Adapting to Climate Change through Architecture

A Thesis

Submitted to the

Faculty of Miami University

In partial fulfillment of

The requirements for the degree of

Master of Architecture

Department of Architecture and Interior Design

By

Hisham Altayeb Abdelrahman Mohamed

Miami University

Oxford, Ohio

2020

Advisor Mary Ben Bonham

Reader Diane Fellows

Reader John Humphries

Reader Mary Rogero

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i. Abstract

An environmental crisis is unfolding around us. Our climate is continuously changing in dramatic rates. This paper explores the impact of climate change on the built environment, with the intent to find solutions for how to understand environmental changes, raise awareness, and eventually overcome the challenges that we face. Environmental challenges can be addressed through building design. One can consider three aspects that can address the way we design and construct our buildings. The first one is how can our architecture be innovative in terms of optimizing our current technologies to achieve unprecedented building performance, and the second one is how can we optimize our energy resources to fit the needs of our environment first, and how can we design our architecture to be satisfied with those optimized resources? The third one focus how can we create architecture that would positively and intelligently adapt and change along with our rapidly changing climate? These questions will be answered throughout presenting a number of case studies that will be analyzed within environmental, socioeconomic, and cultural scopes.

ii. Introduction

The architecture profession has a bigger role in people's life than most of designers might think. It affects the way we live, the way we think, and the way we view the world. A series of questions can arise from here. Can we change the way we think about climate change through architecture? Can we overcome climate change through architecture?

It is very important to point out to the dangers and outcomes of climate change, and how harmful it is to live in a world where these concerns are not comprehensively dealt with because this environmental crisis is already unfolding around us. Architects need to deliver statements to create a sense of awareness throughout methods of data collection and the analysis of constructed buildings for issues surrounding climate change in an architecture scope. Data and content is presented to engage an audience of architects, designers, and citizens of the earth with the issues in hand go present how imminent and serious it is, as we are already 10 years behind the targets that were set out in the Paris Agreements three years ago. "*Pessimism of the intellect, optimism of the will*" said philosopher Antonio Gramsci. Gramsci implies for us to see the world as it really is, and not to see it as we might like it to be. A world where utopian proposals are not a solution for this crisis we have. We need to start designing for the actual world, because only then can designs cater to our earth and its citizens.

I. Problems and causes

Overpopulation

There are a lot of factors that come into play in order to plan for future sustainability, starting from energy, water, land, and biological resources. But often, a very important factor is overlooked, that factor being the number of humans that have to share the consumption of these resources. The population of the world will be as twice as it is now from the current 6.5 billion in less than 60 years, based on a growth rate of 1.2% per year (Population Reference Bureau 2005). Even if international policies of a couple of kids per household were implemented, the population of the world will not see a significant decrease in the growth rate for almost 70 years where it may stabilize at around 13 billion people.

Reports by the World Health Organization has reported that more than 3.6 billion people around the globe are suffering from malnutrition (WHO 2004), which is the largest reported number in history. This malnutrition happens when food resources are insufficient for the demand, expensive, and when political conflict gets in the way of producing or handling these resources. Malnutrition has many effects on people that can go as far as death, it can also increase the chances of diseases such as tuberculosis, malaria, and even HIV. The United Nations Food and Agriculture Organization suggested that the production of grains per capita is now constantly in a state of decrease for the past 20 years (UNFAO 2002). Due to the increase

in the population of the world, more water, food, shelter, energy, and jobs are required to maintain the quality of human lives at equal levels all around the world.

More than 99.9% of the food resources that humans consume come from the land, and even less than 0.01% of those resources come from aquatic sources (UNFAO 2001-02). In turn, food production increases should accompany these statistics in order to meet the increasing population's needs. Yet the cropland around the world has decreased by 20% in the past ten years.

Nearly more than 10 million hectares of farm land are degraded or lost each year due to erosion (Preieser 2005). Erosion is becoming an intense crisis worldwide due to climate changes, including intense and frequent rain events that work to increase the erosion and eventually result in large amounts of sediment that wash into the aquatic eco-systems.

These effects are occurring worldwide but it significantly shows in developing countries where the lower class would use crop residues that usually protect the soil as fuel for cooking and heating. Moreover, humans continue to clear out valuable forests in order to replace the lost agricultural land. An average of less than 0.3 hectare of agricultural land per capita is available around the world, yet a minimum of 0.5 hectare is available per capita in the US and Europe separately. In the United States, croplands occupy almost more than 17% of the total land area in the region. Moreover, sufficient reserves of freshwater are significant for the life of plants and animals, and a big portion of that is used in the agriculture industry. For example, corn

requires around 5 million liters of water per hectare. That being said, it is estimated that more than 65% of all the fresh water in our environment is used in the agriculture industry (UNESCO 2001).

Our climate issues are having major complications for sustainability plans around the world, it is already having significant impacts on the environment, public health, and agriculture. Those impacts are directly affecting cropping seasons, water resources, and of course food production. In order to stop the constantly increasing imbalances between the rapid population growth and the essential resources that they use, humans need to actively preserve agricultural land, energy, freshwater, and all other sorts of resources that our environment provides.

The developed countries population can contribute by decreasing heavy resources consumption, fossil fuels in particular. Other ways can be implemented through improving the nutritional makeup, and developing pest-resistant crops and perennial grains. Ultimately, we cannot grant sustainability for our coming generations until we significantly manage and reduce the overpopulation crisis; we must preserve all essential resources that are significant to maintain a just and fair life quality for humans around the glove while maintaining environmental integrity

Climate and Consumption

The Journal of Industrial Ecology published a study (Diana Ivanova 2015) that shows that our consumptions -from food to worthless house hold ornaments- form more than two thirds of the greenhouse gas emissions around the world, and somewhere between 60 and 70 percent of total material, land, and water use. All of this adds to the significance of taking responsibility of our actions as consumers, and realize how much our habits are affecting the environment, and how much they're accelerating climate change.

The study also showed that about 80 percent of the climate impacts due to consumption are not coming from direct habits such as overconsuming water resources or driving cars as it is understood, but rather they come from sources deeper in those products' creation. The study shows that the amount of water consumption that goes into making frozen food proved that it is way more significant than the amount that goes into household activities, such as showers, landscaping, and washing items.

The researchers at the study also researched the impacts and the causes of climate change per-capita in studies that covered a wide range of countries. The results for those studies were somewhat unexpected; while the United States is almost 3,800 times bigger than Luxembourg, yet, it has a carbon footprint per capita that is almost the same as Luxembourg. The pattern for this study become clearer towards the end: the richer the country, the bigger that country has

an impact on the climate through its people, due to the fact that the richer those inhabitants the more that they consume products that will have a negative impact on the environment.

The researchers have also stated that: “The countries with the highest consumption have about a 5.5 times higher environmental impact as the world average.” (Diana Ivanova 2015)

The study has led to the finding that the United States has the highest percentage of greenhouse gas emissions in the world per capita, it has totaled a 18.6 tonnes of CO2 equivalent as a carbon footprint, which was a unit that the researchers used to showcase the effects of a number of greenhouse gases, such as Sulphur Hexafluoride, Carbon Dioxide, Nitrous Oxide, and Methane. This very large carbon footprint is due to the fact that there is a very huge dominance of the automobile industry that works as the main transportation.

The study showed different results for individual countries that reflected how the electricity mix, and the sources of fuel that those countries used to generate their electric power. The fact that nuclear hydroelectric was very popular in countries like Norway, France, Sweden, and Japan resulted in them having significantly lower carbon footprints than other places that where inhabitants had close income ranges and the only difference was in the fact that they used more fossil fuels to generate their energy. It was surprisingly noticed that in countries such as Norway and Sweden more than half of the environmental impacts came from external imports, since the imported products employed fossil fuels in the process of their production.

II. Design solutions

Adaptive Architecture:

"Adaptation is the evolutionary process whereby a population becomes better suited to its habitat. This process takes place over many generations, and is one of the basic phenomena of biology." (Charles Darwin, p1959).

In the field of architecture the word 'adaptation' is frequently used in relation to the physical and morphological changes in the architectural object. These morphological changes are typically an outcome of the progression of architecture as a social field, technological product, and as an industry. Throughout history a lot of changes affected the understanding of how architecture is received and built. The morphological state of architecture adapts to the era in which the architectural products are created and understood. These adaptations are often the result of changing times, social norms, economic factors, the occupant's needs, and climatic factors. The changes that take place in the environment in a certain period of time, such as a given day, can be considered as a specific change factor that affects an architectural artifact that leads to local adaptation. On the other hand, climate changes that occur over a longer period of time, such as years, would create forces that would change that architecture over the course of that time to survive the changes and sustain the architectural object. Adaptation is considered a long-term procedure in the field of architecture, it shapes and reshapes throughout different eras and generations, where a lot of improvements in the human thought

process, critical thinking skills, technology, and economic support, highly contribute to the adaptive nature of the architecture.

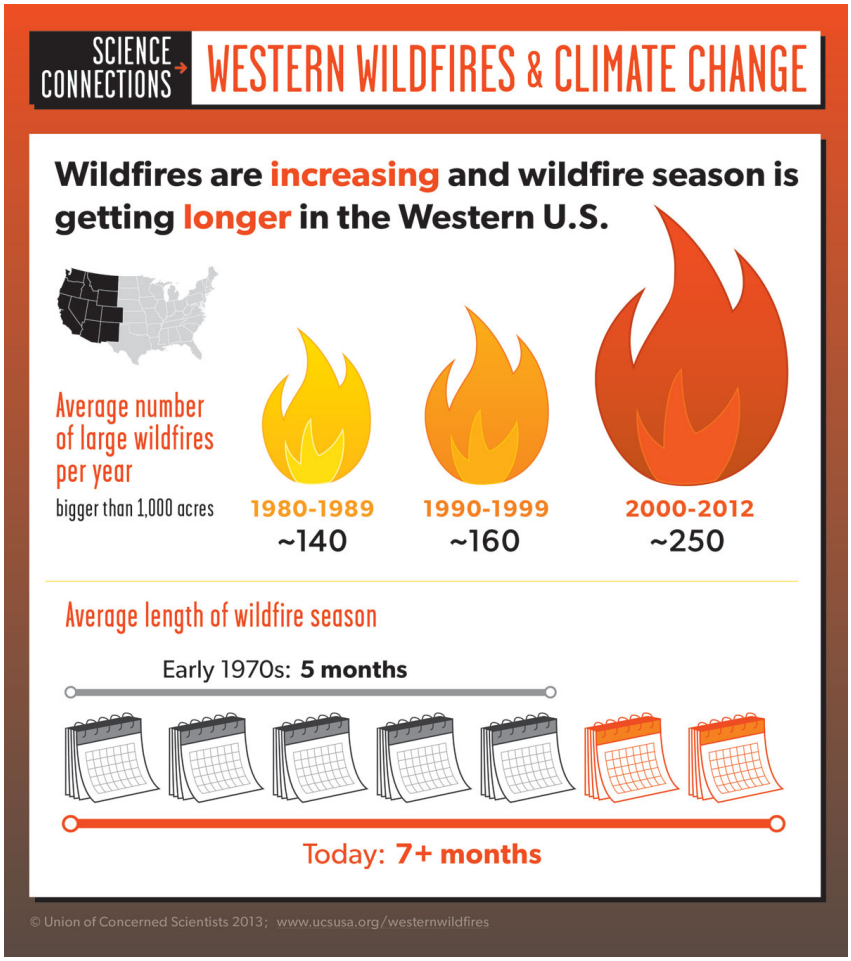
Our style of life is constantly changing by the surrounding forces of nature and climate. These forces are always in a state of inconstancy, with changing degrees and factors of dynamic variables. Which by turn affects our lives by making them in a state of constant flux. Our architecture and the spaces we occupy are bound to be in constant change as well. This change isn't as rapid and as effective as the change that our climate is affected with. Building skins comprise of horizontal and vertical elements that form as protection for the building from external environmental effects, and works to maintain comfort levels of the interiors of the building, and above all work as a support to the building. A building skin fundamentally produces stability, keeps air pressure regulated, and protects the interiors from bioclimatic factors such as heat, sunlight, wind, and rain.

Building skins are considered a very important element in the study and exploration of adaptive architecture, as they function as a medium in which technology can be integrated into the building system in order to react and respond to different climates. Therefore the main characteristics of an efficient and resilient building skin is its ability to affect and react to energy transfer throughout the envelope of the building by enhancement, attenuation, regulation, entrapment, or rejection. (Sushant Verma 2013)

Sites selection

Southern California (Wildfires)

The risk of wildfire continues to increase due to rising temperatures in the western parts of the United States and especially Southern California.

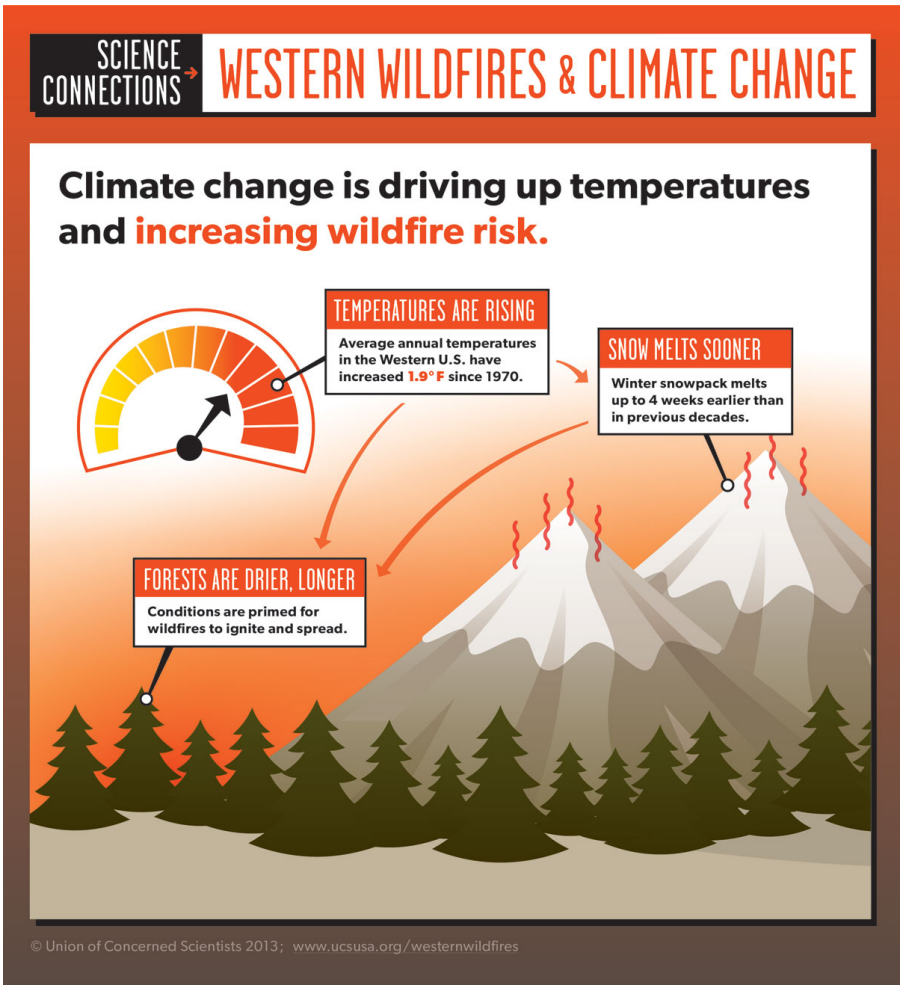


Wildfires are increasing in higher magnitudes throughout those regions. In a span of 15 years almost all states in the western region of the country has gone through significant increases in numbers of large wildfires per year, in comparisons to noticeably lower numbers in the past two decades.

The time period between the first and last large wildfires in a year is defined as wildfire season. We can notice the significant increase of large wildfires in the Western U.S. starting with an average of 140 wildfires per year in the timeframe between 1980

and 1989, which increased in the next decade to an average 160 wildfires, and ending with almost 250 wildfires per year in the time frame between 2000 and 2012.

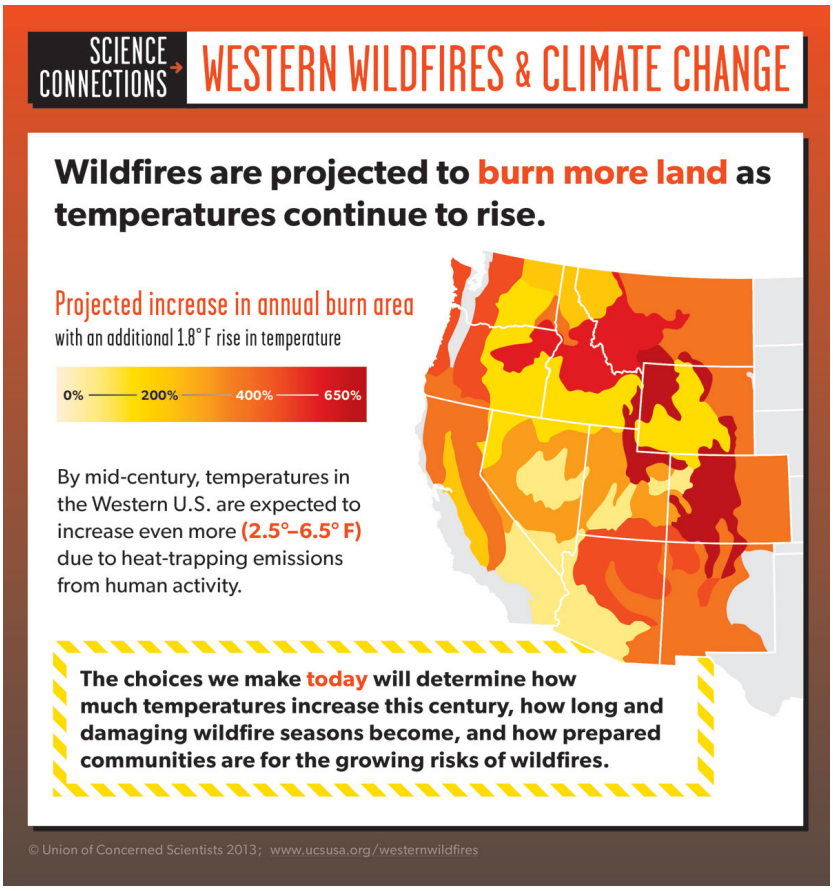
In the last 50 years, temperatures in the Western United States have been increasing faster than they have been for the entire planet. The annual temperature average have increased by almost 2° F, which is considered twice the average of global warming.



Scientists were able to measure the start of snowmelt by calculating the flow measurements within the Western U.S. specific locations, it was noticed that the beginning of spring snowmelt occurred 1 to 4 weeks earlier in the 2010's than it did 80 years ago.

It was also established that increases in annual burn area are highly probable in the near future, these increases depend on the type of ecosystem. While some certain ecosystems expect increases in temperatures, such as the semi-desert and desert of southern Arizona and California, more than it does in the Southern Rocky Mountain Steppe-Forest in central Colorado, it is still expected for all types of ecosystems to go through significant increases in burn area averages.

The expected range of temperature increases in the middle of this century throughout the Western U.S allows for two different possible outcomes, one of them being where we significantly and actively engage in all sorts of successful attempts of reducing heat-trapping emissions in order to target lower ends of emission pathways, and the other being where we take no action and eventually reach the higher end of emission pathways which will lead to very serious consequences.



Darfur (Political conflict)

Climate change and environmental degradation has been one of the main drivers for the conflict in the Darfur region, it has produced threats to instigate a new wave of wars and conflict throughout Africa unless serious measures are taken in order to contain damages and sustain the area from future similar issues, according to a published UN report

"Darfur holds grim lessons for other countries at risk"

Stated by the United Nation Environment Programme (UNEP) in an 18-month study of Sudan.

Over the past 40 years, rainfall has fallen down by up to almost a third in the region, with the Sahara advancing by over one mile per year, which increases the tension between the herders and farmers over the receding farmland and evaporating water which then threatens to restart wars between local tribes in the area after an almost 15 years long peace agreements for the longest civil war Africa has known.

The Nuba tribes in the south have threatened to restart the conflict, for example, since the Arab nomads have moved to southern areas into their territories because of the drought and started cutting down their trees and harvesting their farmlands in order to feed their herds.

The United Nation Environment Programme is investigating into relations between these conflicts and climate and is forming predictions that the implications of climate change on stability will most probably won't be bound to any borders. The studies showed that there is a possible decrease of 70% in crop yields in major areas of the Sahel, which is an ecologically brittle belt that stretches all the way from Senegal to Sudan

"It illustrates and demonstrates what is increasingly becoming a global concern," said Achim Steiner, the United Nation Environment Programme's executive director. "It doesn't take a genius to work out that as the desert moves southwards there is a physical limit to what ecosystems can sustain, and so you get one group displacing another."

It was also stated that the conflicts in Chad "at least in part associated with environmental changes" as well as the conflicts in South Africa being initiated by floods and droughts.

The Darfur conflict has an estimate of casualties in lives that has ranged between 200,000 and 500,000 since it broke out in 2003. The main cause of the war was power and regional rebellions, in which the government responded to those rebellions by forming para-military militia –the Janjaweed- to perform ethnic cleansing campaigns against Sudanese civilians in Darfur. The United Nation Environment Programme study indicated that the truer reason for the conflicts before 2003 was the decreasing rain levels and receeding farmlands. It also

suggested that the desert in the northern part of Sudan has receded towards the south by almost more than 60 miles since 1980, Rainfall has seen significant decreases in rates between 16% and 30%, Climate prediction has suggested that the region will suffer a rise in temperature between 0.5C and 1.5C in the next 40 years, and the yields in the local crops is likely to decrease by 70%

"Almost invariably, we discuss Darfur in a convenient military and political shorthand - an ethnic conflict pitting Arab militias against black rebels and farmers. Look to its roots, though, and you discover a more complex dynamic. Amid the diverse social and political causes, the Darfur conflict began as an ecological crisis, arising at least in part from climate change." Argues the UN secretary-general, Ban Ki-moon

The environmental degradation in Sudan has significantly complicated the conflict in Darfur, it eventually forced more than two and a half million people into refugee camps. Underground water sources are being drained and deforestation is accelerated.

A number of peace deals were signed by the government and the rebels in the past years only to break down months after. Sudanese officials promise to accept the deployment of joint African Union and UN forces into the region, but the United Nation Environment Programme warns that any form of deals or agreements are highly unlikely to last without any investment in sustaining and containing the occurring environmental crisis and adapting to the changing climate in the region. "Simply to return people to the situation there were in before is a high-risk strategy." Said Mr. Steiner.

Rio de Janeiro (Coastal erosion)

Cities around the world are reporting their hottest summers since their records have started, which was the case for Rio de Janeiro. According to many predictions Rio de Janeiro will be the worst affected city by climate change in South America. The readings in the capital are predicted to have drastic temperature increases in the next five years with an average of one degree Celsius. The Urban Climate Change Research Network released a global warning in 2015 that brought more than 500 scientists from 140 cities around the world to look at the situation in Rio de Janeiro.

At the same time, sea levels will continue to rise by almost 15cm in coastal region of the city, which is 1cm more than it is in Lima, Peru, and Buenos Aires, Argentina. Making the projected climate disaster for Rio de Janeiro the worst in South America.

These drastic changes in temperature is predicted to become a leading factor that would negatively affect the public health of the residents of Rio de Janeiro. The main risk translates in the spread of a number of infectious diseases such as gastroenteritis, dengue, and leptospirosis, and cardiovascular and respiratory diseases. Fiocruz (the Oswaldo Cruz Foundation), which is one of the main public health research entities in the world has reached the aforementioned conclusions after conducting different studies in the region. Fiocruz is also leading the core of

the Urban Climate Change Network in Latin America along with The Alberto Luiz Coimbra Institute for Graduate Studies and Research in Engineering (COPPE), a graduate engineering department in the Federal University of Rio de Janeiro

The spread of diseases within the residents in the coastal region of Rio de Janeiro is accelerated by summer floods. The main risk is leptospirosis, a disease that is transmitted through rat urine.

"Many diseases can be aggravated by climate. The city needs to be prepared to face these changes, which primarily affect the lower income population"

States Martha Barata, a researcher in Fiocruz, where she highlights the importance of putting urban planning into account when dealing with climate change issues.

"We cannot continue to build houses and factories in areas which face a high risk of flooding in the future"

She states. The infants and elderly are considered the most groups that are vulnerable to heat, since their organs aren't as adaptive as they should be and they cannot defend themselves. Further projections predict that less than 60 years from now the temperatures in Rio de Janeiro and the city of Cubatao in Sao Paulo will show an increase of 3.4 degrees Celsius. With sea levels rising in rates between 37m and 82cm within the coming 65 years.

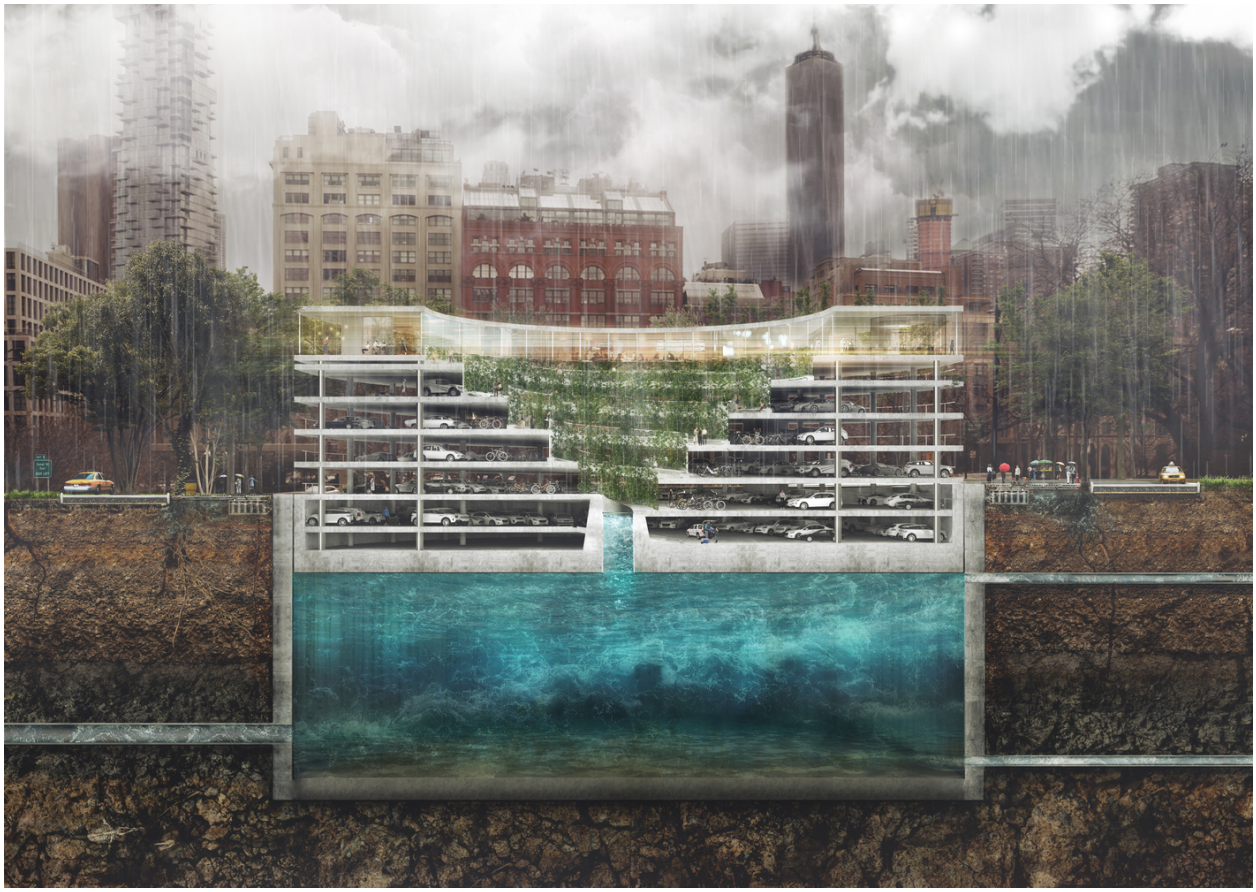
Case Studies

POP-UP

Architects: Tredje Natur

Location: St. John's Park, New York, United States

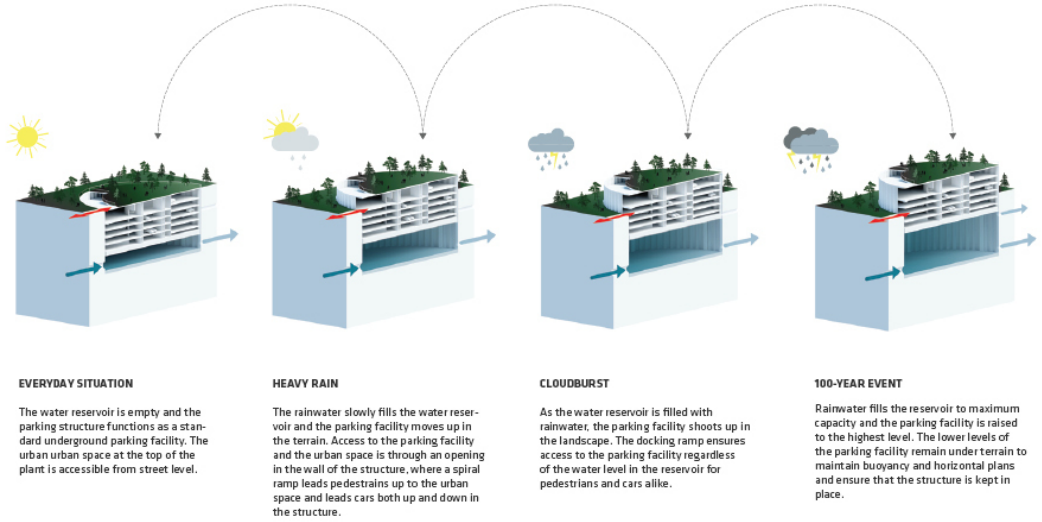
Project Year: 2016



As the population of our planet increases, do does car traffic, pollution, and other climate change issues. Recent studies estimated that almost %30 of urban roadway congestion are drivers searching for parking spaces. The prevailing culture puts cities on constant pressure of

building more and more parking garages, in which they usually win over having more green parks. Additionally, climate change is in continuous challenge to handle a great amount of storm water. The stats from the 2017 Atlantic hurricane season came as proof to this, formed in 13 named storms forming in the ocean, eventually costing more than 210 lives.

A Danish architecture firm, Third Nature, designed a modern-day urban solution for issues of flooding, parking, and lacking green parks. They have developed a water reservoir, a car park, and a stacked green space. The project uses Archimedes principle in order to store rain water and create floating space that would function as a car park



"We sat down with a map showing where the biggest problems with water handling will occur and another map showing where there are the biggest problems with parking. When you put the two maps on top of each other, you can see some places where there is potential for solving two problems with the same concept" said Ole Schroder, partner at THIRD NATURE.

The structure continuously changes heights that in turn changes the city's skyline based on its weather, on summer days the structure exposes a green park with underground parking to optimize the weather and have the visitors enjoy the green spaces. On rainy days the draining system leads the water into pipes that flow below the car park into a reservoir. The parking structure moves higher as the water level rises. The concept fundamentally makes the car park accessible to pedestrians and cars at all times and in all types of weather and water levels.

Hotchkiss Biomass Power Plant

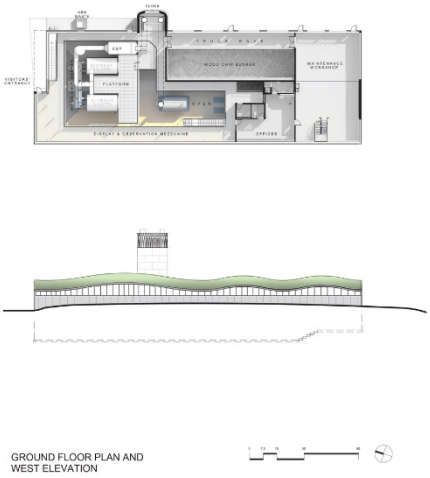
Architects: Centerbrook Architects & Planners

Location: Hotchkiss School, Salisbury, CT 06039, United States

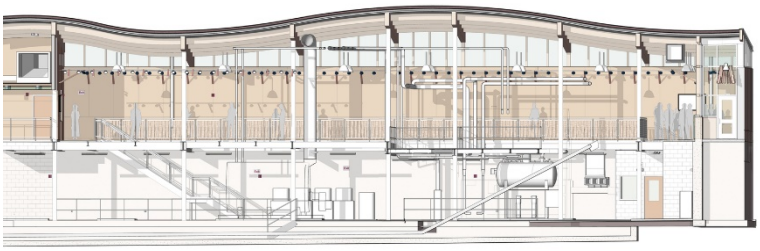
Area: 16500.0 ft2

Project Year: 2012

The project features an exterior design that represents seamless contradicting missions in creating a captivating presence to invite the visitors. The building presents a low undulating profile, capped by a vegetated roof that seamlessly blends with the beautiful surrounding environment in the premises of an independent school's campus.



GROUND FLOOR PLAN AND
WEST ELEVATION



The building harbors a number of potential functions that includes a museum, classroom and a laboratory. It mainly houses a biomass facility that would burn woodchips that are sustainably harvested in order to hear the Hotchkiss School. The facility is used to service more than 600 residents that include students, teachers, and staff. The generated heat is distributed throughout 85 buildings that total an area of 1.2 million square feet. The woodchips used in the facility is designated as a carbon neutral fuel by the IPCC (Intergovernmental Panel on Climate Change). The woodchips are locally sourced and they are a byproduct of sustainably managed forests, replacing around 150,000 gallons of externally imported fuel per year. Greatly cutting emissions, and especially Sulfur Dioxide by more than 90 percent. Moreover waste ash is also collected in order to be used as fertilizer for a variety of gardens that are taken care of by students living in campus, all as a part of the school's commitment to reach a goal of making the campus %100 carbon neutral by 2020

The building is slated to have LEED certification for conservation features which include water-conserving plumbing fixtures, highly efficient mechanical systems, renewable laminated wood structure, and the use of local materials that have high recycled contents. These features eventually result in the reduction of greenhouse gas emissions by nearly a half. The biomass heating is expected to cause massive reductions in the Hotchkiss carbon footprint by more than 6 million pounds of CO2 per year, making this facility one of only three sustainable and highly efficient LEED certified power plants in the United States.

Harvard HouseZero

Architects: Snøhetta
Location: Cambridge, MA, United States
Project Year: 2018

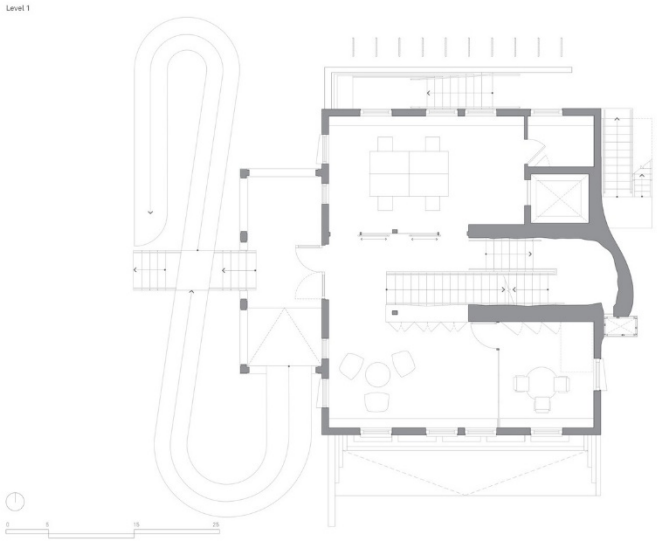
Harvard HouseZero is a project completed by The Harvard Center for Green Buildings and Cities (CGBC) at the Harvard Graduate School of Design (GSD). The project was a retrofitting of the organization's headquarter that was a pre-1940s building into a living-lab and a prototype for energy-positive and ultra-efficient enclosure that would introduce a new way for us to understand and interact with buildings. The design aspiration of the building was to target

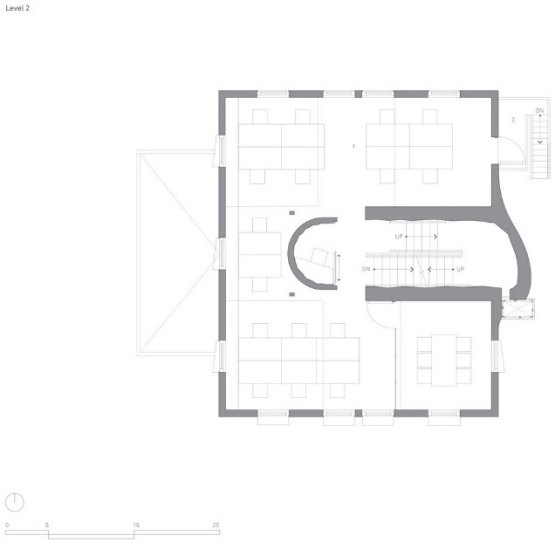
radical and ambitious performance goals, in order to reach heating, cooling, lighting, and electric energy that is almost zero during daytime. The building is intended to produce zero carbon emissions, and to operate with almost 100 percent natural ventilation. The building also aims to eventually generate more energy over its lifespan than what was used for the retrofitting process and its early operation energy consumption.

HouseZero will serve as both a research tool and a workspace, The Center for Green Buildings and Cities aims to use the hundreds of sensors that are integrated into almost all components of the building in order to generate millions of data points that will monitor the performance of HouseZero all the time. The generated data will provide the researchers at Harvard with unprecedented readings and analysis of complex building behavior. Those readings will in turn

be a rich source for computational simulation research that will help the Center for Green Buildings and Cities to develop new data-driven adaptive algorithms, which will promote sustainability, energy-efficiency, and health.

“HouseZero’s flexible, data-driven infrastructure will allow us to further research that demystifies building behavior, and design the next generation of ultra-efficient structures,” said the founding director of the Harvard Center for Green Building and Cities, and the leader and creator of the Harvard HouseZero project, Ali Malkawi. “By creating both a prototype and an infrastructure for long-term research, we hope to raise interest in ultra-efficient retrofits and inspire substantial shifts in the design and operation of buildings.”





“Harvard HouseZero is an extraordinary physical example of efficiency and transformative design.” Said Dean of the Harvard Graduate School of Design and Victoria Wiley Design Professor, Mohsen Mostafavi. “As a living laboratory, it equips Harvard students and

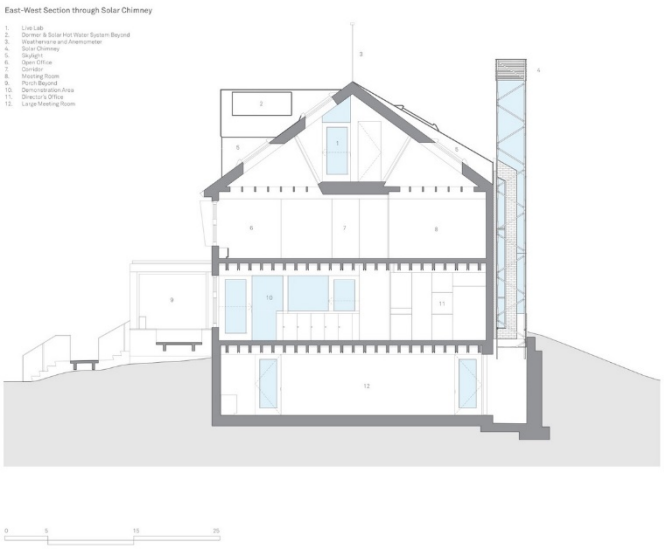
researchers with an unparalleled, innovative infrastructure for exploration and research as they design the next generation of sustainable buildings and cities around the world."

HouseZero works to tackle significant sustainability and energy problems of today's world which is the inefficiency of our building industry. Currently, the building industry in the United States is responsible for more than 40 percent of the energy consumption, with residential buildings being almost a quarter of that percentage. Owners of these buildings usually spend more than 230 billion dollars every year on powering, cooling, and heating almost 113.6 million homes nationwide. HouseZero aims to create efficient plans to reduce energy consumption and reducing costs for property owners

"HouseZero demonstrates how to solve that problem by optimizing current technologies to achieve unprecedented building performance," said Malkawi. "HouseZero challenged us to rethink the conventions of building design and operation to enhance lifelong efficiency and quality of life for occupants."

The high efficiency of the project is based on the integration between implementations of low-tech architectural design solutions and cutting-edge technologies in order to maximize the reduction of energy consumption. This can be portrayed in the ventilation system of the house. It is a fully natural system that is controlled by an actuation system for the windows, which uses complex algorithms and sensors to open and close the windows automatically in order to

maintain and a certain internal environment quality all year round. The building puts comfort first as a priority, so the windows can also be manually opened in order for the inhabitant to have full control in regards to their personal comfort, since comfort is firmly tethered to the instinct of the human.



The house will function as a research facility that aims to redefine our understanding of how can a building connect and respond to its surrounding context and environment in order to promote health and efficiency. The building was designed to interact and respond to the exterior climate in a natural way, rather than approaching the structure as a sealed envelope that disconnects from its surroundings. The building continuously reacts and adjusts in order to reach comfort levels for its inhabitants.

With more research and time, the Center for Green Buildings and Cities will be able to use all the data-driven research and findings from HouseZero in order to implement it in the construction of new buildings as well as future renovations all around the world, with the ultimate goal of reducing the environmental impact that the building industry is causing.

iii. Conclusion

We need to focus on raising awareness by providing statements that shed the light on a number of climate change issues that architects should tackle, taking reference the existing research work done by the AIA to tackle those issues, and providing statements about the additional work architects should conduct in order to address and resolve those issues before it's too late. It is very important for a wide movement for everyone to start to join the 2030 commitment that was adopted by the AIA where all new buildings, developments, and major renovations shall be carbon-neutral by 2030. And then emphasize on the significance of adapting and retrofitting existing buildings that do not fall as part of that challenge, and how the materials for those buildings are a huge part of the carbon footprint of those buildings and what we can do to reduce that footprint. And last but not least we need to stress on the importance of pursuing renewable energy resources as other sources are bound to run out someday.

References

Anderson, Darran. January 23, 2019. *We Need Architecture That is More Than Just Green.* Chicago, Illinois: University of Chicago Press.

Barros, Maria Luisa. October 28, 2015. *Rio Will Be the City Worst Affected by Climate Change in South America.* Rio de Janeiro, Brazil: O Dia.

Borger, Julian. June 23, 2007. *Darfur conflict heralds era of wars triggered by climate change.* London, United Kingdom: The Guardian.

Dahl, Torben. December 14, 2009. *Climate and Architecture.* New York, New York: Routledge.

David Pimentel, Richard P. Cincotta, Phillip Longman, Judy Oglethorpe, Nancy Gelman, Wolfgang Lutz and Richard E. Bilsborrow. April 2016. *Frontiers in Ecology and the Environment.* Washington, DC: The Ecological Society of America.

Dean Hawkes, Jane McDonald, Koen Steemers. October 8, 2013. *The Selective Environment: An Approach to Environmentally Responsive Architecture.* New York, New York: Spon Press.

Diana Ivanova, Konstantin Stadler, Kjartan Steen-Olsen, Richard Wood, Gibran Vita, Arnold Tukker, Edgar G. Hertwich. 2015. *Environmental Impact Assessment of Household Consumption.* Trondheim, Norway: Journal of Industrial Ecology, 526-536.

Edwards, Andres R. June 1, 2015. *The Sustainability Revolution: Portrait of a Paradigm Shift.* Gabriola Island, British Columbia: New Society Publishers.

Leardi, Lindsey. September 25, 2017. *All-In-One Structure Solves Flooding, Parking and the Lack of Green Space in Cities.* New York, New York: ArchDaily.

Paula Melton, AIA Staff. November 13, 2018. *Four Ways Architects Can Fight Climate Change.* Brattleboro, Vermont: AIA.

Planners, Centerbrook Architects and. March 6, 2013. *Hotchkiss Biomass Power Plant.* Centerbrook, CT: Centerbrook Architects and Planners.

Snøhetta. Devember, 2018. *Harvard HouseZero.* Cambridge, Massachusetts: ArchDaily.

Sushant Verma, Pradeep Devadass. 2013. *Adaptive[Skins]: Responsive Building Skin Systems Based on Tensegrity Principles.* London, United Kingdom: AA School of Architecture.