Resiliency in the Built Environment

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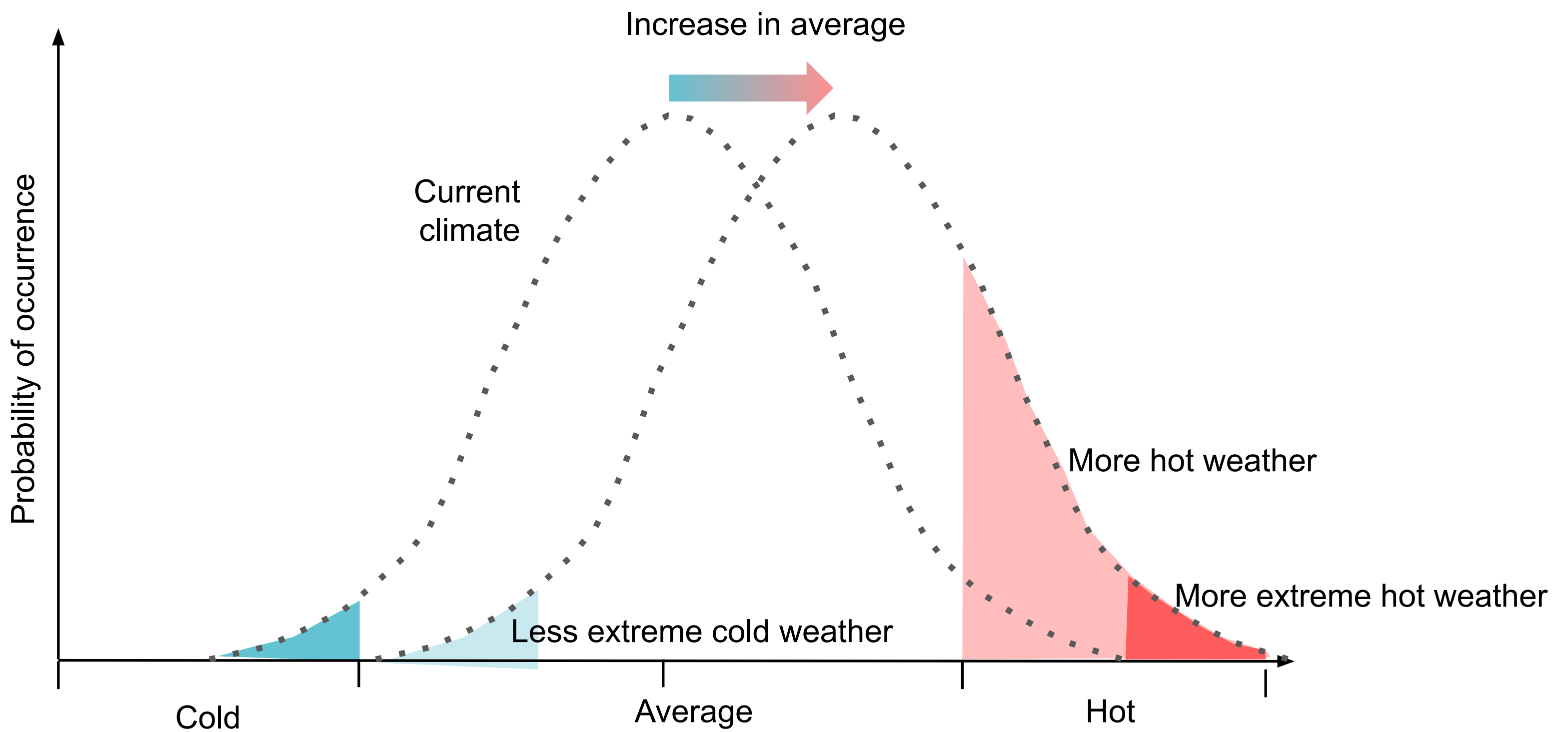
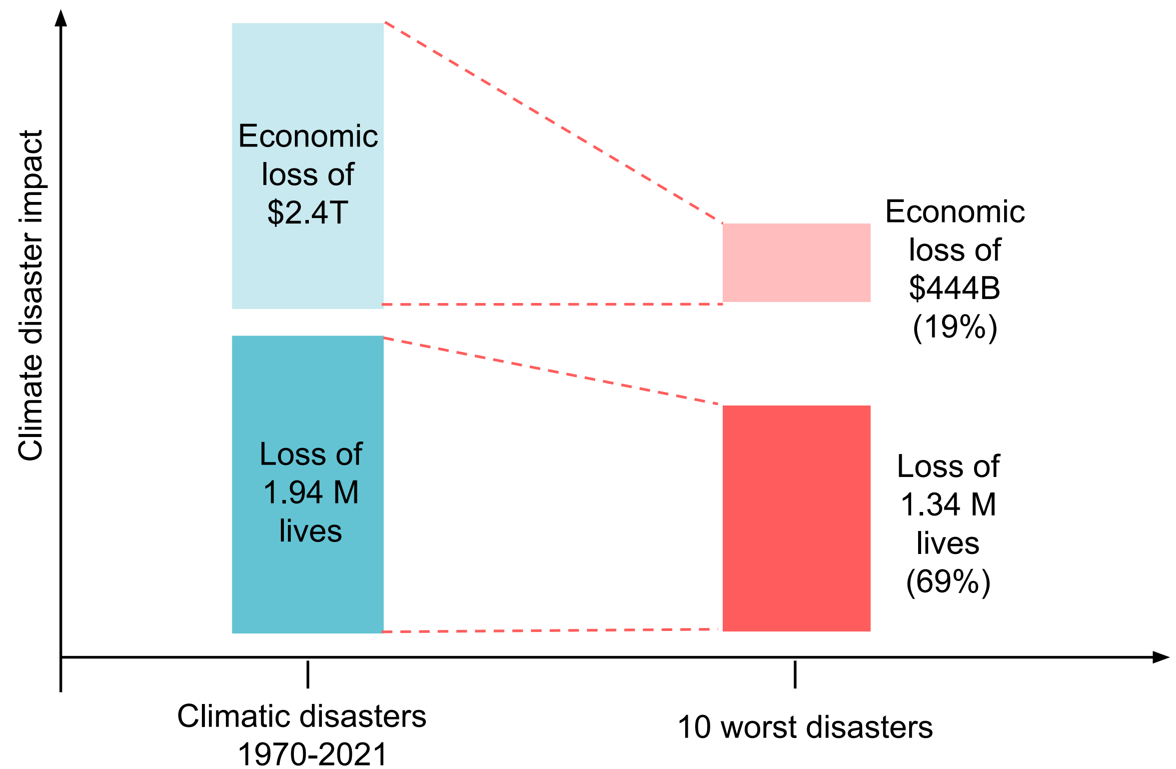
Climate Changes



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

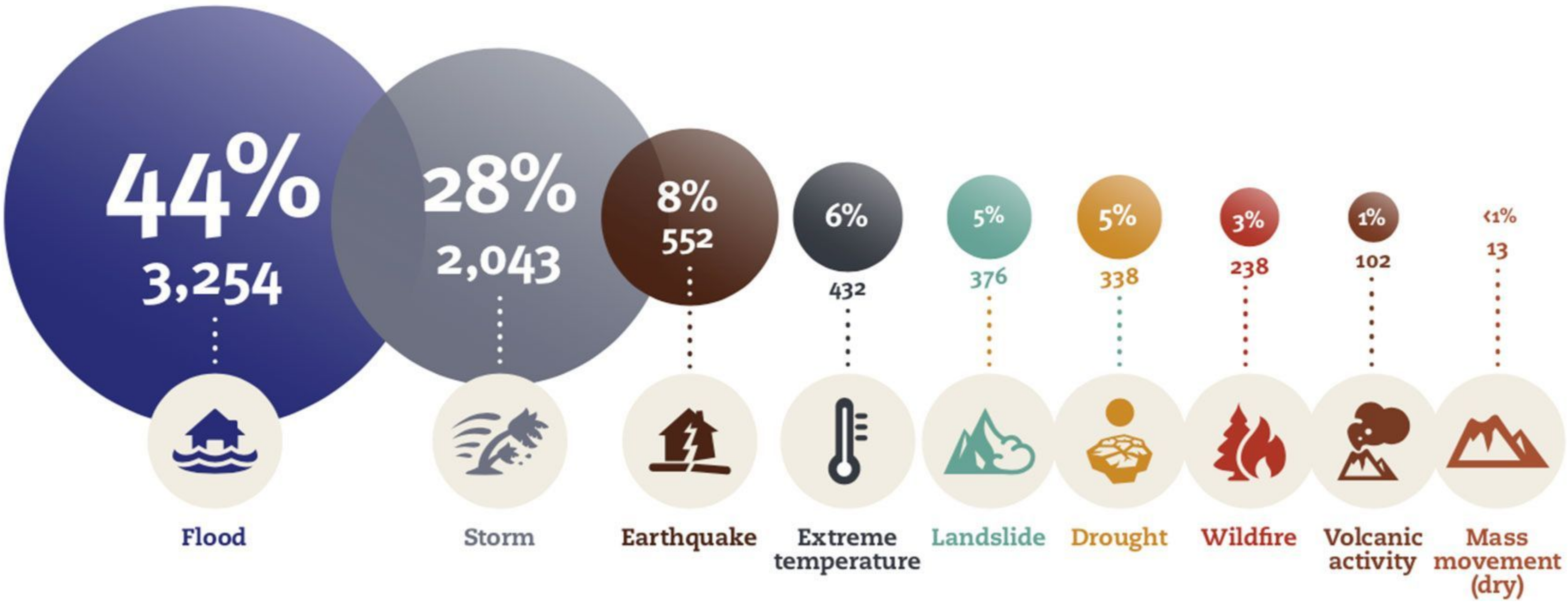
Climate Related Disasters (World)



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

Resilience

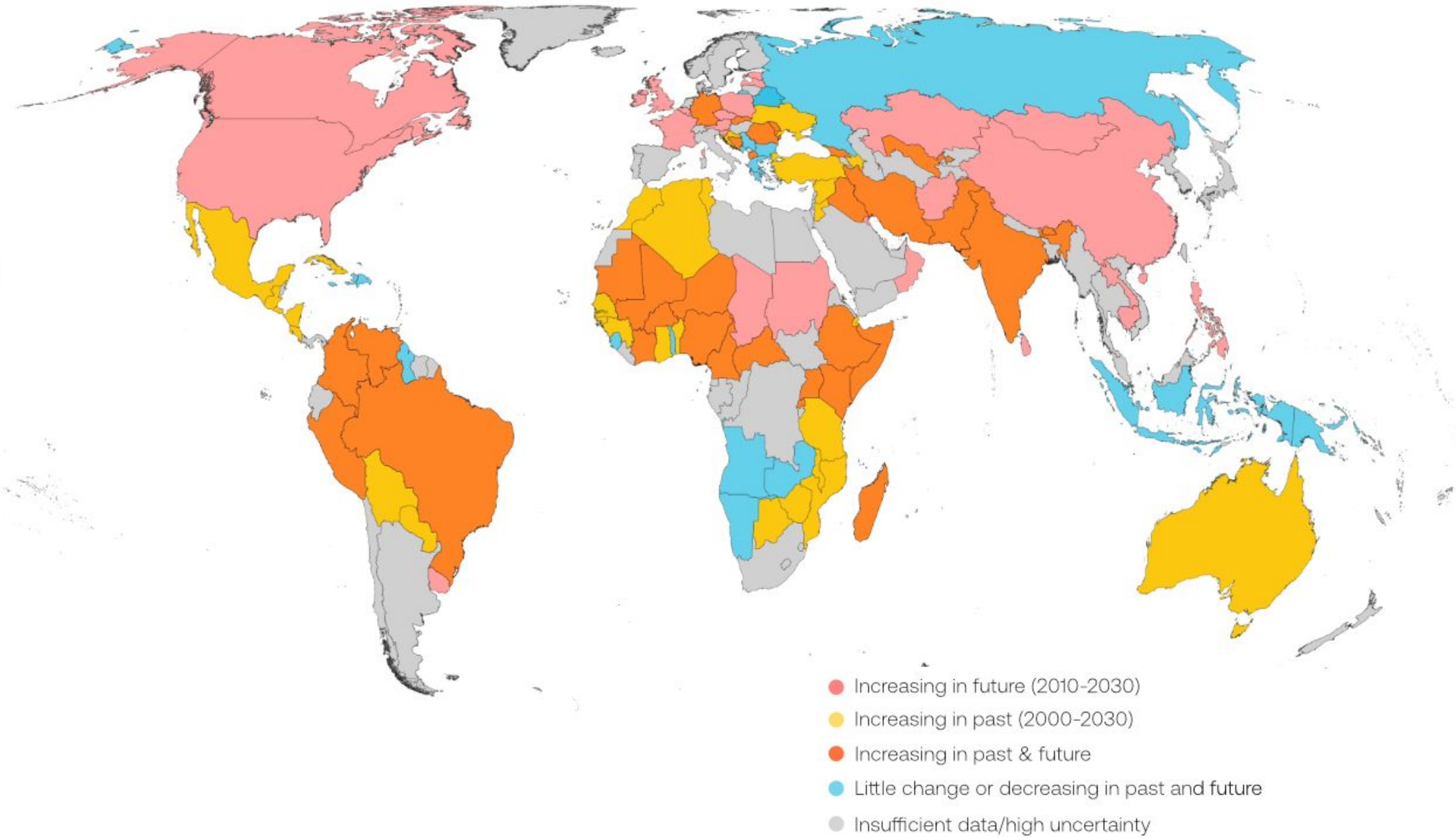
: the capability of a strained body to recover its size and shape after deformation caused especially by compressive stress

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

Toward Resilient Built Environment

water resilient built environment

Global Flooding Risks

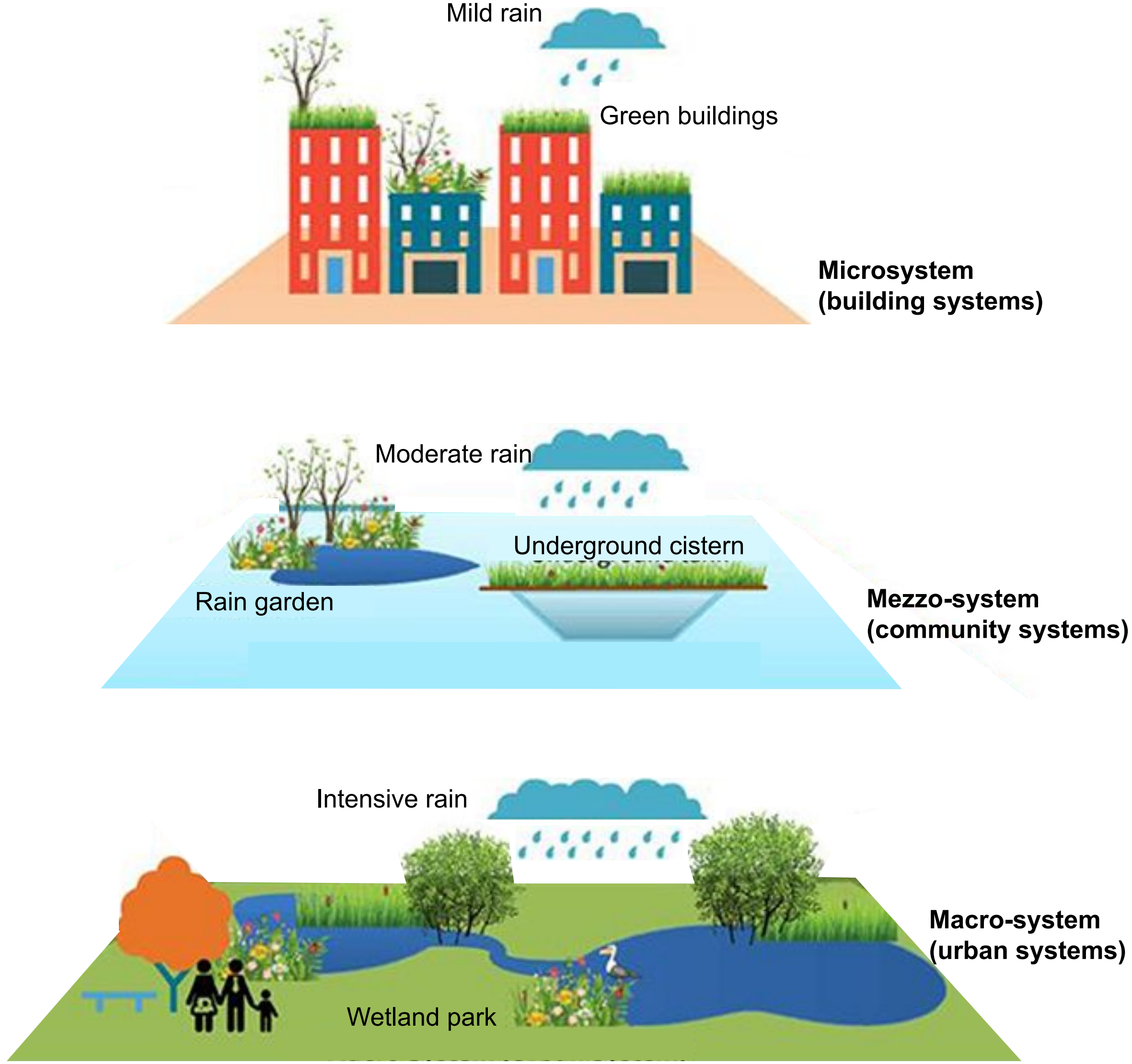


Global Flood Database 2000-2015


TOUR
WORLD

나가는 곳
Storage

Flooding Resiliency Framework



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

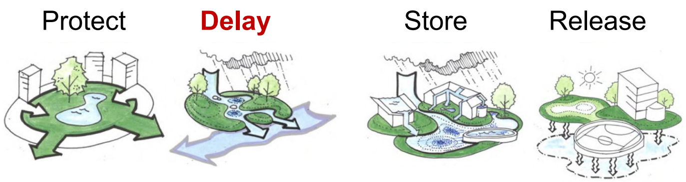
6. Aesthetics: Green roofs can add beauty and value to buildings.

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.

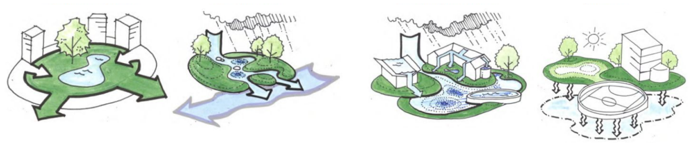
Intensive vs Extensive Green Roof

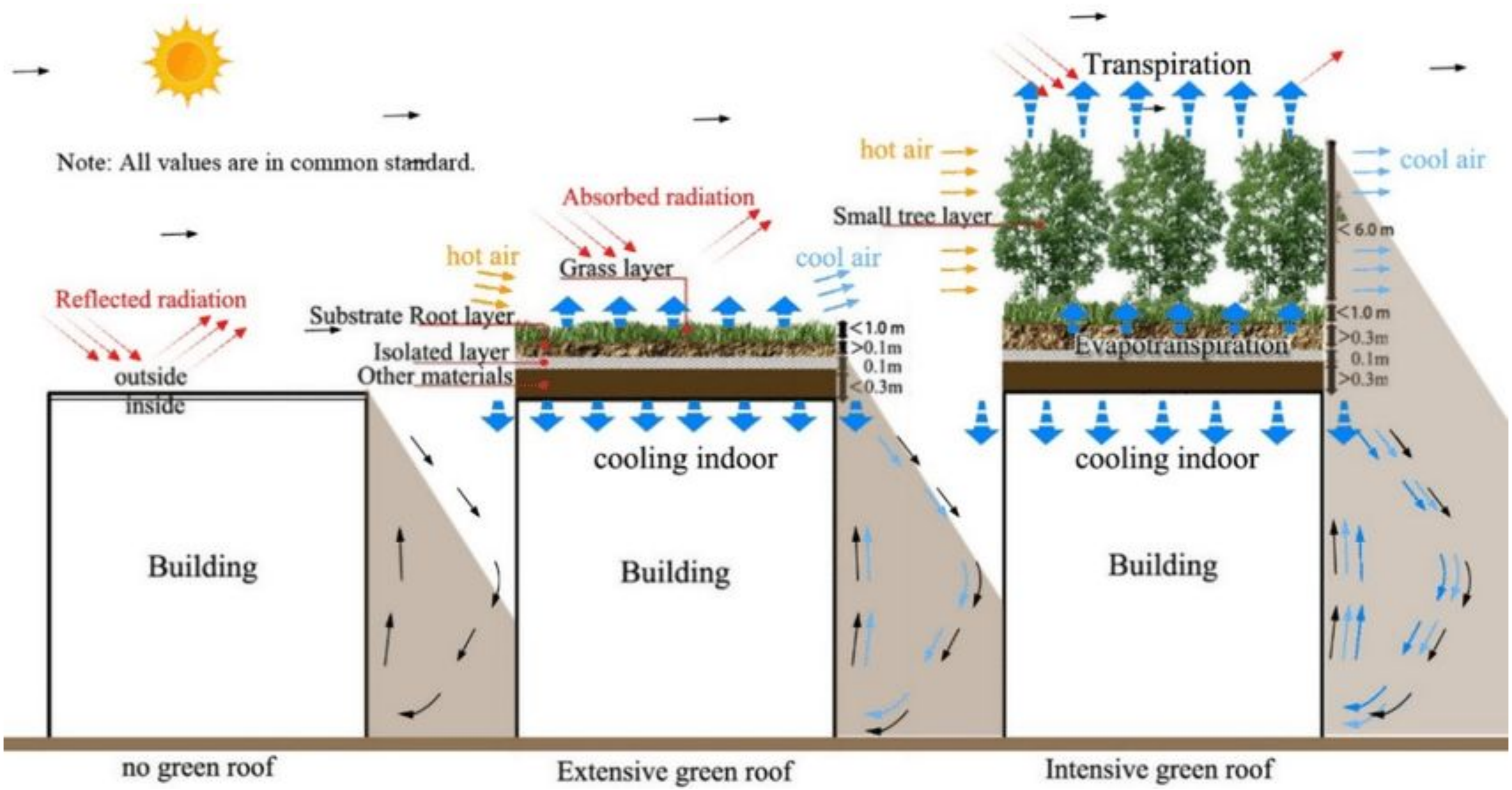


EXTENSIVE GREEN ROOF	SEMI-INTENSIVE GREEN ROOF	INTENSIVE GREEN ROOF
Height: 6- 20 cm	**Height** : 12 - 25 cm	**Height** : 15 cm > 1m
Weight: 60 - 150 kg/m^2	**Weight** : 120 - 200 kg/m^2	**Weight** : 180 - 500 kg/m^2
Vegetation: mosses, sedums, herbs and grasses	**Vegetation** : grasses, herbs and shrubs	**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

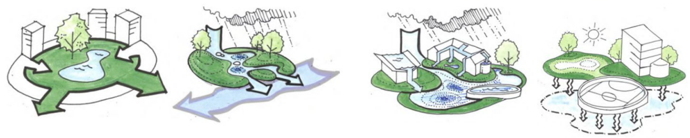


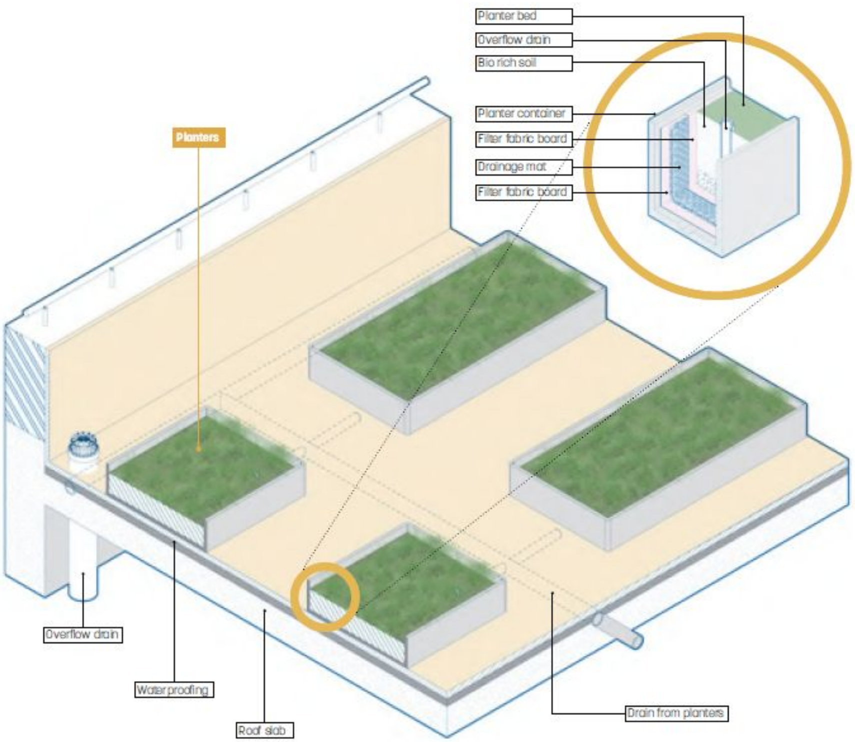


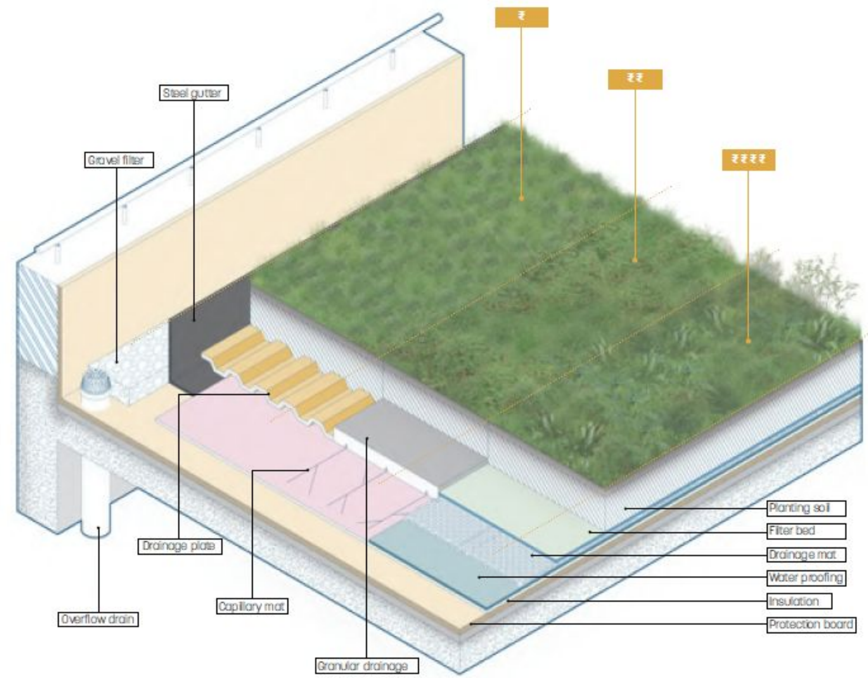
Impact of Morphological Characteristics of Green Roofs on Pedestrian Cooling in Subtropical Climates;
DOI: 10.3390/ijerph16020179

Intensive vs Extensive Green Roof

Protect **Delay** Store Release



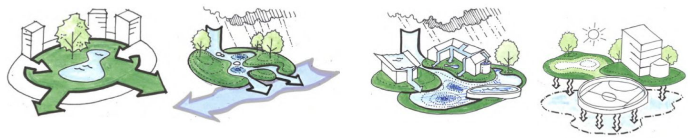


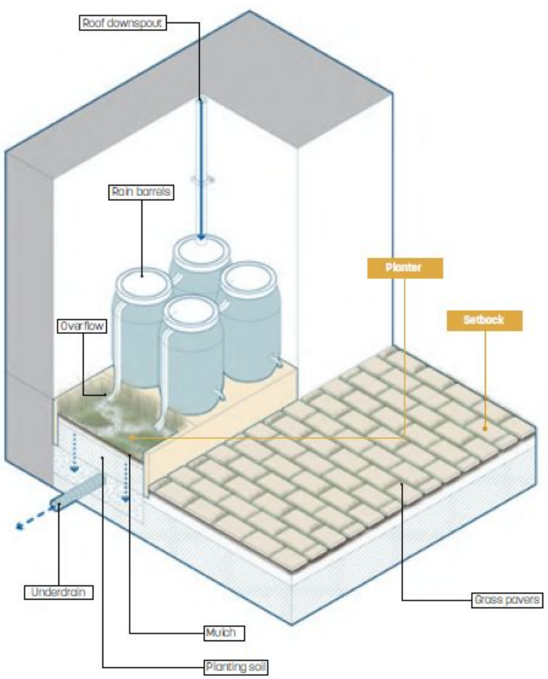


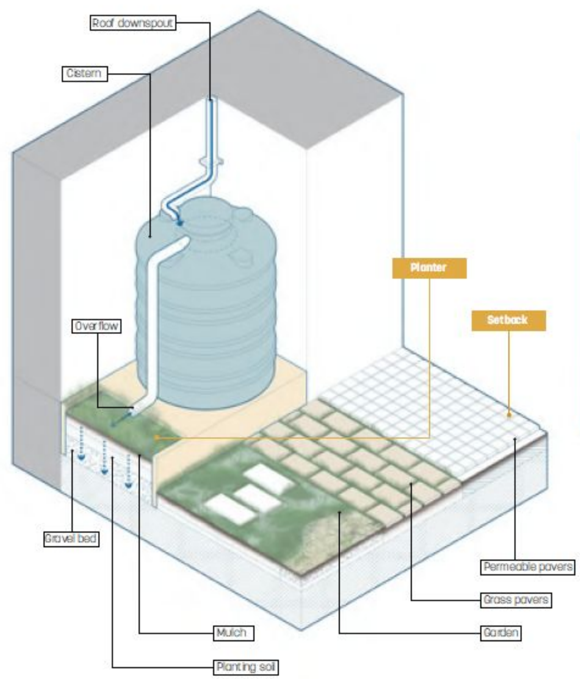
The Sponge Handbook: Chennai, 2019

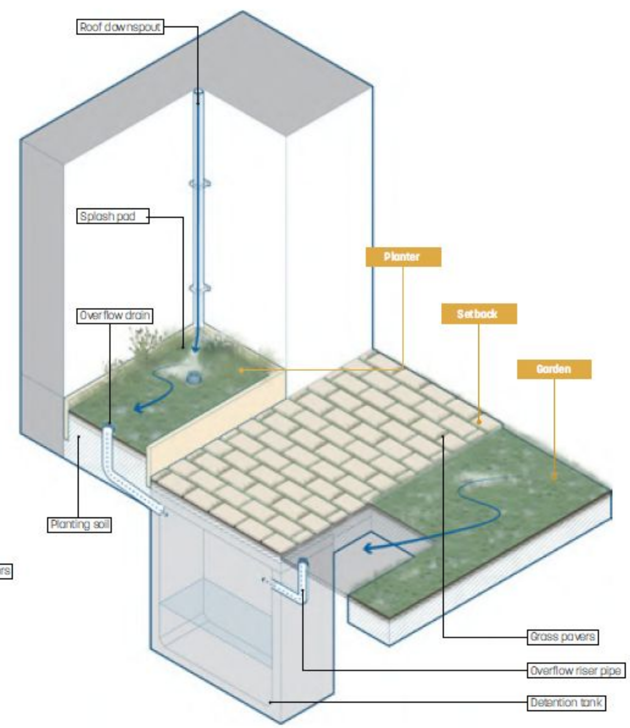
Rainwater Harvesting

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.

Undulated

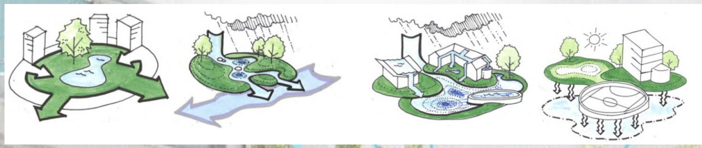
Top award for undulating wildflower green roof at Leeds Skelton Lake Services - Greenscape Magazine

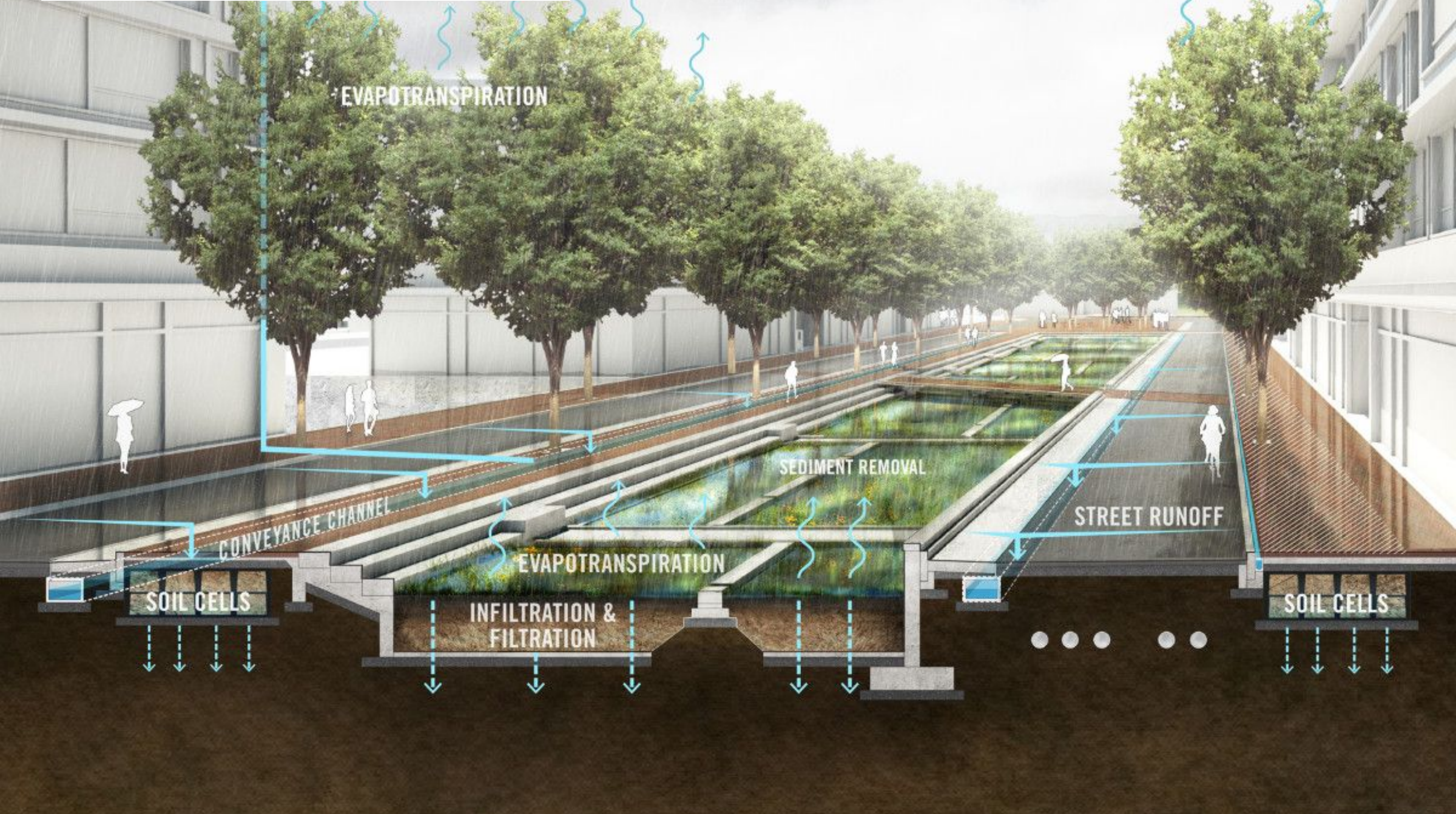
Scolloping

OPTIMIZED GREEN-ROOF SYSTEM RENOLIT ALKORPLAN GREEN

Sponge Street: Bioswale Channel, Sidewalk Planters, Tree Trenches

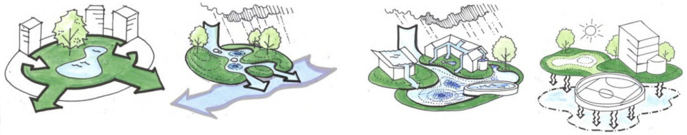
Protect | **Delay** | Store | Release





Sponge Street: Bioswale Channel, Sidewalk Planters, Tree Trenches

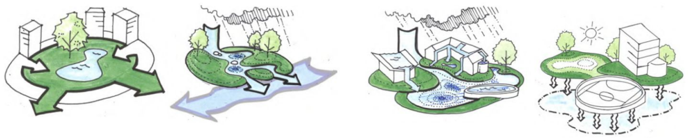
Protect **Delay** Store Release

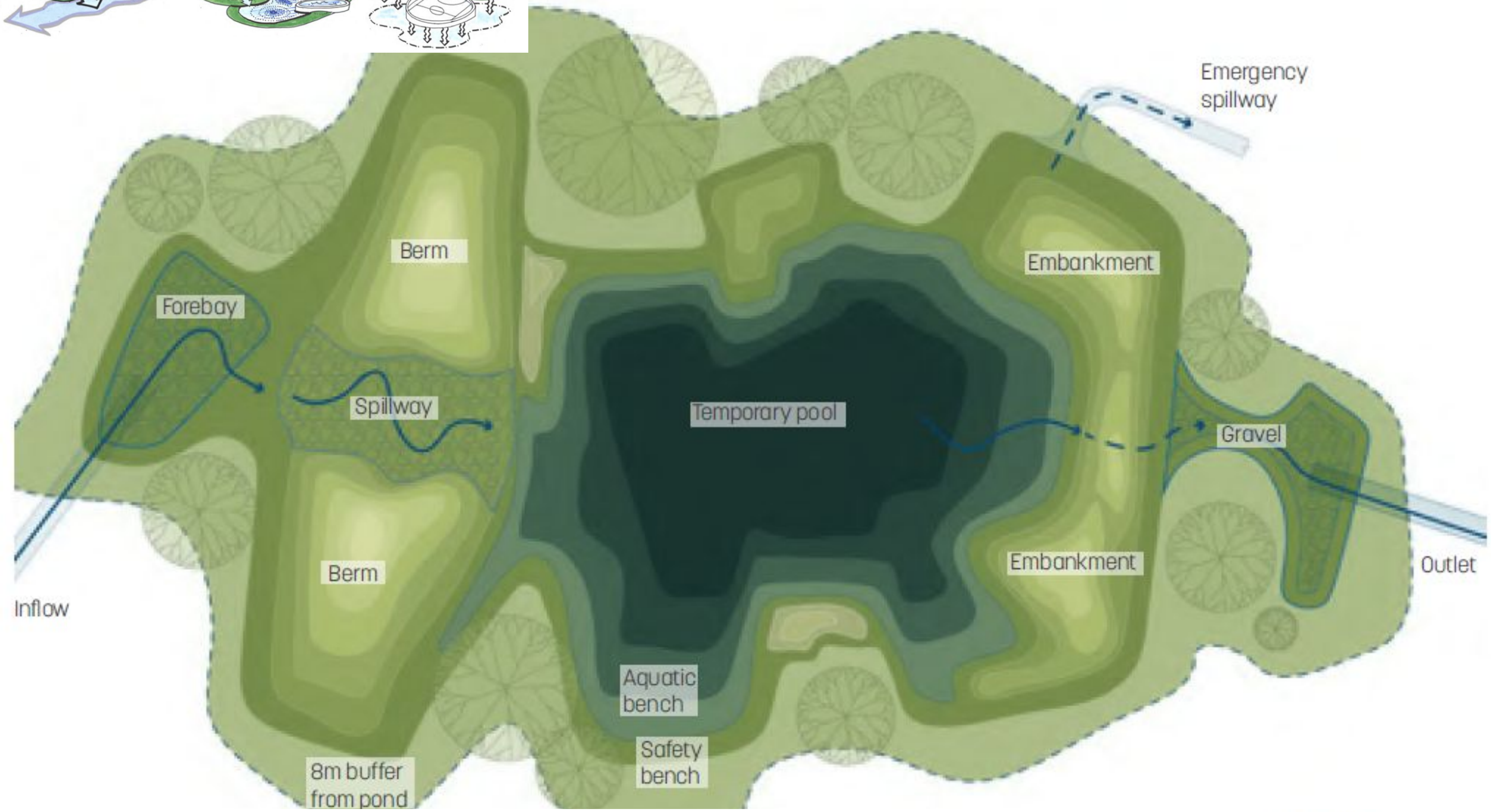


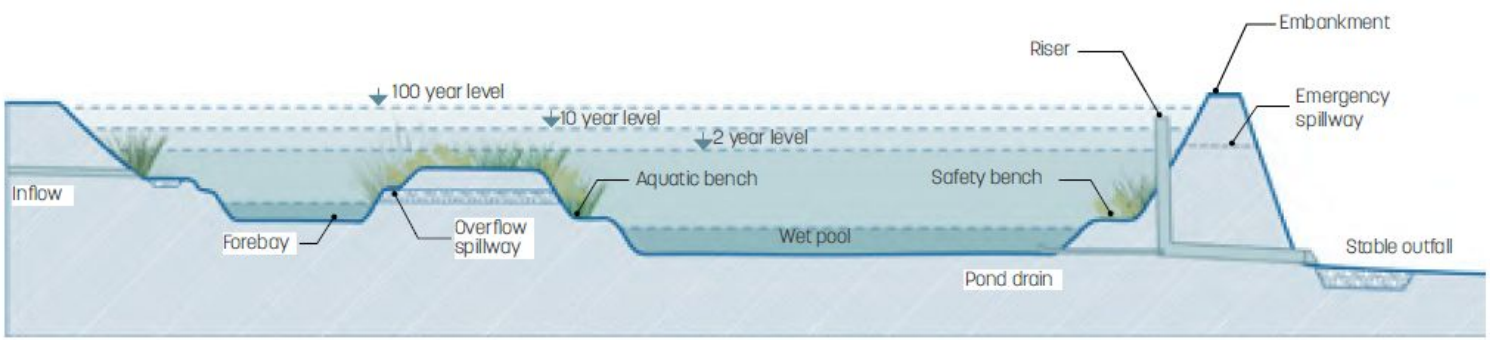
Kongjian Yu @ Turenscape

Flooding Resiliency: Constructed Ponds/Wetlands

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





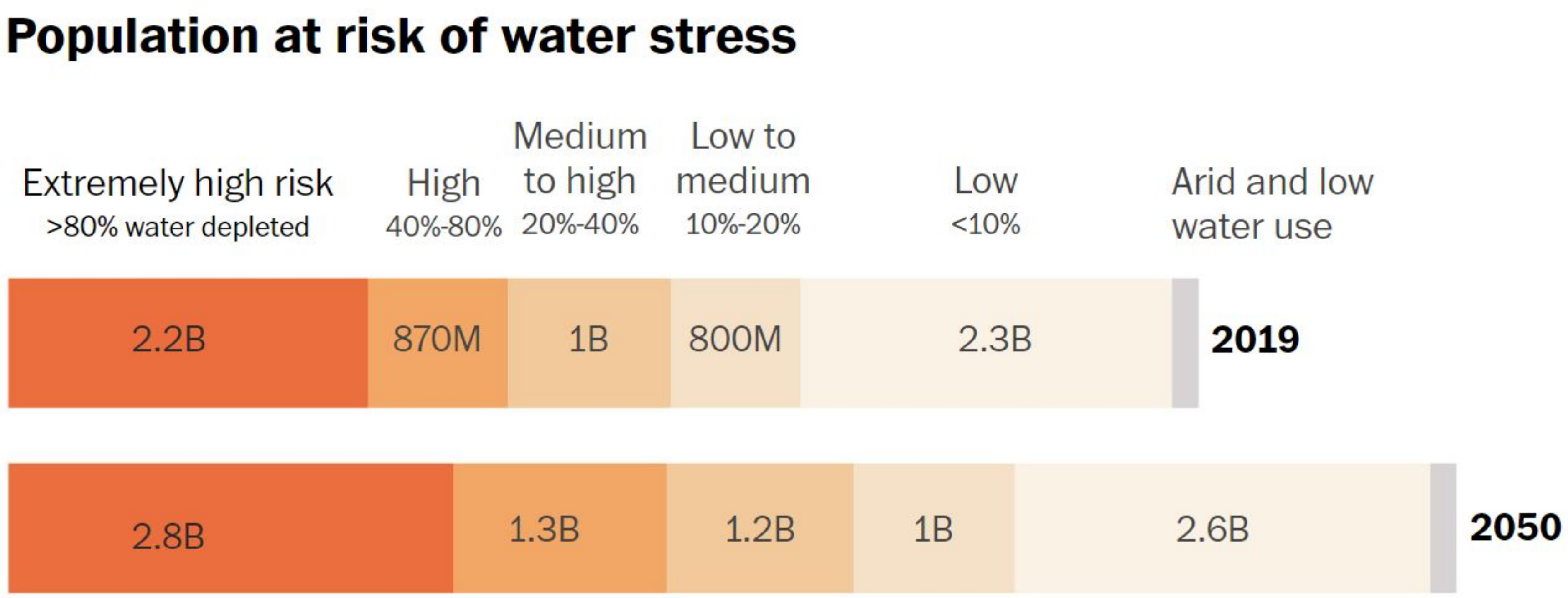


The architect making friends with flooding in MIT Tech Review
Kongjian Yu @ Turenscape


Kongjian Yu @ Turenscape

drought resilient built environment

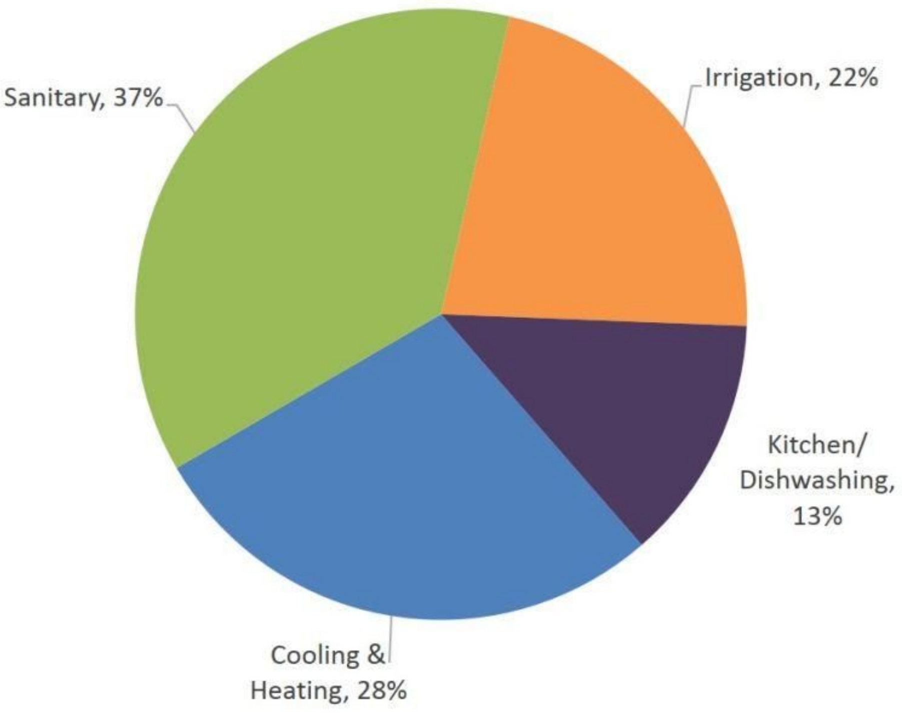
Drought Resiliency



The Washington Post

Drought Resiliency: Reduction of Water Usage

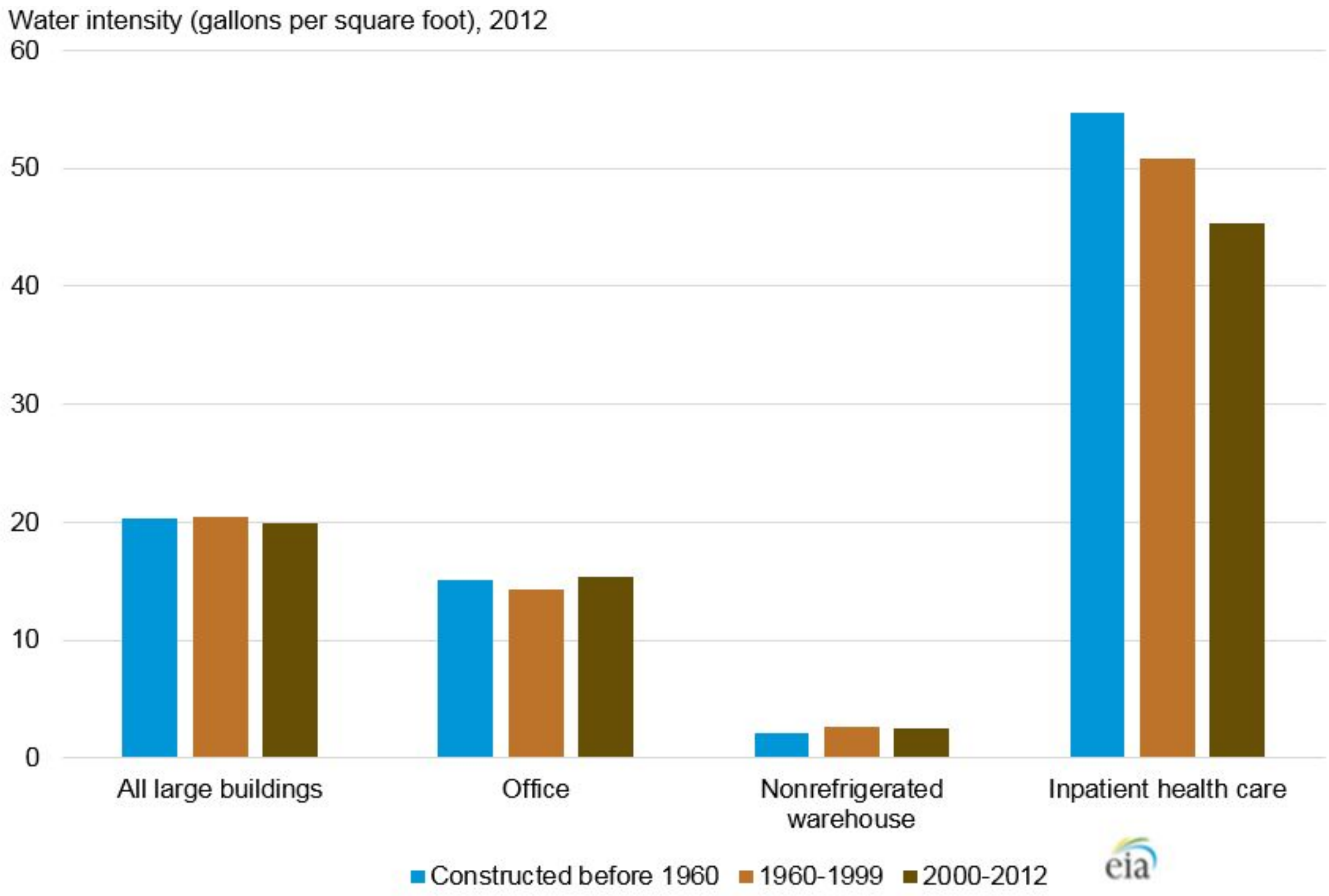
Typical office building energy uses of water: ~17 gallons/sq.ft (2012)



US EPA

Drought Resiliency: Reduction of Water Usage

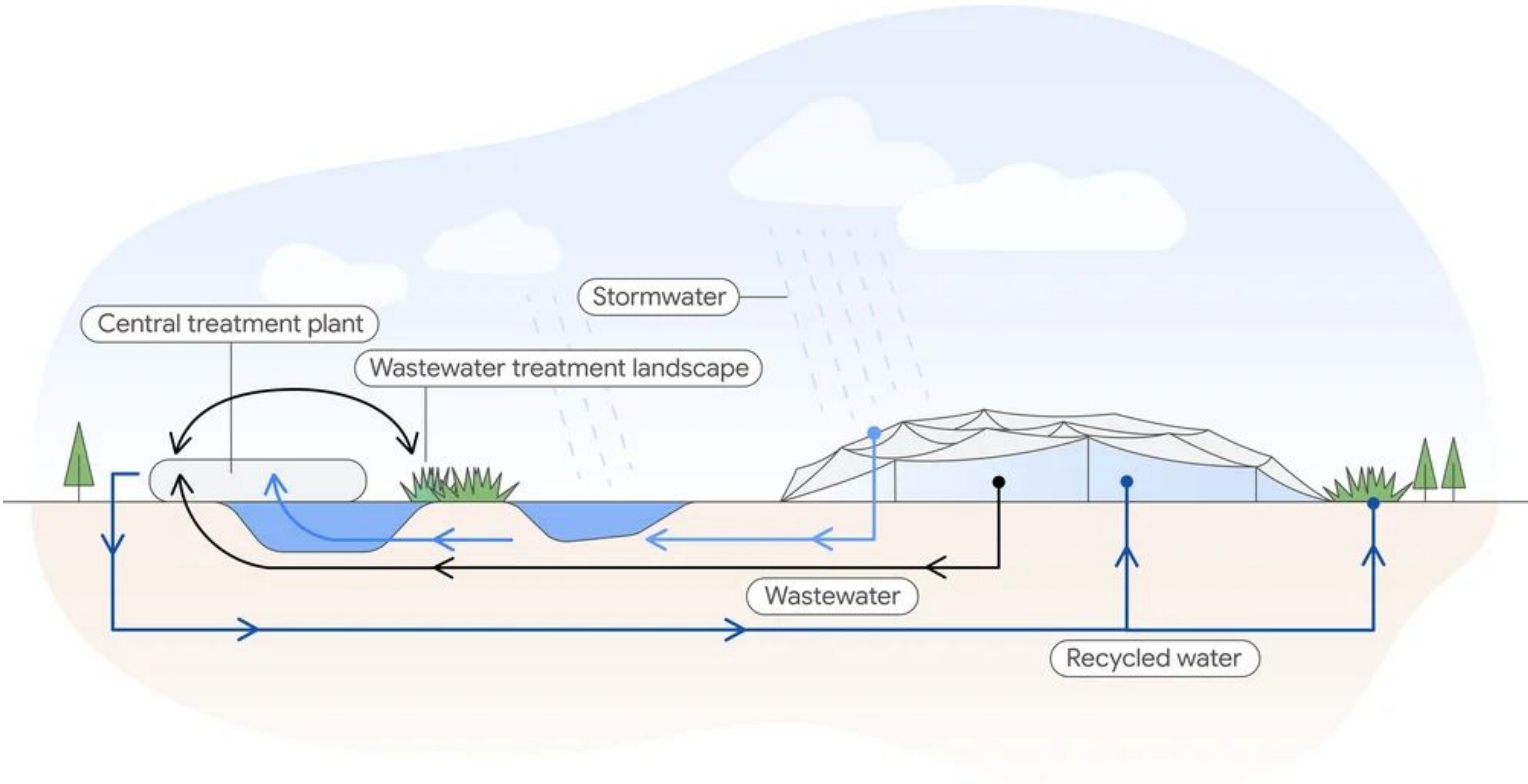
Typical office building energy uses of water: ~17 gallons/sq.ft (2012)
Water intensity varies little by year of construction except in inpatient heath care buildings



Drought Resiliency: Rainwater Collection and Grey Water Treatment

Google HQ, CA

Drought Resiliency: Rainwater Collection and Grey Water Treatment

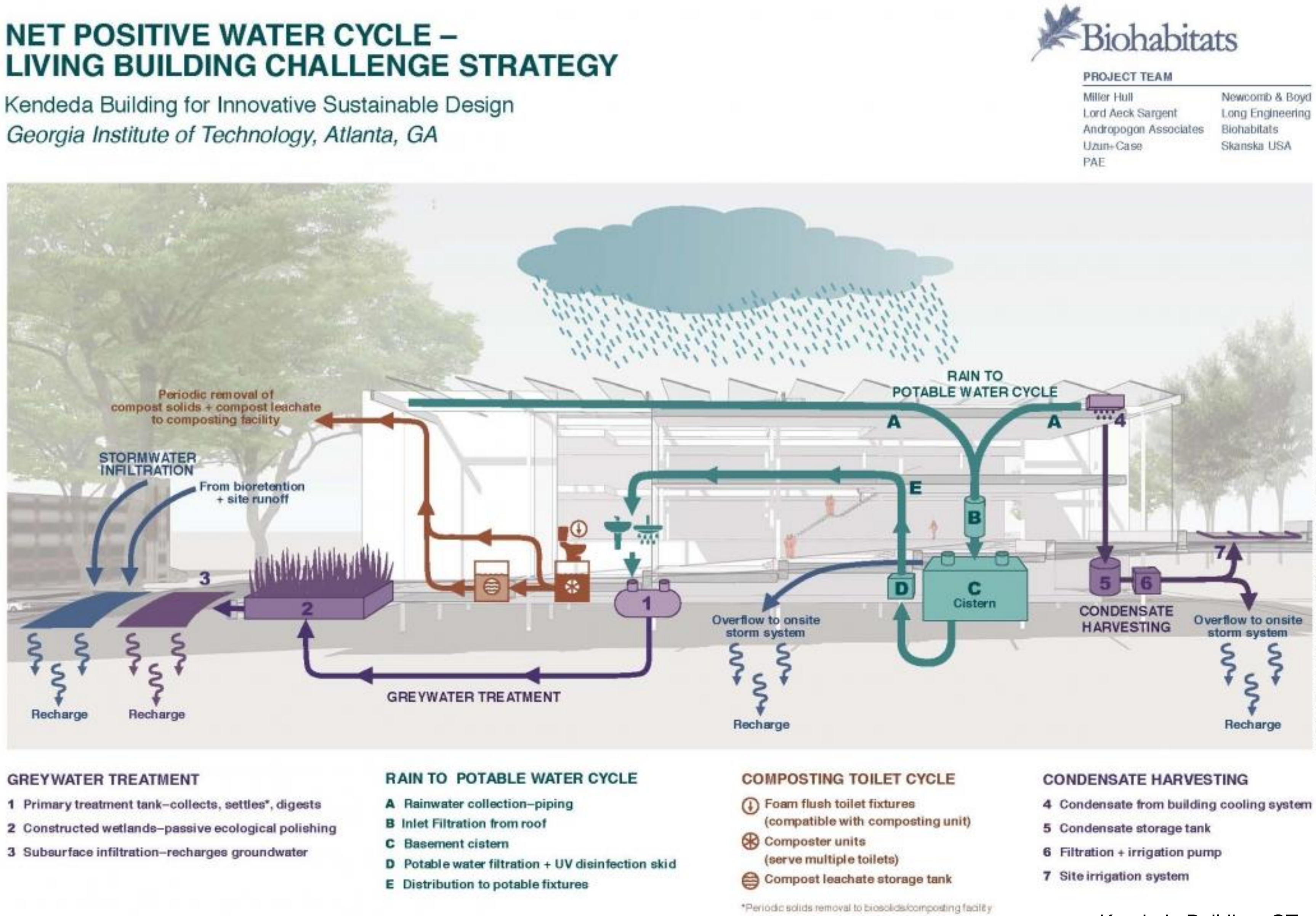


Google HQ, CA

Drought Resiliency: Rainwater Collection and Grey Water Treatment

Kendeda Building, GTech

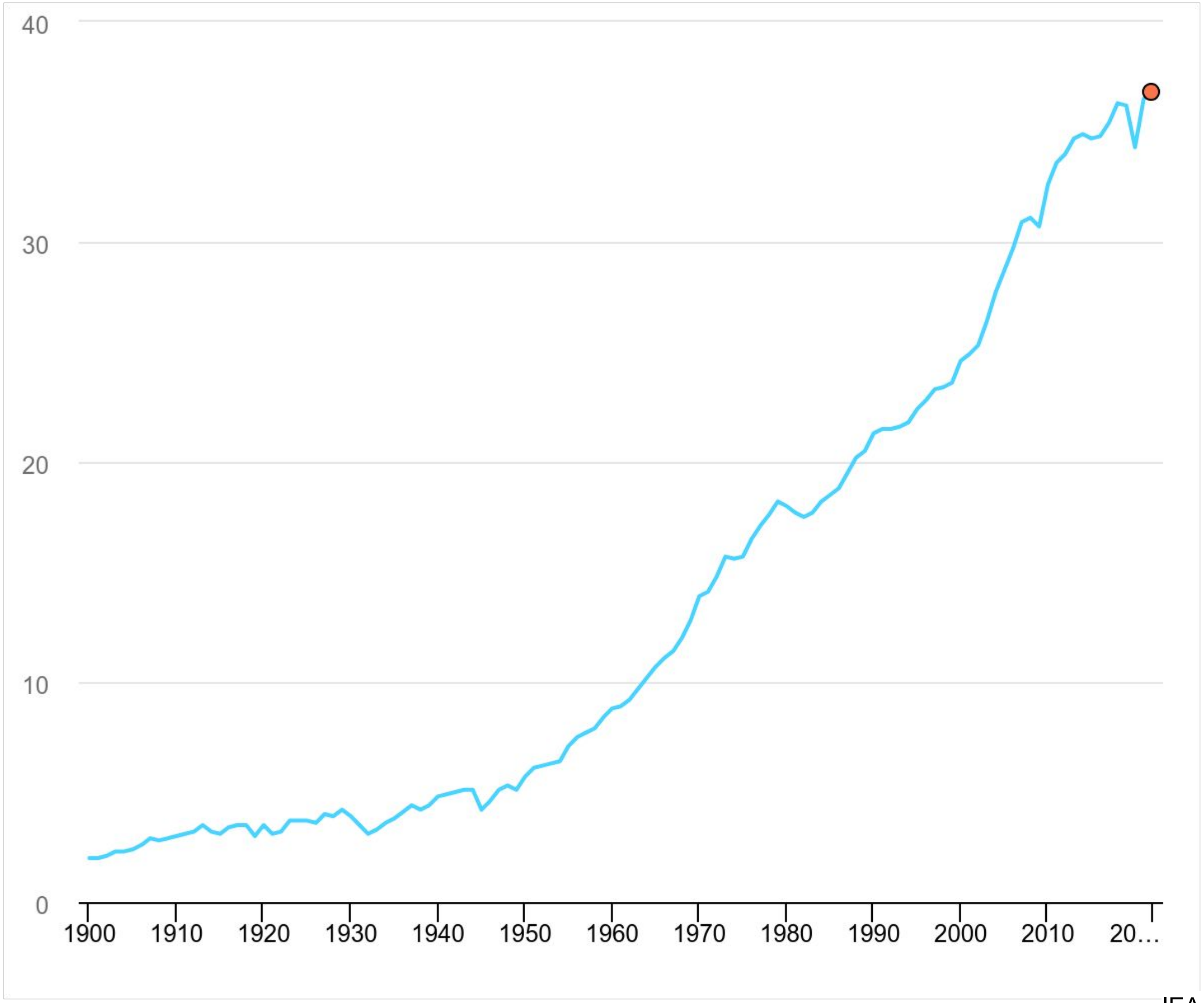
Drought Resiliency: Rainwater Collection and Grey Water Treatment



Kendeda Building, GTech

energy resilient built environment

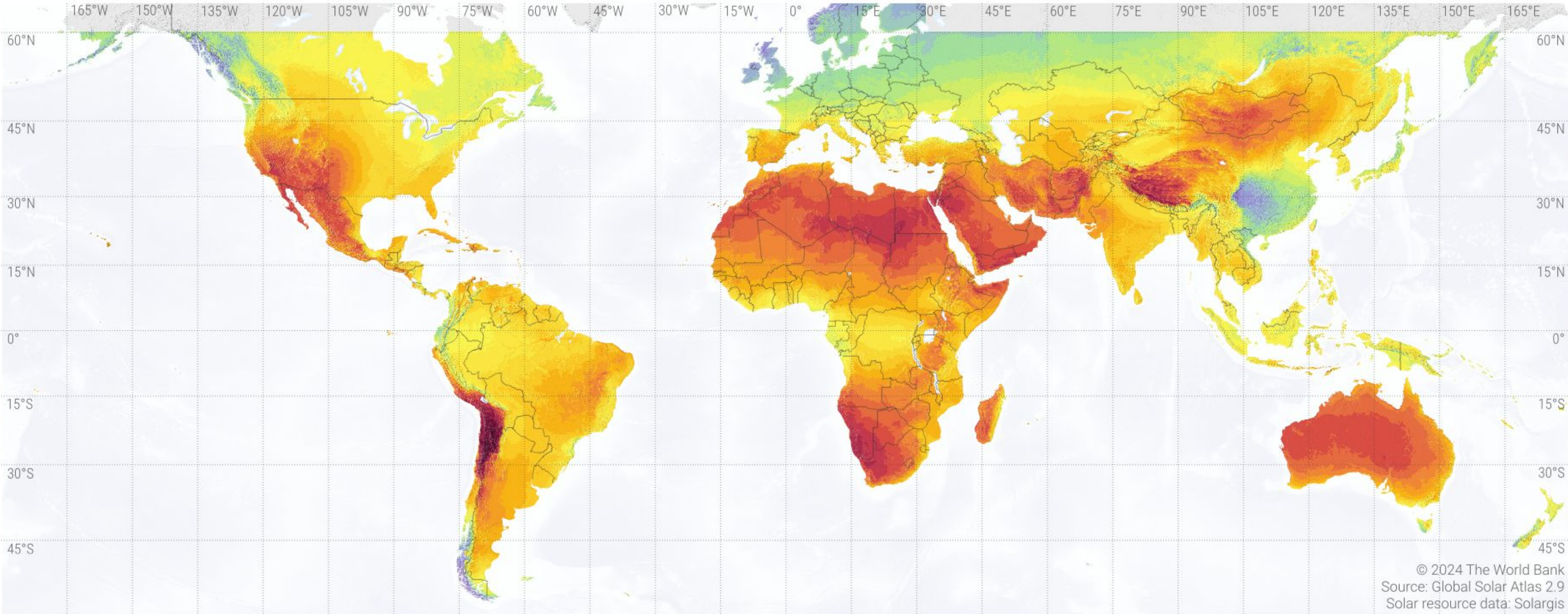
Global CO2 emissions from energy combustion and industrial processes, 1900-2022



SOLAR RESOURCE MAP

PHOTOVOLTAIC POWER POTENTIAL

WORLD BANK GROUP ESMAP SOLARGIS



Long-term average of photovolaic power potential (PVOUT)

Daily totals:	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	5.2	5.6	6.0	6.4	kWh/kWp
Yearly totals:	730	876	1022	1168	1314	1461	1607	1753	1899	2045	2191	2337	

Climate Resilient Hospitals

Health Care Climate Council

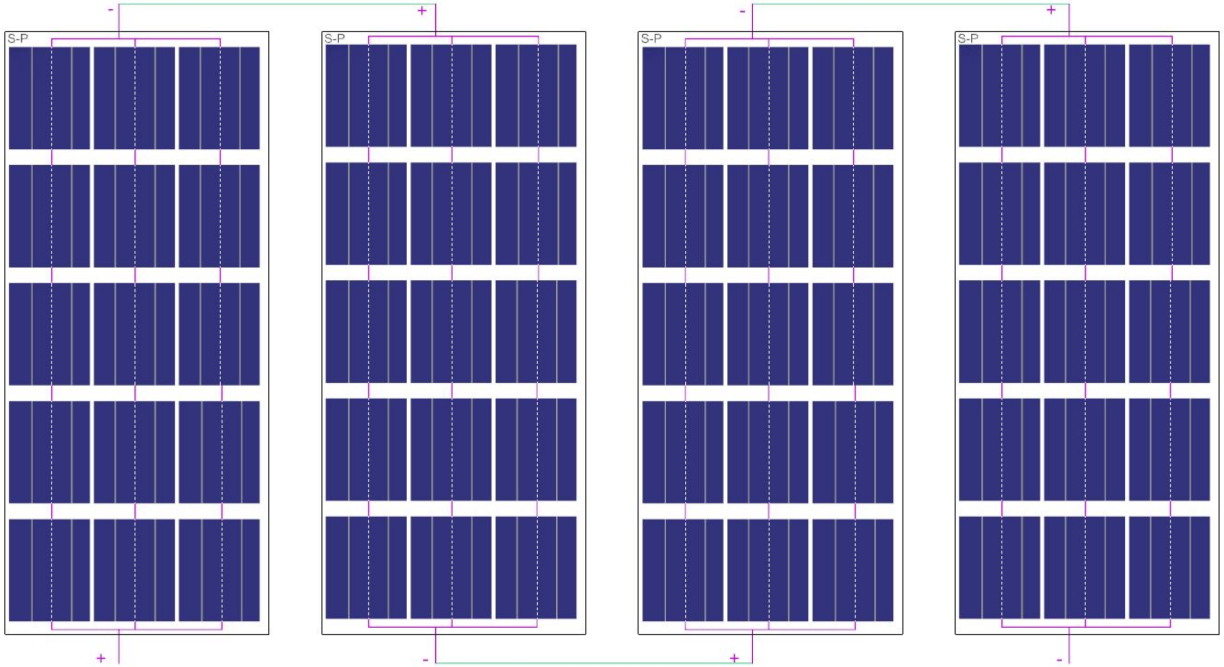
Daily Fuel Consumption by Healthcare and Public Health Sector Facilities

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

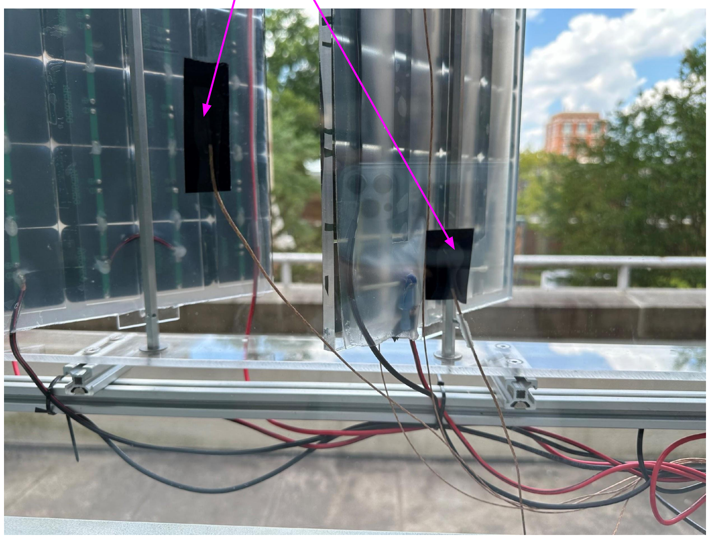
Healthcare Facilities and Power Outages – FEMA.gov

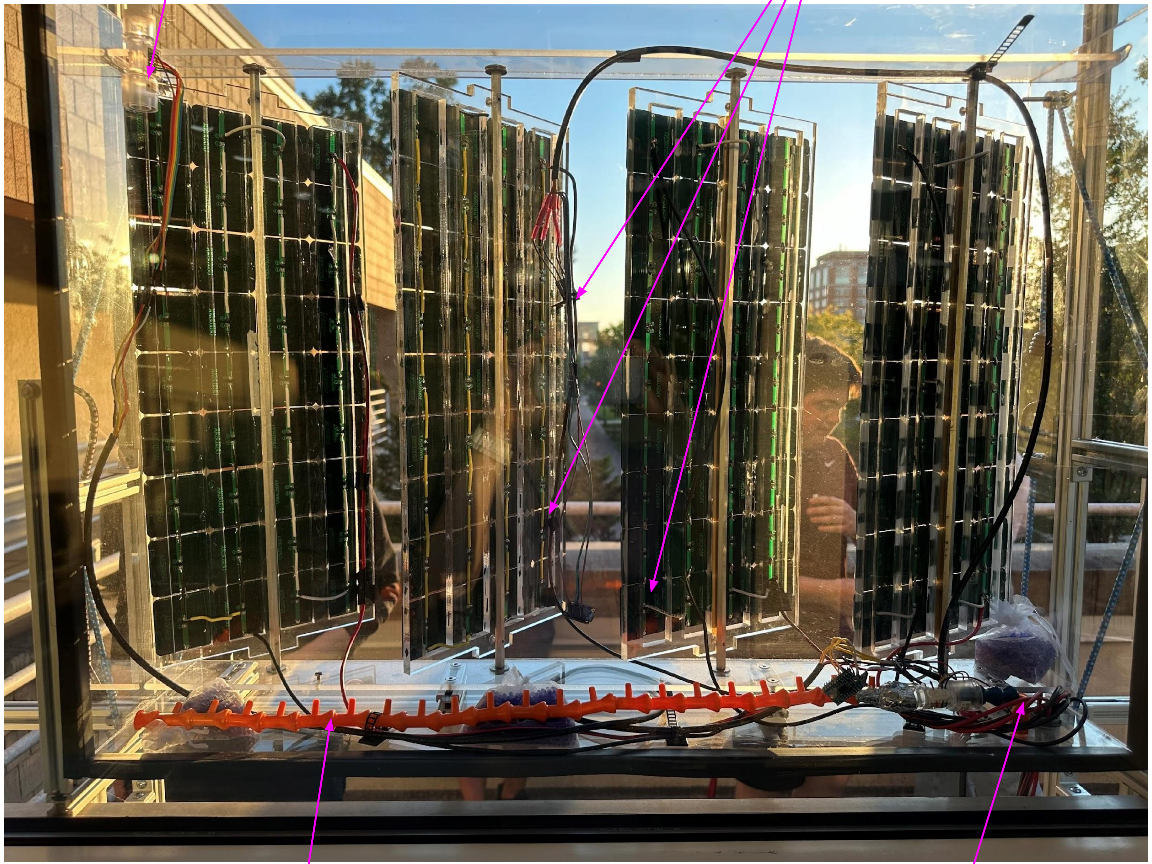
Solar Fin Circuit Connections: Series – Parallel in Closed Cavity Façade System

Mock-up D

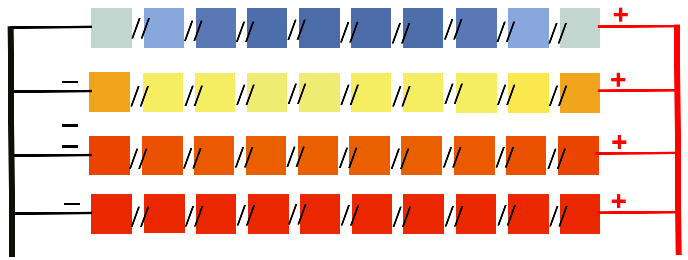


BIPV Environmental Sensors and Data Collection

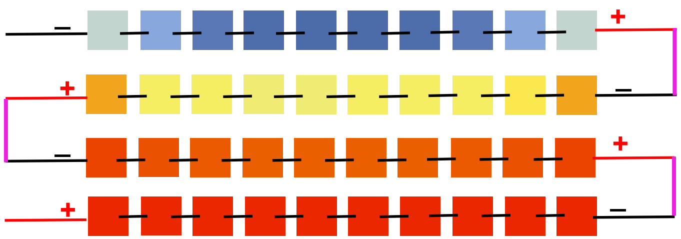




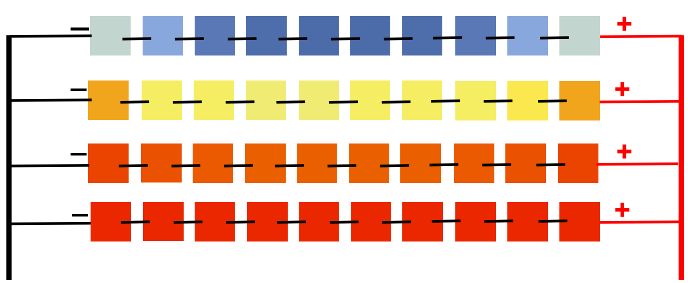
Energy Production Enhancement for BIPV Under Partial Shadow: Series-Series vs Series-Parallel vs Parallel-Parallel



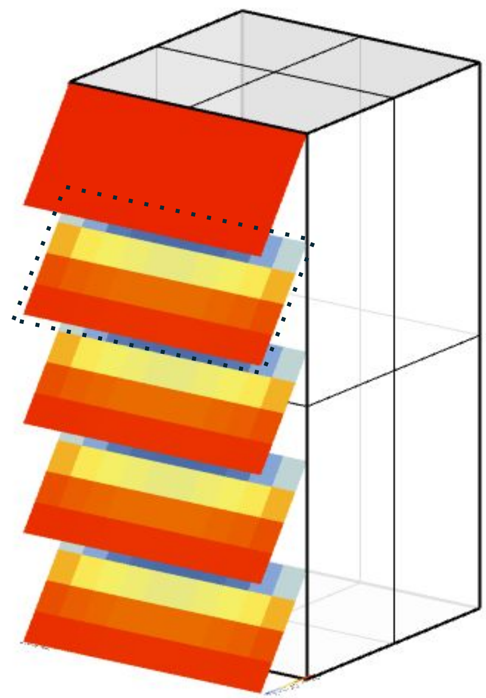
In each string, PV cells are connected in parallel; Strings are connected in parallel



In each string, PV cells are connected in series; Strings connected in series

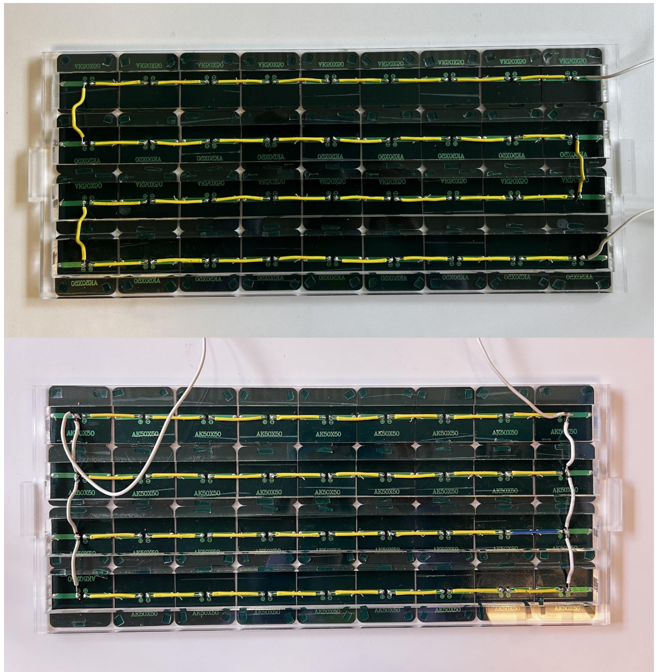


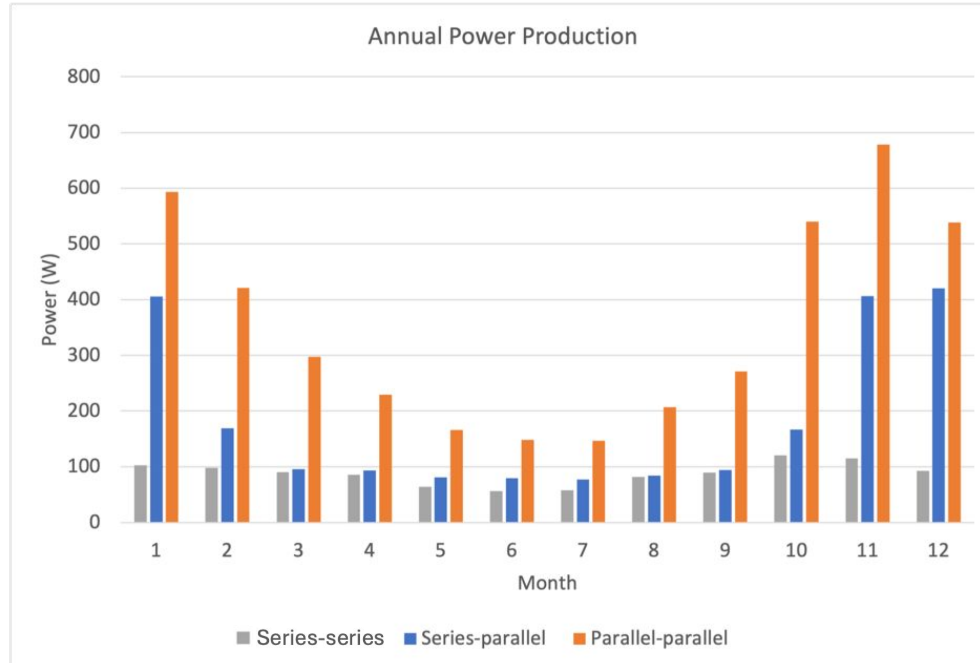
In each string, PV cells are connected in parallel; Strings connected in parallel

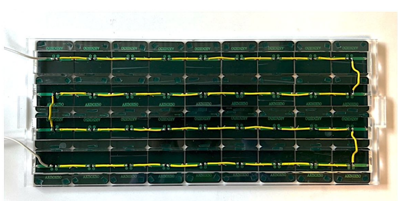


Irradiance levels on PV-louvers south facade

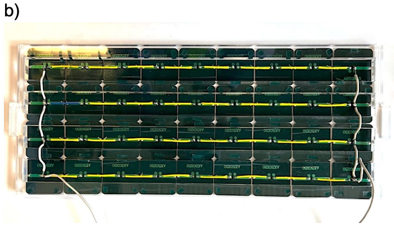
Energy Production Enhancement for BIPV Under Partial Shadow Results: Series-Series vs Series-Parallel

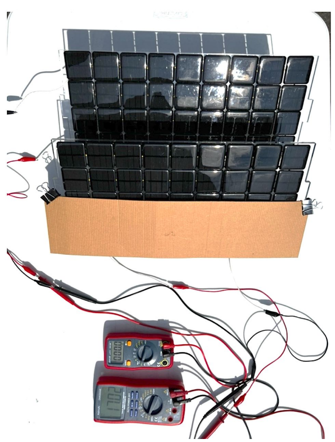






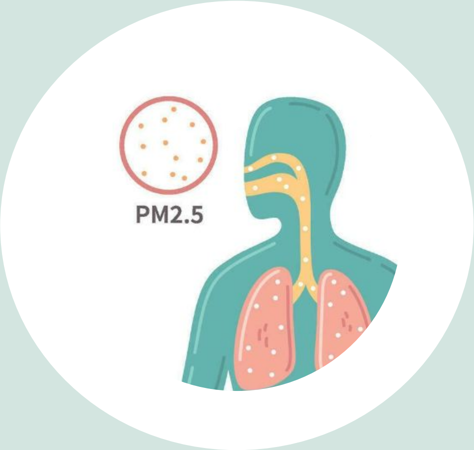
b)





Measured I and V for the series-series PV panel:
In the self-shading condition □ 0.011A and 78V, the generated power output was 0.91 W.
In fully exposed to the sun conditions □ 0.16A and 83V, the generated power output was 13.28 W

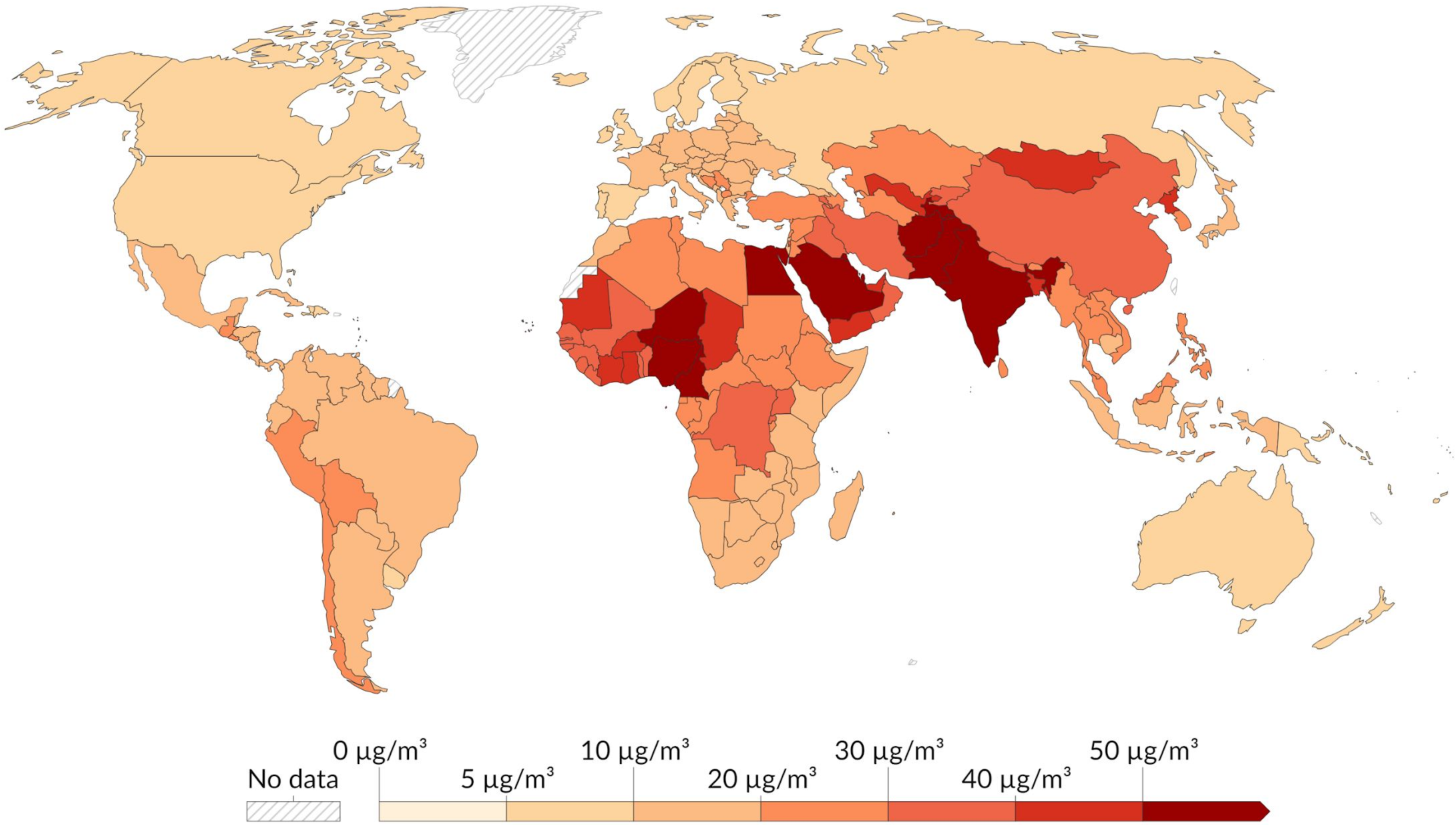
Measured I and V for the series-parallel PV panel:
In the self-shading condition □ 0.4A and 21V, the generated power output was 8.4 W.
In fully exposed to the sun conditions □ 0.64A and 21V, the generated power output was 13.44 W



clean air built environment

Exposure to particulate matter air pollution, 2019

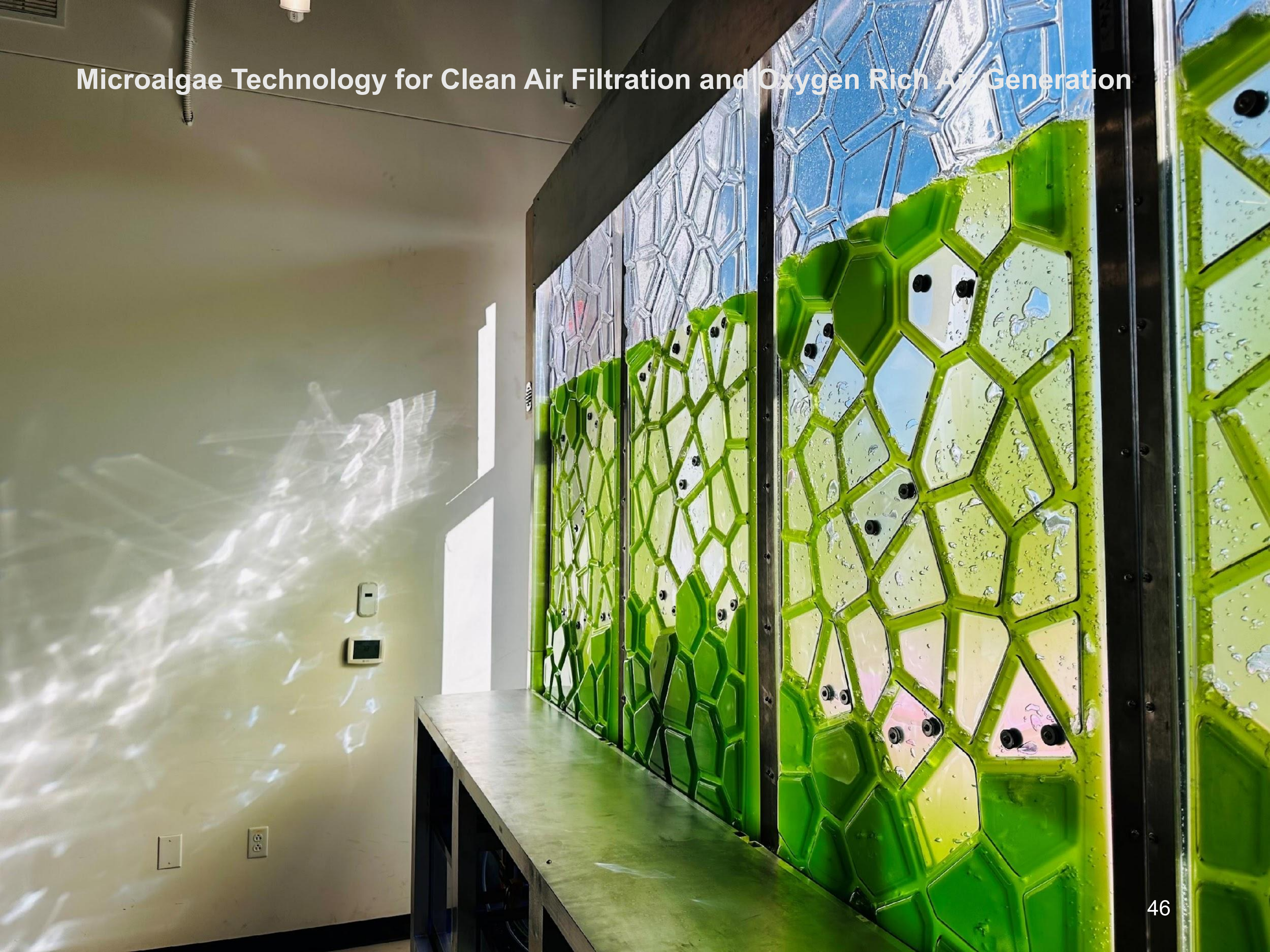
Population-weighted average level of exposure to concentrations of suspended particles measuring less than 2.5 microns in diameter (PM2.5). Exposure is measured in micrograms of PM2.5 per cubic meter (µg/m³).



Data source: World Health Organization - Global Health Observatory (2024)

Note: The WHO's Air Quality Guidelines[1] suggest annual average PM2.5 exposure should be less than 5 µg/m³ in order to minimize the impacts of PM2.5 on human health.

Microalgae Technology for Clean Air Filtration and Oxygen Rich Air Generation



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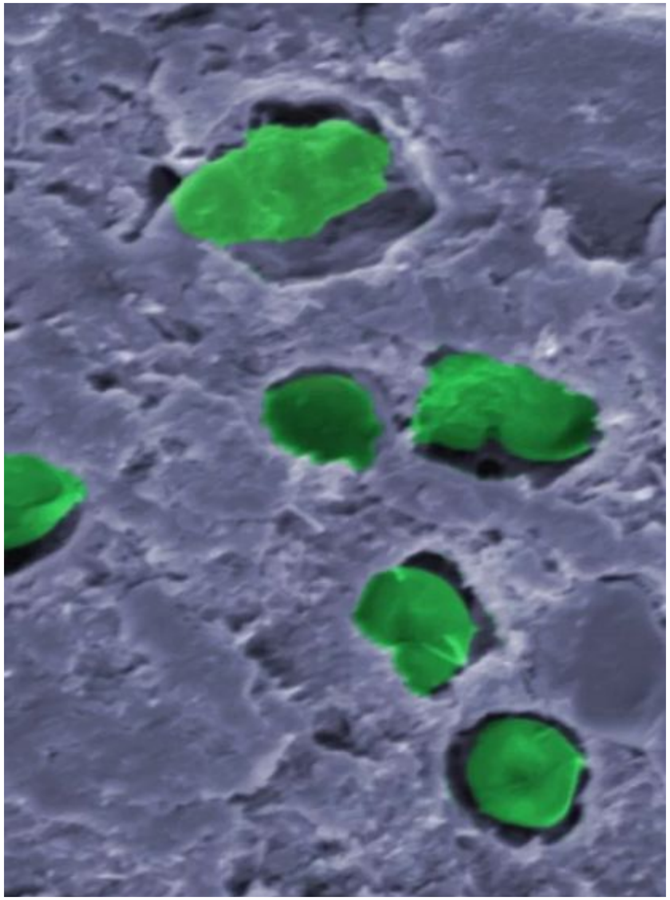


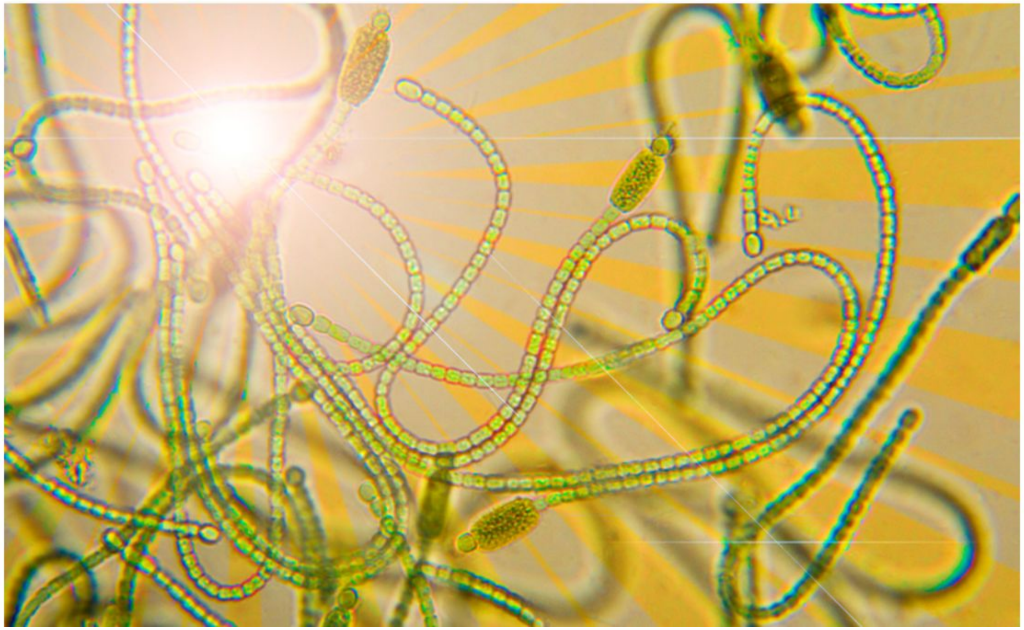
Scientists Just Came Up With a Wild Idea For Making Oxygen on Mars

University of Surrey, England

Zeroing in on the origins of Earth's "single most important evolutionary innovation"

A new study shows oxygenic photosynthesis likely evolved between 3.4 and 2.9 billion years ago.

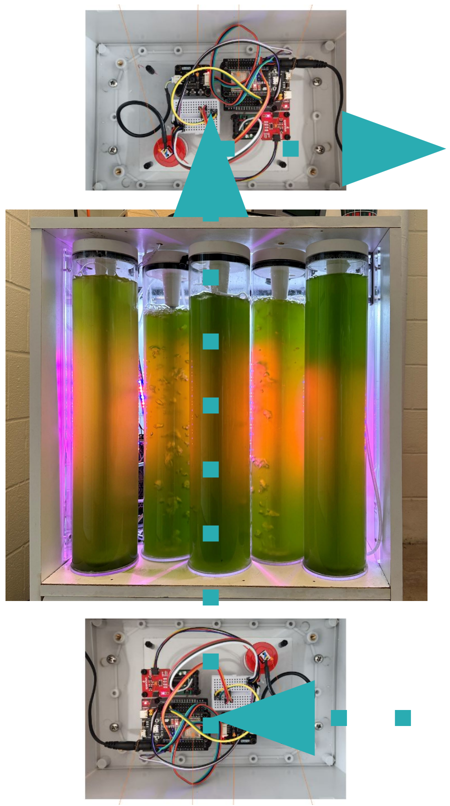
Jennifer Chu | MIT News Office
September 28, 2021




NO TRASH

Microalgae Technology for Clean Air Filtration and Oxygen Rich Air Generation

Oxygen rich clean air exiting
after room air filtered through
microalgae enclosures



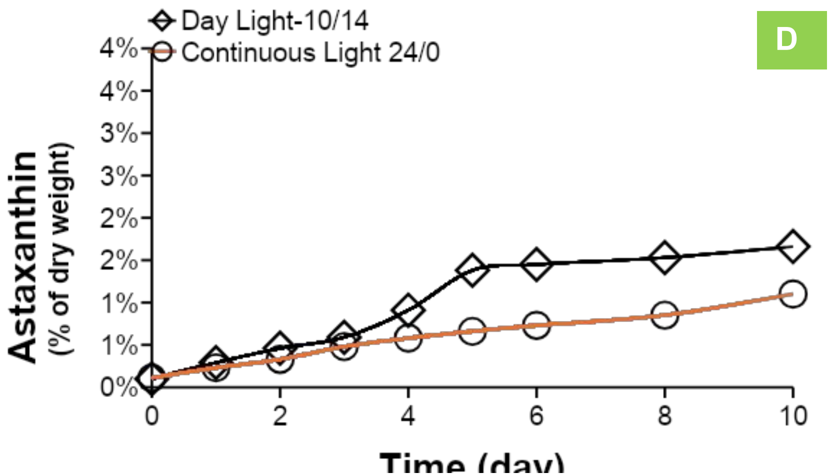
Entering air quality sensors (room air)

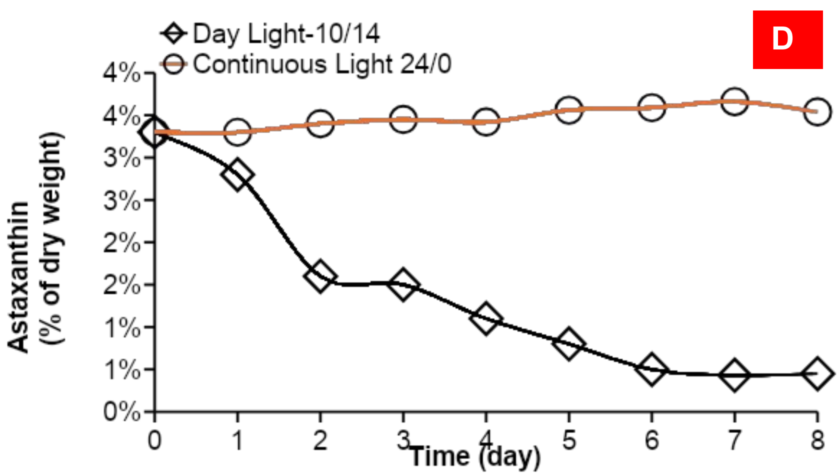
Oxygen rich air generation: YES
Gaseous air pollutants removal: YES
(e.g. VOCs, CO2, O3, NO2 etc.)
Solid air pollutants removal: YES
(e.g. PM, Mold, Pollen etc.)

Vs.

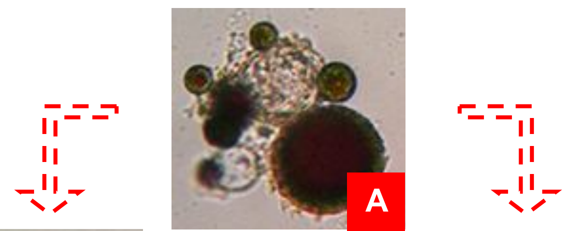
Oxygen rich air generation: NO
Gaseous air pollutants removal: NO
(e.g. VOCs, CO2, O3, NO2 etc.)
Solid air pollutants removal: YES
(e.g. PM, Mold, Pollen etc.)

Core Technology Innovation



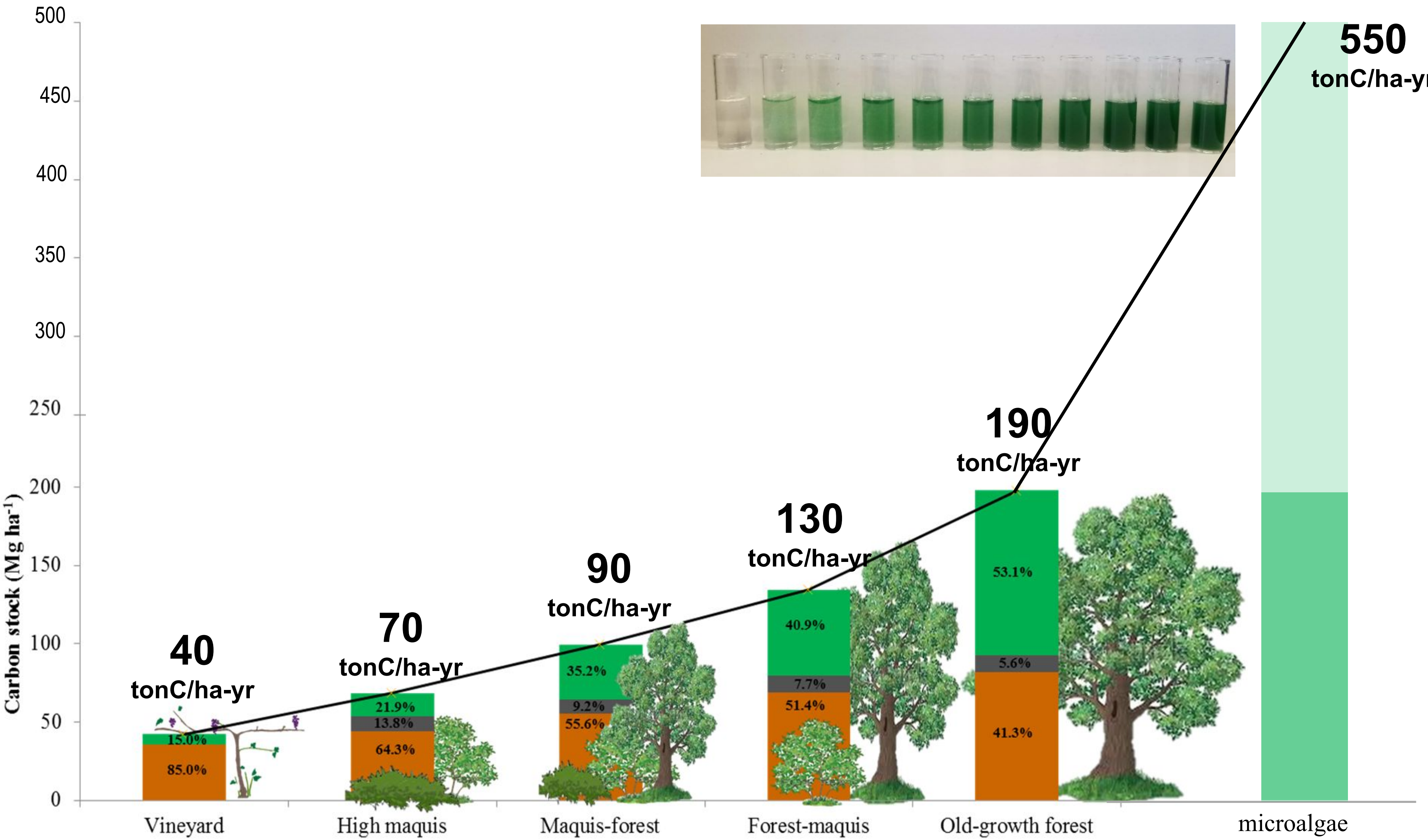


Changes of morphology of green cells of *Haematococcus pluvialis* in 6L Biochromic Crown Shyness Windows. A & B, Dividing cells with daughter cells enclosed by mother cell wall. C, The motile green single cells.



Changes of morphology of red cells of *Haematococcus pluvialis* in 6L Biochromic Crown Shyness Windows. A, Resting red cells, cyst; B & C, Dividing cells with daughter cells enclosed by mother cell wall. D & E, release of motile daughter cells from mother cells.

Environmental, Social, and Economic Sustainability: Effective Carbon Sink



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

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CHARLOTTE

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CITIES PARTNERSHIP