BUILDING BIOMIMETICALLY

by

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the Department of Interior Design

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BUILDING BIOMIMETICALLY

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ABSTRACT

This honors thesis delves into the intersection of architecture and environmental science, with a focus on developing a sustainable Heating, Ventilation, and Air Conditioning (HVAC) system inspired by the ingenious design of Macrotermes Natalensis termite mounds. By analyzing the intricate structure and composition of these mounds, particularly their interconnecting tunnels and passive temperature regulation mechanisms, the study aimed to revolutionize HVAC systems to reduce reliance on fossil fuels. Through the application of biomimicry principles and passive architecture techniques, a novel HVAC system was conceptualized and developed. This system promises to significantly decrease HVAC consumption and costs within the South-Central Region of the United States, consequently mitigating the substantial 4% of greenhouse gas emissions attributed solely to HVAC systems. The culmination of the research led to the creation of a pioneering passive architecture pavilion, seamlessly integrating the features of termite mounds with passive architectural design principles. This pavilion operates entirely through passive regulation, without the need for mechanical ventilation. The proposed system not only addresses current environmental concerns but also exhibits adaptability to future climate change scenarios. It has the potential to catalyze a paradigm shift in HVAC and passive architecture practices worldwide, fostering sustainability and resilience in the face of evolving environmental challenges.

2024

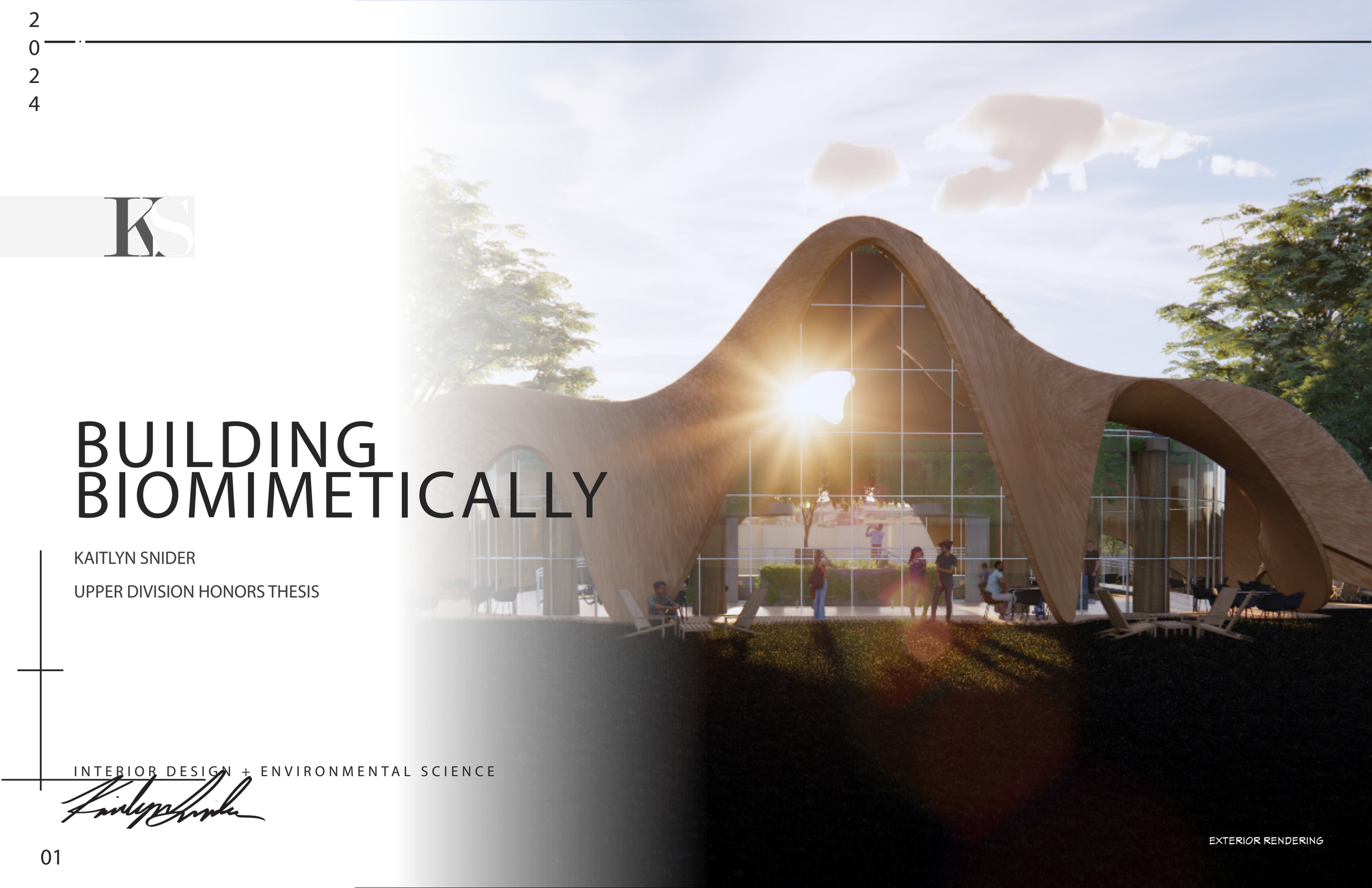
KS

BUILDING BIOMIMETICALLY

KAITLYN SNIDER

UPPER DIVISION HONORS THESIS

INTERIOR DESIGN + ENVIRONMENTAL SCIENCE



EXTERIOR RENDERING

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THESIS INFORMATION

THE QUESTION

How can we utilize the tactics and lessons learned from nature to create more environmentally friendly everyday systems?

THE DIRECTIVE

- Create environmentally friendly buildings
- Reduce our reliance on fossil fuels
- Design a more sustainable heating and cooling system using Biomimicry
- Reduce energy consumption for current HVAC systems

FRONTIERS SCIENCE/TERMITE MOUND DIAGRAM

DEFINE THE PROBLEM

STATEMENT

One of the organisms that has the potential to influence one of the most used everyday systems, heating and cooling,the termite species Macrotermes *natalensis*. The M. *natalensis* utilize their natural surroundings of clay, soil, and dung as well as termite saliva, to build mounds that create a self-regulating, passive heating and cooling system for its inhabitants.

ARGUMENT

While the world advances in technology and practices, termite mounds have remained the same in structure and purpose, not fighting against change but rather adapting and evolving. When it comes to the design of more sustainable practices in design, we can learn from such species as they have proven their methods of passive heating and cooling are successful and stand the test of time.

THE RESEARCH

BIOMIMICRY

Noun. The design and production of materials, structures, and systems that are modeled on biological entities and processes (Oxford Dictionary)

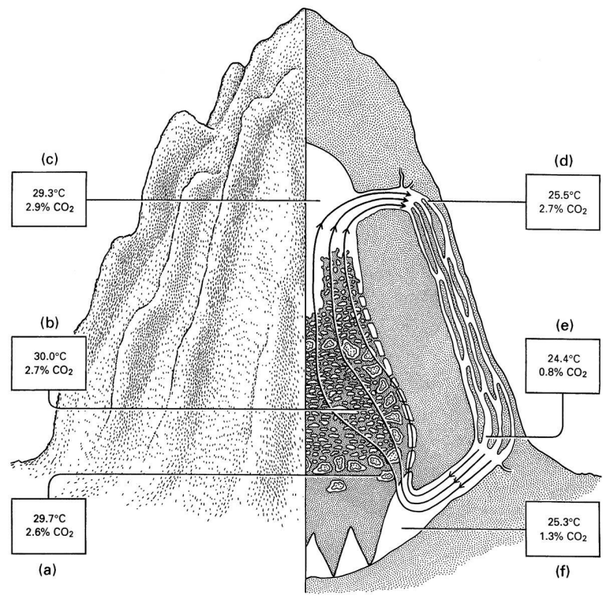
GATHER INFORMATION

TERMITES

M. *natalensis*

- Fungus-growing termite native to South Africa
- Use of natural grounds and surroundings to create mounds
- 8-9 meters high

SHUTTERSTOCK / TERMITE MOUND



SCIENCE DIRECT / SECTION TERMITE MOUND

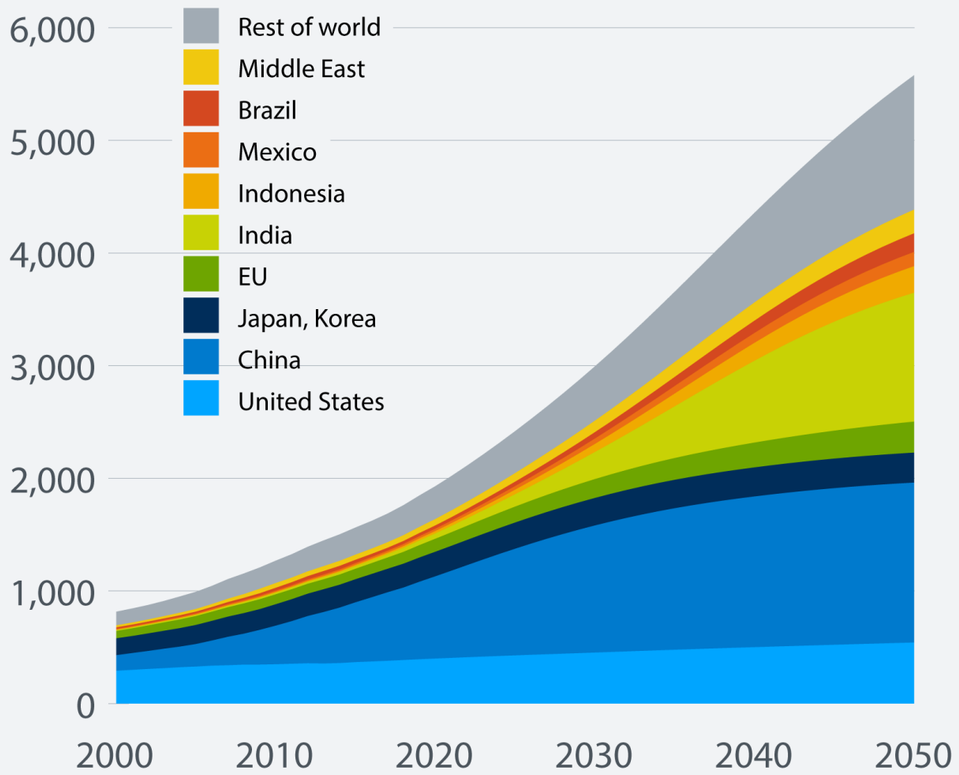
SHUTTERSTOCK / TERMITES

SHUTTERSTOCK / TERMITE MOUND

THE RESEARCH

Growing global demand for cooling

Projected number of air conditioning units in use worldwide (in millions)



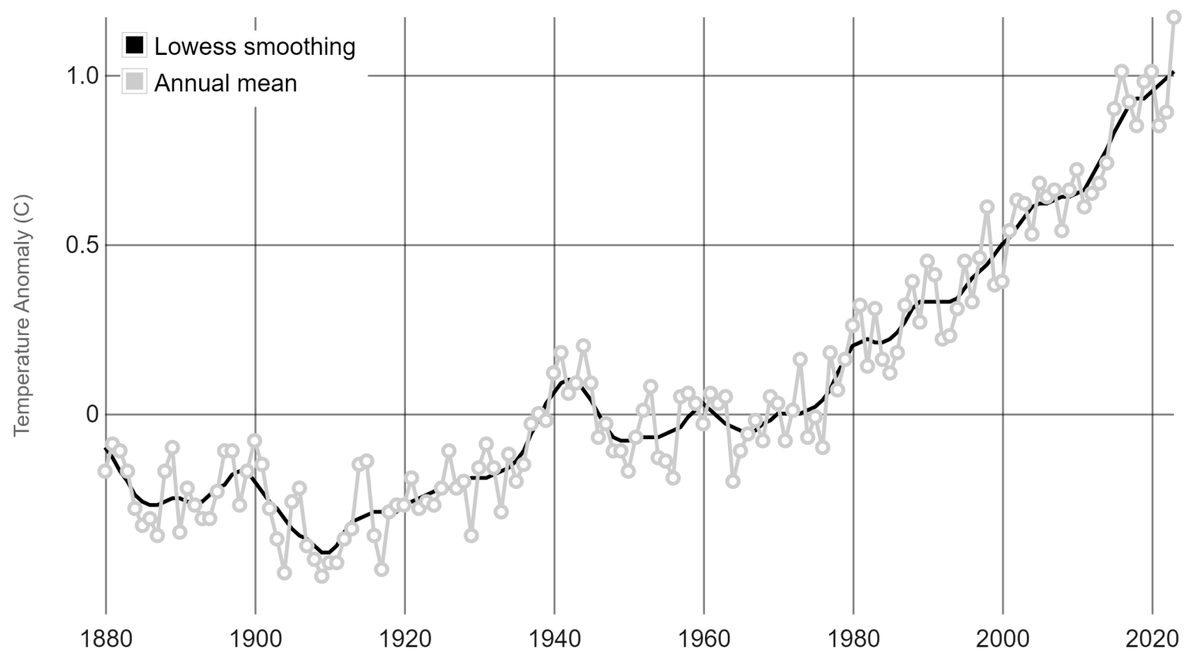
Source: International Energy Agency

HVAC AND CHANGING TEMPERATURES

- Cascading effect that ultimately ends in drastically changing temperatures on earth
- Heating, Ventilation, and Air Conditioning (HVAC) Account for 4% of global greenhouse gas emissions
- Twice the emissions from the aviation industry
- There is a need to adapt as temperatures become more drastic and HVAC use exponentially increases

(Washington Post)

GATHER INFORMATION



Source: climate.nasa.gov

THE RESEARCH

PASSIVE HEATING AND COOLING

- Architectural technique used as early as the Egyptians
- Utilized primarily to promote natural ventilation within interiors by using the surrounding earth and strategically placed elements to direct wind

GATHER INFORMATION

THE HISTORY

- Egyptian reed technique employed the use of evaporative cooling
- Middle Eastern wind catchers would direct air flow and use the principles of thermodynamics of cold air falling and hot air rising

THE TAKEAWAY

- Architects previous implementation of individual techniques as whole within one building rather than focused on a single aspect to be used universally
- Create a more universal system that can move passive architecture towards less of a design principle and more of a design system

SHUTTER STOCK / EGYPTIAN PASSIVE COOLING

SHUTTERSTOCK / WIND-CATCHER

THE CRITIQUE

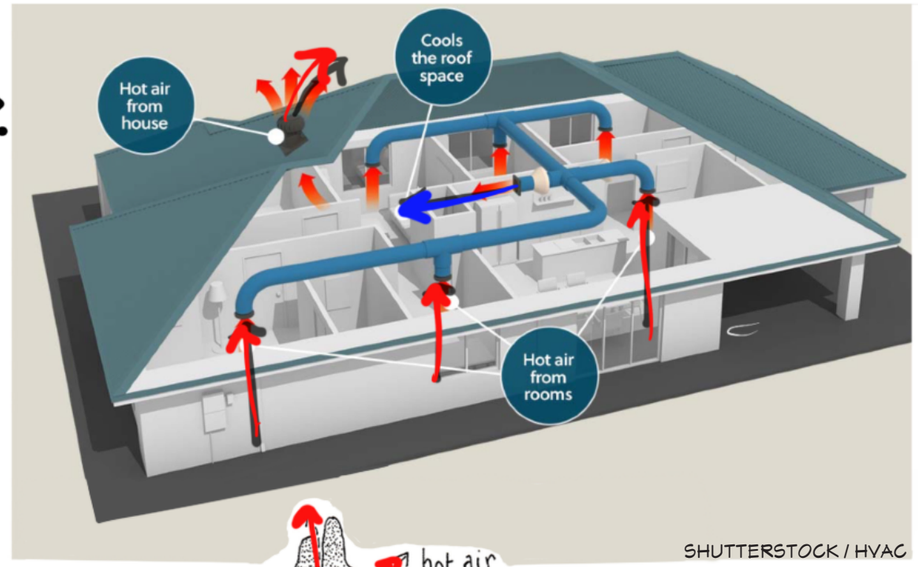
HVAC SYSTEMS

PROS:

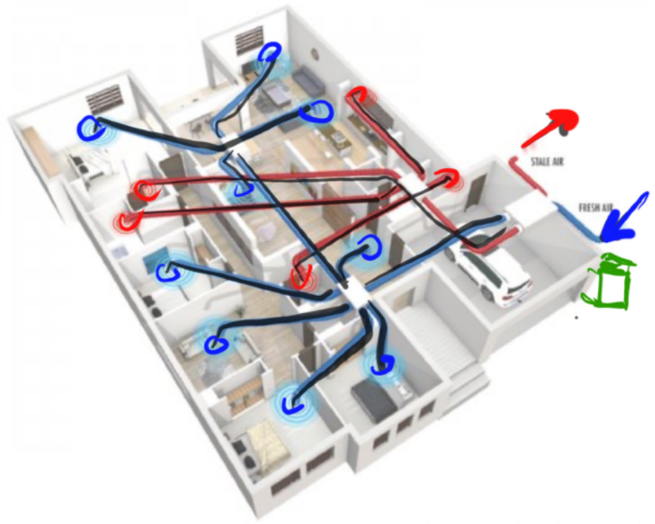
- SEPERATES HOT/ COLD AIR
- DEPOSITS AIR INTO SPECIFIC AREAS
- USES INSULATING MATERIALS

CONS:

- HORIZONTAL DESIGN
- REQUIRES A COOLING AGENT



SHUTTERSTOCK / HVAC



SHUTTERSTOCK / HVAC

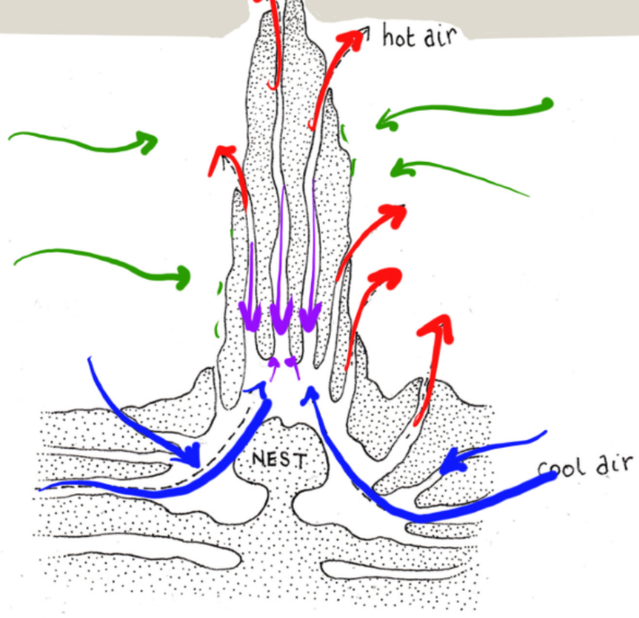
TERMITE MOUNDS

PROS:

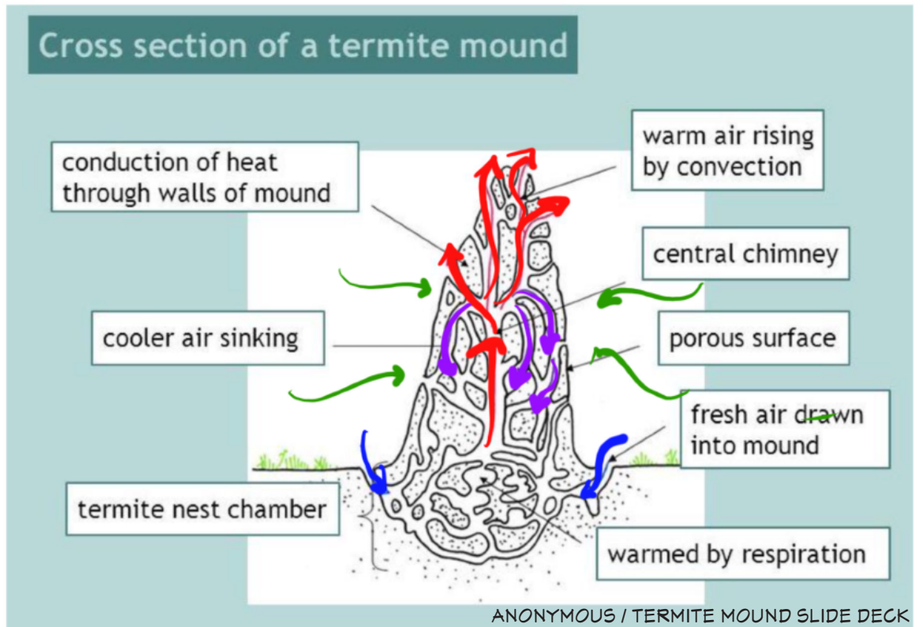
- VERTICAL CONSTRUCTION
- POROUS MATERIAL
- ADAPTABLE
- EVAPORATION TECHNIQUE WITHIN CENTRAL ROOM

CONS:

- MIXES HOT/COLD AIR
- CAN BREAK DOWN IN SEVERE WEATHER



PBS / TERMITE MOUNDS



ANONYMOUS / TERMITE MOUND SLIDE DECK

SIMILARITIES:

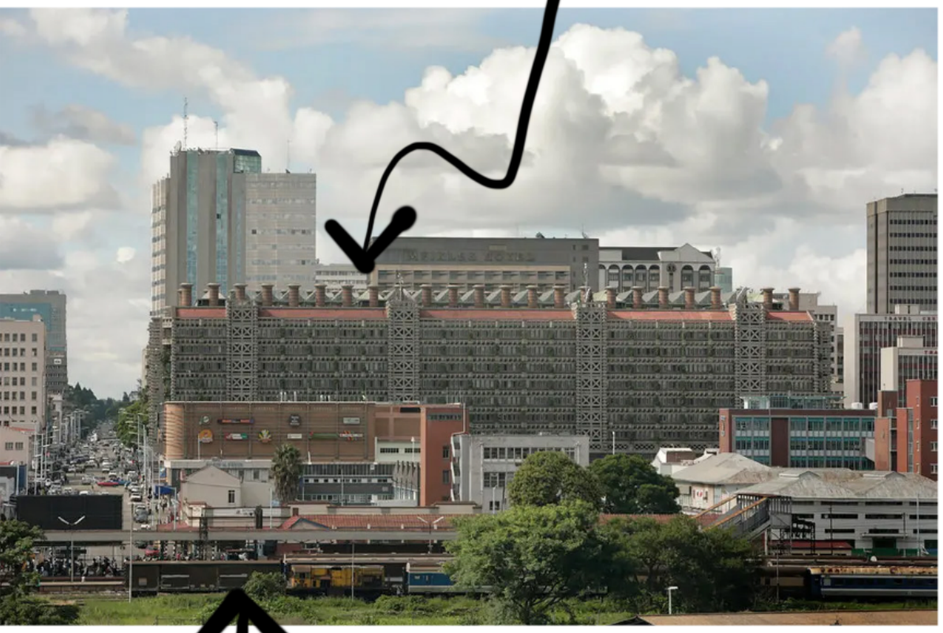
- EXIT CHIMNEYS
- COMPLEX PATHWAYS
- AIR DEPOSITS AND COMES FROM ABOVE

THE PRECEDENTS

THE EAST GATE CENTRE

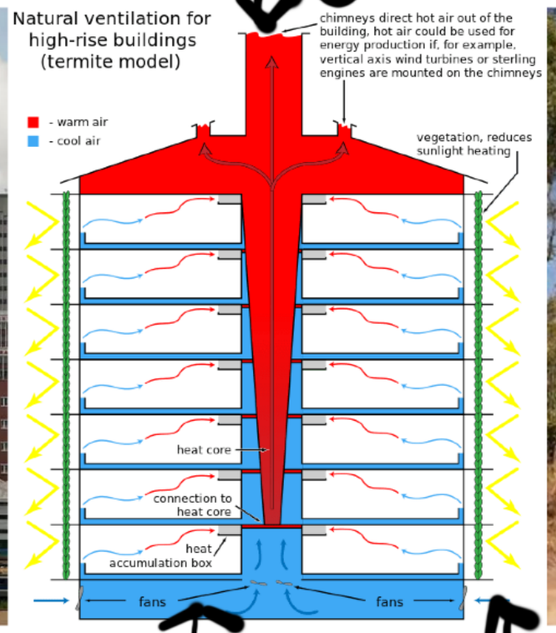
HARARE, ZIMBABWE // 1996

LOTS OF LARGE WINDOWS

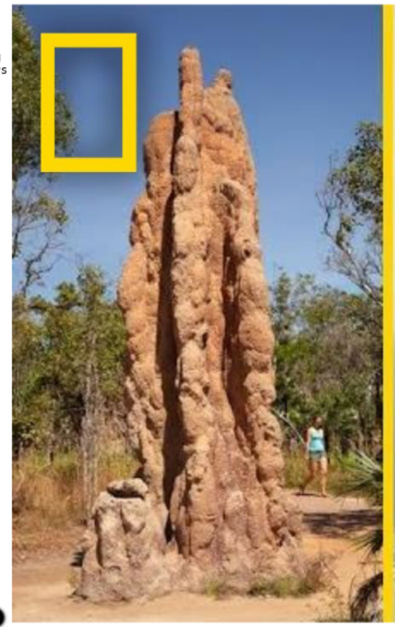


HOT/ARID CLIMATE

EXIT CHIMNEY



AIR FLOWS IN FROM BELOW



VEGETATION FOR EVAPORATIVE COOLING

VERTICAL SYSTEM

PULLS AIR FROM BELOW

ASKNATURE / SHUTTERSTOCK/ EAST GATE CENTERE

THE PRECEDENTS

WINDCATCHERS

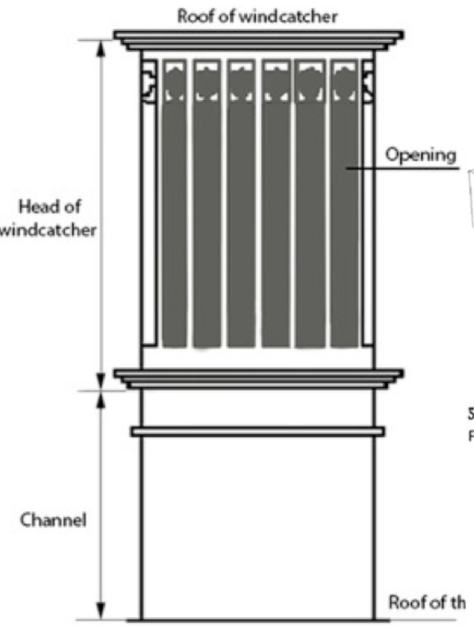
MIDDLE EAST // 14TH CENTURY

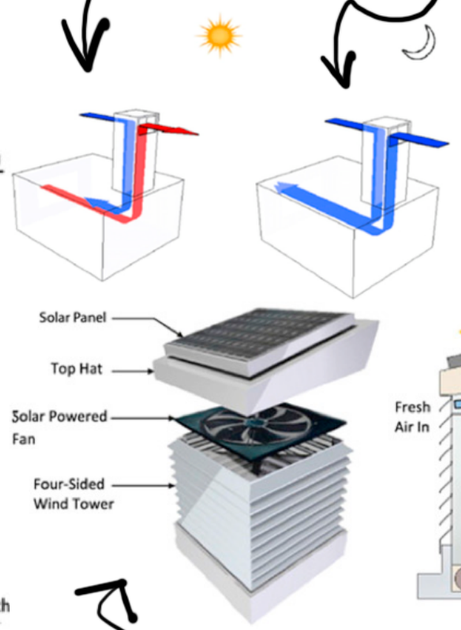
CIRCULAR VENTILATION DURING DAY

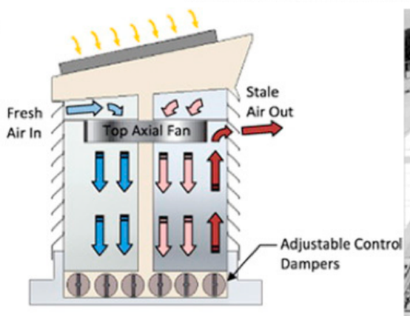
COOL AIR AT NIGHT

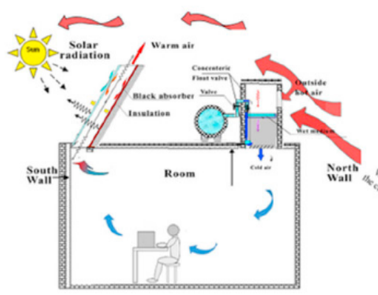
USE OF SOLAR PANELS

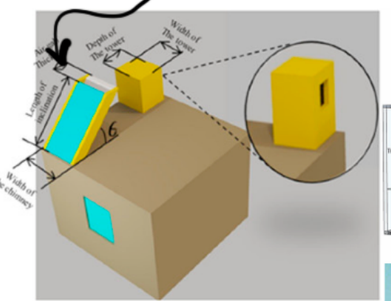
MODERN

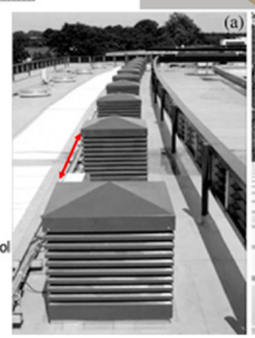


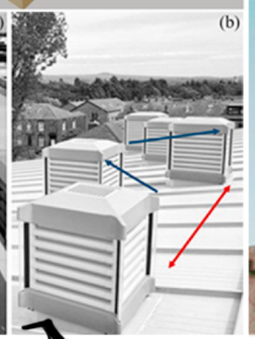


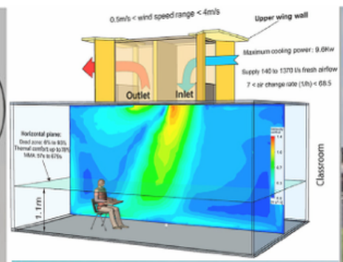












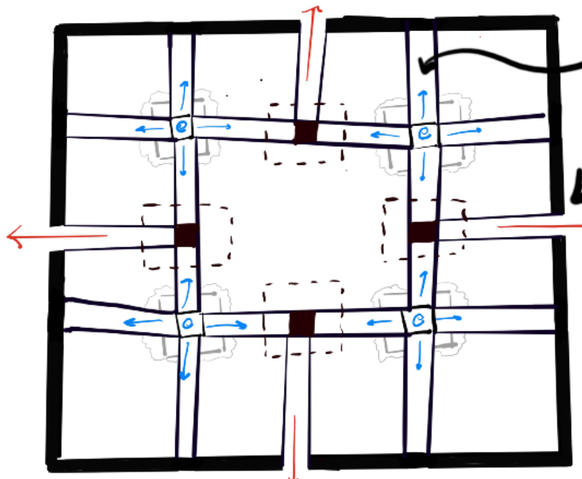
EVOLUTION TO INCORPORATE FANS AND MOVE TO A MORE MODERN LOOK

STAGGERED FORMATION

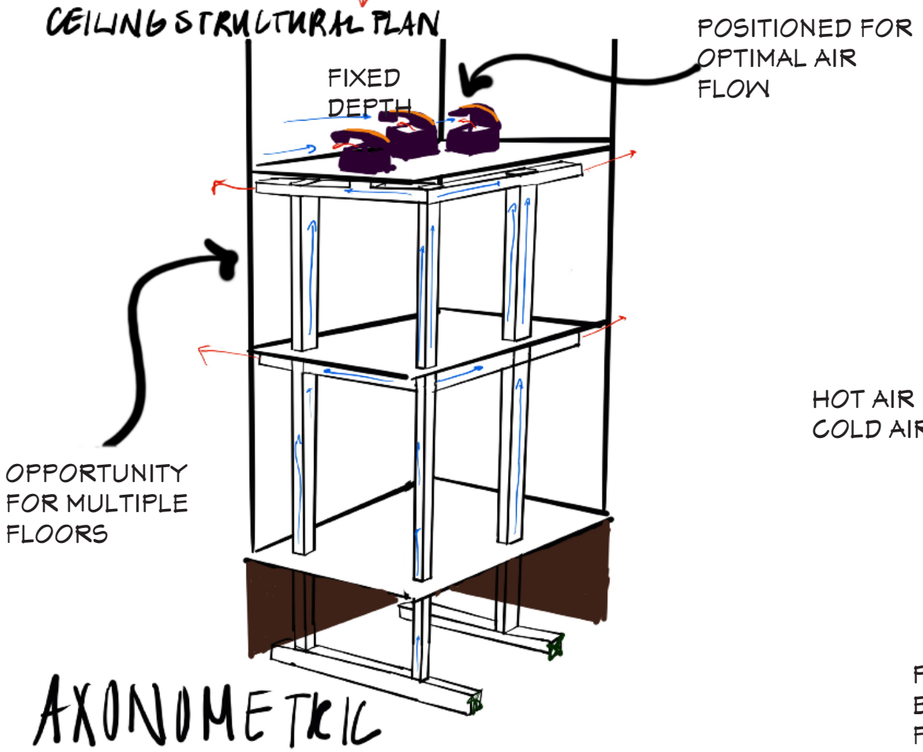
TRADITIONAL

SHUTTER STOCK / SCIENCE DIRECT / WIND CATCHERS

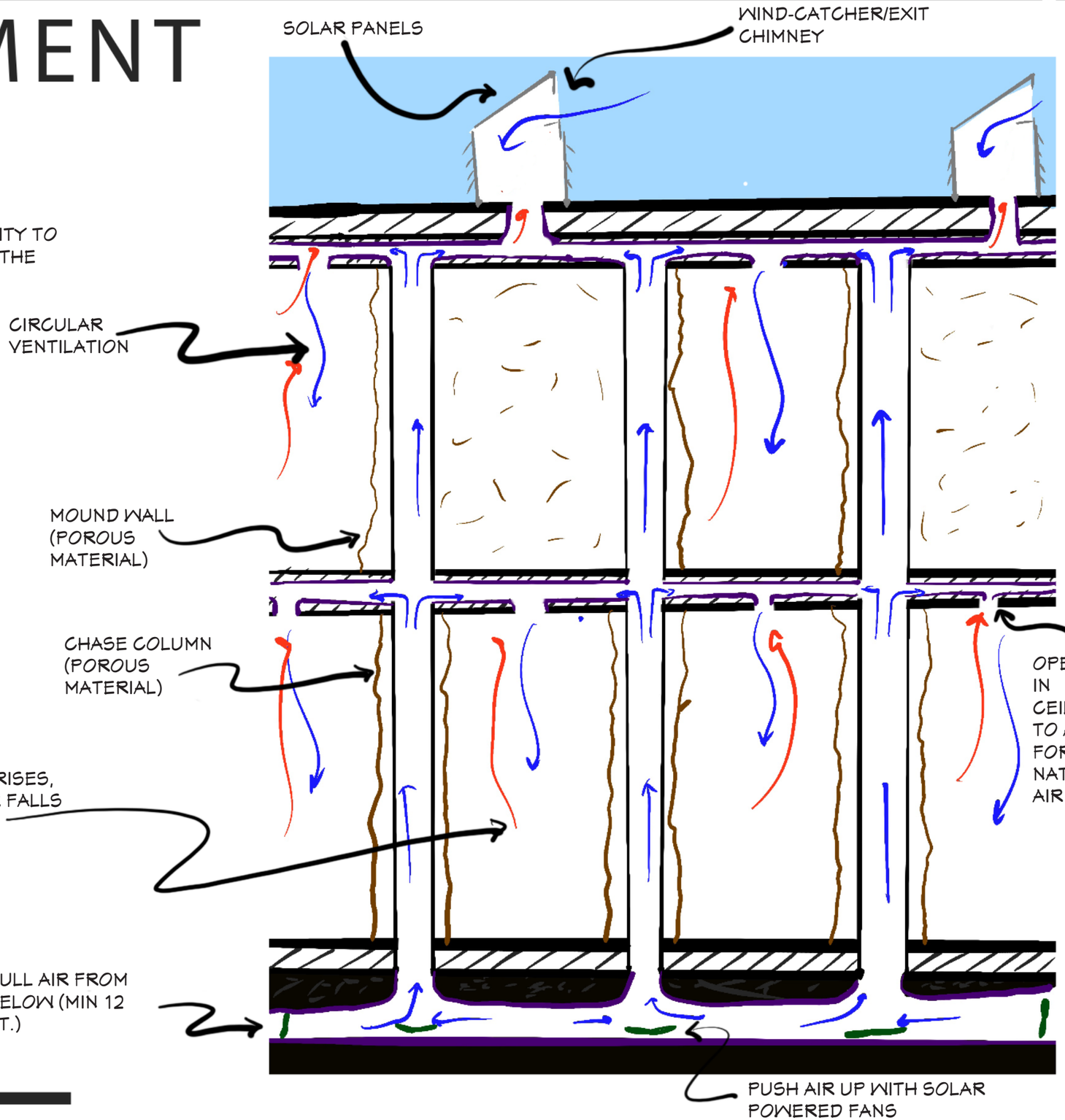
THE DEVELOPMENT



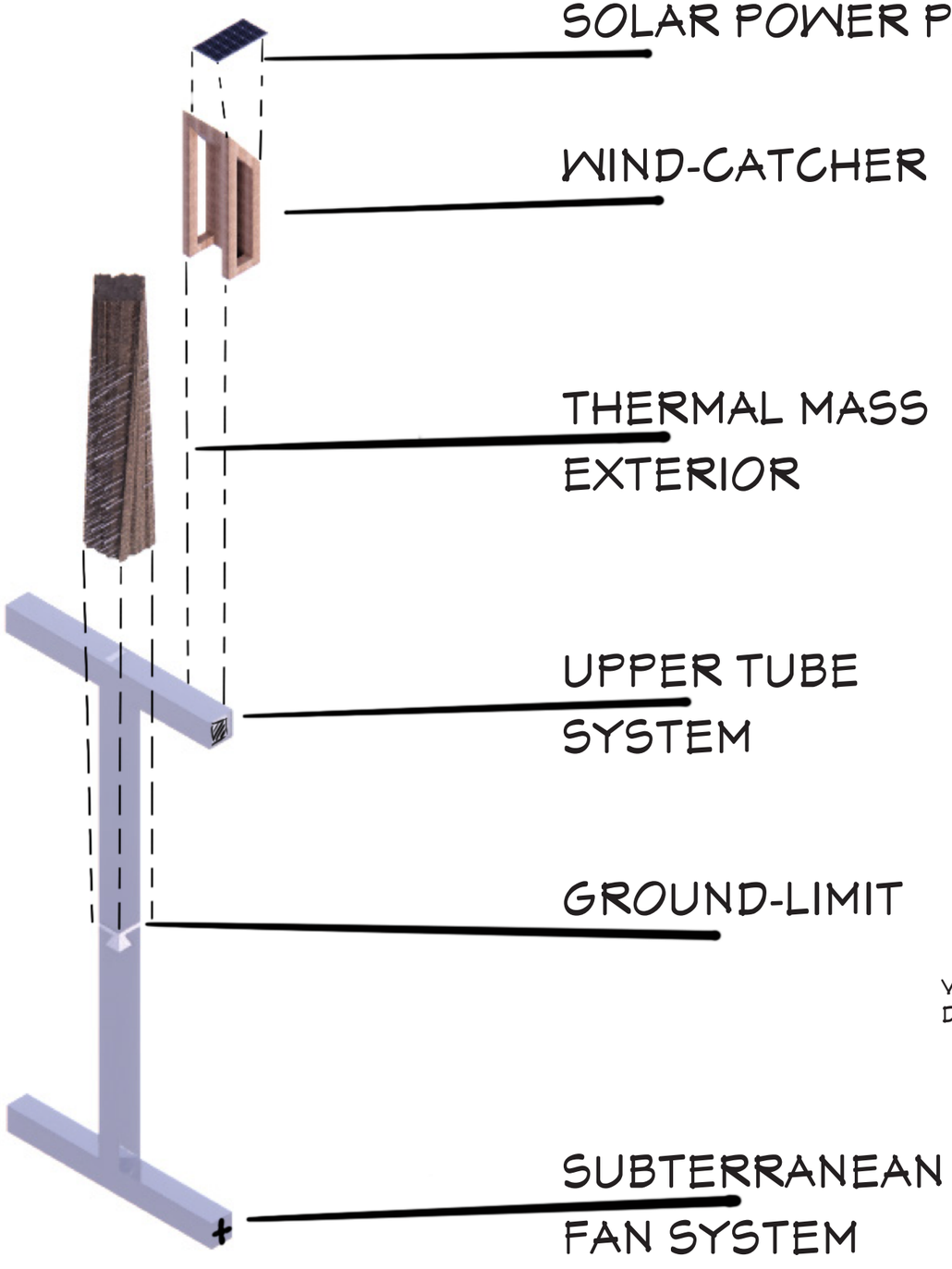
CEILING STRUCTURAL PLAN

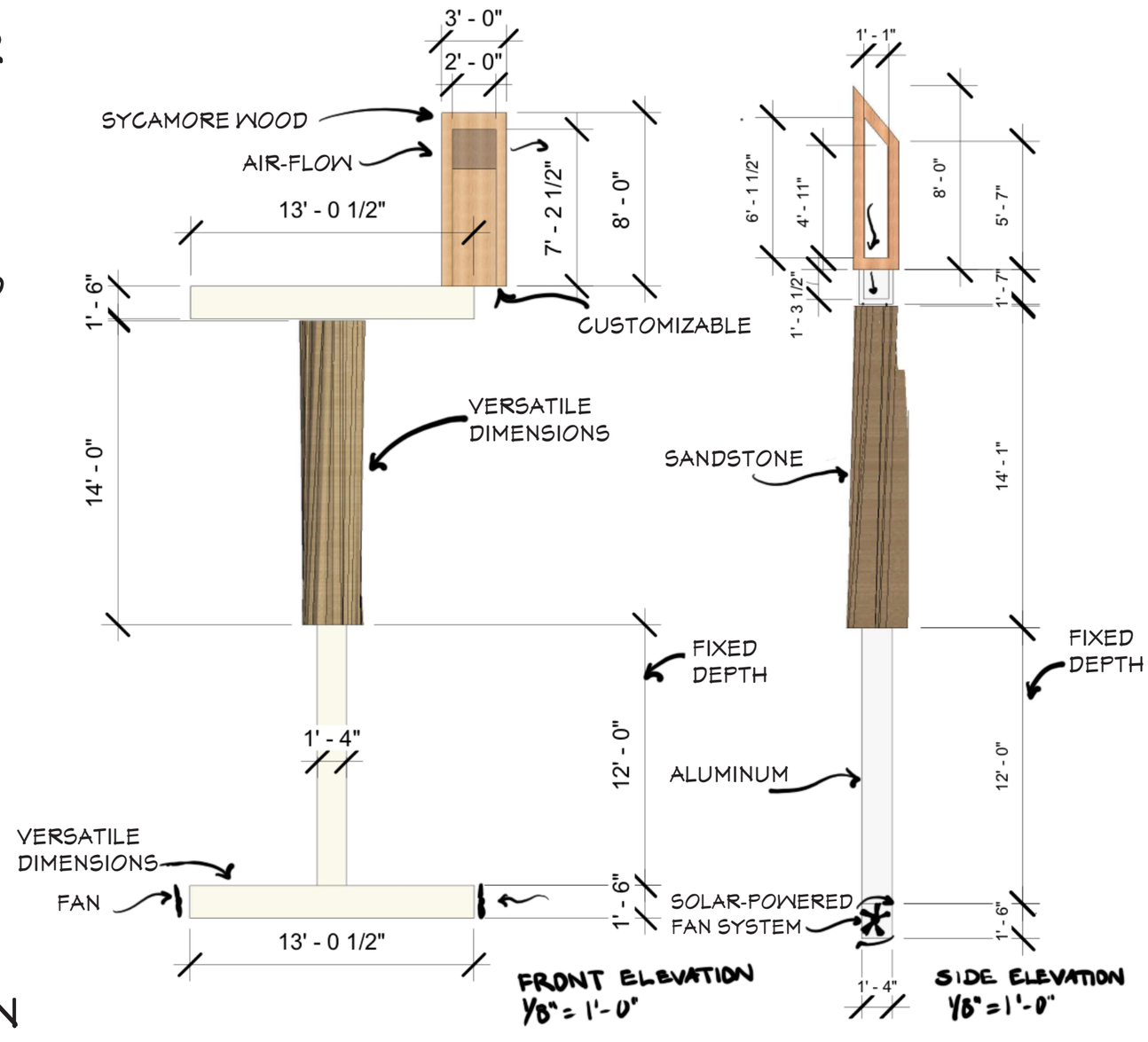


AXONOMETRIC

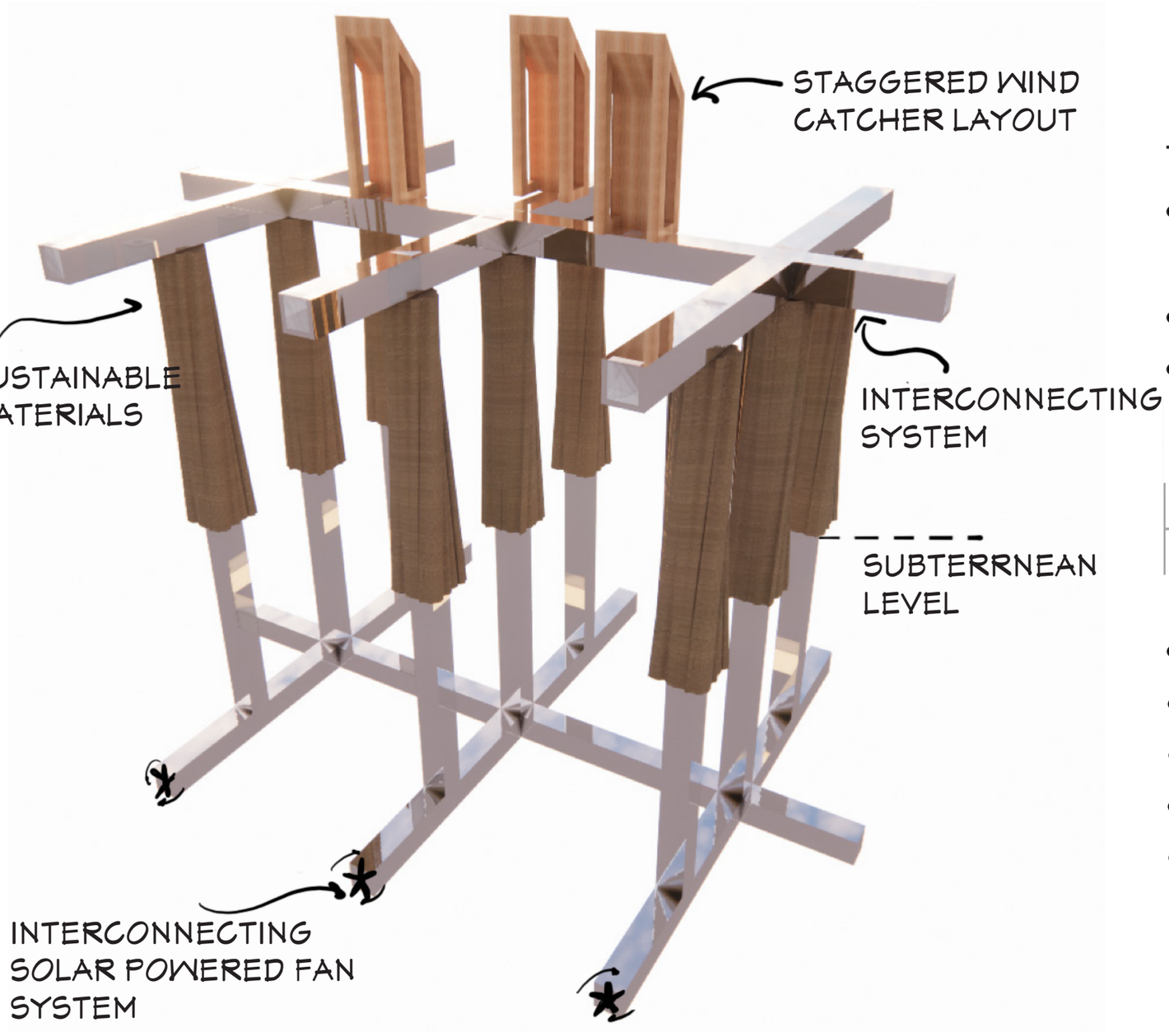


THE SOLUTION





THE SOLUTION



THE NATURAL VENTILATION

- The goal: 90% naturally ventilated during the day; 100% naturally ventilated at night
- Constant interior temperature of 80 degrees Fahrenheit
- Average ventilation cost cut from $2,268 to roughly $226.8 per year, by running the active system only 10% of the time (Self Inc.)

PROTOTYPE ANALYSIS

PASSIVE TECHNIQUES

- Natural Ventilation (termite mounds)
- Evaporation via vegetation
- Wind-catchers for wind tunneling/funneling
- Solar Panels to power the fans that push the air through the system
- Porous material to allow for air flow from all angles

THE IMPLEMENTATION

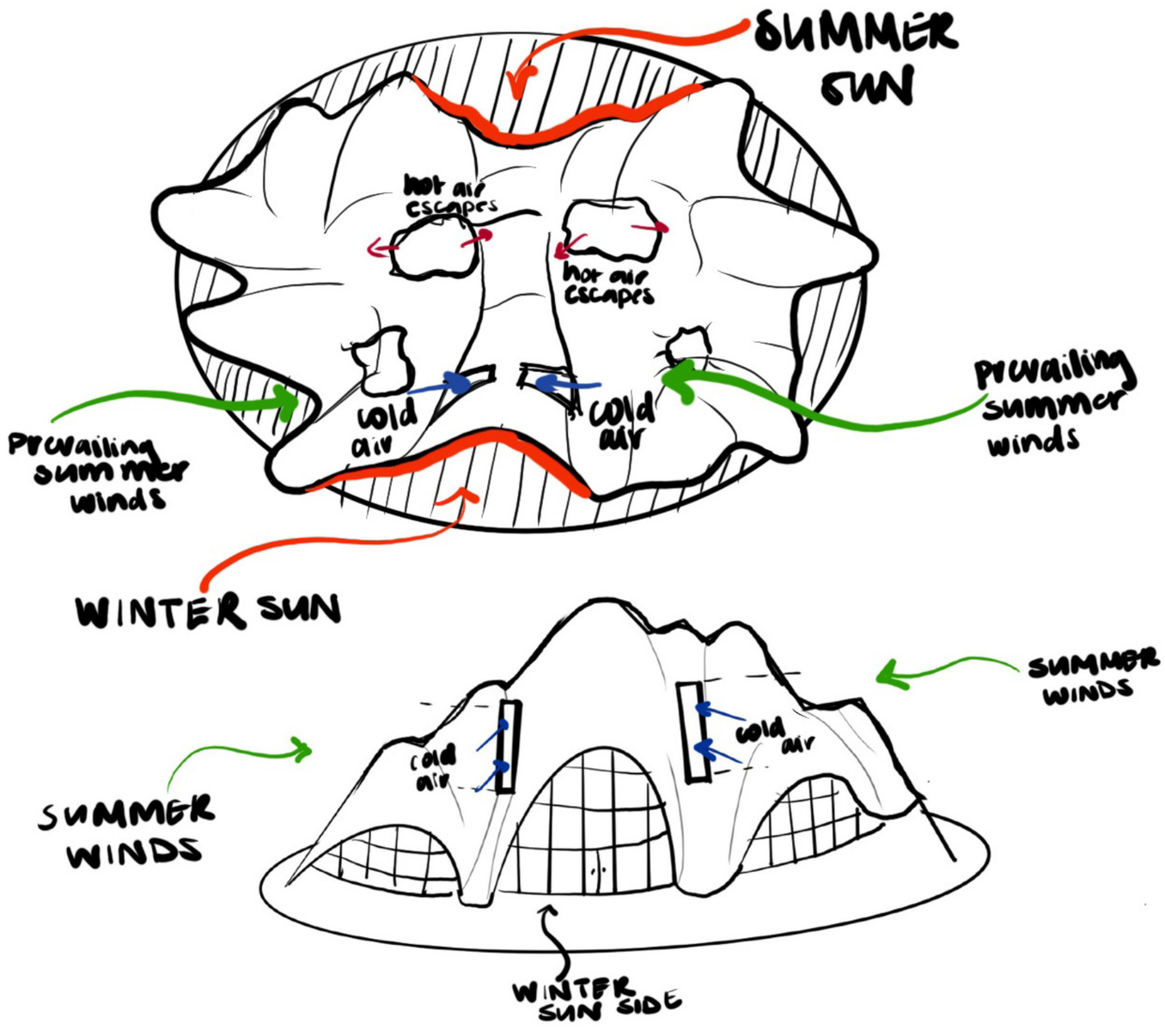
OUTDOOR PAVILION

- Common form of passive architecture
- Utilize shading for passive cooling
- Biophilic element

CONCEPTUALIZE

TEXAS CHRISTIAN UNIVERSITY

- Feature pavilion for environmental architecture
- Utilizes strategic placing for optimal airflow and shading from the sun
- The HVAC system will funnel winds through the wind-catcher, into the tubes as well as up from the ground, dispersing the cool air into the space below while also allowing hot air to escape
- Evaporation cooling within the fountain design and placing of vegetation
- Designed to look like the top of a termite mound
- Used for studying and learning as well as relaxing, inspires interdisciplinary thinking
- Greenhouse inspired



THE SITE

DALLAS // FORT WORTH, TEXAS

- South Central, USA Region
- Temperate Climate
- Resident's spend 48% of their electricity bill on ventilation costs
- Annual Temp High: 76.8 F
- Annual Temp Low: 56.5 F
- Mean Temp: 66.6 F
- 66% average relative humidity
- Prevailing winds: 70 degrees

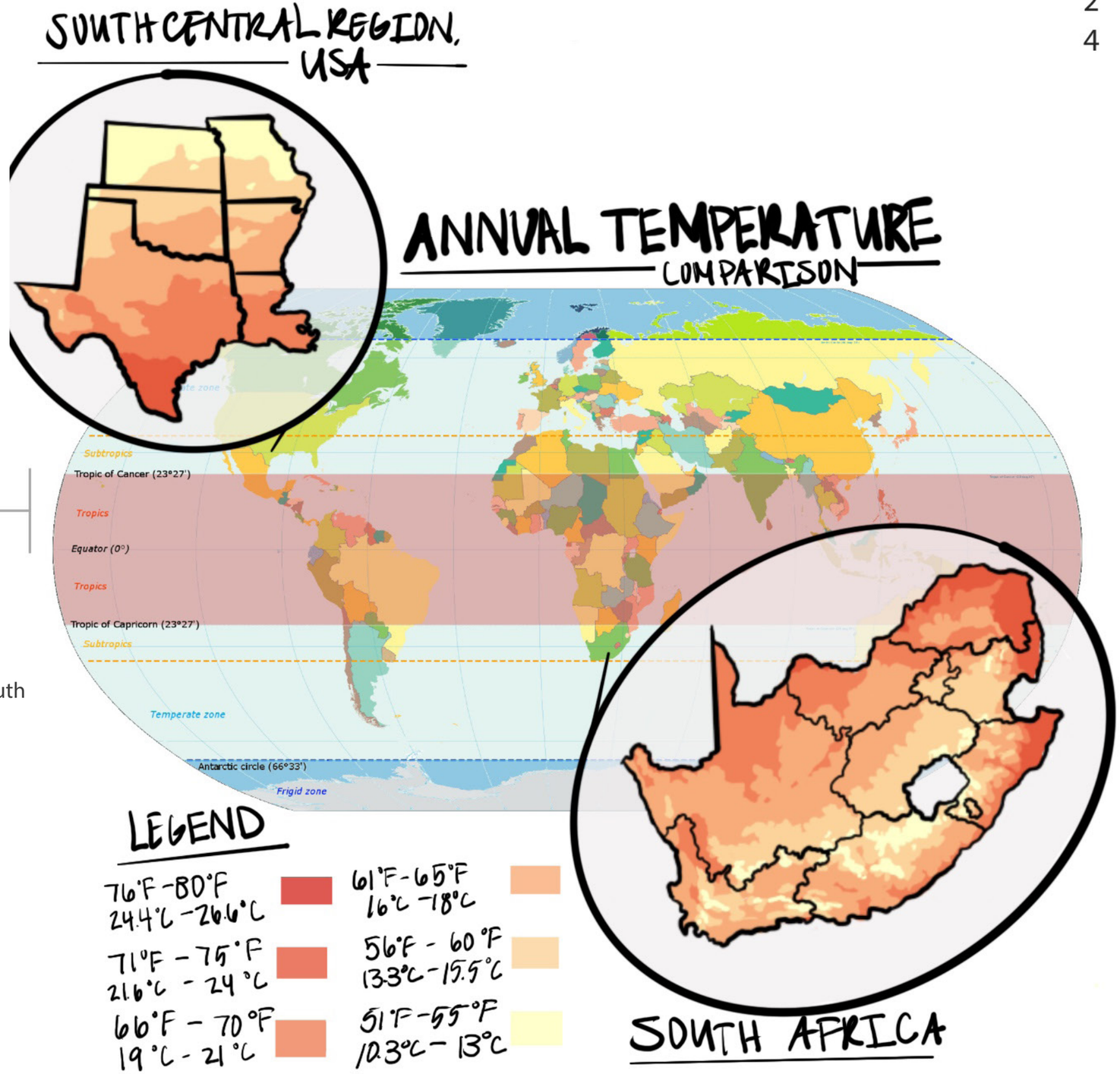
(National Weather Service)

GATHER INFORMATION

SOUTH AFRICA ORIGIN

- The M. *natalensis* Termites are native to South Africa
- Temperate climate, same as the South Central Region
- This system proves it will be successful in Texas since it is already successful in South Africa
- Average Temp High: 78.8 F
- Average Temp Low: 51 F
- Mean Temp: 65 F
- 59.2% average relative humidity

(Climate Knowledge Portal)

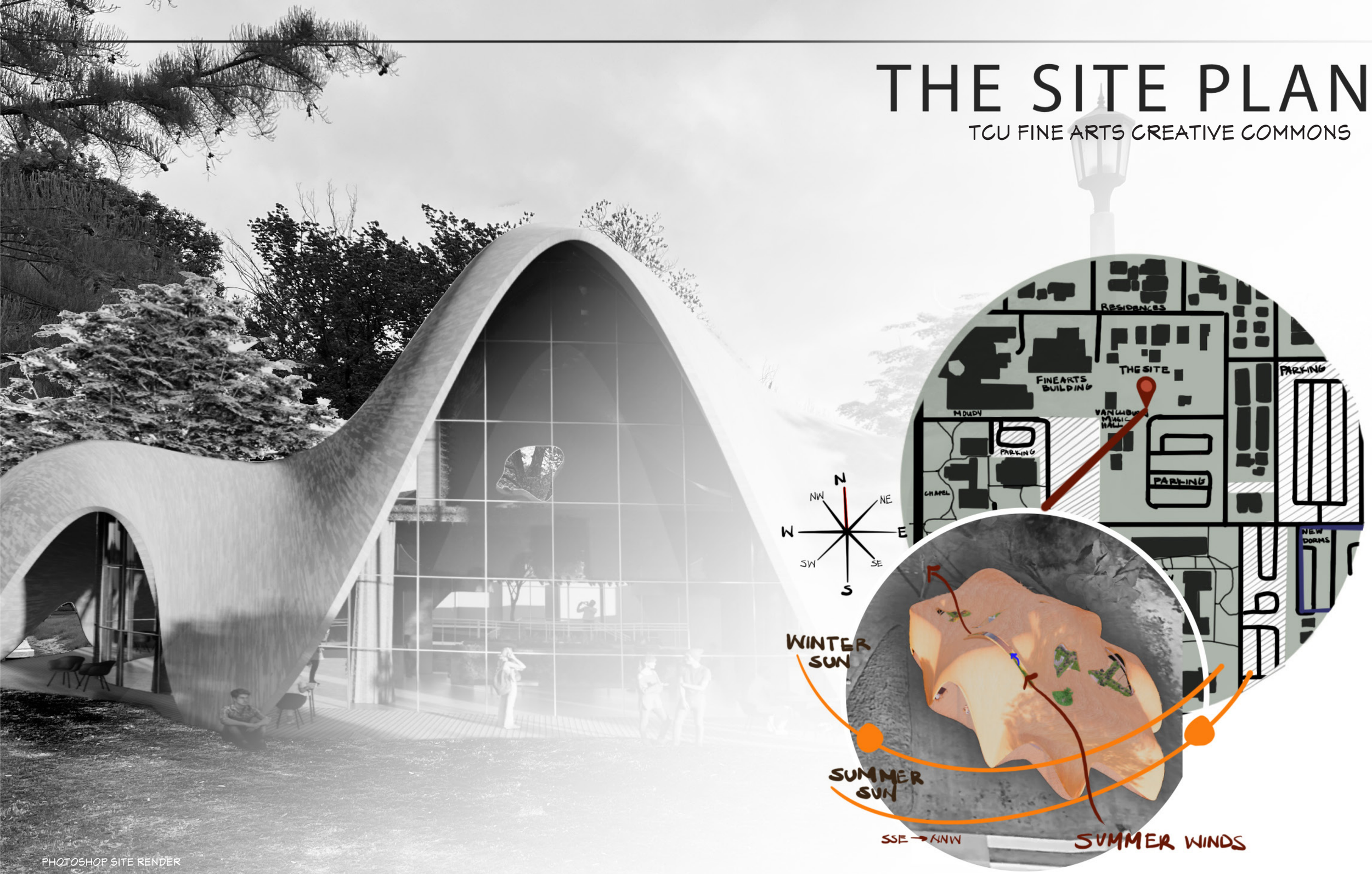


NOAA / NATIONAL WEATHER SERVICE / CLIMATE CHANGE KNOWLEDGE PORTAL

THE SITE PLAN

TCU FINE ARTS CREATIVE COMMONS

PHOTOSHOP SITE RENDER



THE USER PROFILE

FORT WORTH STAR TELEGRAM / STOCKYARDS

TCU / FROG FOUNTAIN

THE COMMUNITY

- DFW Community
- Residents and organizations that hope to reduce the financial impact of HVAC

GATHER INFORMATION

TEXAS CHRISTIAN UNIVERSITY

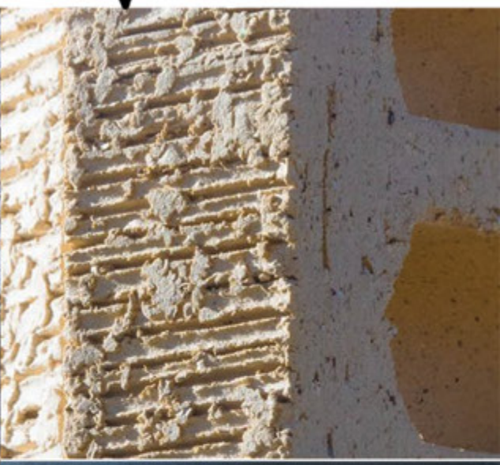
- The specific site for my implementation
- It will aid in the goal to create a wellness focused pavilion
- Provides a stress free environment while also portraying all the different passive ventilation techniques that the world will continue to rely on as global climate change continues to drastically change temperatures

TCU FINE ARTS BUILDING

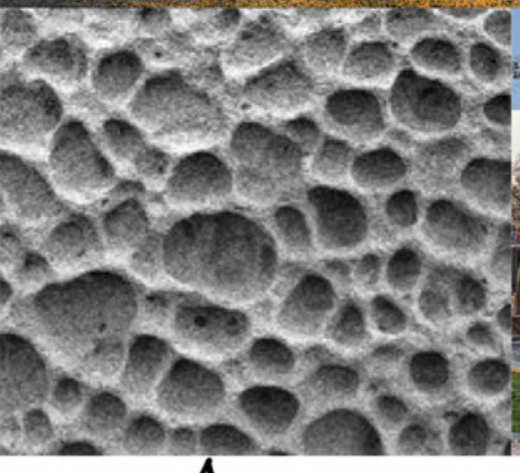
THE PRECEDENTS

VARIOUS VOID HEIGHTS

INTEGRATED WINDOWS & CURVED FACADE FOR SHADING



TCU BUFF BRICK (COLOR



POROUS-LIKE ORGANIC MATERIAL

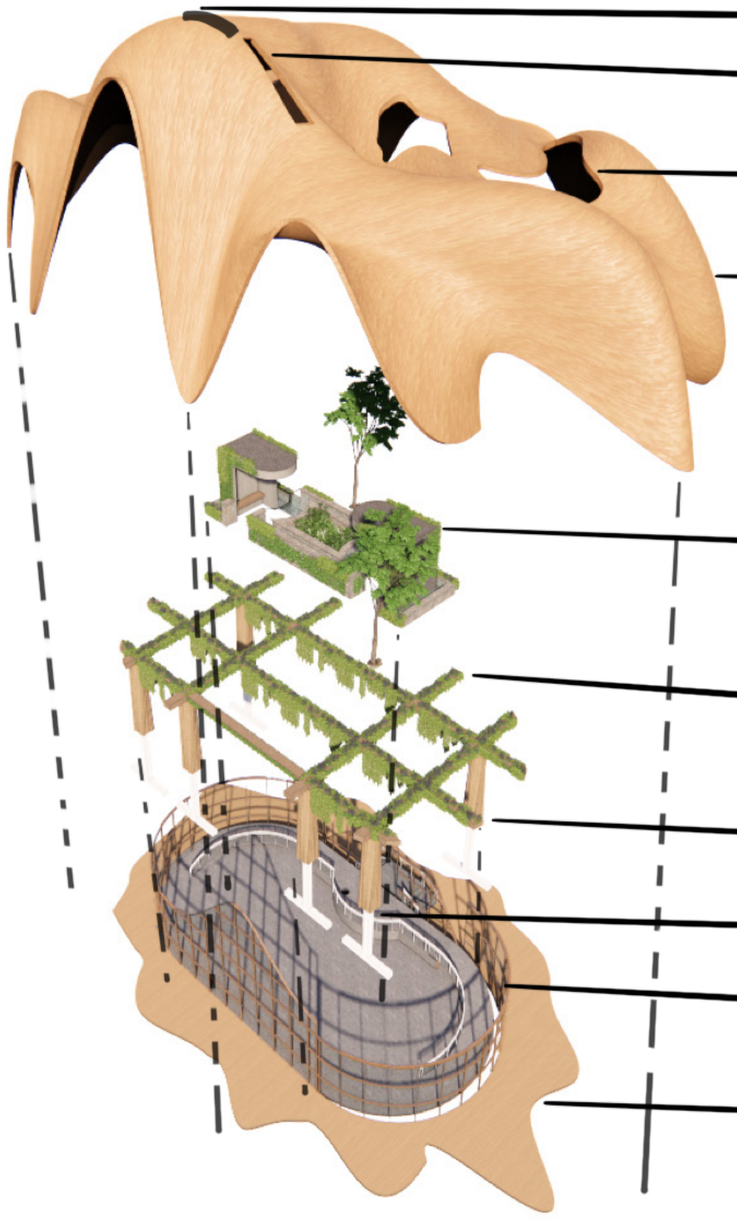
ROOF OPENINGS FOR PLANTING & AIR-FLOW

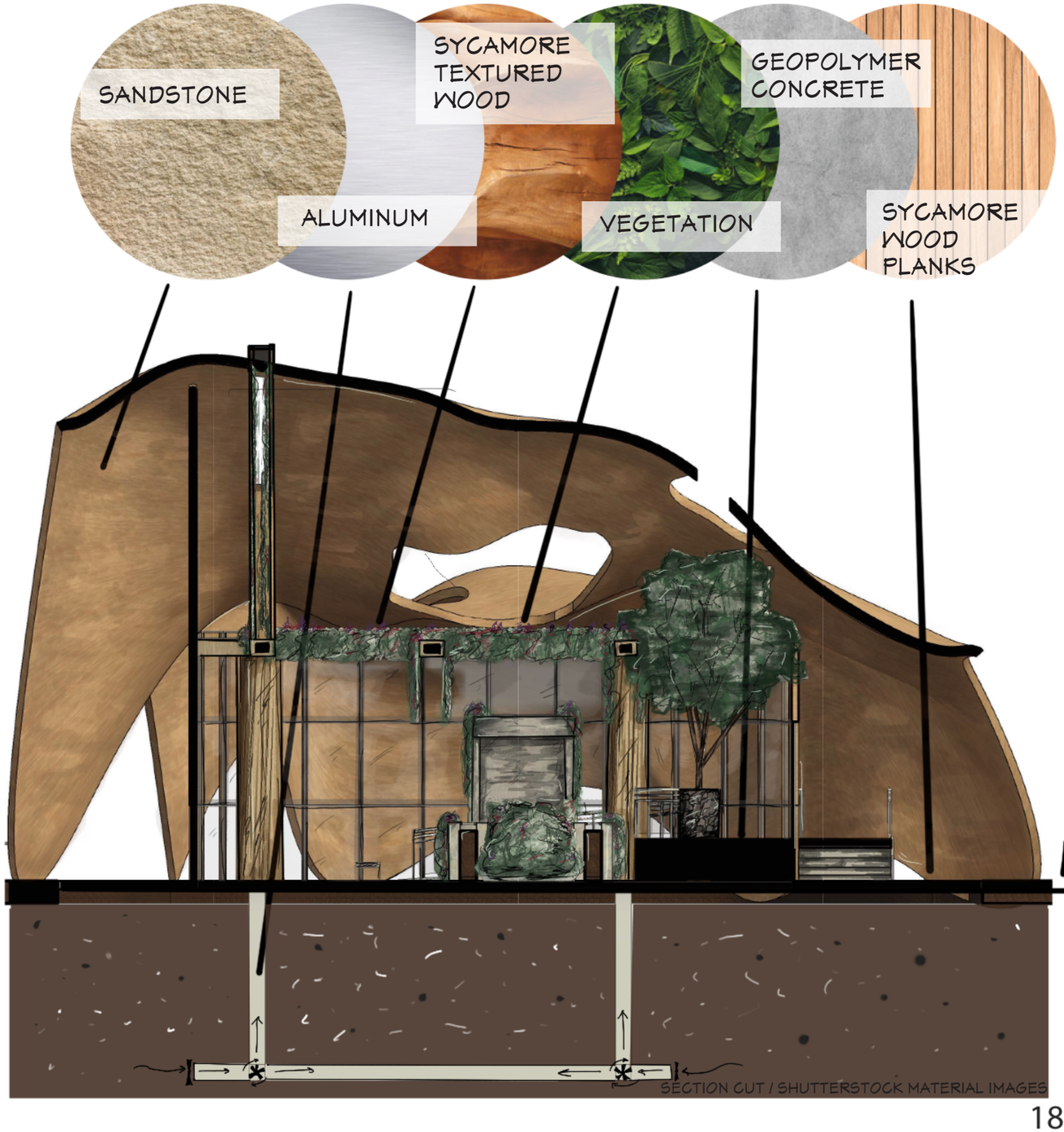
TEMPERATURE REGULATING THERMAL MASS

INTERIOR ORGANIC FORMS

NATURAL HISTORY MUSEUM NY / TCU / SHUTTERSTOCK

THE PASSIVE TECHNIQUES





SECTION CUT / SHUTTERSTOCK MATERIAL IMAGES

THE SIGNIFICANCE

ENVIRONMENTALLY

- Features all forms of natural systems, renewable energy, and sustainable practices in architecture
- Demonstrates how architecture can work and adapt with the environment

PROTOTYPE ANALYSIS

EDUCATIONALLY

- Designed and built using extensive research of natural systems
- Demonstrates the concept of Biomimicry
- Serves as a historical significance of past passive ventilation techniques
- Showcases of a combination of sustainable design techniques that will become an architectural foundation for buildings in the future
- Cultivates and inspires thinking in an interdisciplinary fashion

FORT WORTH BOTANICAL GARDENS GREENHOUSE

SHUTTERSTOCK / GREENROOF

SHUTTERSTOCK / COMMUNITY GARDEN

WALKTHROUGH VIDEO

THE CONCLUSION // FURTHER RESEARCH

CONCLUSION

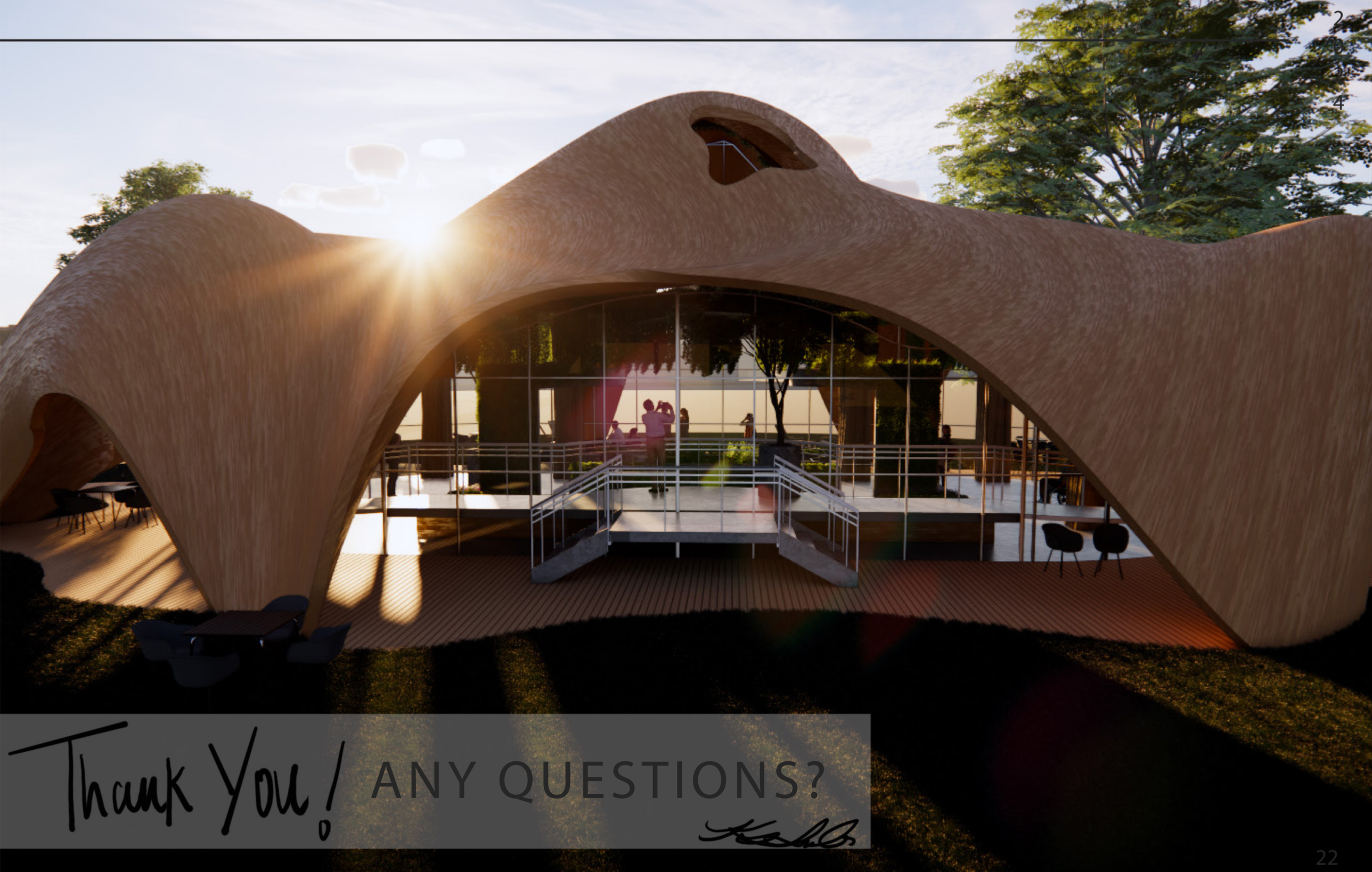
The result of this system is a mainly naturally ventilated building. Creating a temperature controlled environment while using significantly less energy than current building, thus reducing costs for active heating and cooling systems.

FINALIZE & IMPROVE

FURTHER RESEARCH

- Research ways that the system could move closer to being 100% naturally ventilated instead of just 80% or 90%.
- How this system could continue to be adapted to become more universal and easily implemented into current buildings
- Research how this system could be adapted globally, into different countries as well as climates that may not be temperate and would need adjustments to adapt to said climate as well.

FOUNTAIN RENDERING



Thank You! ANY QUESTIONS?

WORKS CITED

Alter, L. (2018). Before Air Conditioning, people kept cool with vernacular architecture. Retrieved from https://www.treehugger.com/air-conditioning-people-kept-cool-vernacular-architecture-4855793

Andréen, D., & Soar, R. (2023). Termite-inspired metamaterials for flow-active building envelopes. Frontiers in Materials, 10. doi:10.3389/fmats.2023.1126974

Architects and climate change: The role of architects. (2023). Retrieved from https://architectureprize.com/the-role-of-architects-and-climate-change/#:~:text=How%20do%20architects%20help%20with,emissions%20and%20saves%20energy%20costs

Bitler, T. (2024). What is HVAC and how does an HVAC system work? Retrieved from https://www.usnews.com/360-reviews/services/hvac-companies/what-is-hvac

Breyer, M. (2023). Termites outsmart humans when it comes to HVAC systems. Retrieved from https://www.treehugger.com/termites-outsmart-humans-hvac-systems-7504653

Casey, C. (2023). Designing an HVAC system for a Passive House. Retrieved from https://www.finehomebuilding.com/2022/10/12/designing-an-hvac-system-for-a-passive-house

Cleveland, C. J. (Ed.). (2004). ScienceDirect. Boston, Massachusetts: Elsevier Inc. .

Climate change predictions. (2024). Retrieved from https://coast.noaa.gov/states/fast-facts/climate-change.html

Crail, C. (2024). HVAC installation: Learn the process in 6 steps. Retrieved from https://www.forbes.com/home-improvement/hvac/hvac-installation/

Dijkstra, M. (2023). Termite Mounds reveal secret to creating “living and breathing” buildings that use less energy. Retrieved from https://www.frontiersin.org/news/2023/05/26/frontiers-materials-egress-complex-termite-mounds-ventilation/

Distributors, U. A. C. (2018). Termite Arcology: The future of HVAC? Retrieved from https://medium.com/@usacd/termite-arcology-the-future-of-hvac-6c0d49ff2b63

EPA, A. (n.d.). BUILDING SCIENCE INTRODUCTION. N/A: Energy Start Qualified Homes.

Fultonk. (2014). The Animal House ~ the incredible termite mound. Retrieved from https://www.pbs.org/wnet/nature/the-animal-house-the-incredible-termite-mound/7222/#:~:text=The%20mound%20is%20constructed%20out,and%20permeate%20the%20entire%20structure

Heating, air conditioning, and refrigeration mechanics and Installers. (2024). Retrieved from https://www.bls.gov/oes/current/oes499021.htm

HVAC diagram photos and images. (n.d.). Retrieved from https://www.shutterstock.com/search/hvac-diagram

IotaComm. (2023). What is the average utility cost per square foot of commercial property? Retrieved from https://iotacommunications.com/portfolio/average-utility-cost-per-square-foot-commercial-property/

Jha, G. (2020). How termites inspired a building that can cool itself. Retrieved from https://medium.com/illumination/how-termites-inspired-a-building-that-can-cool-itself-221c81cbcdcd#:~:text=Although%20these%20termite%20skscrapers%20may,structure%20of%20a%20termite%20mound

Khatri, A. (2023). Architects and environmental issues. Retrieved from https://www.re-thinkingthefuture.com/architectural-community/a7838-architects-and-environmental-issues/#:~:text=Waste%20and%20Debris%20from%20construction,lead%2C%20sanding%20dust%2C%20etc

Lile, S. (2022). HVAC Environmental Impact: HVAC upgrades. Retrieved from https://www.motili.com/blog/hvac-environmental-impact/#:~:text=How%20does%20HVAC%20affect%20the,be%20caused%20by%20air%20conditioning

M., D. (2017). Anatomy of a Central Air Conditioning System. Retrieved from https://www.altitudecomfort.com/blog/anatomy-of-a-central-air-conditioning-system/

N/A. (n.d.). Causes and effects of climate change. Retrieved from https://www.un.org/en/climatechange/science/causes-effects-climate-change#:~:text=Fossil%20fuels%20%E2%80%93%20coal%2C%20oil%20and,of%20all%20carbon%20dioxide%20emissions

Organization. (2023). How does air conditioning work? the science behind AC. Retrieved from https://www.tcl.com/global/en/blog/tips/how-does-air-conditioning-work#:~:text=Warm%20indoor%20air%20is%20cooled,the%20refrigeant%20gas%20is%20compressed

Ouellette, J. (2023). No A/C? no problem, if buildings copy networked tunnels of Termite Mounds. Retrieved from https://arstechnica.com/science/2023/05/intricate-tunnels-of-termite-mounds-could-be-key-to-energy-efficient-buildings/

Passive building principles. (2024). Retrieved from https://www.phius.org/passive-building/what-passive-building/passive-building-principles

Principles of heating and Cooling. (n.d.). Retrieved from https://www.energy.gov/energysaver/principles-heating-and-cooling

Reinhart, C. (2018). Environmental Technologies in Buildings. Cambridge : SDLAB.

Rosario, R. B. N. (2023). Impact of architecture on climate-change and global warming. Retrieved from https://www.re-thinkingthefuture.com/architectural-community/a7924-impact-of-architecture-on-climate-change-and-global-warming/#google_vignette

Singh, K., Muljadi, B. P., Raeini, A. Q., Jost, C., Vandeginste, V., Blunt, M. J., … Degond, P. (2019). The architectural design of smart ventilation and drainage systems in termite nests. Science Advances, 5(3). doi:10.1126/sciadv.aat8520

Solano, J. C., Caamaño-Martín, E., Olivieri, L., & Almeida-Galárraga, D. (2021). HVAC systems and thermal comfort in buildings climate control: An experimental case study. Energy Reports, 7, 269–277. doi:10.1016/j.egyr.2021.06.045

US EPA. (n.d.). Retrieved from https://climatechange.chicago.gov/climate-change-science/future-climate-change#:~:text=Future%20changes%20are%20expected%20to,larger%20future%20changes%20will%20be

What is Biomimicry? (2024). Retrieved from https://biomimicry.net/what-is-biomimicry/#:~:text=Biomimicry%20is%20learning%20from%20and,nature's%20ability%20to%20deter%20collisions

World Bank Climate Change Knowledge Portal. (2021). Retrieved from https://climateknowledgeportal.worldbank.org/country/south-africa/climate-data-historical

London Music Works., London Music Works|ARTIST., & City of Prague Philharmonic Orchestra|ARTIST. (2015). The Best Of Hans Zimmer Vol. 2 . Silva Screen Records.