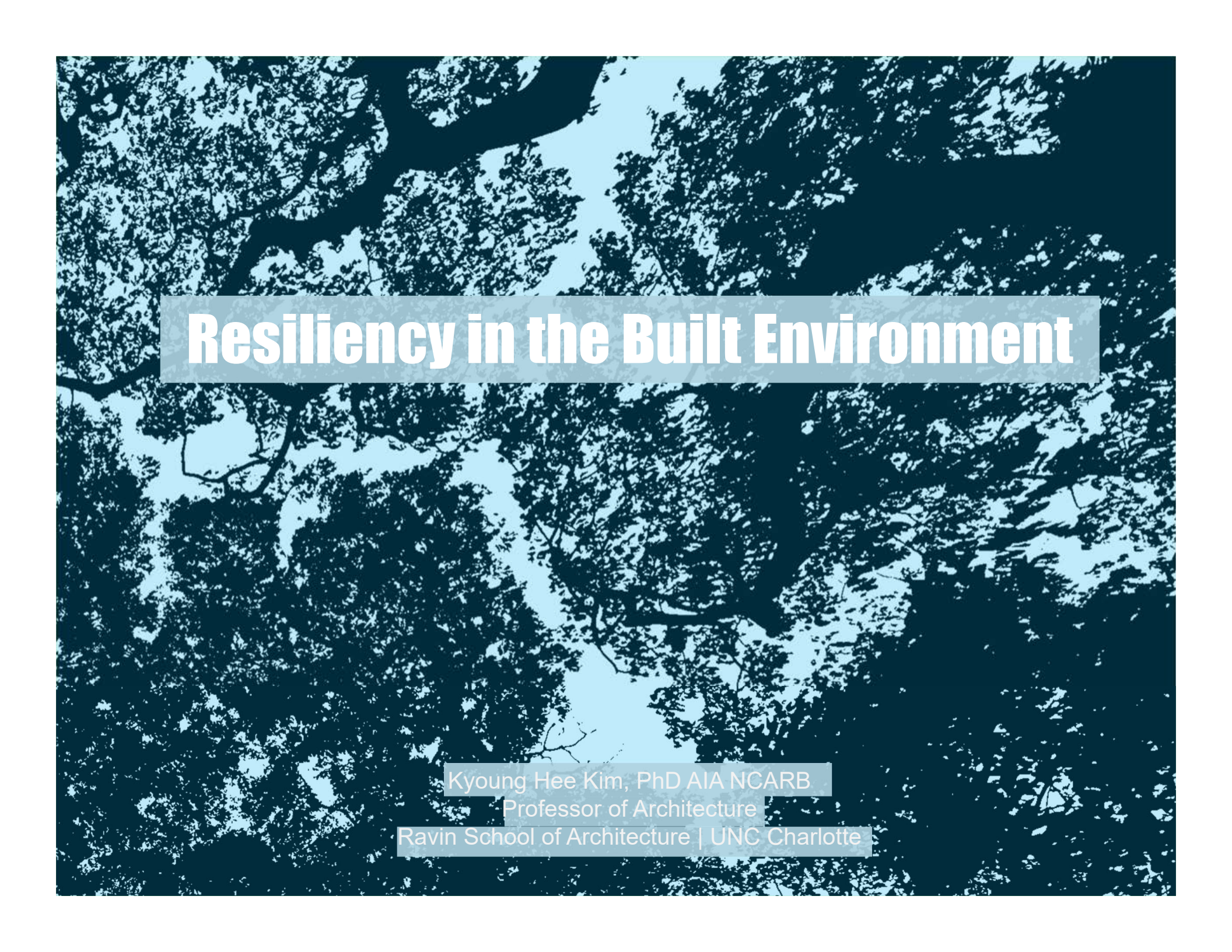




Resiliency in the Built Environment

Kyoung Hee Kim, PhD AIA NCARB
Professor of Architecture

Ravin School of Architecture | UNC Charlotte

NEW YORK TIMES BESTSELLER

DRAWDOWN

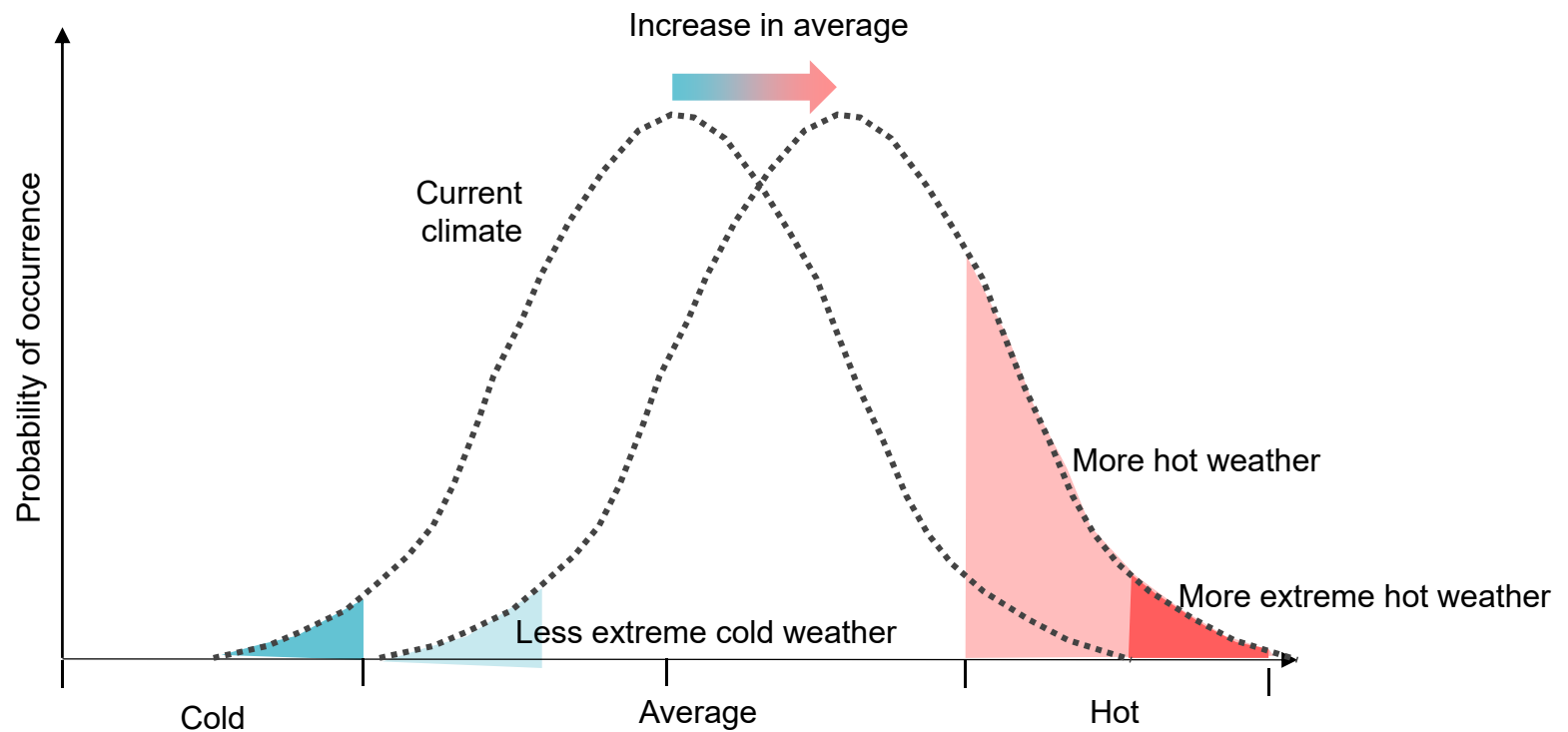
THE MOST COMPREHENSIVE
PLAN EVER PROPOSED TO
REVERSE GLOBAL WARMING
EDITED BY PAUL HAWKEN



THE CLIMATE BOOK

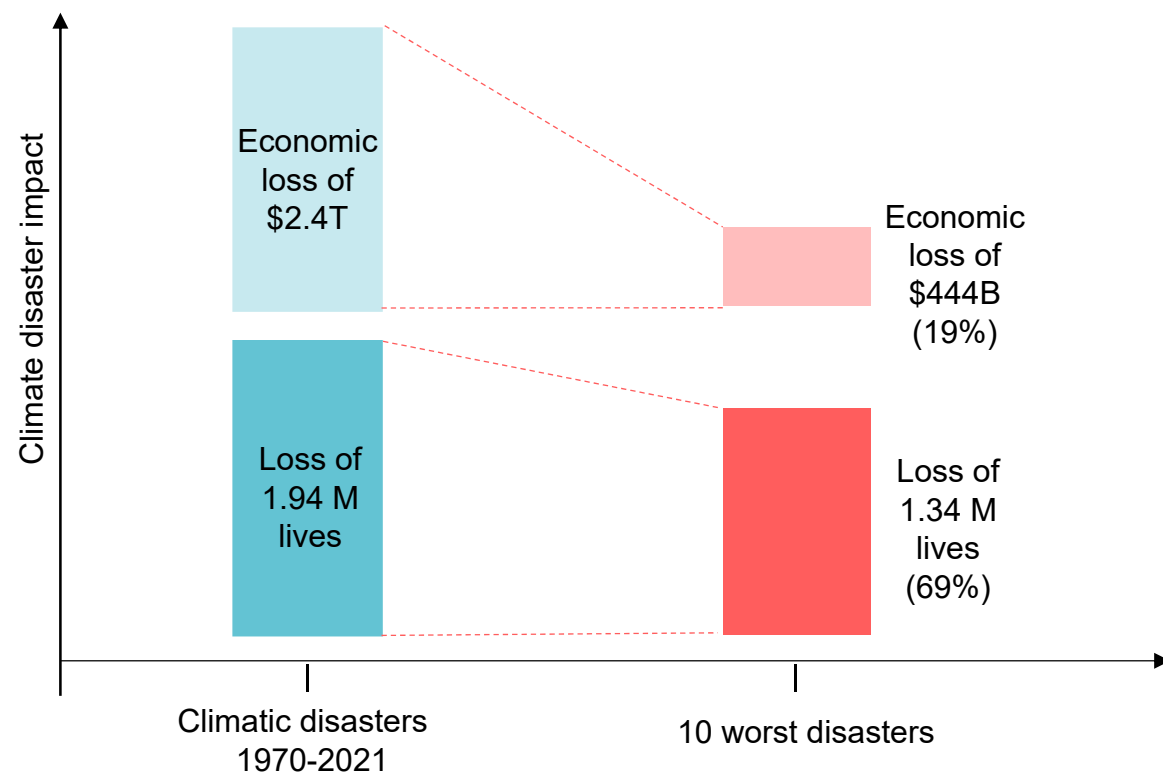
GRETA
THUNBERG

Climate Changes



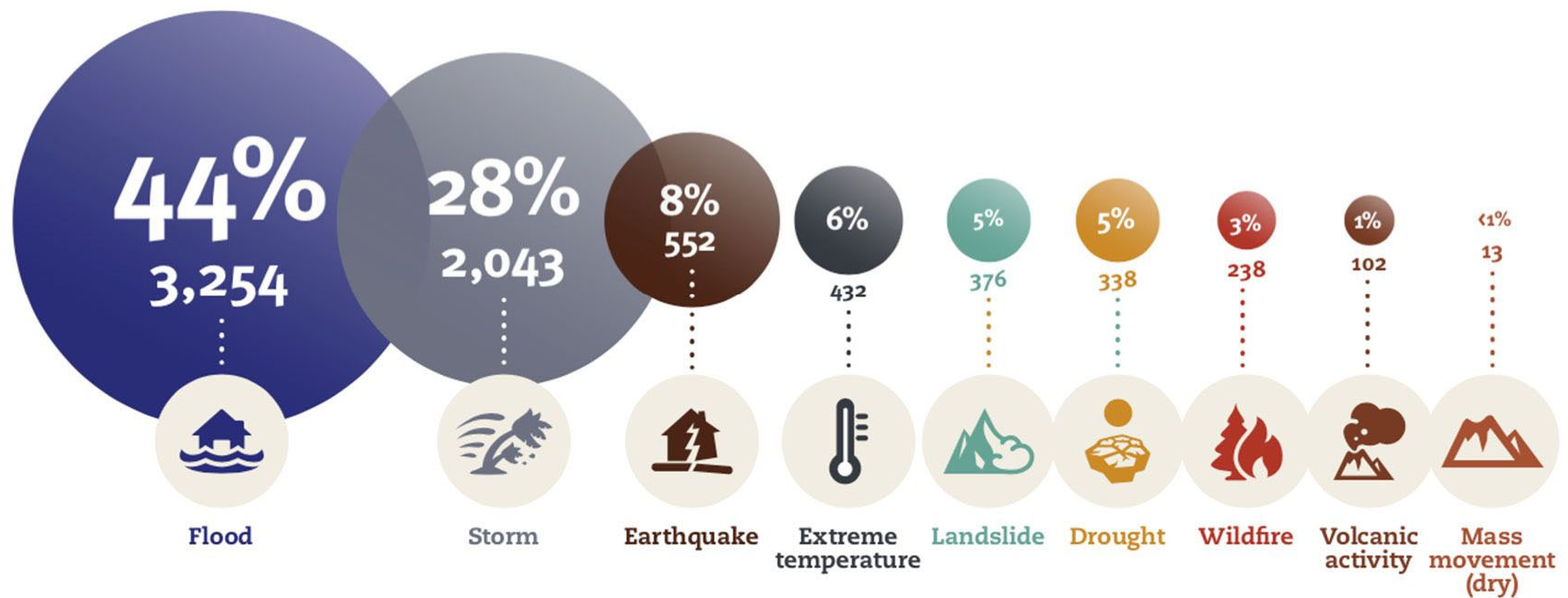
Source: https://19january2017snapshot.epa.gov/climate-change-science/understanding-link-between-climate-change-and-extreme-weather_.html

Climate Related Disasters (World)



Climate Related Disasters (World)

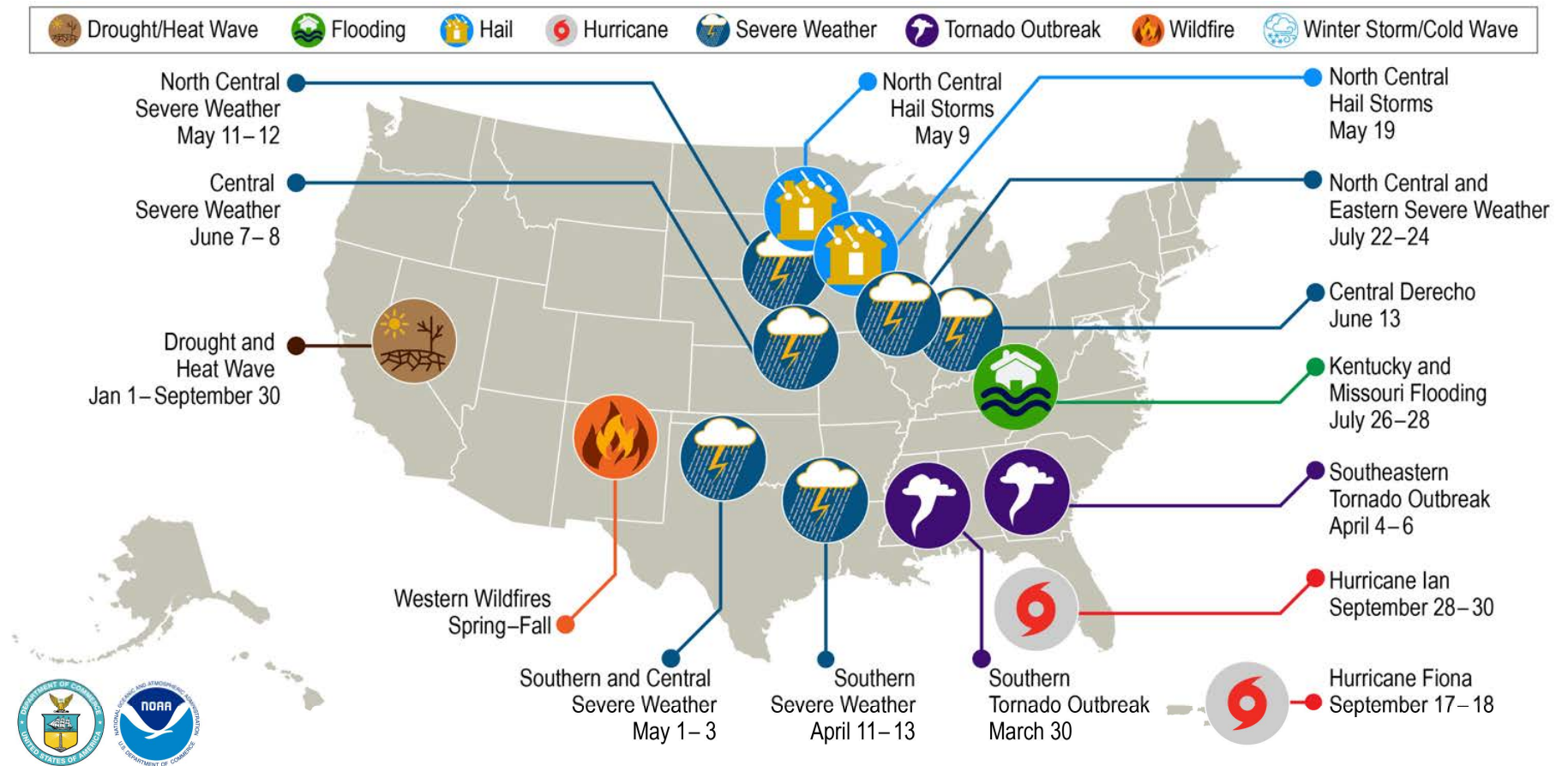
Percentage of occurrences of disasters by disaster type (2000-2019)



Climate crisis: UN warns world risks becoming 'uninhabitable hell' for millions

Climate Related Disasters (USA)

U.S. 2022 Billion-Dollar Weather and Climate Disasters



This map denotes the approximate location for each of the 15 separate billion-dollar weather and climate disasters that impacted the United States January – September of 2022.

Resilience

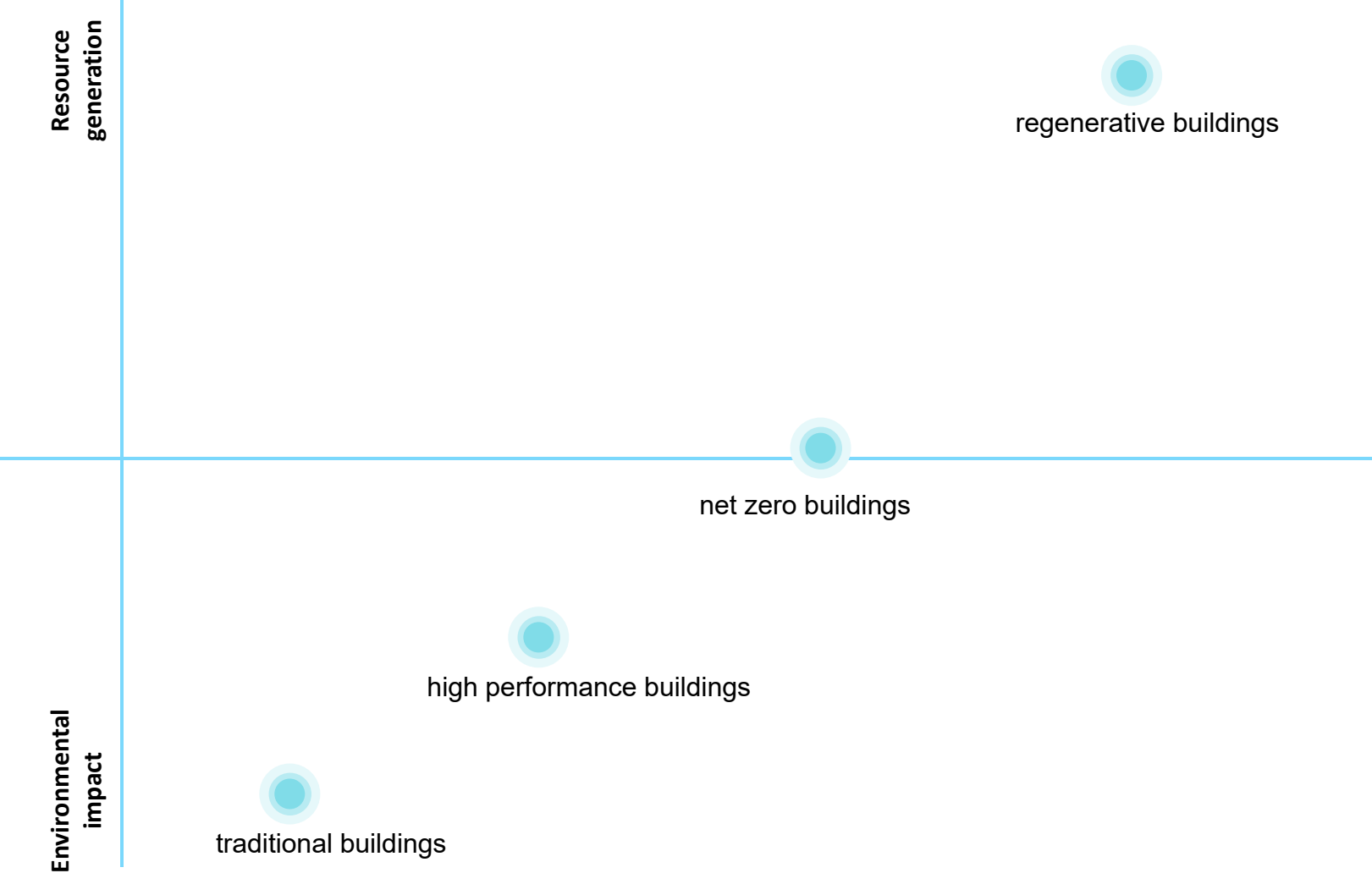
: the capability of a strained body to recover its size and shape after deformation caused especially by compressive stress

: an ability to recover from or adjust easily to misfortune or change

Toward Resilient Built Environment



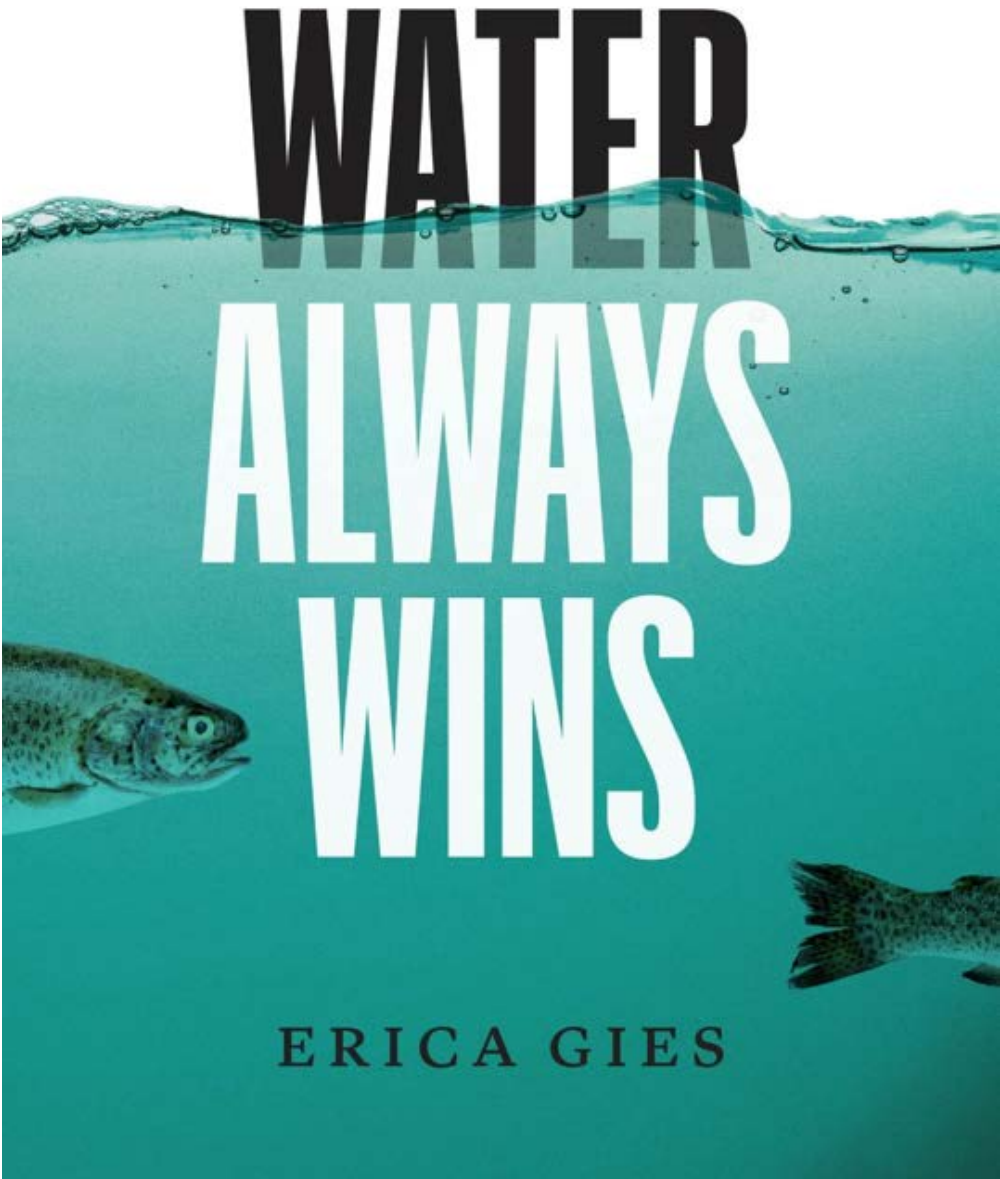
Toward Resilient Built Environment





water resilient built environment

THRIVING IN AN AGE OF
DROUGHT AND DELUGE



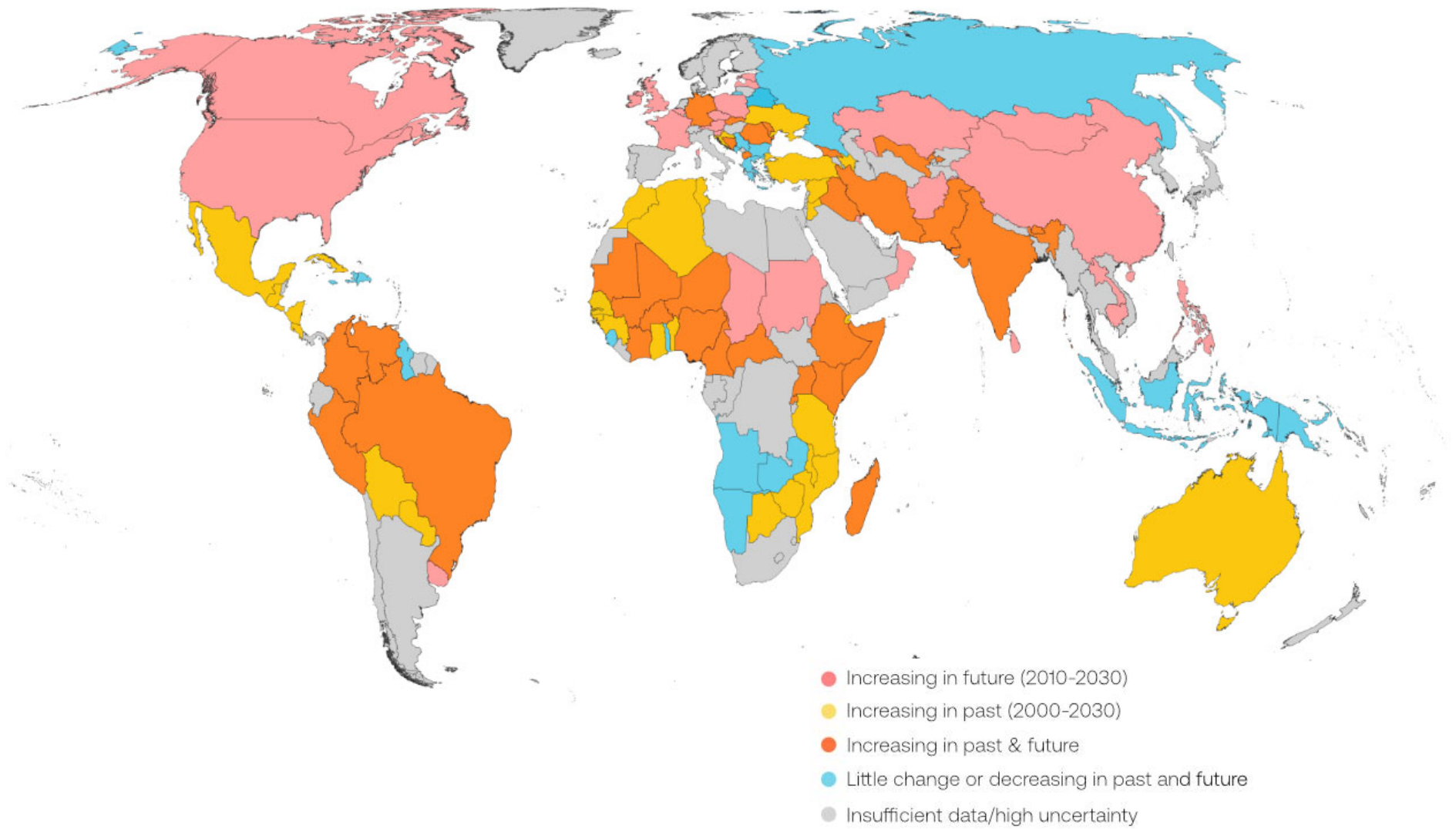
WATER ALWAYS WINS

ERICA GIES

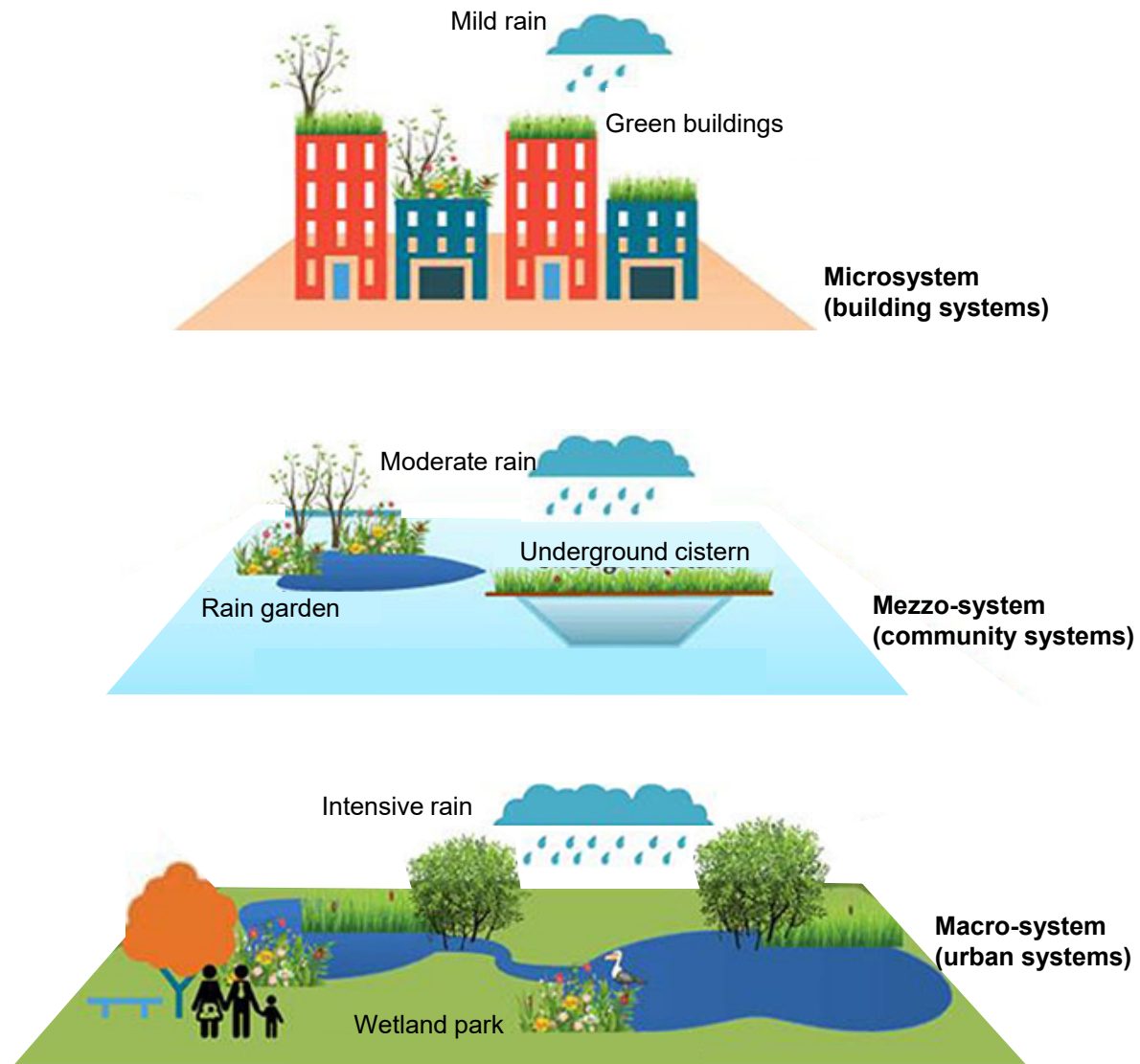
“Modern civilizations tend to speed water away, erasing its slow phases on the land. Gies reminds us that water’s true nature is to flex with the rhythms of the earth: the slow phases absorb floods, store water for droughts, and feed natural systems.”



Global Flooding Risks



Flooding Resiliency Framework



Flooding Resiliency Framework

PROTECT

the city's blue-green systems from development and pollution



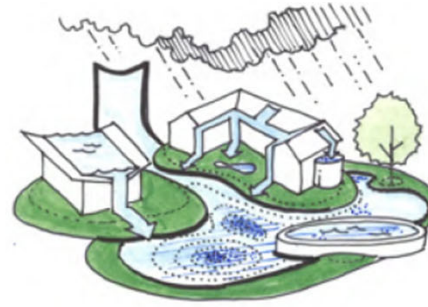
DELAY

stormwater runoff from reaching drains, canals, and rivers



STORE

rainwater in barrels, cisterns, holding ponds, tanks, and reservoirs

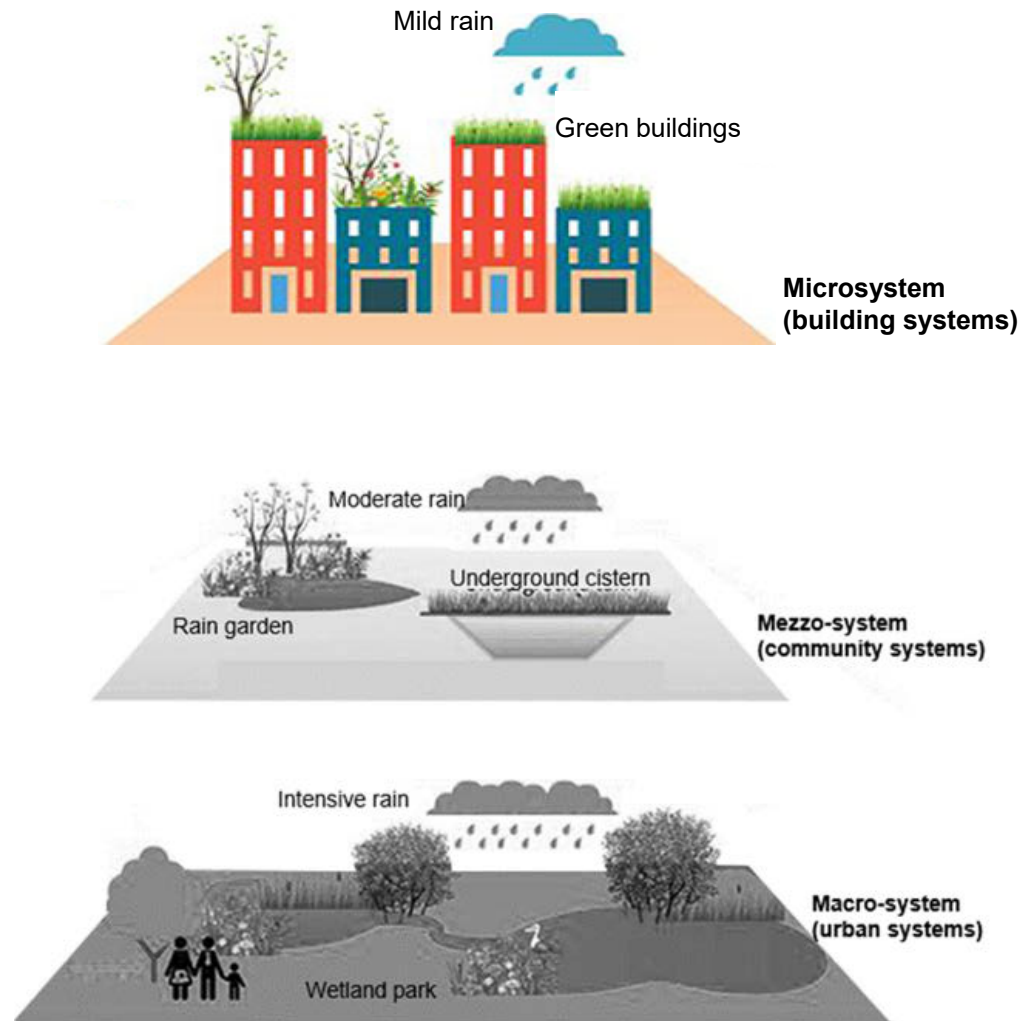


RELEASE

rainwater into the aquifer to recharge groundwater



Flooding Resiliency Framework: Nature Integrated Buildings



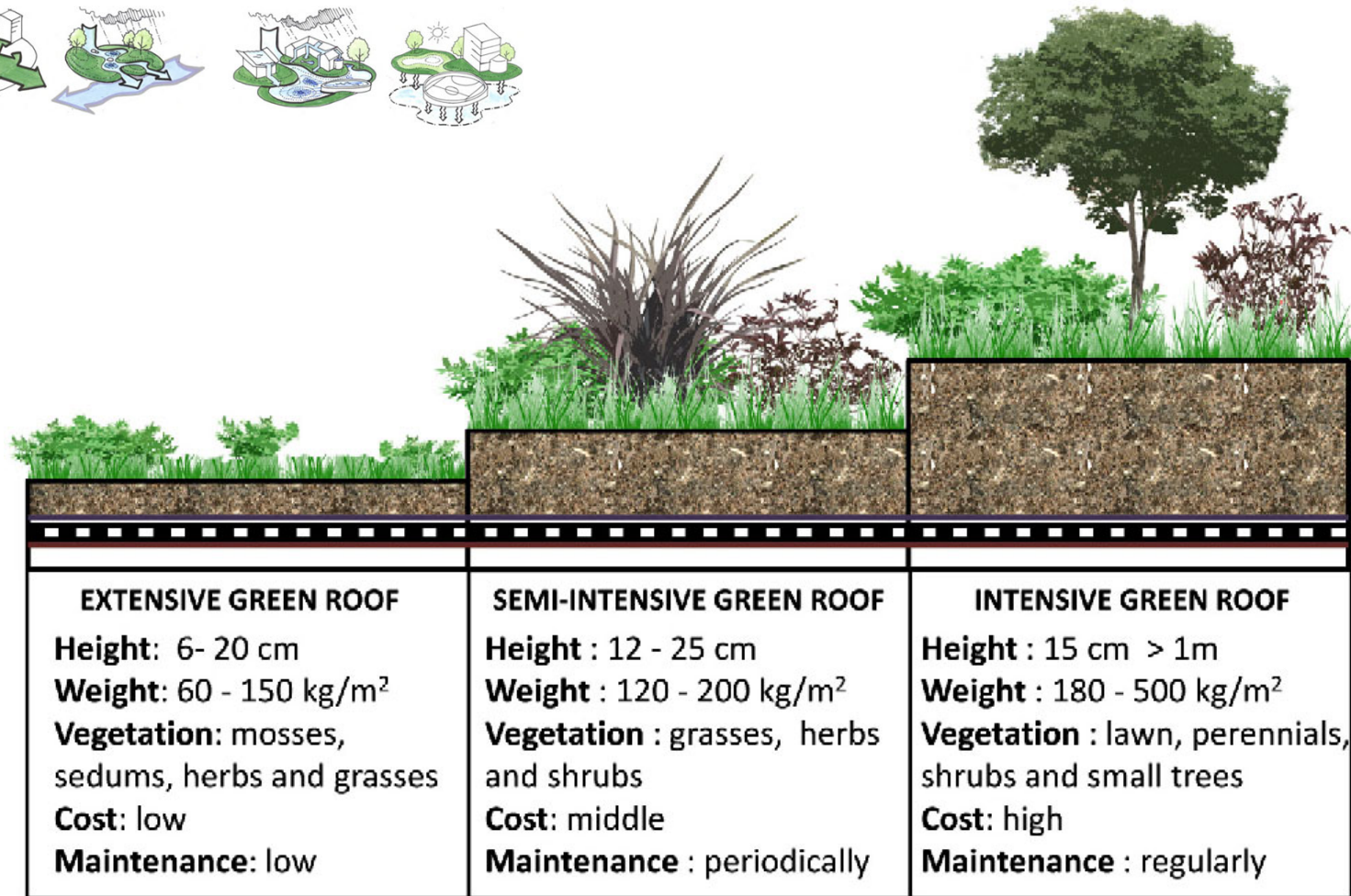
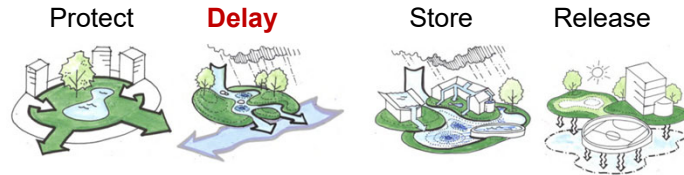
Green Roof

- 1. Stormwater Management:** Most urban and suburban areas contain large amounts of paved or constructed surfaces which prevent stormwater from being absorbed into the ground. The resulting excess runoff damages water quality by sweeping pollutants into water bodies. Green roofs can reduce the flow of stormwater from a roof by up to 65% and delay the flow rate by up to three hours.
- 2. Energy savings:** Green roofs reduce building energy use by cooling roofs and providing shading, thermal mass and insulation.
- 3. Biodiversity and Habitat Protection:** Green roofs provide new urban habitat for plants and animals, like birds and insects, thereby increasing biodiversity.
- 4. Mitigation of Urban Heat Islands:** Cities are generally warmer than other areas, as concrete and asphalt absorb solar radiation, leading to increased energy consumption, heat-related illness and death, and air pollution. Green roofs can help reduce this effect.
- 5. Roof Longevity:** Green roofs are expected to last twice as long as conventional roofs
- 6. Aesthetics:** Green roofs can add beauty and value to buildings.

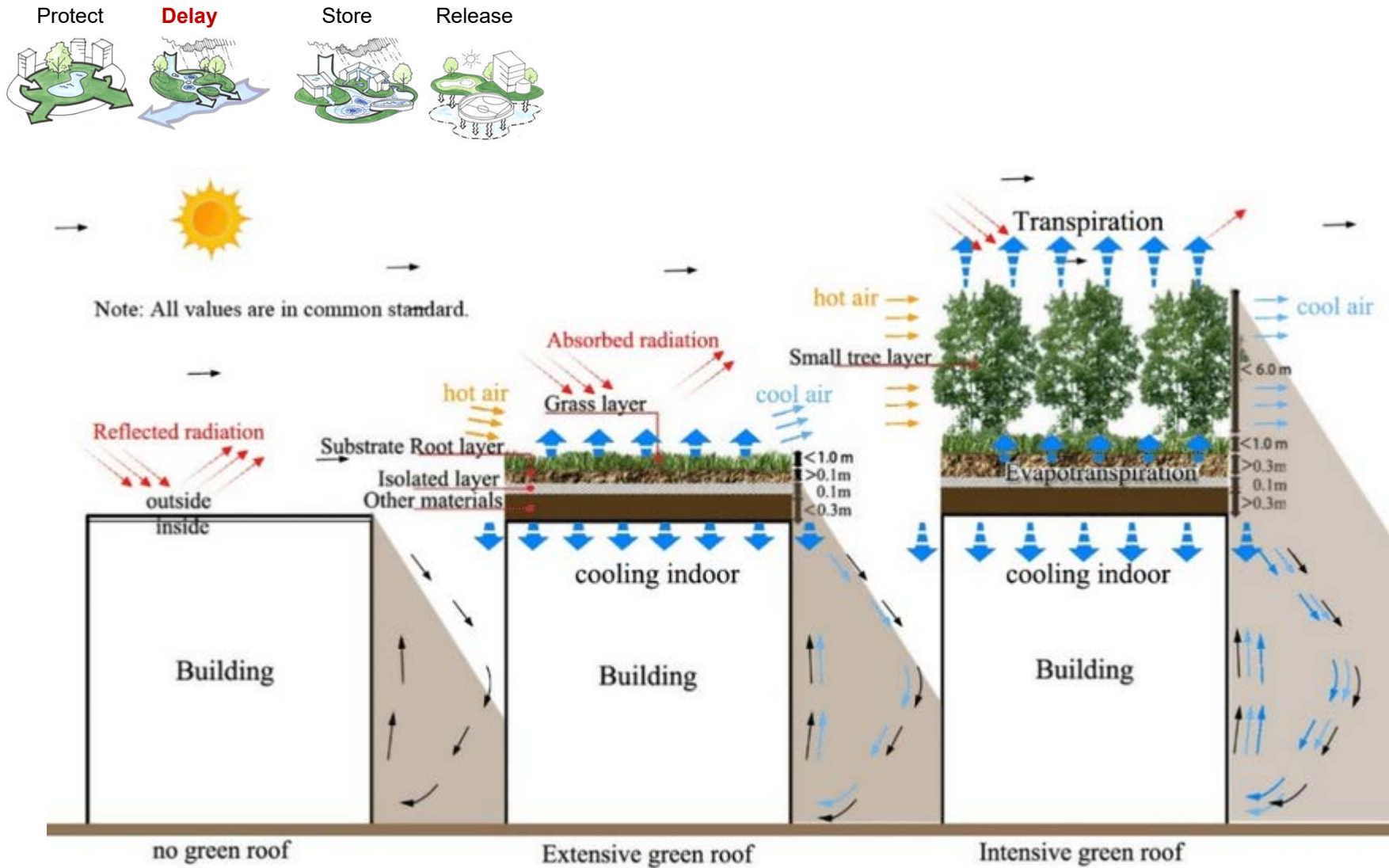
Green Facades

1. **Reduce air pollution.** Plants and vegetation purify the air and play a role in creating cleaner and healthier environments for everyone.
2. **Enhance building energy efficiency.** Green facades create temperate microclimates through summer shading. For winter seasons, its thermal mass helps prevent unnecessary loss of energy, resulting in improved insulation and reduced heating costs.
3. **Reduce urban temperatures.** Transpiration and evaporation of green facades help cooling down the surrounding environment.
4. **Reduce sound transmission.** Green facades provide insulation against noise pollution by absorbing a certain frequency of urban noises.
5. **Mitigate rainwater runoff.** Green facades mitigate rainwater runoff by absorbing and slowing down the flow of heavy rainwater.
6. **Support biodiversity.** Green facades serve as habitats for a wide range of ecosystems that support pollinators, birds, and other wildlife, ultimately contributing to the overall health and balance of our environment.
7. **Reduce stress.** Studies have shown that being near nature can have a calming effect and alleviate anxiety.
8. **Increase productivity and creativity.** Being near nature also sparks inspiration and boosts creativity. Research suggests that incorporating biophilic elements into workspaces can enhance cognitive function, problem-solving skills, and overall productivity.
9. **Improve health and wellbeing.** Green facades improve air quality by filtering pollutants and releasing oxygen into the environment. This not only creates a healthier space for users but also contributes to the ecosystem by reducing carbon footprint in urban areas.

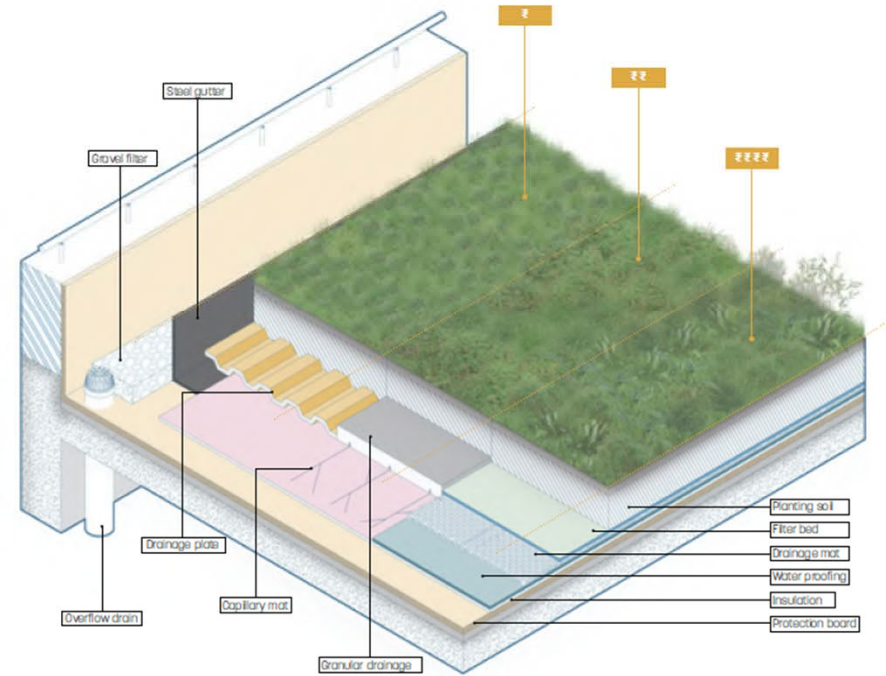
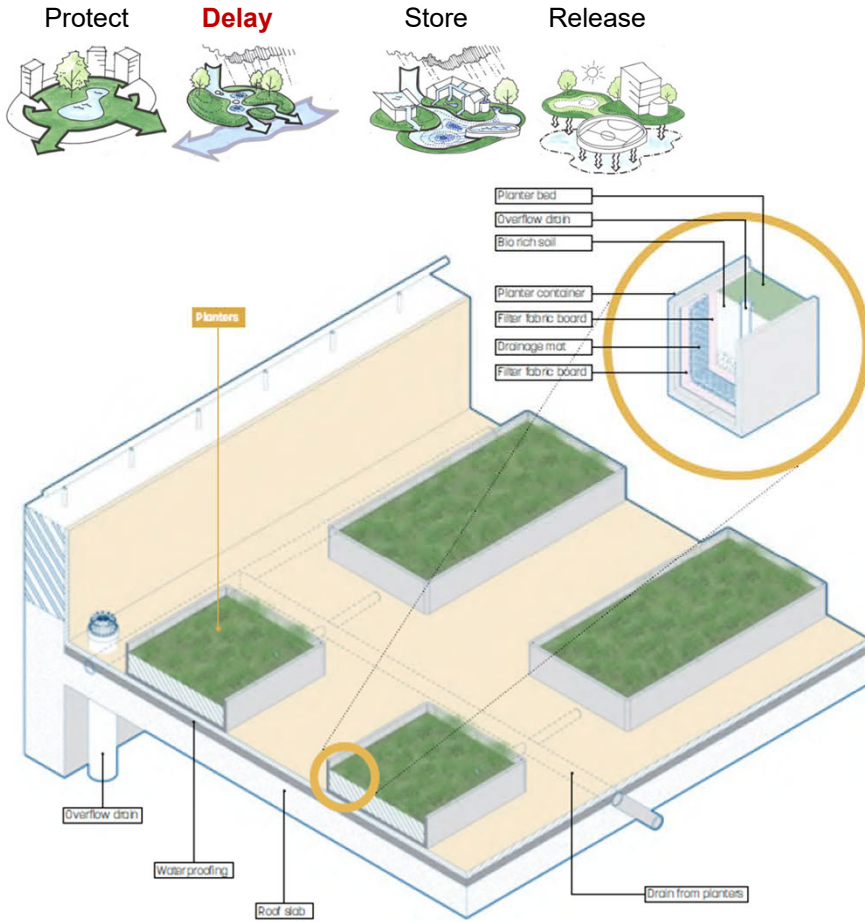
Intensive vs Extensive Green Roof



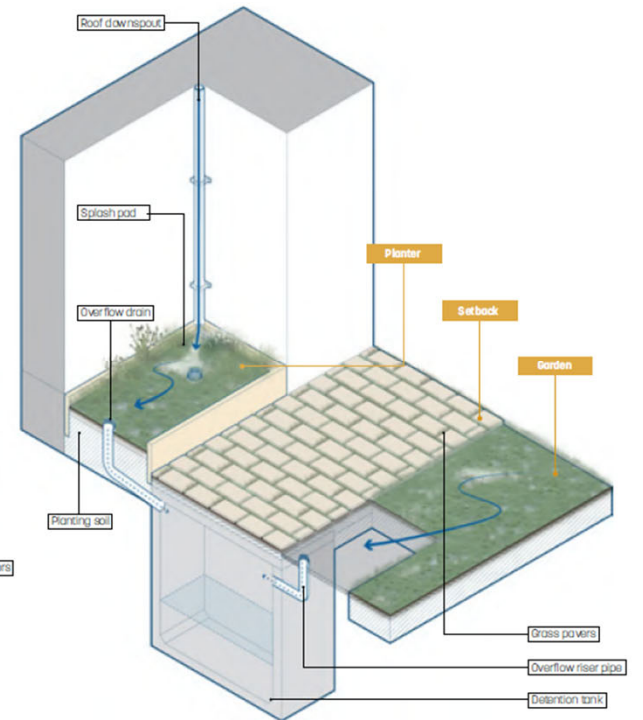
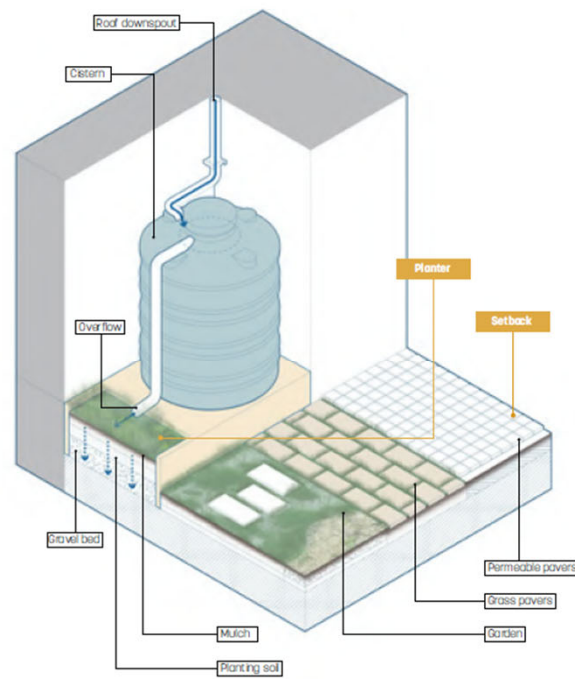
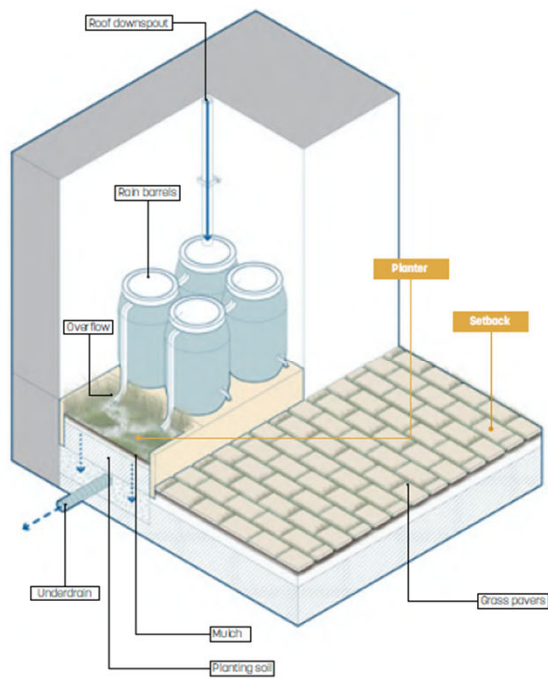
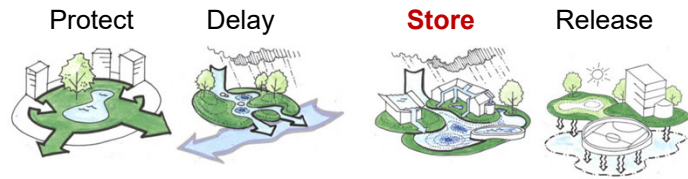
Intensive vs Extensive Green Roof



Intensive vs Extensive Green Roof



Rainwater Harvesting



Sloped



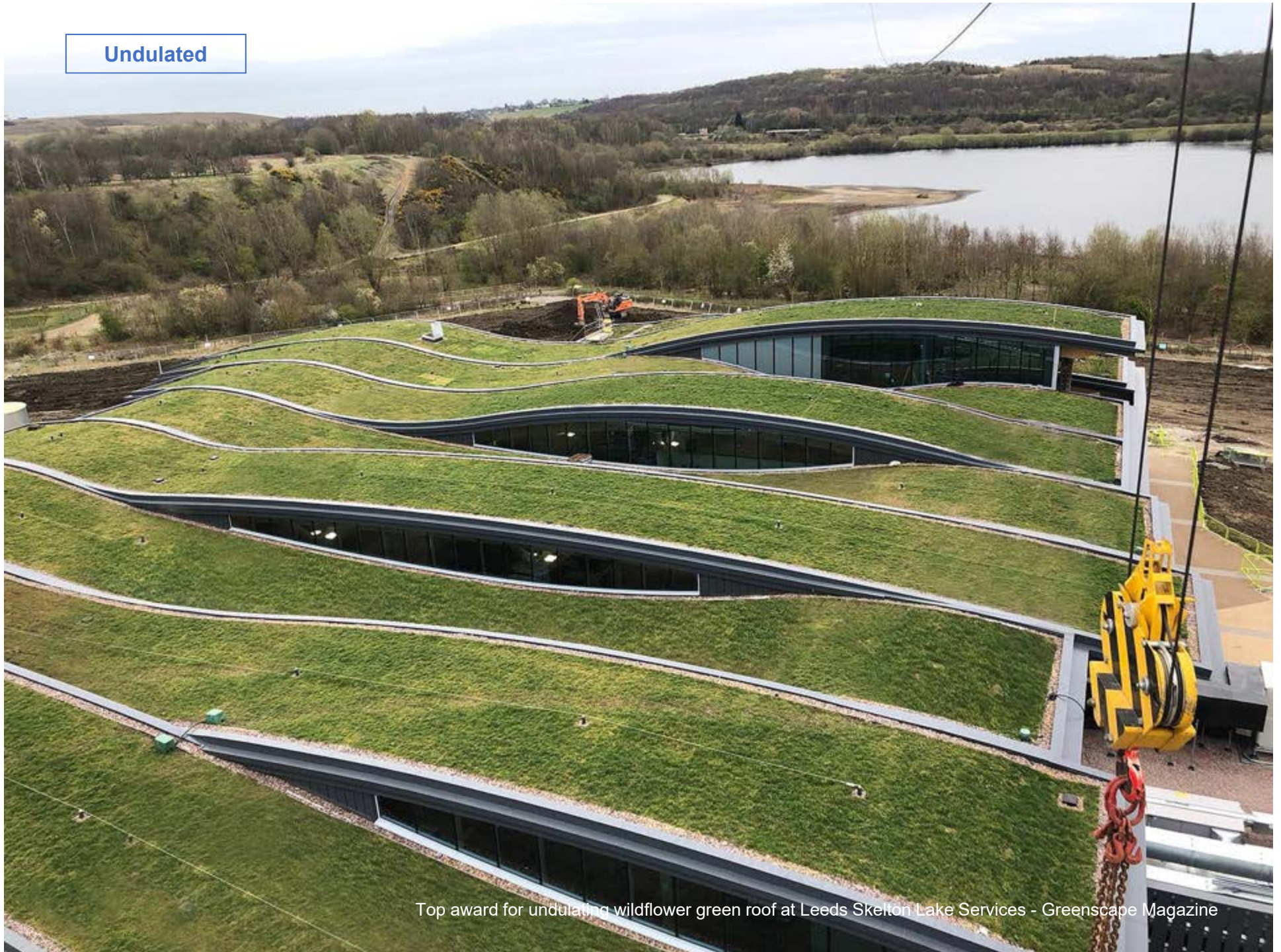
ASLA Headquarters Green Roof



Thammasat University Green Roof

the largest urban rooftop farm in Asia, the 236,806 sq. ft. Green Roof tackles climate impacts by incorporating modern landscape architecture with traditional agricultural ingenuity, the green roof, urban farming, solar roof, and green public space.

Undulated



Top award for undulating wildflower green roof at Leeds Skelton Lake Services - Greenscape Magazine

Scolloping



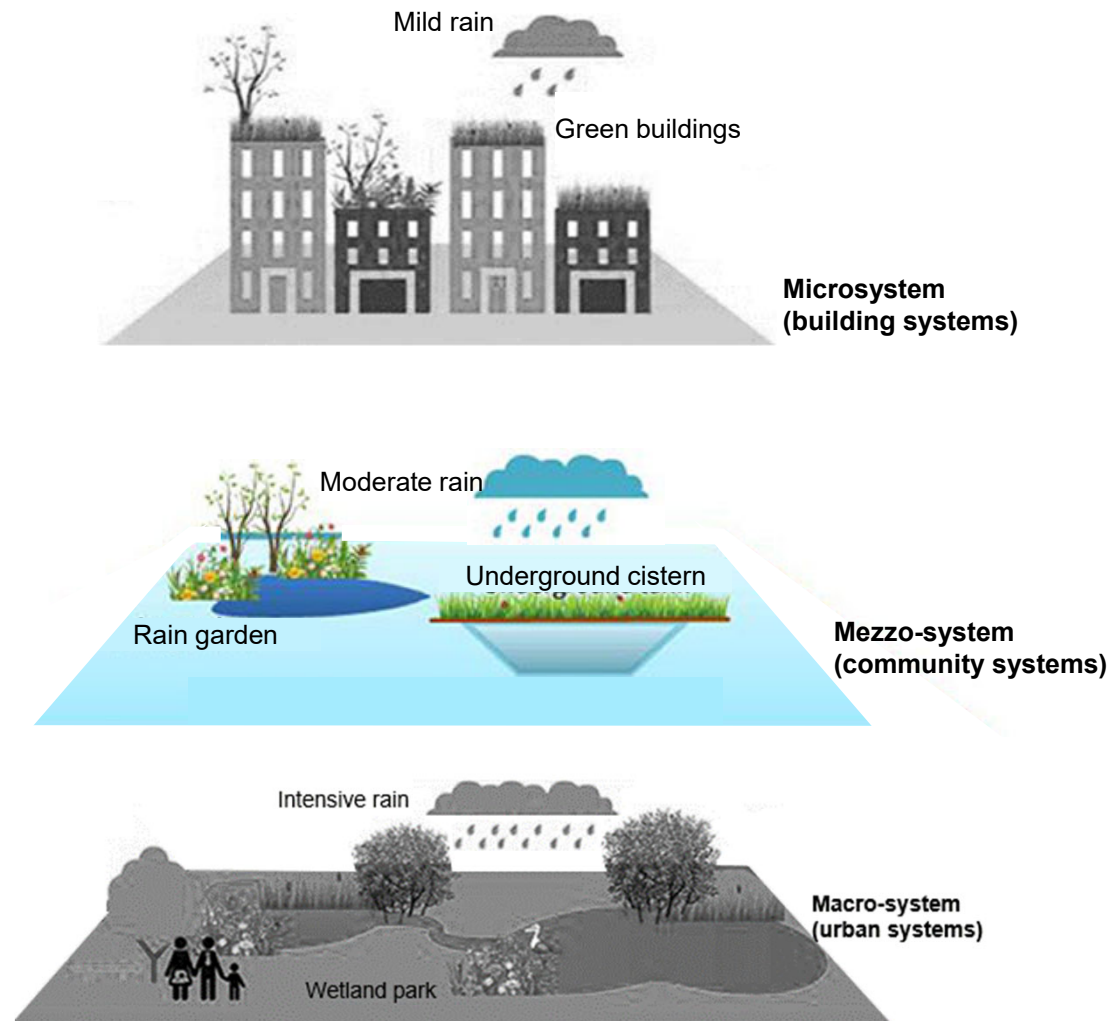
OPTIMIZED GREEN-ROOF SYSTEM RENOLIT ALKORPLAN GREEN

Terraced

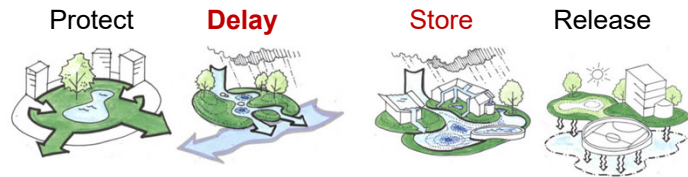


Kongjian Yu @ Turenscape

Flooding Resiliency Framework: Community Systems



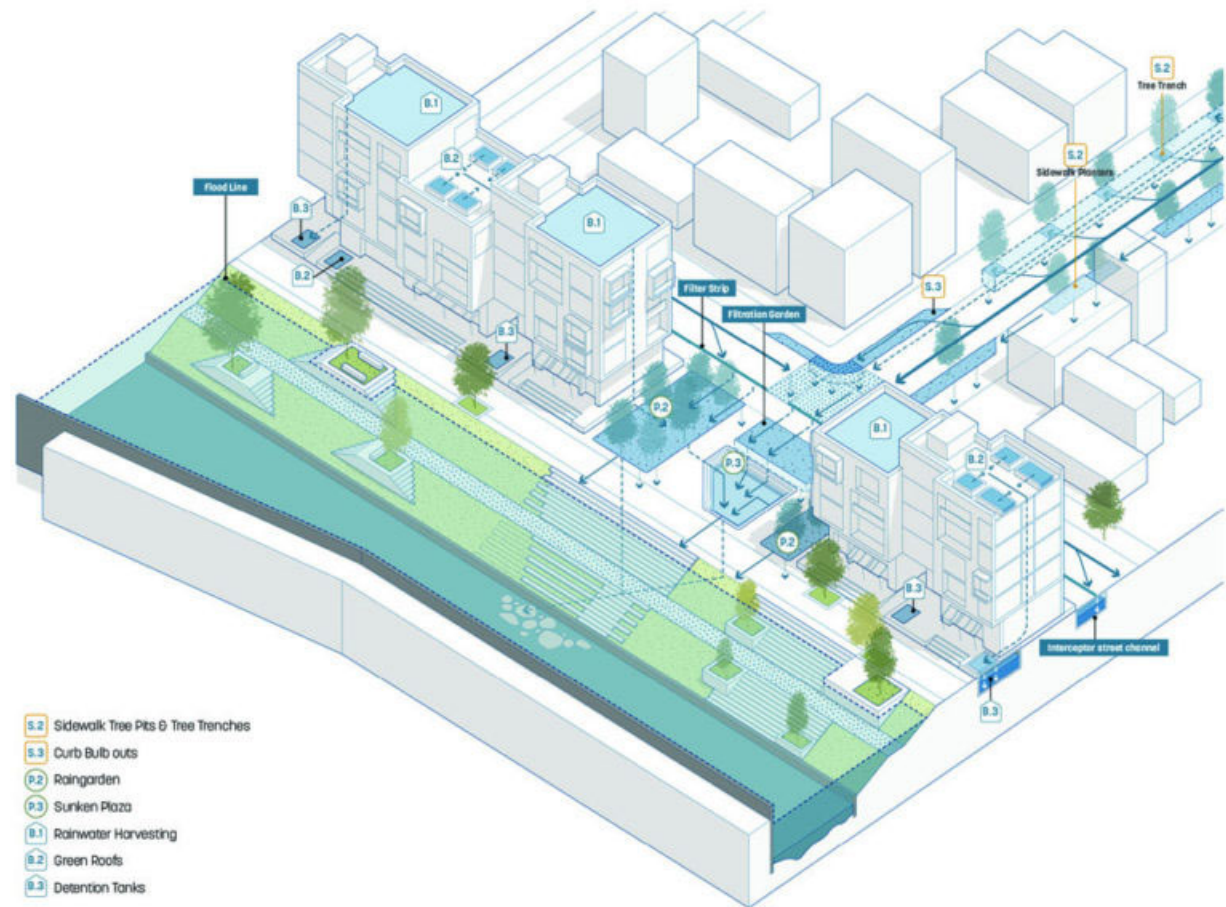
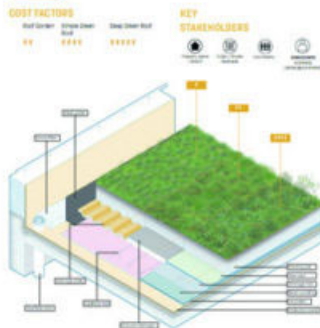
Flooding Resiliency Framework: Community Systems



S.2 SPONGE STREETS: Tree Trenches

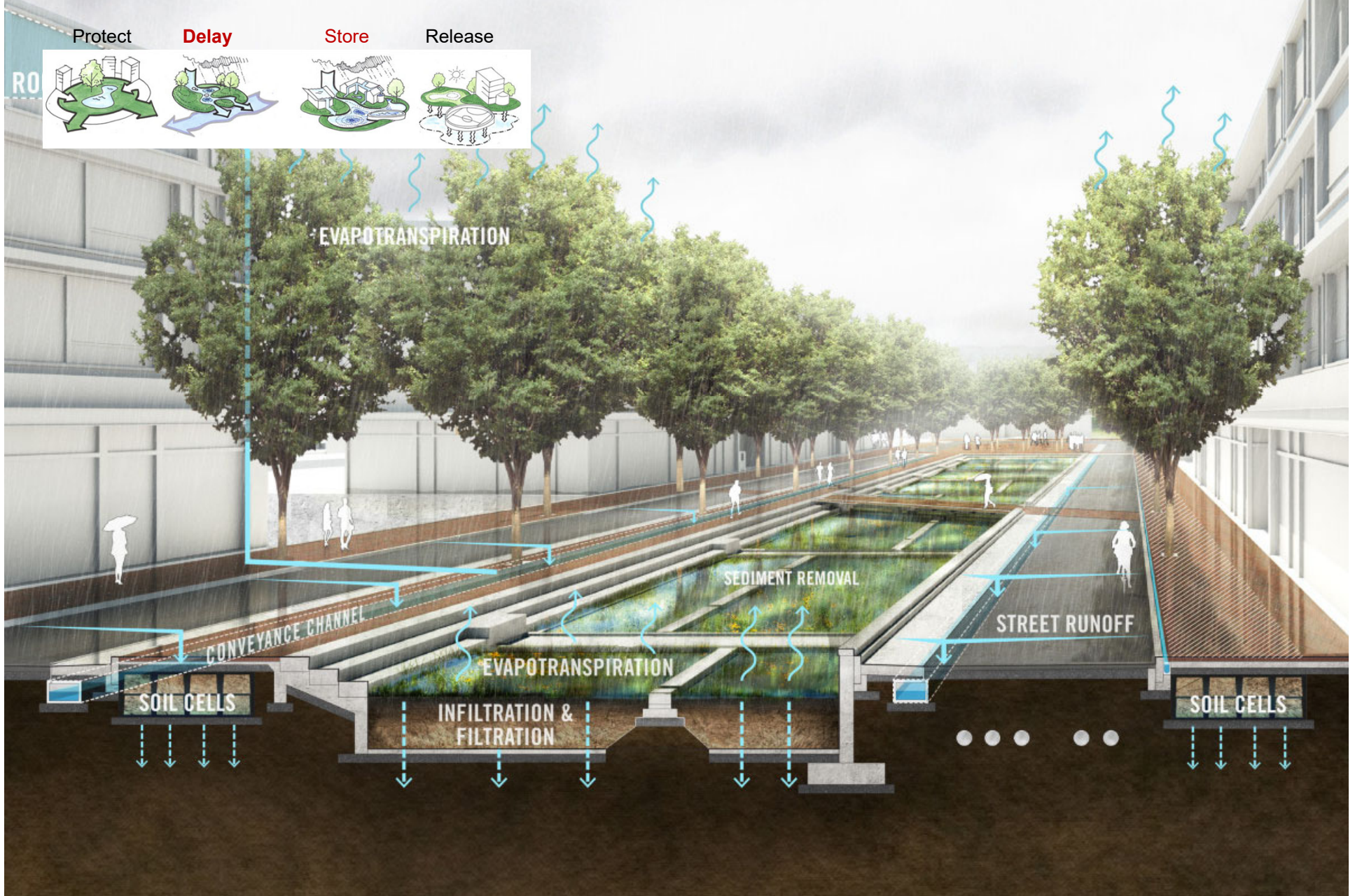


B.2 SPONGE BUILDINGS: Green Roofs



- S.2 Sidewalk Tree Pits & Tree Trenches
- S.3 Curb Bulb outs
- P.2 Rain Garden
- P.3 Sunken Plaza
- B.1 Rainwater Harvesting
- B.2 Green Roofs
- B.3 Detention Tanks

Sponge Street: Bioswale Channel, Sidewalk Planters, Tree Trenches



Sponge Street: Bioswale Channel, Sidewalk Planters, Tree Trenches

Protect

Delay

Store

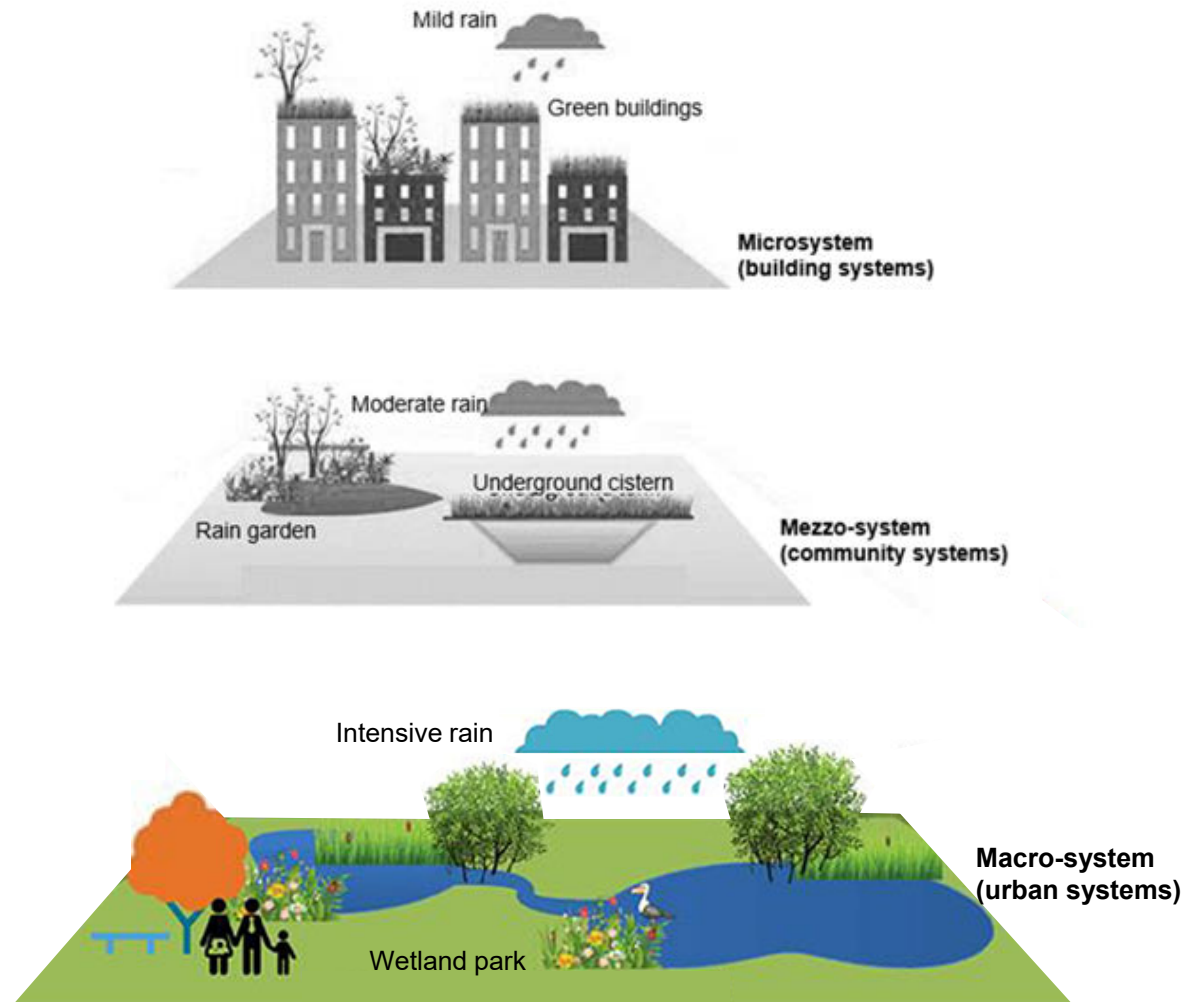
Release



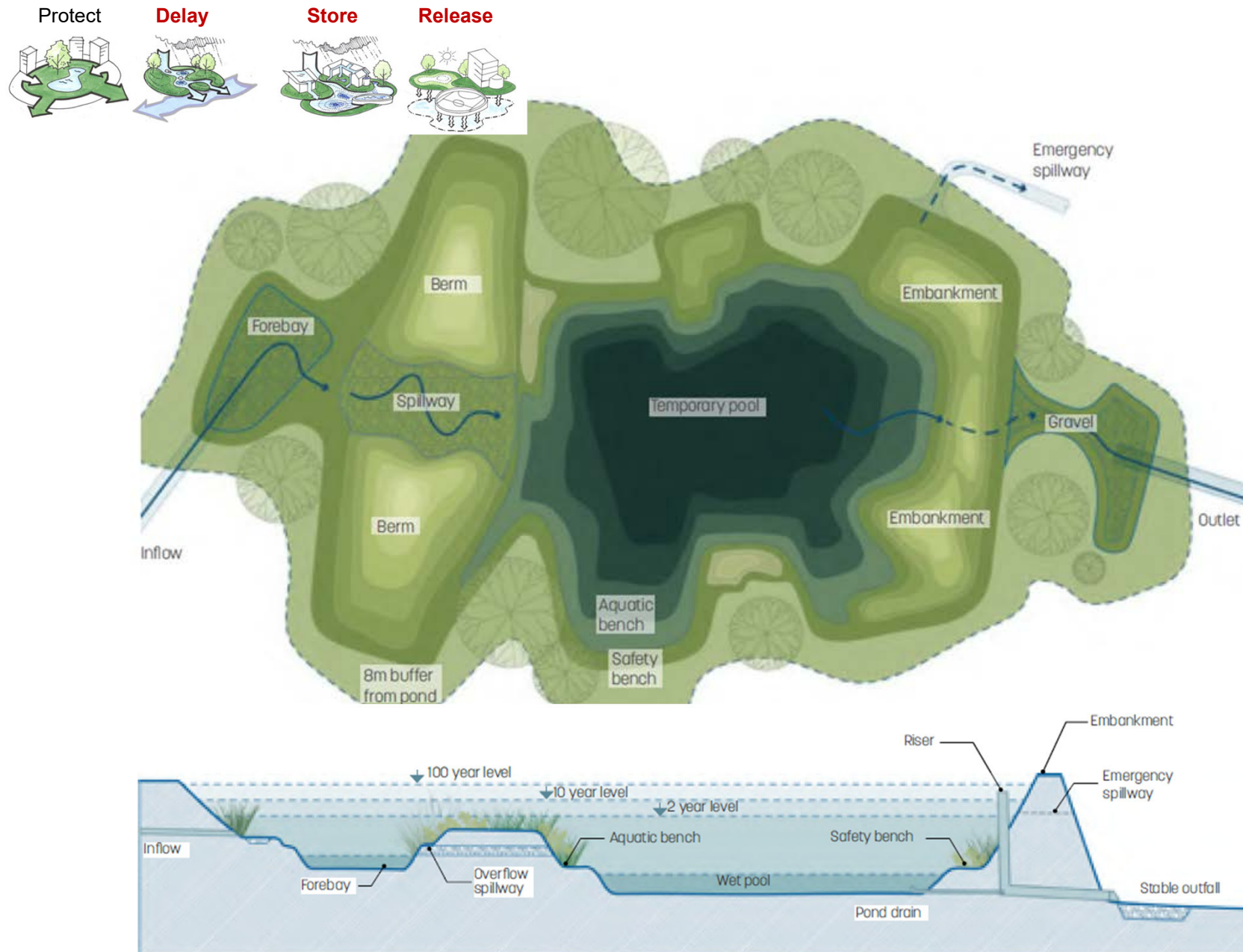
Kongjian Yu @ Turenscape

[A]A STUDIO

Flooding Resiliency Framework: Urban Systems



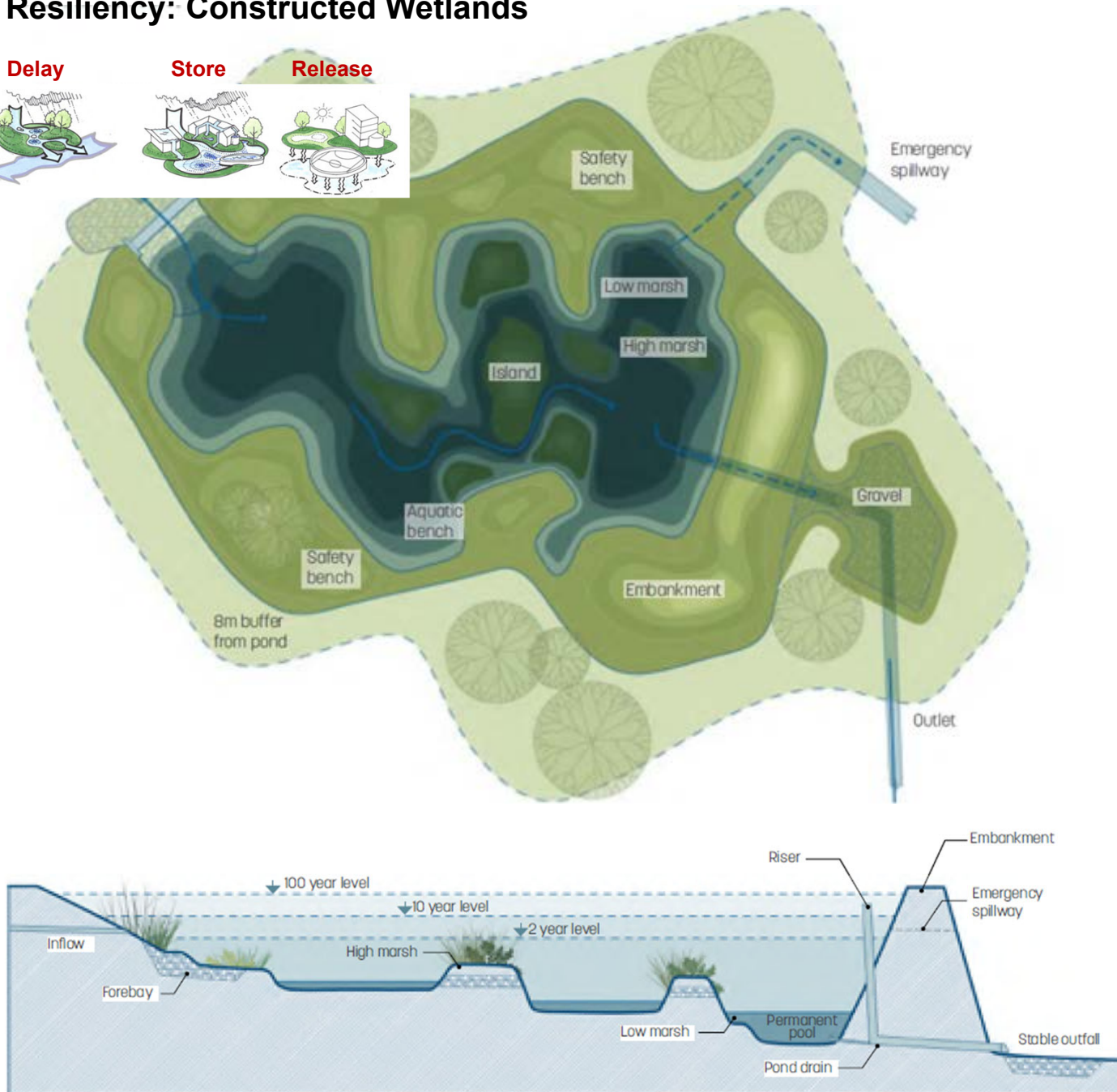
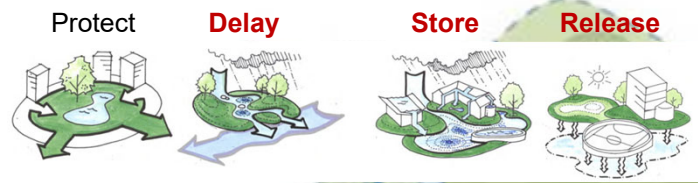
Flooding Resiliency: Constructed Ponds





The architect making friends with flooding in MIT Tech Review
Kongjian Yu @ Turenscape

Flooding Resiliency: Constructed Wetlands





Kongjian Yu @ Turenscape



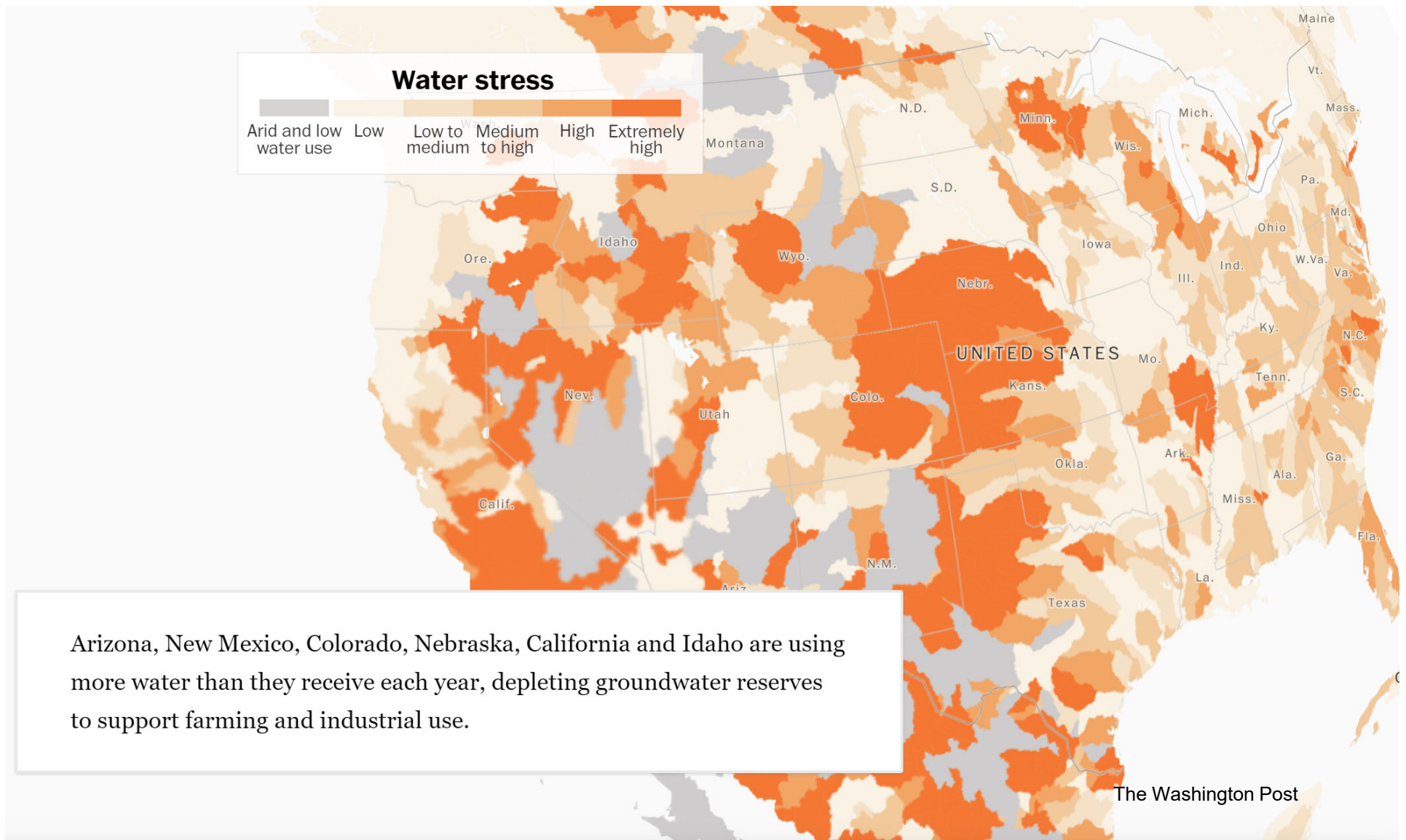
drought resilient built environment

Drought Resiliency

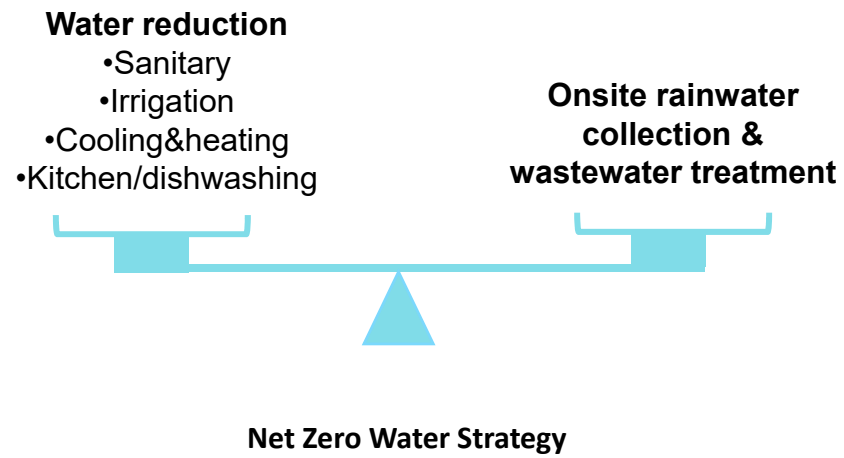
Population at risk of water stress



Drought Resiliency

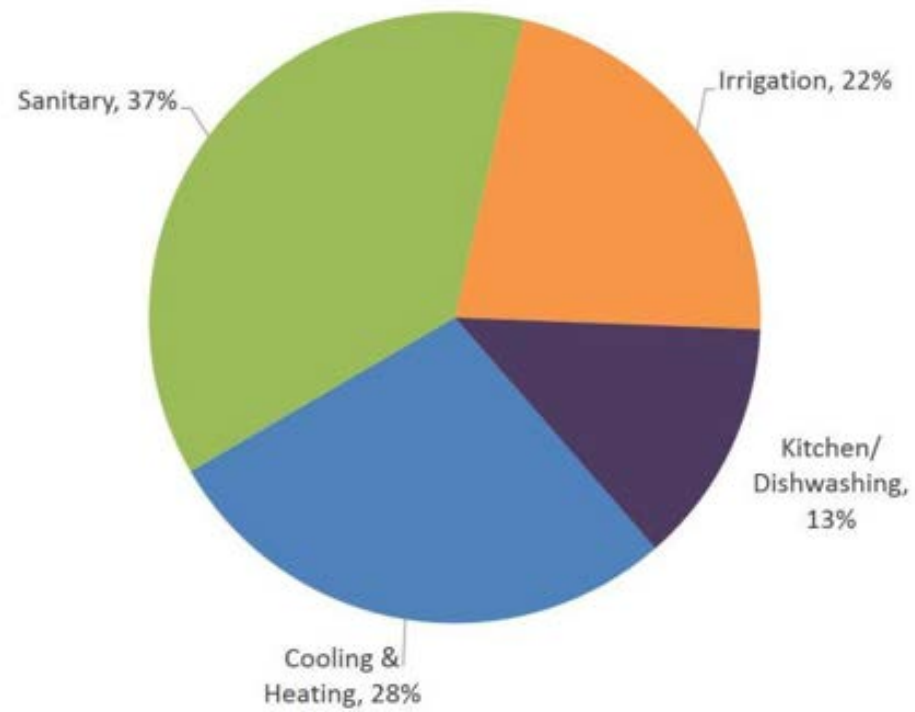


Drought Resiliency



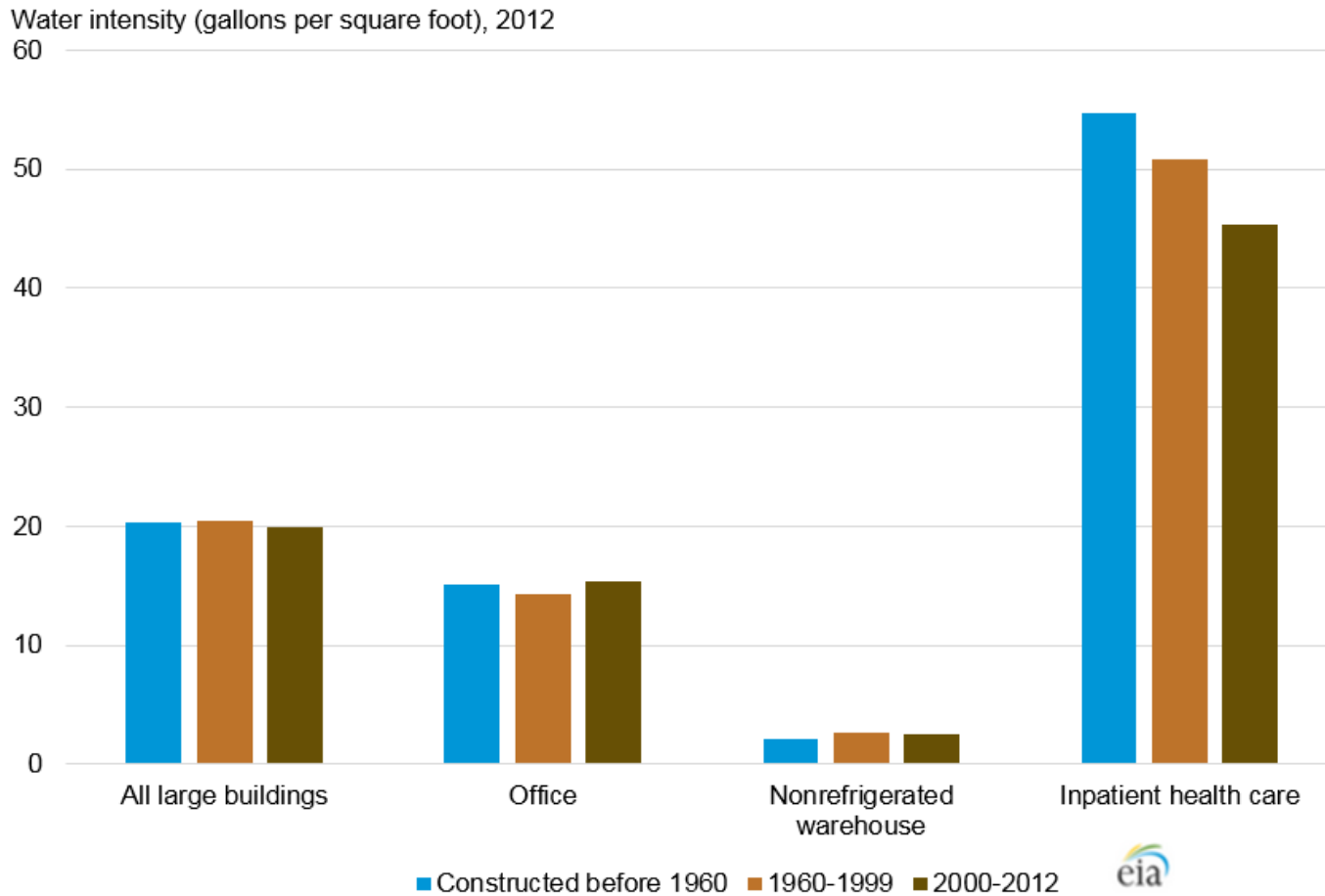
Drought Resiliency: Reduction of Water Usage

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



Drought Resiliency: Reduction of Water Usage

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

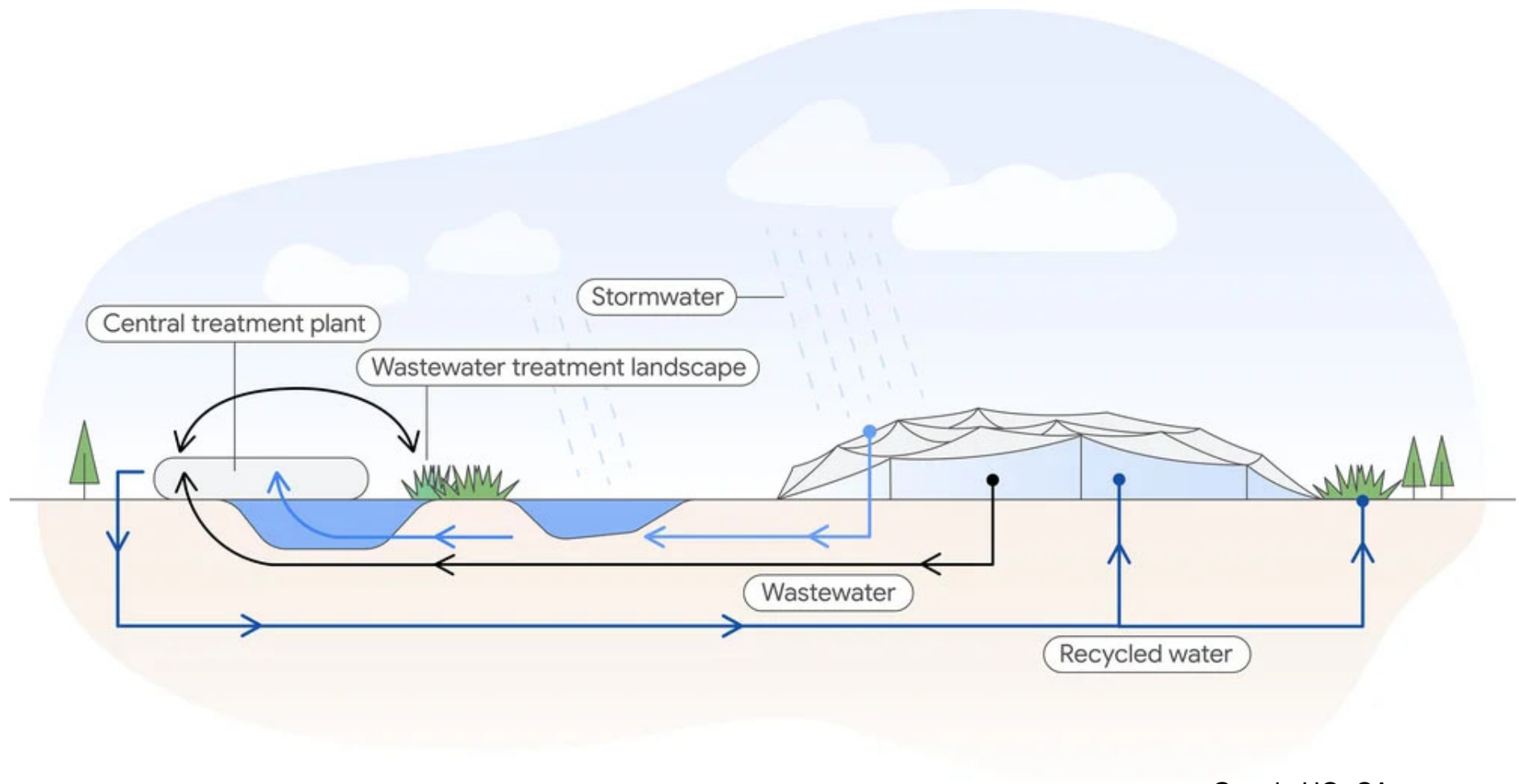


Drought Resiliency: Rainwater Collection and Grey Water Treatment



Google HQ, CA

Drought Resiliency: Rainwater Collection and Grey Water Treatment



Google HQ, CA

Drought Resiliency: Rainwater Collection and Grey Water Treatment



Kendeda Building, GTech

Drought Resiliency: Rainwater Collection and Grey Water Treatment

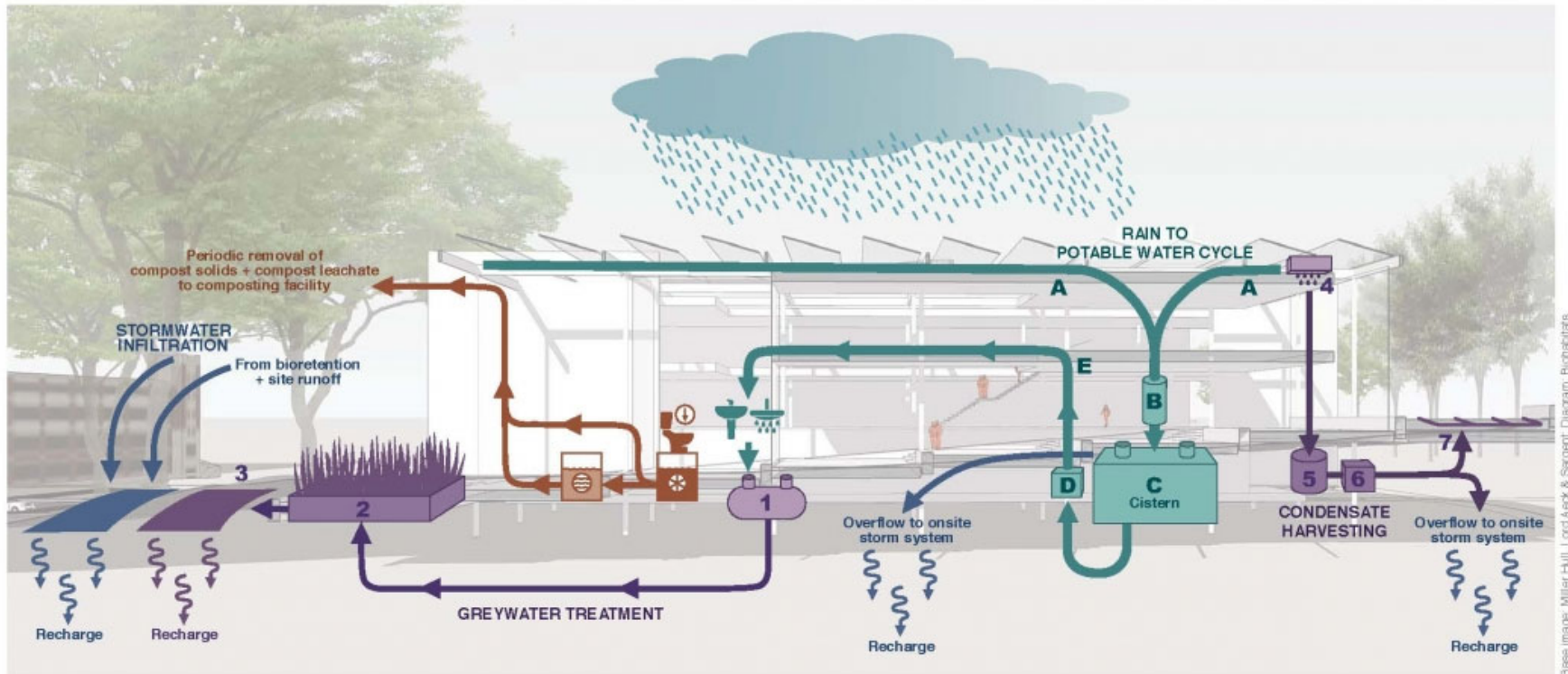
NET POSITIVE WATER CYCLE – LIVING BUILDING CHALLENGE STRATEGY

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

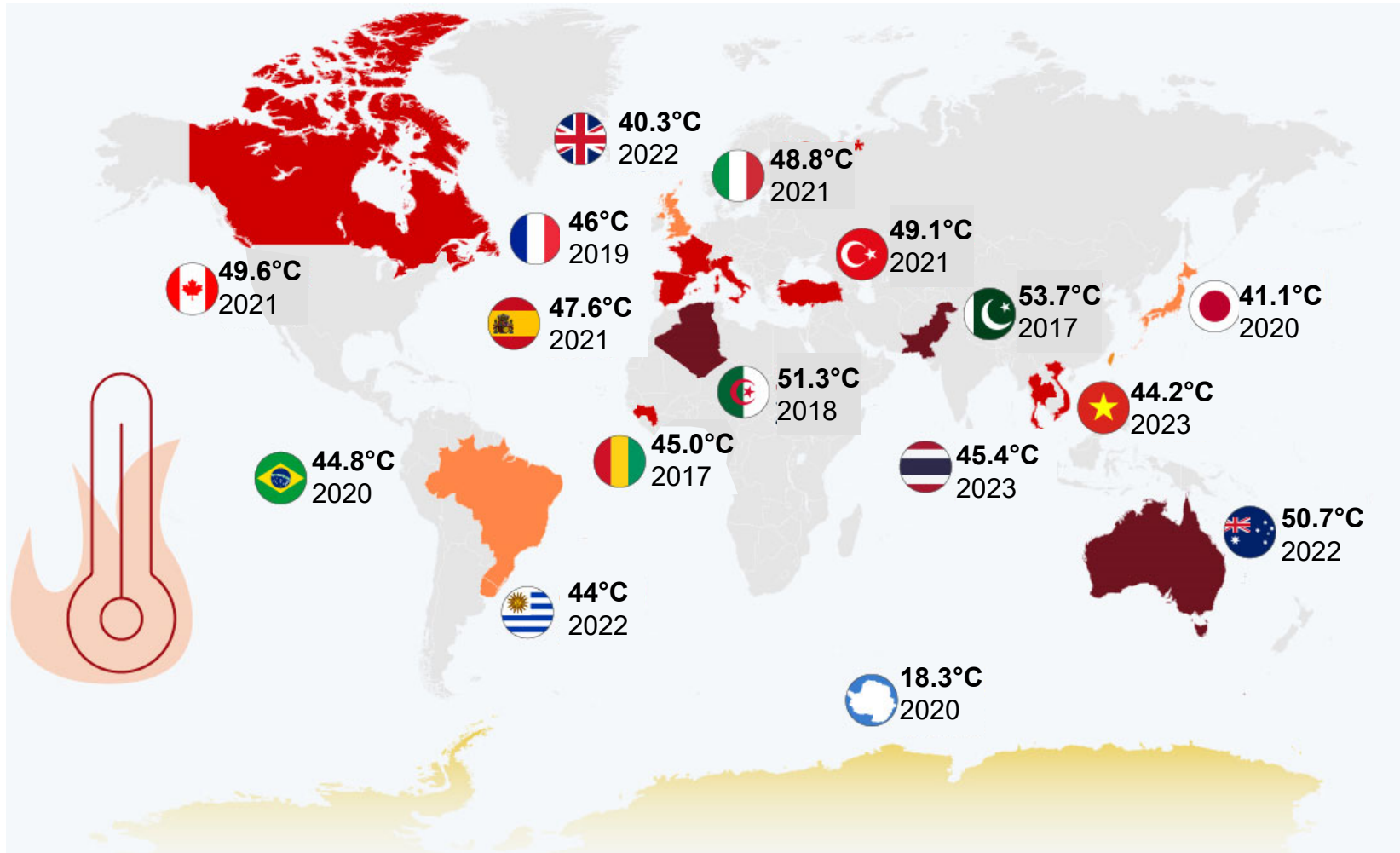
Kendeda Building, GTech



heat resilient built environment

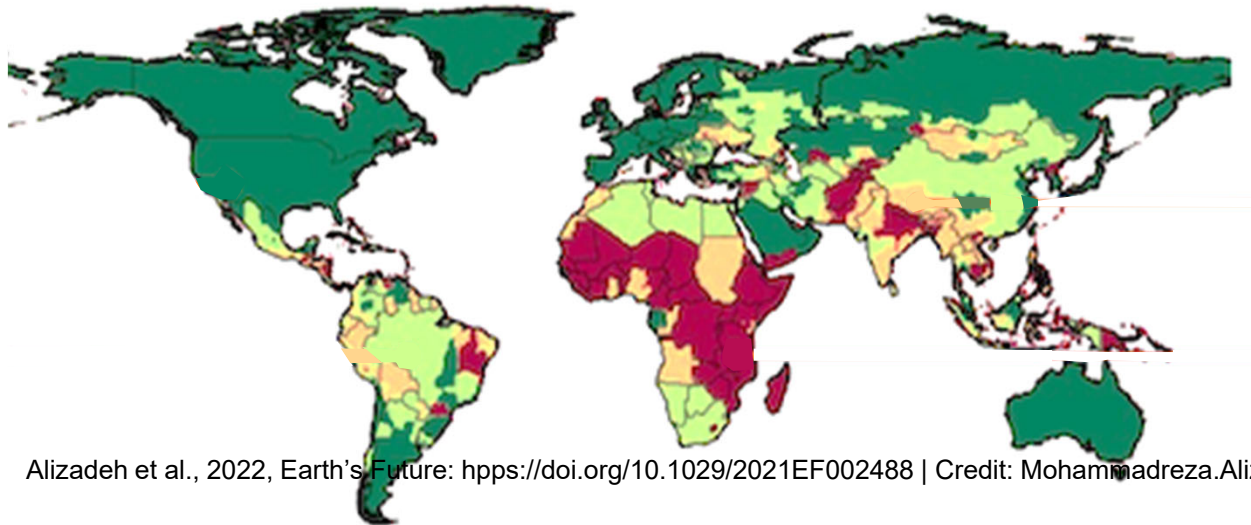
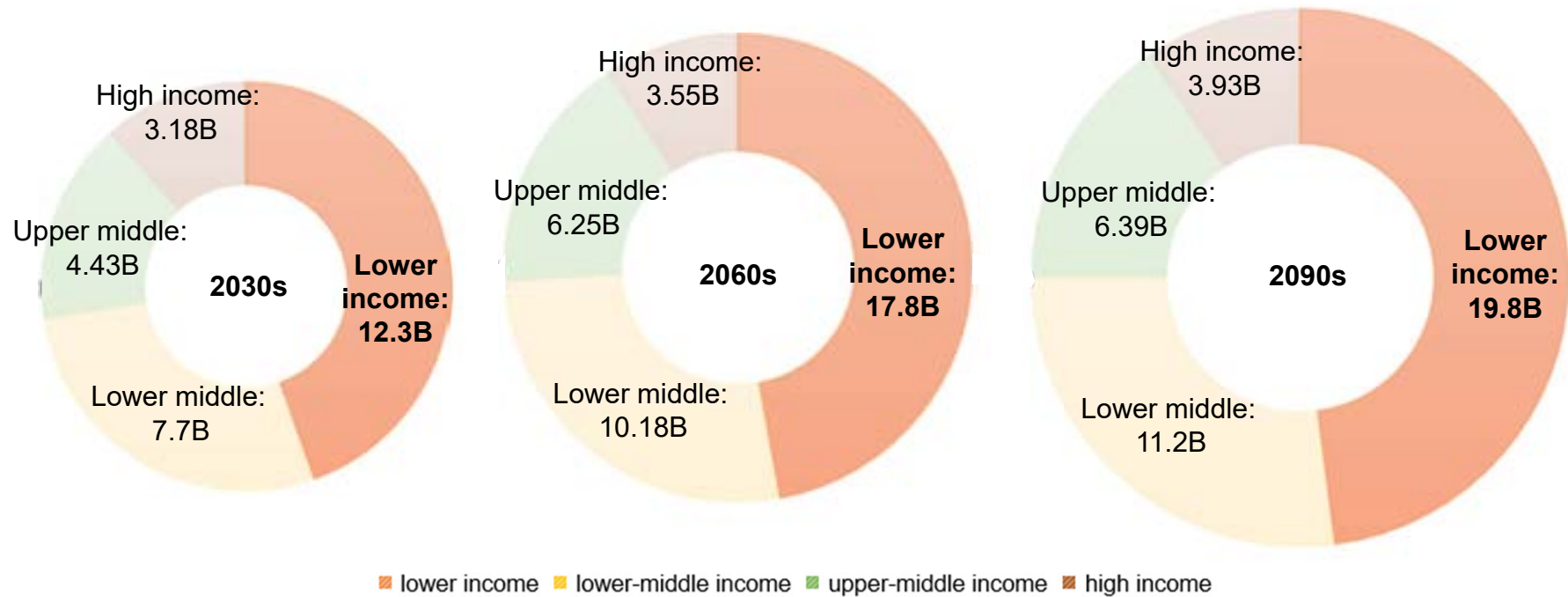
World Recorded Heat Waves

As of July 10, 2023. Recorded during the last six years, in deg C. European record still being validated by the WMO.



Increasing Heat-Stress Inequality in a Warming Climate

Exposure to heatwaves (billion person-days per year)



Alizadeh et al., 2022, Earth's Future: <https://doi.org/10.1029/2021EF002488> | Credit: Mohammadreza.Alizadeh@mail.mcgill.ca

Heat Resilient Design Strategy

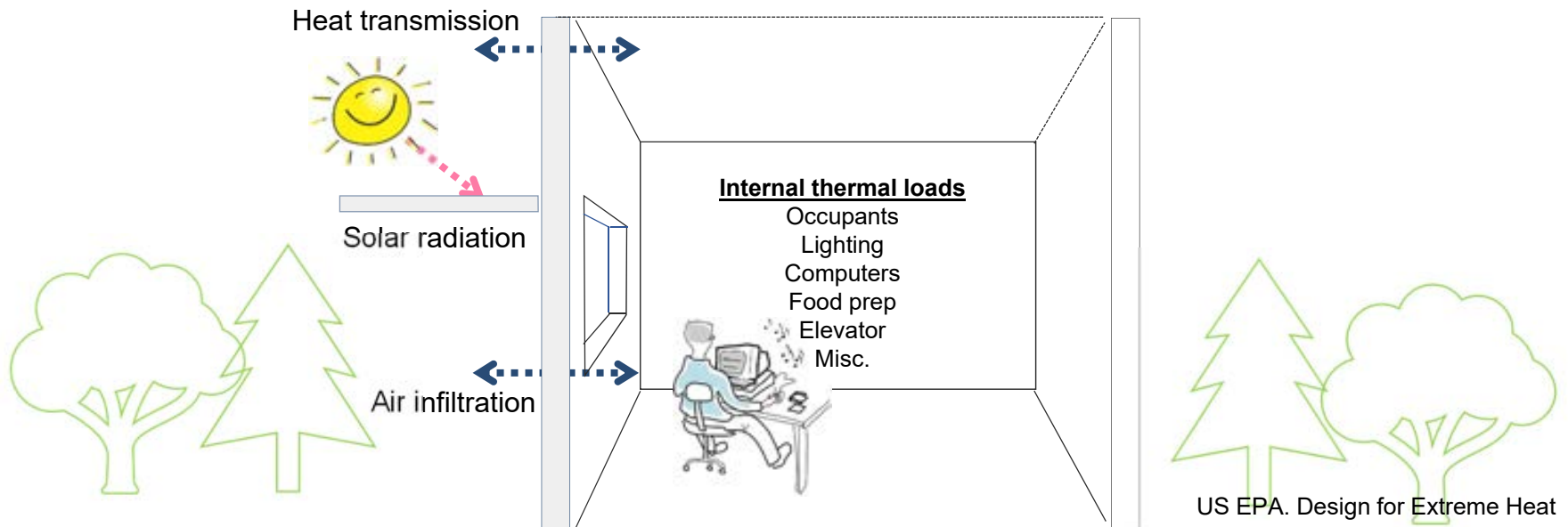
- 1.Minimize heat gain.
- 2.Provide emergency cooling.
- 3.Provide a backup power source with enough capacity to supply emergency cooling.

Heat Resilient Design Strategy

1. Minimize heat gain.
2. Provide emergency cooling.
3. Provide a backup power source with enough capacity to supply emergency cooling.

Bioclimatic Design. Regulation of unwanted heat gain:

1. Plant trees/vegetation and minimize concrete/asphalt surfaces around the building site.
2. Minimize aperture areas especially east-west facing window.
3. Increase shading efficacy – lower SHGC and shading device.
4. Provide air tight construction.
5. Increase insulation.
6. Maximize natural cooling when possible (e.g. roof venting, attic ventilation)
7. Use high solar reflective index (SRI) for building surfaces.



Heat Resilient Design Strategy

1. Minimize heat gain.
2. Provide emergency cooling.
3. Provide a backup power source with enough capacity to supply emergency cooling.

Energy Efficient Building Service Systems:

1. Install Energy Recovery Ventilator for air conditioning.
2. Provide a proper ventilation rate for good fresh air circulation.
3. Use high efficiency appliance for energy savings and locate them in a shaded area.
4. Use LED lighting to reduce internal heat gains.
5. Install ducts with insulated space.

Heat Resilient Design Strategy

1. Minimize heat gain.
2. Provide emergency cooling.
3. Provide a backup power source with enough capacity to supply emergency cooling.

Emergency Cooling System:

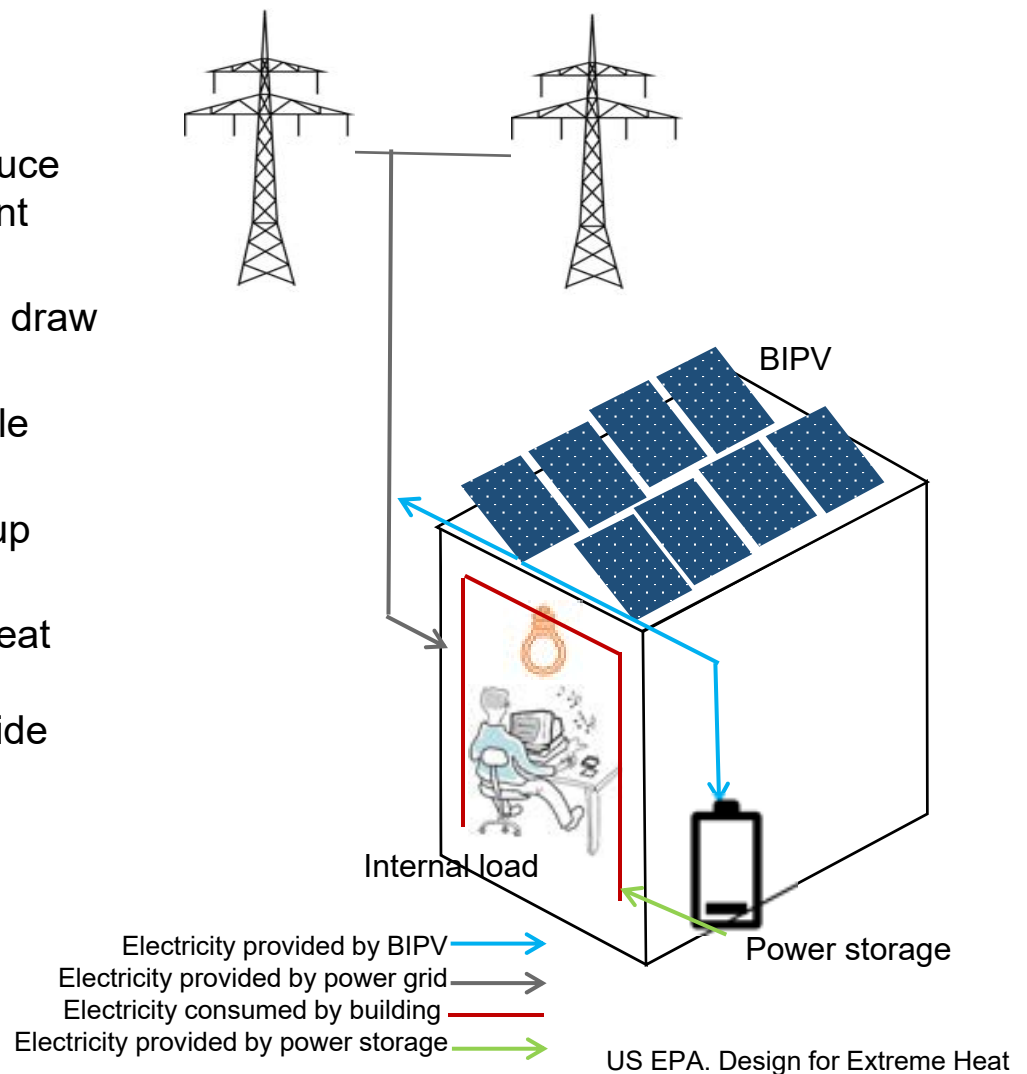
1. Choose right size equipment instead of oversized air conditioning.
2. Ground-source heat pumps are less vulnerable to extreme temperature due to stable ground temperatures.
3. Provide back-up power system in case of power shortage.
4. Consider alternative cooling options such as evaporative cooling (dry climates), ice and cold water refrigeration, fans, night flush, earth coupling, and other natural cooling strategies.
5. Minimize cooking and keep activities to the coolest areas.
6. Use LED lighting to reduce internal heat gains.
7. Install ducts with insulated space.

Heat Resilient Design Strategy

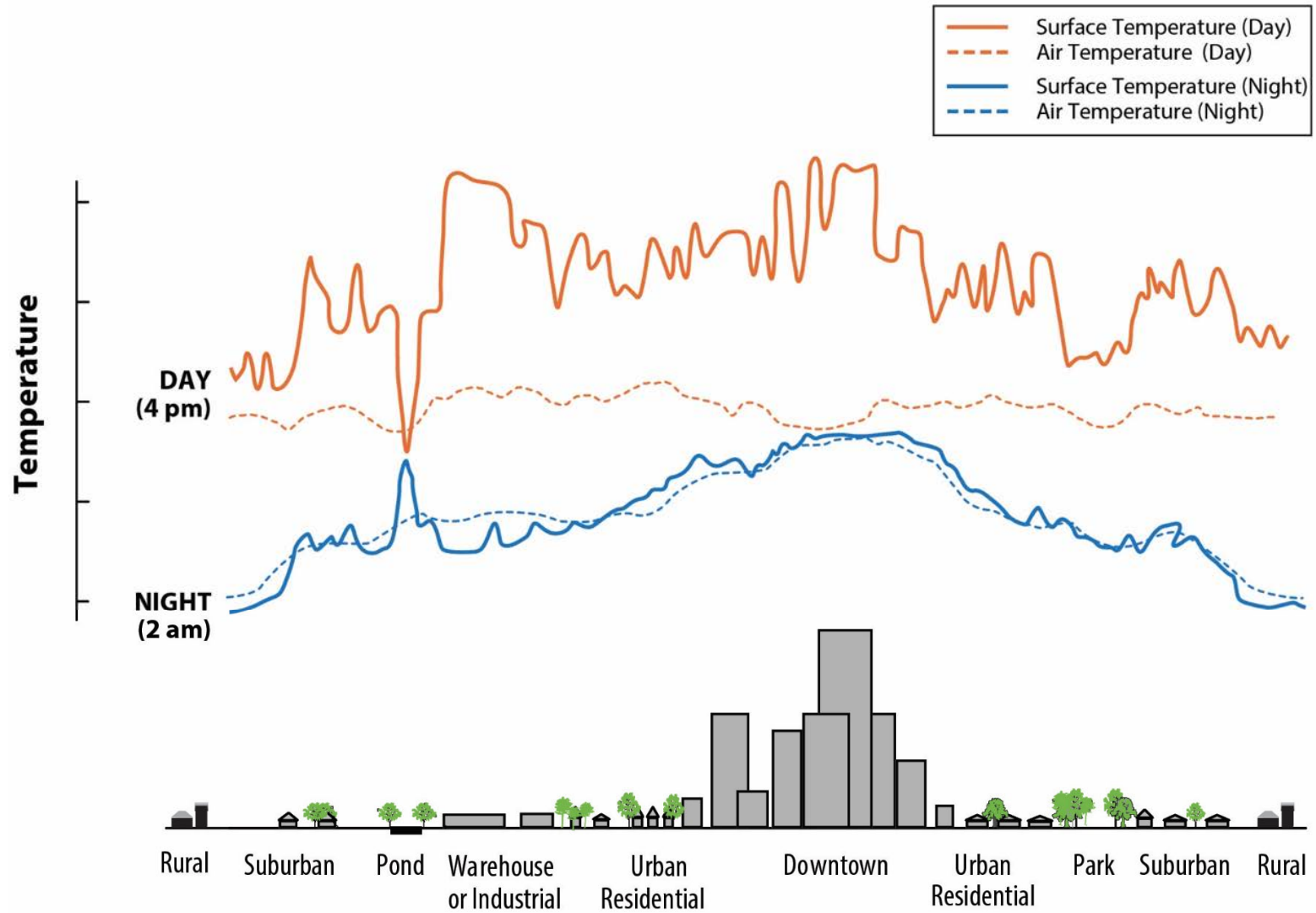
1. Minimize heat gain.
2. Provide emergency cooling.
3. Provide a backup power source with enough capacity to supply emergency cooling.

Back-up Power Systems:

1. Reduce energy consumption. Reduce heat gain and install energy efficient appliances and systems.
2. Prioritize electrical loads to reduce draw on back up power.
3. Install building integrated renewable systems (e.g. BIPV).
4. Install a generator or battery backup power.
5. An extreme heat event with high heat and humidity as well as wild fires aggravates indoor air quality. Provide high MERV filters and ventilations.



Heat Island Inequity



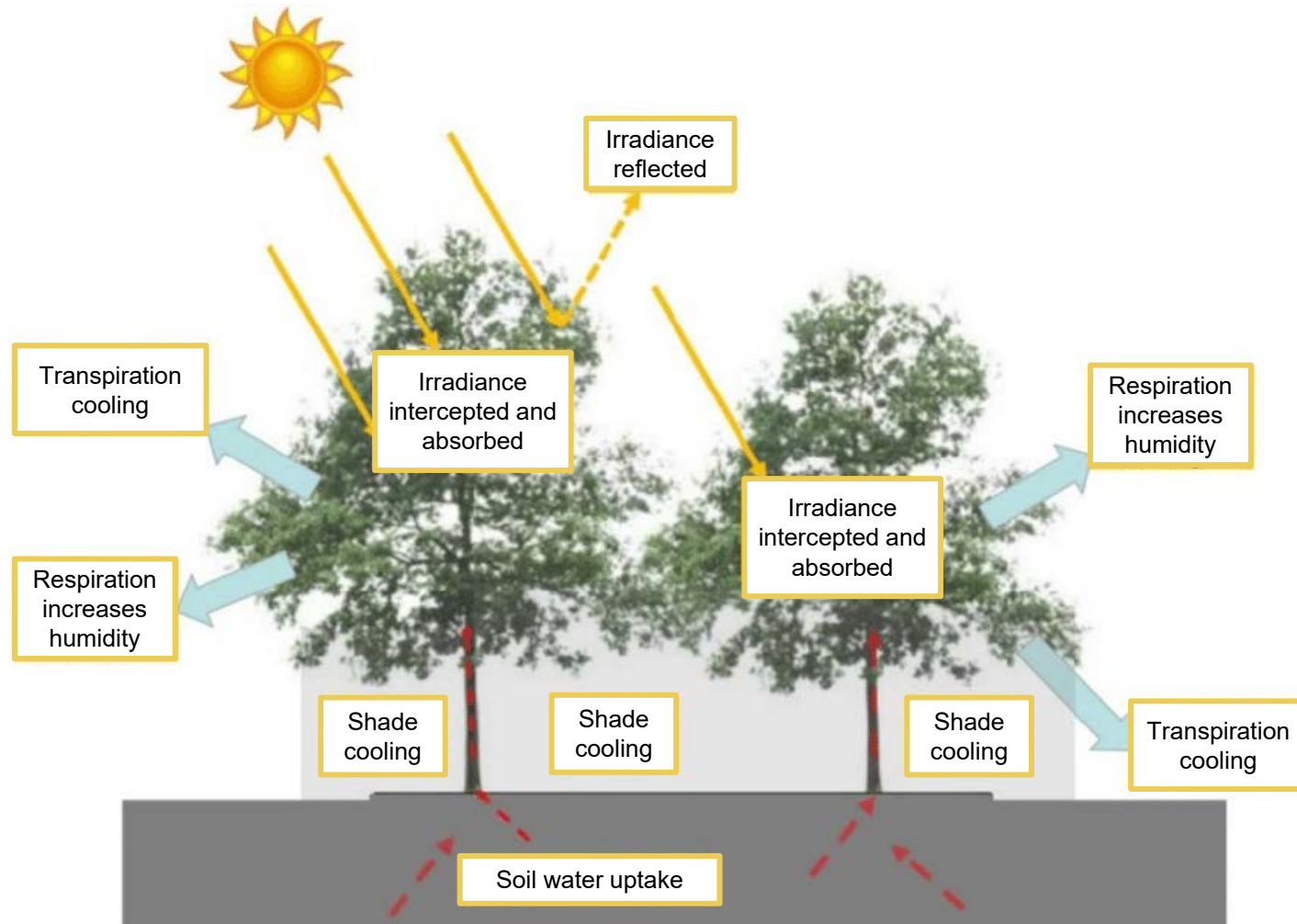
Heat Island Inequity

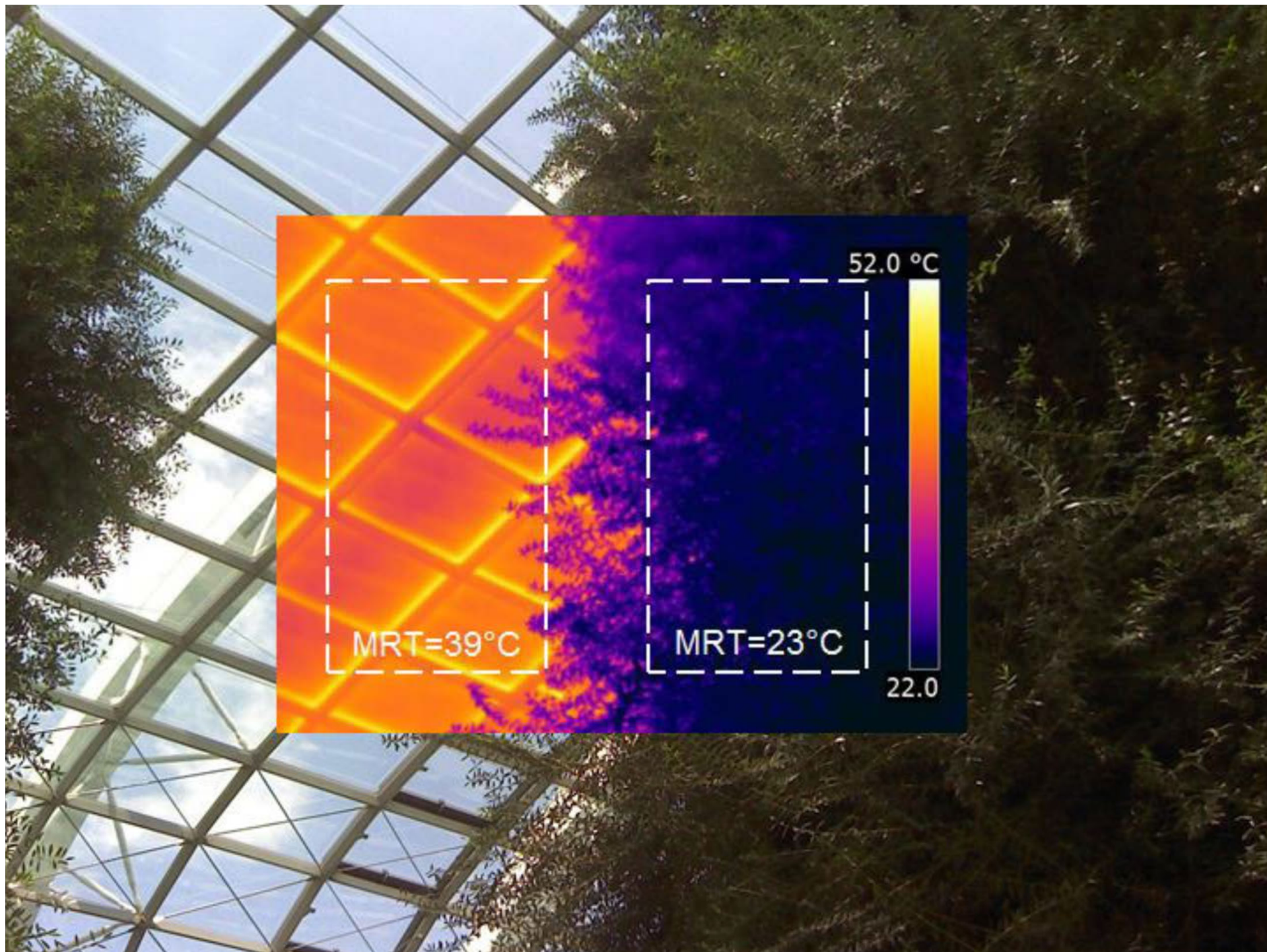
Excessive heat is a financial burden for many people, especially low-income households. For instance, about 30% of all U.S. households report that they have difficulty paying energy bills or that they are unable to cool their homes due to cost concerns.^{[iii](#)} Low-income households also tend to live in less energy-efficient homes that are more expensive to cool.^{[iv](#)} The inability to afford household energy needs, or “energy insecurity,” makes it harder to stay cool, comfortable, and healthy during periods of extreme heat.

Heat Island Inequity

one study analyzed almost 500 U.S. urban areas using 2017 data.¹ This study found that heat island effects were typically less severe in census tracts with higher median incomes and a higher proportions of White people. Neighborhoods with higher numbers of Black residents tended to have more intense heat island effects than other areas

Heat Island Inequity: Cooling Effect of Trees



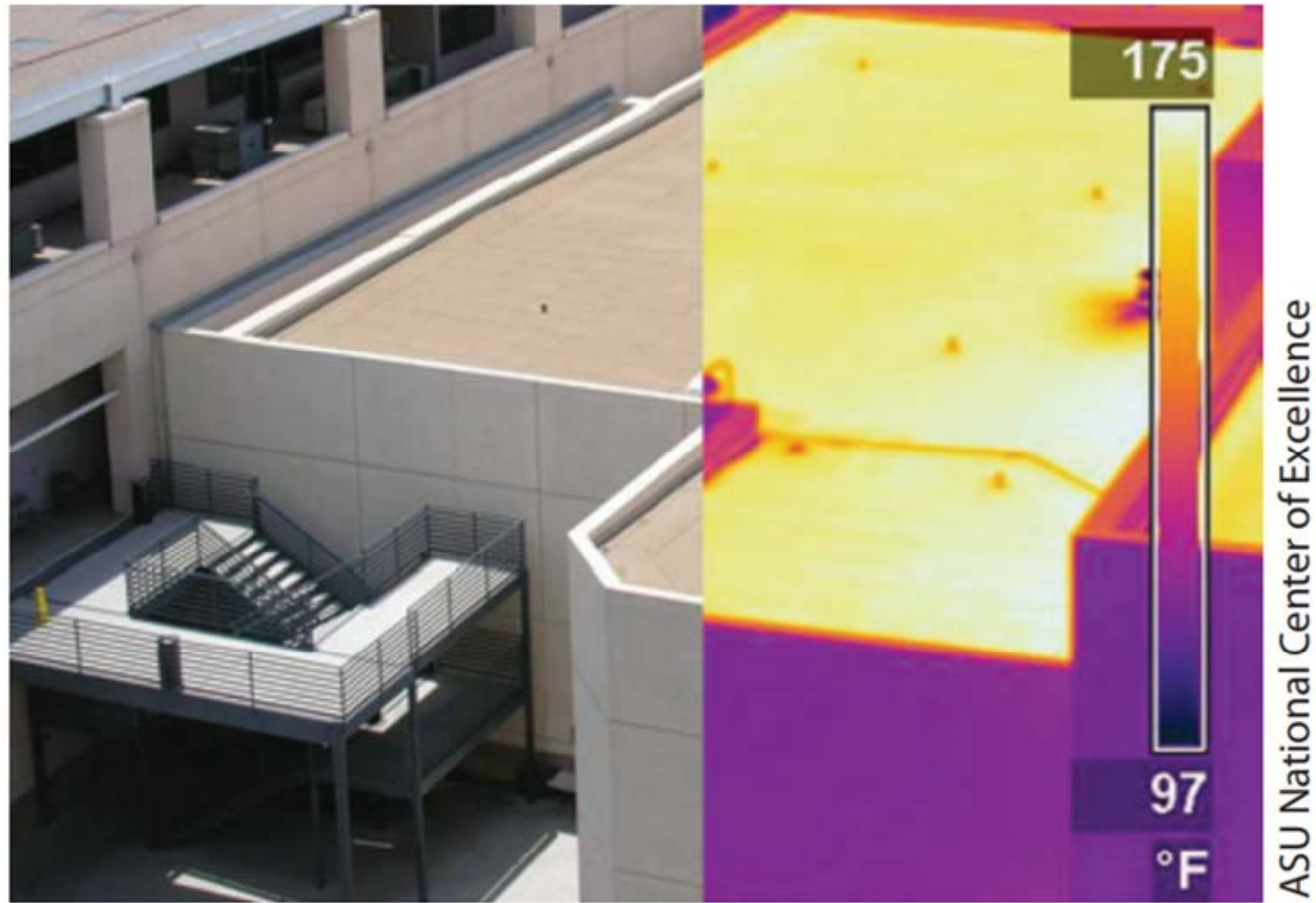


Heat Island Inequity: Cooling Effect of Green Roof



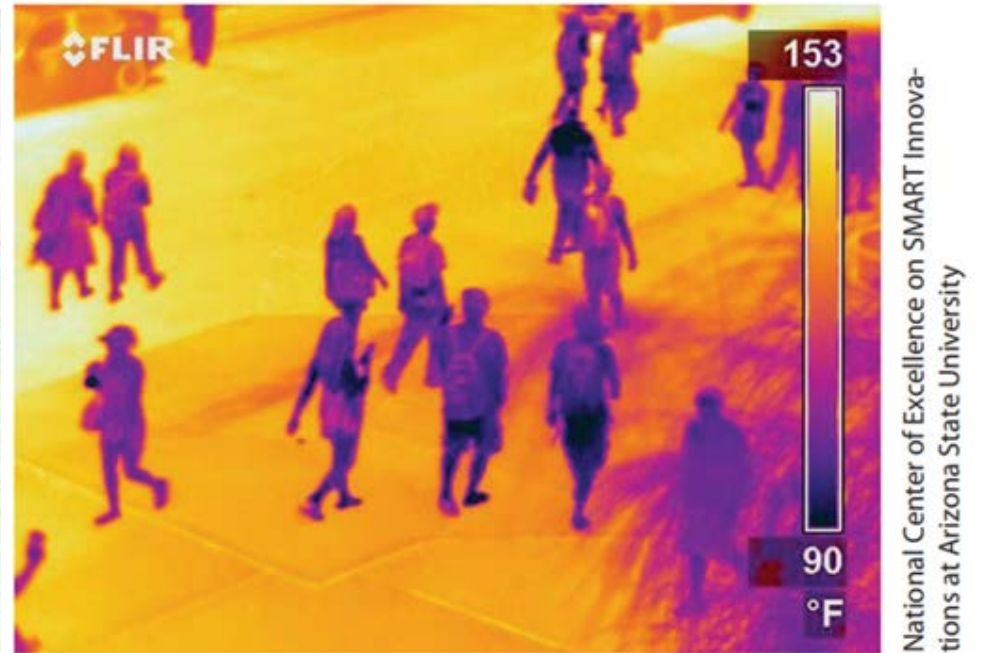
Temperature differences between a green and conventional Roof; green roof measures almost 80degF (40degF) cooler than the neighboring conventional roof

Heat Island Inequity: Cooling Effect of Cool Roof



Temperature of Conventional Roof reached 175degF (80degC)

Heat Island Inequity: Cooling Effect of Cool Pavements



Conventional pavement temperatures reached up to 150degF (67degC)



energy resilient built environment

Climate Resilient Hospitals



Climate Resilient Hospitals



Climate Resilient Hospitals



Health workforce:

Adequate numbers of skilled human recourse with decent working conditions, empowered and informed to respond to these environmental challenges



Water, sanitation hygiene and health care waste management:

Sustainable and safe management of water, sanitation and health care waste services.



Energy:

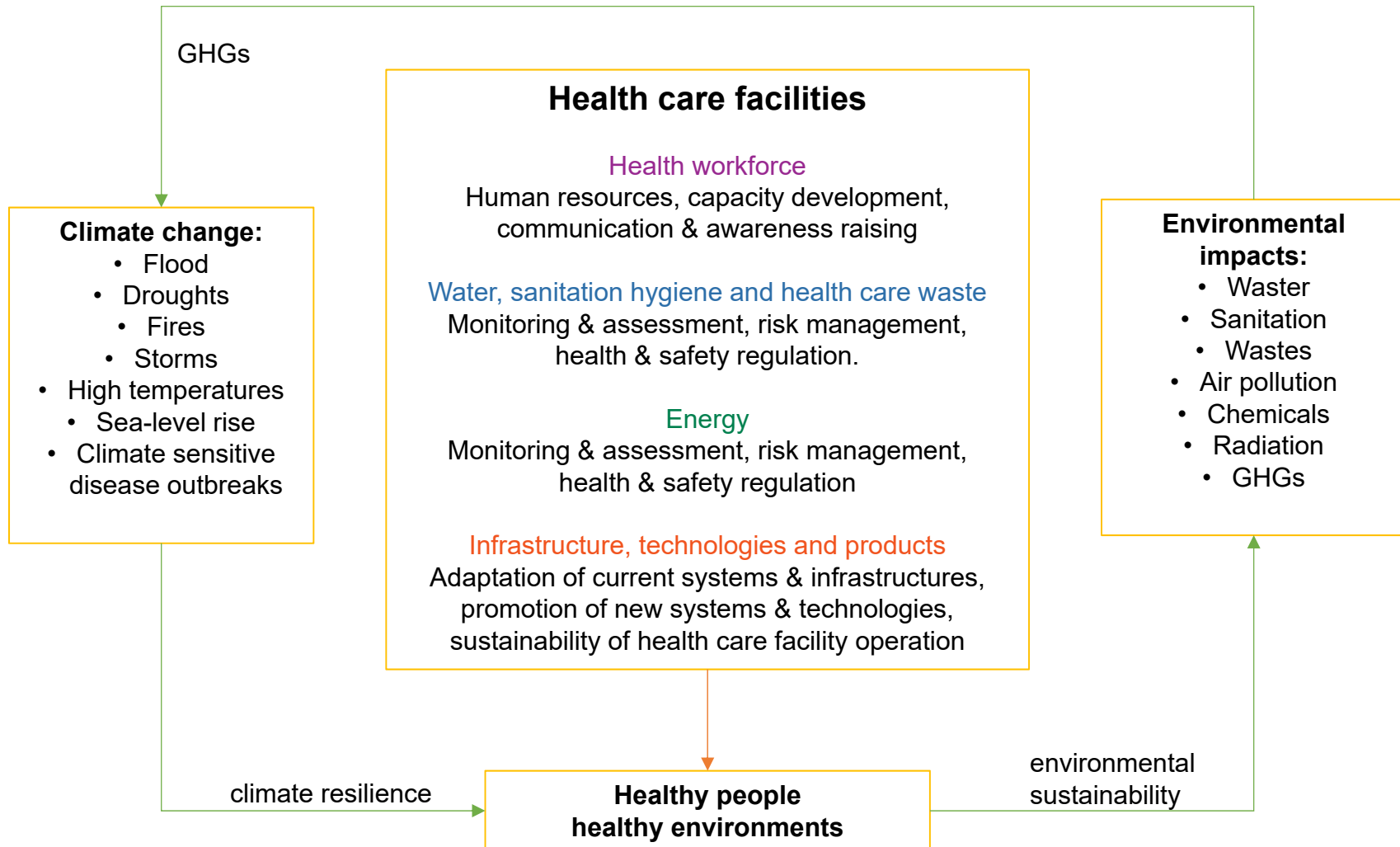
Sustainable energy services.



Infrastructure, technologies and products:

Appropriate infrastructure, technologies, products and processes, including all the operations that allow for the efficient functioning of the health care facility.

Climate Resilient Hospitals



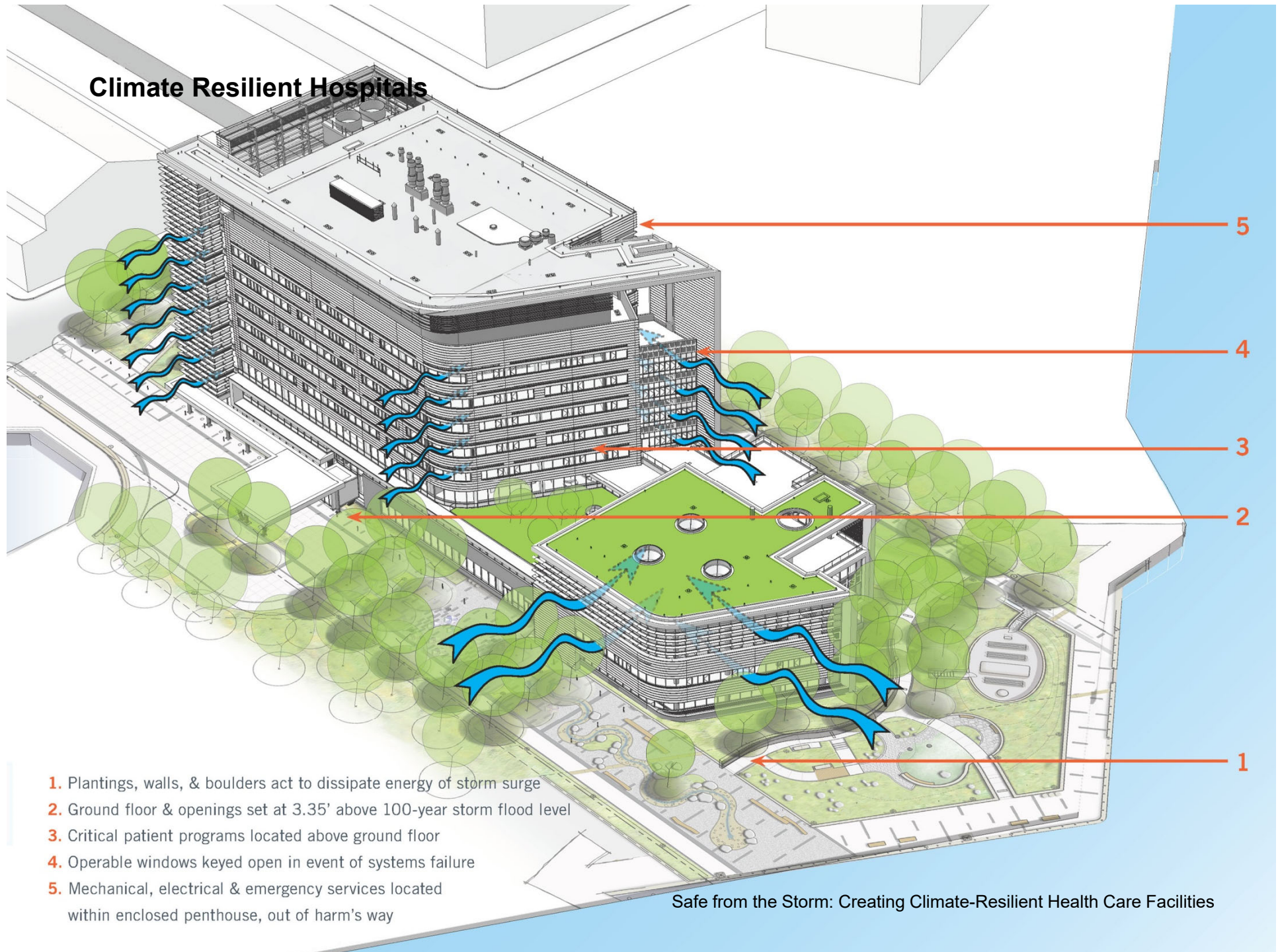
Climate Resilient Hospitals

Daily Fuel Consumption by Healthcare and Public Health Sector Facilities



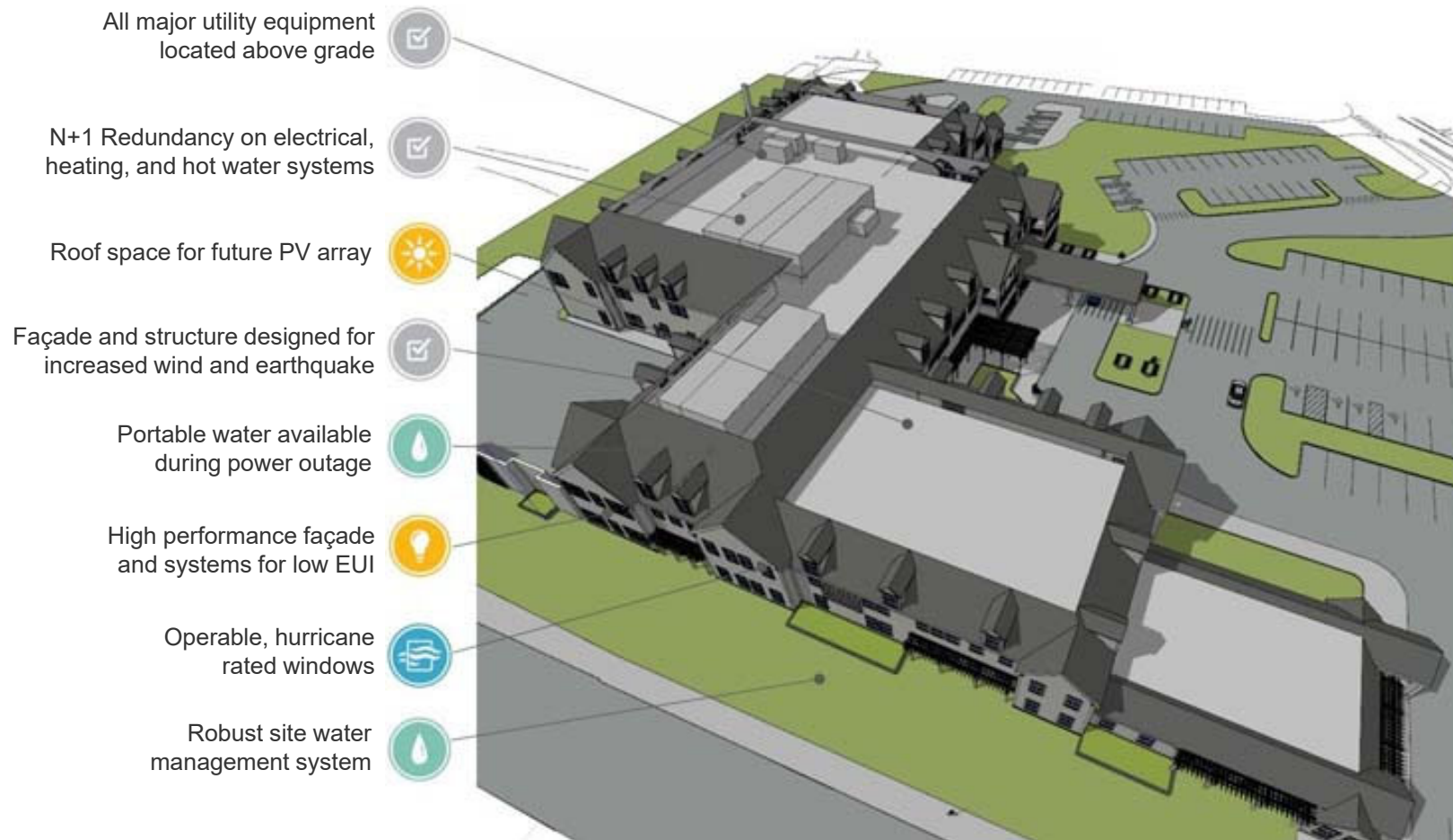
Type of Facility	Generator Size	Fuel Requirement in Gallons (low)	Fuel requirement in Gallons (high)
Hospitals	800kW-2MW	1344	2000
Nursing Homes	100-200kW	168	336
Urgent Care	200-300kW	336	504
Dialysis Center	200-300kW	336	504
Medical Center	200-300kW	336	504
Morgue	100-200kW	168	335

Climate Resilient Hospitals



Safe from the Storm: Creating Climate-Resilient Health Care Facilities

Climate Resilient Hospitals



Storms and Climate Change Prompt Need for More-Resilient Hospital Design

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**