



# Net Zero Design

Kyoung Hee Kim PhD AIA NCARB  
Professor of Architecture  
Director of Integrated Design Research Lab  
Ravin School of Architecture  
UNC Charlotte

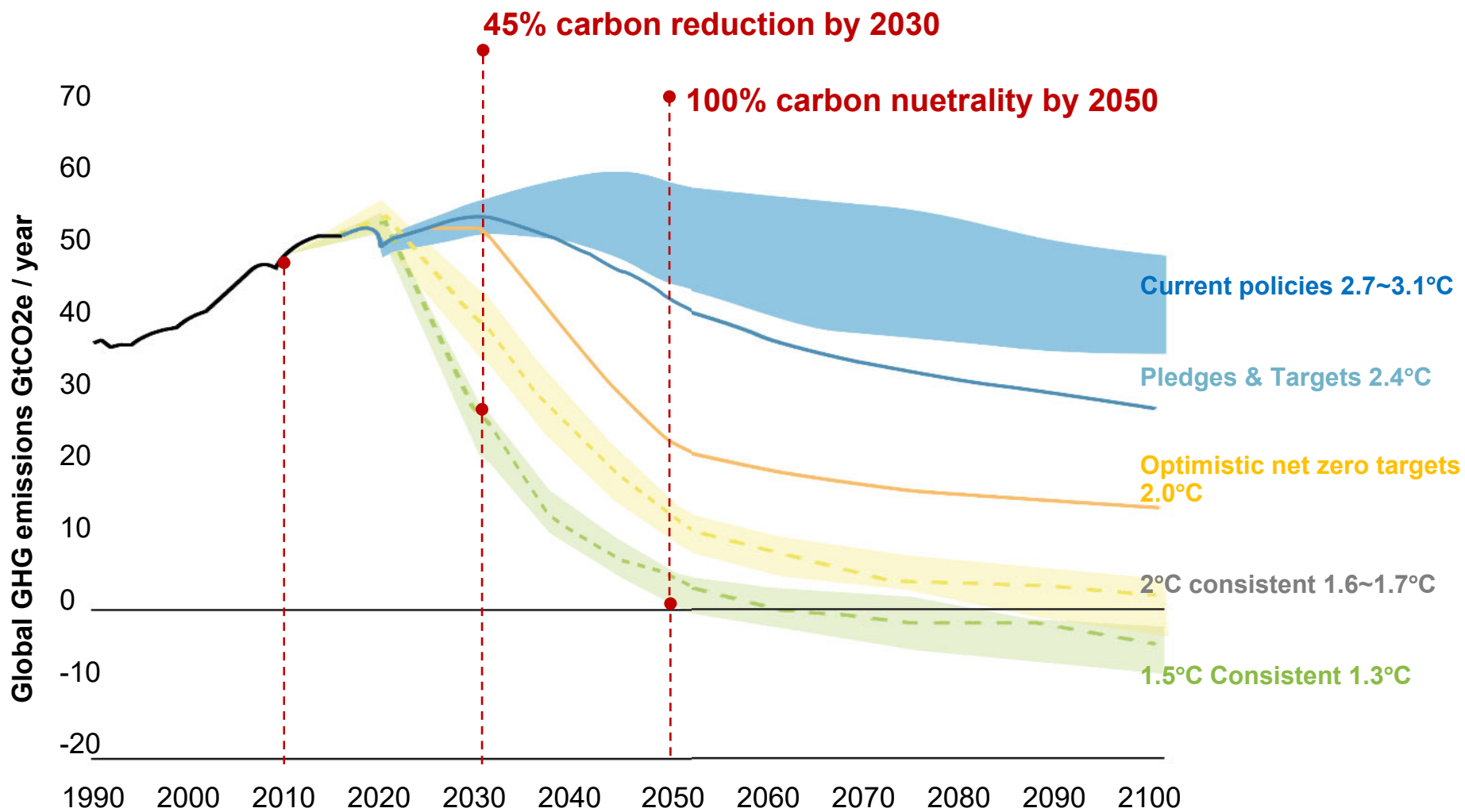
$$I = f(P, A, T)$$

**I: Environment Impact**

**P: Population**

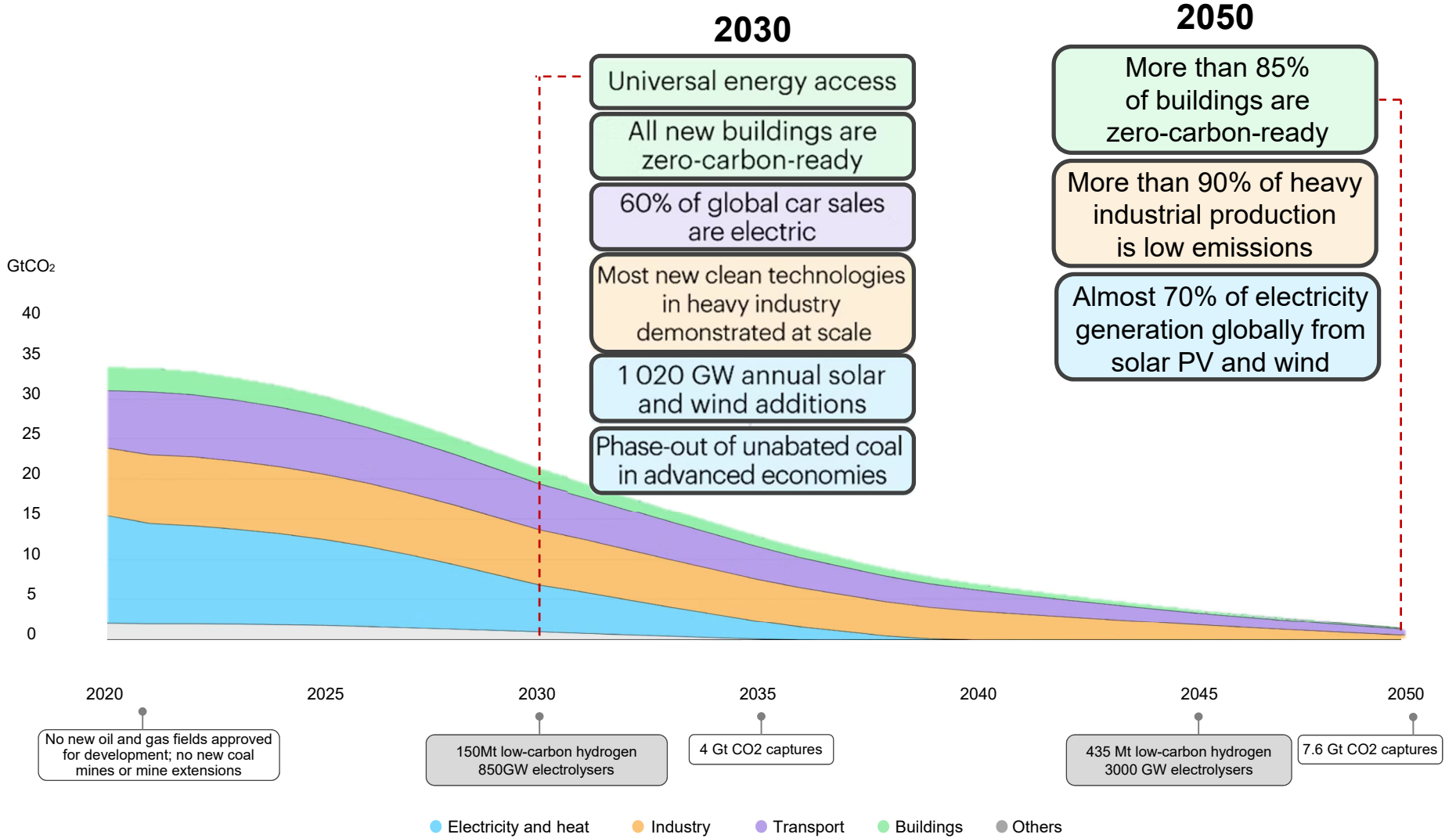
**A: Affluence or consumption per person.**

**T: Technology or Resource utilization**



**World CO<sub>2</sub> Emission Projections for Different Policy Scenarios**

# 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 – 24 countries
- In policy document – 47 countries
- Pledge – 11 countries
- In discussion – 45 countries

<b>Countries</b>	<b>Carbon neutrality target year</b>	<b>Implementation Progress as of 2023</b>	<b>Carbon footprint per country in 2021</b>	<b>Carbon footprint per capita in 2020</b>
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	Pledge	2.7Gton	1.6ton
Japan	2050	In law	1.1Gton	9.5Gton
Indonesia	2060	In discussion	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





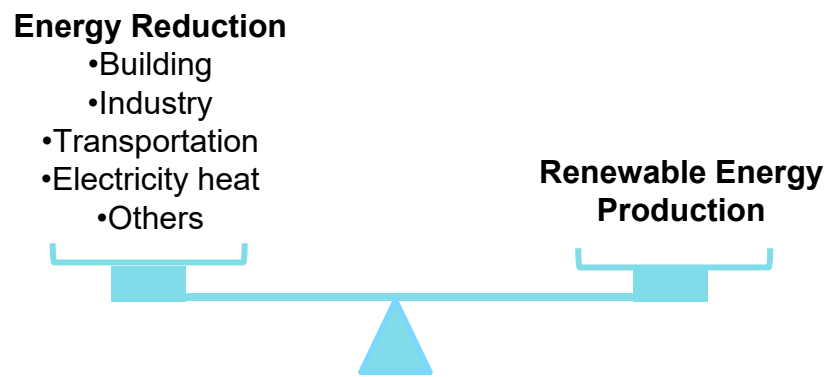
**2.2 billion population increase by 2050**  
**2 trillion sq.ft of new construction By 2050**  
**NYC every month for 35 years**

Source: The New Carbon Architecture, King

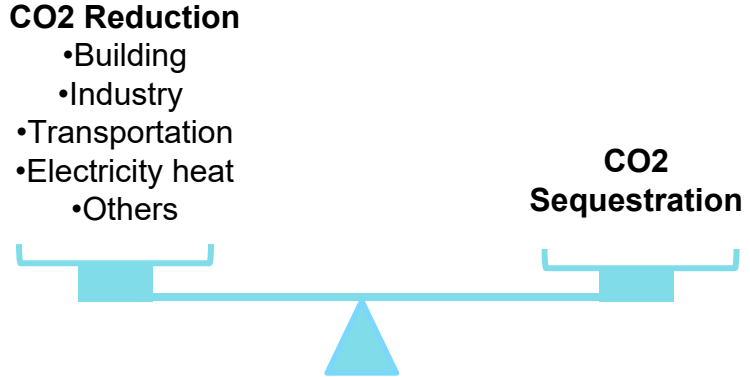
# **Net Zero Energy vs. Net Zero Carbon**



# Net Zero Design Framework

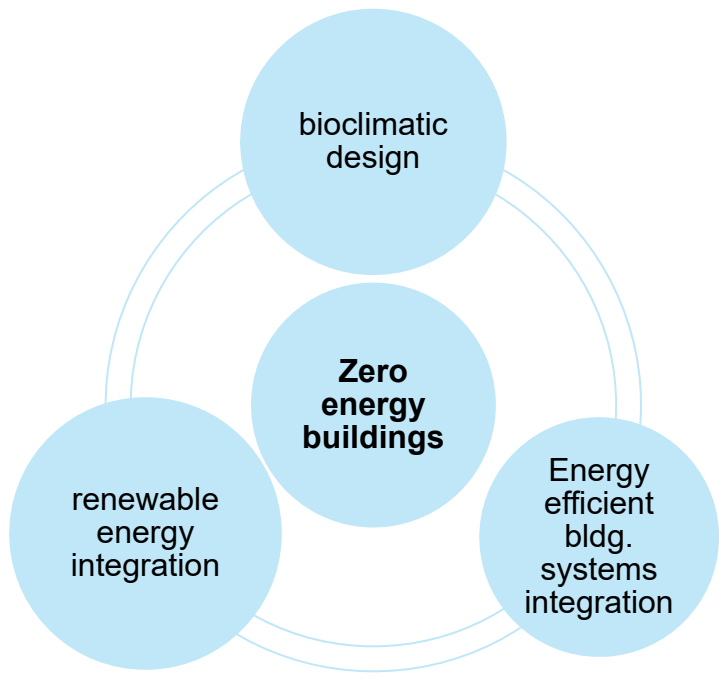


**Net Zero Energy Design Strategy**

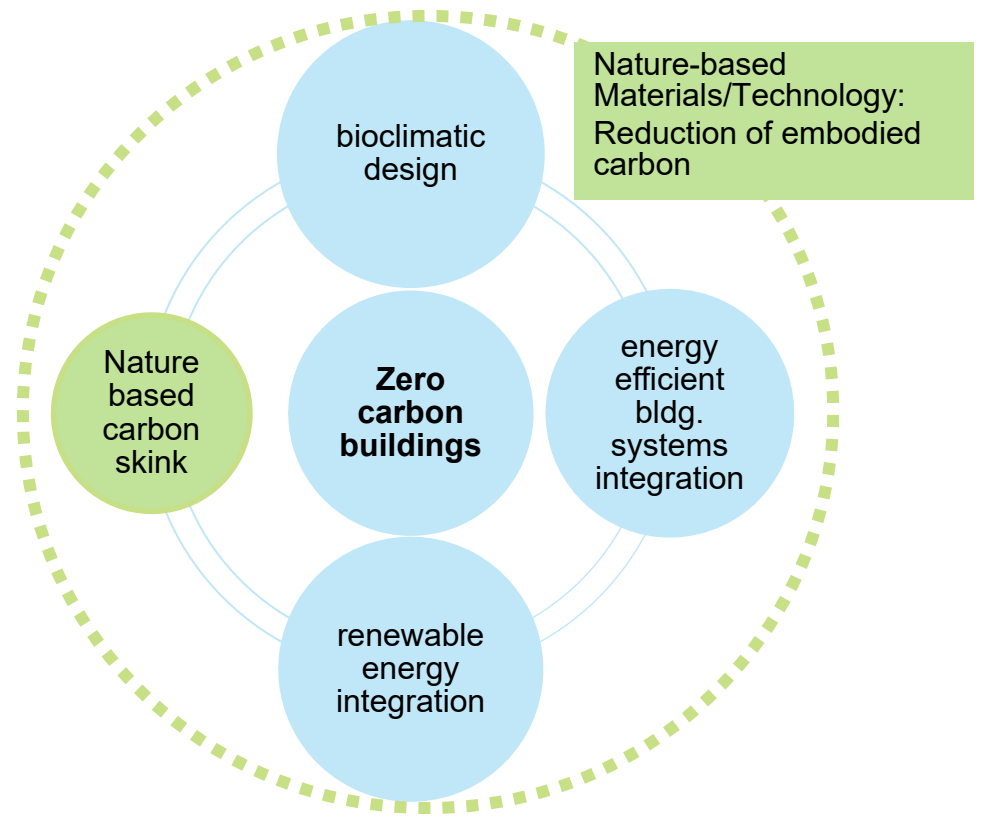


**Net Zero Carbon Design Strategy**

# Net Zero Design Framework



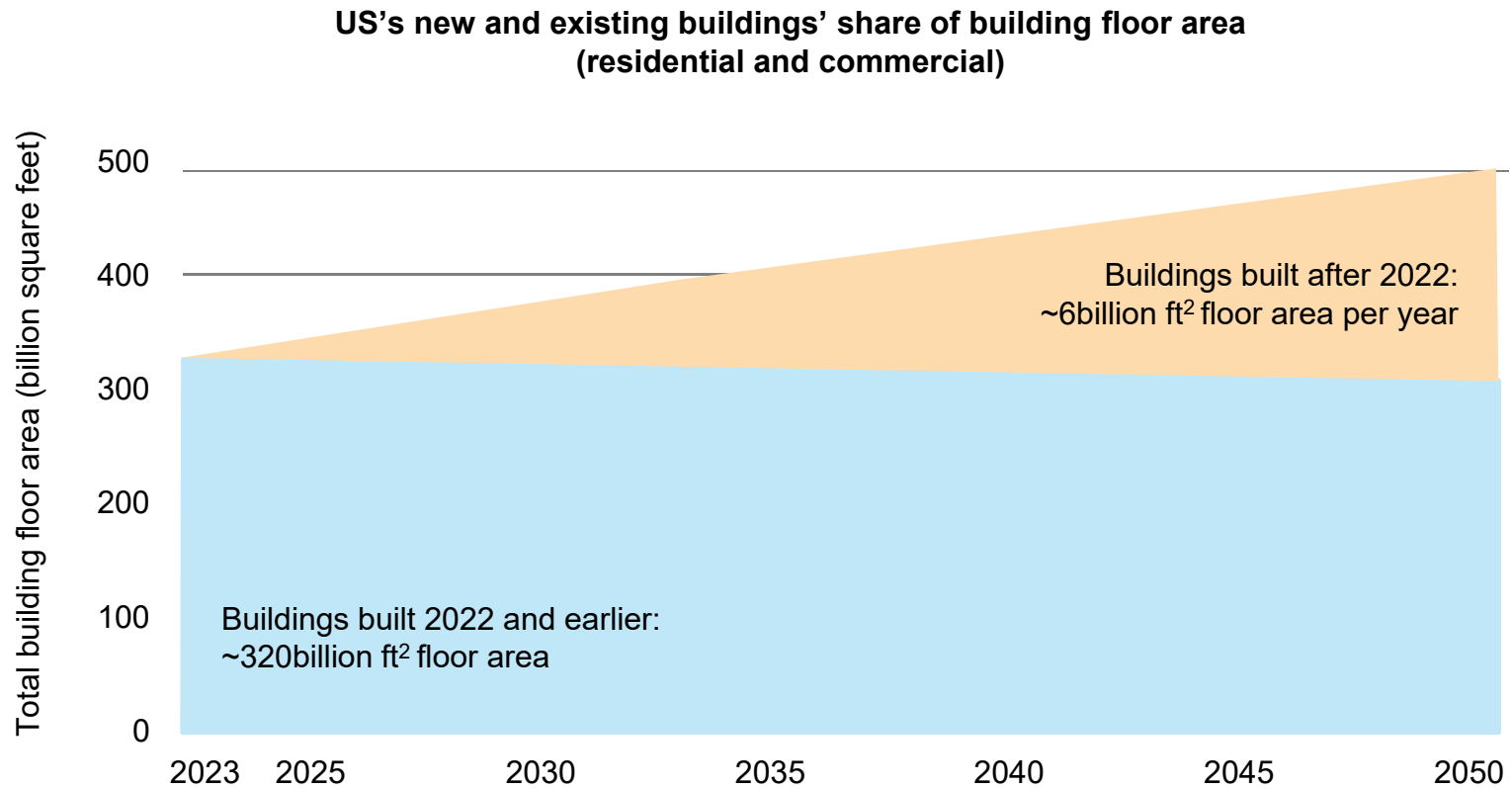
Net Zero Energy Design Strategy



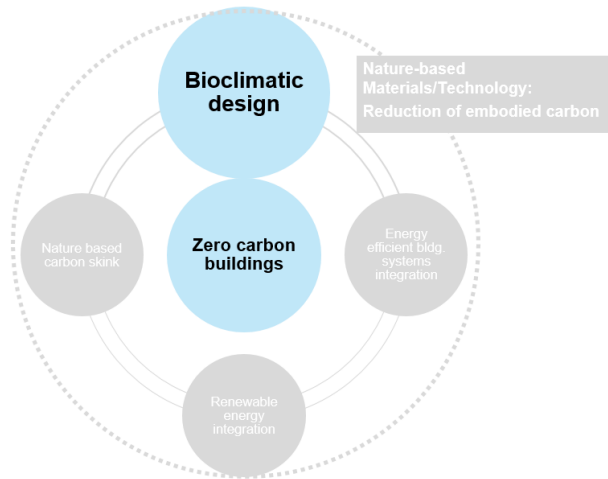
Net Zero Carbon Design Strategy

## US New Construction Prediction

- ~320 Billion ft<sup>2</sup> in 2022
- ~170 Billion ft<sup>2</sup> of additional area by 2050

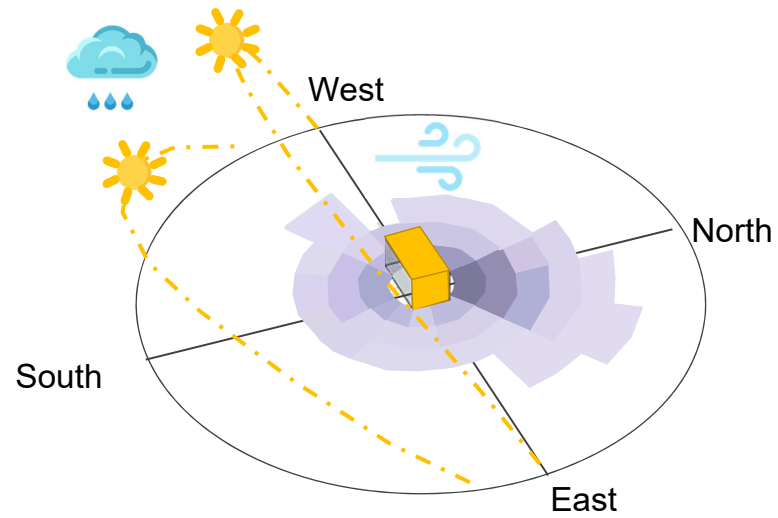


# Net Zero Design: Bioclimatic Design



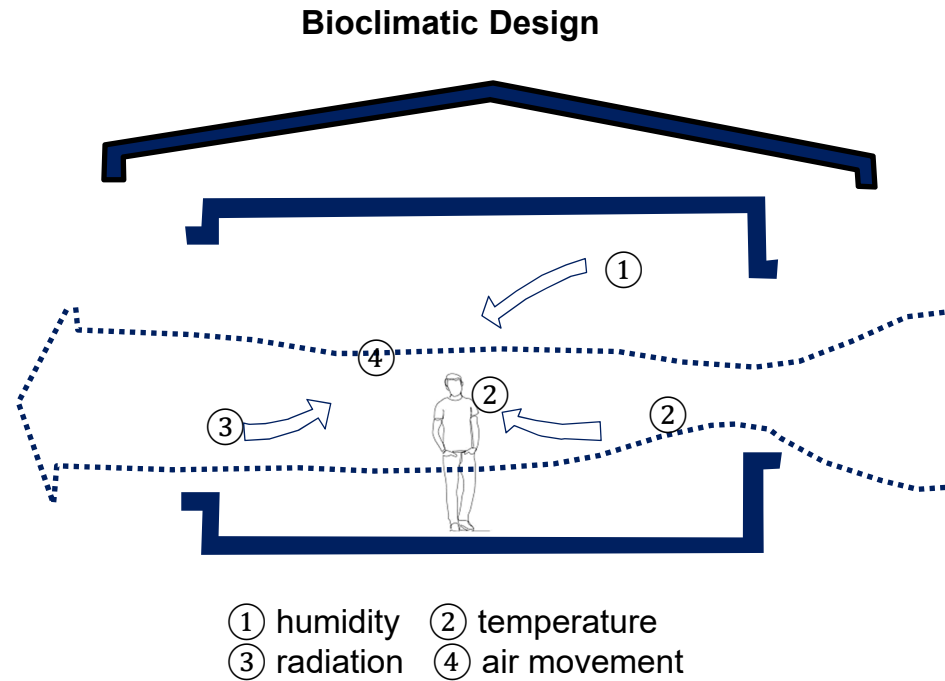
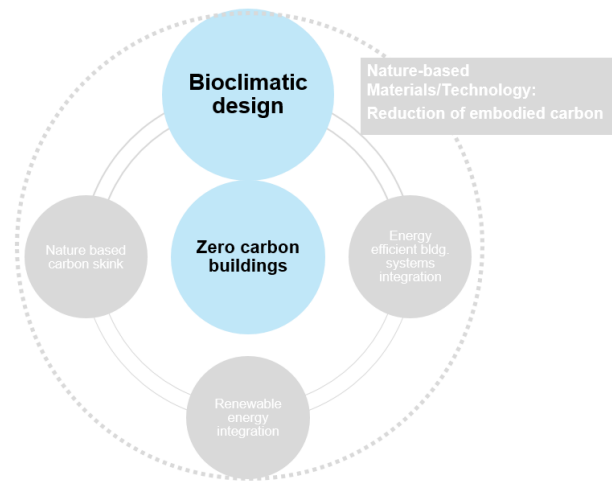
## Net Zero Carbon Design Strategy: Bioclimatic Design

- Building orientations
- Natural cooling and ventilation
- Daylighting
- Rainwater collection



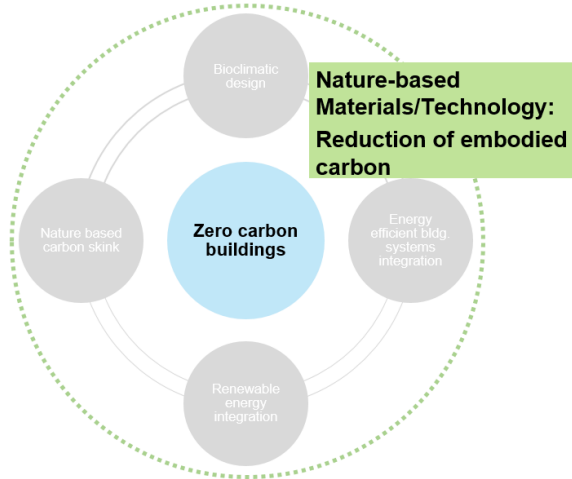


# Net Zero Design: Bioclimatic Design



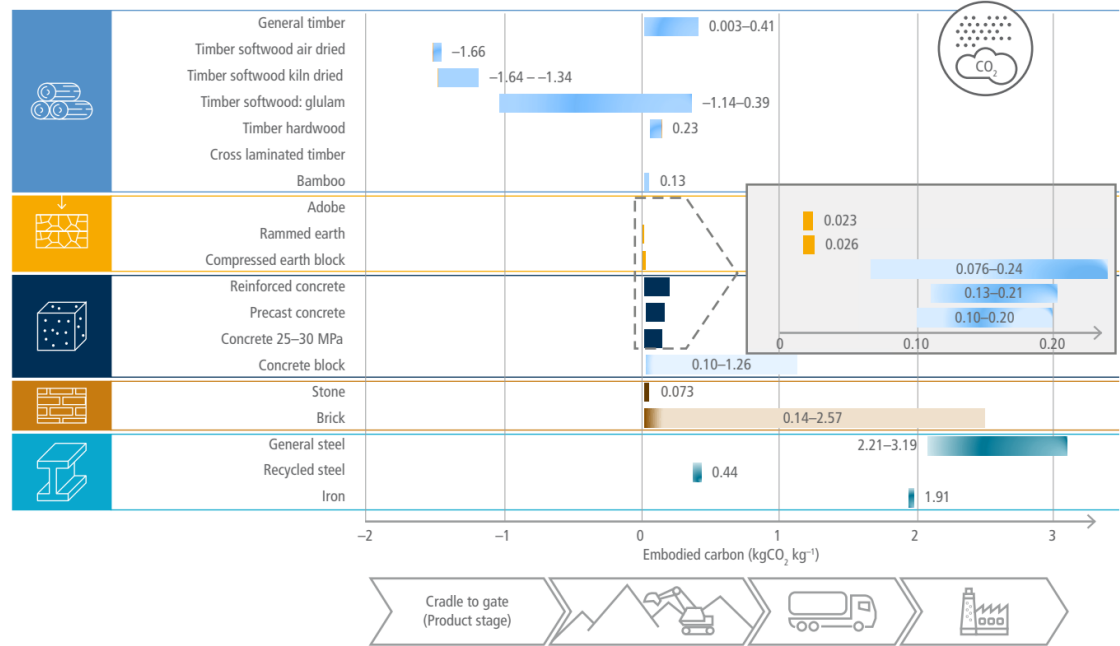
Antonin Raymond, diagram of tropical design principles, from Fry and Drew, *Village Housing in the Tropics*, 1947. *Modern Architecture and Climate*, Baber, 2020.

# Net Zero Design: Nature-based Materials

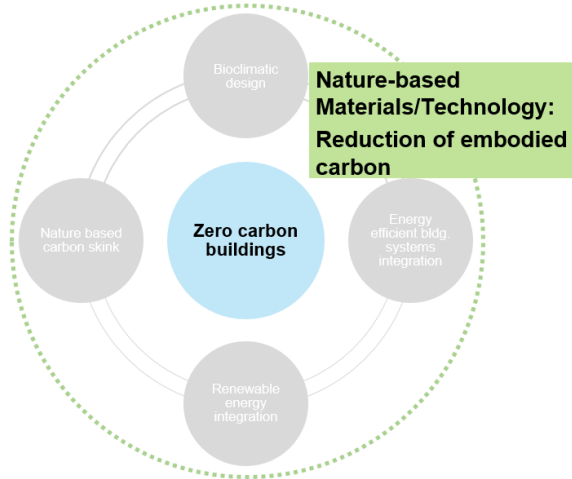


## Embodied Carbon vs. Embodied Energy

- Glulam:  $-0.76\text{kgCO}_2/\text{kg}$  | STL:  $2.7\text{kgCO}_2/\text{kg}$  | Concrete:  $0.15\text{kgCO}_2/\text{kg}$

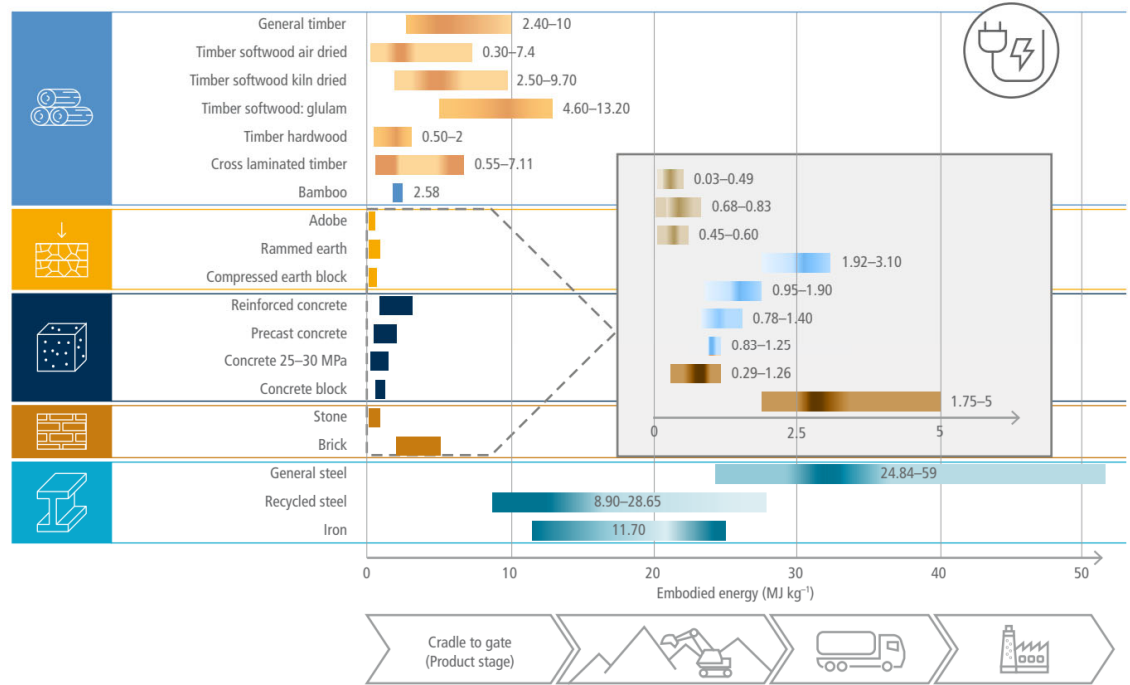


# Net Zero Design: Nature-based Materials



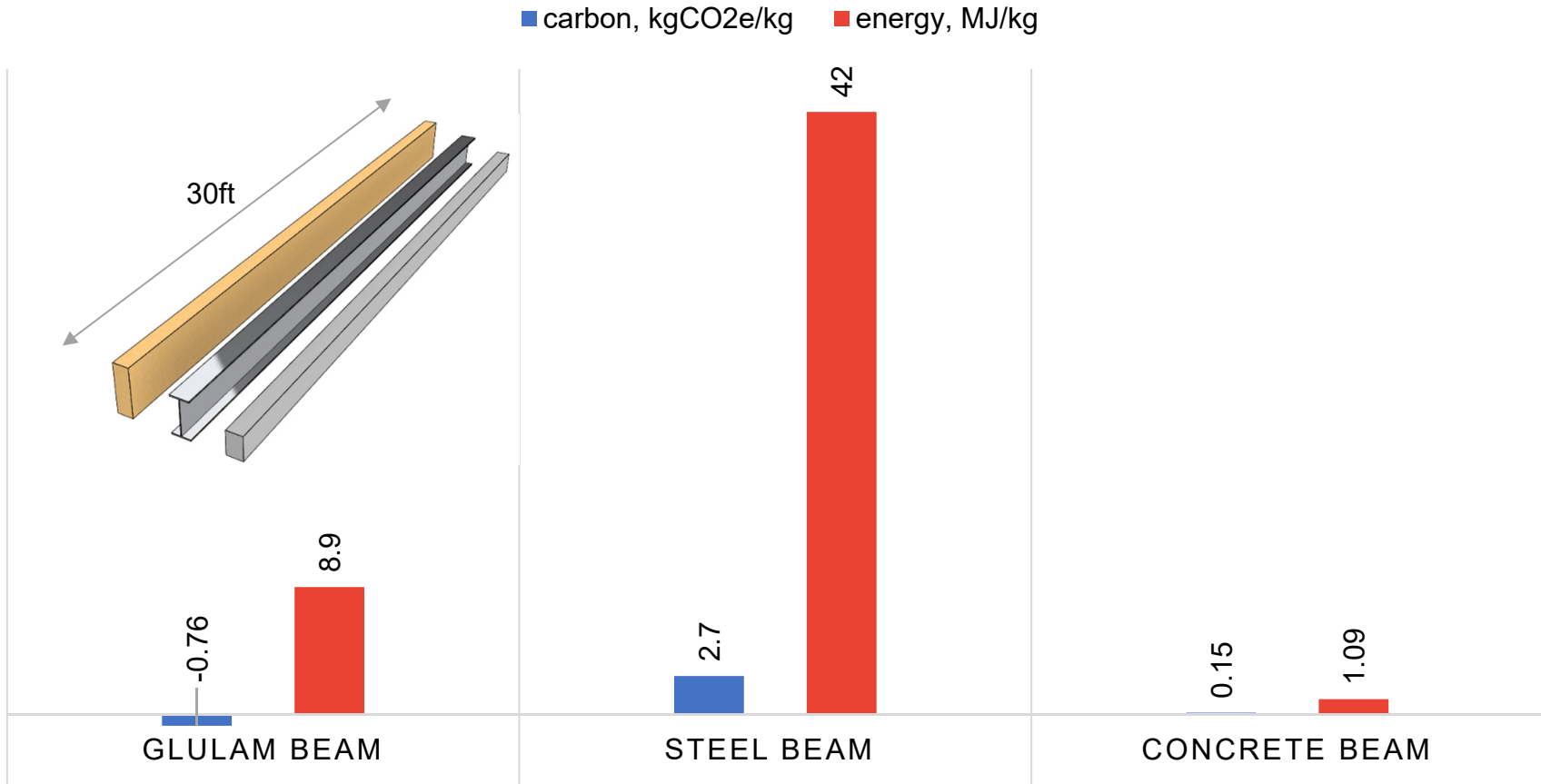
## Embodied Carbon vs. Embodied Energy

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



# Net Zero Design: Nature-based Materials

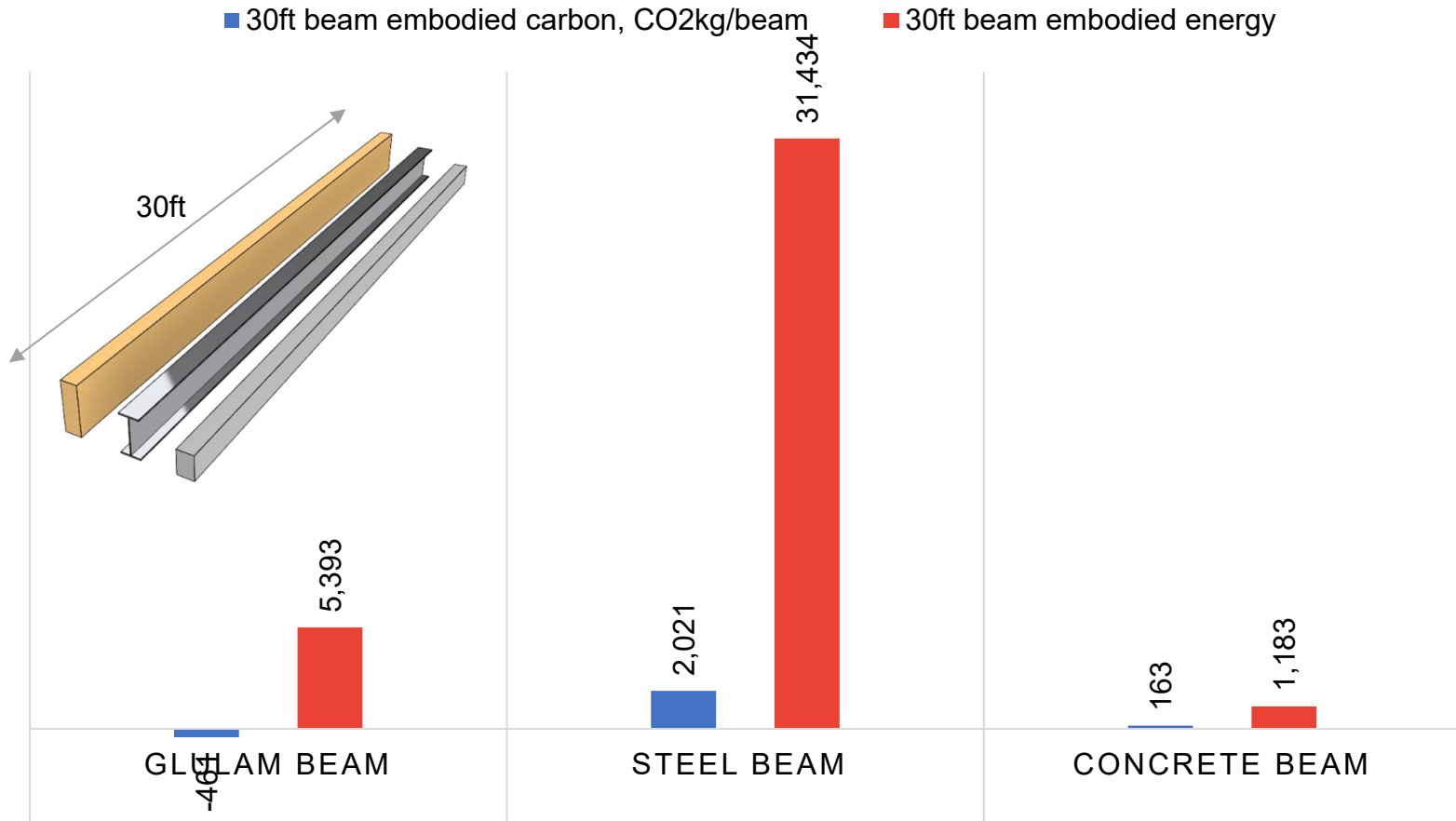
## EMBODIED CARBON AND EMBODIED ENERGY FOR VARIOUS STRUCTURAL MATERIALS





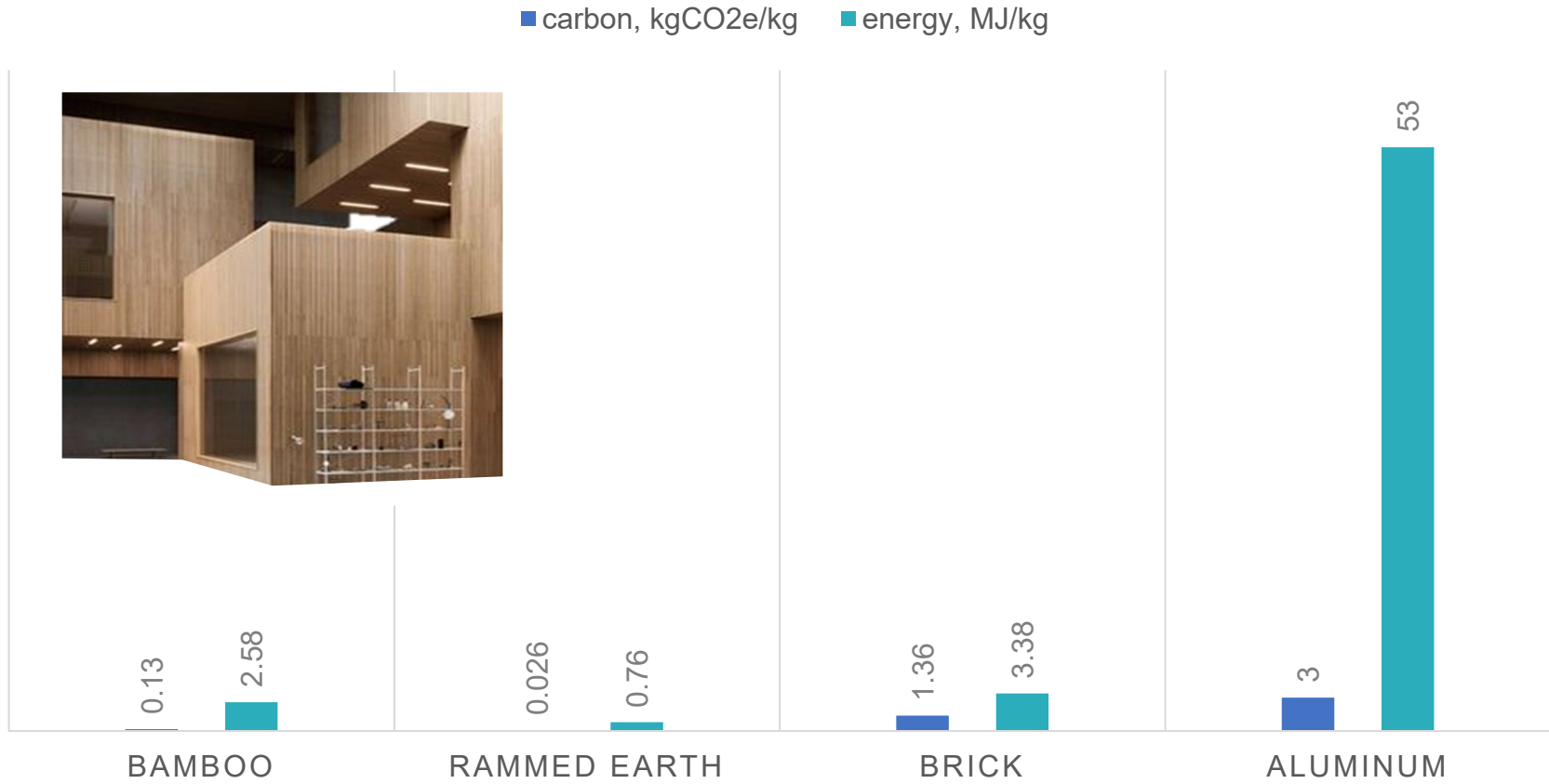
# Net Zero Design: Nature-based Materials

## EMBODIED CARBON AND ENERGY FOR VARIOUS BEAM TYPES (30FT SPAN)

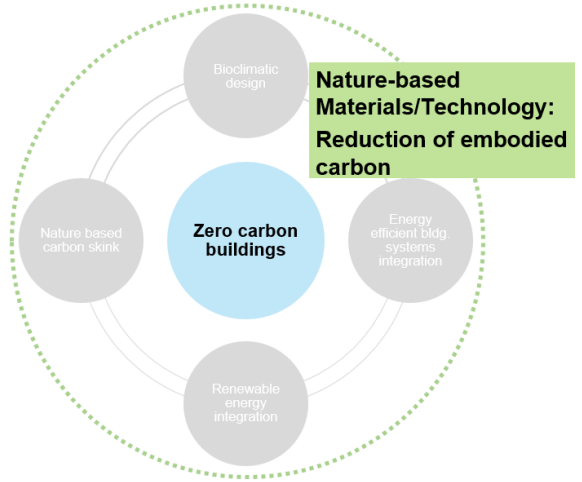


# Net Zero Design: Nature-based Materials

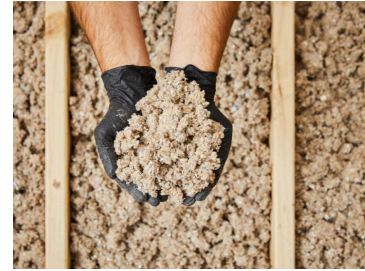
## EMBODIED CARBON FOR VARIOUS FACADE MATERIALS



# Net Zero Design: Nature-based Materials



CLT board



Cellulose GreenFiber



Plyboo® Bamboo



Mycelium structure



Prometheus bioconcrete



Hempcrete



Recycled rubber roofing



UltraTouch™ Denim Insulation

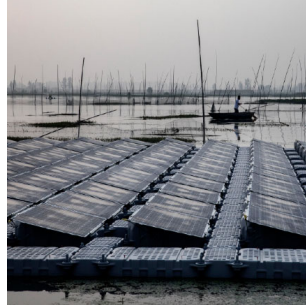


Recycled rubber flooring



# Net Zero Design: Renewable Energy Integration

## Infrastructure



Floatovoltaics, China



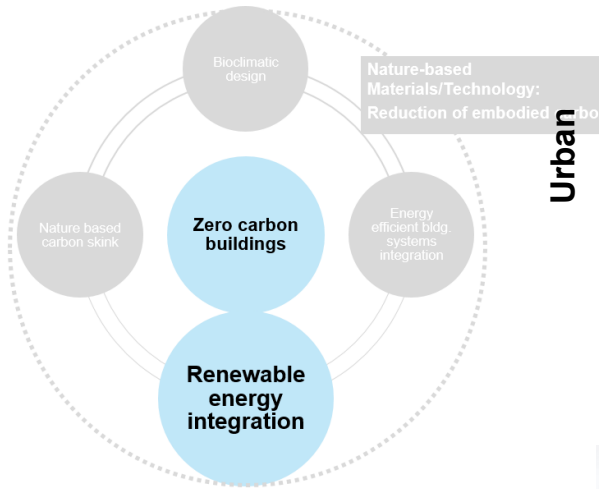
Solar desalination, Netherlands



Solar farm, USA



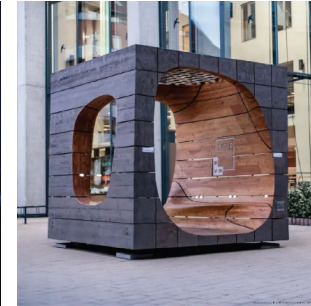
Solar canal, India



## Urban



Solar lamp, Abu Dabi



Fluid Cube, Hungary



Solar acoustic barrier, Canada



Solar parking deck, Sweden

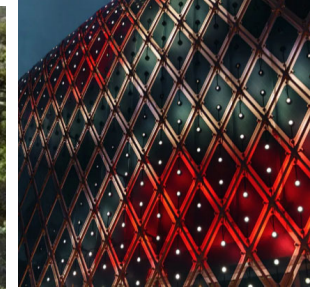
## Buildings



Blauhaus, Germany



Apple HQ, USA



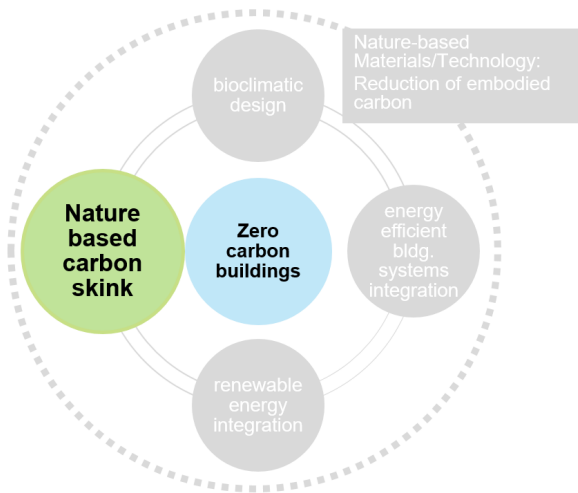
Novartis Pavilion, Switzerland



FKI, Korea



# Net Zero Design: Nature-based Carbon Sink



Park Royal Pickering  
Singapore | WOHA



Wisma Dharmala Tower  
Jakarta, Indonesia | Paul Rudolph



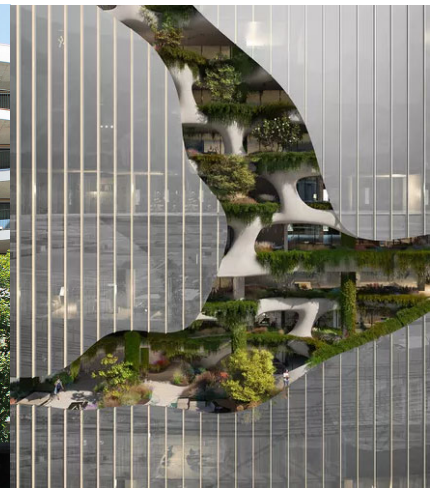
Vertical Forest  
Milan | Stefano Boeri



Le Nouvel Tower  
KL, Malaysia | JNA



Haus E  
Zurich | MSA



Landscape rift  
Denver USA | MAD Architects



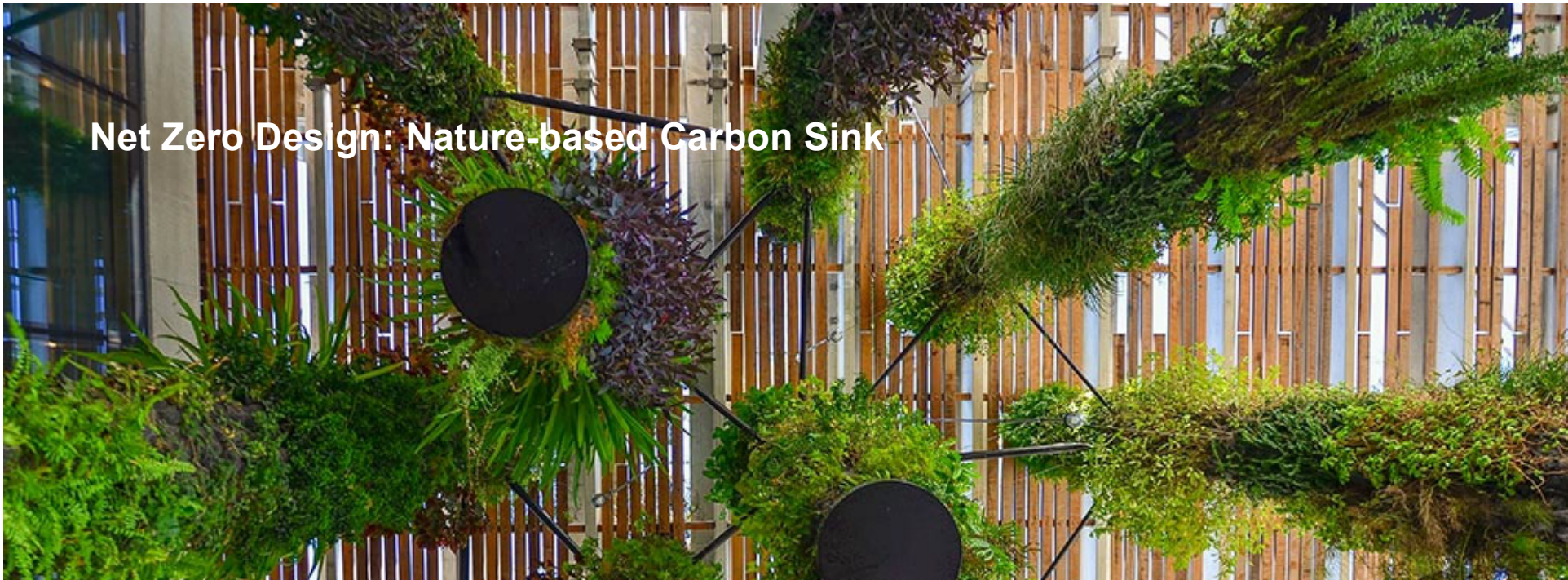
# Net Zero Design: Nature-based Carbon Sink



Southwest Montgomery Complete Street, Oregon. Nevue Ngan Associates

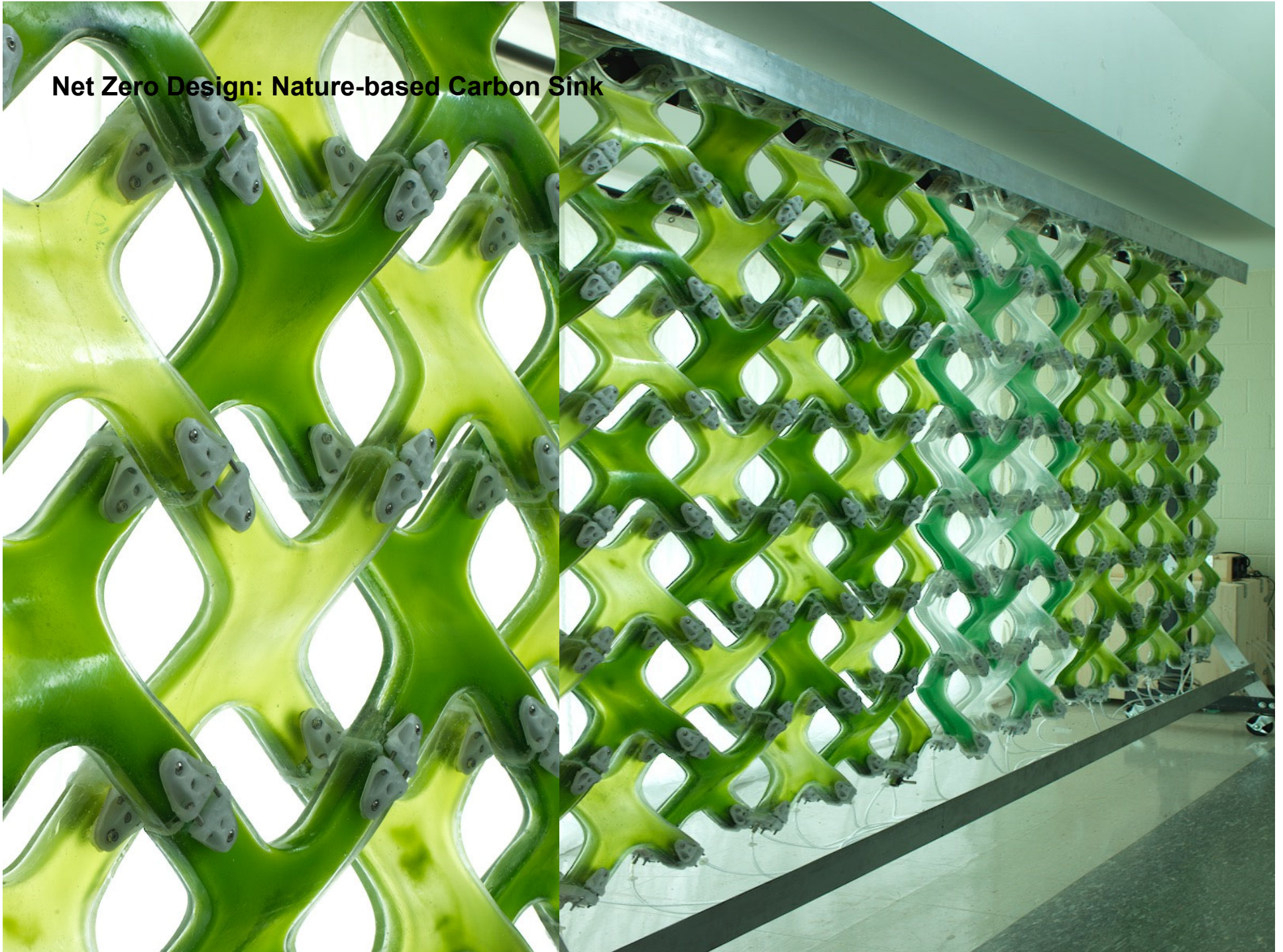


Net Zero Design: Nature-based Carbon Sink

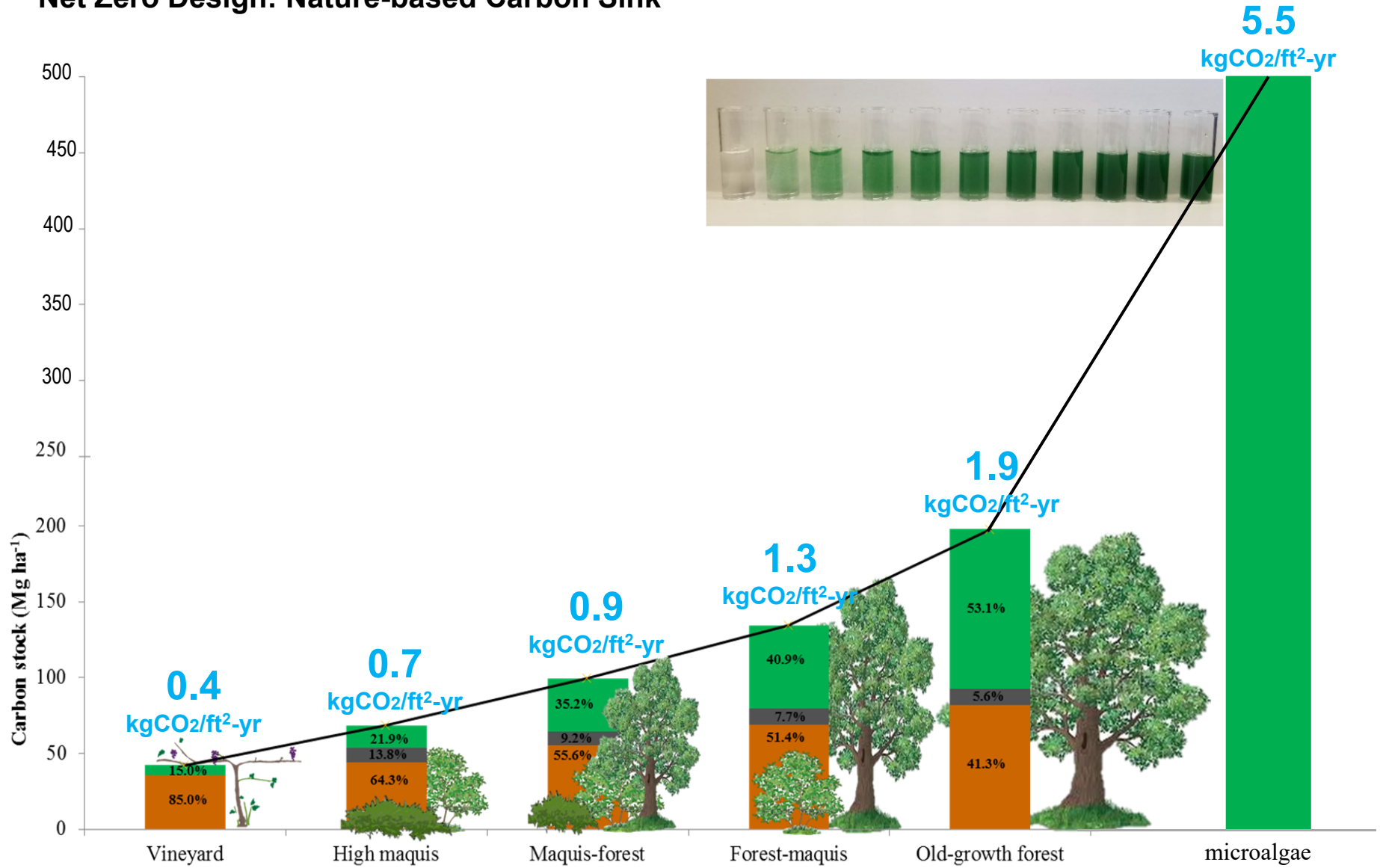




**Net Zero Design: Nature-based Carbon Sink**



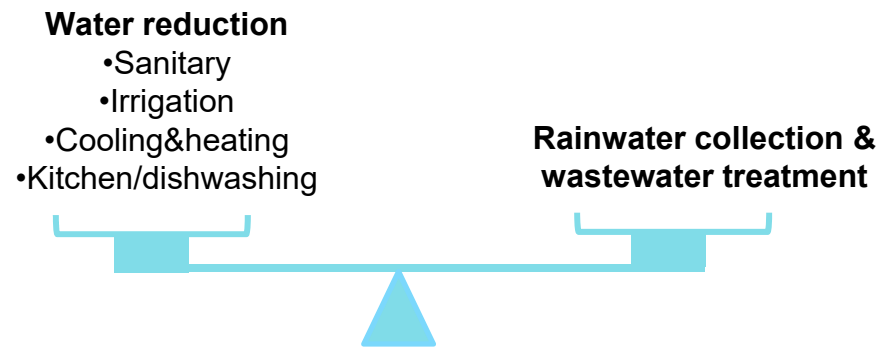
# Net Zero Design: Nature-based Carbon Sink



# **Net Zero Water**

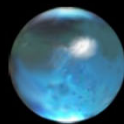
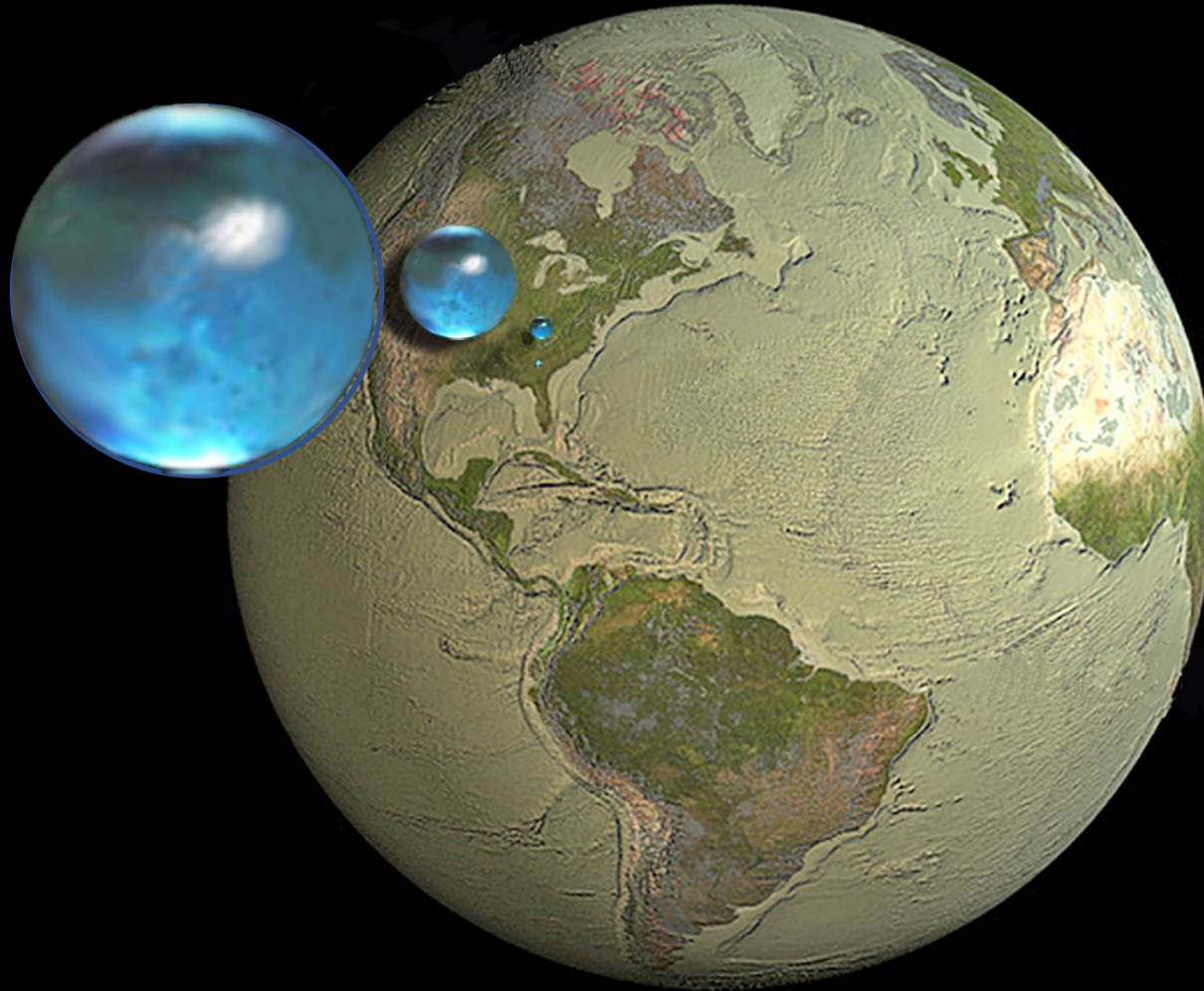


# Net Zero Water Framework



**Net Zero Water Strategy**

# The World's Water



**All water on, in, and above the Earth**



**Liquid fresh water**

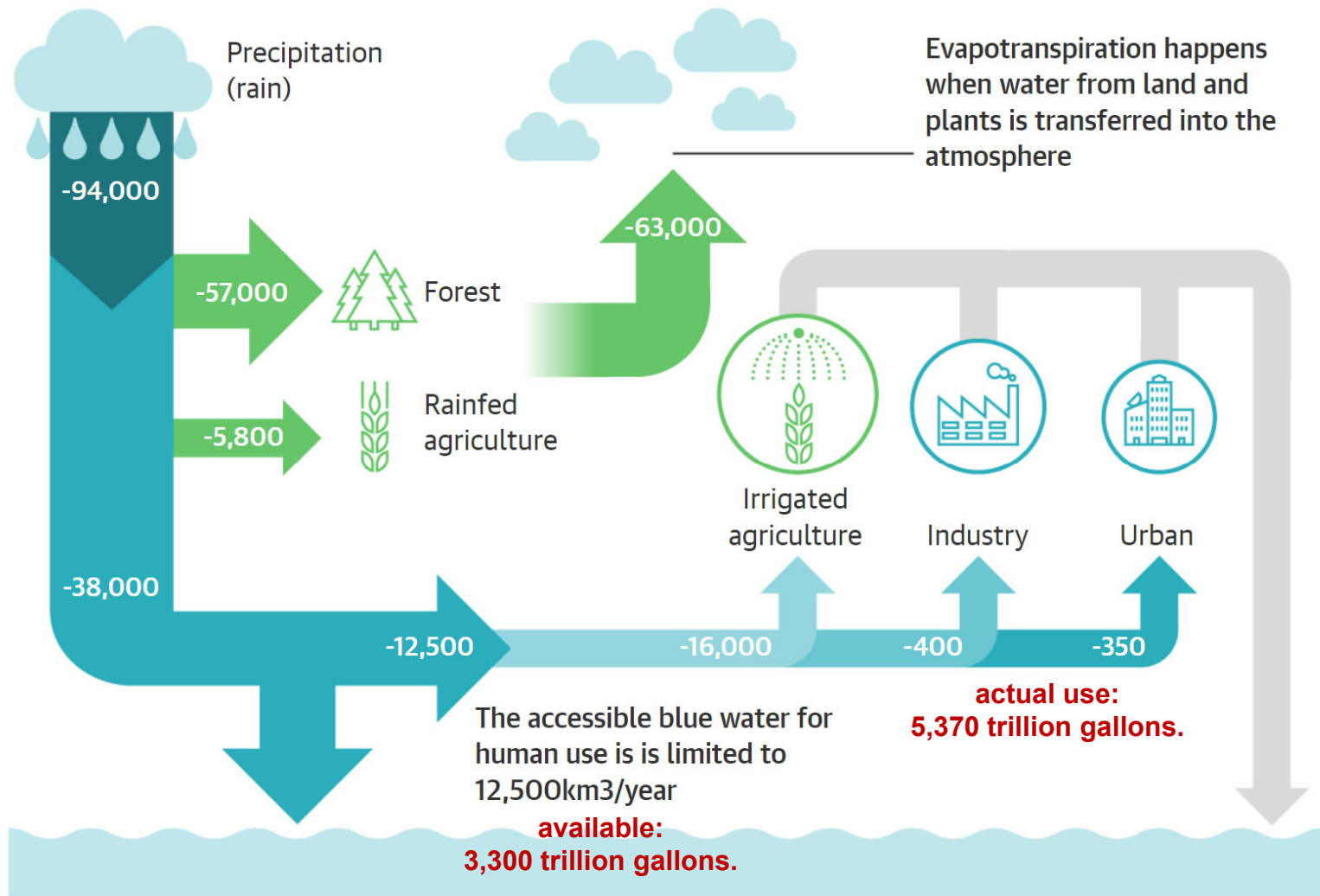


**Fresh-water lakes and rivers**

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

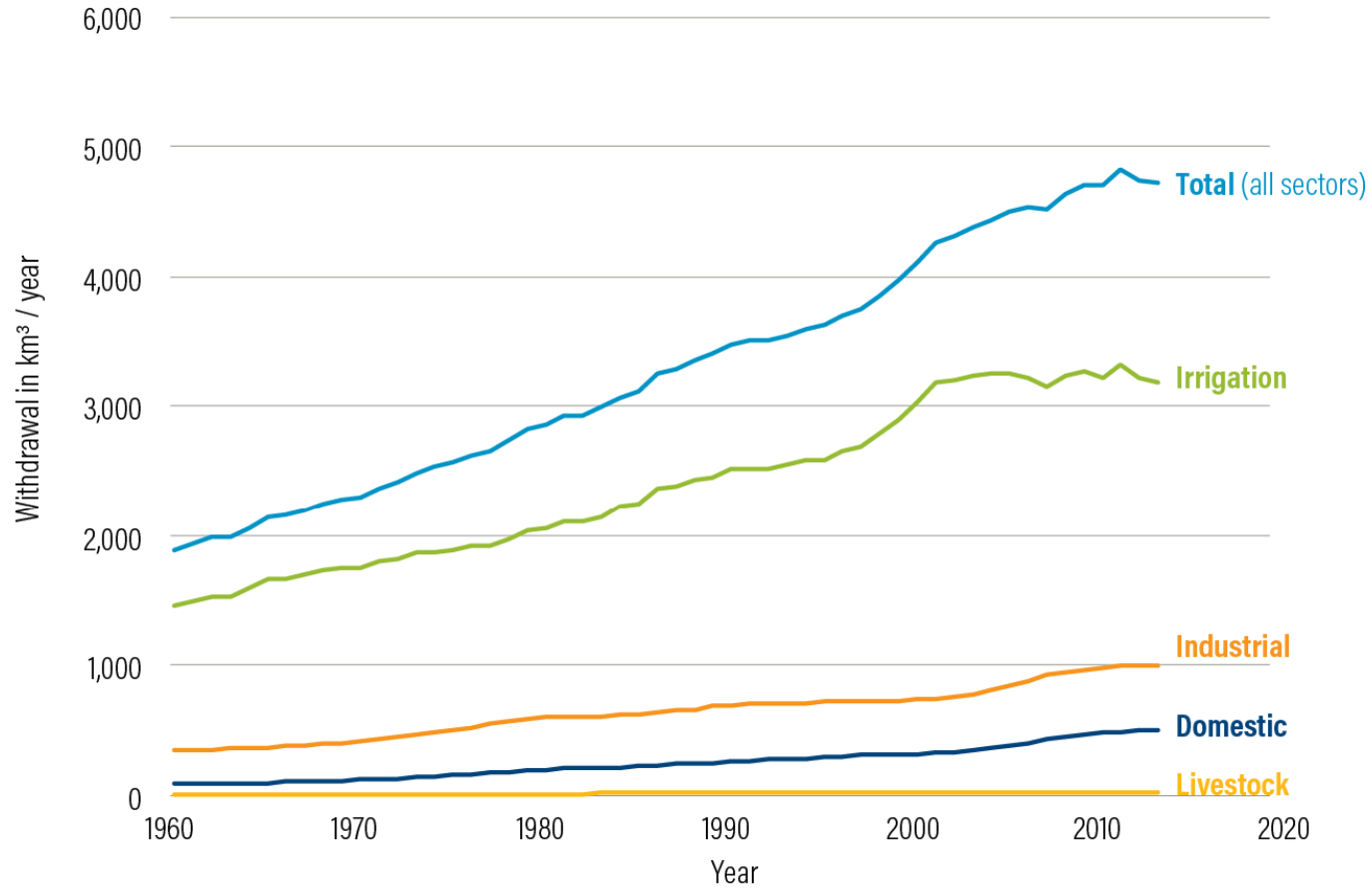




Guardian graphic. Source: Global Commission on the Economics of Water

**North Carolina: 503 miles (810 km) long by 150 miles (241 km) wide.**

## Water withdrawals by sector, 1960-2014

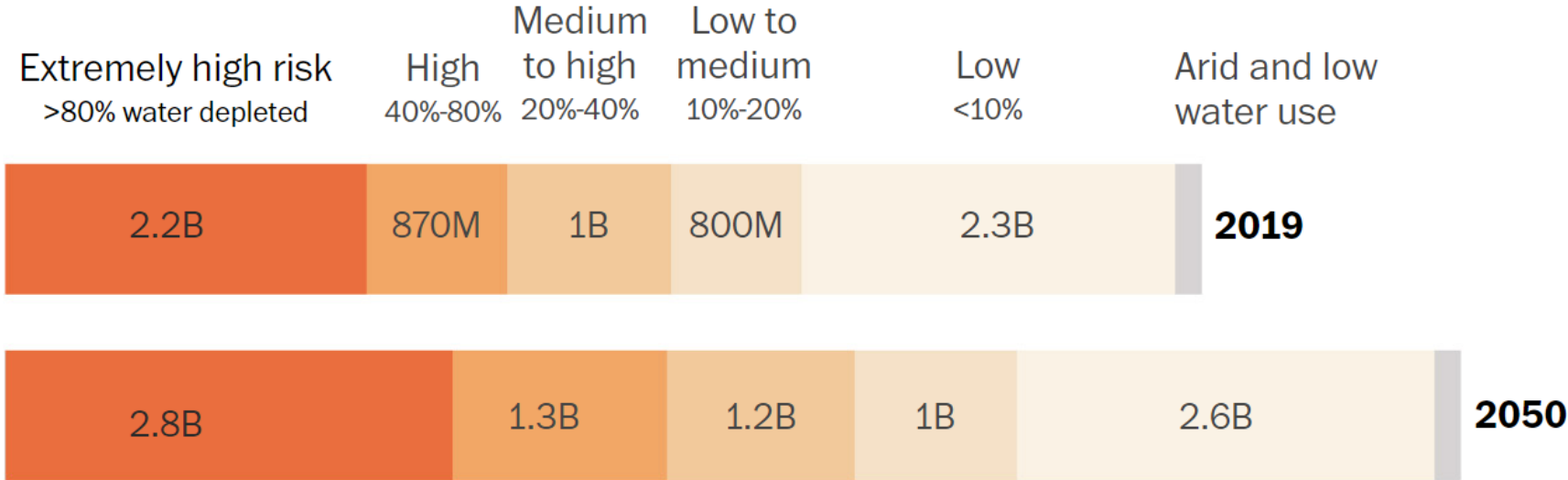


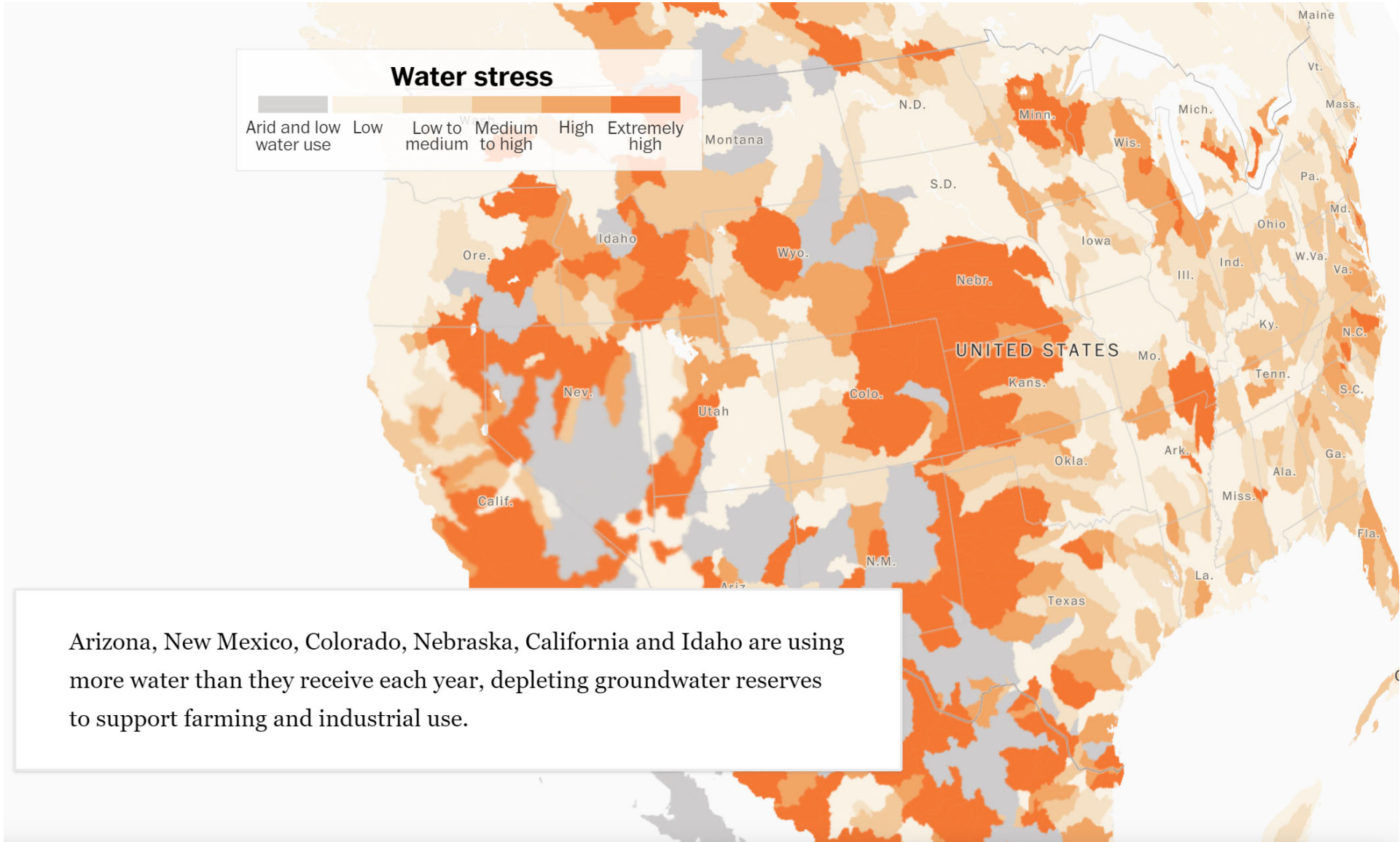
Source: Authors.  
20.2.10



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

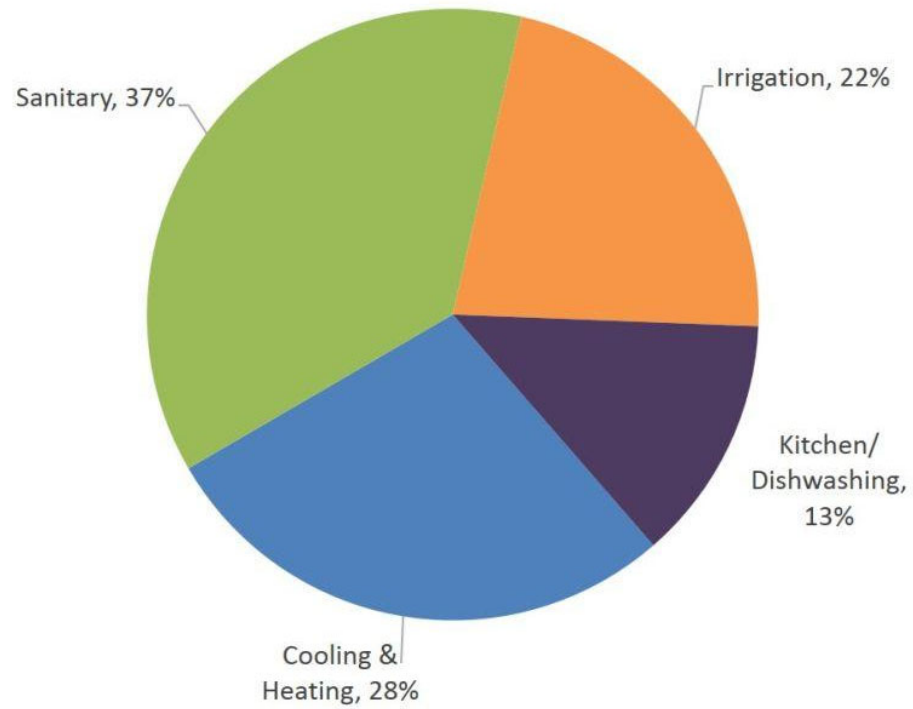
# Population at risk of water stress





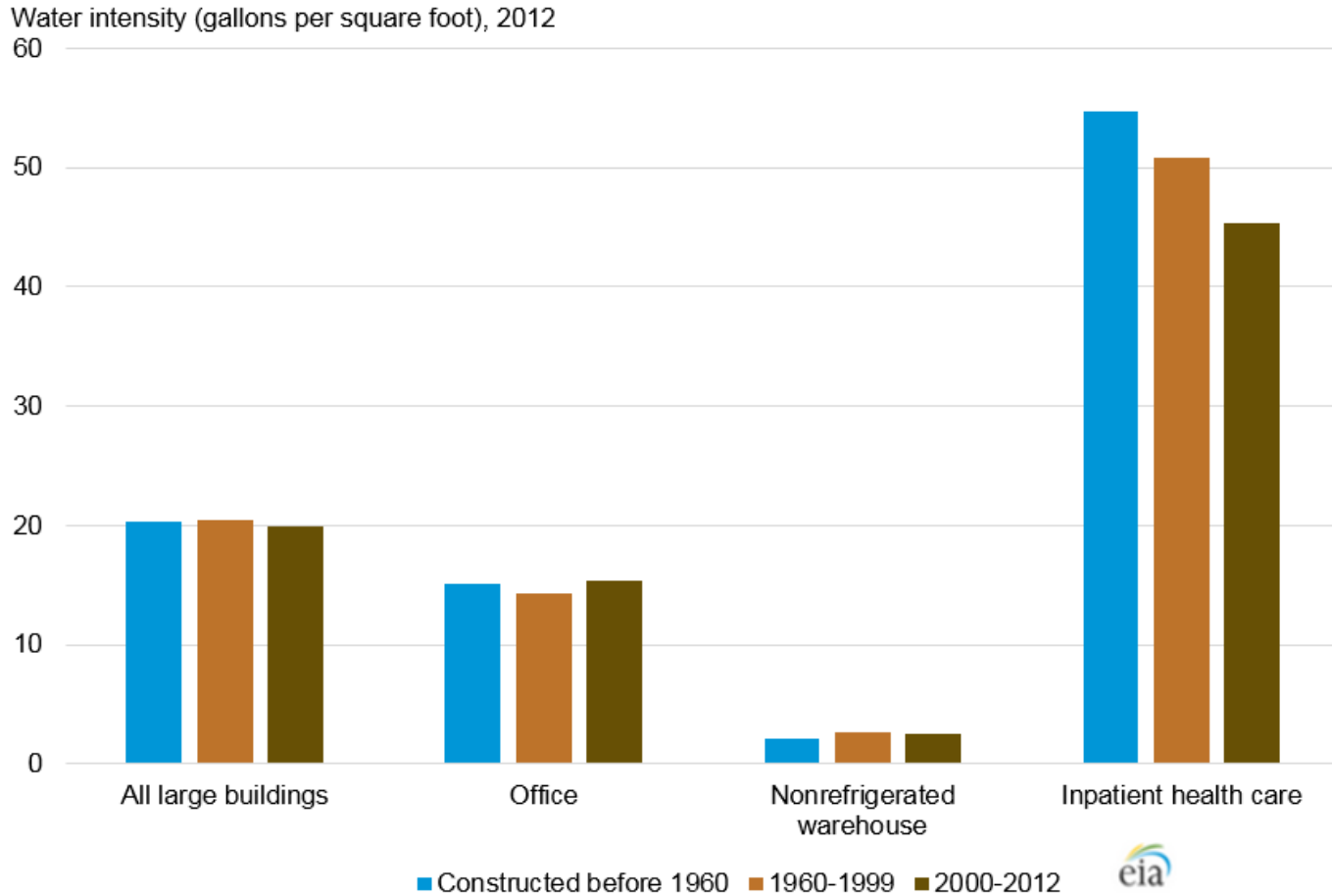
# Water Footprint in Buildings

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



# 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 health care buildings



# Water Footprint in Foods



**650** Barley  
litres of water for one pound (500 g)



**650** Wheat  
litres of water for one pound (500 g)



**1400** Sorghum  
litres of water for one pound (500 g)



**2500** Millet  
litres of water for one pound (500 g)



**650** Toast  
litres of water for one package (500 g)



**750** Cane Sugar  
litres of water for one package (500 g)



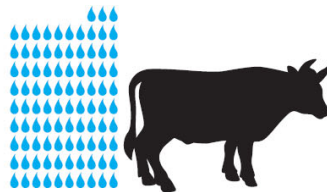
**90** Tea  
litres of water for one pot (750 ml)



**840** Coffee  
litres of water for one pot (750 ml)



**2500** Burger  
litres of water for one burger (150 g beef)



**4650** Beef  
litres of water for one steak (300 g)



**1000** Milk  
litres of water for one litre



**2500** Cheese  
litres of water for one big piece (500 g)

This poster, its design, and the artwork it features may only be used, reprinted, or redistributed with written permission by Timm Kakeritz. © 2010 Timm Kakeritz, [www.watraswater.eu](http://www.watraswater.eu)



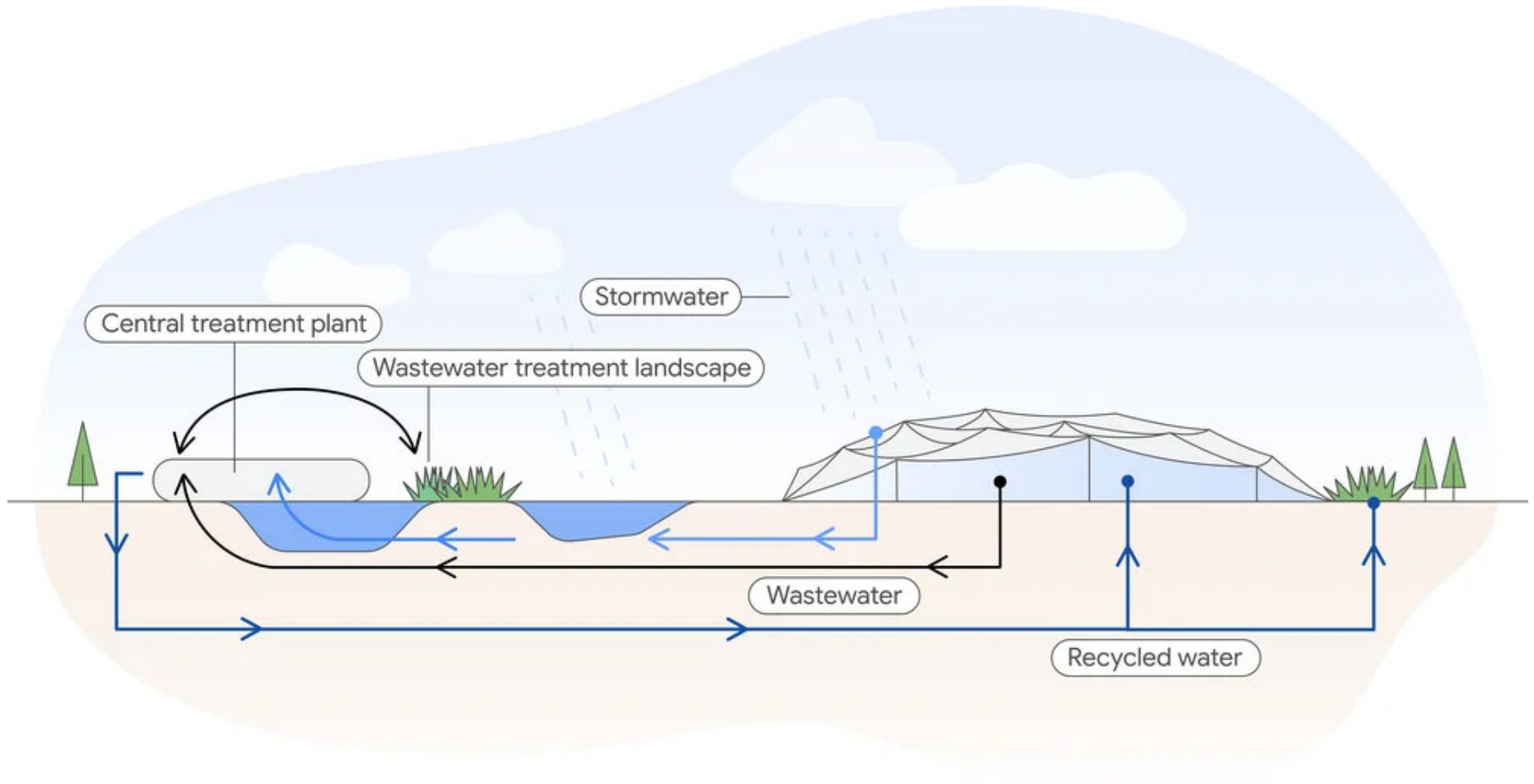
## Net Zero Water Framework: Rainwater Collection + Grey Water Treatment



Google HQ, CA



# Net Zero Water Framework: Rainwater Collection + Grey Water Treatment



## Net Zero Water Framework: Rainwater Collection + Grey Water Treatment



Kendeda Building, GTech



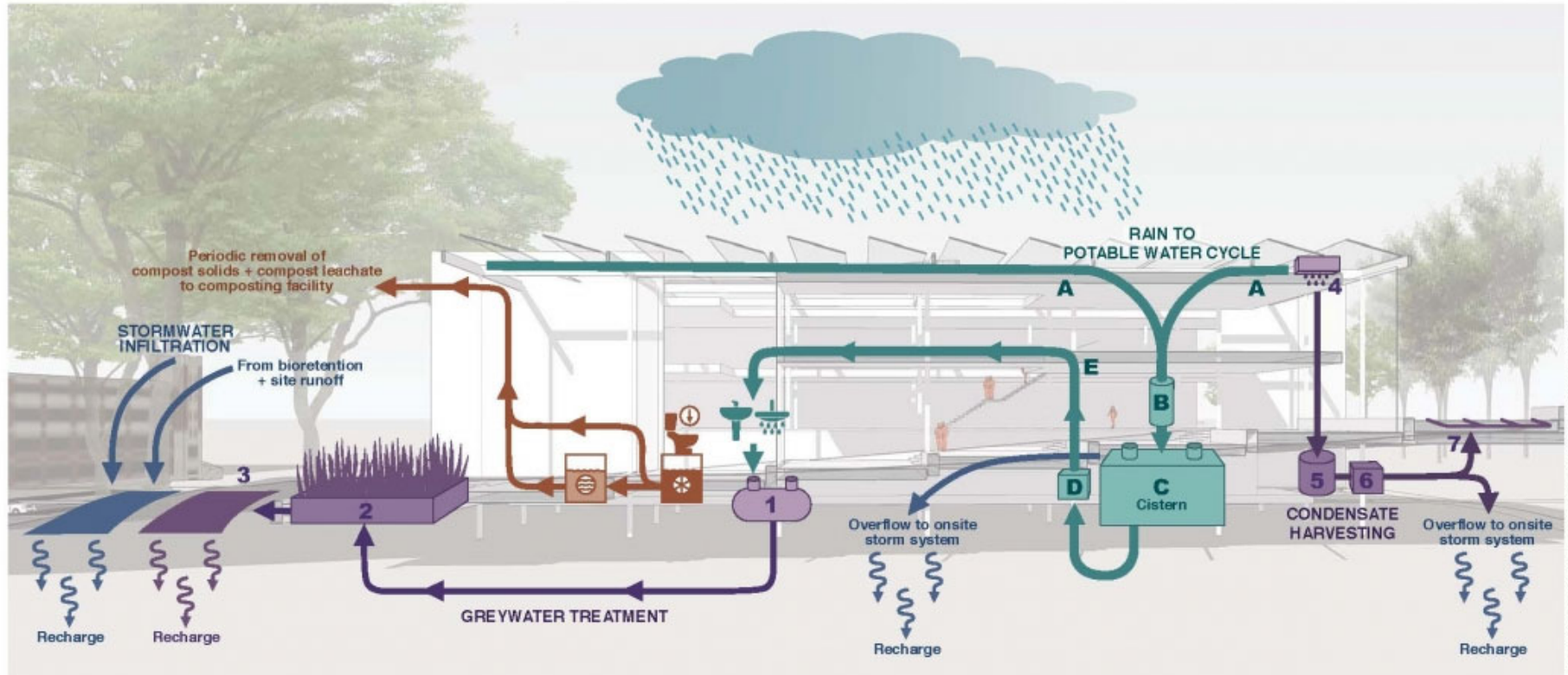
# NET POSITIVE WATER CYCLE – LIVING BUILDING CHALLENGE STRATEGY

Kendeda Building for Innovative Sustainable Design  
Georgia Institute of Technology, Atlanta, GA



## PROJECT TEAM

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



Base image: Miller Hull, Lord Aeck & Sargent, Diagram: Biohabitats

### 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

- 1 Foam flush toilet fixtures (compatible with composting unit)
- 2 Composter units (serve multiple toilets)
- 3 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, GTech

**Net Zero Waste**



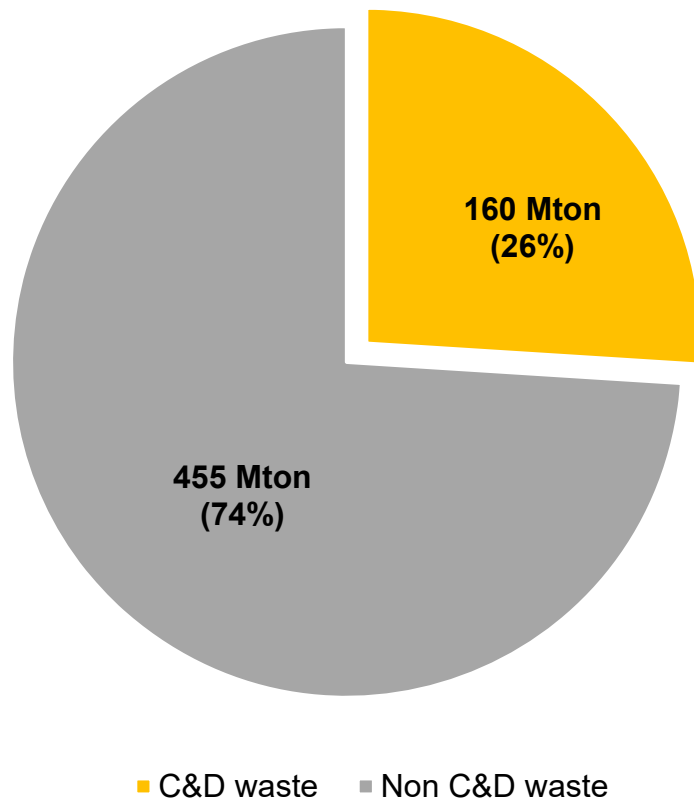


## **2.1 Billion Annual Municipal Wastes Generated Worldwide**

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

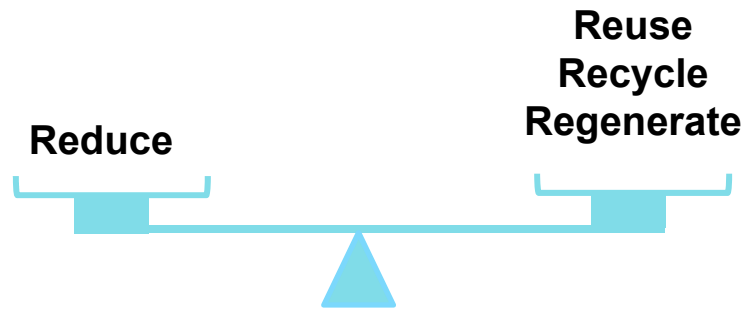


## US Solid Waste: 615 Mtons in 2008



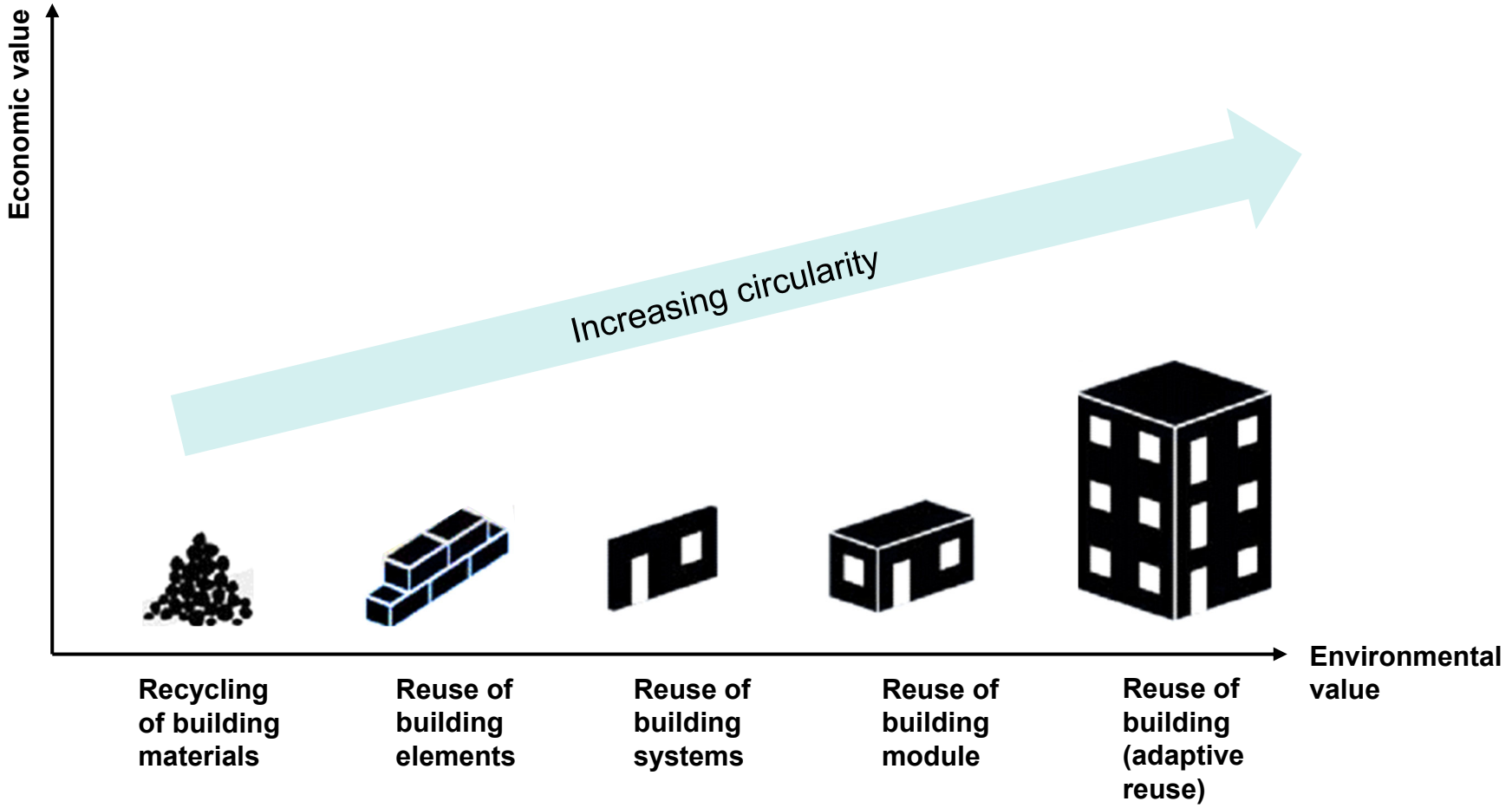
1. Recycled or reused: 20~30% (32-48 Mton)
2. Discarded: 70~80% (112-128 Mton)
  - Lumber (40%)
  - Asphalt products (14%)
  - Soil/fines (11%)
  - Concrete/rock/brick (11%)
  - Gypsum board (10%)
  - Other (14%)

# Net Zero Waste Framework



Net Zero Waste Strategy

# Circular Economy



# Circular Economy

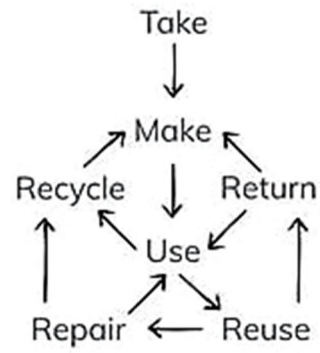
## LINEAR ECONOMY



## RECYCLING ECONOMY

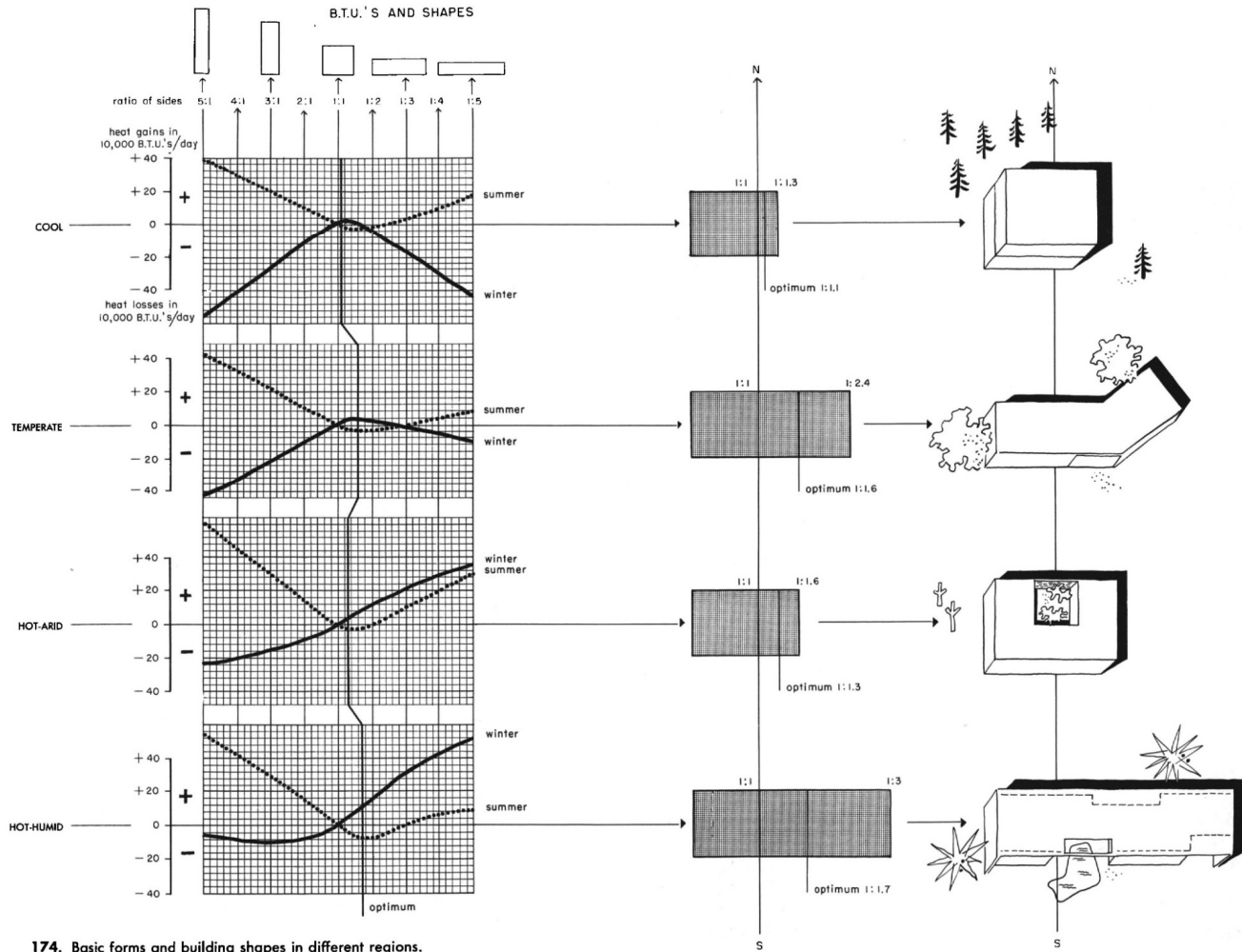


## CIRCULAR ECONOMY



# Circular Economy: Reduce

## - Building enclosures vs Material uses

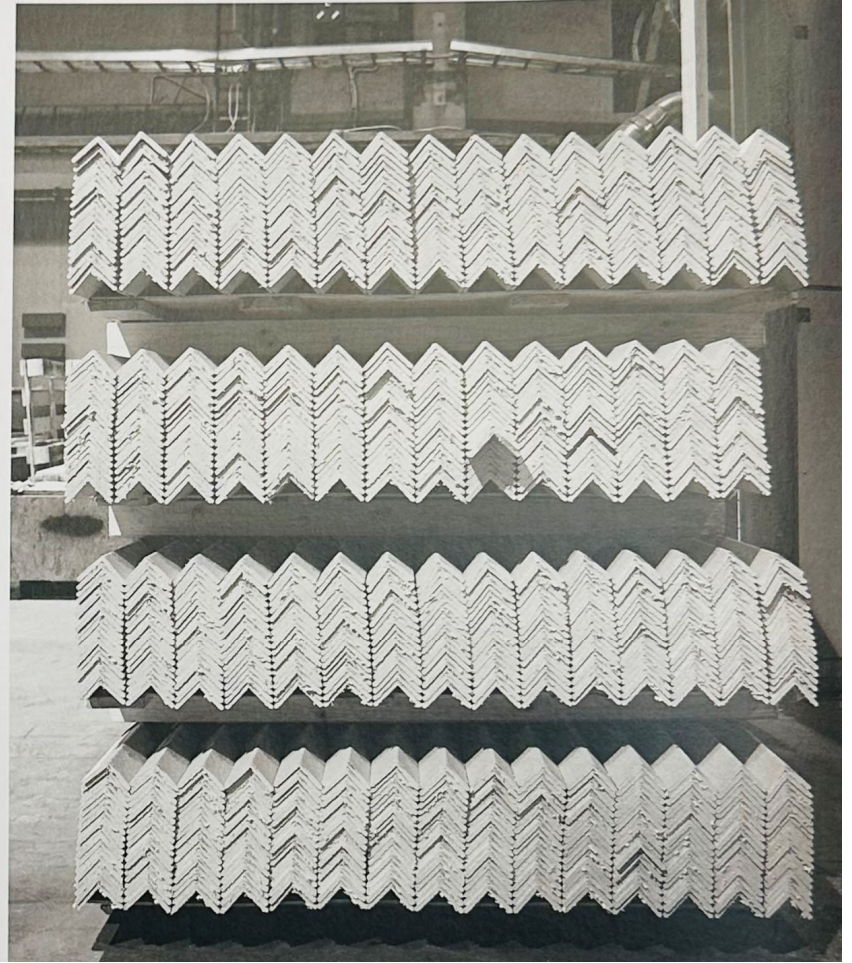
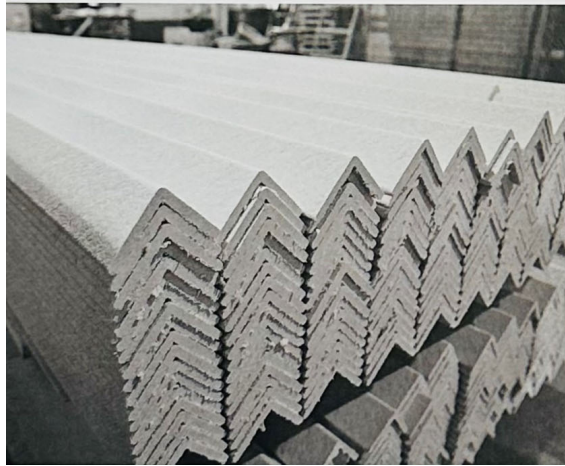
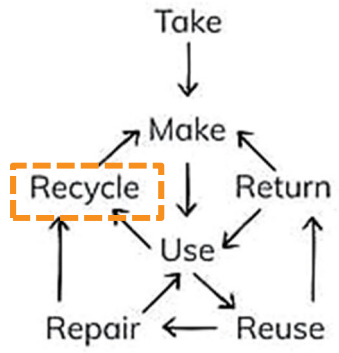


174. Basic forms and building shapes in different regions.



# Circular Economy: Recycle

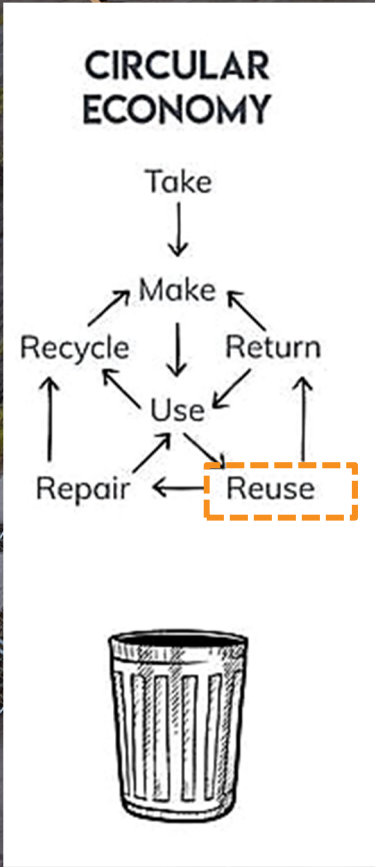
## CIRCULAR ECONOMY



Resource: label printer waste  
Manufacturer: UPM biocomponents, Finland  
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

Kyoung Hee Kim, PhD AIA NCARB  
Professor of Architecture  
Director of Integrated Design Research Lab  
UNC Charlotte  
kkim33@uncc.edu



**U.S.-ASEAN SMART  
CITIES PARTNERSHIP**