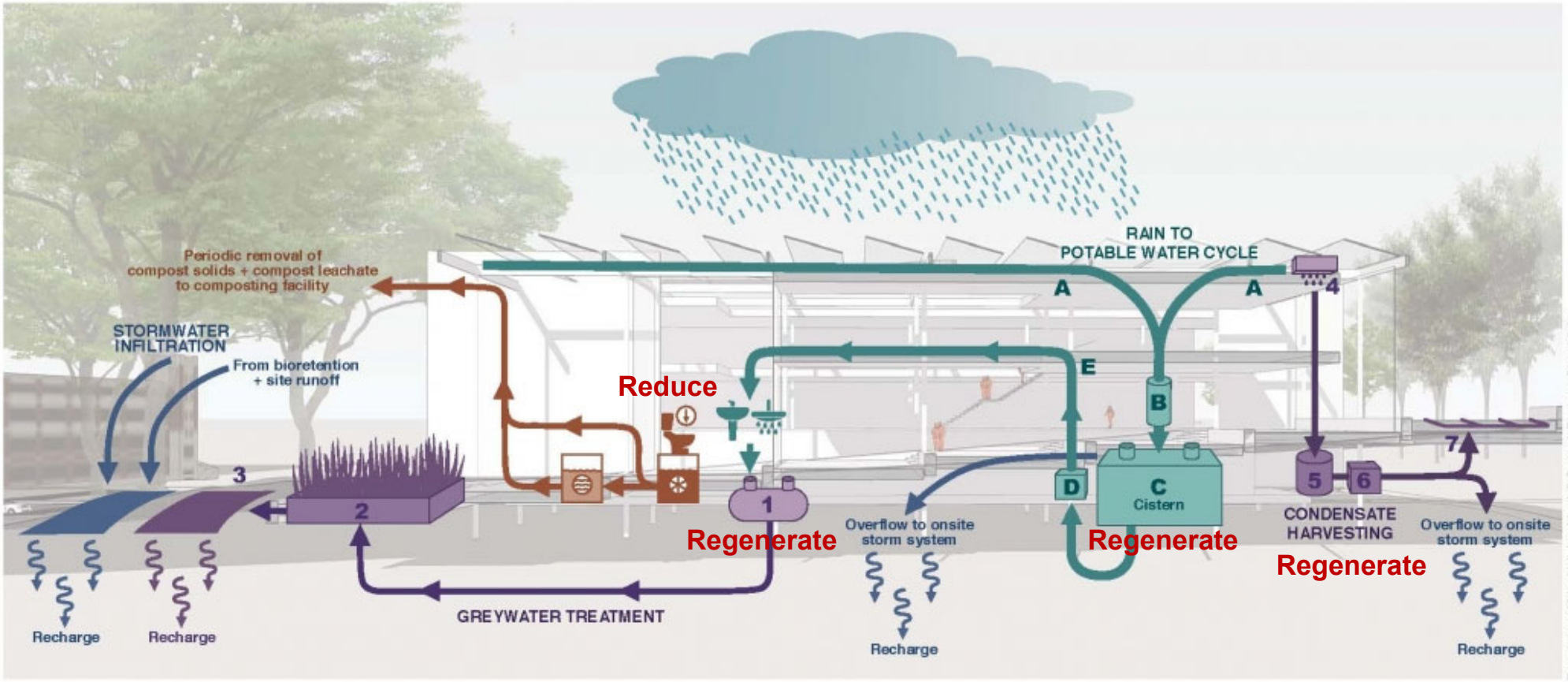
Kendeda Building for Innovative Sustainable Design

Georgia Institute of Technology, Atlanta, GA

Biohabitats

PROJECT TEAM

Miller Hull	Newcomb & Boyd
Lord Aeck Sargent	Long Engineering
Andropogon Associates	Biohabitats
Uzun+Case	Skanska USA
PAE	



GREYWATER TREATMENT

1 Primary treatment tank–collects, settles*, digests

2 Constructed wetlands–passive ecological polishing

3 Subsurface infiltration–recharges groundwater

RAIN TO POTABLE WATER CYCLE

A Rainwater collection–piping

B Inlet Filtration from roof

C Basement cistern

D Potable water filtration + UV disinfection skid

E Distribution to potable fixtures

COMPOSTING TOILET CYCLE

Foam flush toilet fixtures (compatible with composting unit)

Composter units (serve multiple toilets)

Compost leachate storage tank

*Periodic solids removal to biosolids/composting facility

CONDENSATE HARVESTING

4 Condensate from building cooling system

5 Condensate storage tank

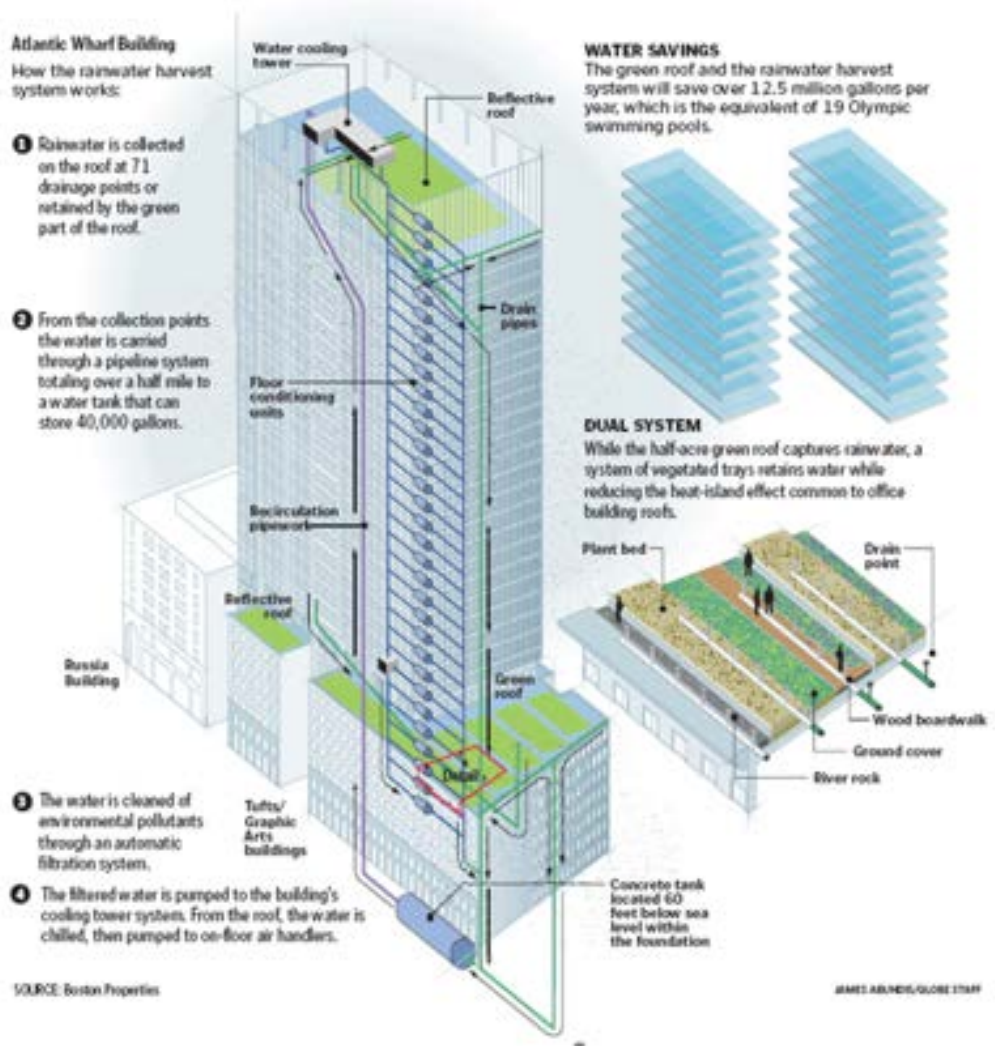
6 Filtration + irrigation pump

7 Site irrigation system

Kendeda Building, GeorgiaTech, 2019

Zero Water Design:

- Reduce: Water fixtures/Compost Toilet
- Re/Generate: Rainwater Collection/Greywater Treatment/Cooling Tower Water Collection

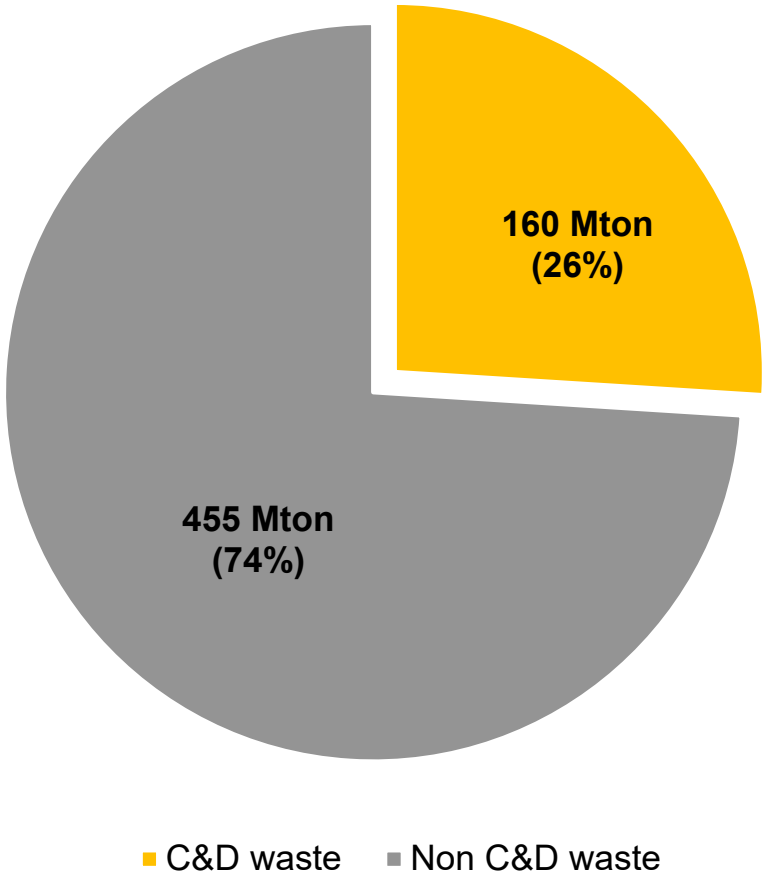


Atlantic Wharf, Boston

Zero Waste Design

The Guardian. US produces far more waste and recycles far less of it than other developed countries

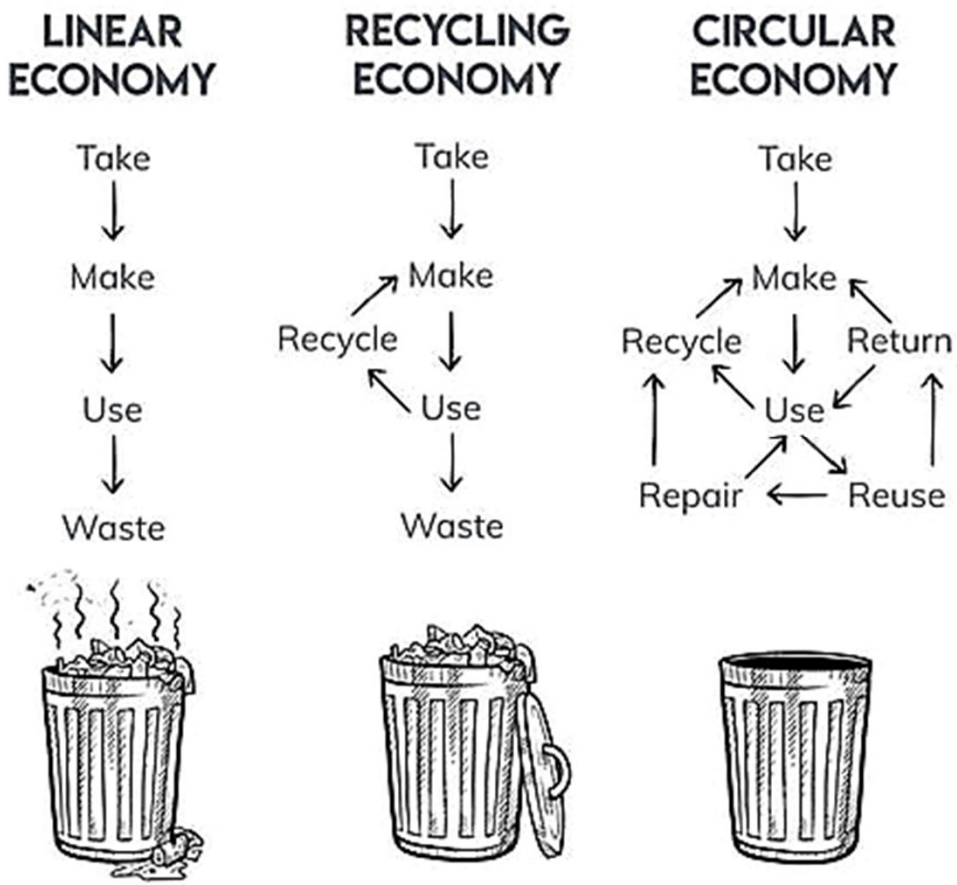
US Solid Waste: 615 Mtons in 2008



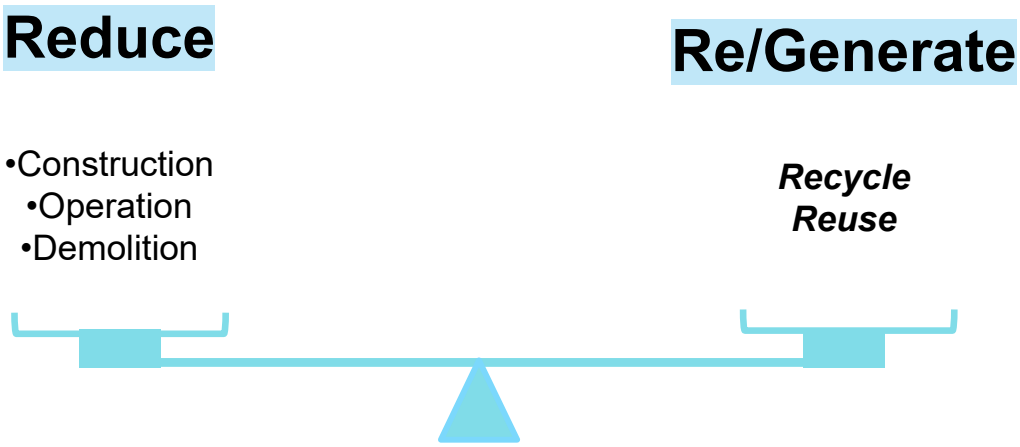
1. Recycled or reused: 20~30% (32-48 Mton)
2. Discarded: 70~80% (112-128 Mton)
    - Lumber (40%)
    - Asphalt products (14%)
    - Soil/fines (11%)
    - Concrete/rock/brick (11%)
    - Gypsum board (10%)
    - Other (14%)

The Ellen MacArthur Foundation's report on the Economics of a Circular Economy

Circular Economy

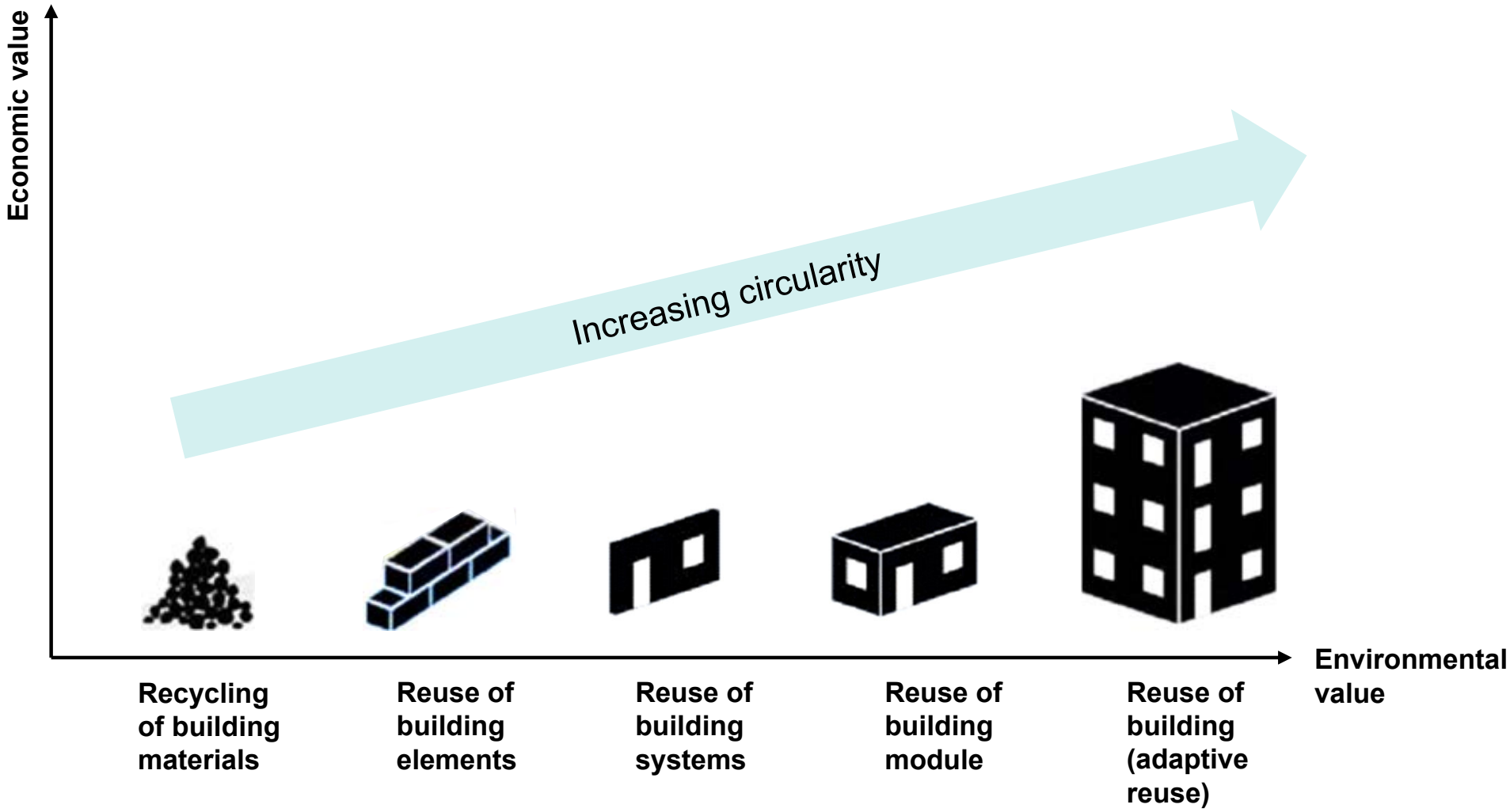


Net Zero Waste Framework



Zero Waste Strategy

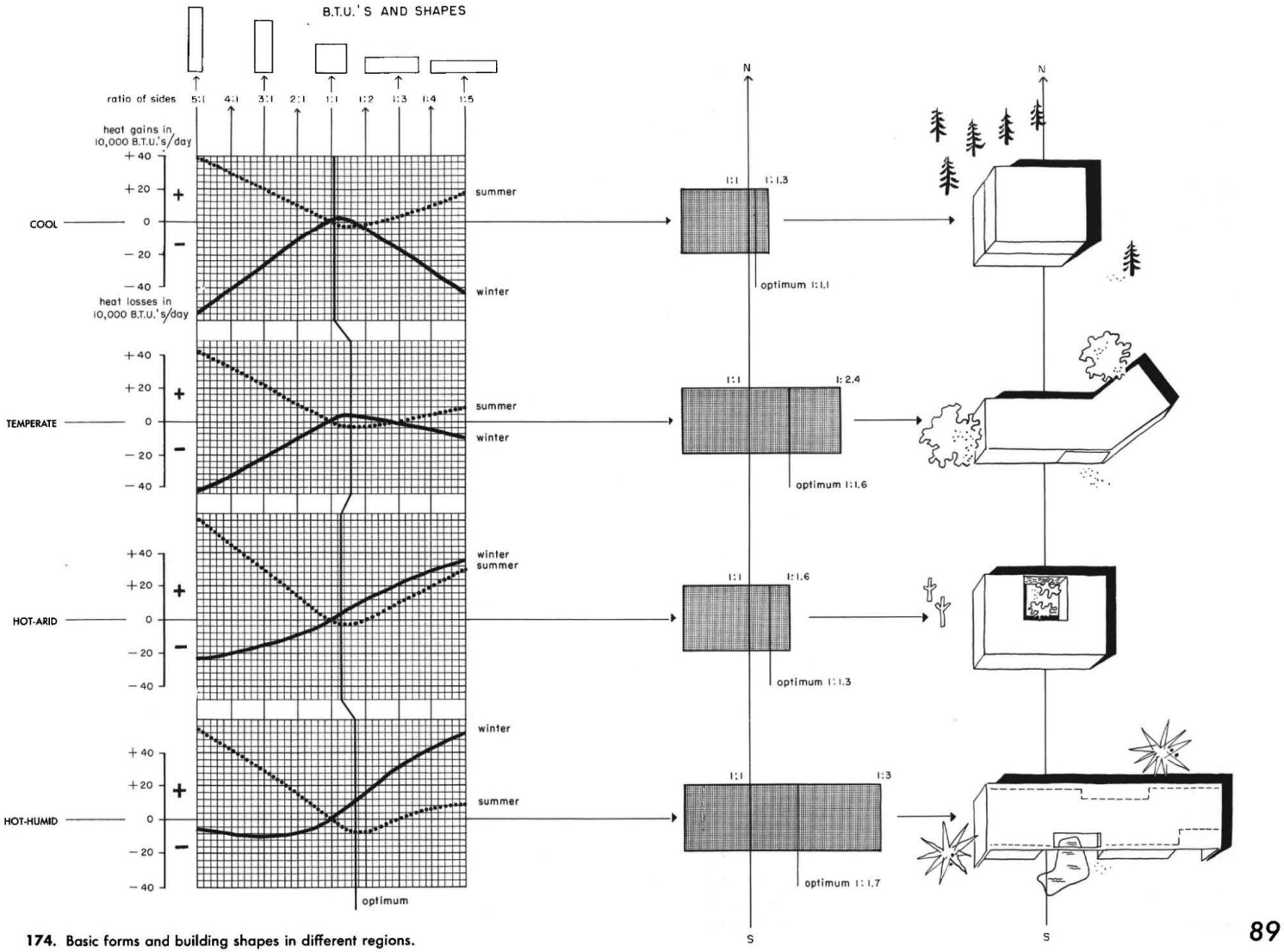
Circular Economy



https://iopscience.iop.org/article/10.1088/1757-899X/471/9/092051/pdf

Circular Economy: Reduce

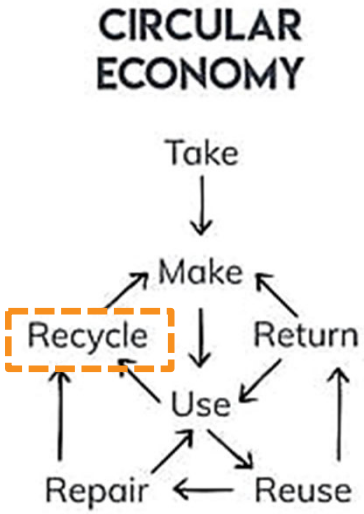
- Building enclosures vs Material uses



174. Basic forms and building shapes in different regions.

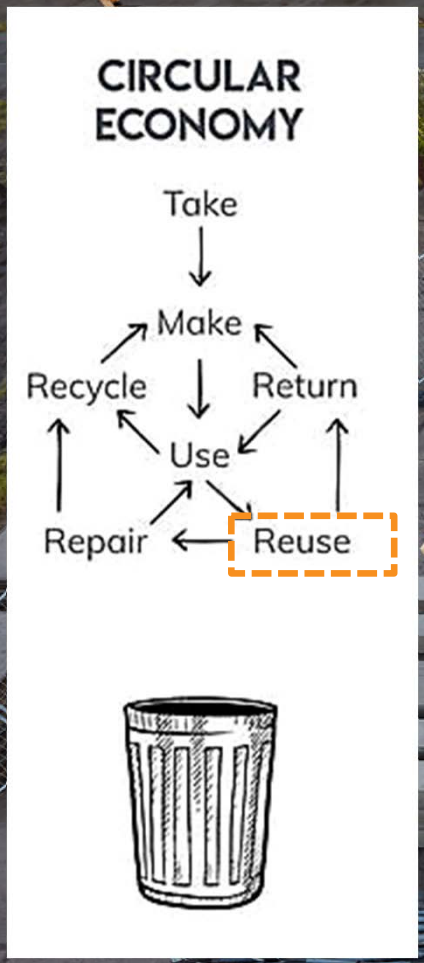
Design with Climate. Olgyay & Olgyay, 1963

Circular Economy: Recycle



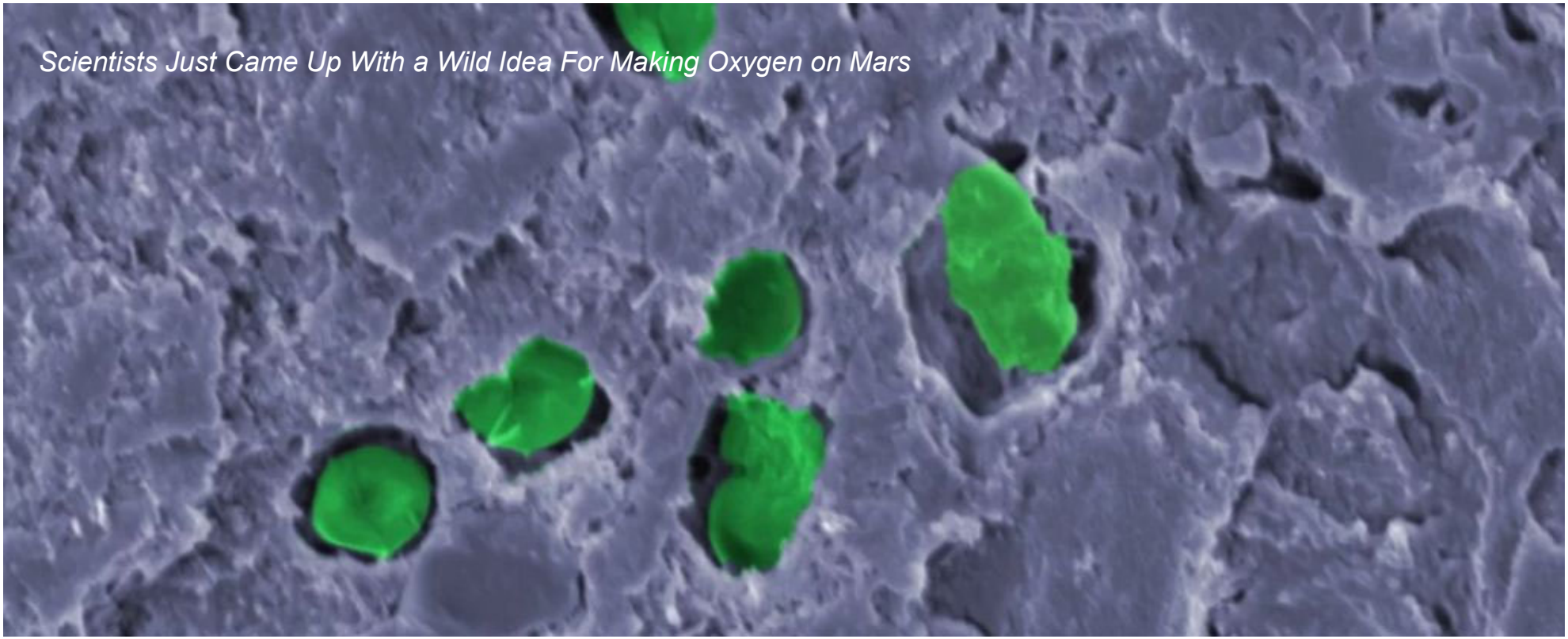
Resource: label printer waste
Manufacturer: UPM biocompoents, Finnand
Designer: Shigeru Ben Architects, France
Product directory: load-bearing, waterproofing

Circular Economy: Reuse



People's Pavilion / bureau SLA + Overtreders W, The Netherlands

Circular Economy: Re/Generate



Microalgae as bio-coating

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CHARLOTTE

USASCP

U.S.-ASEAN SMART CITIES PARTNERSHIP