Resiliency in the Built Environment

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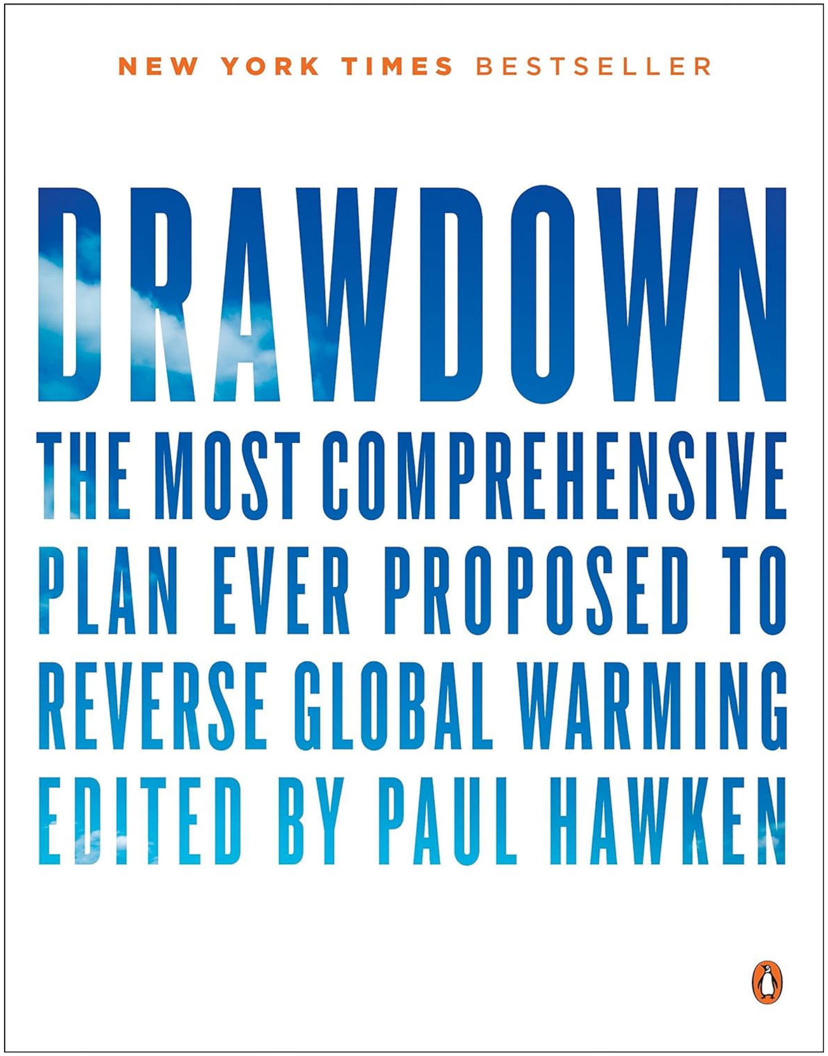
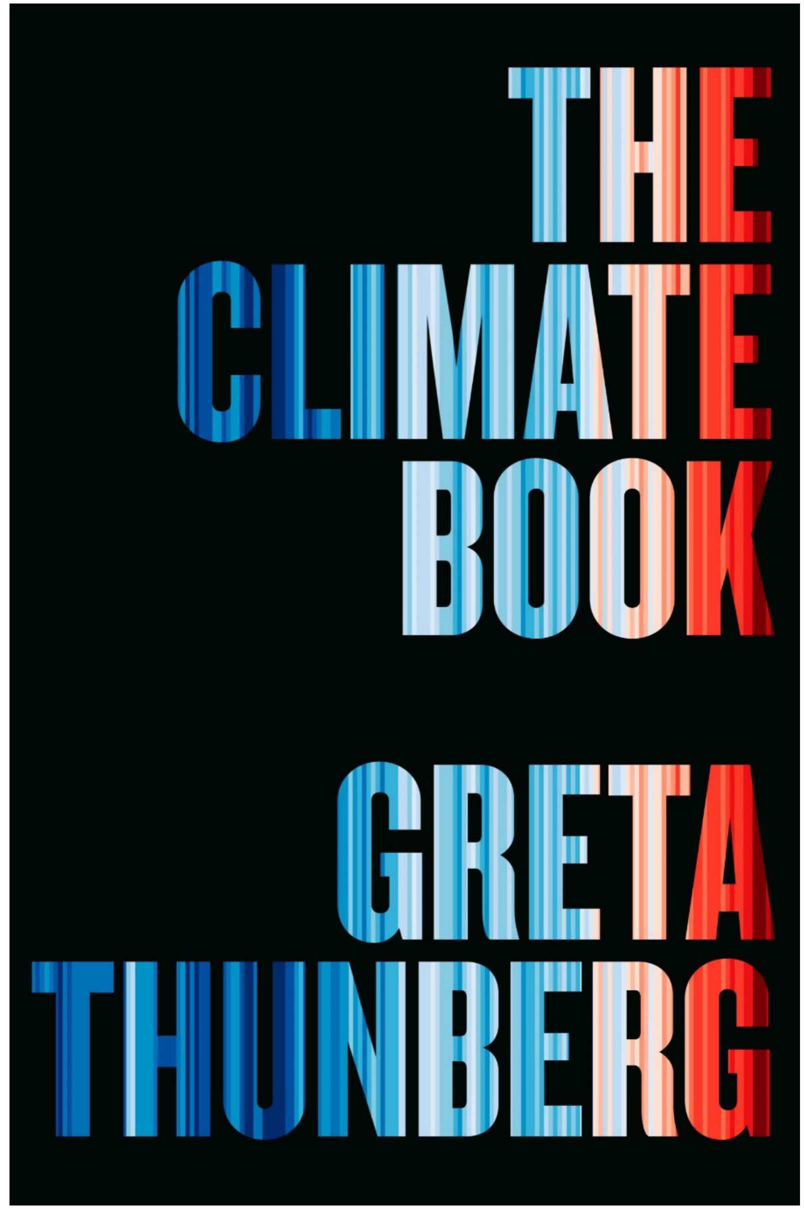
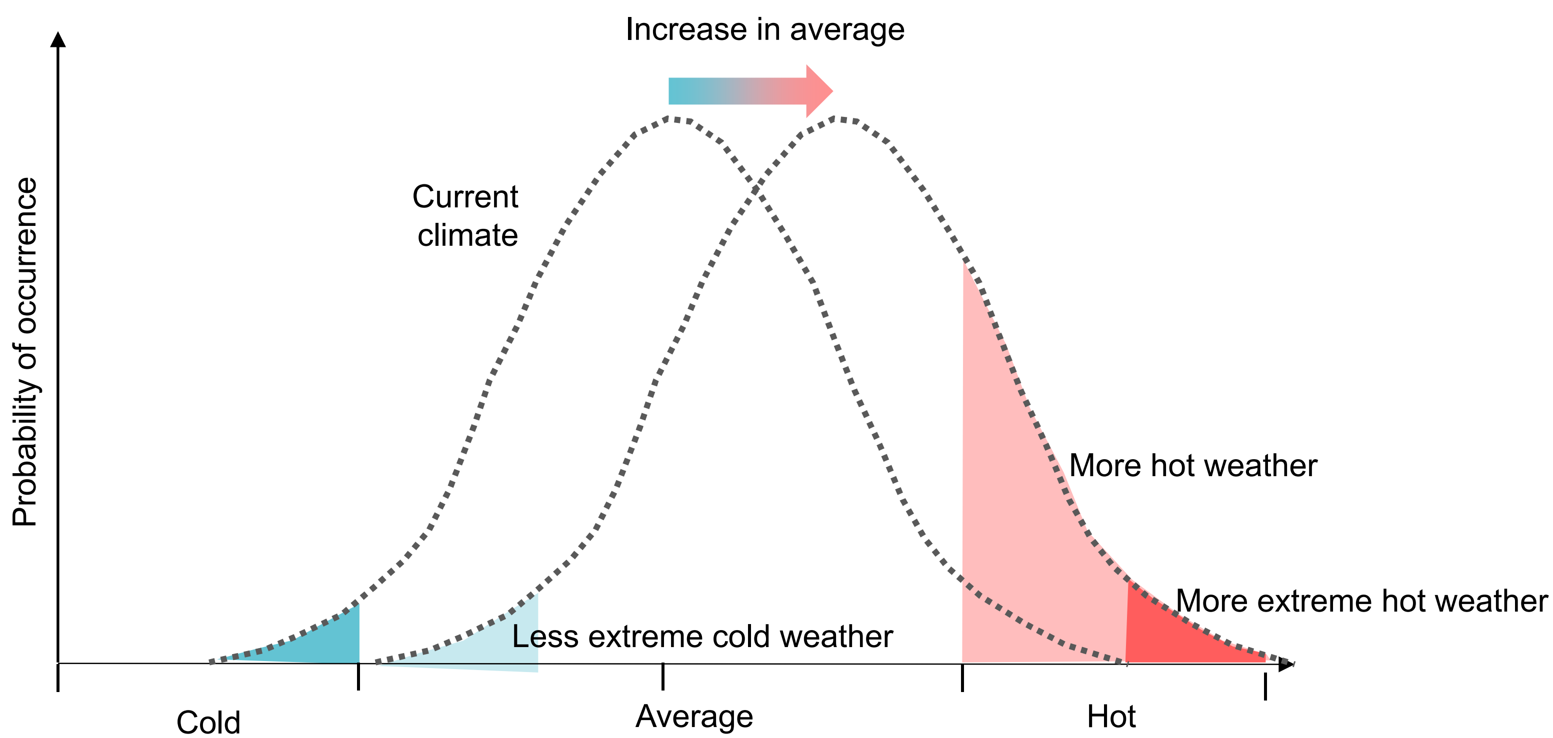

NEW YORK TIMES BESTSELLER
DRAWDOWN
THE MOST COMPREHENSIVE PLAN EVER PROPOSED TO REVERSE GLOBAL WARMING
EDITED BY PAUL HAWKEN

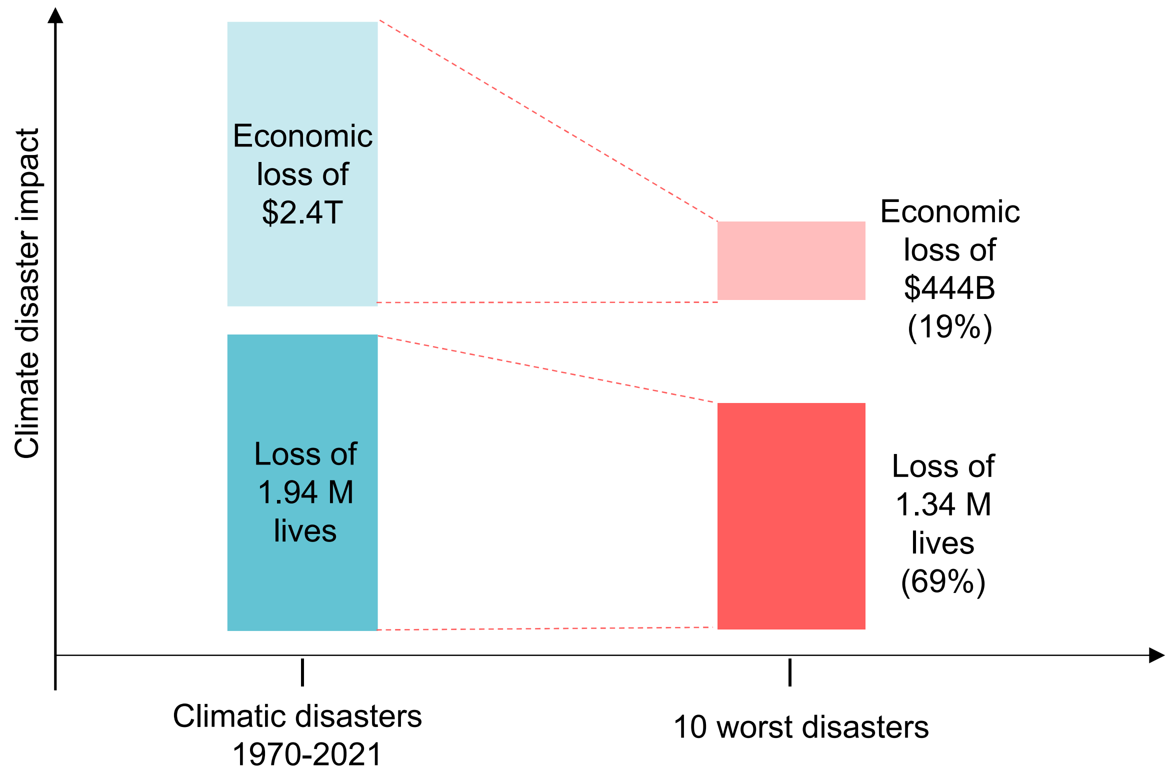

THE CLIMATE BOOK
GRETA THUNBERG

Climate Changes



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

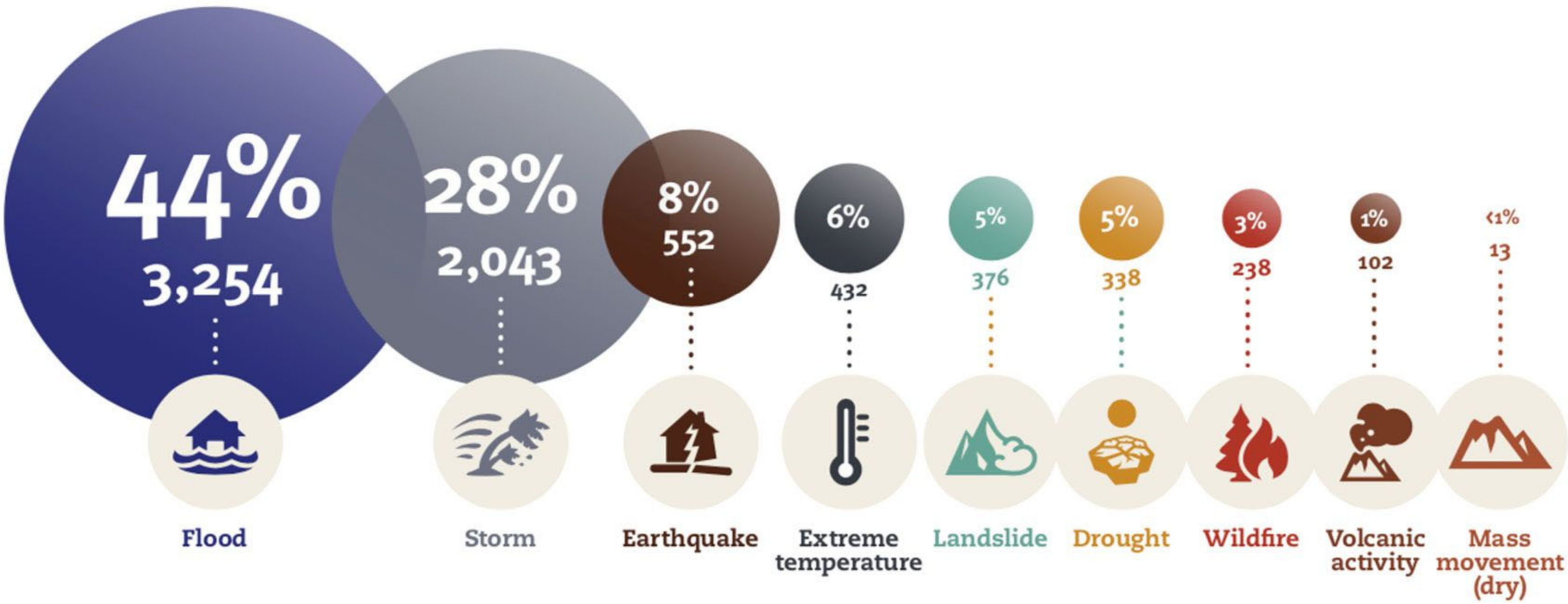
Climate Related Disasters (World)



World Meteorological Organization, 2014

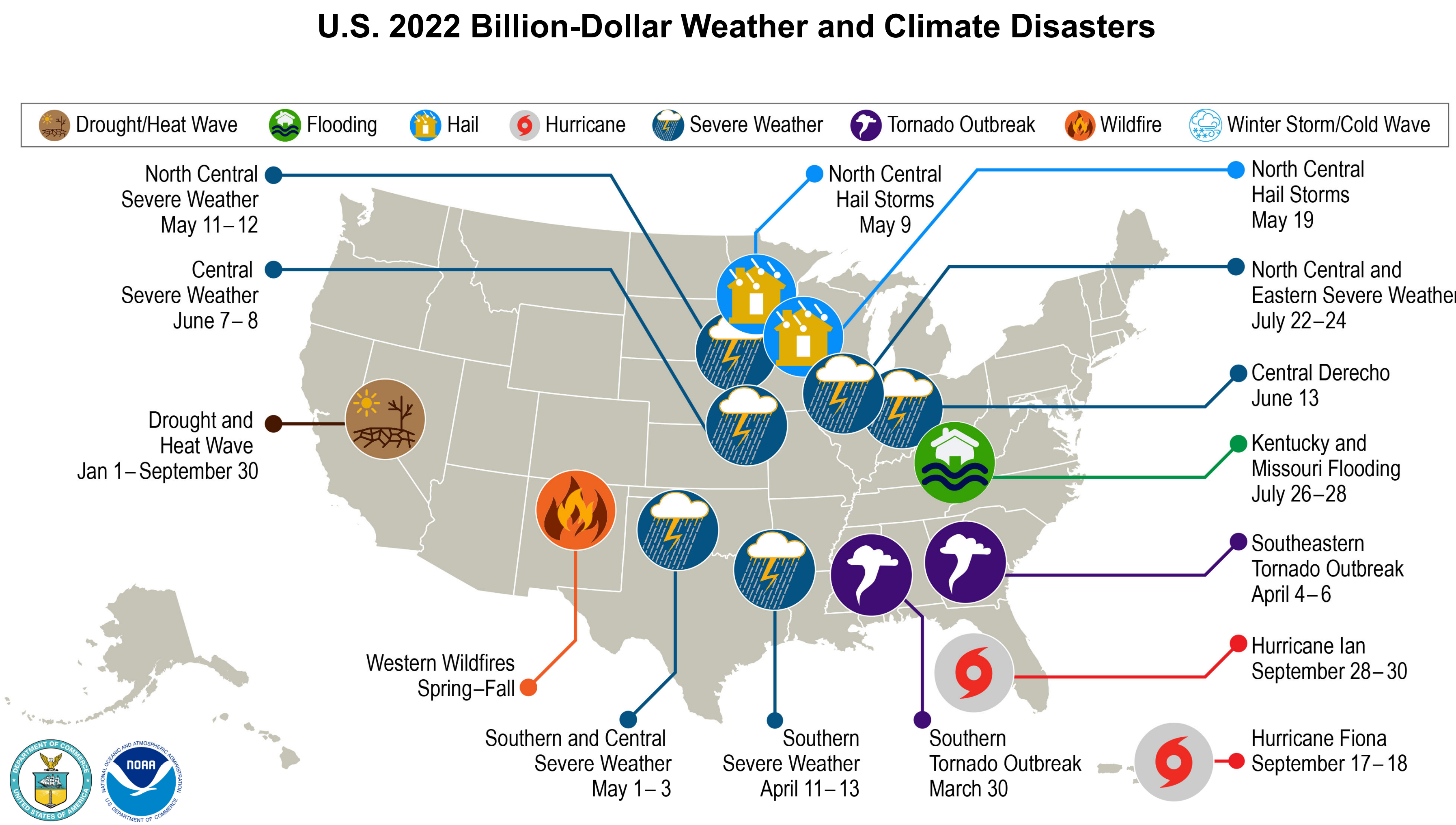
Climate Related Disasters (World)

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)



*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.***

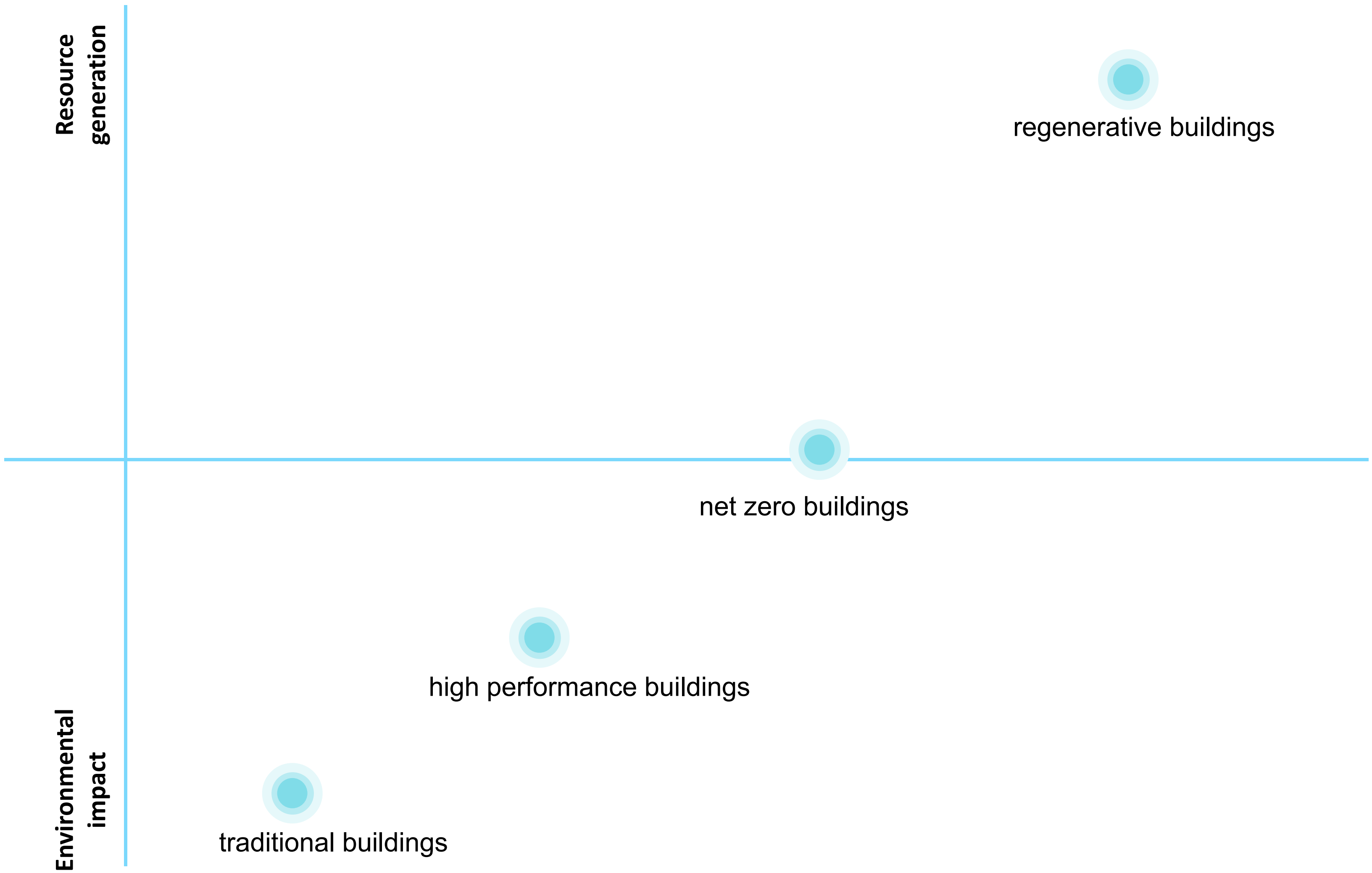
Resilience

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

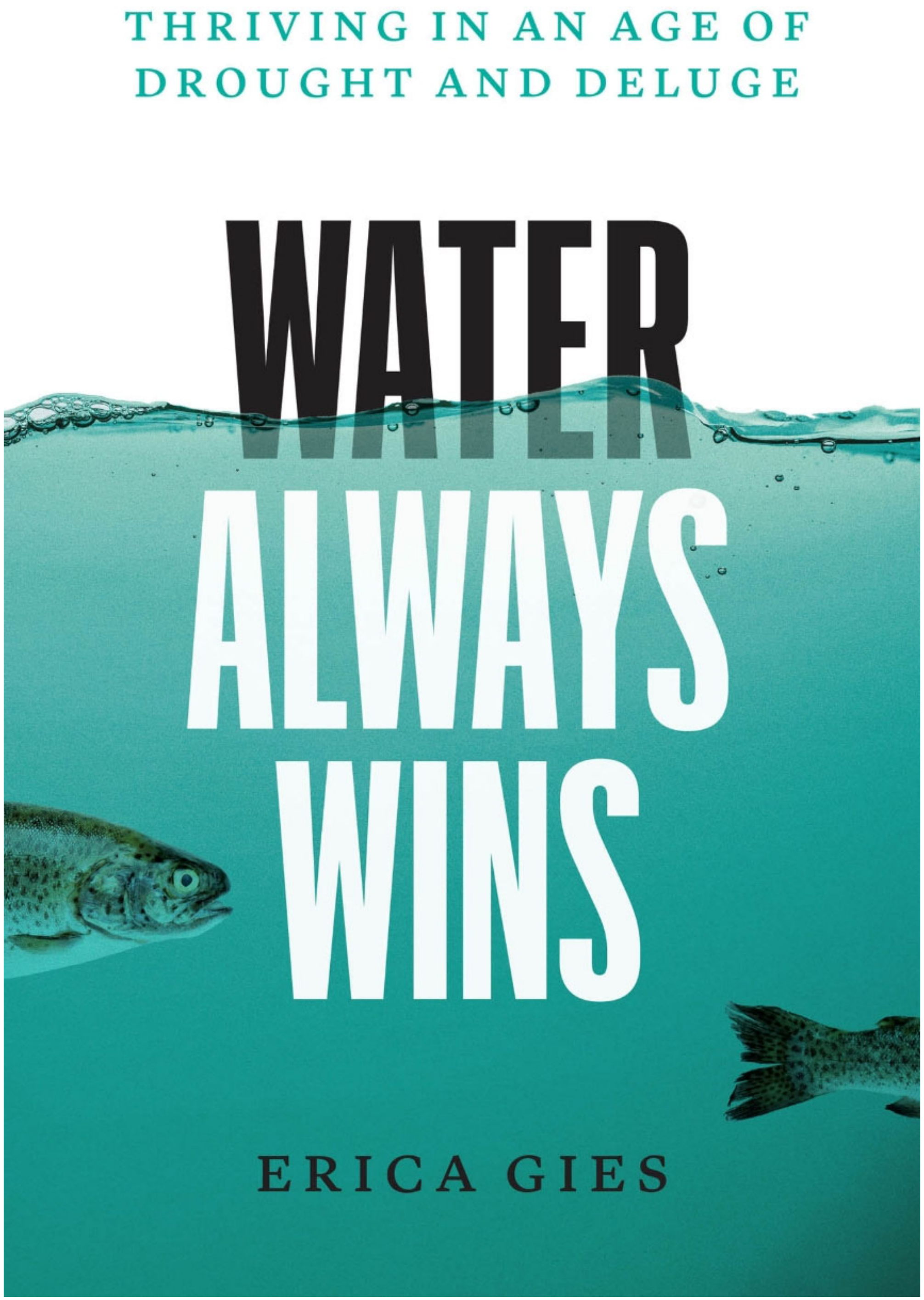
: an ability to recover from or adjust easily to misfortune or change

Toward Resilient Built Environment

Toward Resilient Built Environment



water resilient built environment

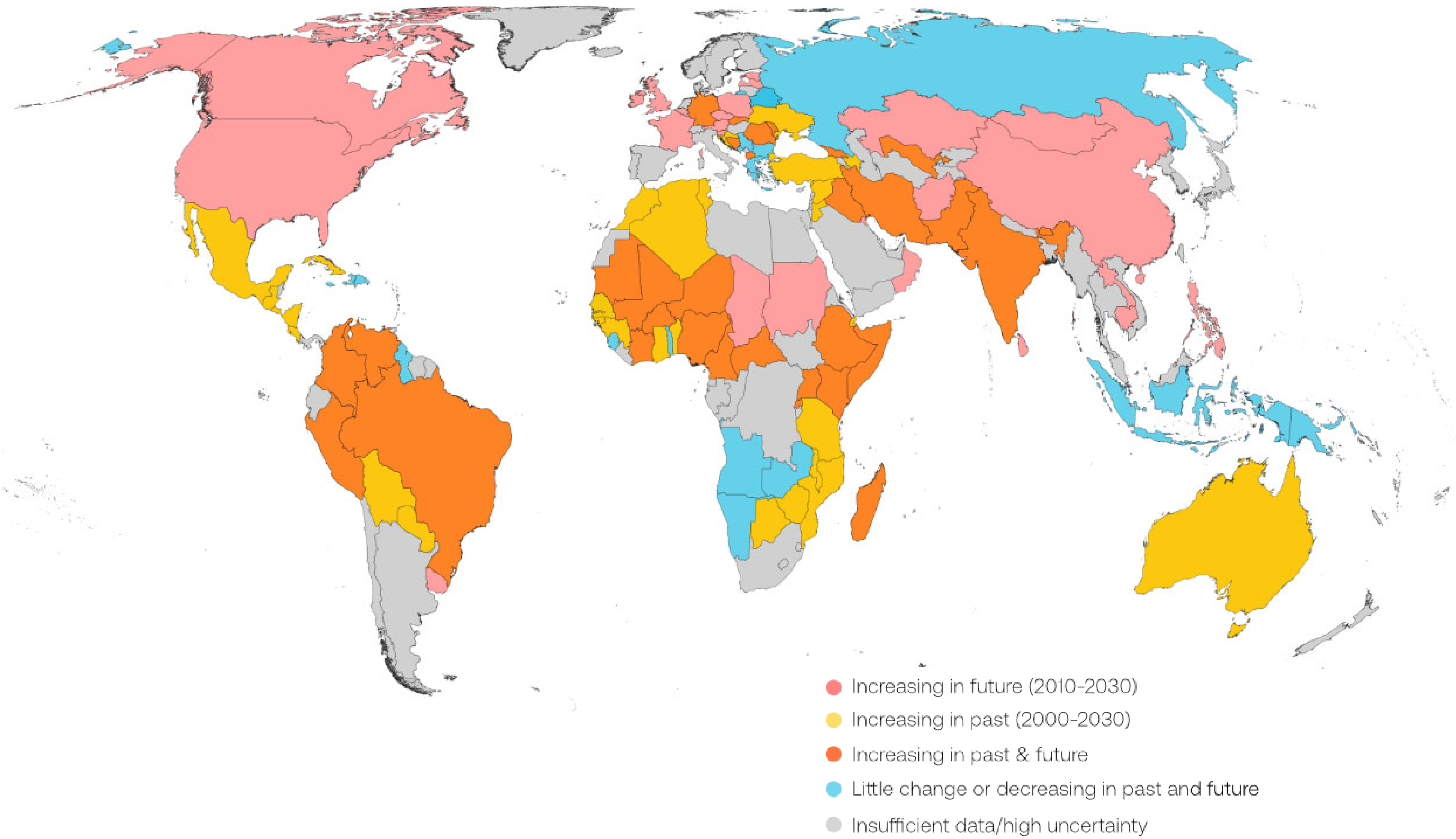


“Modern civilizations tend to speed water away, erasing its slow phases on the land. Gies reminds us that water’s true nature is to flex with the rhythms of the earth: the slow phases absorb floods, store water for droughts, and feed natural systems.”


TOUR
WORLD

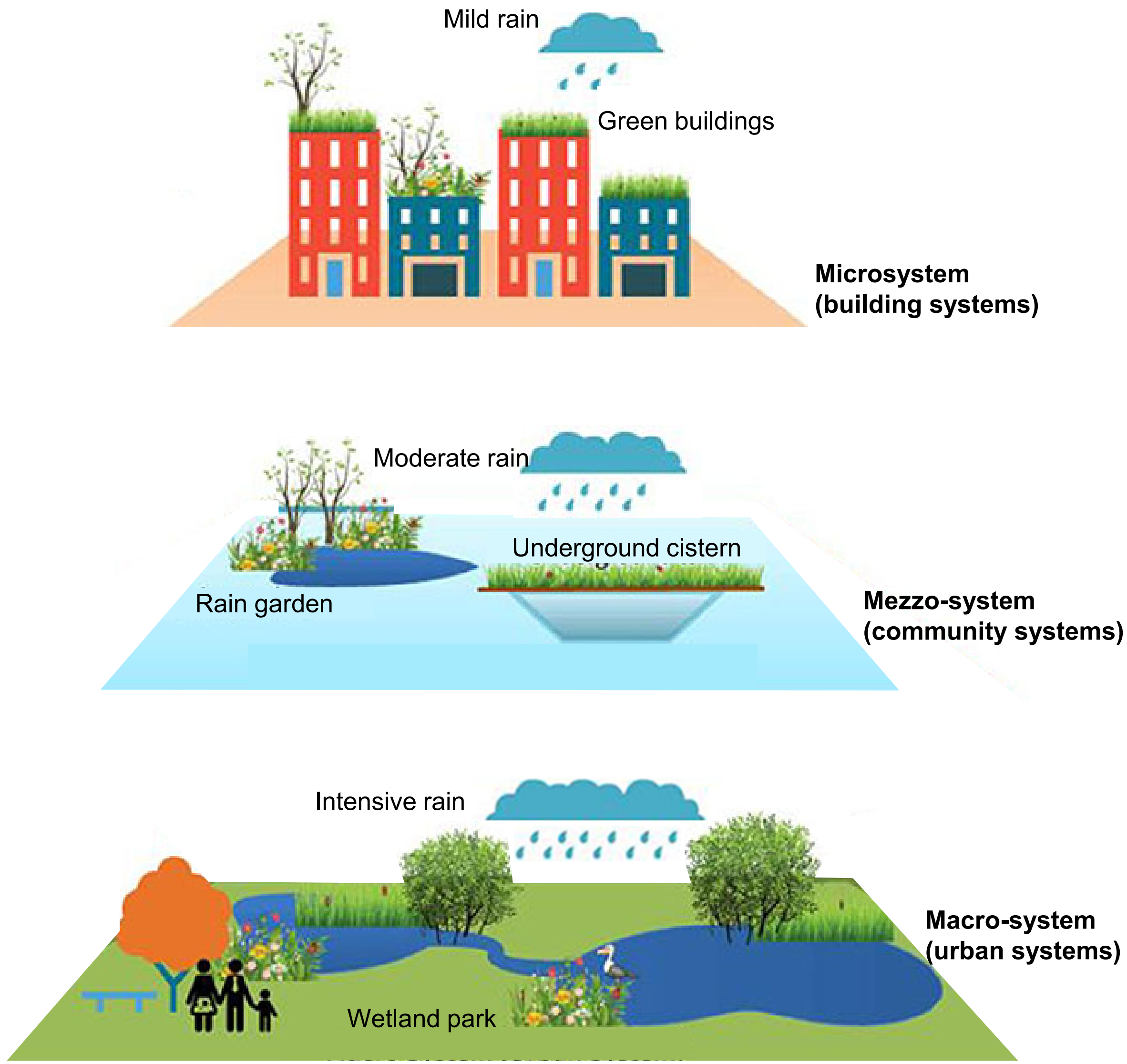

나가는 곳
Storage

Global Flooding Risks



Global Flood Database 2000-2015

Flooding Resiliency Framework



Qi et al. Exploring the Development of the Sponge City Program, 2021

Flooding Resiliency Framework

PROTECT

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

DELAY

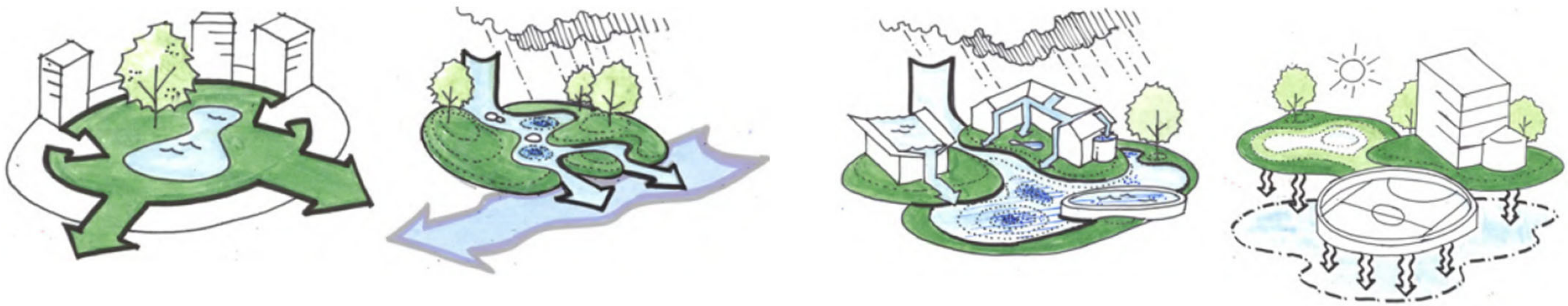
stormwater runoff from reaching drains, canals, and rivers

STORE

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

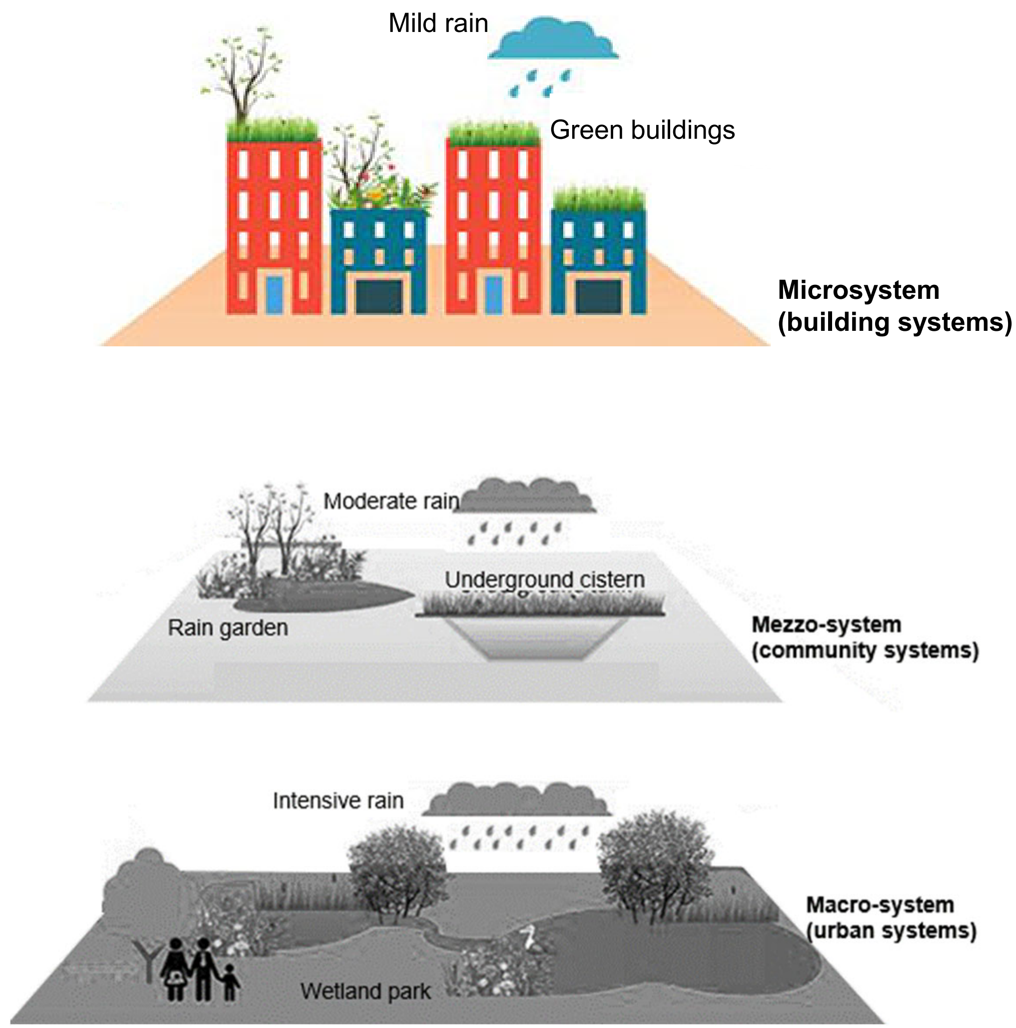
RELEASE

rainwater into the aquifer to recharge groundwater



The Sponge Handbook: Chennai, 2019

Flooding Resiliency Framework: Nature Integrated Buildings



Qi et al. Exploring the Development of the Sponge City Program, 2021

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.

US GSA

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.

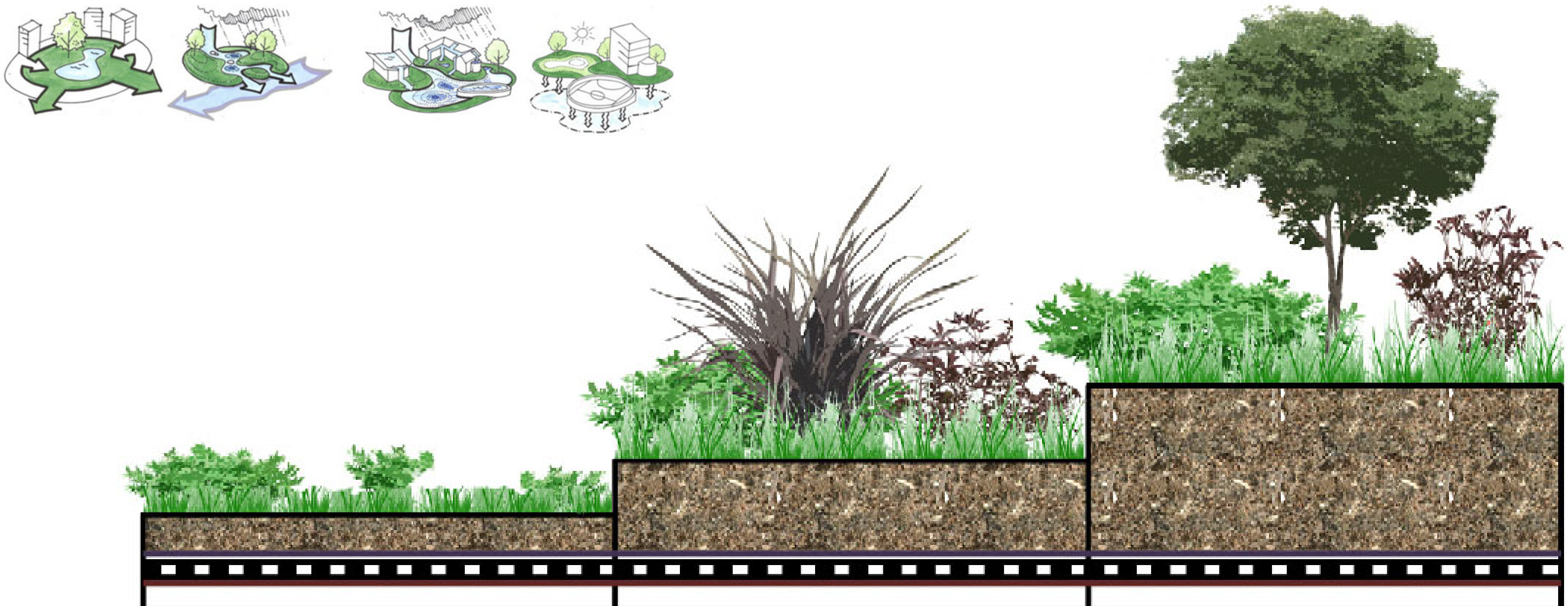
7. **Reduce stress**. Studies have shown that being near nature can have a calming effect and alleviate anxiety.

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

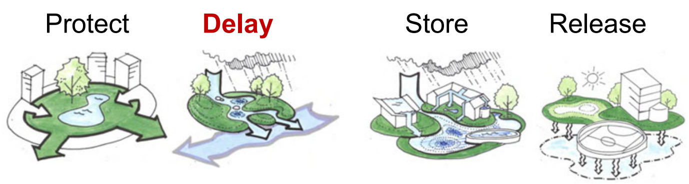
Protect **Delay** Store Release

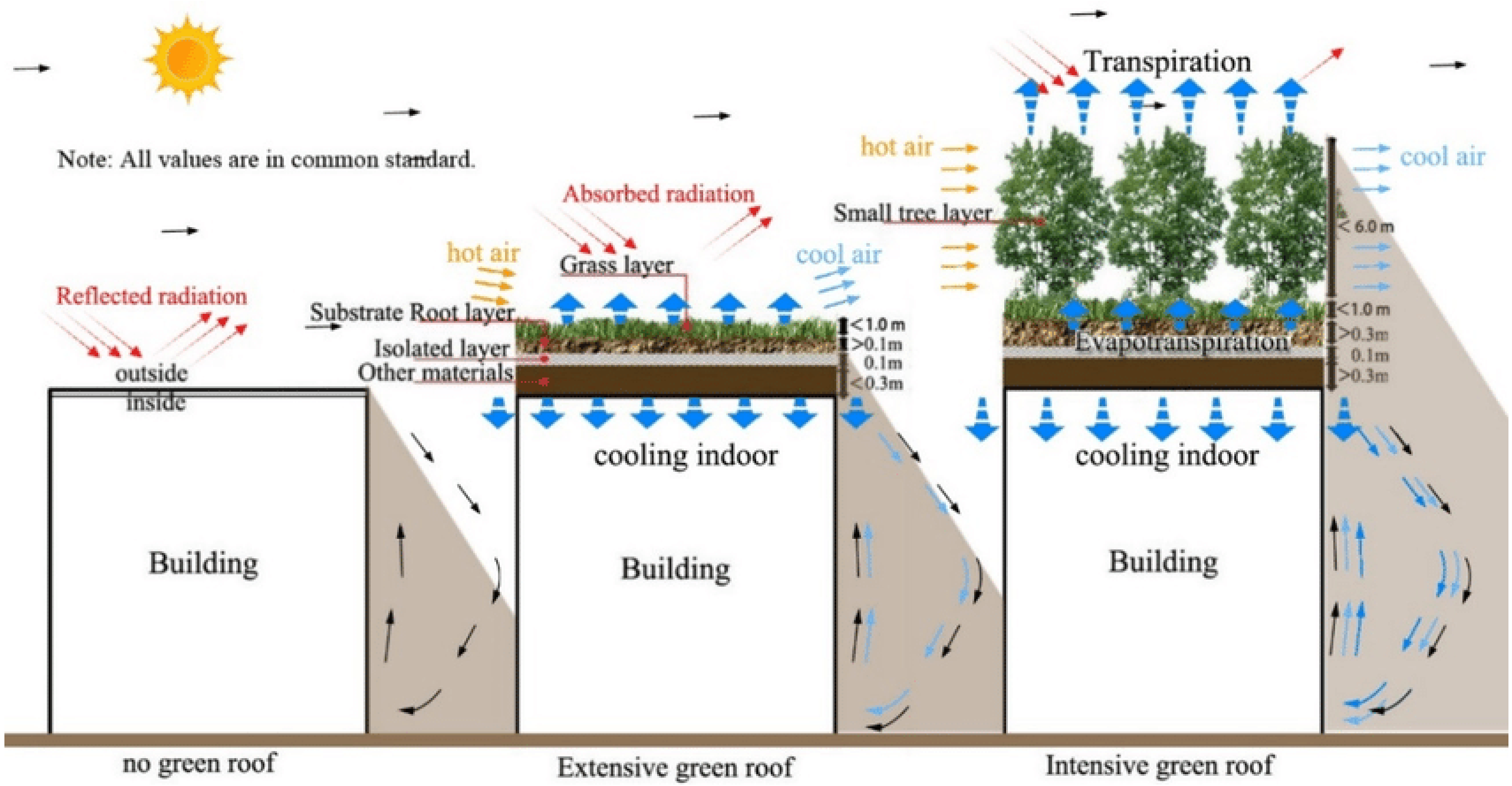


EXTENSIVE GREEN ROOF	SEMI-INTENSIVE GREEN ROOF	INTENSIVE GREEN ROOF
Height: 6- 20 cm	**Height** : 12 - 25 cm	**Height** : 15 cm > 1m
Weight: 60 - 150 kg/m²	**Weight** : 120 - 200 kg/m²	**Weight** : 180 - 500 kg/m²
Vegetation: mosses, sedums, herbs and grasses	**Vegetation** : grasses, herbs and shrubs	**Vegetation** : lawn, perennials, shrubs and small trees
Cost: low	**Cost**: middle	**Cost**: high
Maintenance: low	**Maintenance** : periodically	**Maintenance** : regularly

Green roof systems: a study of public attitudes and preferences in southern Spain;
10.1016/j.jenvman.2013.04.052

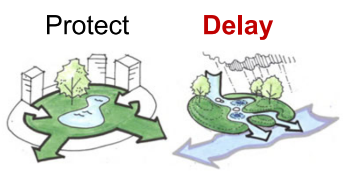
Intensive vs Extensive Green Roof

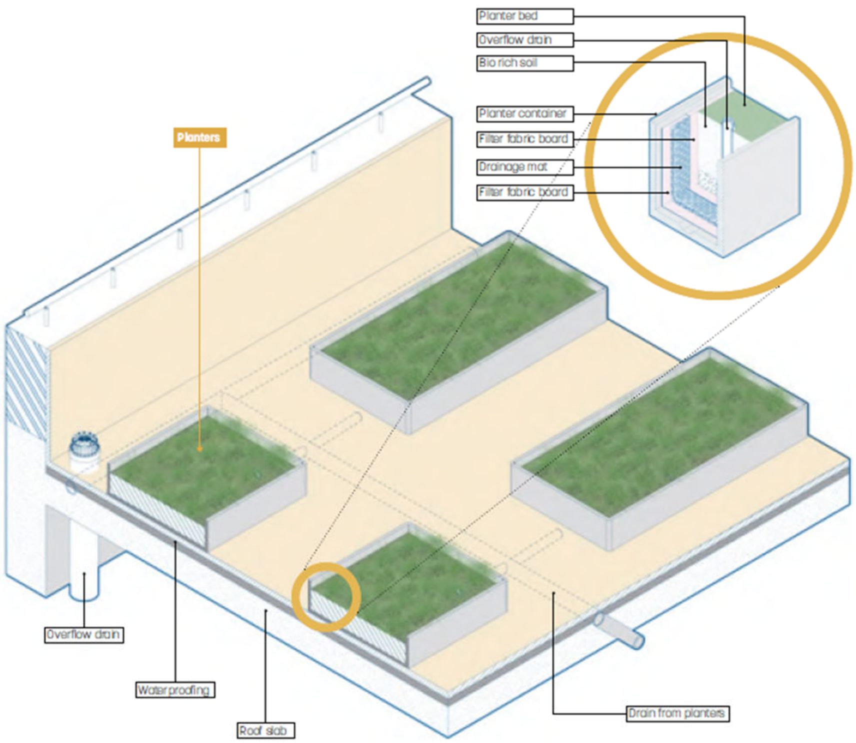


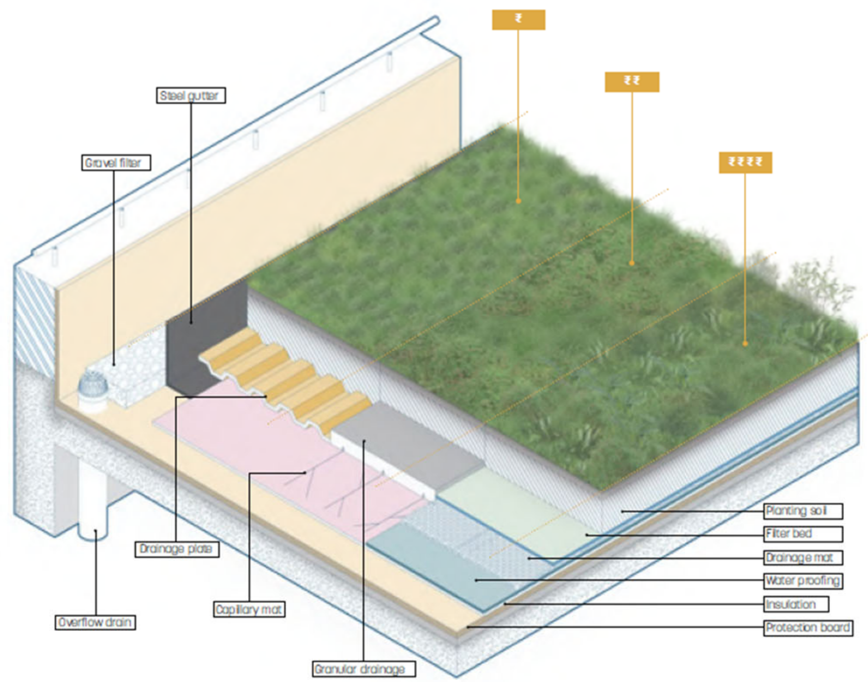


Impact of Morphological Characteristics of Green Roofs on Pedestrian Cooling in Subtropical Climates;
DOI: [10.3390/ijerph16020179](https://doi.org/10.3390/ijerph16020179)

Intensive vs Extensive Green Roof



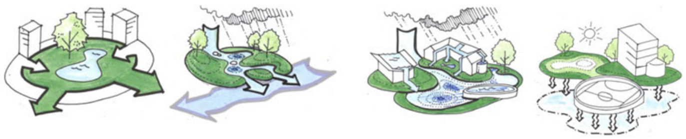


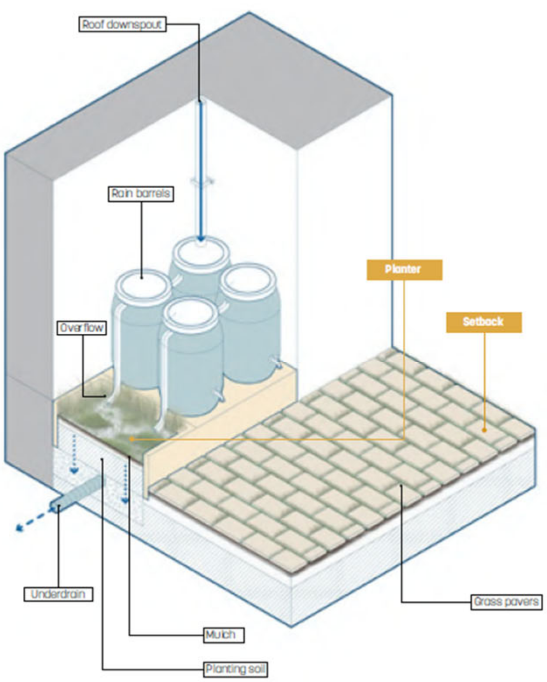


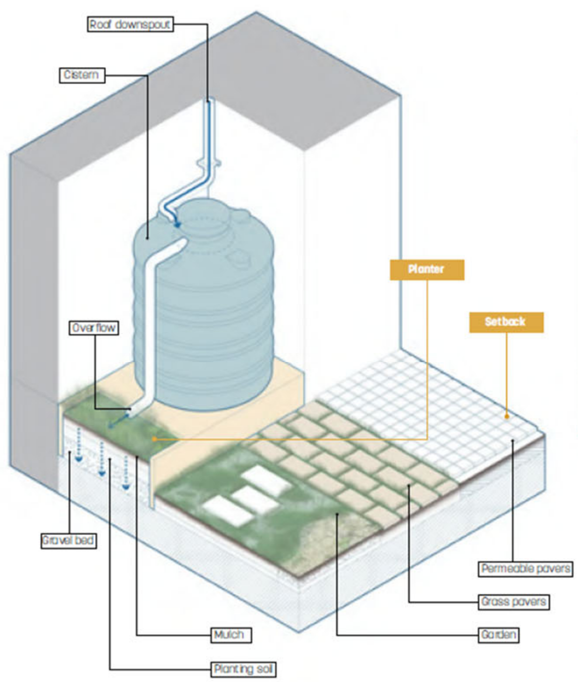
The Sponge Handbook: Chennai, 2019

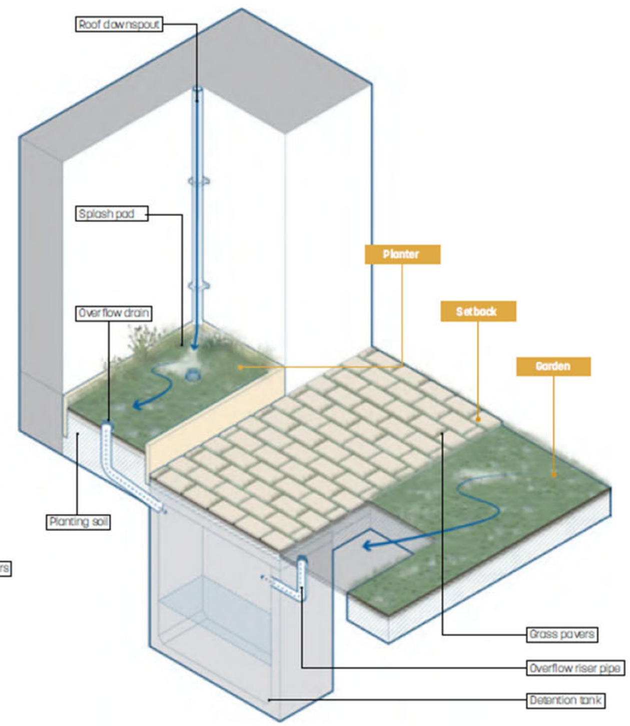
Rainwater Harvesting

Protect Delay **Store** Release









The Sponge Handbook: Chennai, 2019

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.

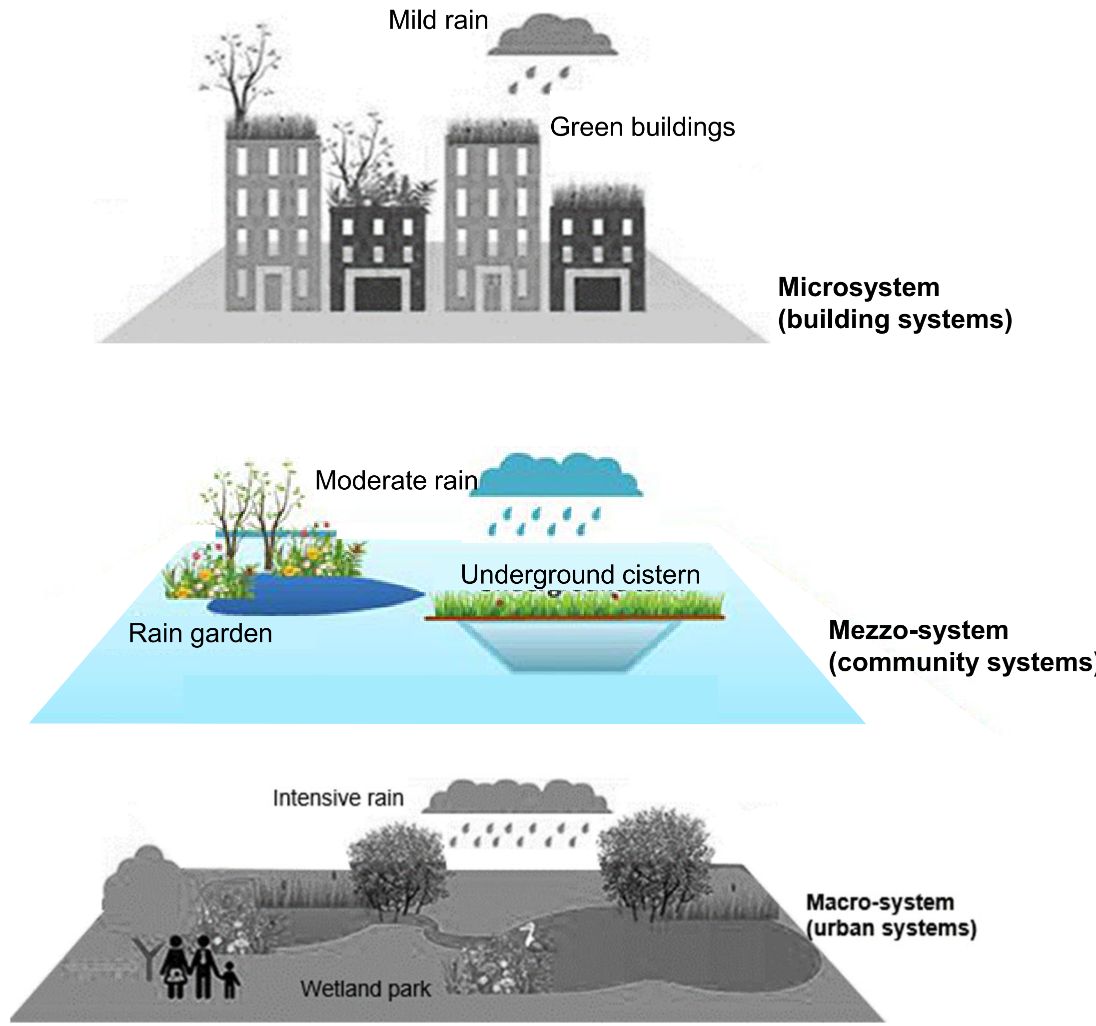
Top award for undulating wildflower green roof at Leeds Skelton Lake Services - Greenscape Magazine

Scolloping

OPTIMIZED GREEN-ROOF SYSTEM RENOLIT ALKORPLAN GREEN

Terraced

Flooding Resiliency Framework: Community Systems



Qi et al. Exploring the Development of the Sponge City Program, 2021

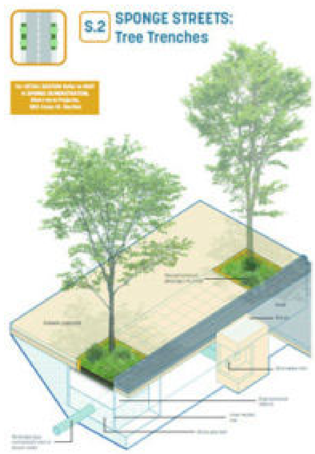
Flooding Resiliency Framework: Community Systems

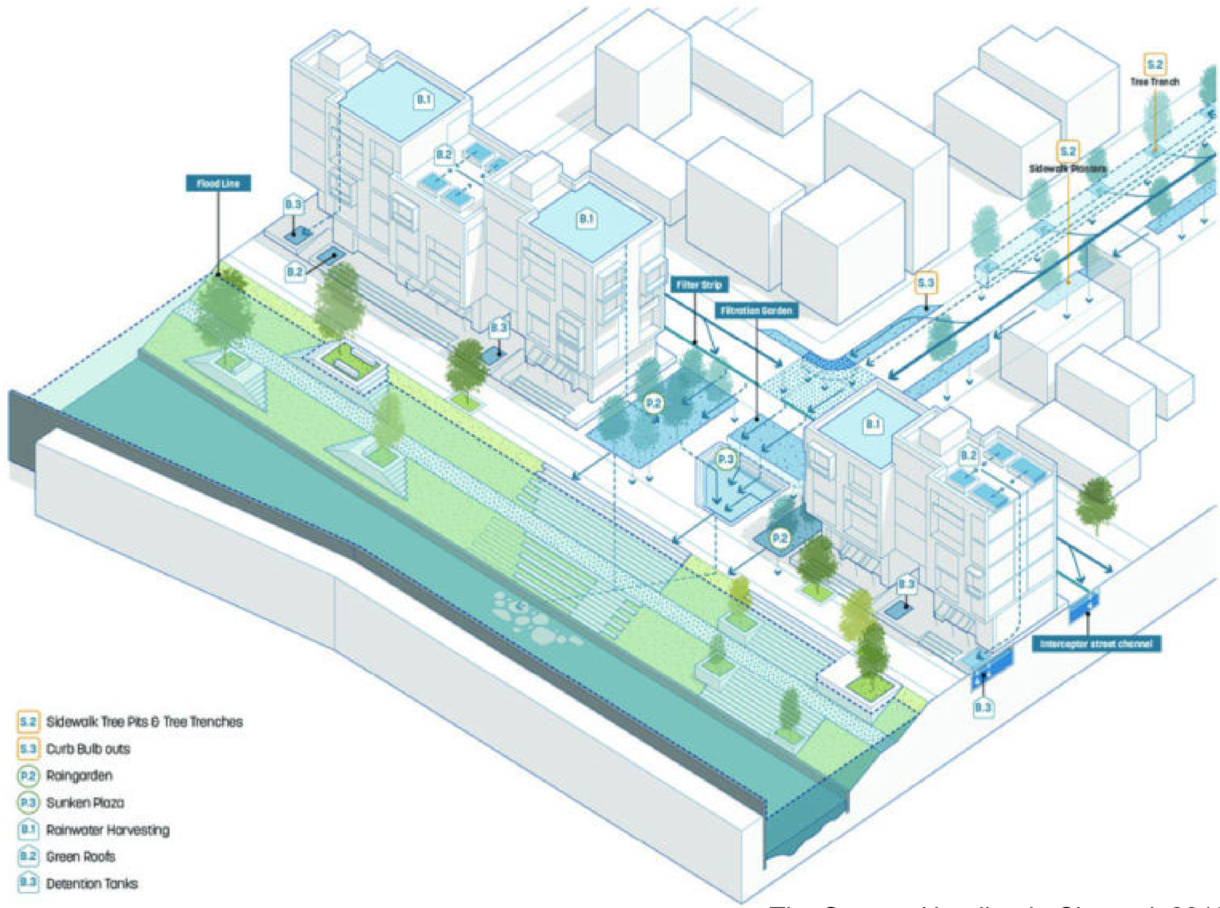
Protect


Delay


Store

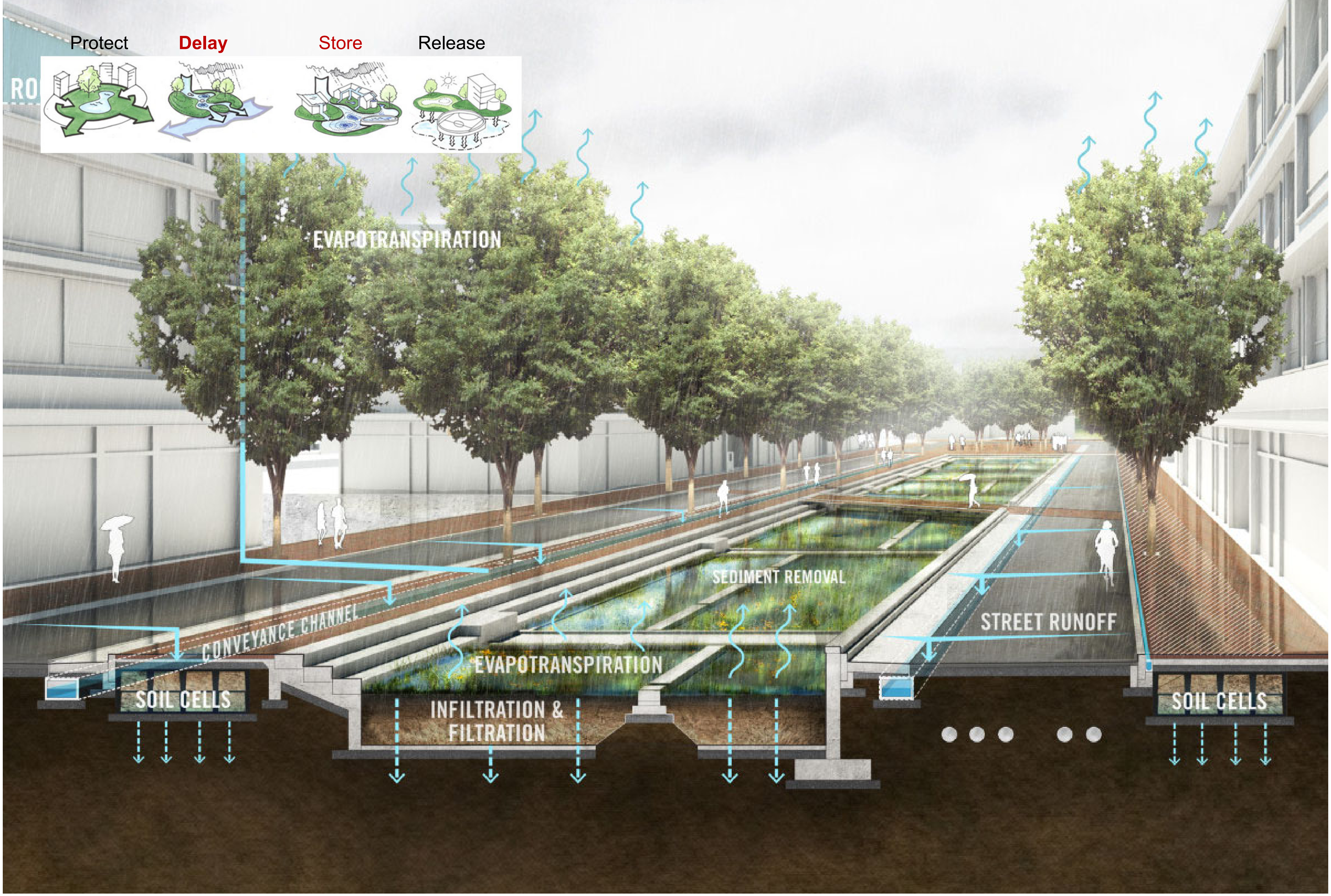

Release



The Sponge Handbook: Chennai, 2019

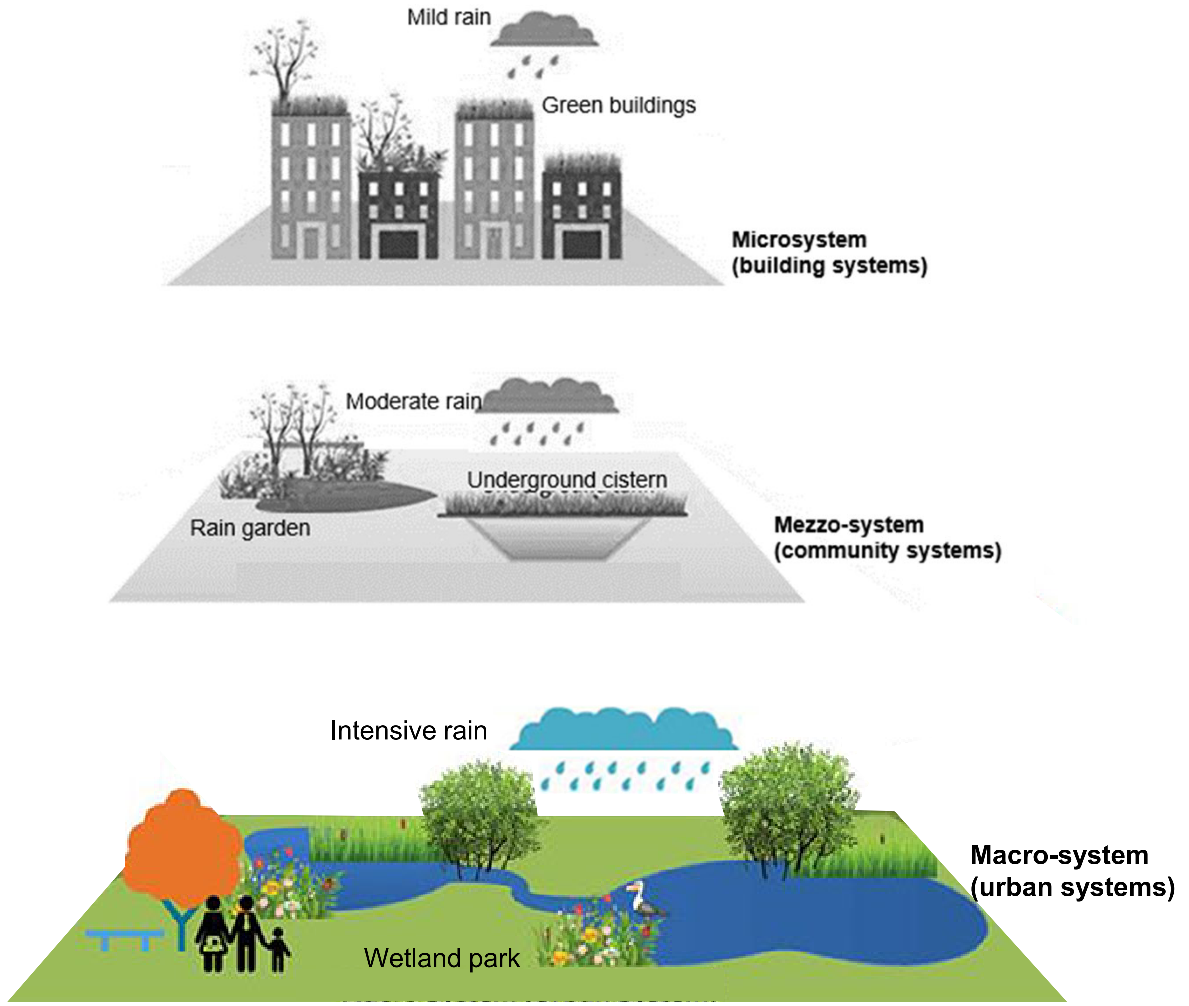
Sponge Street: Bioswale Channel, Sidewalk Planters, Tree Trenches



Sponge Street: Bioswale Channel, Sidewalk Planters, Tree Trenches

Kongjian Yu @ Turenscape

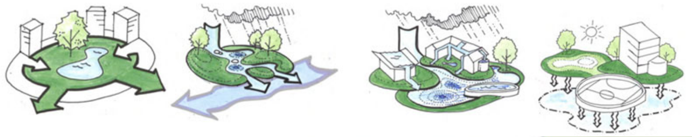
Flooding Resiliency Framework: Urban Systems

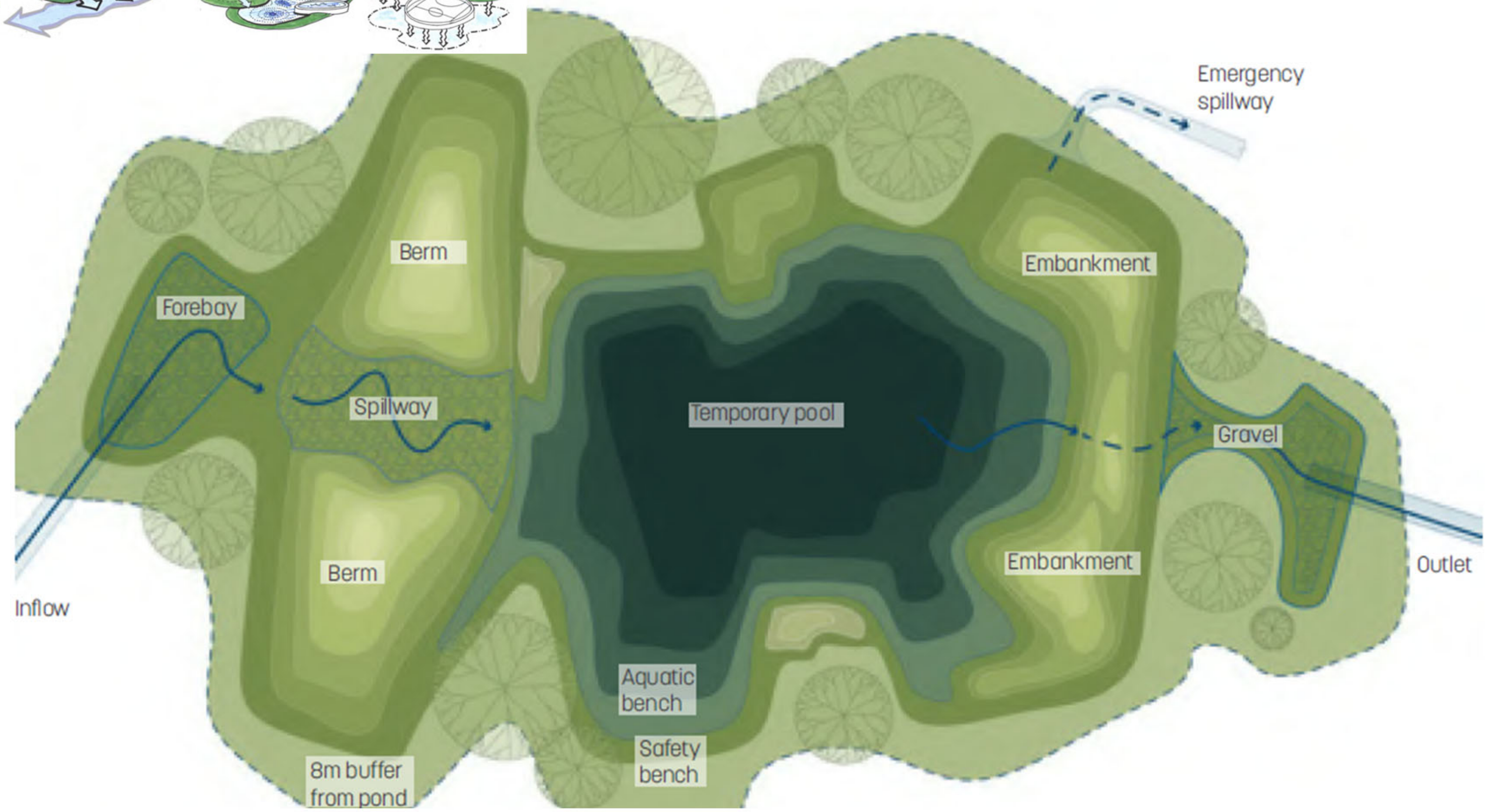


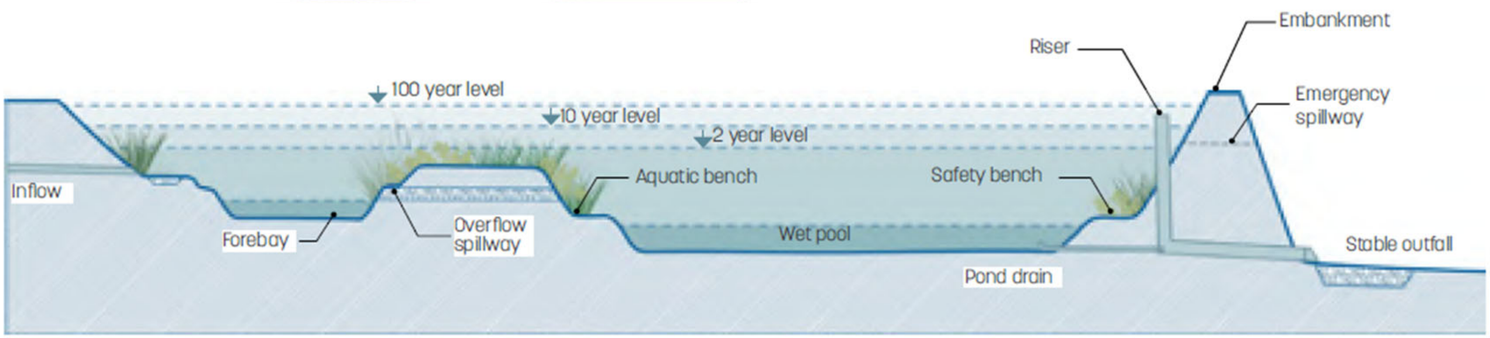
Qi et al. Exploring the Development of the Sponge City Program, 2021

Flooding Resiliency: Constructed Ponds

Protect **Delay** **Store** **Release**

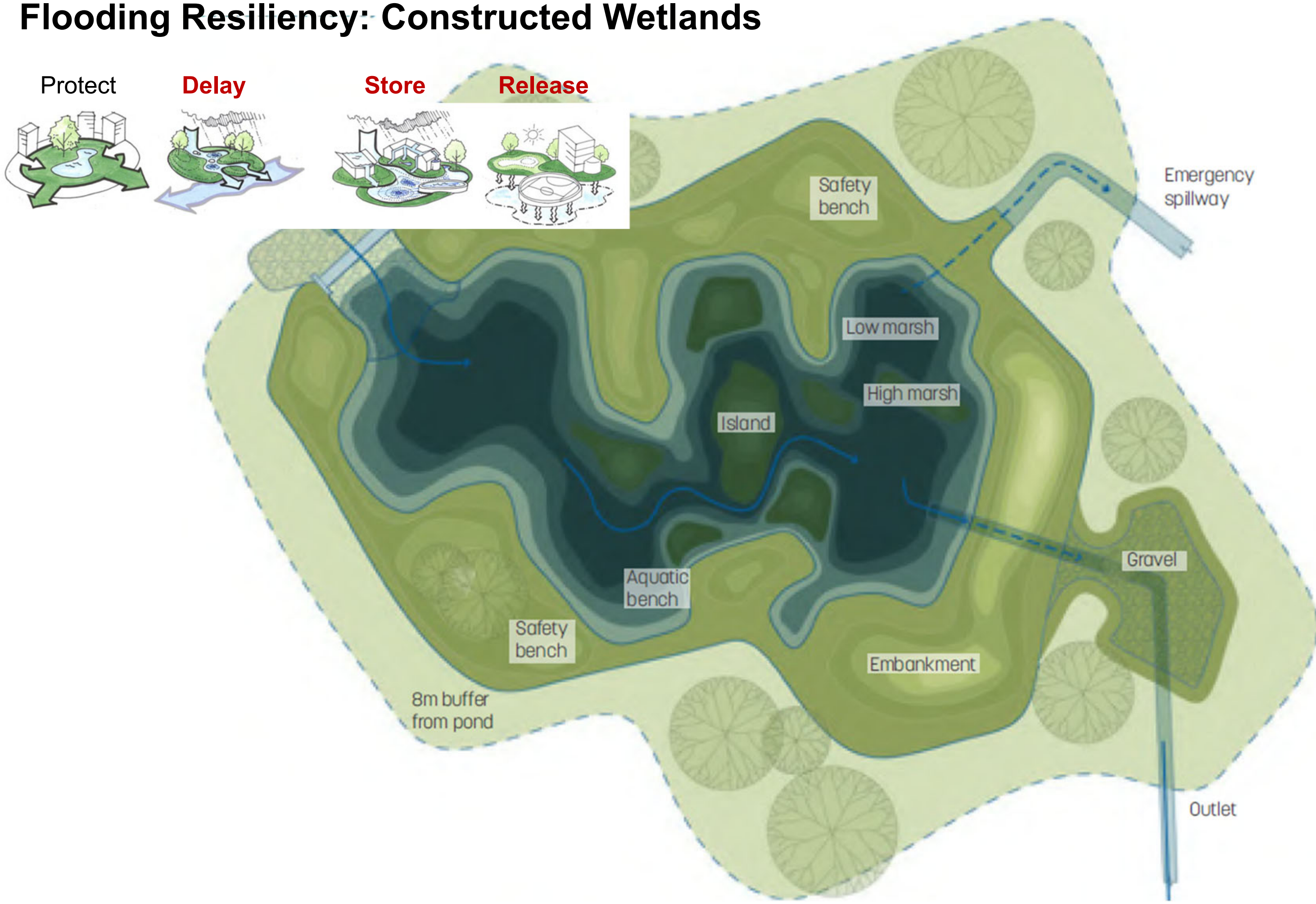


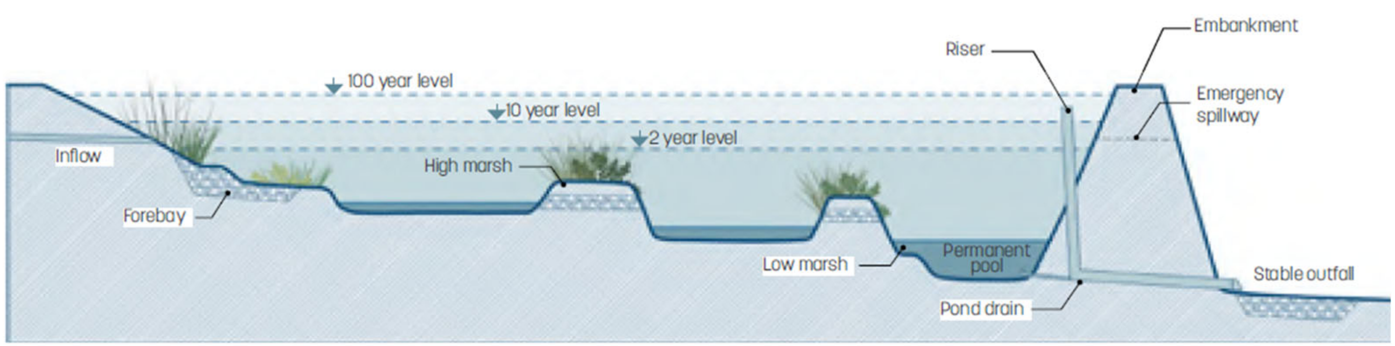




The architect making friends with flooding in MIT Tech Review
Kongjian Yu @ Turenscape

Flooding Resiliency: Constructed Wetlands

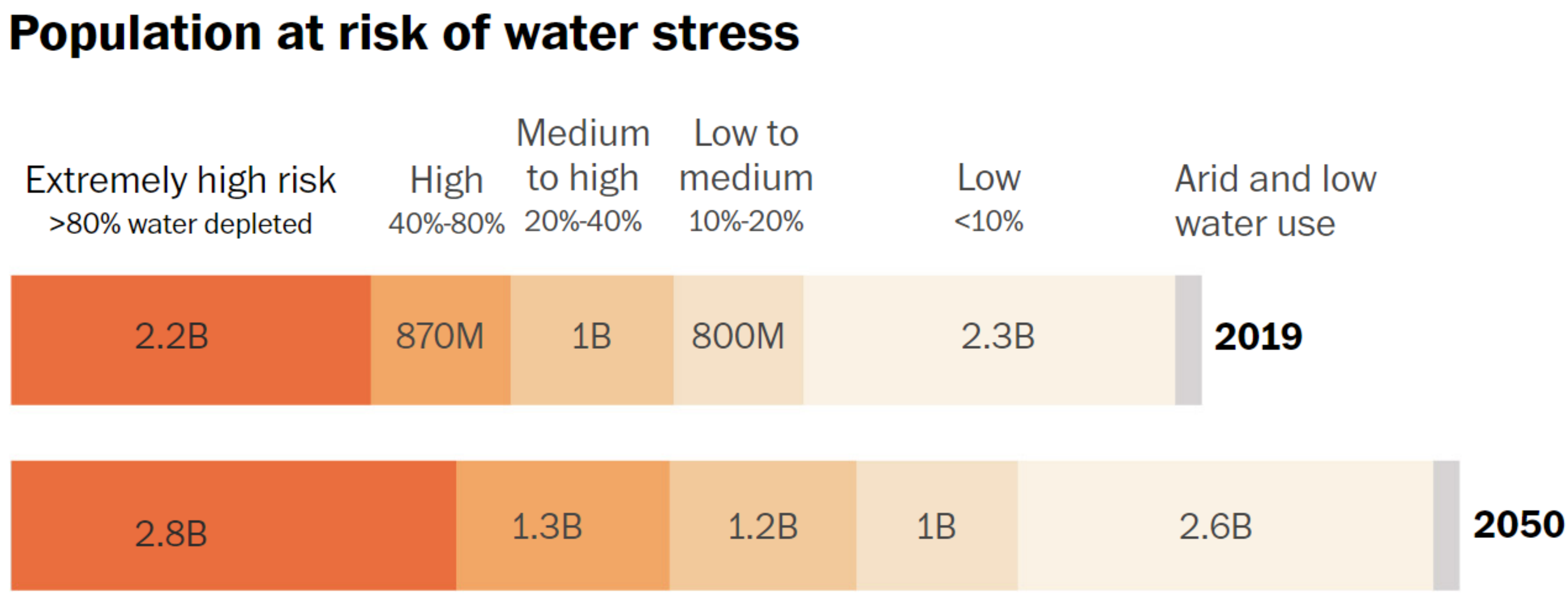





Kongjian Yu @ Turenscape

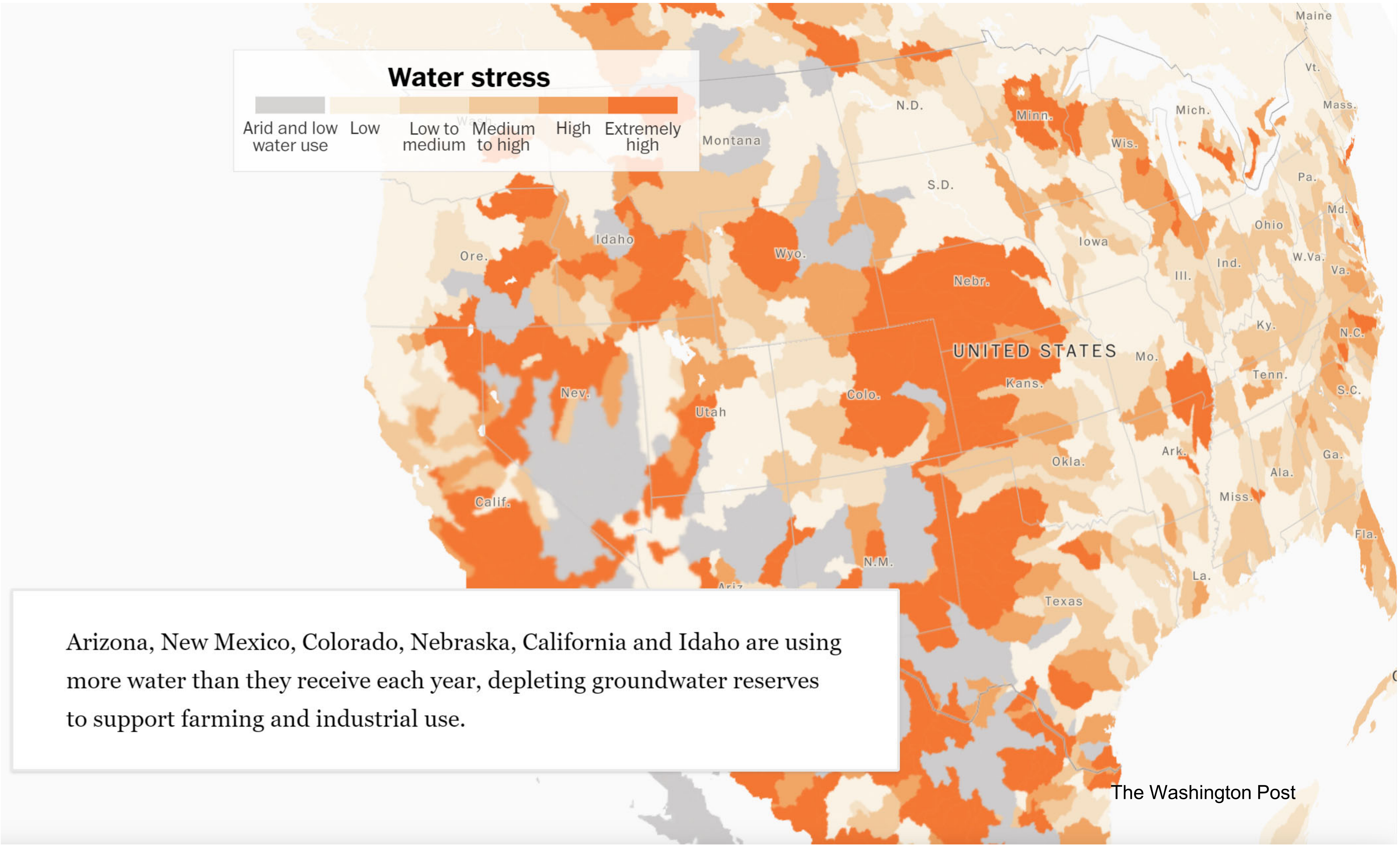
drought resilient built environment

Drought Resiliency



The Washington Post

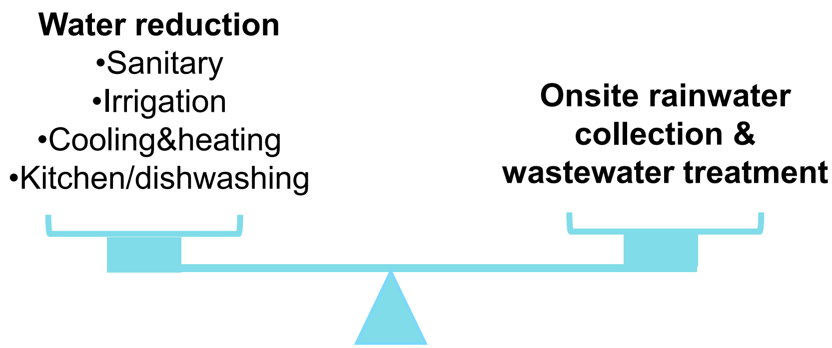
Drought Resiliency



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

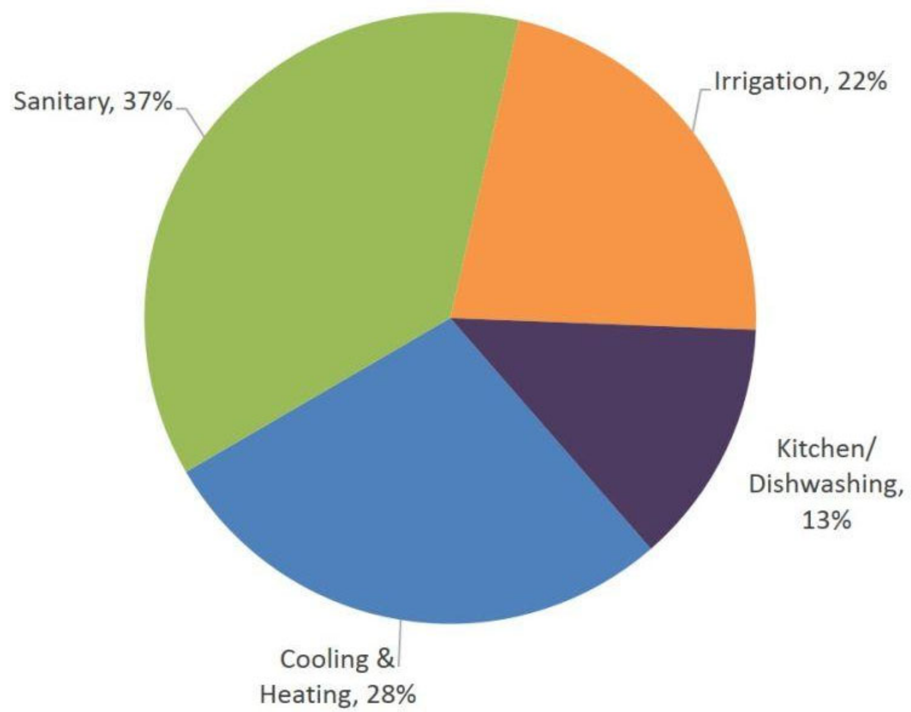
Drought Resiliency



Net Zero Water Strategy

Drought Resiliency: Reduction of Water Usage

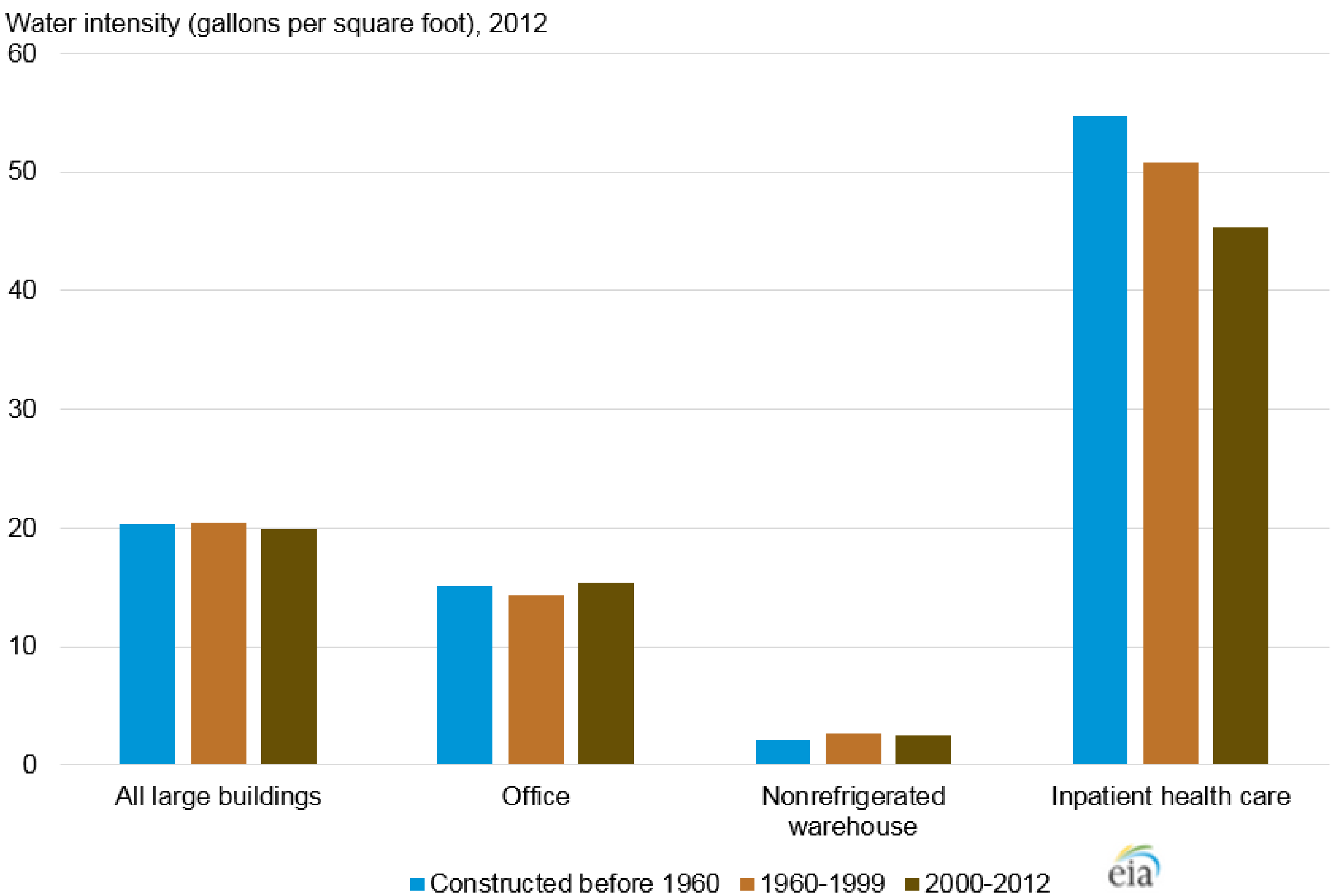
Typical office building energy uses of water: ~17 gallons/sq.ft (2012)



US EPA

Drought Resiliency: Reduction of Water Usage

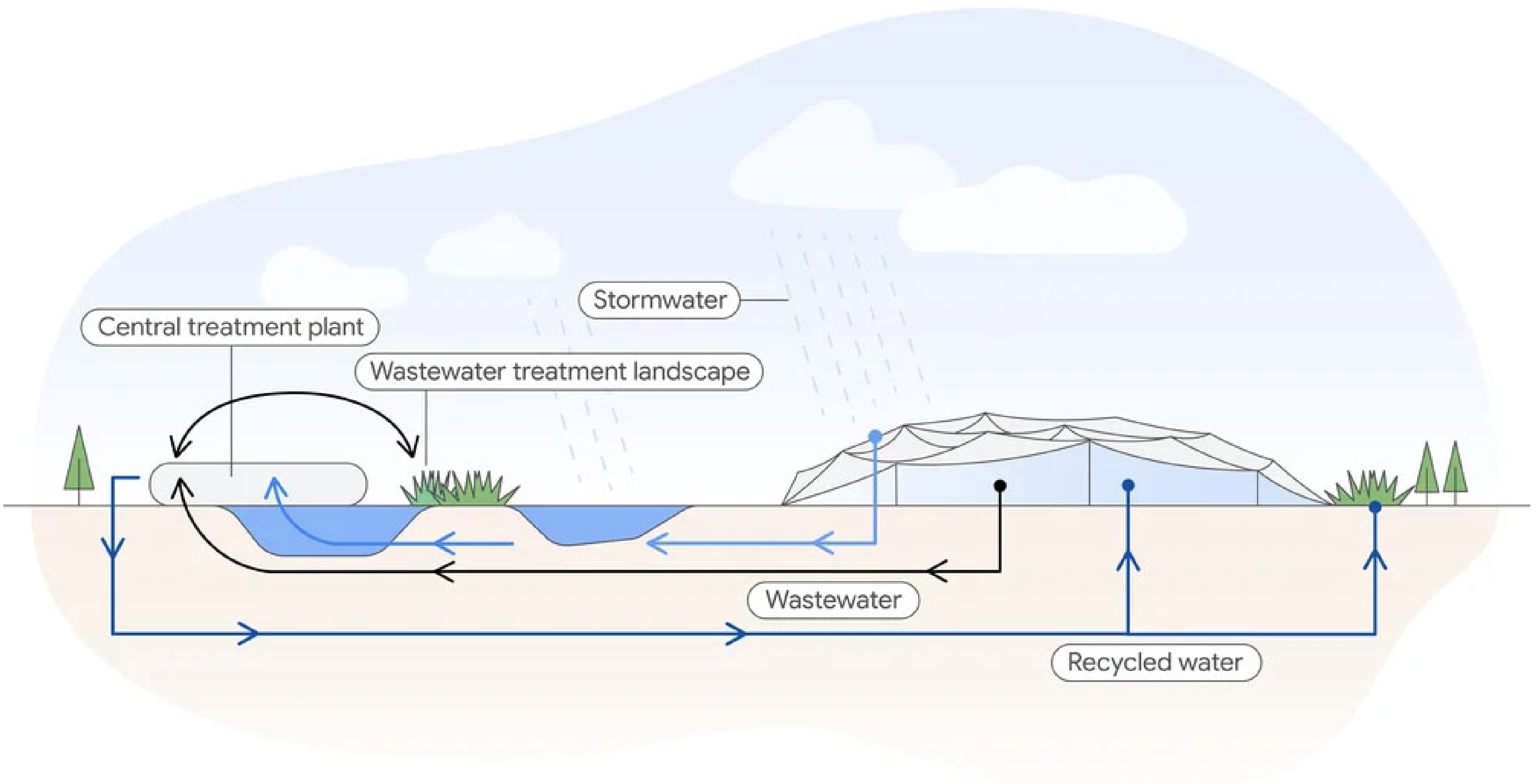
Typical office building energy uses of water: ~17 gallons/sq.ft (2012)
Water intensity varies little by year of construction except in inpatient heath care buildings



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

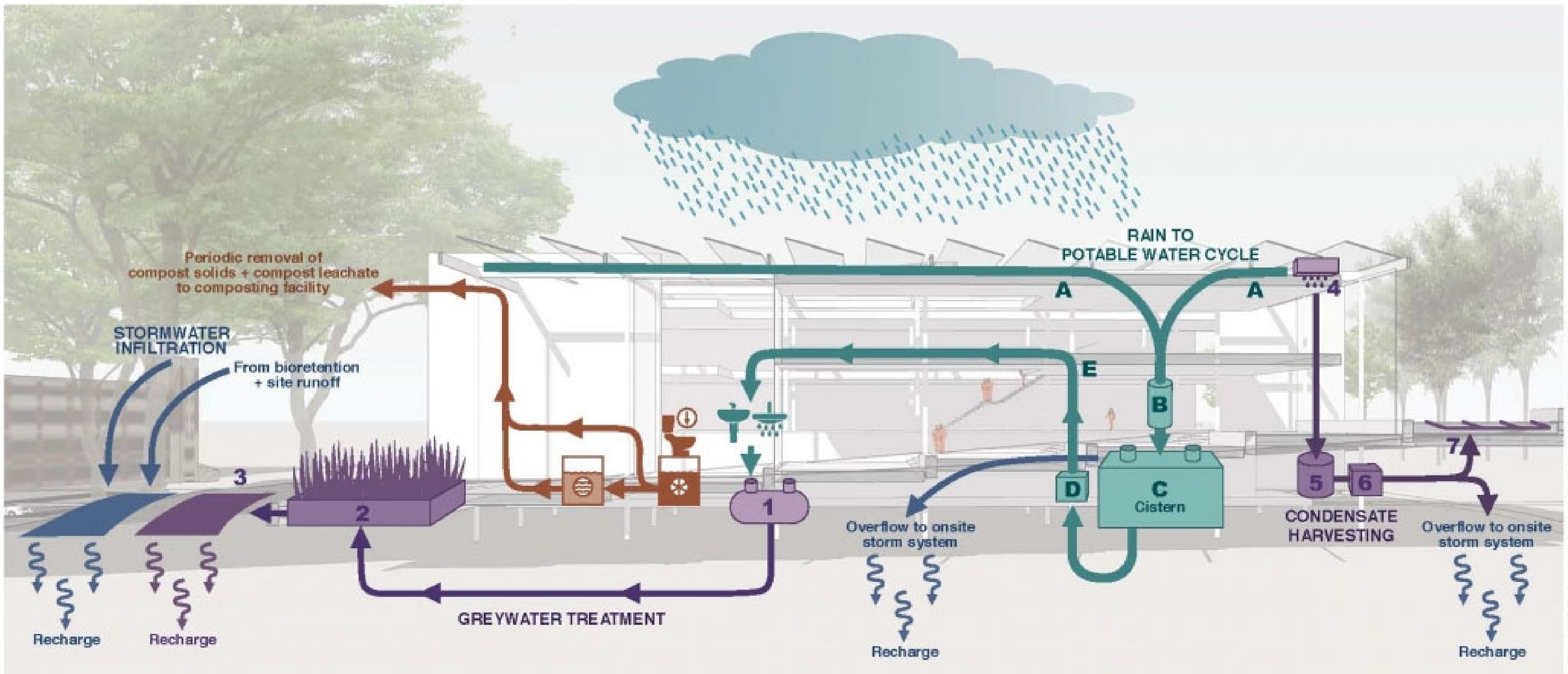
Kendeda Building for Innovative Sustainable Design

Georgia Institute of Technology, Atlanta, GA

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

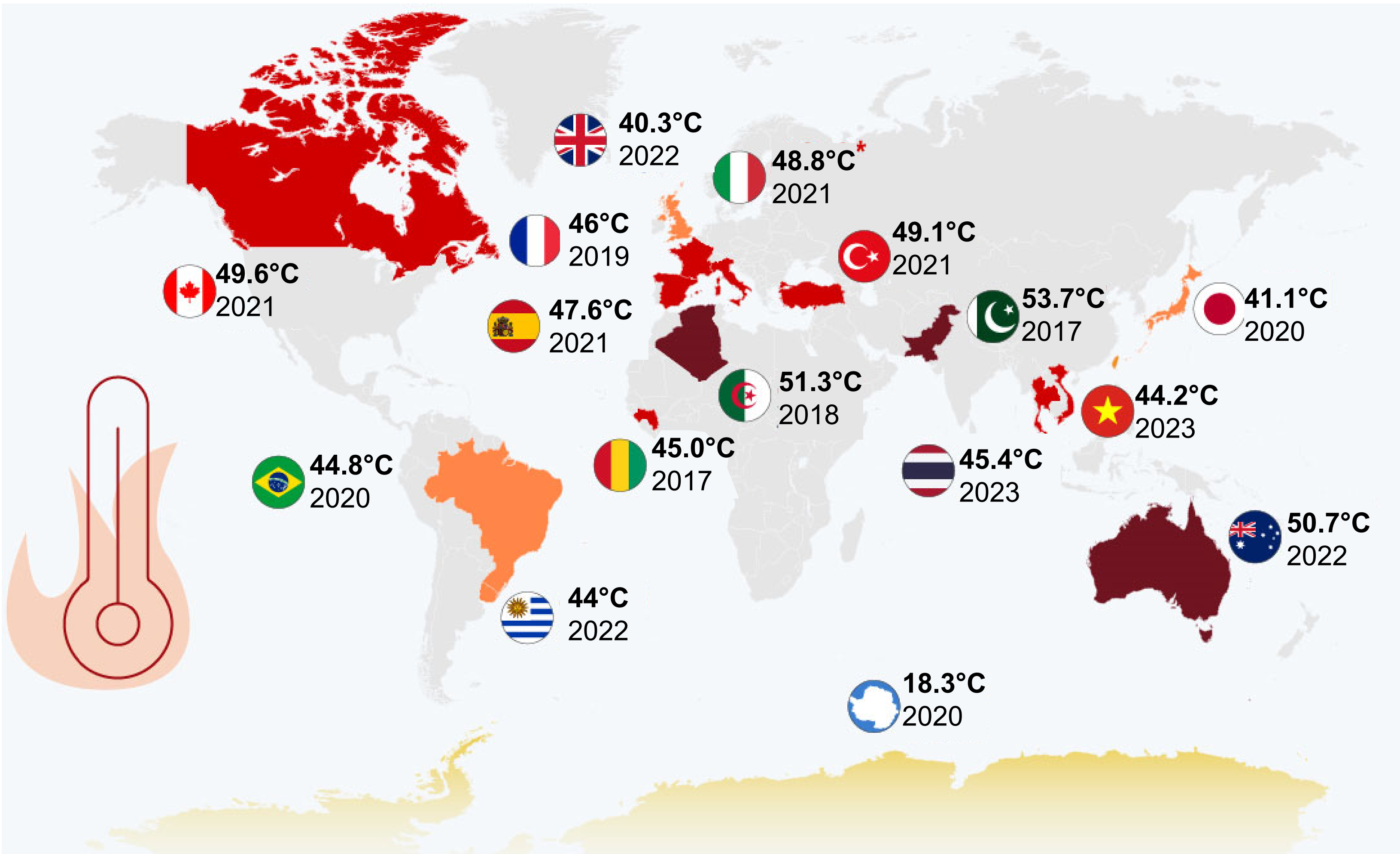
7 Site irrigation system

Kendeda Building, GTech

heat resilient built environment

World Recorded Heat Waves

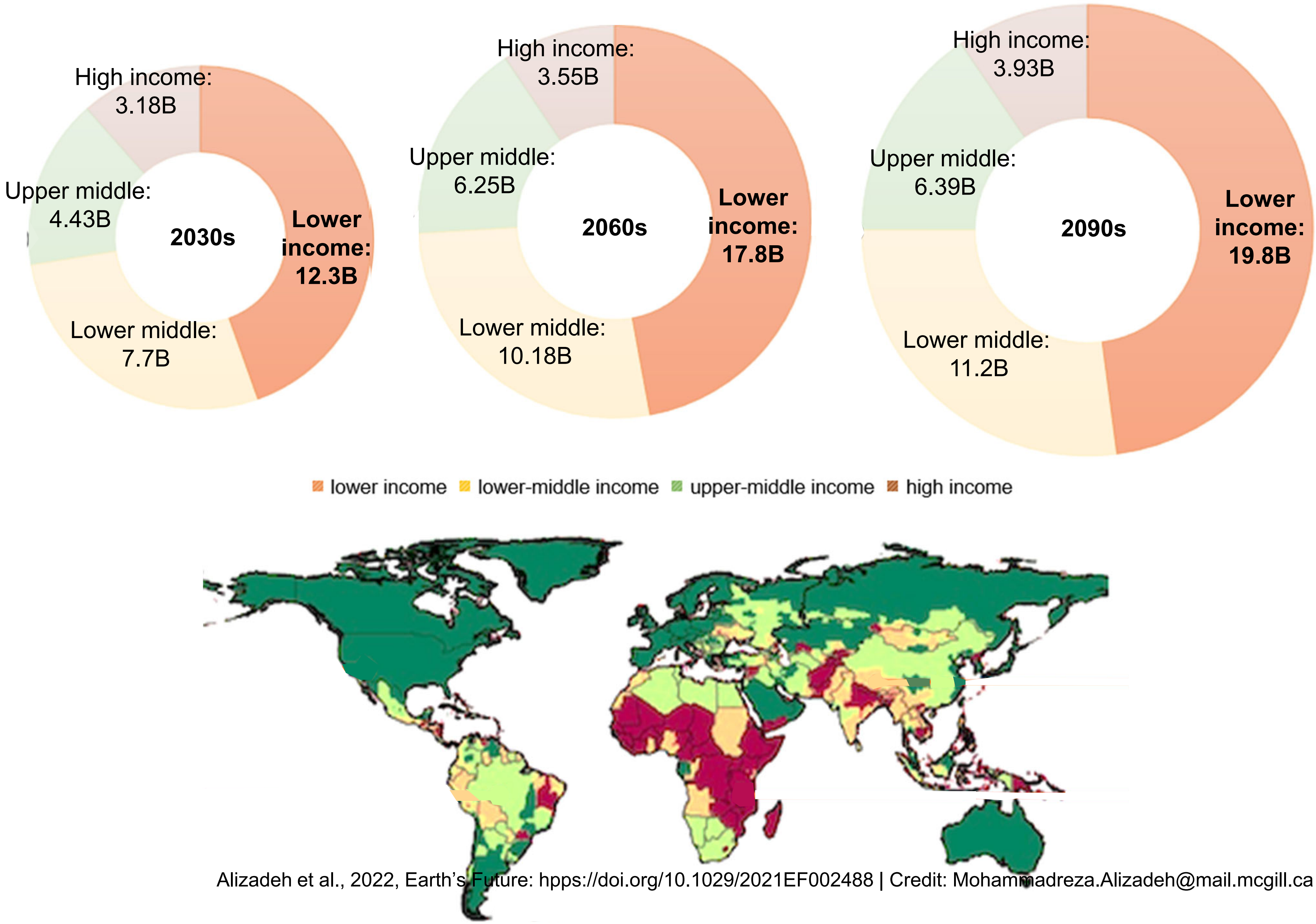
As of July 10, 2023. Recorded during the last six years, in deg C. European record still being validated by the WMO.



World Meteorological Organization, Statista research

Increasing Heat-Stress Inequality in a Warming Climate

Exposure to heatwaves (billion person-days per year)



Alizadeh et al., 2022, Earth's Future: hpps://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.

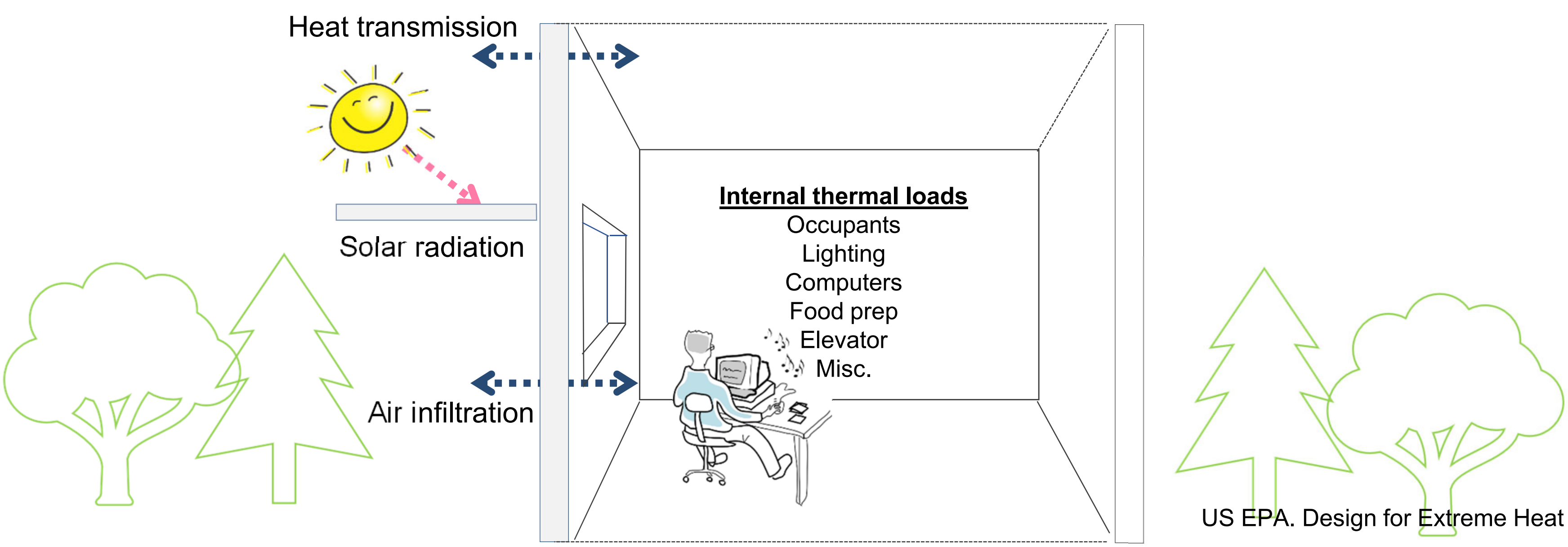
US EPA. Design for Extreme Heat

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.



US EPA. Design for Extreme Heat

Heat Resilient Design Strategy

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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.

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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.

US EPA. Design for Extreme Heat

Heat Resilient Design Strategy

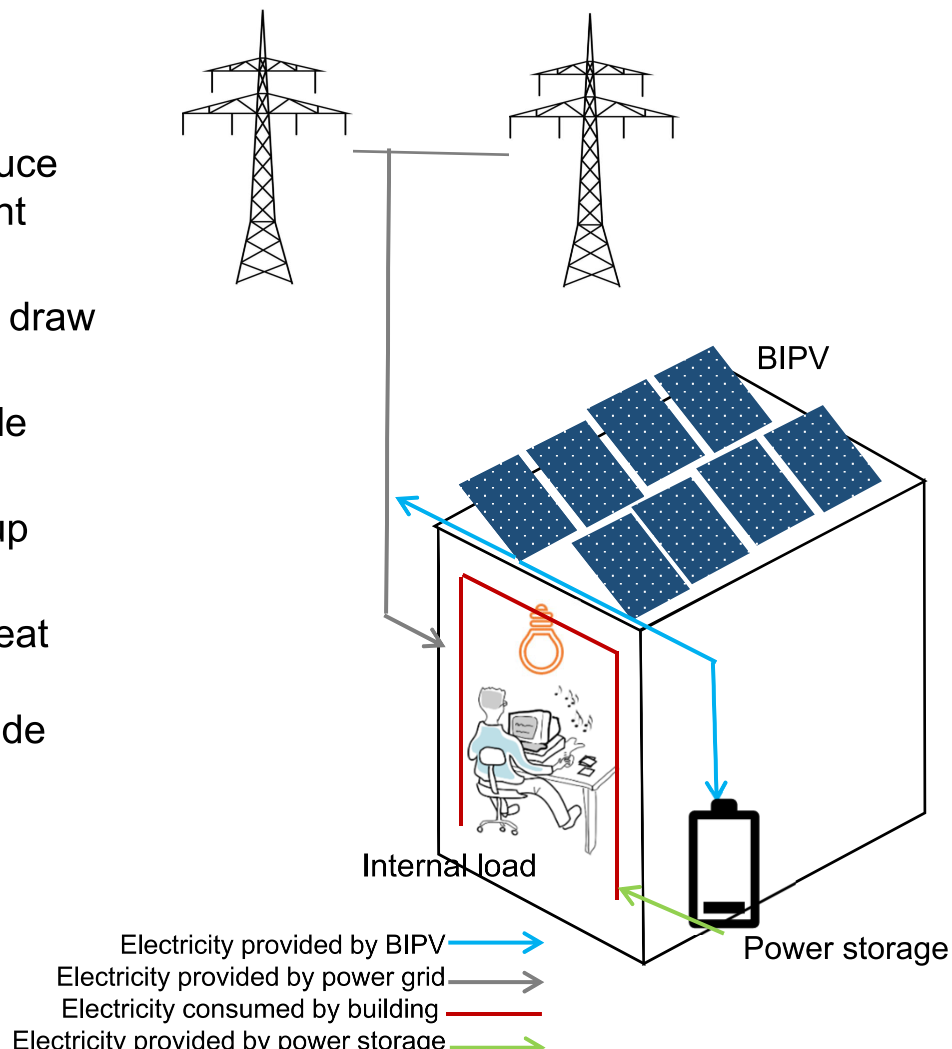
1.Minimize heat gain.

2.Provide emergency cooling.

3.Provide a backup power source with enough capacity to supply emergency cooling.

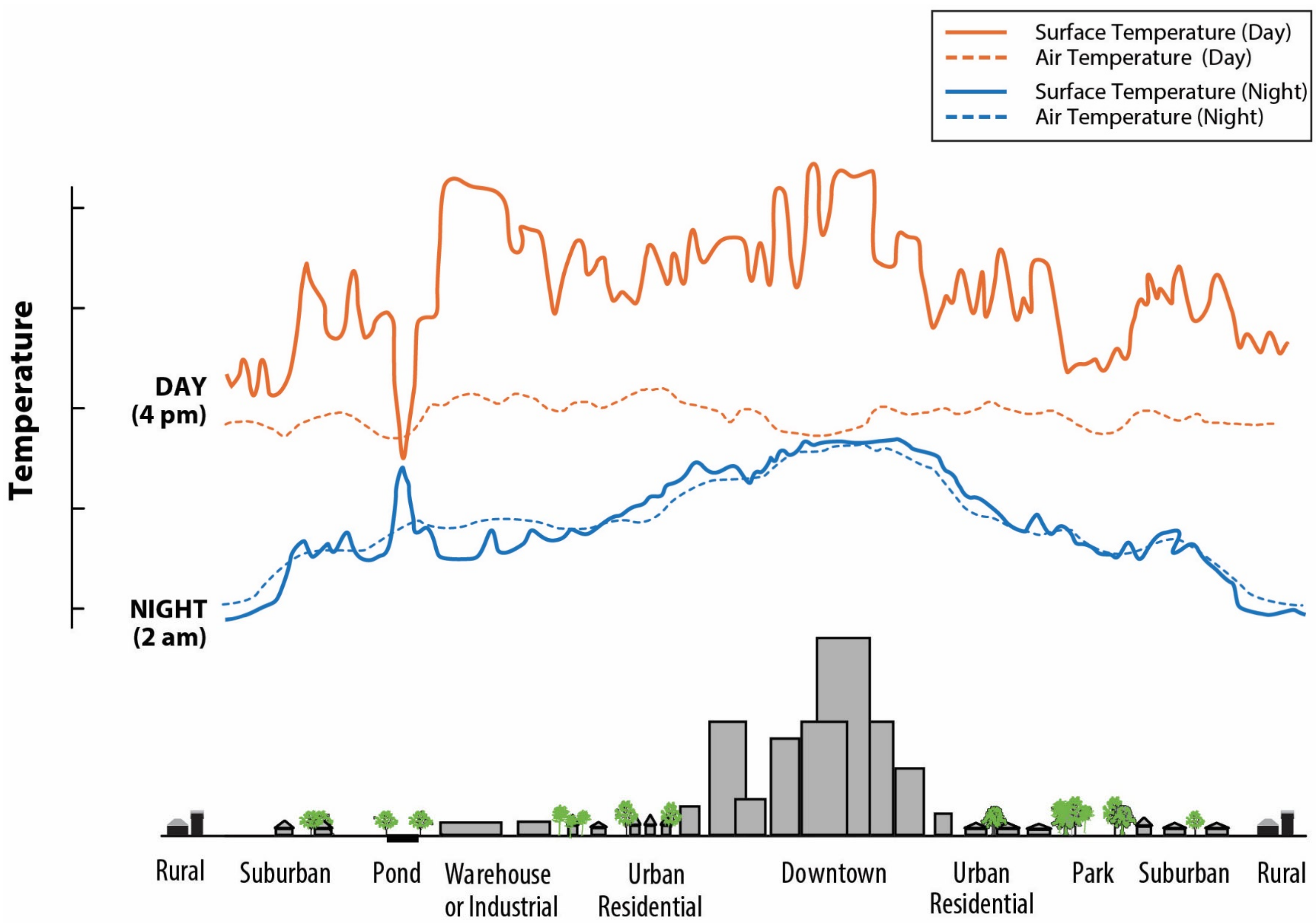
Back-up Power Systems:

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.



US EPA. Design for Extreme Heat

Heat Island Inequity



US EPA. Heat Islands and Equity

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.*

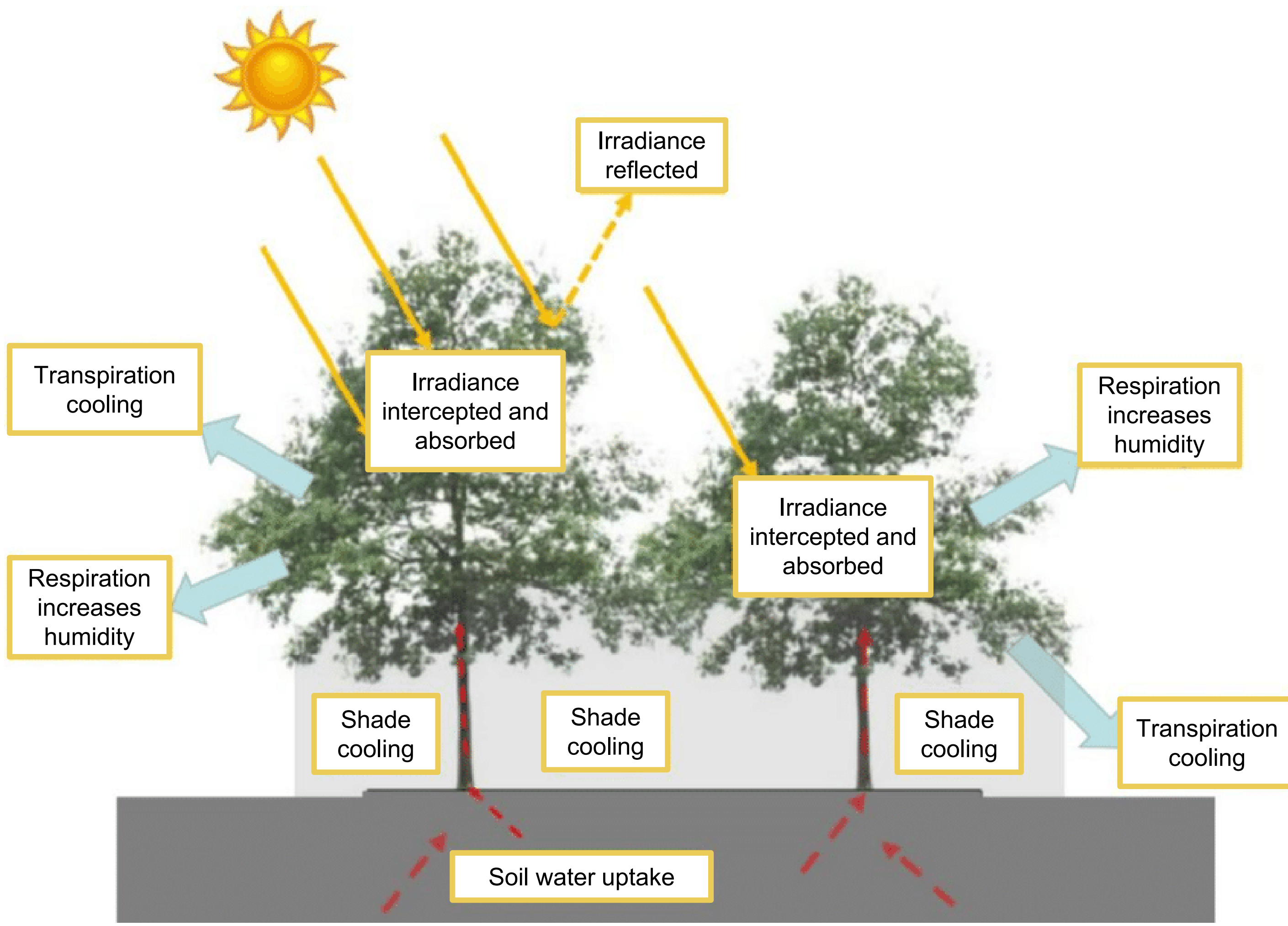
US EPA. Heat Islands and Equity

Heat Island Inequity

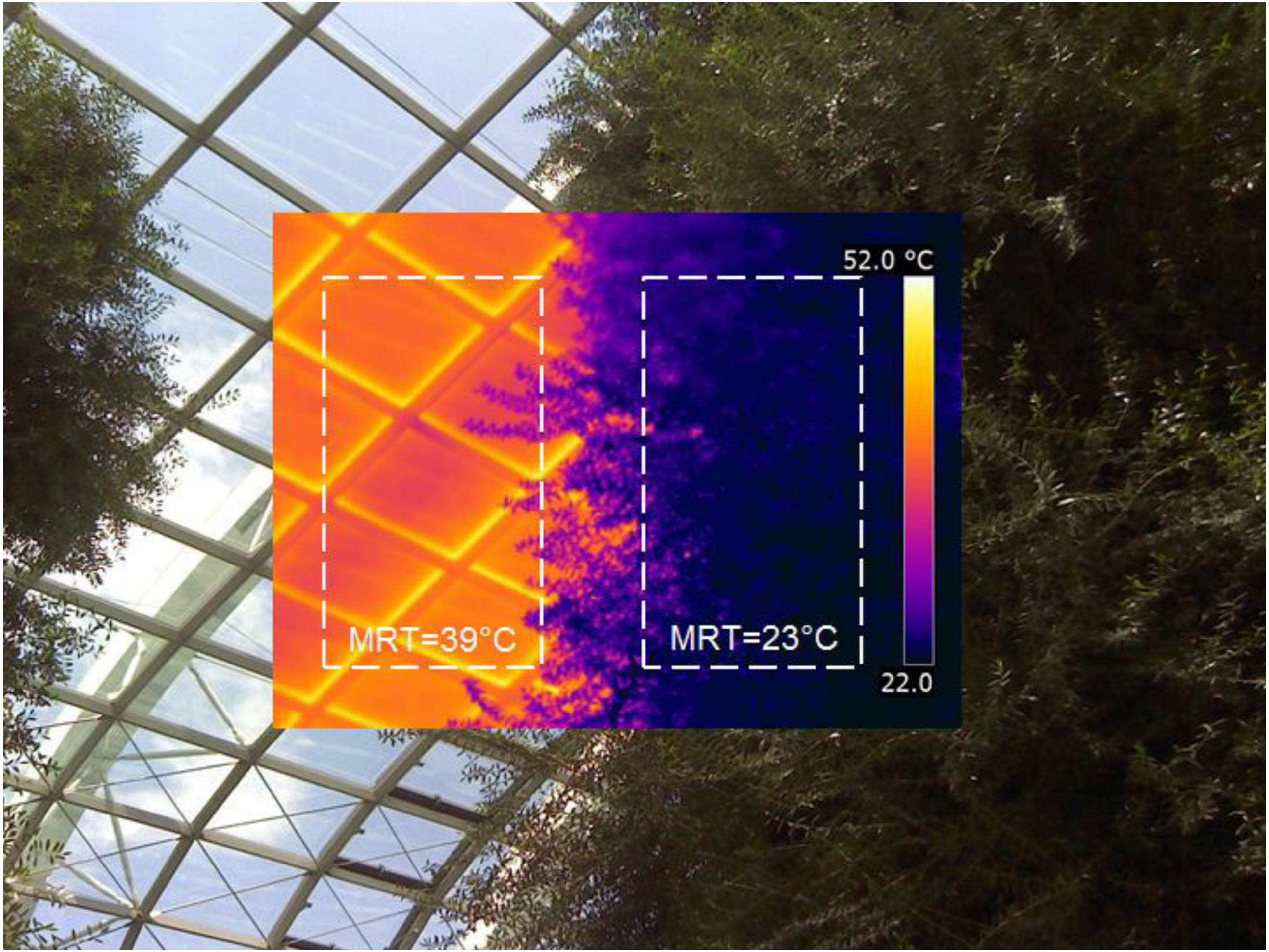
one study analyzed almost 500 U.S. urban areas using 2017 data.[i] This study found that heat island effects were typically less severe in census tracts with higher median incomes and a higher proportions of White people. Neighborhoods with higher numbers of Black residents tended to have more intense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

US EPA. Heat Islands and Equity

Heat Island Inequity: Cooling Effect of Trees



Cooling effect of trees. 10.3934/environsci.2019.6.417


52.0 °C
MRT=39°C
MRT=23°C
22.0

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

US EPA. Heat Islands Compendium

Heat Island Inequity: Cooling Effect of Cool Roof

Temperature of Conventional Roof reached 175degF (80degC)

US EPA. Heat Islands Compendium

Heat Island Inequity: Cooling Effect of Cool Pavements

National Center of Excellence on SMART Innovations at Arizona State University

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

US EPA. Heat Islands Compendium

energy resilient built environment


Climate Resilient Hospitals
GENERATOR
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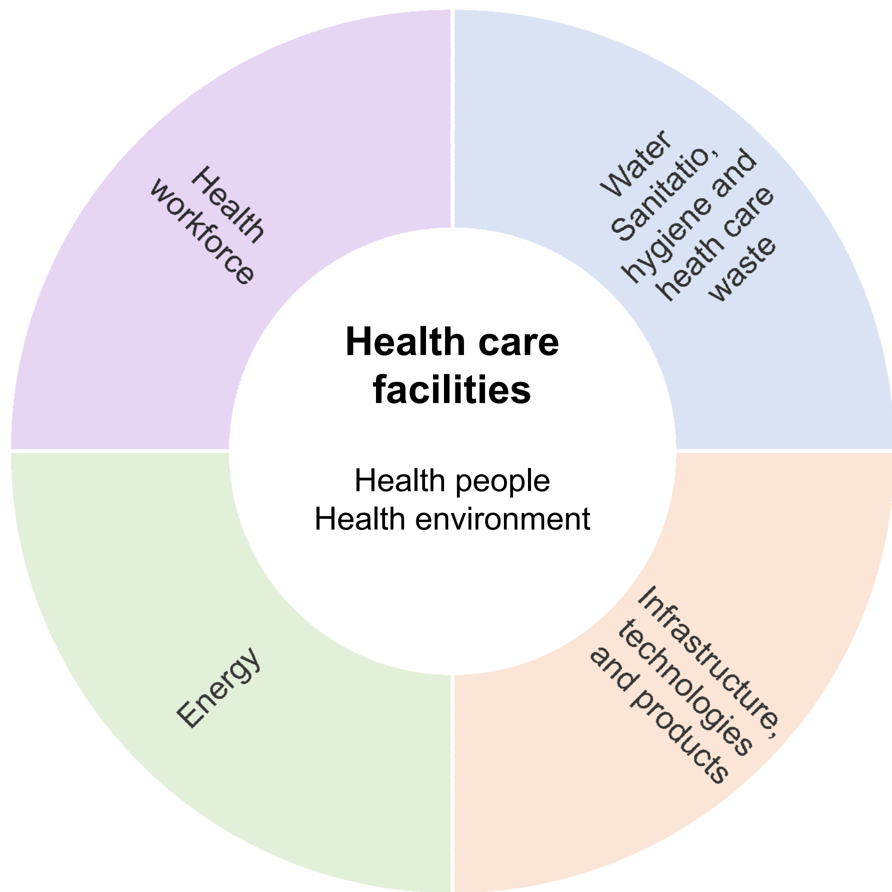
CAFETERIA
COMMUNITY C
RECEIVING
H
EMERGENCY
Health Care Climate Council

Climate Resilient Hospitals



World Health Organization, 2020

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:

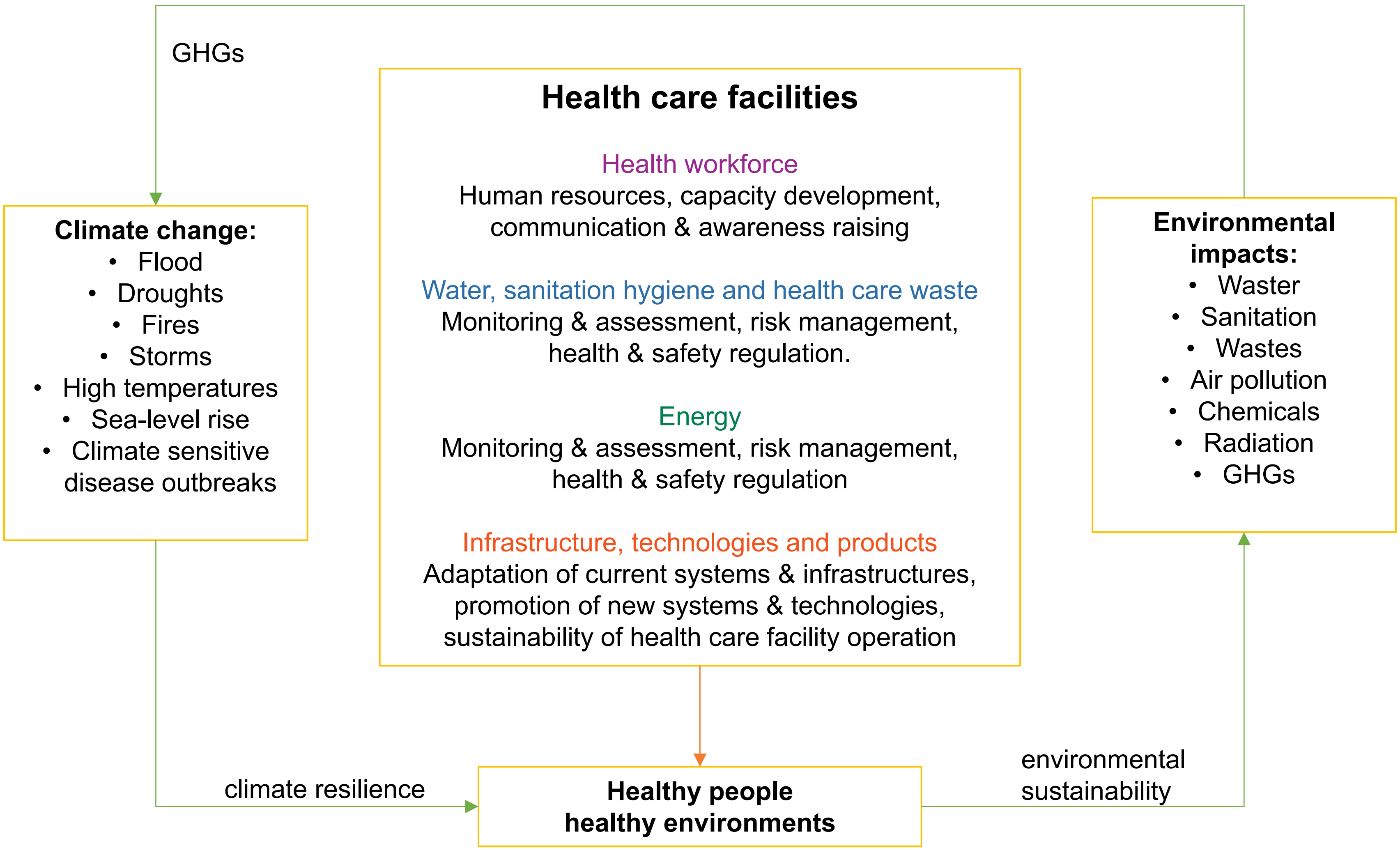
Sustainable energy services.

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.

World Health Organization, 2020

Climate Resilient Hospitals



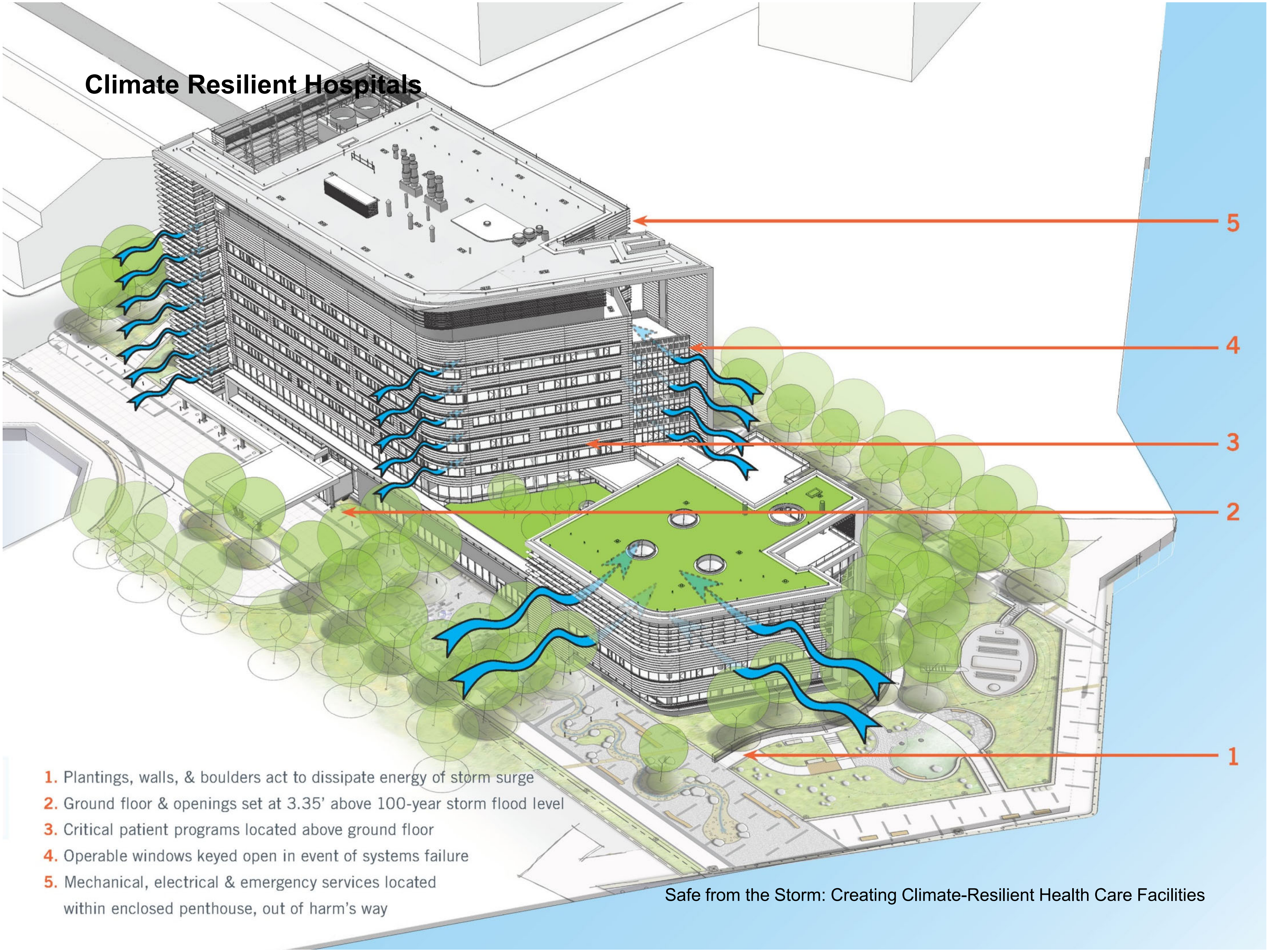
World Health Organization, 2020

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

Healthcare Facilities and Power Outages – FEMA.gov

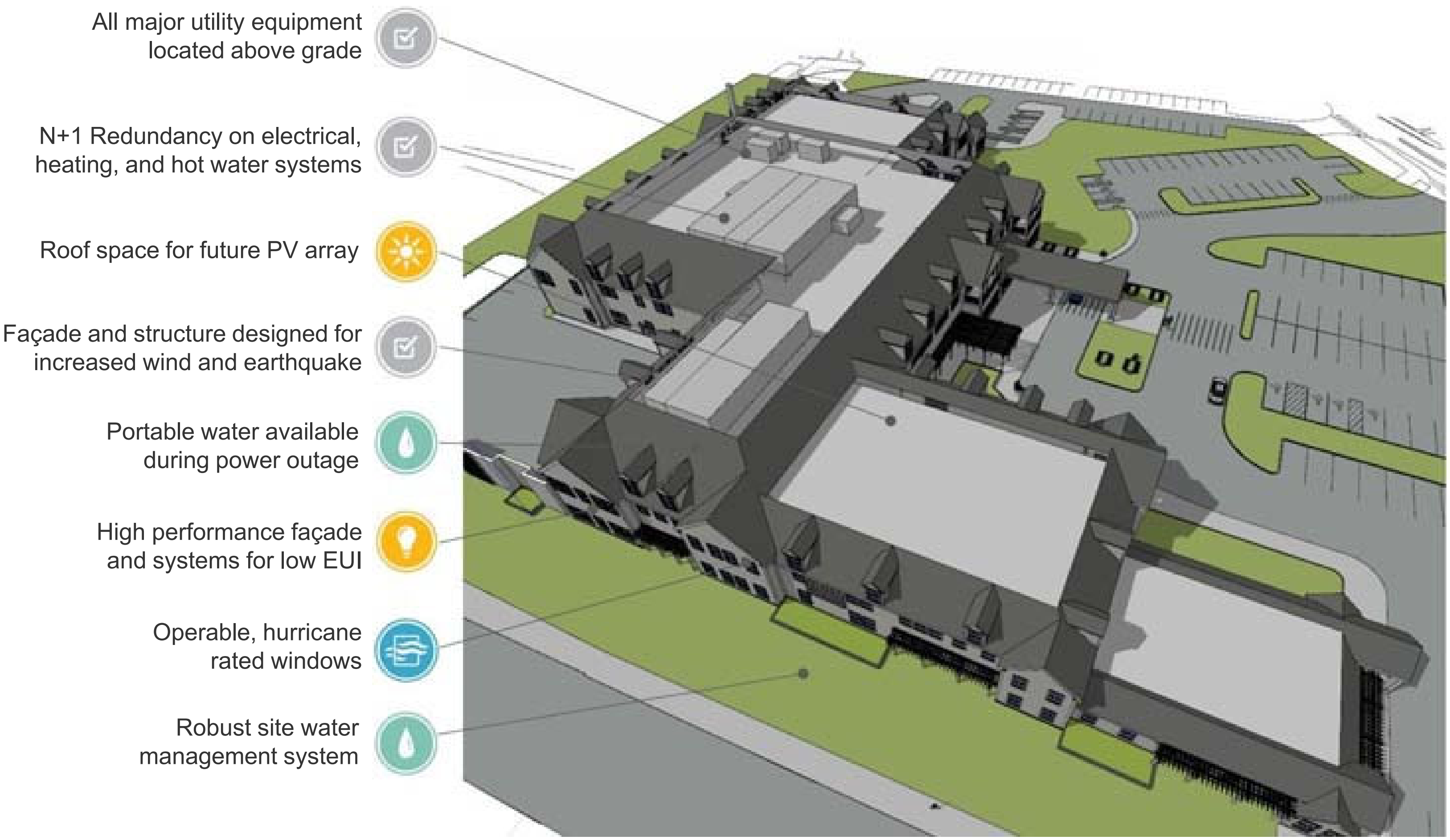
Climate Resilient Hospitals



1. Plantings, walls, & boulders act to dissipate energy of storm surge
2. Ground floor & openings set at 3.35' above 100-year storm flood level
3. Critical patient programs located above ground floor
4. Operable windows keyed open in event of systems failure
5. Mechanical, electrical & emergency services located within enclosed penthouse, out of harm's way

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

Climate Resilient Hospitals



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

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CHARLOTTE

USASCP U.S.-ASEAN SMART CITIES PARTNERSHIP