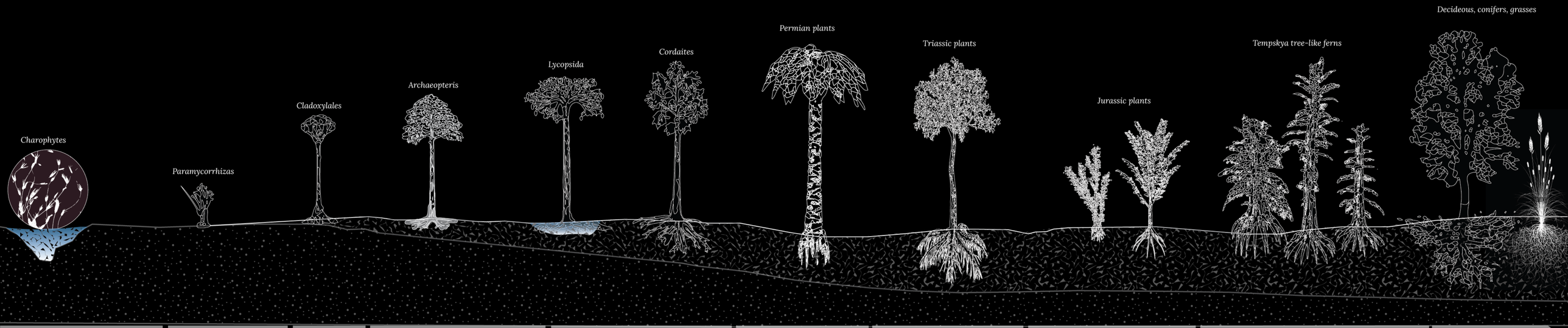
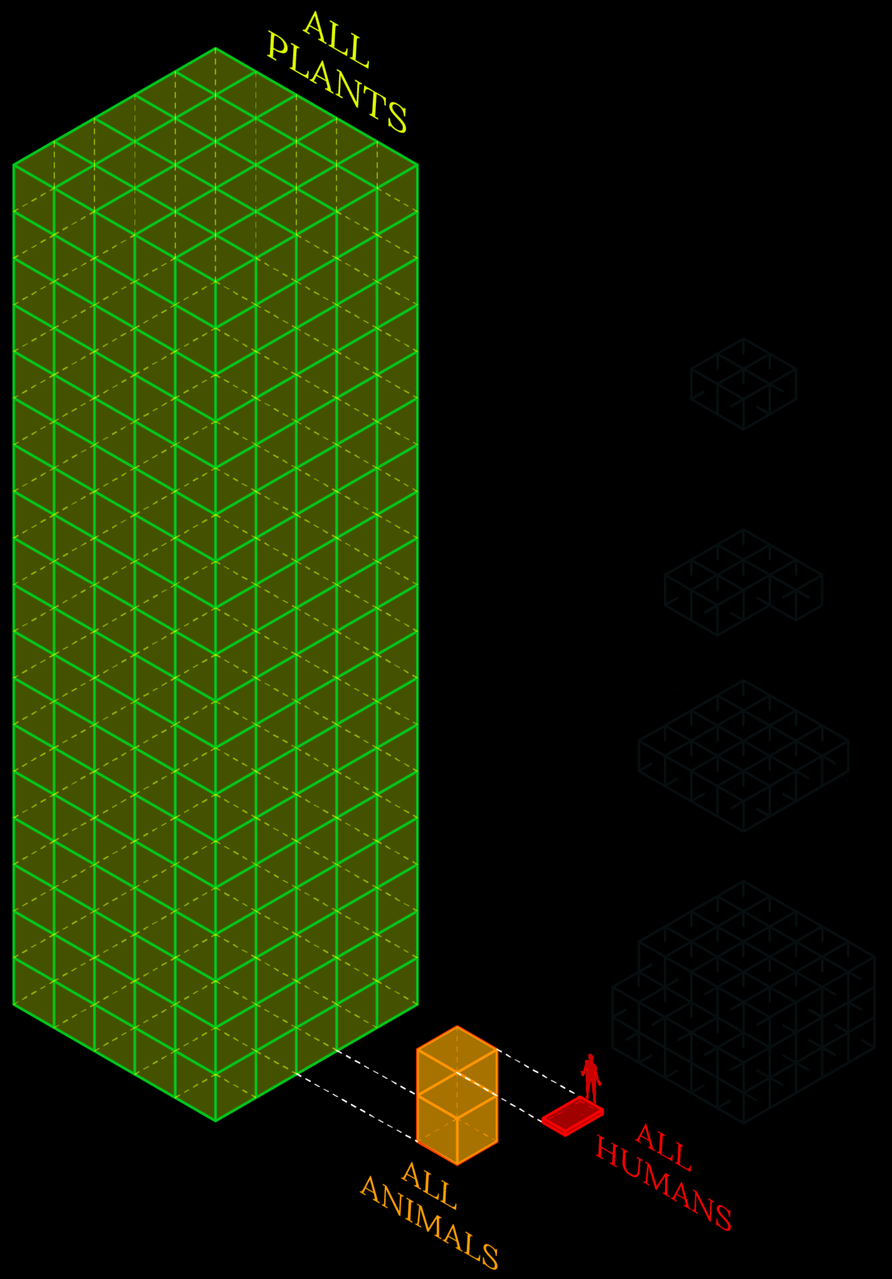
Africa in the 21st Century: The Biomass Revolution

Yale MacMillan Center at 1-54 Contemporary African Art Fair
October 16, 2025
Mae-ling Lokko

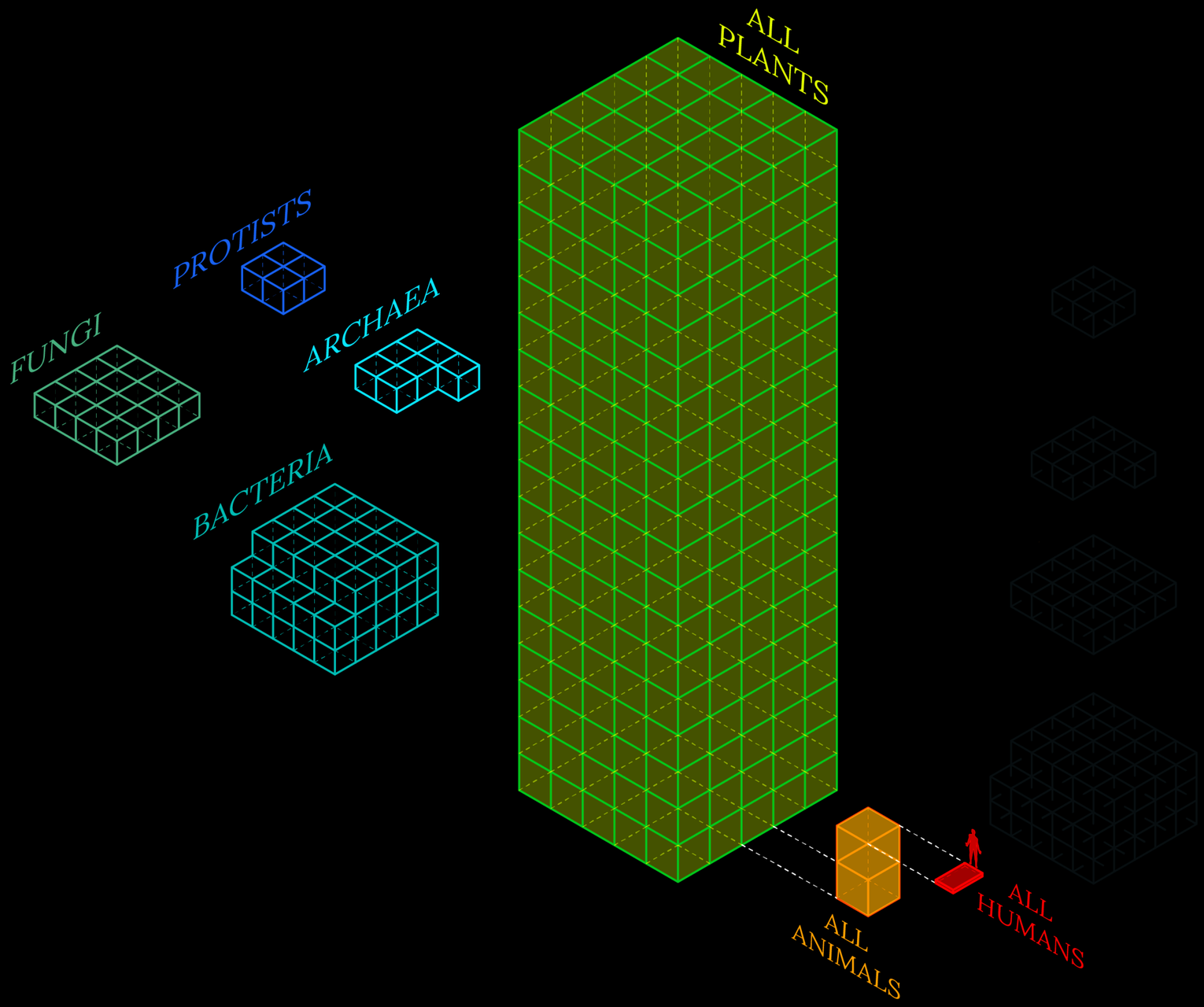


CAMBRIAN | ORDOVICIAN | SILURIAN | DEVONIAN | CARBONIFEROUS | PERMIAN | TRIASSIC | JURASSIC | CRETACEOUS

544 millions years ago ← 410 millions years ago ← 286 millions years ago ← 213 millions years ago ← 23 millions years ago



Adapted from VOX, Data sourced from Bar-On, Y. M., Phillips, R., & Milo, R. (2018). The biomass distribution on Earth. *Proceedings of the National Academy of Sciences*, *115*(25), 6506-6511.



Adapted from VOX, Data sourced from Bar-On, Y. M., Phillips, R., & Milo, R. (2018). The biomass distribution on Earth. *Proceedings of the National Academy of Sciences*, *115*(25), 6506-6511.

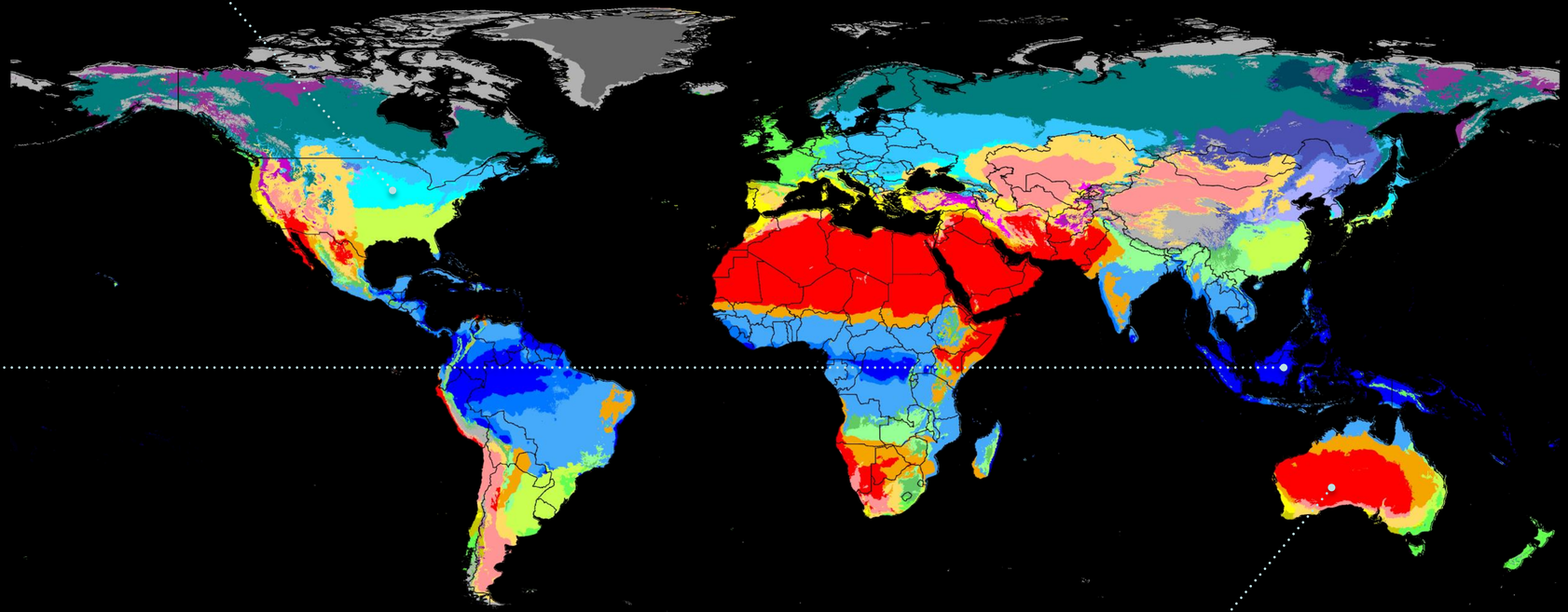
Plant-based Köppen-Geiger Climate Classification System

Af Am As Aw BWh BWk BSh BSk Csa Csb Csc Cwa Cwb Cwc Cfa Cfb Cfc Dsa Dsb Dsc Dsd Dwa Dwb Dwc Dwd Dfa Dfb Dfc Dfd ET EF

Köppen-Geiger D Vegetation

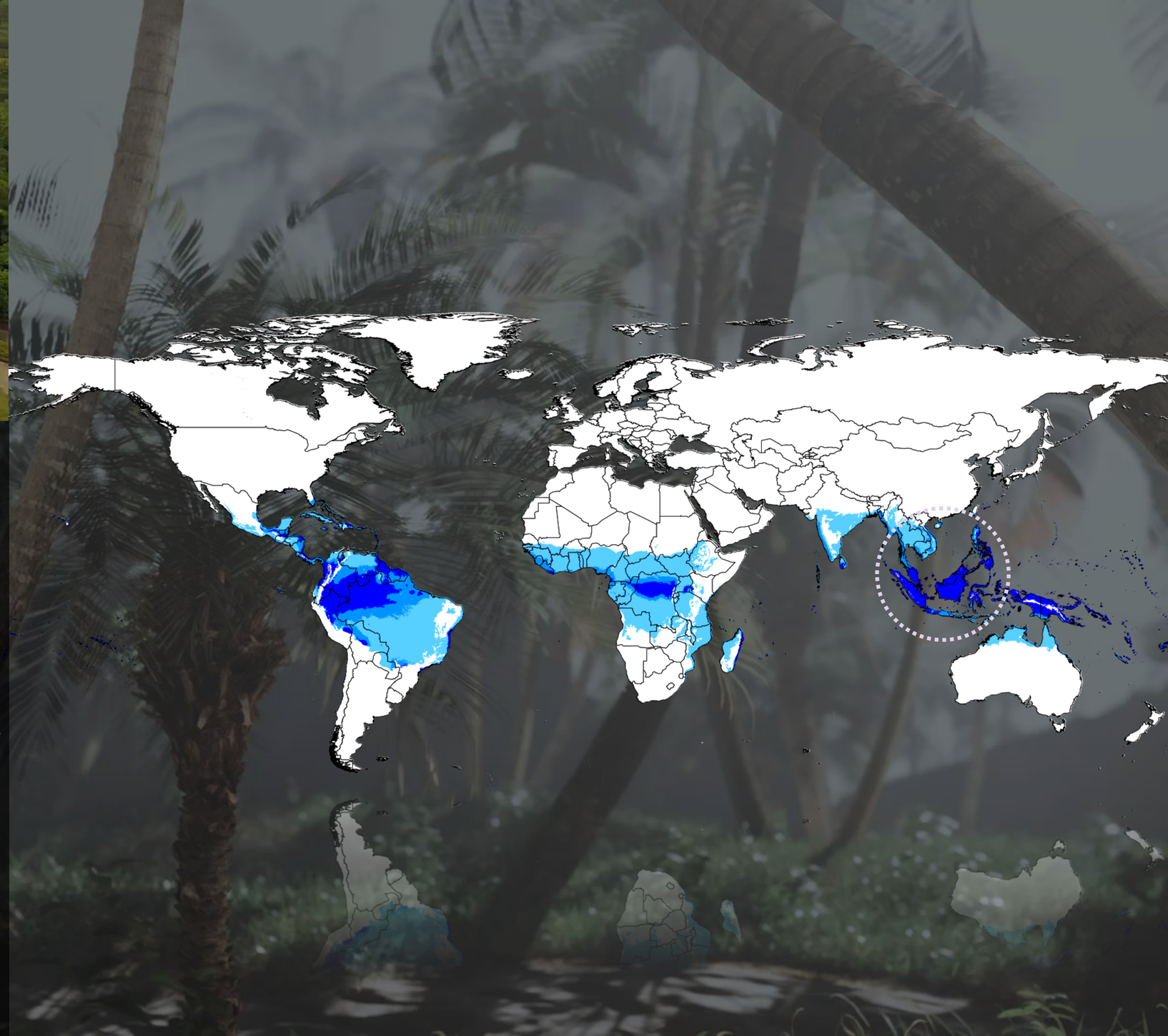
Köppen-Geiger A Vegetation

Köppen-Geiger B Vegetation



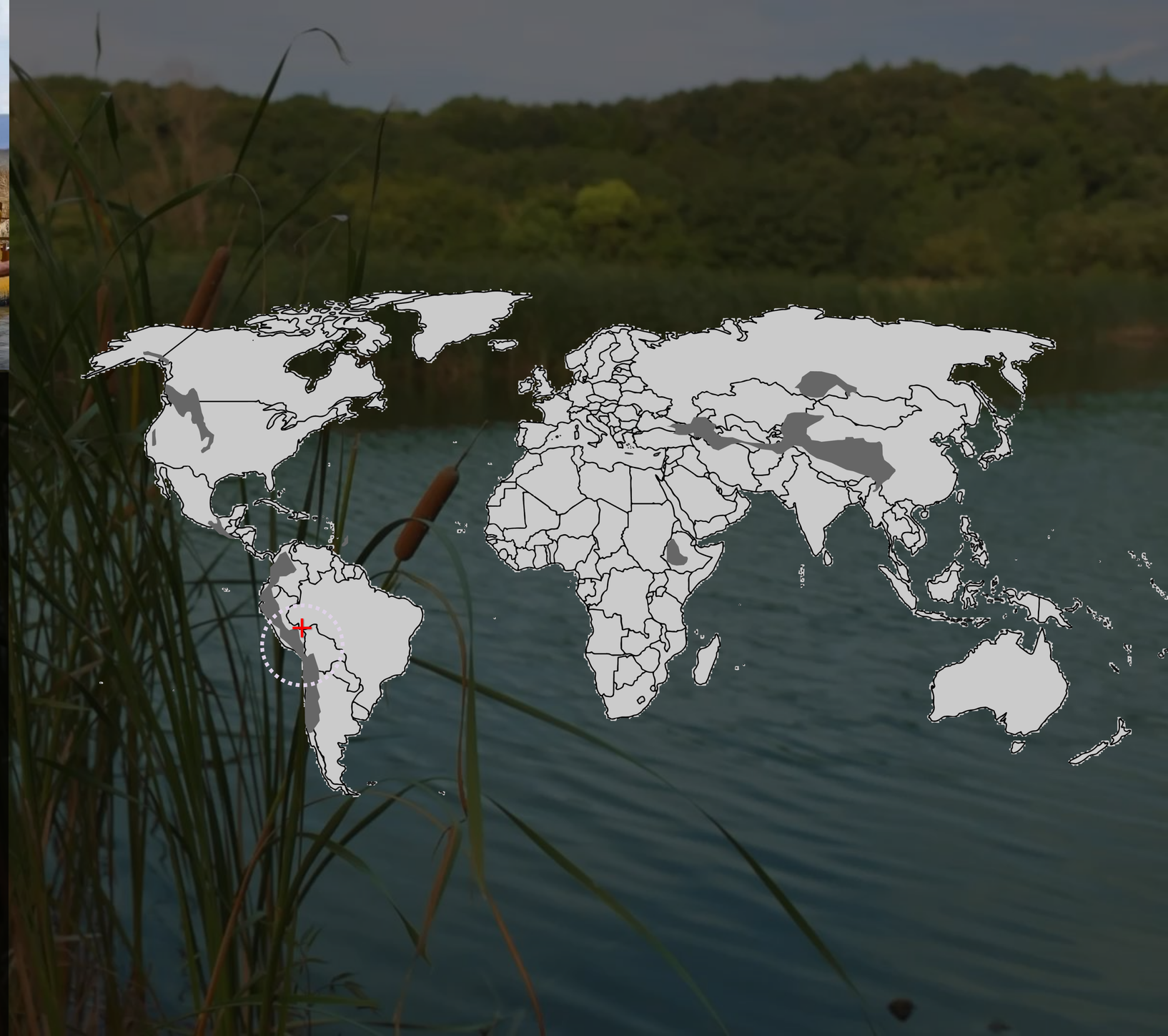

Rumah Gadang, Indonesia


rumah gandang
toraja
nagari
rumah adat
rumah joglo
kampung
rumah adat bali




3:30


reed boats
reed roofs
reed huts
reed walls
reed instruments
reed foundation
reed arches



Plant Scale

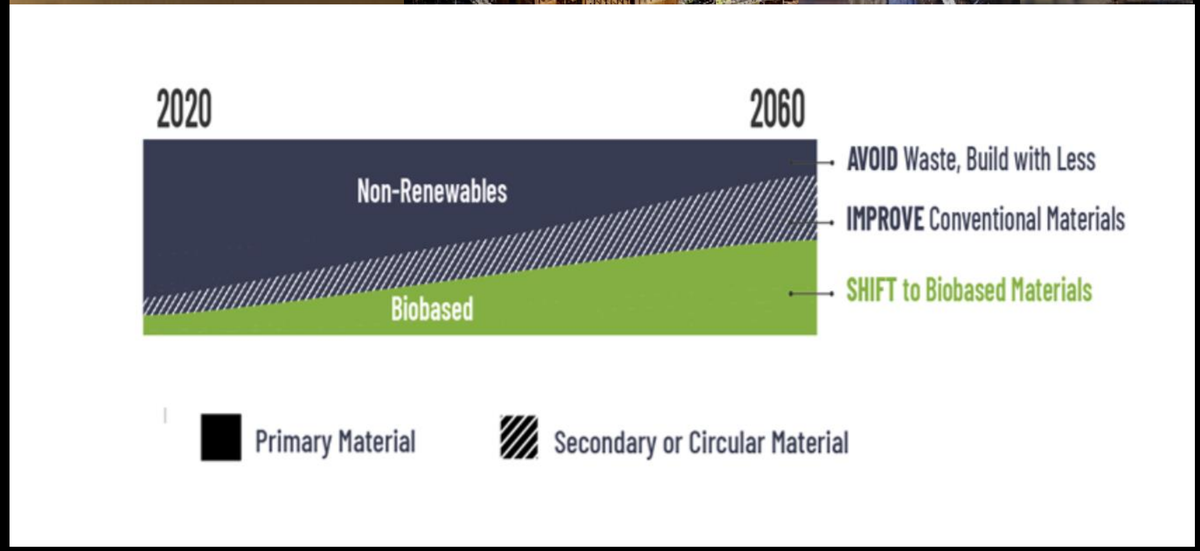
(v) to rise at a rate or standard

BUILDING MATERIALS AND THE CLIMATE: CONSTRUCTING A NEW FUTURE

UN environment programme

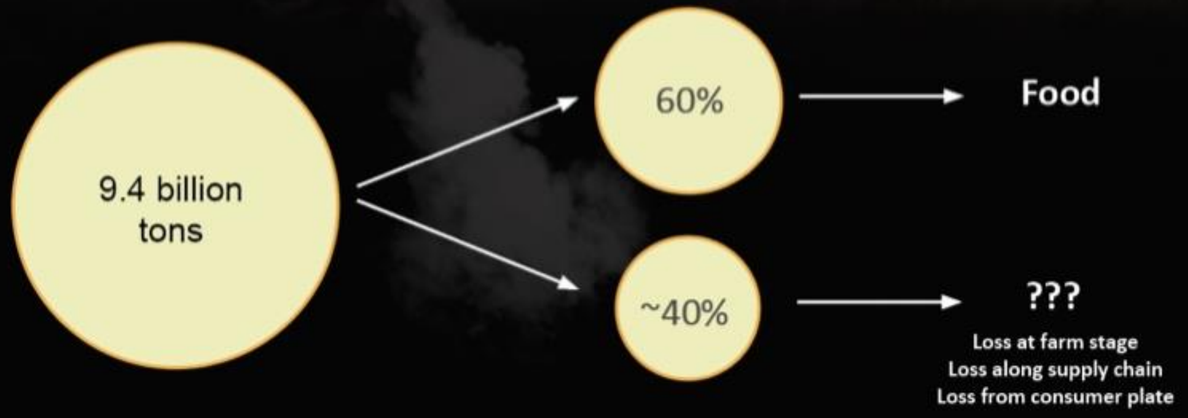
Global Alliance for Buildings and Construction

Yale cec

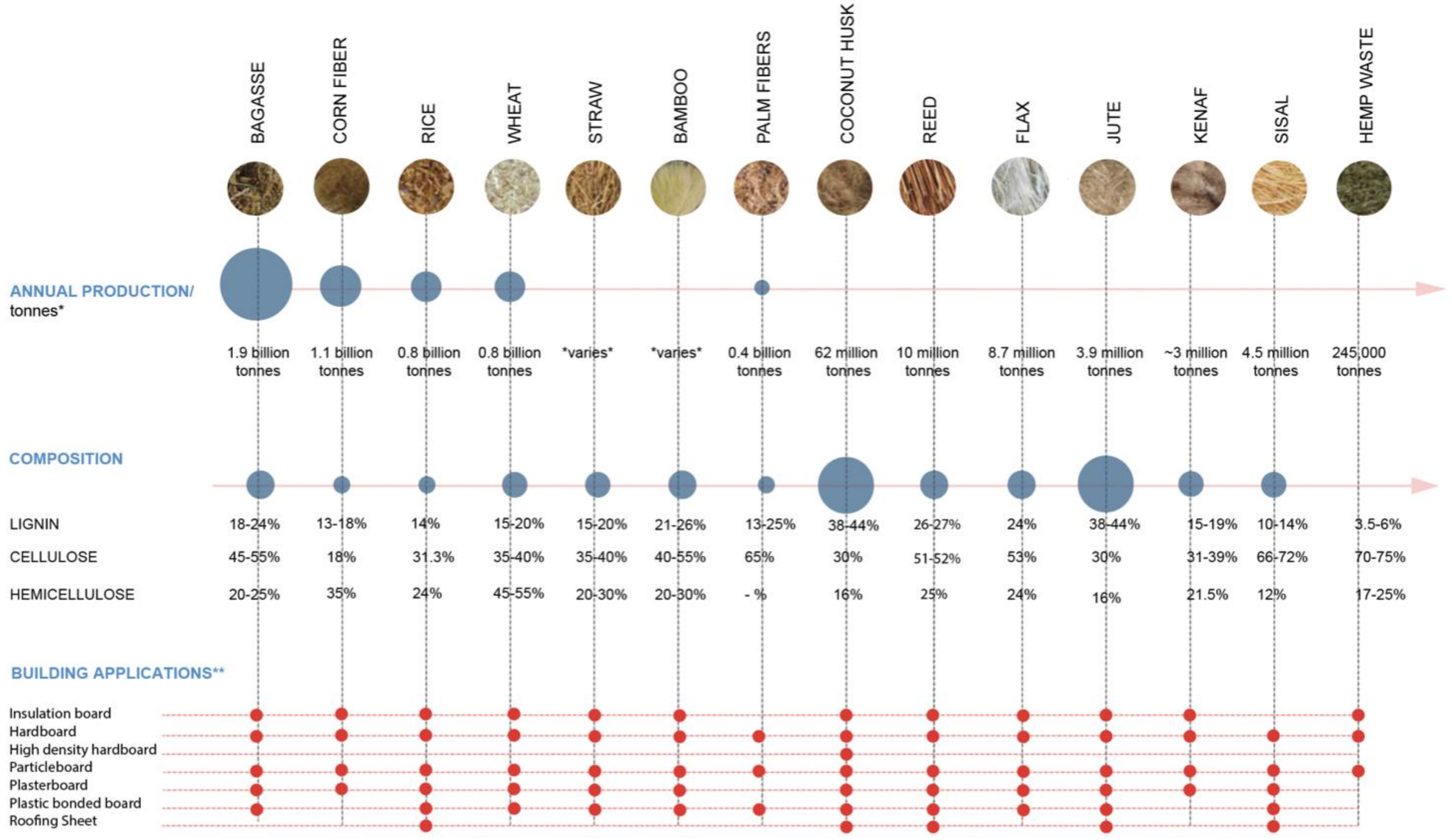


Source: United Nations Environment Programme, Yale Center for Ecosystems + Architecture (2023). Building Materials and the Climate: Constructing a New Future. Nairobi.

- 9.4 billion tons of agricultural crops were grown in 2019.[1]
- < 40% of this crop material is wasted.[2]

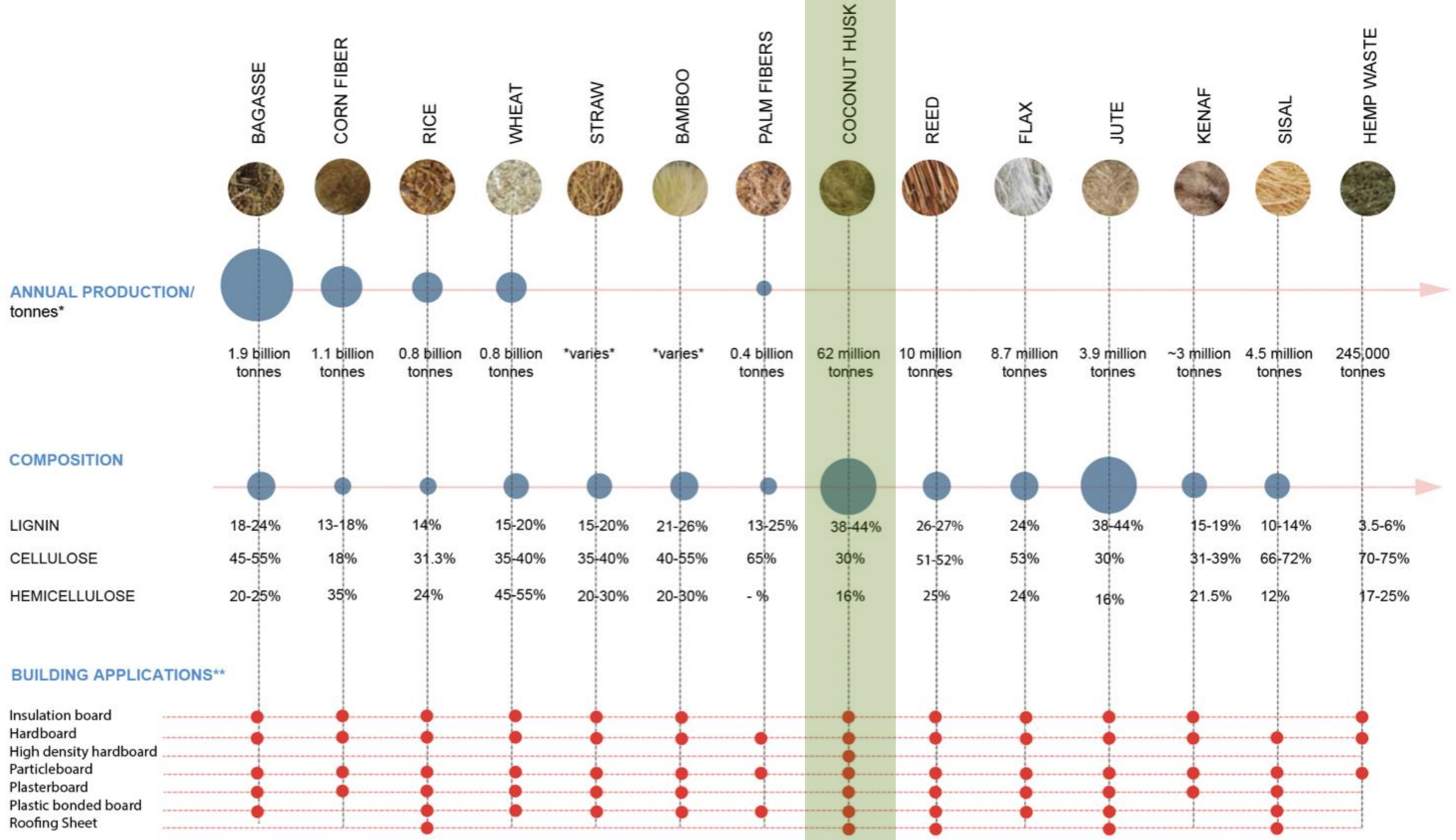


1. Food And Agriculture Organization, FAOSTAT 2021. https://www.fao.org/3/cb4477en/online/cb4477en.html#chapter-2_1
2. WWF-UK (2021) Driven to waste: The Global Impact of Food Loss and Waste on Farms.
3. Projected Pop Growth Map. United Nations, Department of Economic and Social Affairs, Population Division: World Urbanization Prospects, the 2011 Revision. New York 2012



Updated Annual Production (tonnes) : Food And Agriculture Organization, FAOSTAT 2021. https://www.fao.org/3/cb4477en/online/cb4477en.html#chapter-2_1

**Based on 80 year survery of agro-based products done by the Forest Products Laboratory of the USDA Forest Service and the Department of Forestry at the University of Illinois, Urbana-Champaign.
***difficulty in estimation of quantity due to unmonitored and undocumented wild growth of agro-resource



Updated Annual Production (tonnes) : Food And Agriculture Organization, FAOSTAT 2021. https://www.fao.org/3/cb4477en/online/cb4477en.html#chapter-2_1

**Based on 80 year survery of agro-based products done by the Forest Products Laboratory of the USDA Forest Service and the Department of Forestry at the University of Illinois, Urbana-Champaign.
***difficulty in estimation of quantity due to unmonitored and undocumented wild growth of agro-resource

Zico coconut water campaign mural by Overall Murals, 2014. Image source: Overall Murals

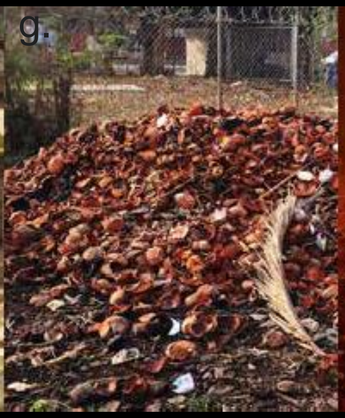
The Underbelly of Superfood Production

Evaluating the underbelly of coconut export economies, in particular its ubiquitous generation of low-value waste or “unusable” surplus, offers new frontiers for relationship building between research and production enterprises. Similar to the scale of annual waste generation observed in global agricultural value chains, ranging between ten to fifty billion tons of dry material, the large quantities of husk waste which forms seventy percent of every coconut epitomizes the growing problems and opportunities of low-value surplus economies.[8] For one, existing surplus remains largely within the domestic region, lengthening the residency and impacts of value circulation among local stakeholders and production landscapes. Secondly, the highly distributed and variable nature of coconut husk wastes necessitates the collapse of distance, and consequent unalienation of its research and production infrastructure stakeholders.

Excerpt from “Coconut Diaries”, June 2021

e-flux Architecture

Coconut Farmer in Asamankese, Ghana 2014
Photo credit: John Kamau



a) farmer holding coconut seedling

b) copra being separated from husk

c) cooperative coconut oil production

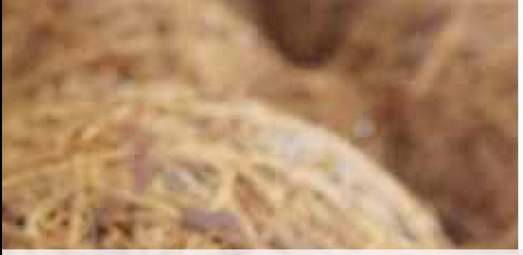
d) export of dehusked coconut to Nigeria

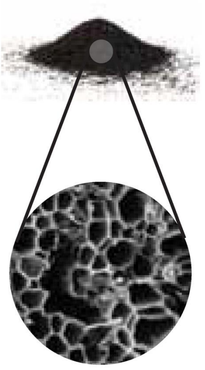
e) urban coconut water consumption

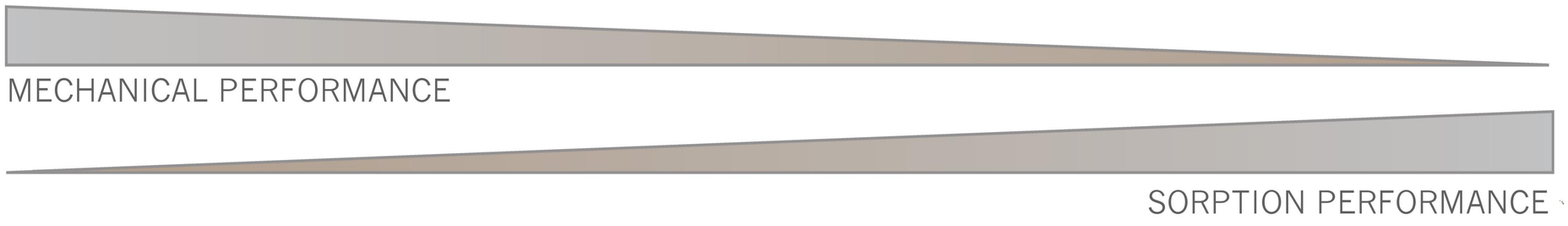
f) stationary point-of-sale for coconut water

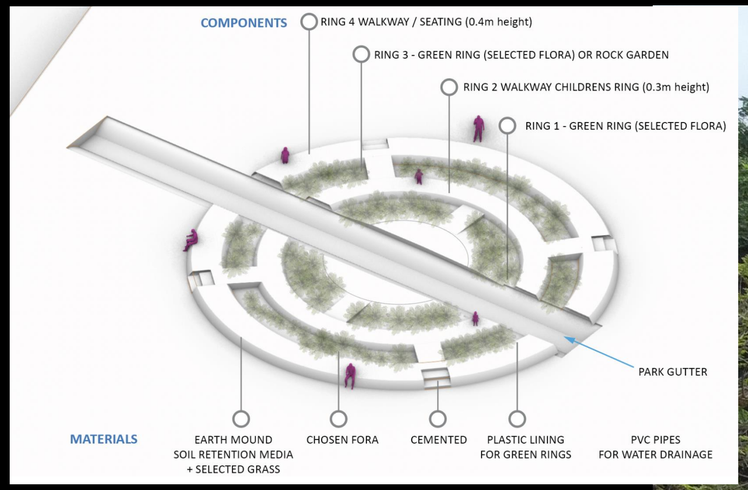
g) urban husk dump site

h) open air burning of coconut husk at night in urban setting



PRODUCT	High Density Self-Binding Boards	Low-Density Polymeric Matts	Desiccant System		Sorption System
	STRUCTURAL BOARDS	LOW DENSITY POLYMERIC MATS	PITH DUST	FIBER MAT	ACTIVATED CARBON
					
	3D MODULAR FORMS		x500 10µm	x1,700 10µm	X500 50µm
					
TARGET BUILDING APPLICATION	EXTERIOR FACADE & INTERIOR PANELS	INSULATION, DEHUMIDIFICATION	←	DEHUMIDIFICATION AIR FILTRATION →	



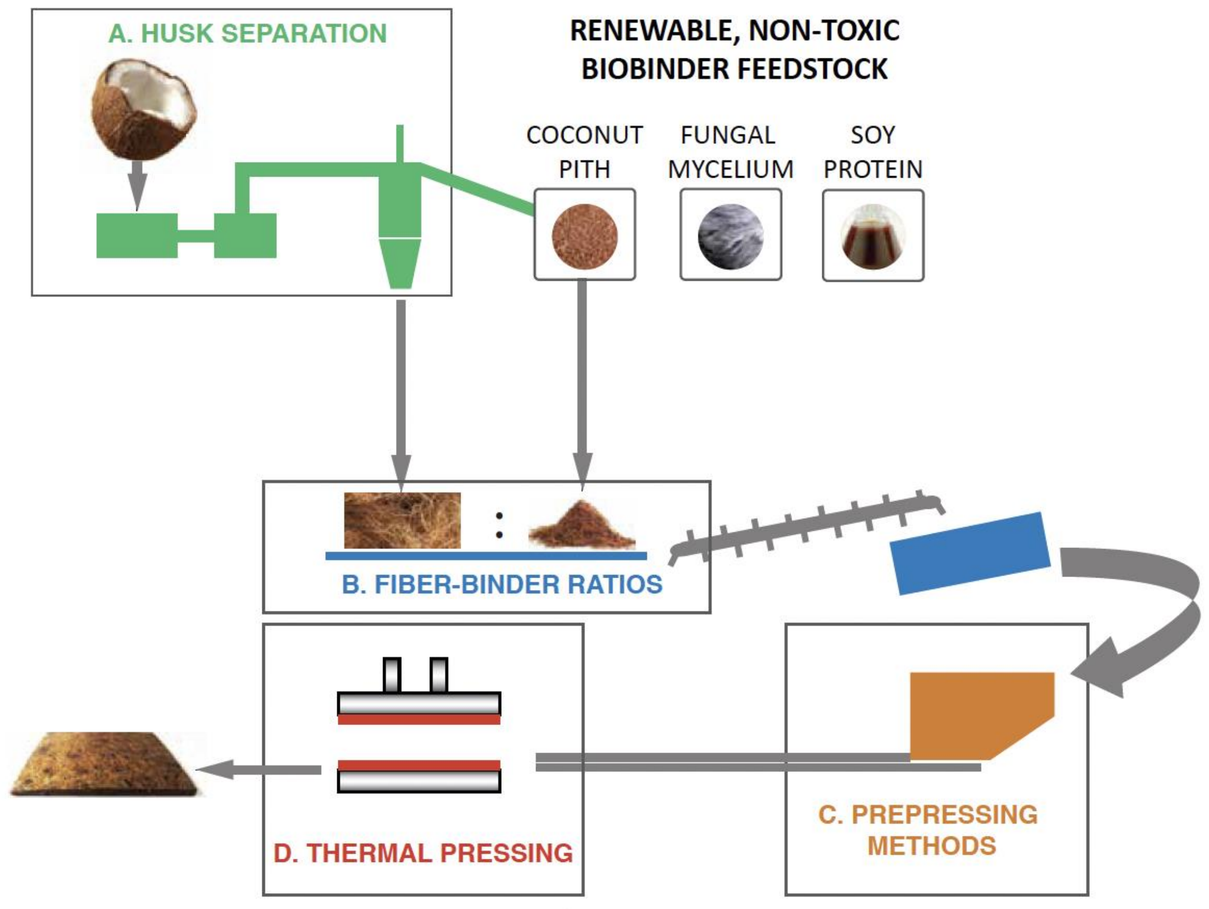


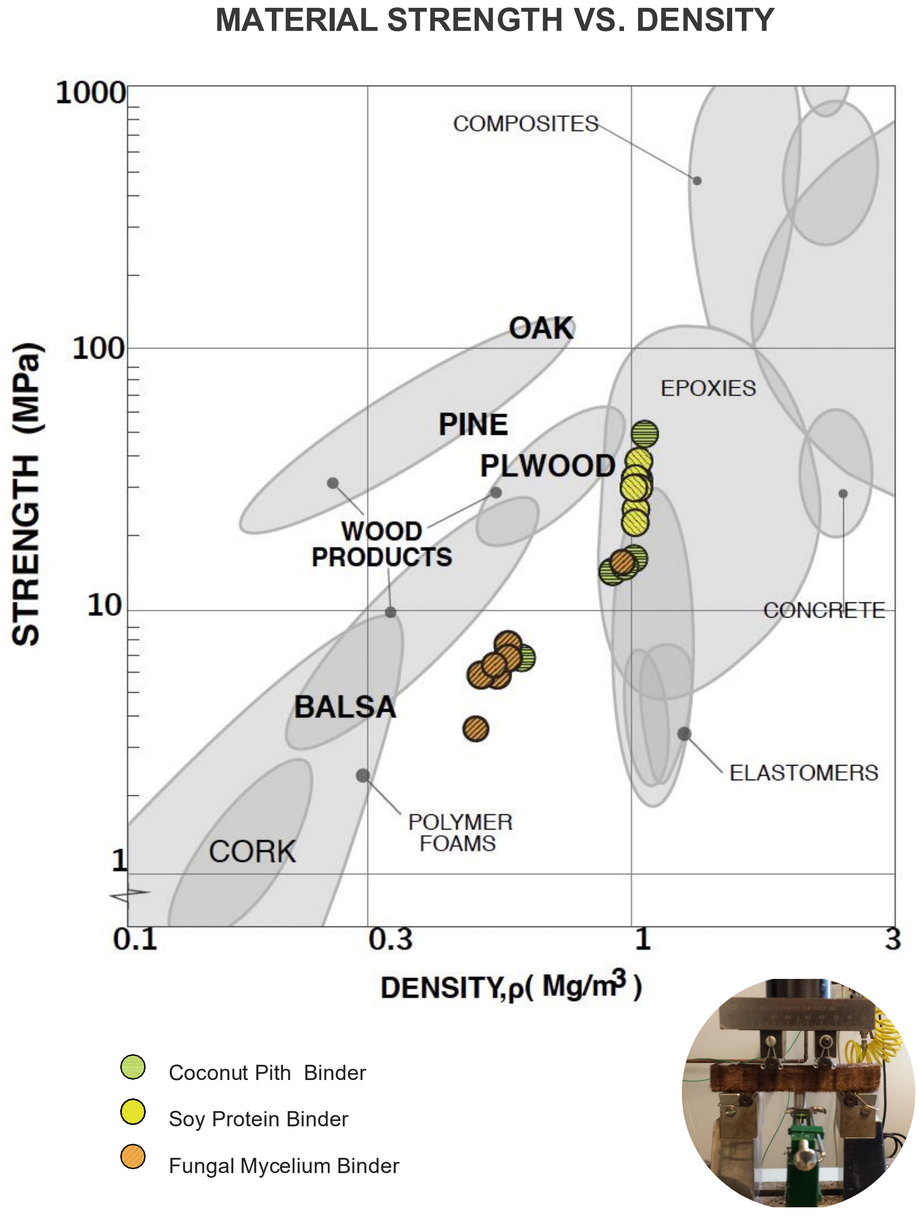
BRITISH COUNCIL | Architecture Design Fashion

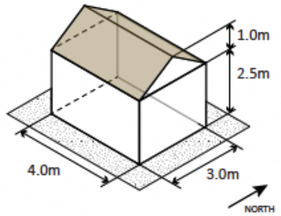
willow

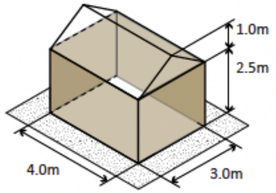
THE MIDUNU INSTITUTE FOR THE PRESERVATION OF AFRICAN CULINARY HERITAGE

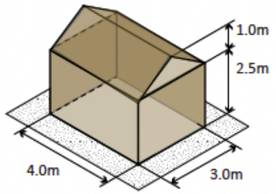
Ashesi D:Lab


A. HUSK SEPARATION
RENEWABLE, NON-TOXIC
BIOBINDER FEEDSTOCK
COCONUT
PITH
FUNGAL
MYCELIUM
SOY
PROTEIN
B. FIBER-BINDER RATIOS
C. PREPRESSING
METHODS
D. THERMAL PRESSING


MATERIAL STRENGTH VS. DENSITY
STRENGTH (MPa)
1000
100
10
1
0.1
0.3
1
3
DENSITY,ρ(Mg/m3)
COMPOSITES
OAK
EPOXIES
PINE
PLWOOD
WOOD
PRODUCTS
CONCRETE
BALSA
ELASTOMERS
POLYMER
FOAMS
CORK
Coconut Pith Binder
Soy Protein Binder
Fungal Mycelium Binder

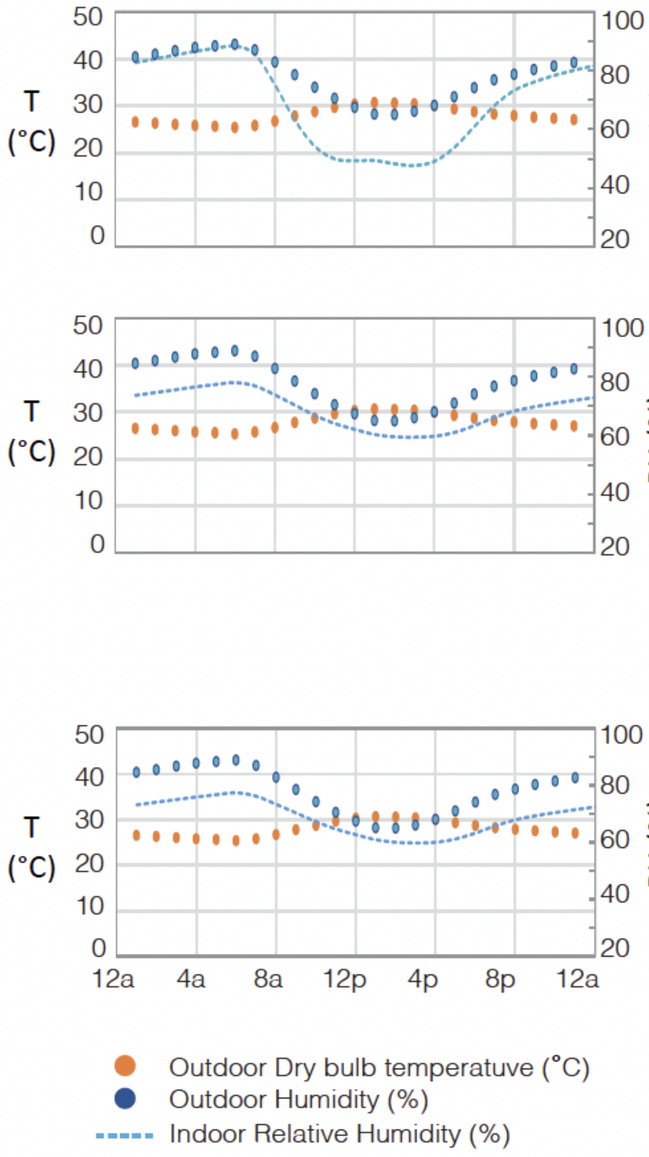


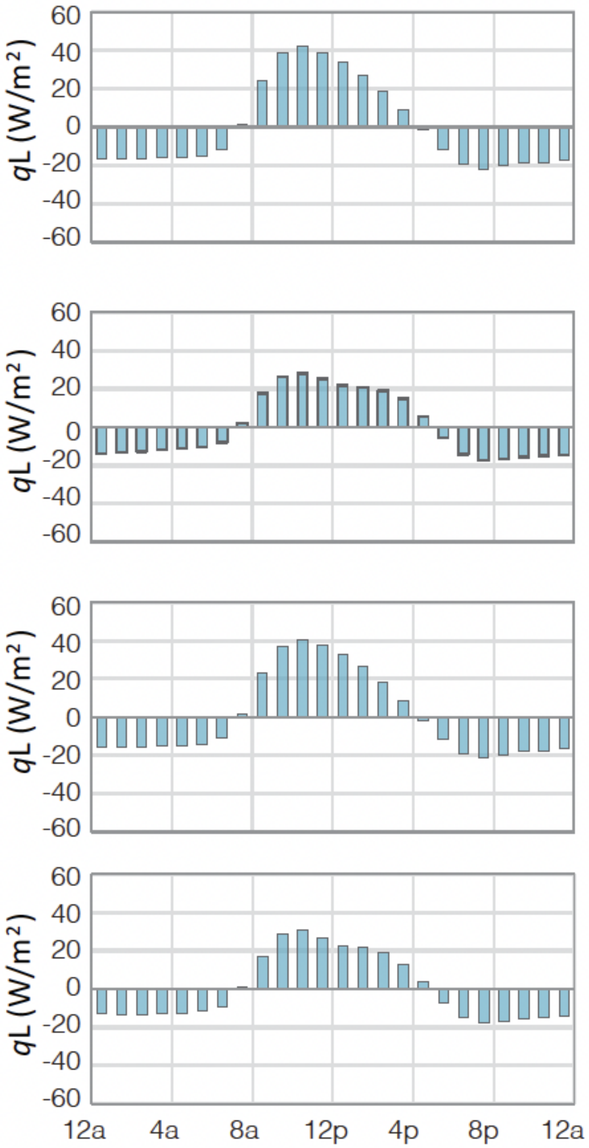


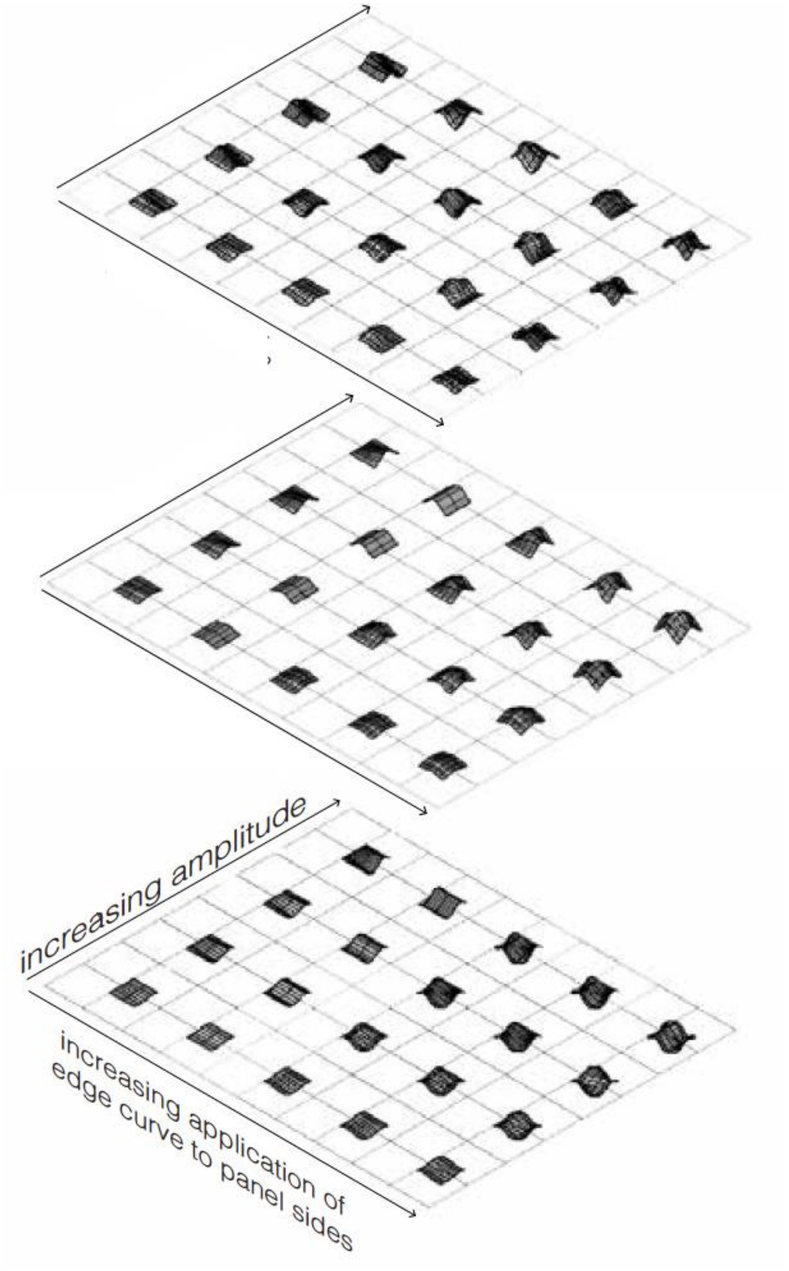


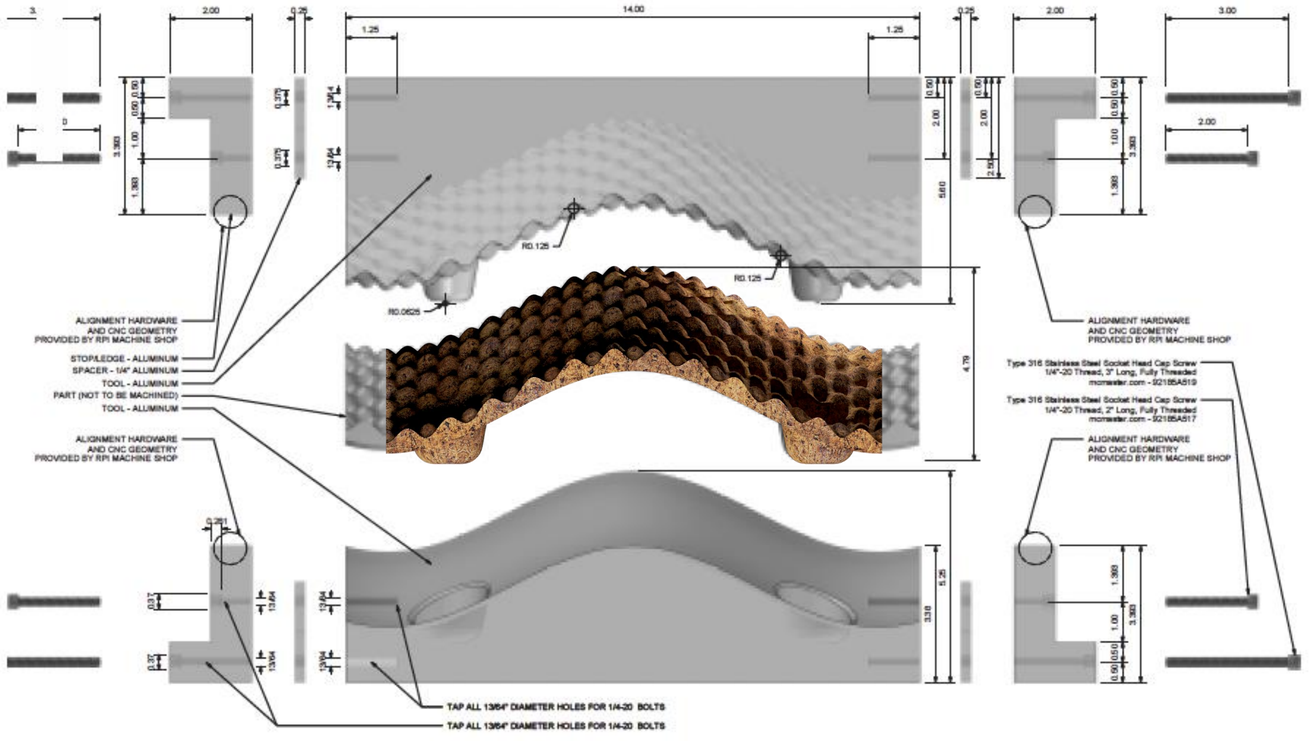
INDOOR ENVIRONMENT CONDITIONS

MOISTURE FLUX ACROSS COCONUT FIBERBOARD









Left: Form Matrix Credit: Mae-ling Lokko

Top: Drawing of Aluminum mold, Credit: Josh Draper

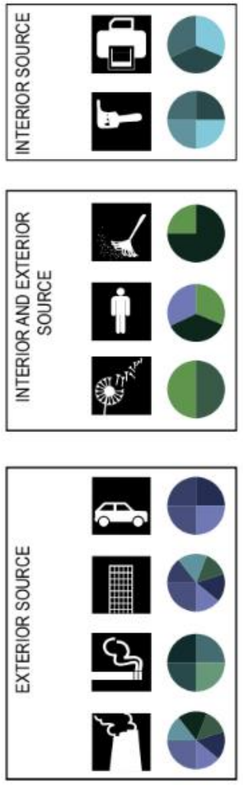
nexus-ny

MULTISCALAR POLLUTANT SOURCE CHARACTERIZATION

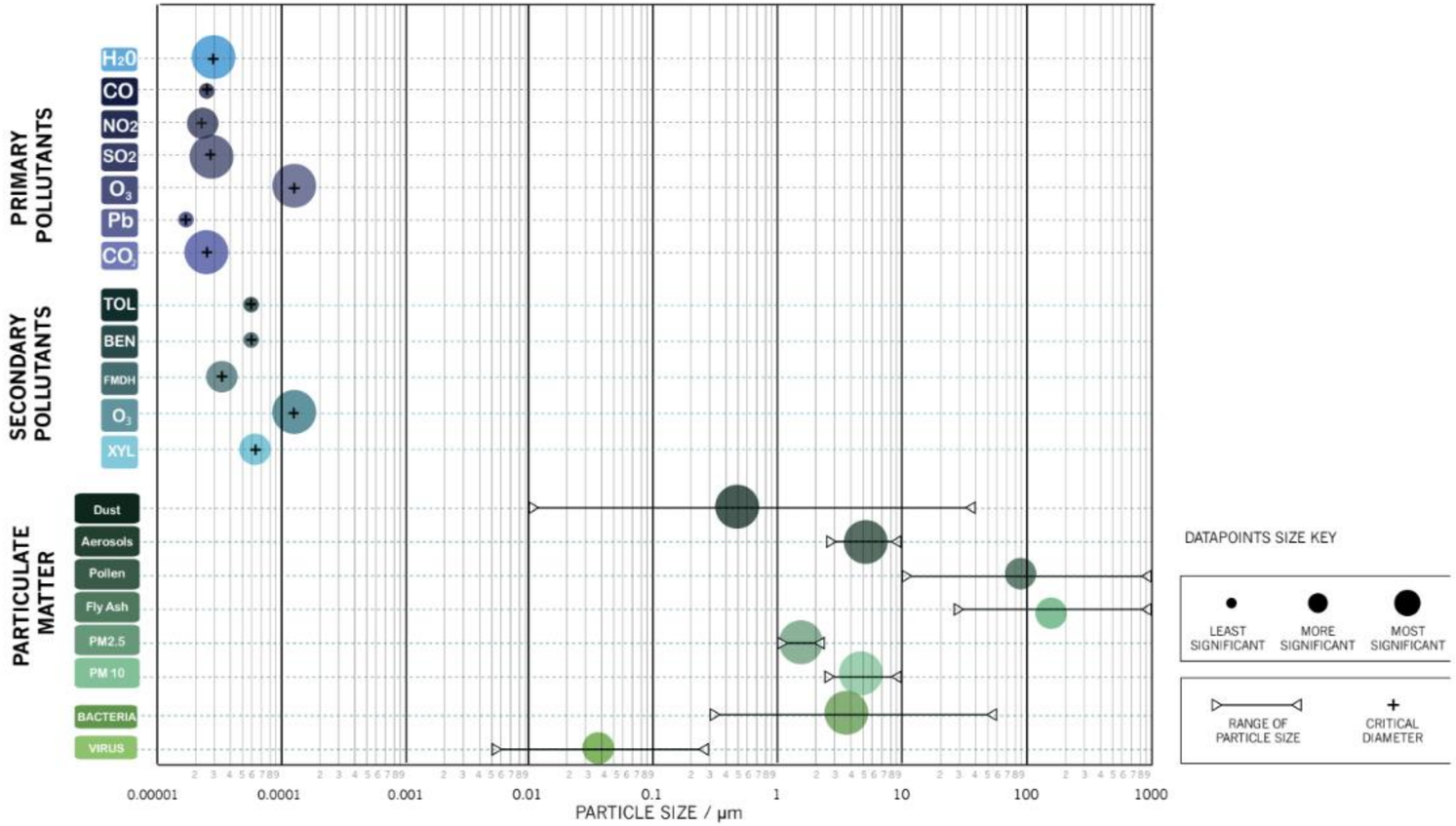
RANGE OF COCONUT-DERVIED SORTION TECHNOLOGIES

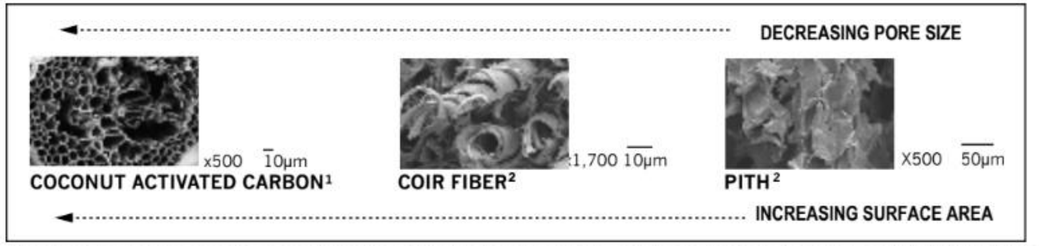
CHARACTERIZING SORPTION OF AIR CONSTITUENT WITHIN INDOOR AND OUTDOOR STEAMS BY VARIOUS COCONUT MEDIA

MAJOR SOURCES OF POLLUTANT



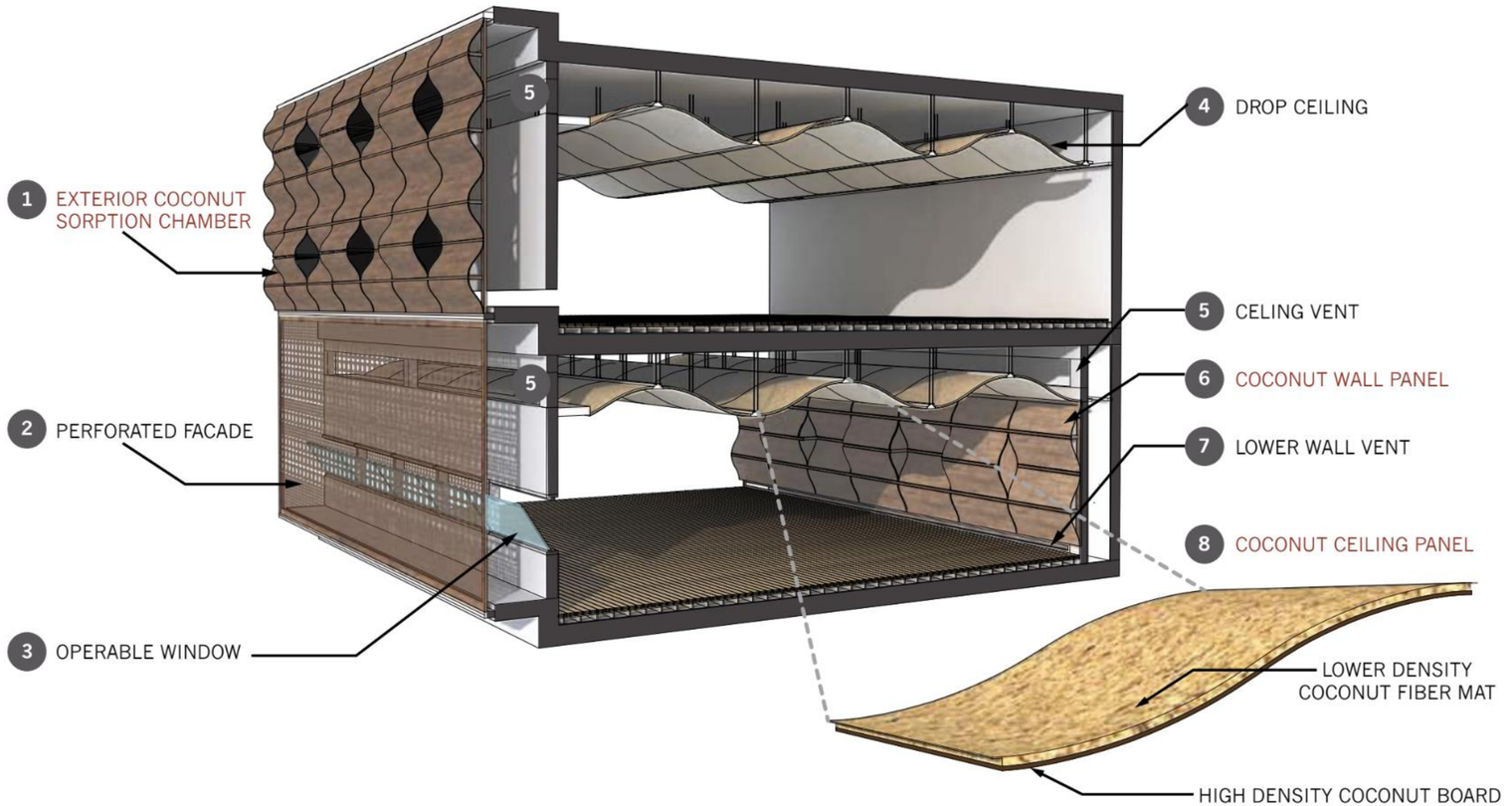
POLLUTANT QUANTITIES, NEW YORK CITY

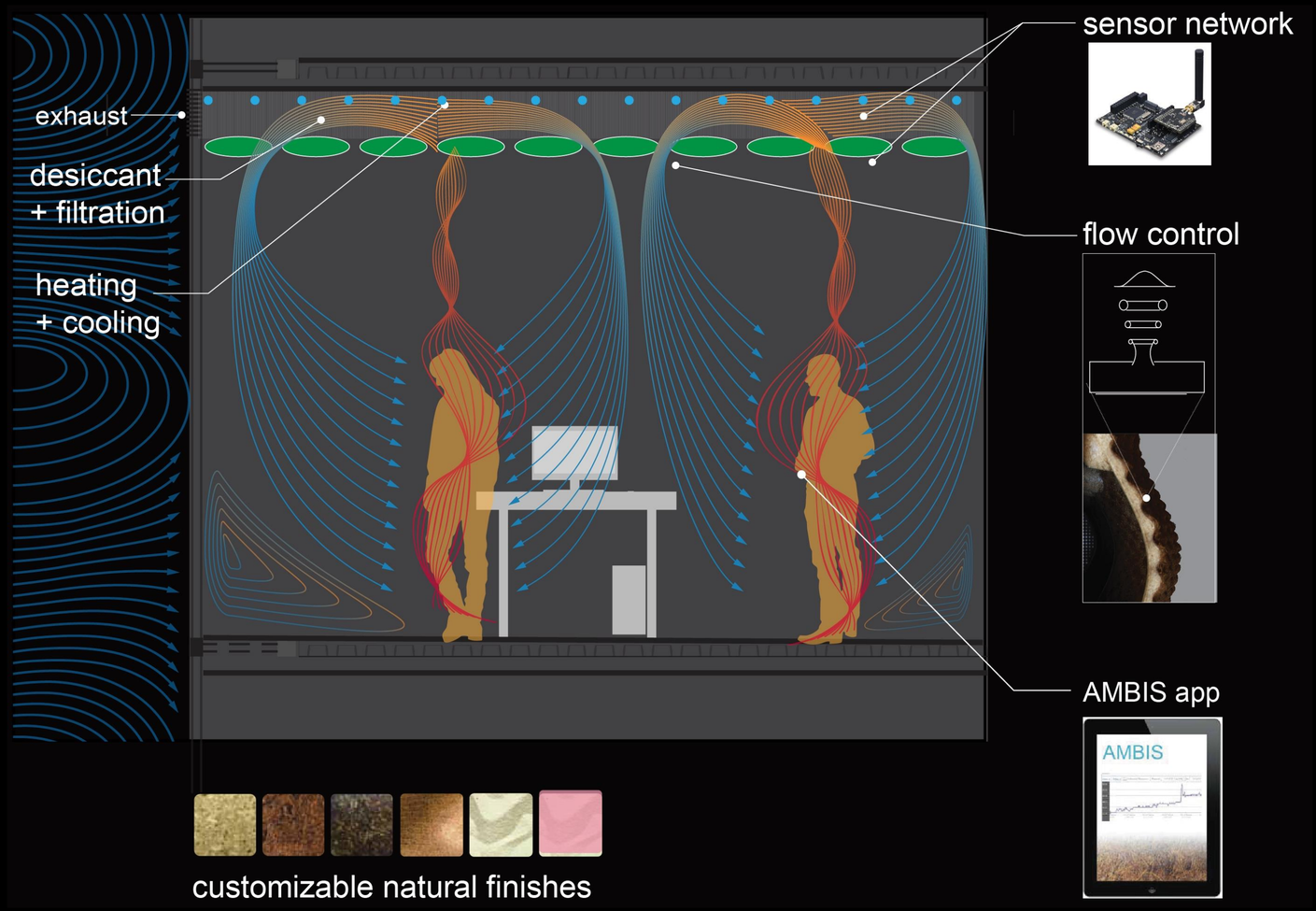


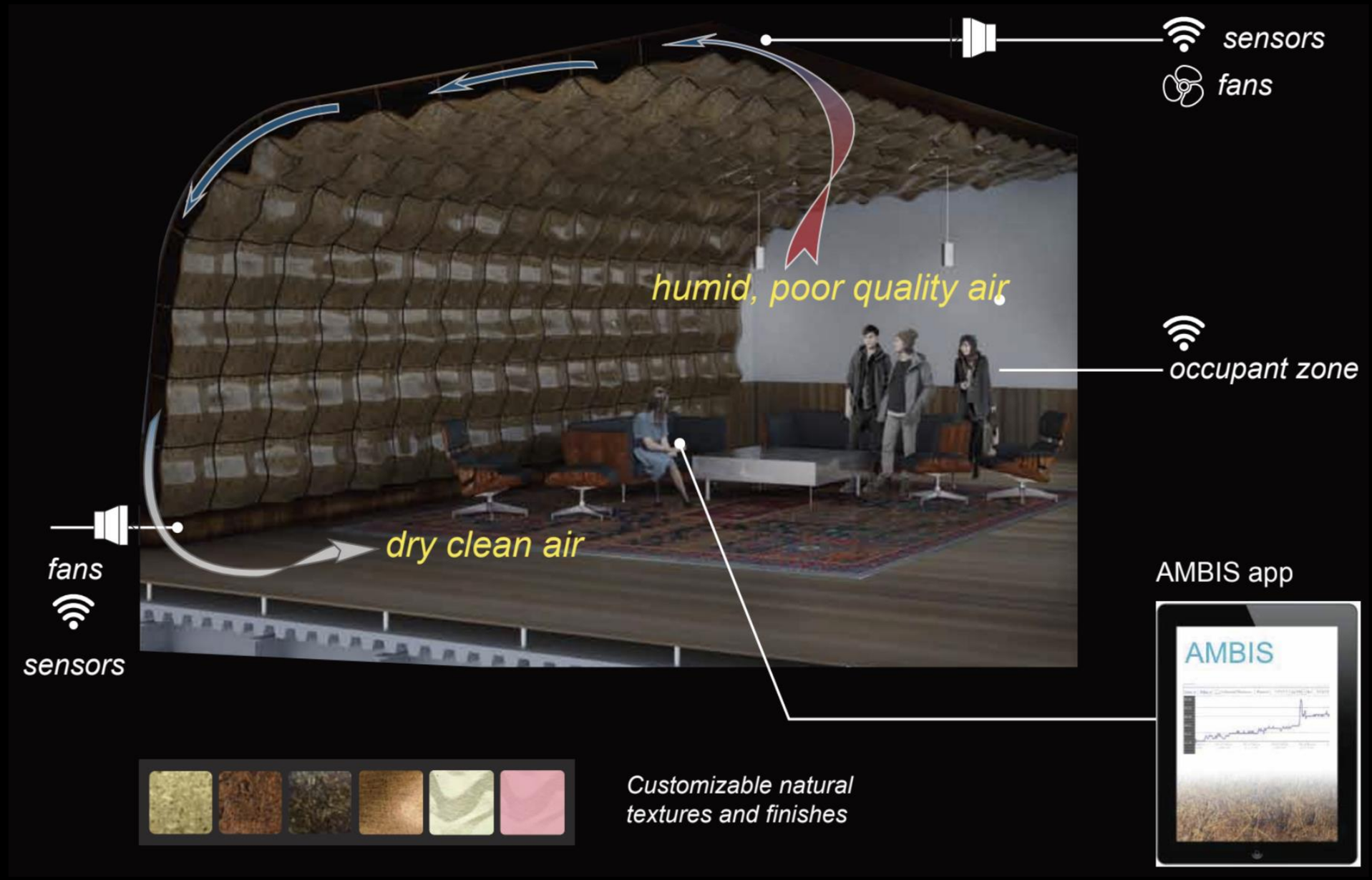


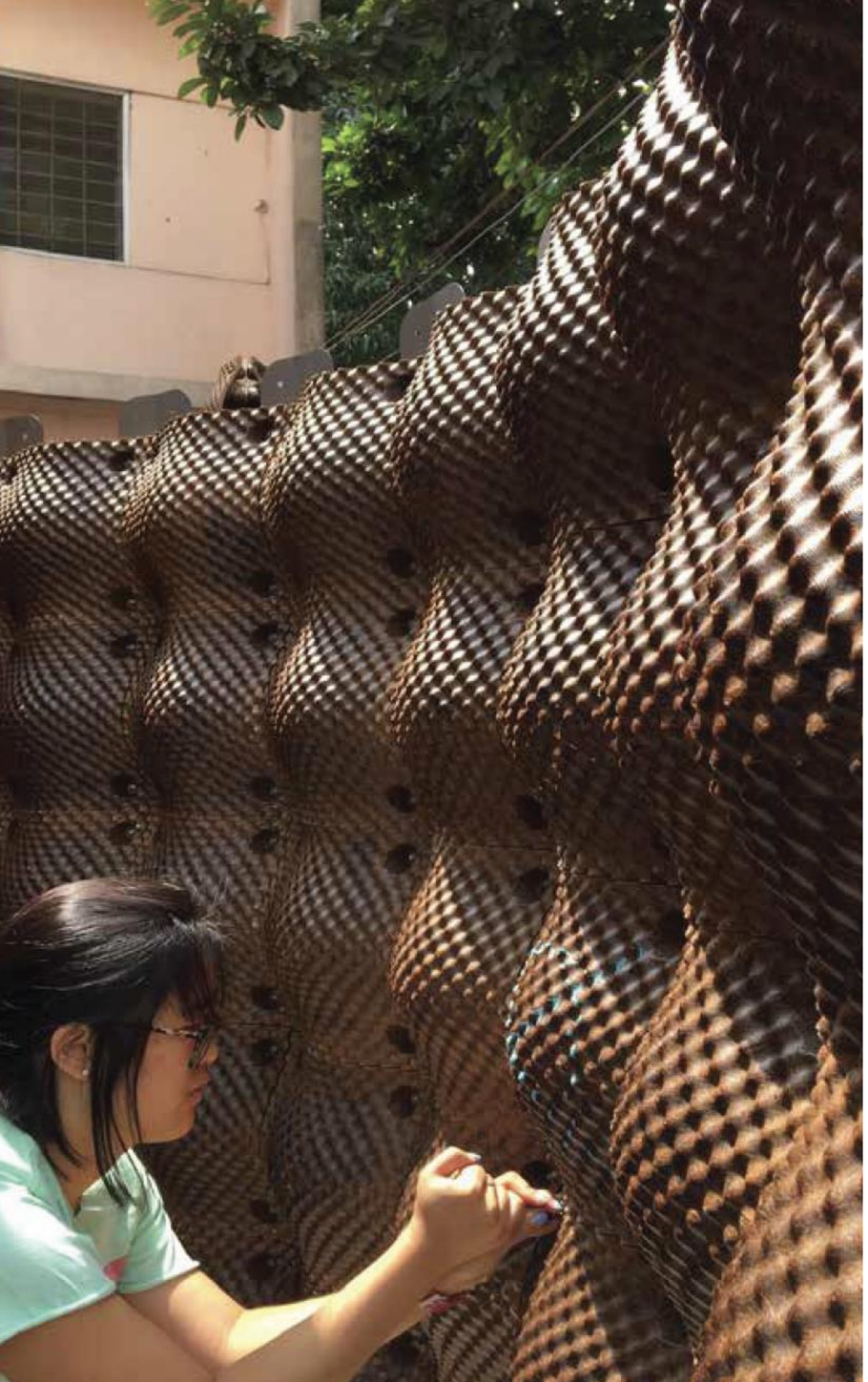
1. Tan, I. A. W., Ahmad, A. L., & Hameed, B. H. (2008). Adsorption of basic dye on high-surface-area activated carbon prepared from coconut husk: Equilibrium, kinetic and thermodynamic studies. Journal of Hazardous Materials, 154(1), 337-346.Chicago

2. Van Dam, J. E., van den Oever, M. J., Teunissen, W., Keijsers, E. R., & Peralta, A. G. (2004). Process for production of high density/high performance binderless boards from whole coconut husk: Part 1: Lignin as intrinsic thermosetting binder resin. Industrial Crops and Products, 19(3), 207-216.

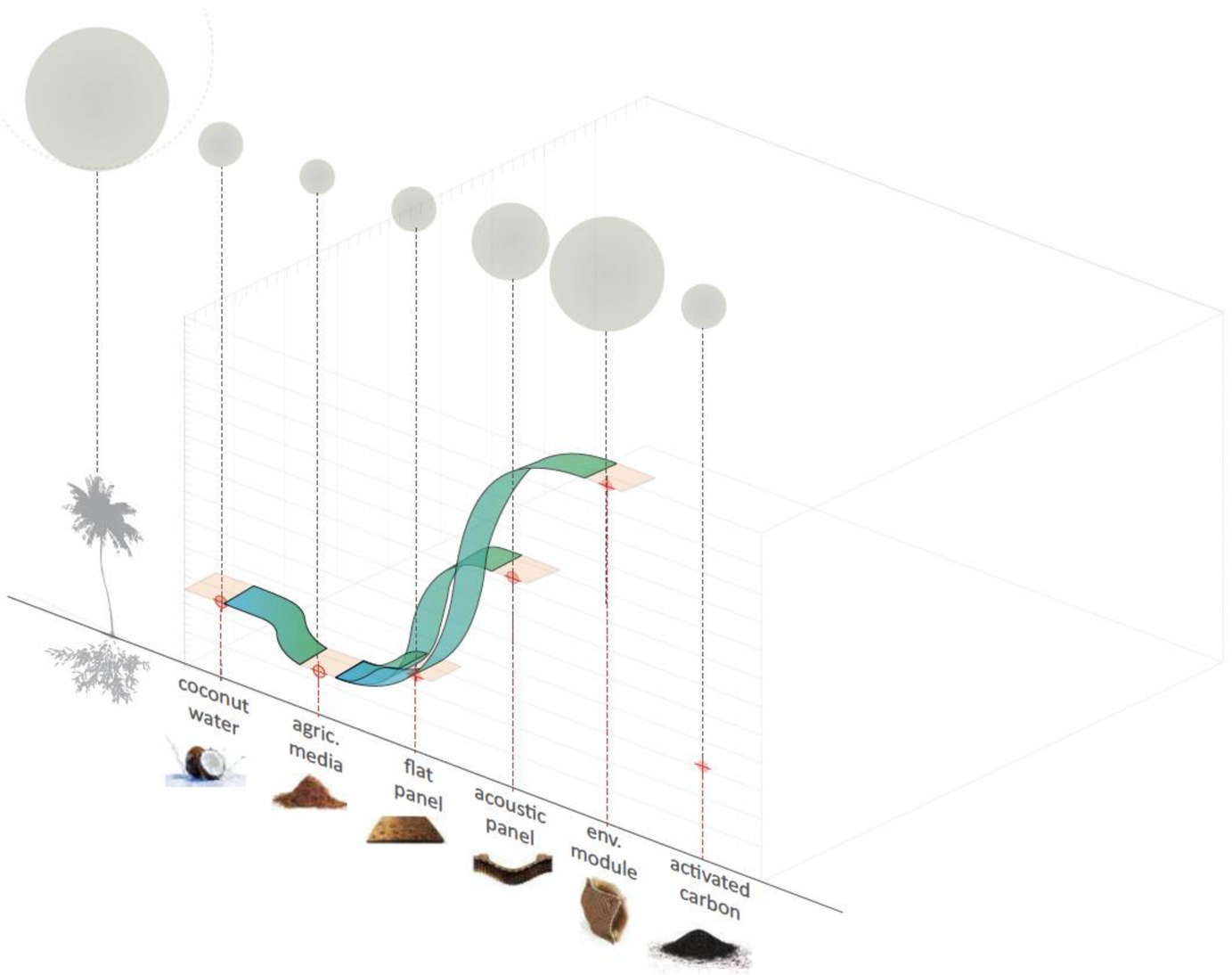

1 EXTERIOR COCONUT SORPTION CHAMBER
2 PERFORATED FACADE
3 OPERABLE WINDOW
4 DROP CEILING
5 CELING VENT
6 COCONUT WALL PANEL
7 LOWER WALL VENT
8 COCONUT CEILING PANEL
5
5
LOWER DENSITY COCONUT FIBER MAT
HIGH DENSITY COCONUT BOARD


exhaust
desiccant
+ filtration
heating
+ cooling
sensor network
flow control
AMBIS app
AMBIS
customizable natural finishes

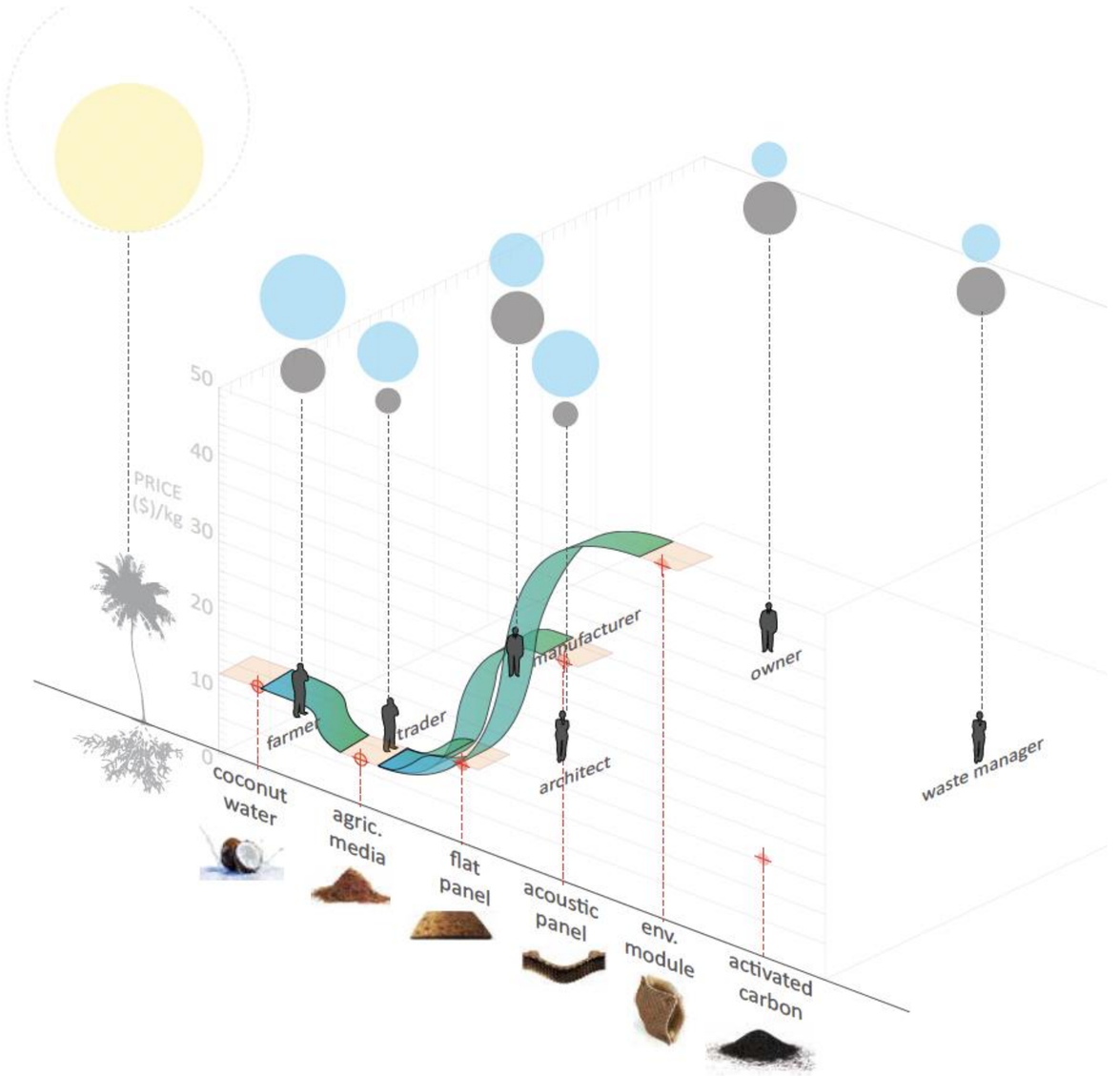

sensors
fans
humid, poor quality air
occupant zone
fans
sensors
dry clean air
AMBIS app
AMBIS
Customizable natural
textures and finishes



Value Identification and Generation

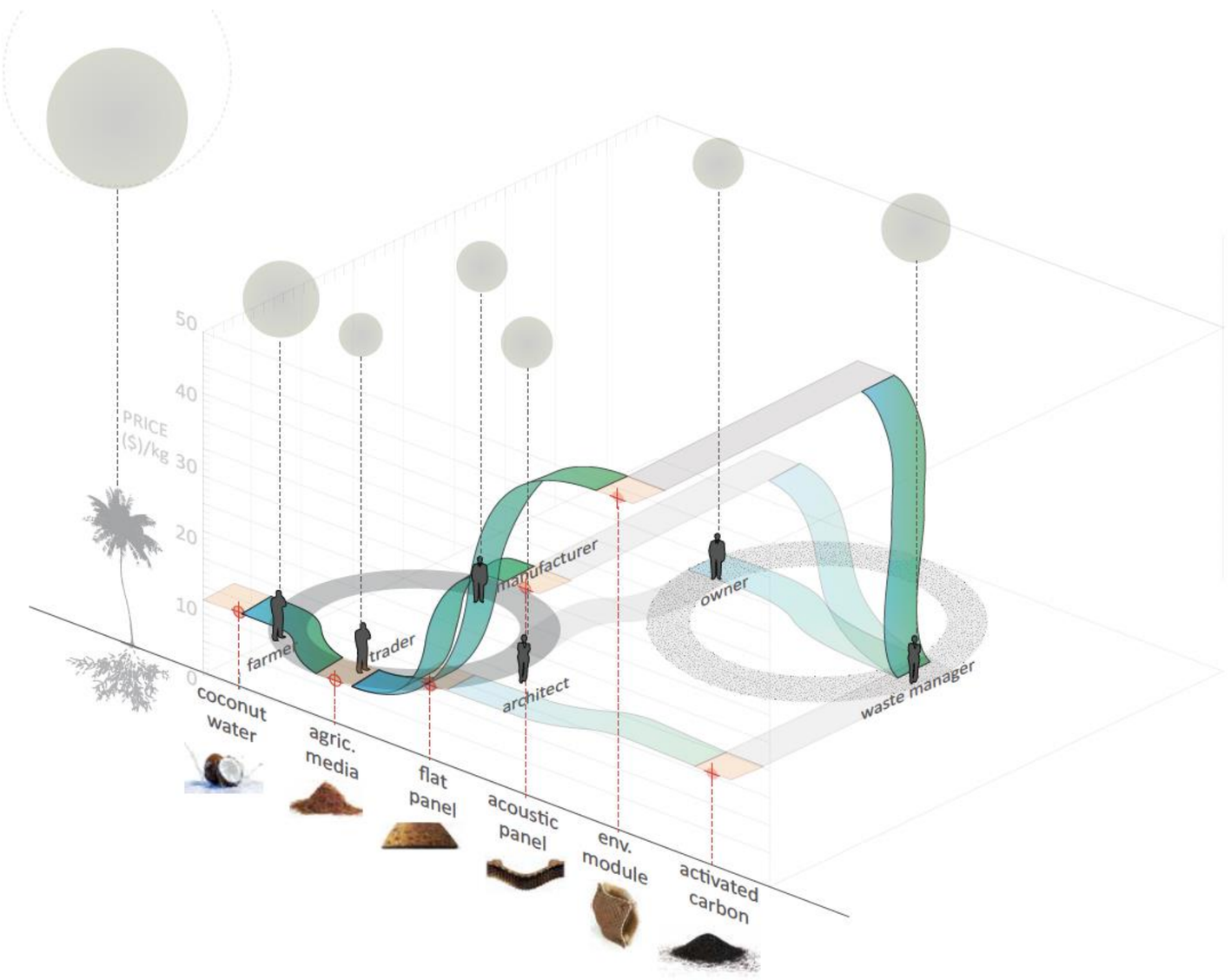


Value Translation



Coconut farmer, 2011
Photo credit: John Kamau

Value Circulation



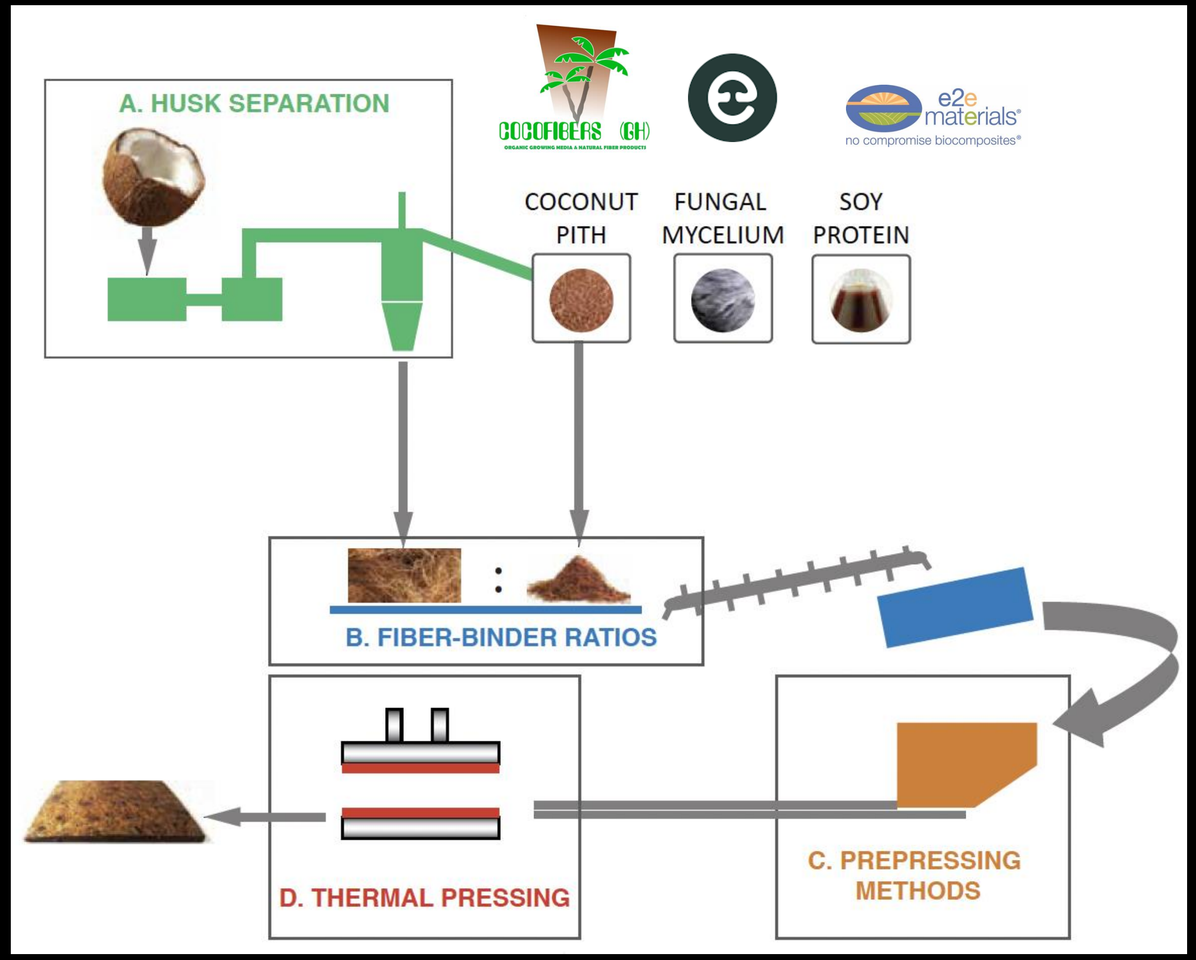
Plant Scale

x:y

(n) a ratio or system of grouping in a series of steps according to a standard of relative size or amount

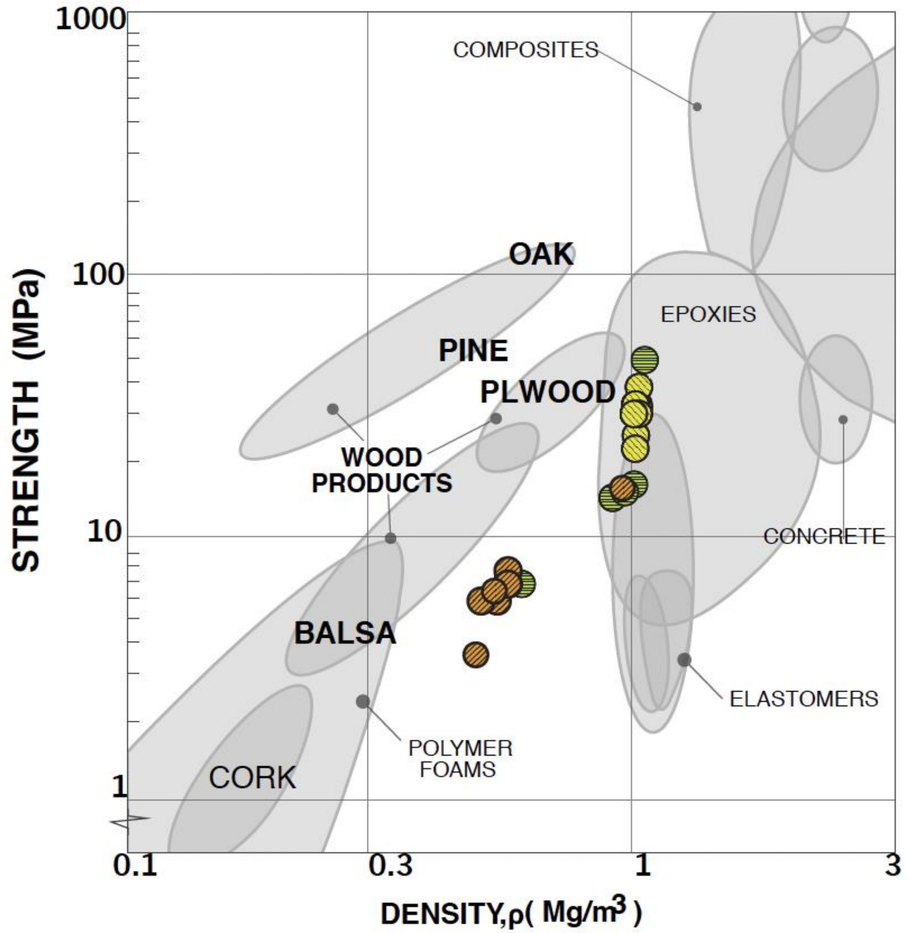

New York, USA
Accra/Tema , Ghana


coconut
coco nucifera



Lokko, Mae-ling, Michael Rowell, Anna Dyson, and Alexandra Rempel. 2016. "Development of Affordable Building Materials Using Agricultural Waste By-Products and Emerging Pith, Soy and Mycelium Biobinders." In the 32nd International Conference on Passive and Low Energy Architecture Proceedings, edited by Pablo La Roche and Marc Schiler, 881-887. Los Angeles: PLEA 2016.

MATERIAL STRENGTH VS. DENSITY



Coconut Pith Binder

Soy Protein Binder

Fungal Mycelium Binder

Pressing of Coconut AMBIS Module at e2e Materials
Credit: Mae-ling Lokko

Coconut Module Prototype

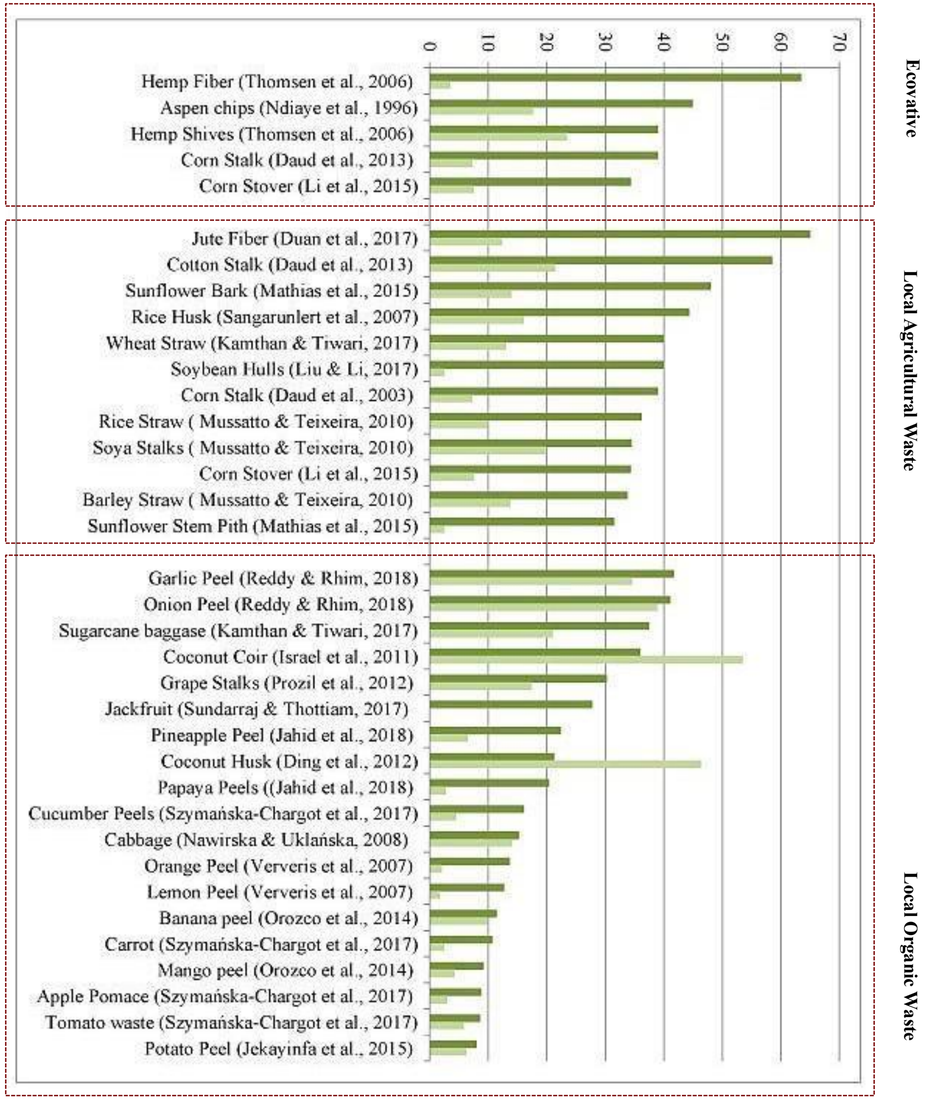
Photo Credit: Tanner Whitney (RPI)

Center for Architecture, Science and Ecology (CASE-RPI) + e2e Materials
Research Team: Mae-ling Lokko, Josh Draper, Clayton Poppe, Michael Rowell, Kelly Winn, Anna Dyson
Funding: NEXUS NY

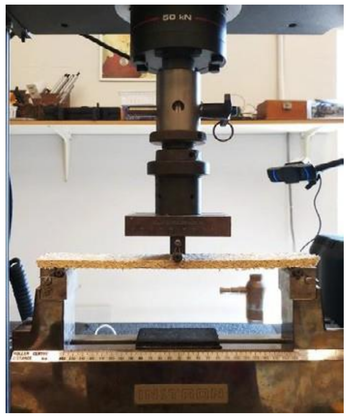
“Fungi make worlds. They also unmake them.”

Merlin Sheldrake,
Entangled Life: How Fungi Make Our Worlds, Change Our Minds & Shape Our Futures

Close video mycelium eating hemp waste
Video credit: Monika Koeck from Hack the Root project



(above) Growth Day 1-6 - Mycelium Lemon Peel Boards (right) 3-Point Beng Mechanical Test
Photo Credit: I. Ridwana



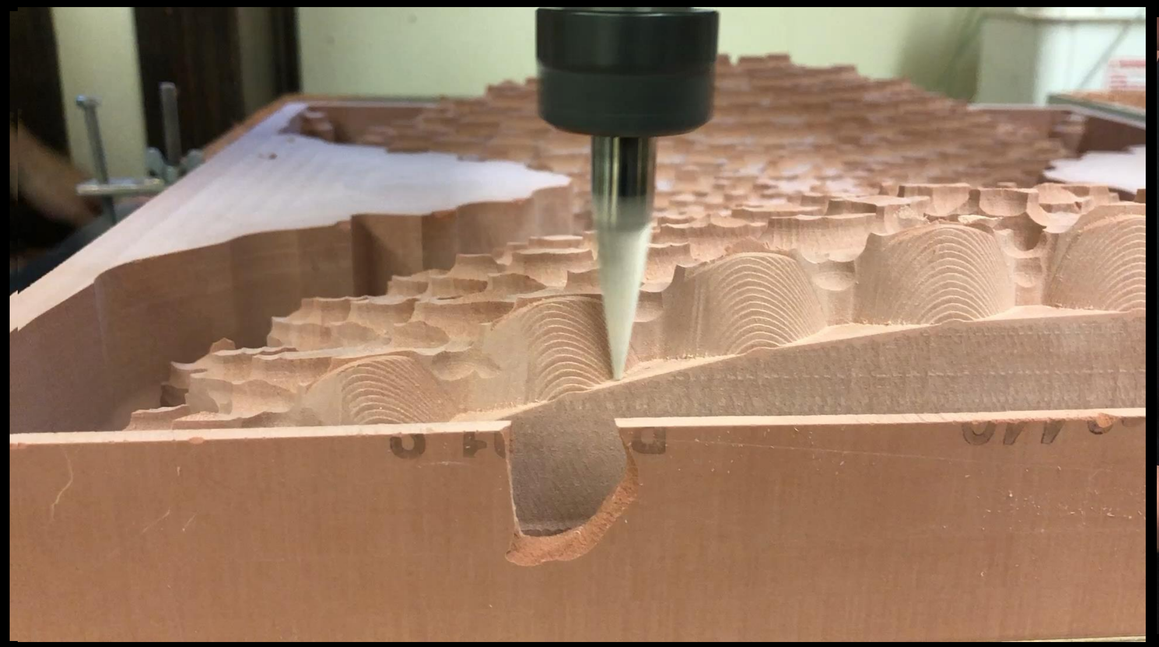
Paper: Ridwana, Iffat and Mae-ling Lokko. 2021. Investigating scales of performance: Ecomanufacturing of mycelium biocomposites in an informal settlement in Dhaka, Bangladesh. 2021 Architecture Research Centers Consortium Conference: Performative Environments. Winner; Best Paper Award

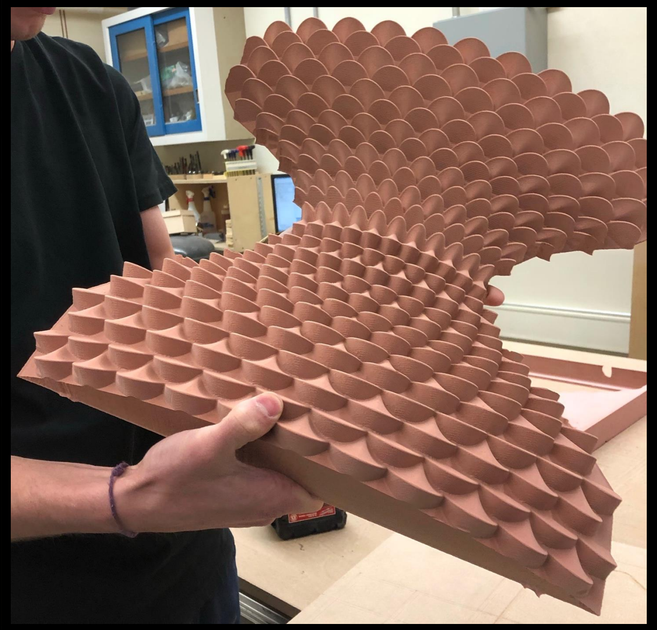
Funding: RPI and LUMA Foundation

Funding:
Royal Institute of British Architects (North)
Liverpool Biennial
CAVA
Arts Council England

ecovative

MAGICAL™ MUSHROOM COMPANY





MAKING OF AGROCOLOGIES PANEL
Credits: Mae-ling Lokko

Mycelium Factory Floor, Ecovative 2018
Credits: Elisabeth Press for “Hack the Root” exhibition

MAKING OF AGROCOLOGIES PANEL
Credits: Mae-ling Lokko

Mycelium panels grown by *Magic Mushrooms, UK*
Healing Meadow
Mae-ling Lokko
Photo Credit: Selma Gurbuz

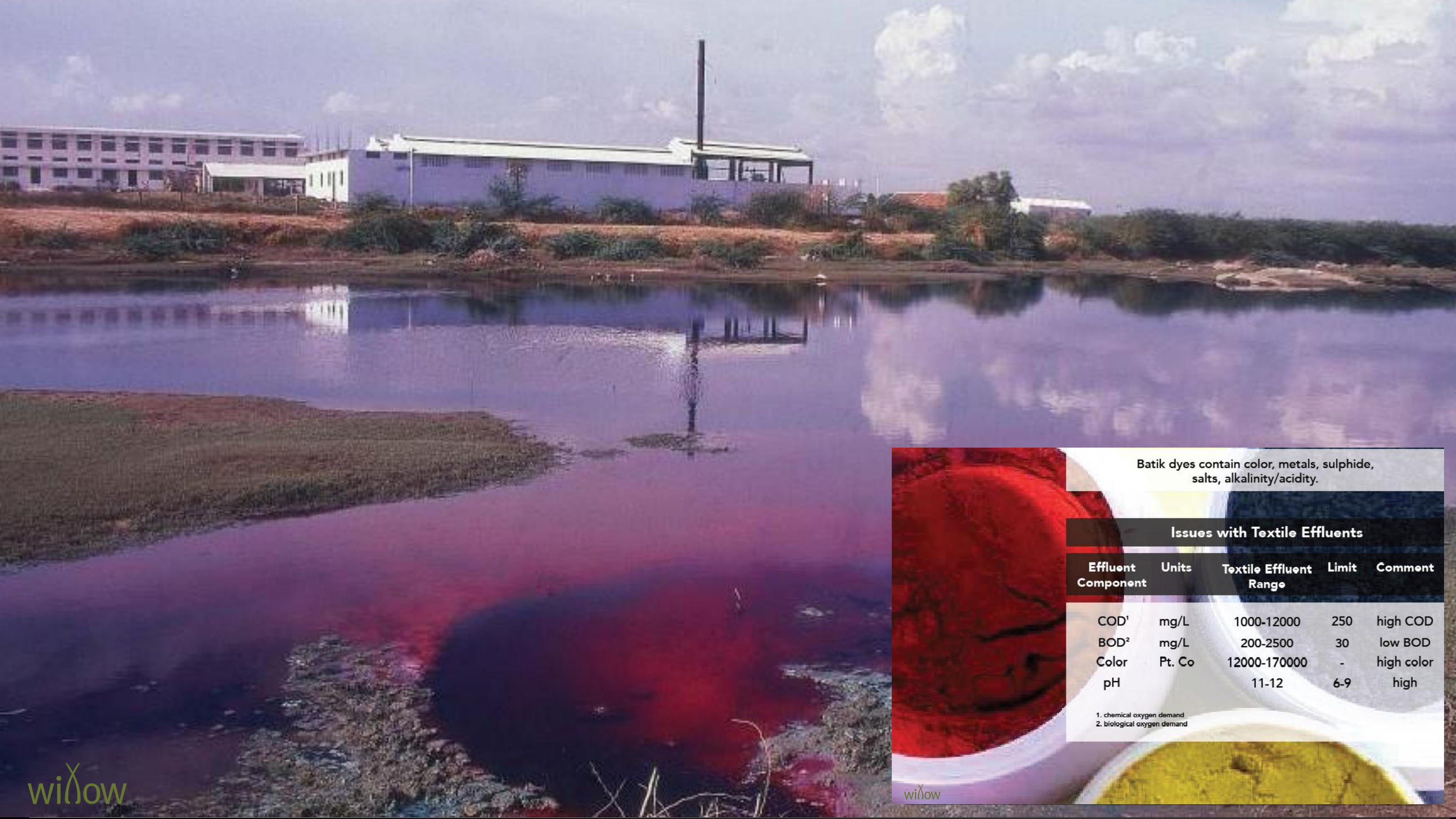
Healing Meadow in “Grounds for Return”
Mae-ling Lokko, 2022
Photo Credit: Selma Gurbuz

Mycotunnel, in “Grounds for Return”
Mae-ling Lokko, 2022
Photo Credit: Selma Gurbuz

Groundmurmurs, 2021, Sonsbeek Biennial
Mae-ling Lokko and Gustavo Crembil
Credit: Ibrahim Mahama

Plant Scale

(n) an ordered, usually numerical means of assigning value



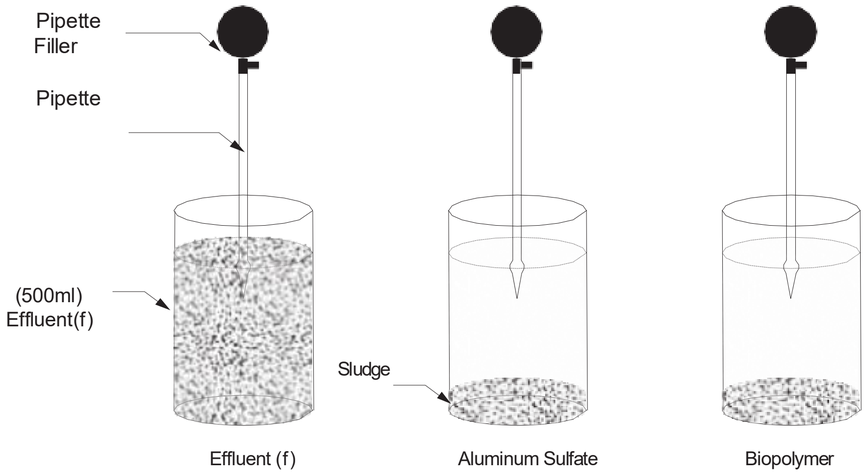
Batik dyes contain color, metals, sulphide, salts, alkalinity/acidity.

Issues with Textile Effluents

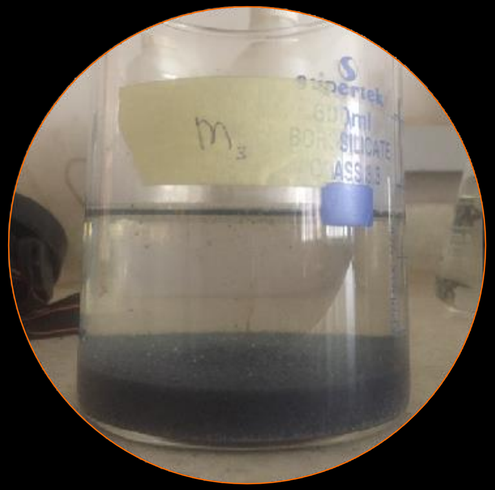
Effluent Component	Units	Textile Effluent Range	Limit	Comment
COD[1]	mg/L	1000-12000	250	high COD
BOD[2]	mg/L	200-2500	30	low BOD
Color	Pt. Co	12000-170000	-	high color
pH		11-12	6-9	high

1. chemical oxygen demand
2. biological oxygen demand

	Aluminum Sulphate (Alum)	Ferric Chloride	Polyaluminum Chloride (PAC)	Moringa
COST (GHC / kg)	700	570	>700	free - low cost
SUPPLY	local pharmaceutical suppliers, swimming pool treatment companies	local pharmaceutical supplier	imported	local moringa producers



t = 2 min



t = 6 min

Near-term Horizon

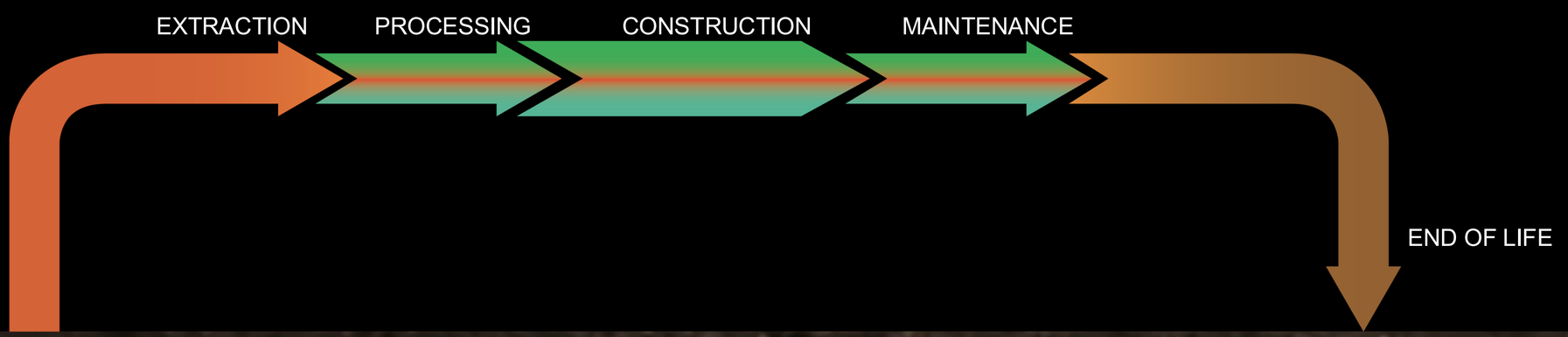
+ Use of water treatment sludge by-product sludge as raw materials for earth block and rammed earth masonry

Mid-Far Term Proposition

+ Transition to natural dyes

Geointell Housing Ghana, Samuel Siaw
Prep for Prototype 0 Build

Photo of Pigmented Rammed Earth Wall, Hive Construction
Prototype 0 Build



How can circular material life cycle design be used center **soil health** as the ultimate goal of cross-sectoral material performance?

Soil Sister Classes

Material Bank

Carbon Sink

Non-toxic Circular

Regenerative Materials

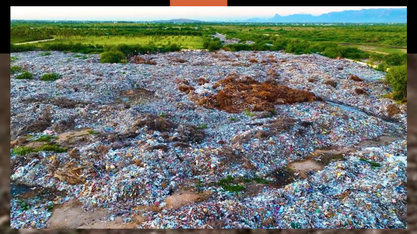
Material Bank

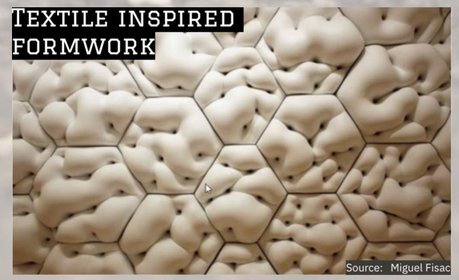
Dehydrated shredded cotton shirt panels

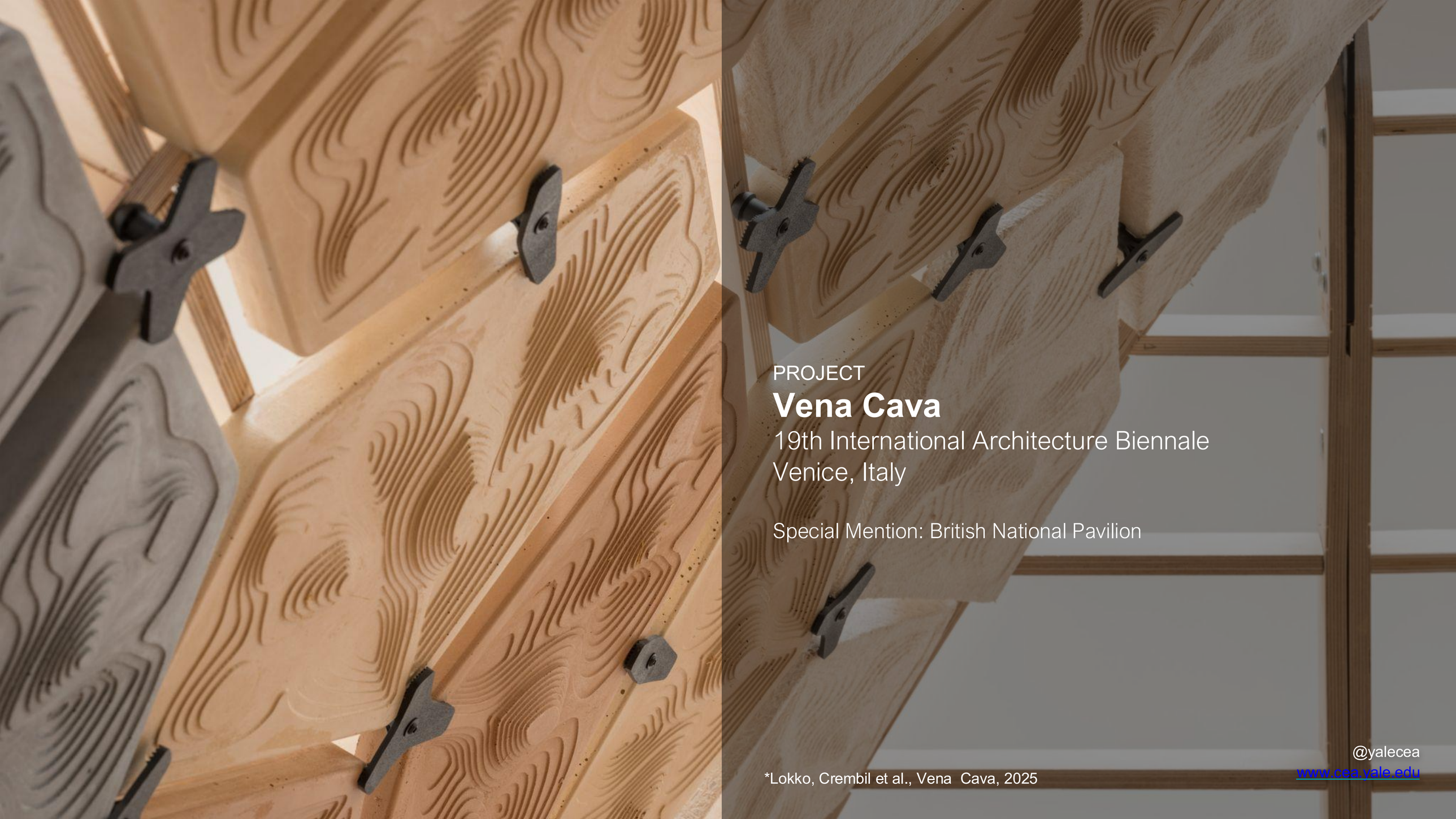
100 g textile fibers
15 g cassava glue
5 g citric acid
3 g sugar
water

EXTRACTION → PROCESSING → CONSTRUCTION → MAINTENANCE → END OF LIFE

RECYCLING
IMPROVED
DEGRADATION







PROJECT

Vena Cava

19th International Architecture Biennale
Venice, Italy

Special Mention: British National Pavilion

*Lokko, Crembil et al., Vena Cava, 2025

@yalecea
www.cea.yale.edu

YALE CENTER FOR ECOSYSTEMS + ARCHITECTURE
Yale CEA

PROJECT

Vena Cava

19th International Architecture Biennale
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*Lokko, Crembil et al., Vena Cava, 2025

@yalecea
www.cea.yale.edu

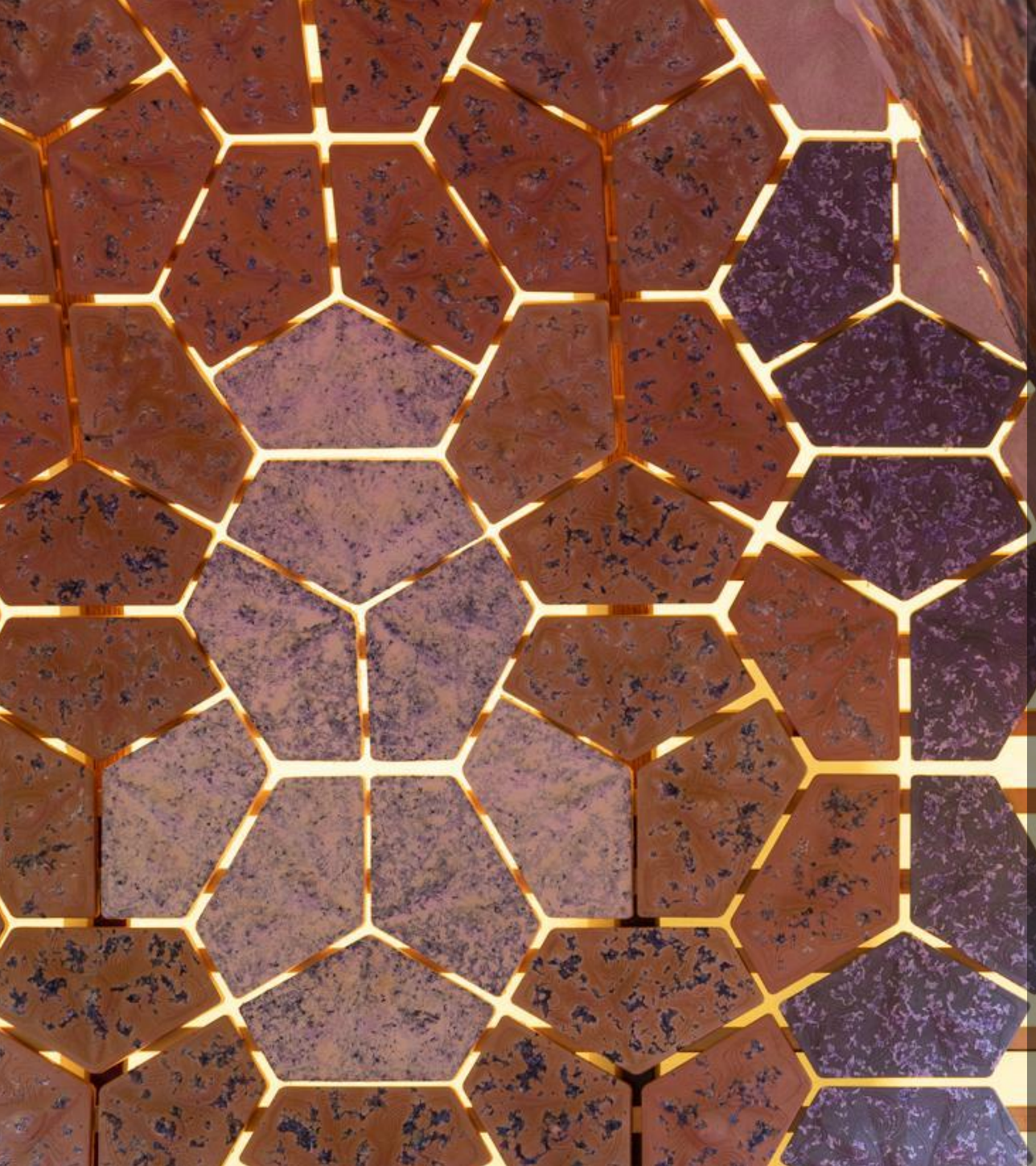
HKW Pavilion 2025

PROJECT

Ileum Pavilion

Haus der Kulturen Der Welt,
Berlin, Germany

*Lokko et al., HKW Pavilion, 2025



PROJECT

Ileum Pavilion

Haus der Kulturen Der Welt,
Berlin, Germany

*Lokko et al., HKW Pavilion, 2025

Fig. 1. Diverting Second Hand Clothing from being washed downstream to Ghana's Coastline

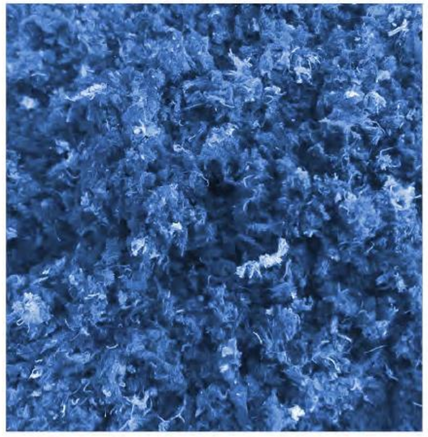


Fig. 2. Shredded Cotton from Second Hand Clothing

Fig. 3. Ileum's Shredded Cotton Geopolymer Panel

Carbon Sink (Biomass)

BIOCOMPOSITES

NON-TOXIC BINDERS
EMBODIED CARBON
DESIGN FOR BIODIVERSITY
MATERIAL EFFICIENCY
OPTIMIZATION OF PARTICLE AND FIBER SIZE AND LAYOUT

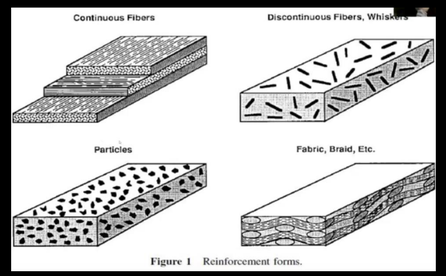


Figure 1 Reinforcement forms.

EXTRACTION → PROCESSING → CONSTRUCTION → MAINTENANCE → END OF LIFE → REUSE

WOVEN BIOFIBERS


Source: Yul Tziki

THERMALLY PRESSED


Source: Stora Enzo

CNC MILLED


Source: Adam Schofield

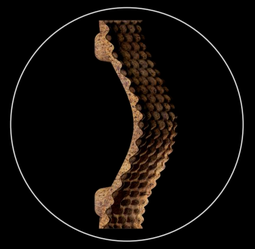
Biocomposites Prototypes

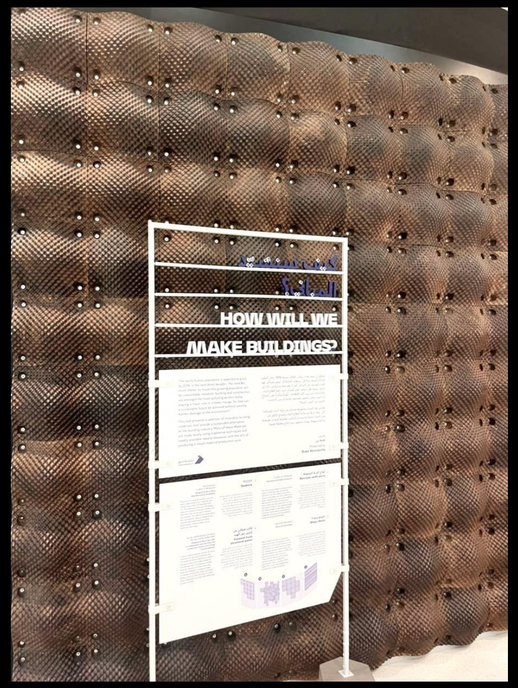
3D PRINTED


Source: Adam Schofield

Installation of Coconut Panel at Chale Wote 2016, Ghana
Photo Credit: Josh Draper

Installation of Coconut Panel at Chale Wote 2016 , Ghana
Photo Credit: Saray Reynolds





Installation of Coconut Panel at Museum of the Future in Dubai
2021-present
Photo Credit: Gonzalo Herrero Delicado

Door of No Return, 2021
Goree Island, Senegal
Source: Mae-ling Lokko

Threshold of Return, detail
Z33, Belgium (2022)
Mae-ling Lokko

Non-toxic Circular (Masonry)

COMPRESSED STABILIZED EARTH BLOCK (CSEB)

CEMENT STABILIZED CSEBS
SAND = 50%
SILT - 15 %
GRAVEL = 15%
CLAY = 20%
CEMENT = >3-5%

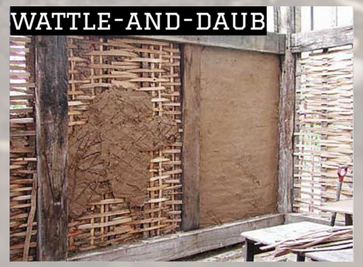
LIME STABILIZED CSEBS
CLAY = 35%
SAND = 30%
SILT - 20 %
GRAVEL = 15%
LIME = 2-6%

HTTPS://WWW.EARTH-AUROVILLE.COM/COMPRESSED_STABILISED_EARTH_BLOCK_EN.PHP

EXTRACTION → PROCESSING → CONSTRUCTION → MAINTENANCE → END OF LIFE

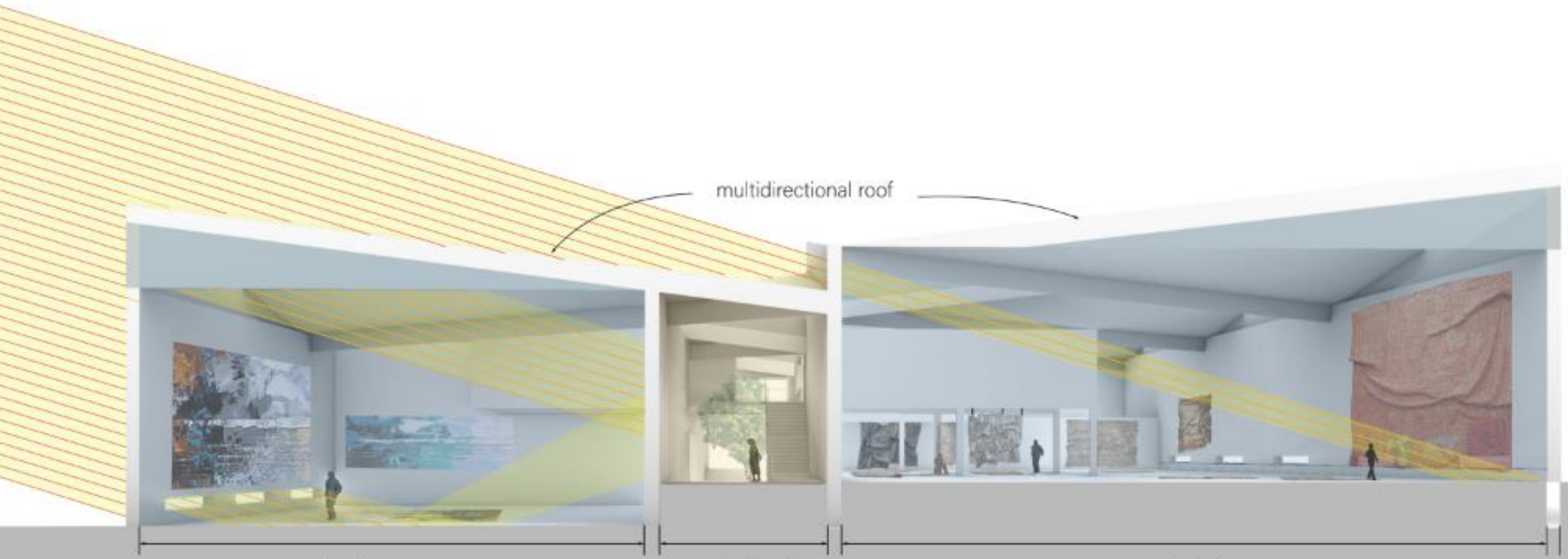
SAFE BIODEGRADATION

Non toxic biobinders:
- Geopolymers
- Biobased SCMs and additives
- Clay renders



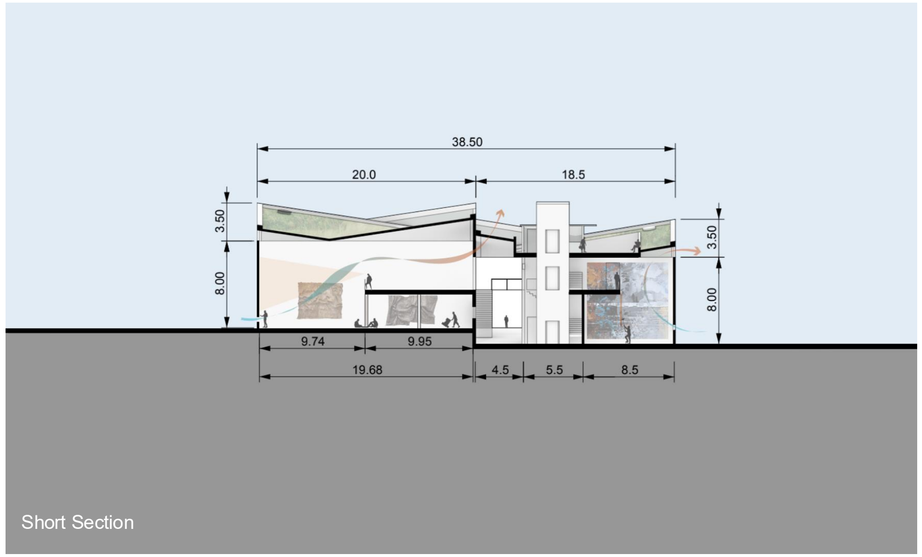
Shard Song
El Anatsui
Efie Gallery, Dubai
Curator: Mae-ling Lokko

Society Woman's Cloth (Gold)
2006
El Anatsui
Yale Art Gallery, New Haven

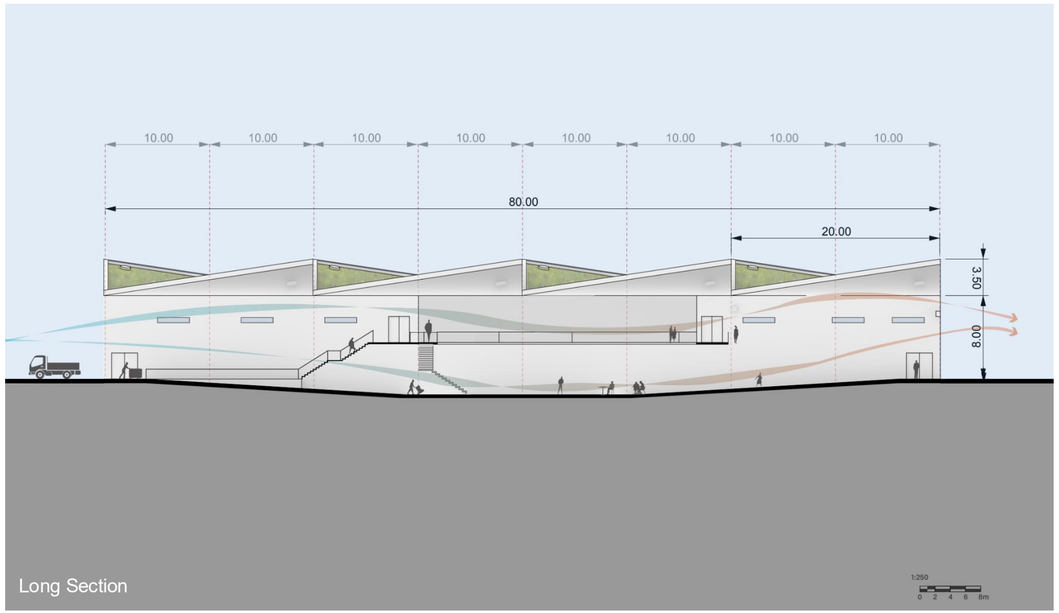


EL ANATSUI STUDIO

Concept Design
Mae-ling Lokko



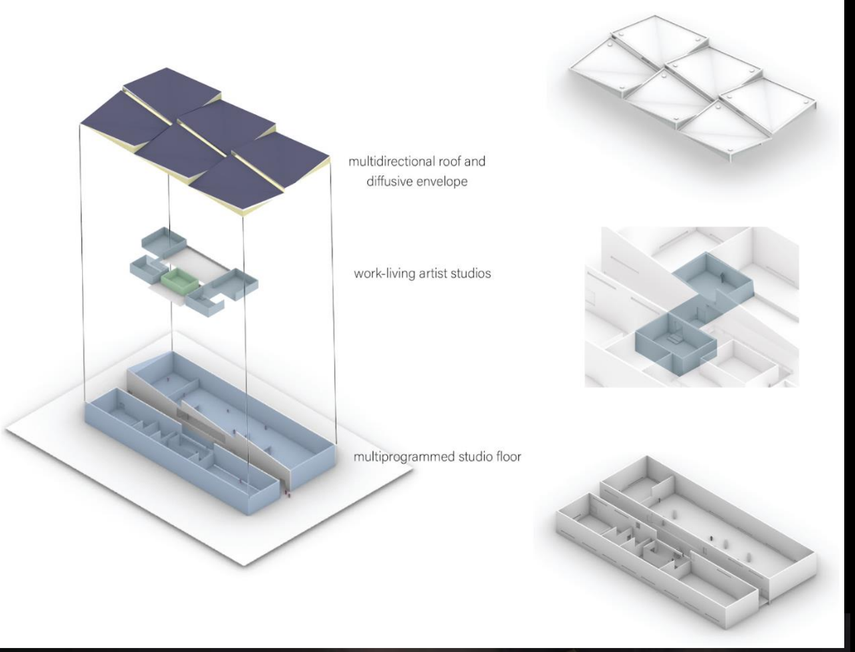
Short Section



Long Section

EL ANATSUI STUDIO , 2024

Design Team: Mae-ling Lokko and Jessica Bristow
Architect of Record: Tekton Consult (Tony Asare)
Contractor: Jake Construction
(Left) Credit: Mae-ling Lokko
(Right) Photo Credit: **Paa Kwesi Etsibah**



EL ANATSUI STUDIO

Design Team: Mae-ling Lokko and Jessica Bristow
Architect of Record: Tekton Consult (Tony Asare)
Contractor: Jake Construction
Photo Credit: **Paa Kwesi Etsibah**

Ventilated Earth Block Wall
EL ANATSUI STUDIO
Team: Samuel Siaw (GeoIntell), Mae-ling Lokko, Mohamad Aly Etman
Photo Credit: Paa Kwesi Etsibah

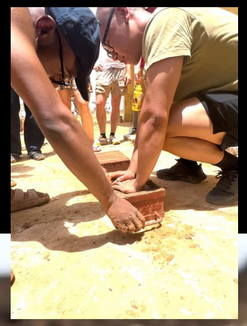
Regenerative Materials

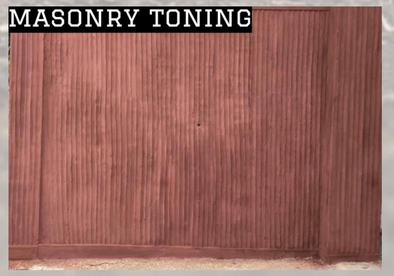
BIOGENIC COLOR

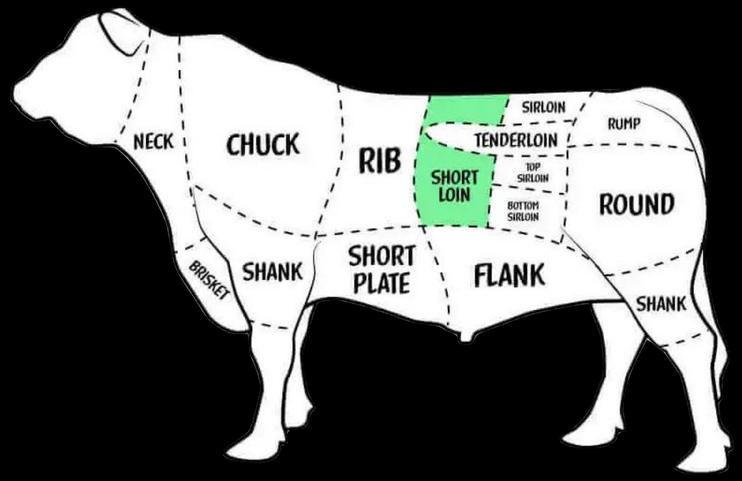
DYEBATH WATER CONSUMPTION
DYEBATH WATER QUALITY
DYEBATH EFFLUENT QUALITY
DYE FERMENTATION
COLOR FADING PERFORMANCE
SOLAR / THERMAL PERFORMANCE OF BIOGENIC COLOR
OFFGASSING AND LEACHING OF BIOGENIC COLOR

EXTRACTION PROCESSING CONSTRUCTION MAINTENANCE END OF LIFE

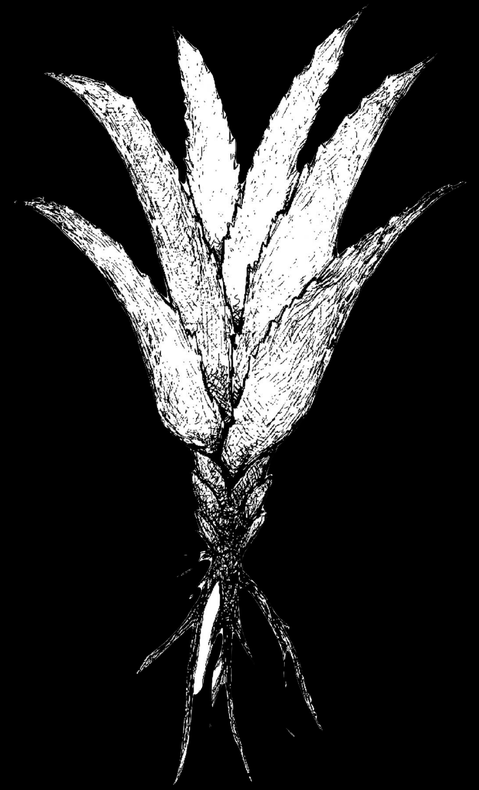
SAFE
BIODEGRADATION






NECK
CHUCK
RIB
SHORT LOIN
SIRLOIN
TENDERLOIN
TOP SIRLOIN
BOTTOM SIRLOIN
RUMP
ROUND
BRISKET
SHANK
SHORT PLATE
FLANK
SHANK

Regenerative Materials



Aloe Vera
NATURAL PALETTES
Sasha Duerr

Seasonal Color Wheel
Sasha Duerr

Soil Sisters