EXTREME ENVIRONMENT ARCHITECTURE

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To my grandmother.

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ABSTRACT

Global industrialized processes in architecture often abandon site-specific knowledge in architectural design traditions and spatial qualities that have allowed for sustainable and resilient designs. Parallel to this reality, science and technology have new and innovative approaches and solutions than what is currently applied to building design and construction. To meet the challenges of Climate Change and our planets limited resources, we as architects and engineers are developing new materials and technologies for near Extreme Environmental change. Buildings will constitute a primary challenge in the 'battle' to mitigate the causes and effects of climate change, in that, primarily, we tend to spend a very large share of our time in them which I am trying to explore as an architect's point of view, and applied to architectural design. What are these materials? What are these technologies and applications? In short, the study will explore new materials and innovative designs that are applicable to extreme living conditions.

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INTRODUCTION

1.1 Climate Change and Architects

Climate change is happening around us today and its impacts on our lives will be far worse than commonly acknowledged. It argues that many modern buildings are not only 'unsustainable' but are also having a catastrophic effect on the global climate. In a uniquely frank argument, Susan Roaf[1] illustrates that the only way we can hope to survive the following century, with our societies intact, is if we begin to radically reduce CO2 emissions from our buildings, to stop building climatically disastrous 'modern' buildings and to develop a new generation of 'resilient', regionally appropriate, low-impact buildings, powered by clean, renewable energy, in which we can survive comfortably, in a warming world and in the dark cities of the future.

1.2 Denser cities, why not go higher

Not only we will move toward to extreme environment, but also more people will be living in bigger cities. The city has become an important new starting point in the quest for architecture. At a time of extreme urbanization, unharnessed urban growth has led many architects to rethink the way that buildings are designed for the global metropolis. It is

1. Susan Roaf. 2005. *Adapting buildings and cities for climate change : a 21st century survival guide.* Amsterdam Boston: Architectural Press. isbn: 0750659114.

no longer practical or desirable to impose the standardized, idealized planning of the 20th century. Rather than viewing the city as a fixed entity, architects are now seeking direct inspiration from the existing urban environment and learning from its ever-changing state that resists predetermination. Alexander[2] writes The city, in all its complexity, has become a realm of invention and a space for possibilities where new designs can be tested. This is as apparent in the work that architects are undertaking in the informal settlements, or favelas, of Latin America, as in the more regulated spaces of Wasington DC, New York or Paris.

1.3 Architecture Materials of Tomorrow

For future material research was done by Stamatina Th. Rassia[3]. In Cities for Smart Environmental and Energy Futures: Impacts on Architecture and Technology presents works written by eminent international experts from a variety of disciplines including architecture, engineering and related fields. Due to the ever-increasing focus on sustainable technologies, alternative energy sources, and global social and urban issues, interest in the energy systems for cities of the future has grown in a wealth of disciplines. Some of the special features of this book include new findings on the city of the future from the macro to the micro level. These range from urban sustainability to indoor urbanism, and from strategies for cities and global climate change to material properties.

2. Alexander Eisenschmidt. 2012. *City catalyst : architecture in the age of extreme urbanisation.* Chichester: Wiley. isbn: 1119972663.

3. Stamatina Rassia. 2014. *Cities for smart environmental and energy futures : impacts on architecture and technology.* Heidelberg: Springer. isbn: 3642376606.

CHAPTER 2
FUTURE OF ARCHITECTURE IN EXTREME CLIMATES

The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO). Every five to seven years the IPCC publishes an Assessment Report (AR) providing a comprehensive synthesis of information about human-induced climate change. The Reports focus on three key aspects: the physical science of climate change (Working Group I), impacts, adaptation, and vulnerability (Working Group II), and mitigation strategies (Working Group III). In 2007 the IPCC was awarded the Nobel Peace Prize in recognition of its work to disseminate knowledge about climate change and actions needed to counteract the risks.

Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) defines 'climate' as 'average weather' and is usually described in terms of the "mean and variability of temperature, precipitation and wind over a period of time ranging from months to millions of years"[1]

1. IPCC. 2013a. Annex ii: climate system scenario tables. Chap. AII in *Climate change 2013: the physical science basis. contribution of working group i to the fifth assessment report of the intergovernmental panel on climate change,* edited by T.F. Stocker et al., 1395–1446. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. isbn: 978-1-107-66182-0. doi:10.1017/CBO9781107415324.030. www.climatechange2013.org.

2.1 Earths Climate System

The system governing the climate on Earth consists of many sub-systems linked together in a non-linear fashion. The many interlinkages amongst them make it difficult to predict the overall behavior of the global climate in response to a variation in a single sub-system like, for example, the atmosphere. The state of the atmosphere is interactively influenced by other sub-systems such as the oceans, the cryosphere, the biosphere and the lithosphere.

Considering the complex interactions between the various sub-systems, to cause a significant alteration in the global climate, one (or more) of the following causes (often referred to as climate forcing) must occur[2]:

1. Alteration of the Earths orbit and movements;
2. Variation in the intensity of solar radiation;
3. Shift in the geological equilibrium of the planet;
4. Variation in the equilibrium of oceanic currents;
5. Modification of the Earths albedo;
6. Changes in the composition of the atmosphere due to human activity.

These driving forces operate on different time scales ranging from very long geological eras up to a more human era. In addition, there are many complex feedback mechanisms in the climate system that can either amplify or diminish the effects of an alteration in one

2. Knut H. Alfsen. 2000. *Climate change: scientific background and process.* Oslo, Norway: CICERO, Center for international climate / environmental research.

of the sub-systems, generating internal reactions whose effects are difficult to predict due to the complex ramifications amongst the various factors involved. For example, evidence from ice cores testify that our planet has in several occasions during its paleoclimatic history abruptly shifted between climate extremes due to positive feedback loops.[3]

Earth's climate has varied with time, both locally and globally, ever since the planet formed some 4.5 billion years ago. Ice Age of 20,000 years ago, the little Ice Age that hit Europe in the early Middle Age, the following medieval warm period and the cooling of the 17 th , 18 th , and 19 th centuries. In these variations, carbon dioxide concentration is believed to have regularly played an important role.[4]

Carbon is a key element for life on Earth forming the basis of all the plants, animals and micro-organisms. Its concentration in the atmosphere has helped stabilizing the climate on Earth through the 'carbon cycle', a combination of biological, chemical, and physical processes where the atmospheric CO2 is absorbed by biota, rocks and ocean water, then being released back in the ecosystem with the death and decomposition of living organisms, with the weathering of rocks and volcanic eruptions.

A high concentration of carbon dioxide in the atmosphere leads to a warm and humid climate that in turn leads to more rock erosion and consequently to a stronger capsize for atmospheric CO2. On the contrary, low carbon dioxide concentrations induce a colder climate resulting in possible glaciations, with an ice cover that protects rocks from erosion

3. Peter Smith. 2005. *Architecture in a climate of change : a guide to sustainable design.* Oxford, Boston: Elsevier/Architectural Press. isbn: 9780750665445.

4. IPCC. 2013b. *Climate change 2013: the physical science basis. contribution of working group i to the fifth assessment report of the intergovernmental panel on climate change.* 1535. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. isbn: 978-1-107-66182-0. doi:10.1017/CBO9781107415324. www.climatechange2013.org.

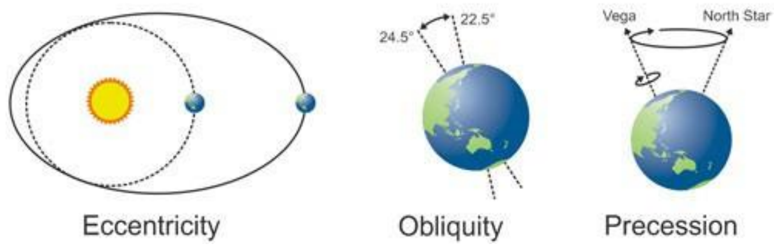

Figure 2.1: Milankovitch cycles

and thus reduce CO_2 sinking. These cyclical feedbacks tend to stabilize the global climate system in the long run[5].

The release of CO_2 is offset by carbon sinks, and the climate system would be in a dynamic equilibrium with the energy received from the Sun if it were not for external forcing which could alter this balance, as it has happened several times in the paleoclimatic record of our planet.

2.1.1 Alteration of the Earth's orbit and movements

The past climate fluctuations have been due to variations in Earth's orbit eccentricity, axial tilt and precession, occurring over thousands of year-cycles. These orbital changes are generally referred to as 'Milankovitch cycles', which change the amount of solar radiation received at each latitude in every season, although they can hardly affect the global annual mean (Figure 1. Schematic of the Earth's orbital changes).

The Milankovitch cycles have been linked to the start and end of Ice Ages, although there are still several scientific uncertainties about how these alterations can be triggered.

5. Knut H. Alfsen. 2000. *Climate change: scientific background and process.* Oslo, Norway: CICERO, Center for international climate / environmental research.

It has been calculated that the Earth's current orbital configuration is like that of the warm interglacial period of 400,000 years ago, probably signifying that we may be in the early stage of an interglacial episode. Yet, the next large reduction in northern summer insolation is not expected before 30,000 years[6].

2.1.2 Variation in the intensity of solar radiation

Another cause of climate change in the past has been linked to variations in the energy output of the Sun. On a short scale of time, the solar output is known to vary over the 11-year solar 'sunspot cycle'. While the total intensity of the solar radiation does not vary much during this period, alterations in the mean temperature over land in the northern hemisphere have been correspond to this phenomenon. On a longer scale, as an effect of the Sun's evolution as a star, the solar radiation has increased its intensity by approximately 30% since the creation of the solar system. Although the solar radiation was considerably less intense at that early stage, the primordial terrestrial atmosphere contained probably much more CO, and thus the 'natural' greenhouse effect contributed to keep the planet warm.

2.1.3 Shift in the geological equilibrium of the planet

Movements of tectonic plates contribute to the dynamic effect of the atmosphere concurrent with the rotary motion of the Earth and cause changes in atmospheric pressure. Much

6. IPCC. 2013b. *Climate change 2013: the physical science basis. contribution of working group i to the fifth assessment report of the intergovernmental panel on climate change.* 1535. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. isbn: 978-1-107-66182-0. doi:10.1017/CBO9781107415324. www.climatechange2013.org.

warmer times than present have occurred in the Earth's paleoclimatic history due to shifts in the geological equilibrium of the planet, the formation of volcanoes and a consequently higher CO2 concentration in the atmosphere. Sudden Changes in carbon concentration have also been linked to subduction phenomena (tectonic plates). In this process, vast quantities of CO2 and debris are suddenly released, cooling the climate in the short term, and to a warming effect in the long term, since CO2 has a longer life in the atmosphere than dust and debris.

2.1.4 Variations in the equilibrium of oceanic currents

As a warming of the climate system forced by other external factors, surge of water of melting ice and increased rain can flow in the oceans affecting deep ocean currents. Warm surface water migrates from tropical seas to the North Atlantic heating up the north-western shores of Europe. This current gradually becomes colder until it reaches Greenland, and pulls more warm water from the tropics keeping active the current. The stopping of oceanic currents would however be a reversible process, since colder conditions would decrease the melting of ice up to a point where a new balance would be found.

2.1.5 Modification of the Earths albedo

Albedo of Ice cap is another example of forcing that could be responsible for climate change. Ice has a much greater reflectivity than water and land masses, and thus it causes solar radiation to be reflected to space rather than be absorbed by the surface and warm the

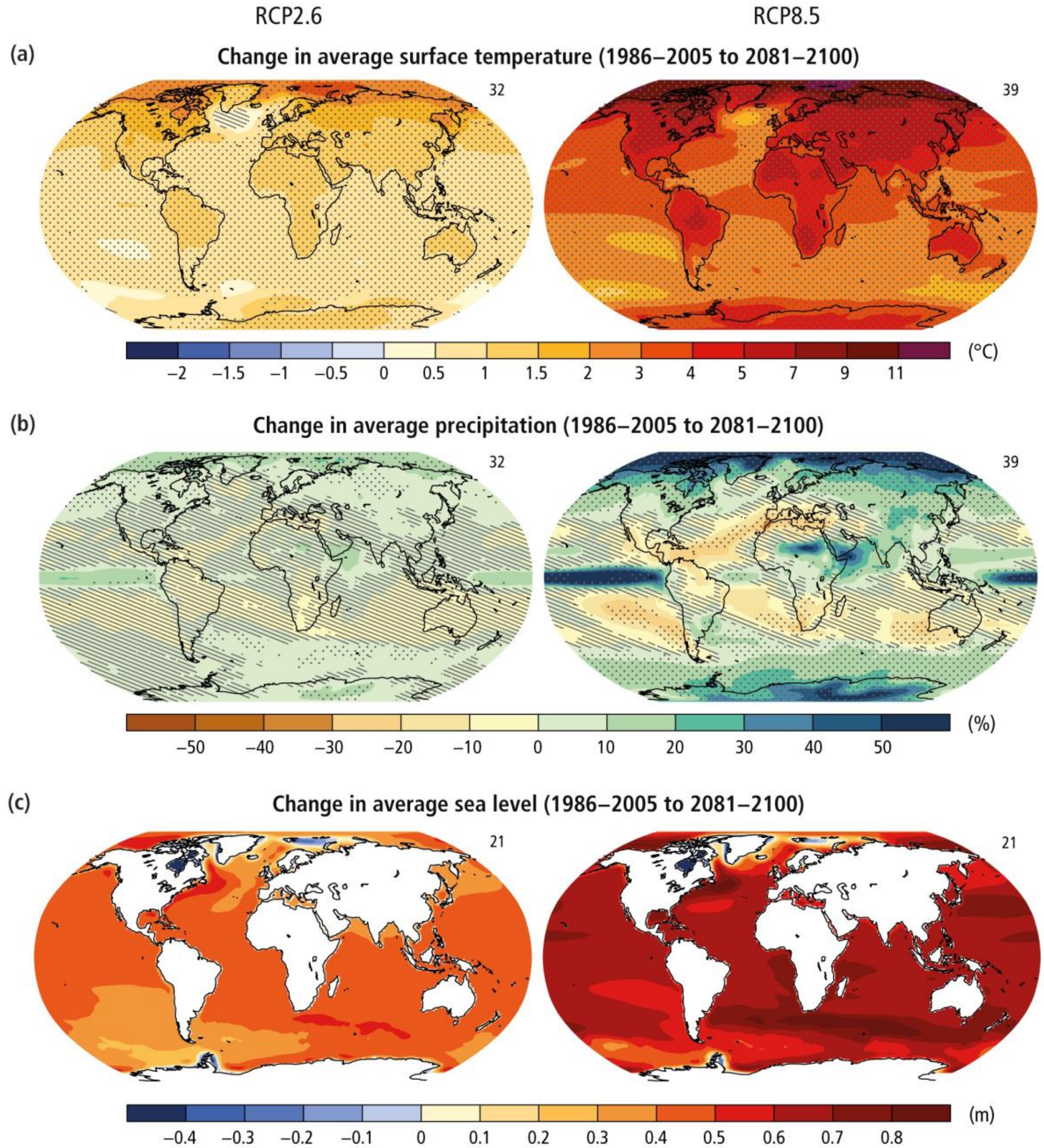

Figure 2.2: Coupled Model Intercomparison Project Phase 5 (CMIP5) multi-model mean projections from AR5 WG1

climate system. A reduction in ice cover due a climate change could eventually lead to even warmer conditions until a further climate change would intervene to shift the equilibrium of the system.

2.1.6 Changes in the composition of the atmosphere due to human activity

Human Activity is one of the most researched area on interdisciplinary academics and policy makers around world that currently changes in the atmospheric concentration of greenhouse gases. Carbon has been slowly locked in the Earth's system over millions of years; yet, since the Industrial Revolution, humans have been releasing CO2 in the atmosphere at a rate unprecedented. In addition, agriculture and industrial activities have resulted in the constantly increasing emission of other greenhouse gases such as methane, nitrous dioxide, and halocarbons, which are significantly affecting the climate by altering the Earth's energy budget.

Some scientists believe that the human influence on the climate system could be dated back at a far earlier time than the Industrial Revolution, the concern of our time is about climate changes comparable in magnitude to the global average difference between a glacial and an inter-glacial period, that projected to occur in a matter of decades rather than thousands of years.

Humans have always been moderate to the changes of climate, their adaptation capacities or eventually migrating to milder zones. Today our number has grown to a point where there

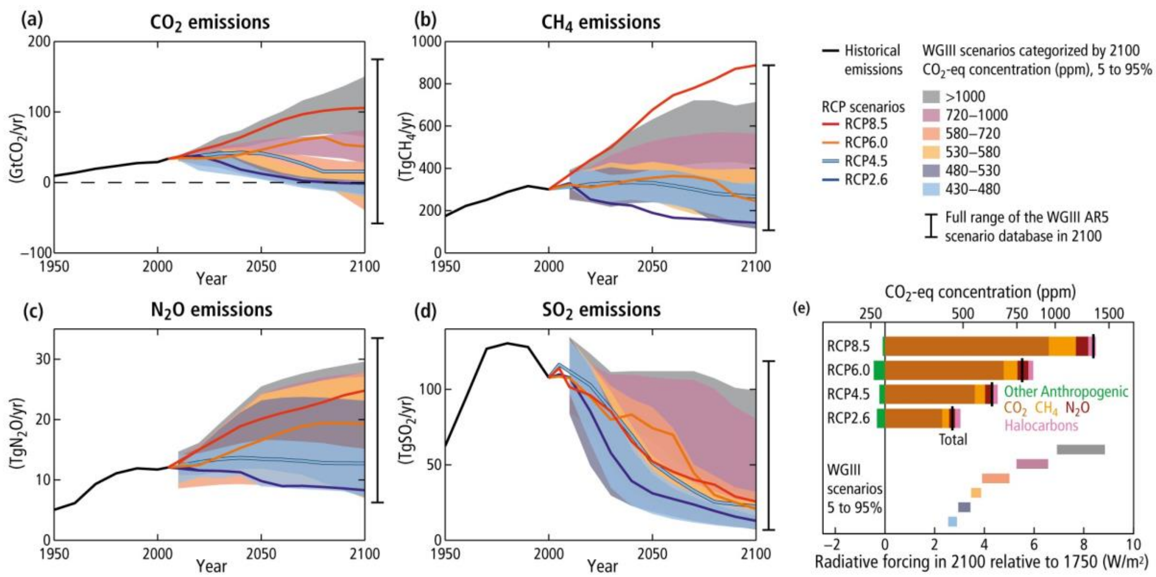

Figure 2.3: Emission scenarios and the resulting radiative forcing levels for the Representative Concentration Pathways (RCPs, lines) and the associated scenarios categories used in AR5 WG3

is no room for large-scale migrations should a major climate shift make this necessary[7]. The challenge humans must face today is thus to put in place mitigation actions necessary to prevent the planet crossing the threshold into a process of irreversible global warming that could have disastrous impacts on many aspects of life, and to develop strategies to make their settlements and activities adapt to forthcoming new climate conditions which seem unavoidable.

2.1.7 Greenhouse Effect

The climate of the Earth is powered by the Sun and predominantly in the visible part of the electromagnetic spectrum. The amount of energy reaching the higher strata of the Earth's

7. Tim Flannery. 2005. *The weather makers : the history and future impact of climate change.* Melbourne: Text Publishing. isbn: 1920885846.

atmosphere each second on a surface area of 1m2 facing the Sun during daytime is about 1370 Watts. Since the Earth is nearly spherical, a greater amount of solar radiation arrives for a given surface area in the tropics than at higher latitudes, where sunlight strikes with a constantly decreasing angle. Energy is then transported from tropical regions to northern or southern latitudes via atmospheric and ocean circulation.

Part of the energy that reaches the Earth is reflected directly back into space by the atmosphere, while the remaining fraction is captured by land, biota, oceans, ice caps and, to a lesser extent, by gases. The total quantity of energy absorbed per second by the terrestrial system amounts approximately to 240 W/m2 .

To balance this absorbed solar radiation, the Earth must re-radiate back in space the same amount of energy. Considering that the Earth is much colder than the Sun, it emits radiative energy at much longer wavelengths, i.e. in the infrared part of the spectrum. Once emitted, some of this infrared radiation is absorbed by gases in the cooler upper atmosphere and is radiated back to the surface; this is what is called the 'greenhouse effect'. The warming effect of greenhouse gases is thus a natural process, which, incidentally, is conducive to life on our planet. Without this warming, the average temperature at the Earths surface would be about 30C colder than the average +14C currently enjoyed, and below the freezing point of water, making life as we know it simply not possible.

Nevertheless, human activities of the last two centuries - primarily the burning of fossil fuels and the clearing of forests - have greatly intensified this natural greenhouse effect, initiating a chain of events which, as we are now starting to realize, can lead to drastic climate change.

2.2 Mitigation and Adaptation in Architecture

It is possible to make reasonably confident predictions on the repercussions that climate change will have on most aspects of life on Earth, and consider their consequences on the future of human activities. The contribution of Working Group III (Mitigation of Climate Change) to the Fifth Assessment Report of the IPCC indicates some actions to be considered, to curb human impacts and mitigate harmful consequences for the environment as a whole. These actions include primary measures to be applied within the energy and building sectors, but also on transports, industry, agriculture, forestry and waste management. By implementing these strategies, ”energy efficiency options could sensibly reduce CO_2 emissions with net economic and environmental benefits, improving comfort, social welfare and enhancing energy security”[8].

Buildings will constitute a primary challenge in the ’battle’ to mitigate the causes and effects of climate change, in that, primarily, we tend to spend a very large share of our time in them, some cases more than 90% of our day, whilst they also house the biggest part of our social, business, cultural and private activities. In addition, human settlements have undoubtedly been proven to be one of the very contributors to the current climate crisis[9].

8. IPCC. 2014. *Climate change 2014: mitigation of climate change. contribution of working group iii to the fifth assessment report of the intergovernmental panel on climate change.* 1435. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. isbn: 978-1-107-05821-7. http://www.ipcc.ch/report/ar5/wg3/.

9. Koen Steemers. 2003. Towards a research agenda for adapting to climate change. *Building Research & Information* 31 (3-4): 291–301. doi:10.1080/0961321032000097692. http://dx.doi.org/10.1080/0961321032000097692.

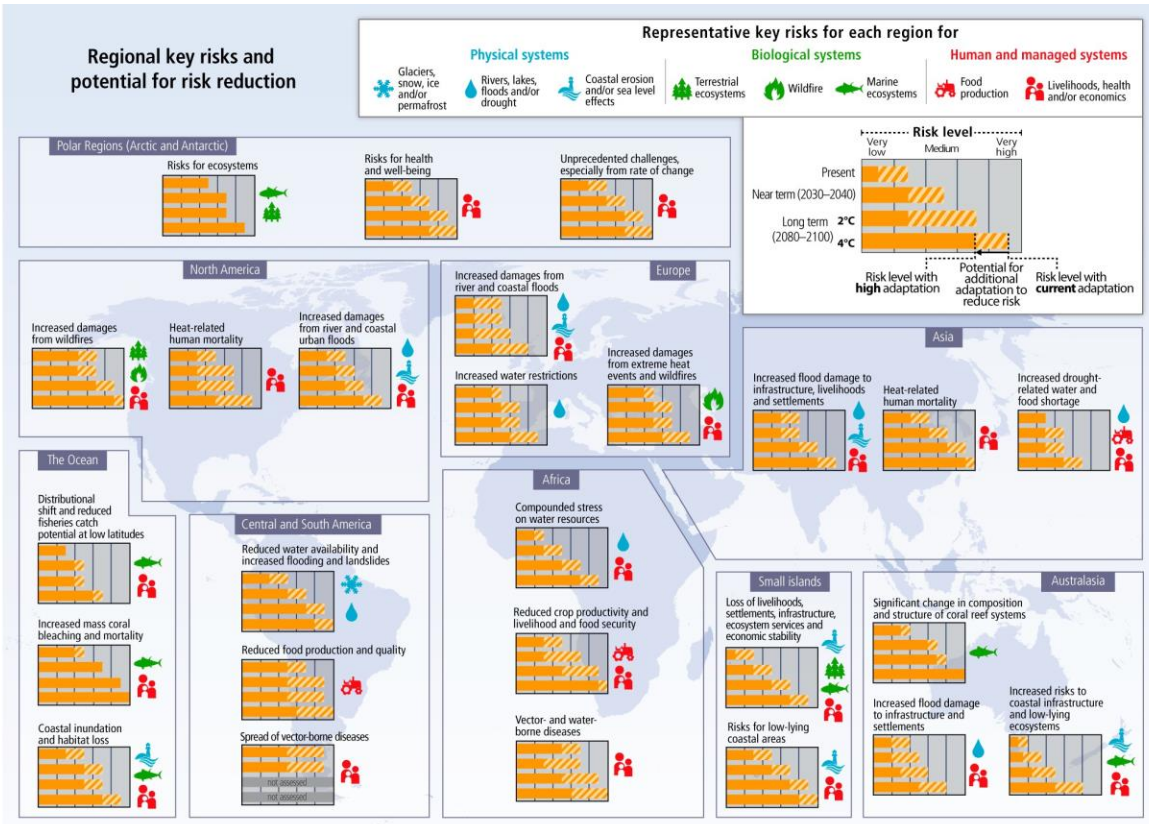

Figure 2.4: Representative key risks for each region, including the potential for risk reduction through adaptation and mitigation, as well as limits to adaptation. from AR5 WG2

Between 1970 and 1990, direct emissions from buildings have increased by 26%, not including the electricity the buildings consume. Considering also the electricity required for the functioning of mechanical systems and services (such as heating and cooling), the total increase of direct and indirect emissions from the construction sector is much higher than direct emissions alone[10]. Buildings consume enormous amounts of energy during their entire life-cycle (from construction, through operation, to dismantle) depleting nonrenewable resources and releasing greenhouse gases in the atmosphere. Their energy budget is accounted nowadays for more than half of worldwide consumptions (mostly coming from the burning of oil, coal and natural gas), significantly contributing to the very causes of climate change. The development of design strategies for buildings to reduce their dependency on fossil fuels, curb their energy demands, exploit clean power sources and minimize their wastes becomes thus mandatory.

The measures suggested by the IPCC define a clear path that developed economies, together with emerging countries, should take on the road to reducing the pressure of human habitats on the environment to avoid dramatic consequences. In this context, advances in technology can clearly play a major role by making viable practical ways to use cleaner and renewable forms of energy without increasing the Earths carbon budget and enhancing the quality of building design from the environment.

In the recent advances in knowledge, it is possible to identify a range of 'sustainable' low-energy technologies that could contribute to curb the stress that mankind is imposing

10. IPCC. 2014. *Climate change 2014: mitigation of climate change. contribution of working group iii to the fifth assessment report of the intergovernmental panel on climate change.* 1435. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. isbn: 978-1-107-05821-7. http://www.ipcc.ch/report/ar5/wg3/.

on the climate system. However, to successfully reduce humans' climate forcing, innovation in the production and management of energy in built environments will have to be coupled with more responsive (and responsible) design strategies for both new and existing buildings.

To effectively mitigate long-term impacts and adapt in the short-term to inevitable climate alterations, the challenge is thus to identify and effectively put in place the design methodologies by which sustainable technologies can be integrated with current building models in order to guarantee the continuous social and economic growth of human developments, at the same time, limiting emissions and effectively responding to the consequences of climate alterations which are expected in the next few decades. As a matter of fact, it is the overall design of the building(structure, envelope, interiors, and services), rather than the mere application of advanced technology per se that governs the delicate balance amongst the factors determining the conditions inside and outside of built spaces.

2.2.1 Building Design of the Future

IPCC Fifth Assessment Report, amongst the key sectorial mitigation technologies and practices which are suggested to be applied within the design of built environments before 2020 and 2050 in completion, an essential role is to be played by "integrated design" of buildings, which should be exploiting advances in technology and implement both passive and active techniques in order to provide comfort for their users and reduce their energy requirements[11].

11. IPCC. 2014. *Climate change 2014: mitigation of climate change. contribution of working group iii to the fifth assessment report of the intergovernmental panel on climate change.* 1435. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. isbn: 978-1-107-05821-7. http://www.ipcc.ch/report/ar5/wg3/.

In the attempt to provide simple and straightforward guidelines for the integrated and sustainable design of buildings able to mitigate their pressure on the environment. Thermal performances, ventilation, light distribution, visual comfort, etc. are all variables that need to be carefully balanced according to specific requests, distinct environmental contexts, climate scenarios, and contingent technical choices. In addition, architecture is expected not only to serve the simple task of a filter against the elements, but also to provide the service functions that its users are accustomed to[12]. This raises the practical question of how to make building design progress in order to satisfy contemporary needs and, simultaneously, reduce energy consumptions and consequent environmental impacts.

To achieve these goals, a new integrated design process has to be developed that could potentially lead towards an innovative and progressive architecture, one that could easily and sustainably respond to current, as well as predicted, climate conditions and contextual situations.

2.2.2 Building Energy Codes

Countries can implement codes with various levels of stringency: voluntary codes, mandatory codes, or some mixture depending on the region or state. This stringency metric is a basic reporting of the status of the building codes in a country. In China, Canada, and the United States, the national government does not have authority to pass mandatory building codes; however, many states and provinces in those countries have adopted codes. In these cases, if

12. Paul Hawken, Amory B. Lovins, and L. Hunter Lovins. 2010. *Natural capitalism: creating the next industrial revolution.* London: Earthscan. isbn: 9780935728361.

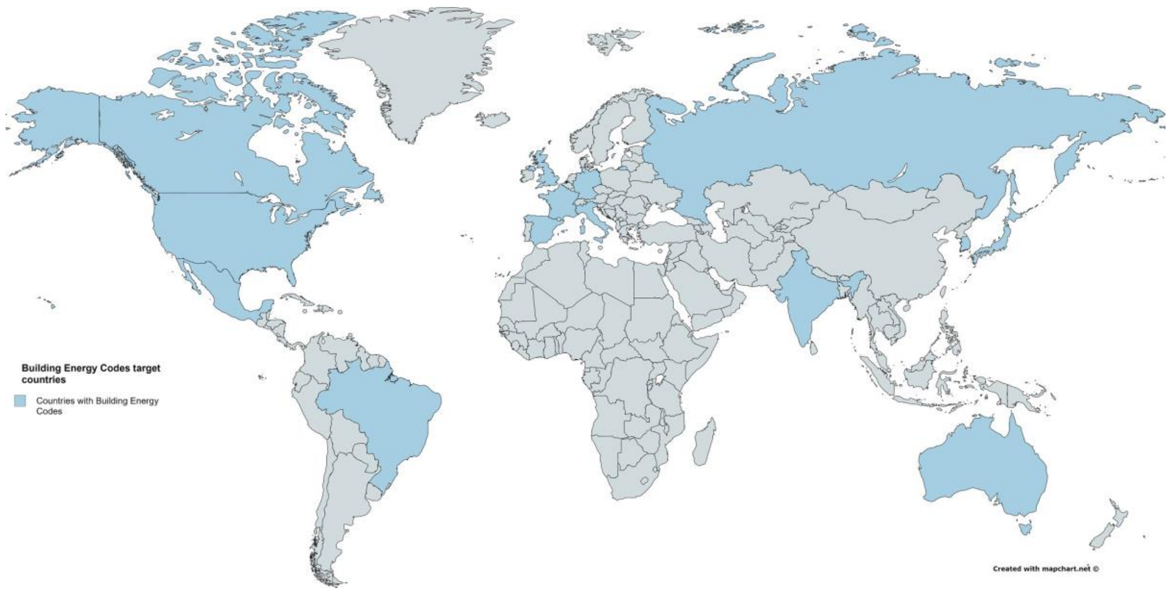

Figure 2.5: Countries with Building Energy Code

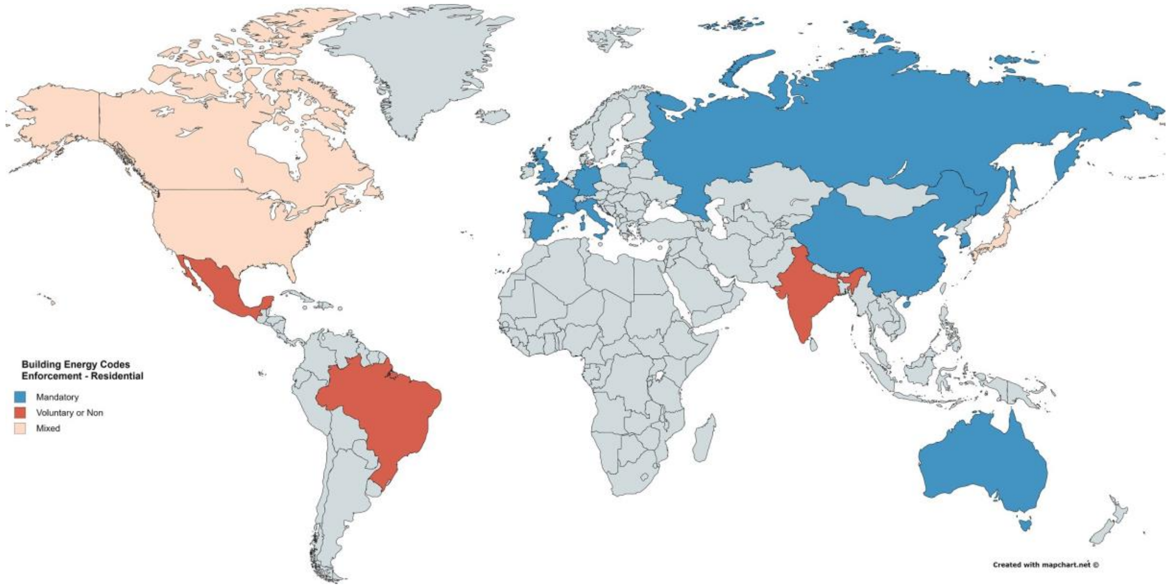

Figure 2.6: Countries with Building Energy Code-Residential

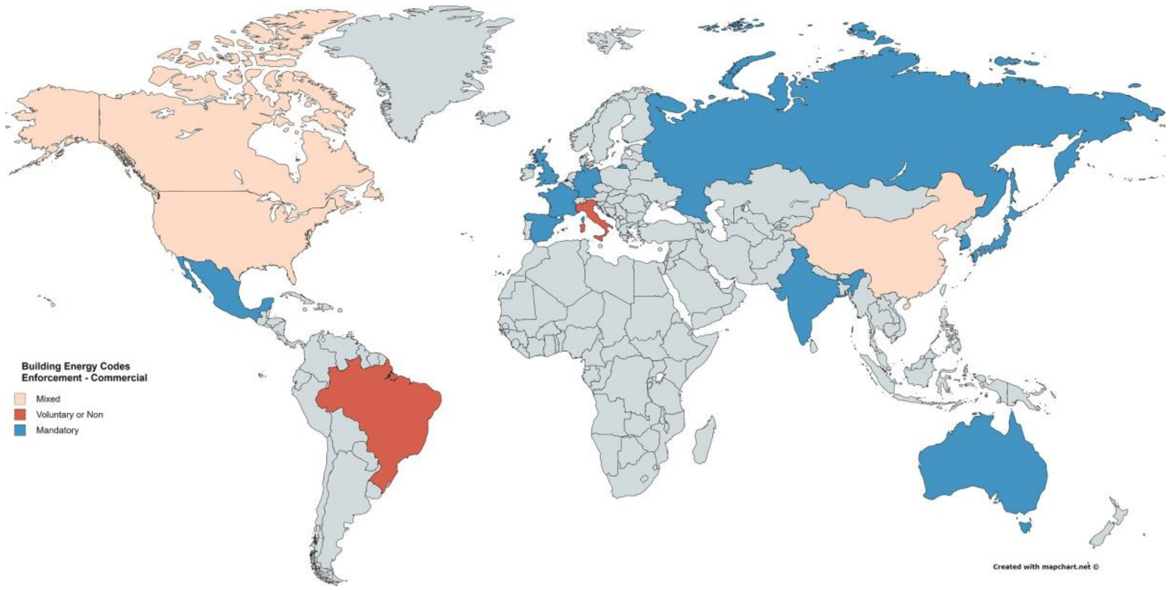

Figure 2.7: Countries with Building Energy Code-Commercial

most the population is within a jurisdiction with a code in place. In contrast, many countries create mandatory building energy codes that cover the entire country.

2.2.3 Technical Requirements

1. **Window U-Factor and Shading/Solar Heat Gain Coefficient.** The U-factor measures the rate of heat transfer through a window and rates how well the window insulates. The solar heat gain coefficient measures the fraction of solar energy transmitted and indicates how well the window blocks heat caused by sunlight.

2. **Lighting Efficiency Requirements.** Minimum standards for high-efficiency lighting and lamps and/or lighting controls are included in some building codes.

3. **Heating and Cooling Requirements.** Heating and cooling requirements refer to the efficiency of a buildings heating, ventilating, and air-conditioning (HVAC) systems.

4. **Air Sealing.** Sealing the ”envelope” or ”shell” includes getting rid of air leaks throughout a home, such as around windows and doors, and holes in attics, basements, and crawlspaces. These leaks can be sealed using caulk, spray foam, weather stripping, and other sealants.

5. **Technical Installations.** Building energy codes that contain details for technical installations of appliances and equipment and/or contain requirements for access to appliances for regular inspection

6. **Design, Position, and Orientation.** Design requirements include architectural programming requirements for all the functions in the building and their relationship to one another, including energy efficiency targets, primary functions, occupancy and time of use, daylight potential and electric light requirements, indoor environmental quality standards, equipment and plug loads, acoustic quality, and safety and security.

2.3 Future is Denser

For years in the western world. It was thought to be blasphemous to build higher than a church spire. The stories of the old testament warned against reaching too close to the heavens. The builders of the tower of Babel declared: ”Come, let us build us a city and a tower with its top in the heavens. And let us make a name for ourselves, lest we be scattered upon the face of the whole earth”[13]

13. New International Version, Gen. 11:4

Figure 2.8: The Tower of Babel by Pieter Bruegel the Elder (1563)

But god punished them for building a monument to humanity and not to God by confusing their language so they could no longer work together. This story is used as the source of our worlds languages for the religious and some still use it as an argument against our modern world, but it has interesting undertones for the development of our cities.

For centuries, the church spire remained as the focal point of most western cities. The Trinity Church was the largest building in New York until year 1890 when the New York World Building was completed. This marked an end to the Cathedral dominated skylines of many cities across the world. Those church spires served as a symbol of piety, but The New York World Buildings height allowed Joseph Pulitzer to expand his growing business without having to find a large swath of land on the outskirts of the city.

Growing taller served a practical purpose and it still does in many cases. Its that demand

Figure 2.9: The Trinity Church

Figure 2.10: Hong Kong skyline with night lights

Figure 2.11: Rendering of Hong Kong International Airport Expansion

for space that truly drives up the average height of buildings in cities. Cities like Hong Kong do not have any high-rise buildings, but the average height of buildings in Hong Kong is among the highest in the world and that is largely driven by the lack of space available. Hong Kong confined by the sea on one side and the Chinese border on the other while having a very mountainous landscape.

There are not a huge amount of land to build on. These forced buildings to grow taller to accommodate the citys population. When Hong Kong needed to expand their International Airport, there was little space available. Instead they decided to level two islands outside the city to create a new artificial Island, where the new airport is now located. This project added 1% to the total surface area of Hong Kong. When space is limited, humans are forced to get inventive to cope, but in many cities across the world space is not an issue and these cities usually decide to expand outwards.

Figure 2.12: Untitled IV, Nevada 2010, photo taken by Christoph Gielen

2.3.1 Urban Sprawl

Urban sprawl and its been a topic of debate lately, with calls to stop this decentralization of cities. Urban sprawl requires little micro-management of resources, you simply continue to expand current utilities and roads and approve buildings on cheaper undeveloped land. Its an easy solution to a growing population, but it creates many problems of its own and is completely unsustainable as populations grow.[14]

We can not simply keep expanding the city and allowing those problems to escalate. It has

14. F Benfield. 1999. *Once there were greenfields : how urban sprawl is undermining americas's environment, economy, and social fabric.* New York: Natural Resources Defense Council. isbn: 9781893340176.

huge environmental and social impacts. One of the most obvious is an increasing commute time. With an increasing city diameter, the distances we must cover to reach the city center increases and it is incredibly difficult to serve these far flung suburban neighborhoods with adequate public transport. This results in a city dependent on the car, our least efficient form of transport. This not only has a social impact, as long commute times are one of highest and most controllable factors that affect our happiness, but the average American spends 17,600 minutes behind the wheel a year, much of that is spent in gridlock traffic, thats equivalent to spending almost an extra 37 days at your traditional 8 to 9 hours to job, but it also has a direct impact on pollution and air quality in the city too. Thats 17,600 minutes of a car polluting the environment. Reducing a citys dependence on cars reduces our carbon footprint on this world. Urban sprawl affects our environment in other ways too.

Spreading our cities creates water distribution problems. Ireland is thought that up to 50% of the treated water is lost through pipe leakage[15] and that problem is not unique to Ireland. In 2010 it was reported that 3.3 billion liters of water was being wasted in the England and Wales through pipe leakage. Reducing the sprawl reduces the length of pipes needed and thus reduces the chances of leakages and the problem can be attenuated further by creating buildings with self-sustaining water supplies. This is becoming a growing trend and consideration among engineers.

Figure 2.13: Taipei 101 and the skyline of Taipei

2.3.2 LEED - Leadership in Energy and Environmental Design

LEED or Leadership in Energy and Environmental Design is one of the most used green building certifications used worldwide. It rates how resource efficient buildings are in their construction, energy use and water use. The Taipei 101 was awarded LEED's highest certification with a platinum certificate. It achieved this with its own dedicated water management systems and low-flow water fixtures. This design ideology helped the Taipei 101 to decrease its potable water consumption by at least 30 percent compared to the average building consumption, saving about 28 million liters of potable water annually.

When we consider that in America landscape irrigation is estimated to account for nearly one third of residential water use, totaling nearly 9 billion gallons of water per day. It would

15. RTE News. 2015. *More than 40% of water supply expected to be lost.* https://www.rte.ie/news/2015/0213/679825-water/.

be vastly more sustainable for a world where water is in ever increasing demand to create cities where we have a larger percentage of LEED certified high-rise residential buildings. This goes beyond just environmental impacts, there are several socio-economic motivations to creating more high-rise buildings too. I pointed out that the urban sprawl results in longer commutes and the roads and public transportation needed to facilitate those commutes are not free. They need to be maintained and built with government budget and while building up is costly, that cost and risk is usually incurred on private contractors and the costs of building up starts to decline once you reach a certain height. To build a skyscraper there are a number fixed costs, but many of these costs do not increase with the height of the building.

Fixed costs like the cost of land, legal fees and design costs can be offset by building higher. If the building is built on a 100 square metre plot of land and the building has 40 stories, each floor only takes up 2.5 square meters of land. That has obvious economic advantages, especially when you consider design and material costs only start to go up when you reach around the 40th floor and that critical height is likely to go up as technology improves.

2.3.3 The Tall - Burj Khalifa

Buildings like the Burj Khalifa may be just exuberant displays of wealth, but they do serve as technology demonstrators. For 25 years, the tallest building in the world was the Sears Tower, now known as the Willis Tower. It uses a bundled tube structure, which maximizes

Figure 2.14: Burj Khalifa with Dubai's skyline

the amount floor space, but if we scale this building to the size of the Burj Khalifa. Its floor space would be dominated by structural elements and the interior would have no natural light. The buttressed core of the Burj Khalifa provides the structural integrity needed to reach these heights, while maximizing both the window access and usable space.

This is vital knowledge and experience to have to allow building heights to keep growing while keeping costs down. One may be thinking why are not there more high-rises buildings. If there are all these benefits, there must be reasons that we are not building more of them. The primary reason we are not building higher is because of city planning and regulatory problems.

Figure 2.15: 1960's Arial Photo of New York

2.3.4 The Big - New York

Take New Yorks growth in the early 20th century as an example, building heights were growing and many were unhappy with it. At the time 5th Avenue was filled with stately mansions, homes to the wealthy families of New York like the Carnegies and Rockefellers. They worried that unless building heights were restricted, 5th avenue would turn into a dark cannon, overshadowed by these towering behemoths. These worries led to 1916 zoning resolution which allowed buildings to grow in height, but restricted their width as they grew. This is one of the primary reasons so many buildings in New York built during that era taper towards their top. It was a measure to prevent buildings from blocking the sunlight below, but the regulation had loop holes and architects quickly exploited them. Between

1916 and 1960 the city's zoning code was amended 2500 times.[16] The 1961 Zoning Resolution brought in strict rules and introduced a new floor to area ratio rule that restricted buildings heights according to the district they were. "By the end of the 1920s the setback skyscraper, originally built in response to a New York zoning code, became a style that caught on from Chicago to Shanghai,"[17] observe Eric Peter Nash and Norman McGrath.

The floor to area ratio set how much floor space could be built on a plot of land. A floor to area ratio of 2 means you can build a 2 story building on your full plot or a story building on half your plot. R1, R2 and R3 districts are low density zones like Staten Island and the Jamaica Estates in Queens and they have a floor to area ratio of 0.5. Whereas major thoroughfares in Manhattan are R9 and R10 districts which have floor to area ratios of 7.5 and 10 respectively. This floor to area ratio rule put pressure on designers to allocate more space to open plazas or other public spaces around the building to facilitate a taller tower, whereas the 1916 zoning laws resulted in tiered buildings that started right on the sidewalk. The 1961 zoning code encouraged privately owned public space to ease the density and claustrophobia of a high-rise city and I think we can all agree that is a move in the right direction. Zoning regulations like this are important to prevent brainless growth that destroy a citys character, but sometimes they are overzealous and prevent modernization altogether.

16. Edward Glaeser. 2011. *Triumph of the city : how our greatest invention makes us richer, smarter, greener, healthier, and happier.* New York: Penguin Press. isbn: 9781594202773.

17. Eric Nash. 2010. *Manhattan skyscrapers.* New York: Princeton Architectural Press. isbn: 9781568989679.

2.3.5 The Traffic - Washington DC and LA

Take Washington DC zoning code that has been in place for over 100 years with little change. The Height of Buildings act of 1910 prevents any building beyond 40 meters in height. That is incredibly restrictive and it has resulted in a city where the tallest structure is a giant stone obelisk and this thing. Even with a relatively small population, Washington has some of the worst traffic in the US. A study released this year by INRIX found that the people of Washington DC waste an average of 75 hours per year in traffic. That means their journeys take 75 hours more than if there was no congestion. They were second only to Los Angeles, who waste an average of 81 hours a year in traffic. LA is often singled out as the key example of this problem of unchecked outward growth.

It was a key theme in the movie Her, where the car dominated urban sprawl of the present is apposed with a vision of a glossy, clean, high-rise future for LA. The main character Theodore lives in a highly-developed downtown LA. He lives in a high-rise building and works in a high-rise building. Hes able to walk between them and cars seem to have ceased to exist, he instead uses the extensive metro system to get around. The movie even designed a futuristic subway map of LA. To create this vision of the future, the producers digitally enhanced the citys existing skyline.

While also mixing in shots from present day LA with numerous shots from Shanghais Pudong district, like this pedestrian sky bridge which allowed Spike zone to film Theodore wandering through the urban jungle without having the cars at street level interfering with the illusion of a city that has transcended the need for personal transport. That transfor-

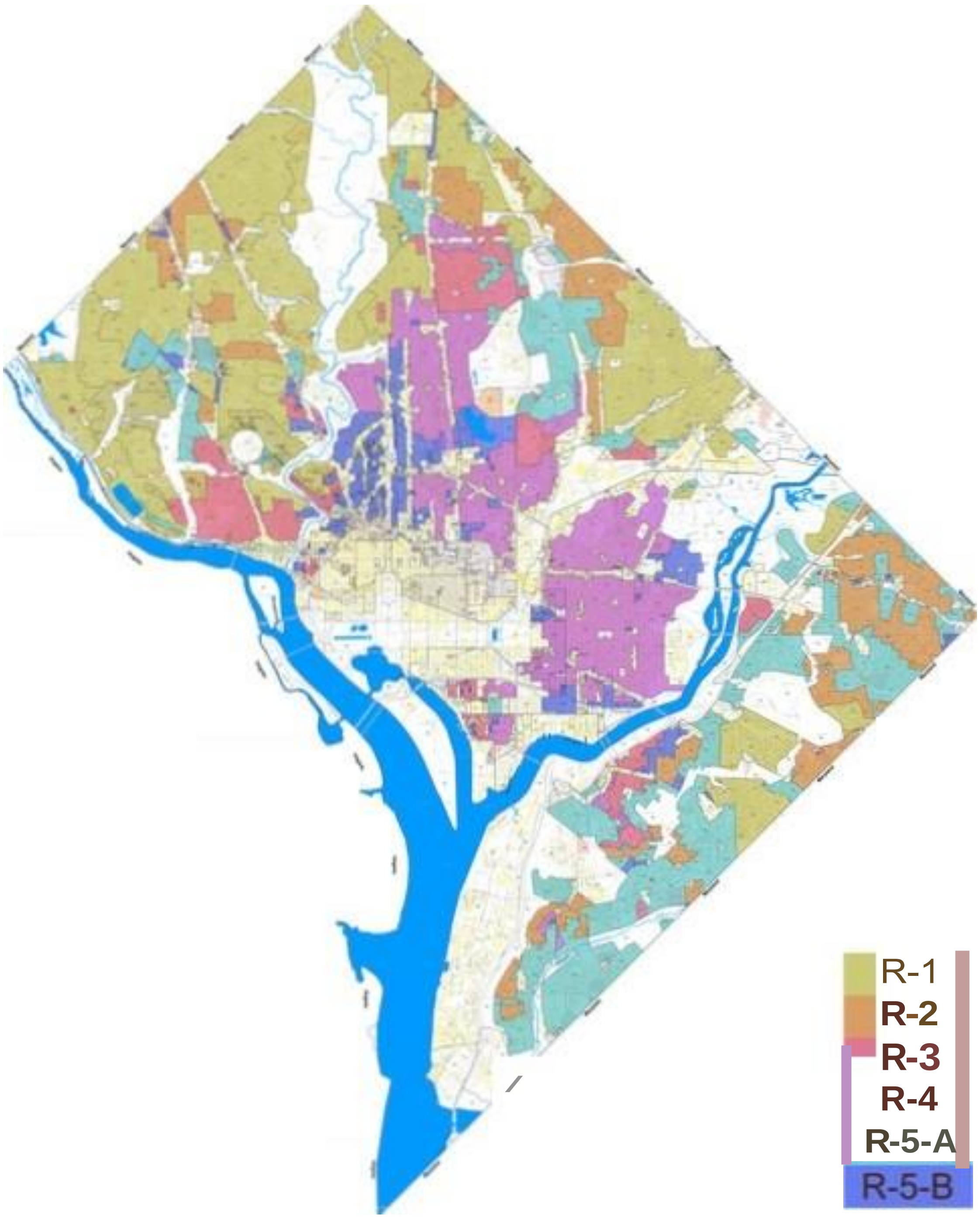

Figure 2.16: Washington DC zoning code

Figure 2.17: the movie Her filmed in Pudong Shanghai to render Future LA

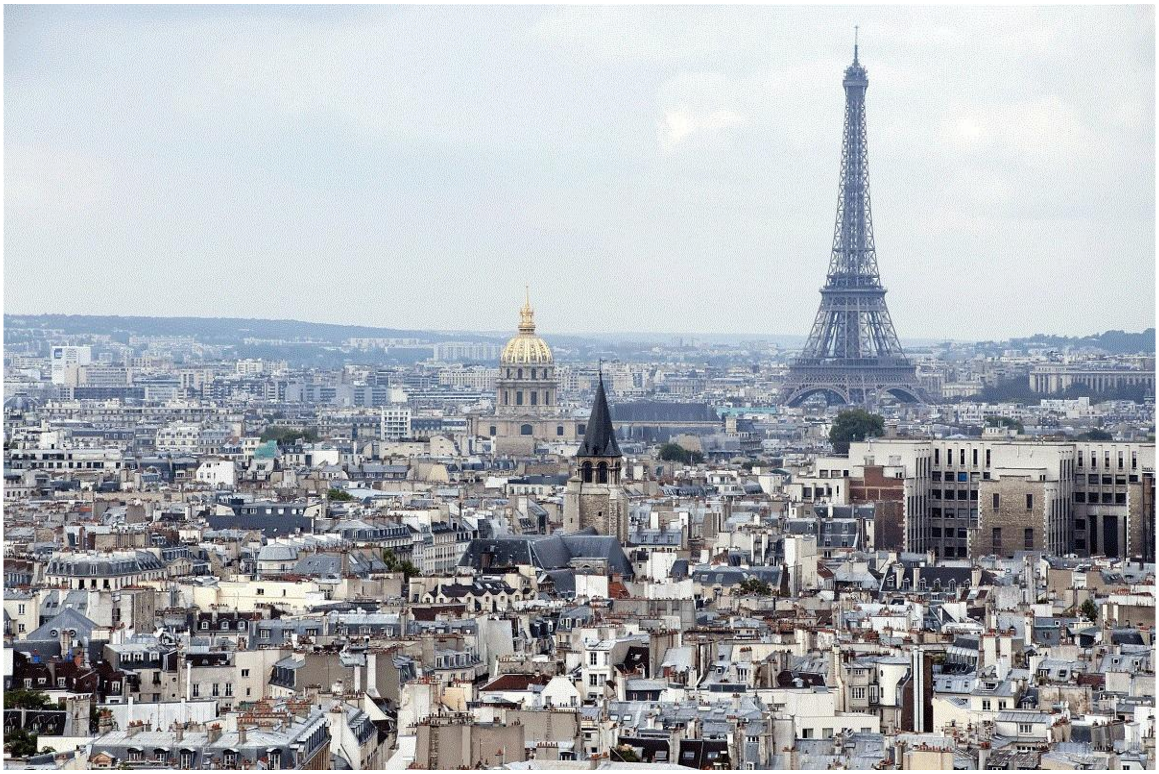

Figure 2.18: Skyline of Paris

mative change seems implausible and not likely in the near future, but cities can undergo metamorphosis when money and regulations are not an issue.

2.3.6 The Renovation - Paris

Take the mid-19th century renovation of Paris as an example. Paris was once described by one of its residents as an immense workshop of putrefaction, where misery, pestilence and sickness work in concert, where sunlight and air rarely penetrate. terrible place where plants shrivel and perish, and where, of seven small infants, four die during the year. This is an incredibly stark description of Paris, when present day Paris is often fawned over for its wide boulevards, amazing architecture and extensive public transport system.

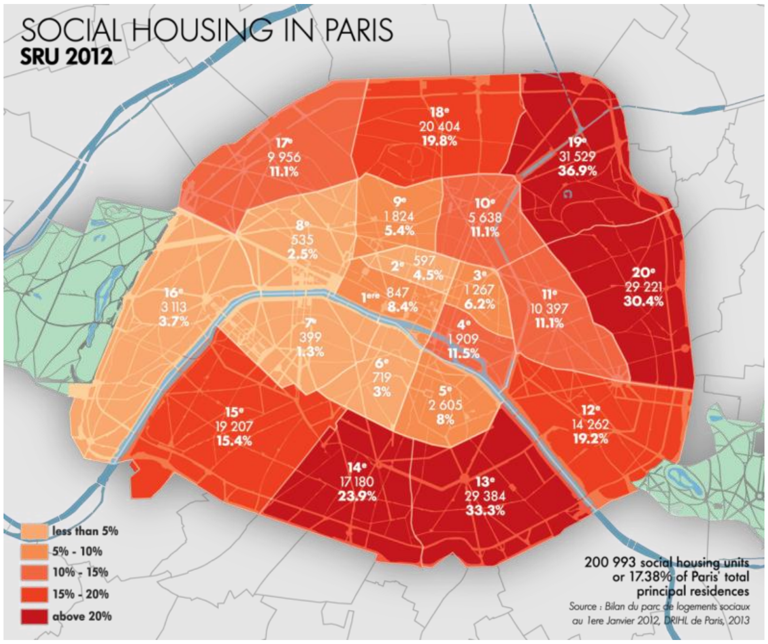

Figure 2.19: Social Housing in Paris

Paris of old was plagued with problems caused by the outdated planning of its medieval past. Paris needed renovation and Napolean III made it possible by giving the money and power needed to Baron Haussmann. He transformed these narrow streets and old dilapidated buildings into spacious boulevards. (Rue de Rivoli) He revamped all of these streets in red and created two new parks for the cities residents. Napolean III and Haussmann helped transform Paris into the charming city of light that 16 million tourists now visit every year. But it may be time to start rethinking Paris city planning once again. The lack of housing in central Paris has caused prices to raise so high that only the rich can afford it. Forcing the working-class families of Paris to the outskirts of the city. Creating huge disparity of wealth between the center and outskirts.

The map of Social housing of Paris shows the concentration of social housing as a percentage of total residences, with the largest percentages being located furthest from the city

Figure 2.20: The Montparnasse Tower and Paris skyline

center and even now these people are being forced further outside the city limits as gentrification occurs. Paris is no stranger to revolts of the working class with notable riots in 1968, 2006 and just this year Paris saw more riots as new labor laws were passed giving employers more power to increase working hours, decrease holidays and decrease pay. The lack of affordable housing compounds these social problems and the main cause of these prices is Parisians unwillingness to build over existing buildings. During Haussmanns renovation of Paris height restrictions on buildings were raised from 16.5 to 19 meters, but the transformation of Paris took place in a time where elevators did not exist.

In 1967 the height restrictions were lifted and the Montparnasse Tower was constructed soon after. A building that is loathed by Parisians. It sticks out from the surrounded buildings like a sour thumb. There is a fine line between progress and regression. Paris renovated to rid itself of the claustrophobic narrow streets of the past, building higher without thought will bring it right back to that. The construction of this building resulted in the

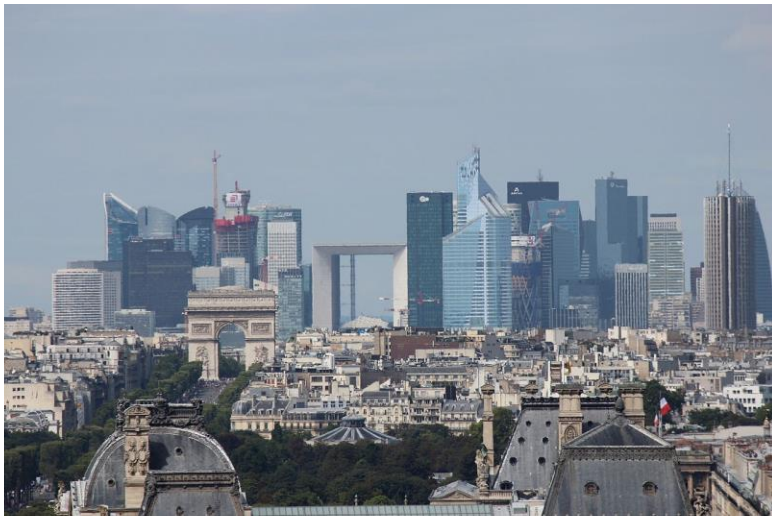

Figure 2.21: La Defense

height restriction being reduced to 25 meters for central Paris.

France is a heavily regulated country and when its rulers decide they do not want change, change will not occur. But one part of Paris proves that modern high-rise buildings can be introduced without destroying the character of the city. La Defense is Europe's largest purpose built business district housing 180,000 daily workers. La Dfense proves that skyscrapers can be incorporated into the historic background of Paris without destroying its charm, but La Defense is a financial district. It was built to create office space and houses just 25,000 permanent residents. There is little motivation to build high-rise buildings to reduce housing prices as it is cheaper to push people to the outskirts of the city.

Paris is not alone in these problems, London has been criticized for the same problems and the effects of this gentrification of working class neighborhood. There is no easy way of balancing preservation and growth, but we need to put our countries leaders under more pressure to consider this and not just follow the cheap easy route, because the problems will only get worse as our populations grow. If we allowed those height restrictions to stop us from building on 5th Avenue, the world would have been deprived of iconic buildings like the Empire State and Flat Iron Buildings. Great cities are not static, they constantly change and move with the times.

The greatest of our modern cities like New York and Singapore function because their height enables a huge number of people to work and live on a small piece of land. That is something our world is going to need going forward as our populations continue to grow.

2.4 New Material for the Future

The role of forests in carbon and climate mitigation may seem to be very straightforward. Since trees capture carbon as they grow and forests store massive quantities of it, it is easy to conclude that trees and forests should be treated as carbon sinks and left alone. But this kind of thinking reflects an incomplete understanding of the role of forests in carbon mitigation. In reality, forests have multiple roles to play in carbon mitigation, and forest management can help to optimize those roles. When forests are sustainable managed, wood is carbon-neutral, and acts as a repository of carbon, either as growing stock or as a value-added product[18].

Timber for construction is one of the many forest products used around the world. It is used in buildings both large and small; here we consider timber for the construction of buildings of six or more storeys, and the biochemistry and chemistry of wood modification

18. J. Bowyer. 2011. *Managing forestsfor carbon mitigation.* Dovetail Partners, Inc. http://www.idahoforests.org/img/pdf/DovetailManagingForestCarbon1011.pdf.

that could enable much larger buildings. There is ample global supply for the foreseeable future, and although there is a worldwide trend towards deforestation, it is generally due to clearing land for agriculture rather than logging for timber. Nevertheless illegal logging remains a concern.

2.4.1 Carbon Sequestration in Wood

Besides forming a natural ecological habitat as we covered in IPCC reports, forests are an important carbon sink by filtering CO2 out of the air and absorbing this in the biomass of the tree as biogenic carbon. The sustainable use of wood in durable products reduces the rise in CO2 levels in the atmosphere, thus acting as a brake on the greenhouse effect.

When you choose to build a building you have a choice of materials like concrete and steel or wood, and wood is the only material grown by the sun. As I like to say, its the only building material that uses photosynthesis to be generated. We do not have to build a photovoltaic panel to harness the sun. Nature has already done that for us, whereas steel and concrete, as good as those materials are, they represent 14% to 31% of mans fossil fuel use goes into the making and manufacturing of just steel and concrete[19]. Forest and trees have advantage of both being lower energy materials to work with, but also trees soak up CO2 as they grow. When you harvest them that CO2 is stored in the material, The material becomes a sink for carbon dioxide.

Trees sequestered carbon dioxide from the atmosphere faster when they are young, thus

19. *Using more wood for construction can slash global reliance on fossil fuels.* http://news.yale.edu/2014/03/31/using-more-wood-construction-can-slash-global-reliance-fossil-fuels.

the continuous sustainable harvesting of the forest makes Carbon Sequestration faster. That is really the exact opposite of most other materials that we build with in the world, and so trees have this very unique role in helping us counteract climate as long as the trees come from sustainable forest practices.

Although there are many misconceptions about this issue, for the sake of climate protection, actually the best thing to do is to preserve the forest through responsible management, while harvesting as much wood as sustainable from plantations in temperate and boreal climates for production of durable products such as furniture or construction products, which will act as additional carbon stores while providing the forest the opportunity to regenerate and produce new biomass (acting as additional carbon store).

While in the tropical regions deforestation is still continuing, in temperate regions such as in Europe and North America the net forest area, including the corresponding carbon stock, has been increasing steadily for several decades due to afforestation.

Demand of good quality certified tropical hardwoods suitable for outdoor use is higher than supply, resulting in illegal logging which, in turn, leads to the deforestation of tropical rainforests. Note that there are many other causes for deforestation besides illegal timber harvesting, such as the conversion of forest land to agriculture land, and forest fires.

2.4.2 A Brief History of Engineered Wood

The core principle of engineered wood construction, the lamination of small pieces of wood to create a product that is more than the sum of its parts, is not a new idea. German

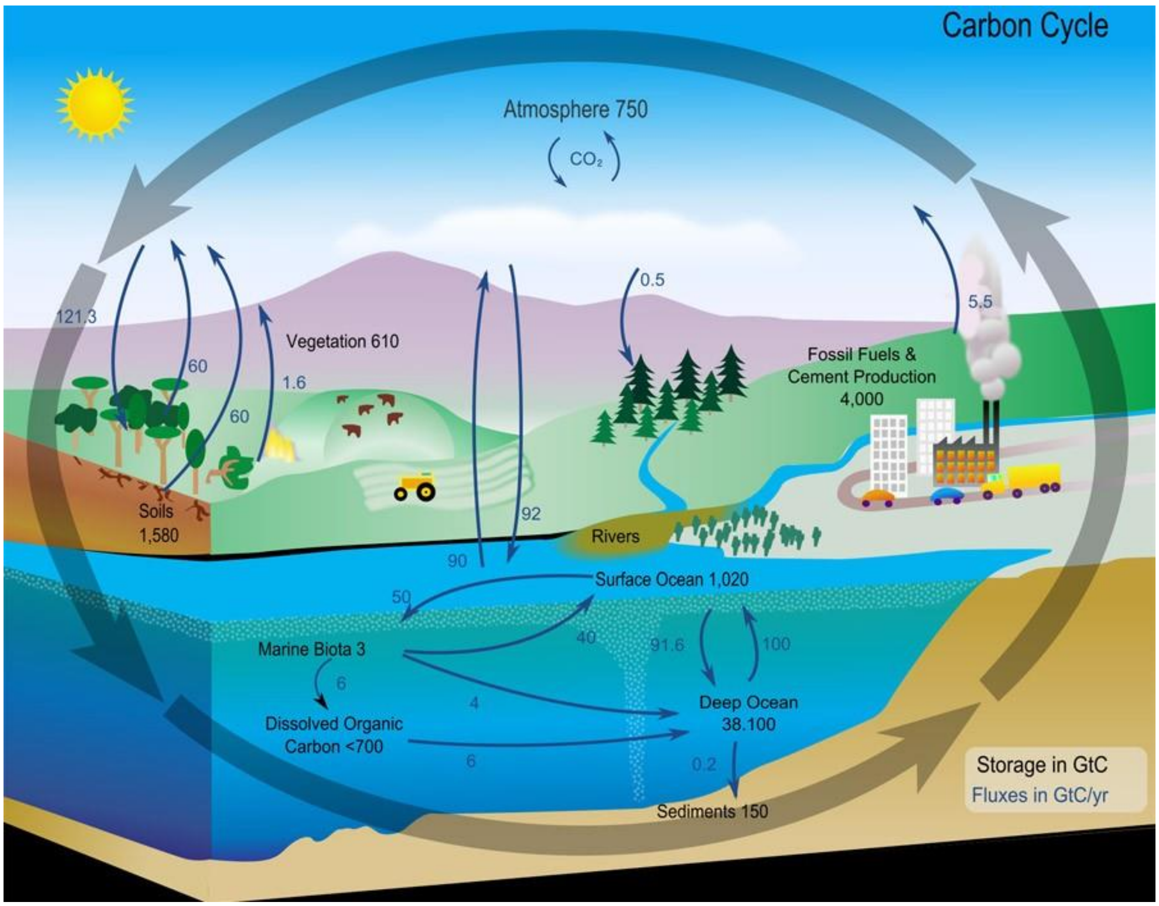

Figure 2.22: Carbon Cycle Diagram by NASA

and English architects and engineers made significant advances in laminated wood processes during the 18th and 19th centuries but the capability to produce these new materials was not streamlined enough for widespread use until the early 20th century. It was the industrialization of material production in the first half of the 20th century that really brought engineered wood into the future. The innovations of this era are responsible for the production processes used to make contemporary glue-laminated beams and the development of other engineered wood materials like plywood[20].

Plywood came of age in the United States in the 1940s due to technological advances and required production volumes brought on by WWII. It was declared an essential war material and the U.S. Government took control of production facilities, increasing their output volumes and efficiency of production to meet wartime needs. At this time there were about 30 war-time plywood production mills that were producing 1.2 and 1.8 billion square feet annually.

Plywood was a vital part of the war effort in nearly every division of the military. The Army built plywood barracks to house infantrymen because the material was so fast and easy to work with. The Navy built PT patrol boats out of the material that were notoriously light, fast, and easy to repair. The U.S. Air Force not only built plywood gliders that were used for reconnaissance missions, but the British Royal Air Force even built light bombers and spy planes like the Mosquito out of plywood because of blockades restricting imports of other materials[21]. Also notable are the experiments in bent wood processes done by Charles

20. Christian Muller. 2000. *Holzleimbau = laminated timber construction.* Basel Boston: Birkhauser-Publishers for Architecture. isbn: 9783764362676.

21. *History of apa, plywood, and engineered wood.* https://www.apawood.org/apas-history.

and Ray Eames for the U.S. military in the late 1930s and early 1940s. The Eames were hired by the military to investigate plywood forming for the construction of leg splints to be used by sailors, and in aircraft seats to be used in fighter planes, where light weight and long-term comfort are key issues[22].

2.4.3 Cross-Laminated Timber (CLT)

Cross laminated timber (CLT) refers to large panels that are created by laminating dimensional lumber. The panels can be very large depending on the structure requirements. Because they are very thick, they have the excellent fire properties of large timbers. Because they cross-laminated like plywood, they are very stable. Finally, because they are manufactured in a factory, quality control is very high and prefabricated panels can be easily and rapidly put together on the building site.

For example, for a CLT building in Britain, a four-person crew was able to assemble an entire floor of the nine-storey building in just three days. Cross-lamintated panels can be used to create very large and structurally-sound buildings. A seven-storey CLT structure that was tested for earthquake resistance suffered no damage. CLT is now being manufactured and used in Europe. There are now four producers in North American and perhaps more on the way, as builders, wood products manufacturers and building code officials learn more about this exciting new option.

The 2015 International Building Code (IBC) and 2015 International Residential Code

22. Pat Kirkham. 1998. *Charles and ray eames : designers of the twentieth century.* Cambridge, Mass: MIT Press. isbn: 9780262611398.

recognize CLT products manufactured according to the ANSI/APA PRG-320: Standard for Performance Rated Cross-Laminated Timber. Under the 2015 IBC, CLT at the required size is specifically stated for prescribed use in Type IV buildings. However, CLT can be used in all types of combustible construction wherever combustible framing or heavy timber materials are allowed. The National Design Specification (NDS) for Wood Construction is referenced throughout the IBC as the standard for structural wood design, including CLT. The 2012 IBC does not explicitly recognize CLT, but the 2015 IBC provisions for CLT can be a basis for its use under alternative method provisions[23].

2.4.4 Nail-Laminated Timber (NLT or Nail-lam)

Nail Laminated Timber is created by fastening individual dimensional lumber, stacked on edge, into one structural element with nails. In addition to being used in floors, decks and roofs, nail-lam panels have been used for timber elevator and stair shafts. NLT offers a consistent and attractive appearance for decorative and exposed to view applications. Sheathing can be added to one top side to provide a structural diaphragm and allows the product to be used as a wall panel element.

NLT is far from newits been used for more than a centurybut is undergoing a resurgence as part of the modern mass timber movement. Commonly used in floors, decks, and roofs, it offers the potential for a variety of textured appearances in exposed applications, and wood structural panels can be added to provide a structural diaphragm. NLT has also been used

23. *Mass timber in north america.* http://www.usgbc.org/education/sessions/mass-timber-north-america-10386963.

to create elevator and stair shafts in midrise wood-frame buildings.

Advantages of NLT include the ability to use locally available wood species and the fact that specialized equipment generally isnt necessary. An NLT system can be created via good on-site carpentry, though some suppliers do offer prefabrication, and this can have benefits depending on the scale and complexity of the project. Prefabricated NLT panels typically come in sizes up to 10 feet wide and 60 feet long, with wood sheathing preinstalled. When detailing NLT systems, designers need to account for moisture movement.

The IBC recognises NLT and provides guidance for structural and fire design. No product-specific ANSI standard is required, as the structural design of each element is covered by the NDS and applicable grading rules. NLT can be used in all types of combustible construction[24][25].

2.5 Case Studies in Mass Timber and new Technologies

Widely known definition of "Mass timber is a category of framing styles often using large panelized solid wood construction including CLT, NLT or glulam panels for floor and wall framing"[26].Mass timber structures offer sustainable advantages over steel and concrete because wood is a naturally renewable resource with relatively low embodied energy. Advance-

24. *Mass timber in north america.* http://www.usgbc.org/education/sessions/mass-timber-north-america-10386963.
25. *Nlt panels.* https://structurecraft.com/materials/mass-timber/nail-laminated-timber.
26. *Tall wood / mass timber building products.* http://www.rethinkwood.com/tall-wood-mass-timber/products.

Figure 2.23: Bird's eyes view of Metropol Parasol

ments in structural wood materials, such as cross laminated timber (CLT), have made larger and taller structures possible and opened up the possibility for wood to replace steel and concrete in many applications.

2.5.1 The Largest Wooden Structure - Metropol Parasol

Located at Plaza de la Encarnacion, The mushroom shaped Kerto LVL[27] the world's largest wooden structure. The Metropol Parasol project was part of the redevelopment of the Plaza de la Encarnacon, designed by J. MAYER H. Architects, this project becomes the new icon for Seville, a place of identification and to articulate Seville's role as one of the worlds most fascinating cultural destinations.

Metropol Parasol is approximately 50 meters long, 75 meters wide and 28 meters high.

27. *Lvl panel - kerto-q lvl.* http://www.metsawood.com/global/Products/kerto/Pages/Kerto-Q.aspx.

Figure 2.24: Construction of Metropol Parasol

The elements are glued Kerto-Q LVL, which are arranged in an orthogonal grid of 1.5 by 1.5 meters. Kerto wood elements were manufactured at Mets Woods building component factory in Aichach, Germany, comprising a total volume of approximately 2,500 m of parallel laminated veneer lumber (LVL).

Kerto-Q is cross-bonded Kerto, meaning that one fifth of the veneers are glued cross-wise. This structure improves the lateral bending strength and stiffness of the panel, thus increasing the shear strength when used as a beam. With cross bonded veneers, there is an substantial reduction in moisture-dependent variations across the width of the panel[28].

28. *Lvl panel - kerto-q lvl.* http://www.metsawood.com/global/Products/kerto/Pages/Kerto-Q.aspx.

Figure 2.25: Brock Commons features two concrete stair cores and a hybrid wood-and-steel floor structure. by Acton Ostry Architects

2.5.2 The Tallest Wooden Structure - Brock Commons student residence

This is the tallest mass wood hybrid building in the world at 53 meters tall, with housing 404 students of today, February 2017. After the completion of two freestanding concrete cores, it took less than 70 days to finished the building with prefabricated timber components.

It also had all the big names on the Mass Timber industry, local structural engineering firm Fast + Epp, and tall-wood adviser Architekten Hermann Kaufmann, in Vorarlberg, Austria, Brock Commons utilizes a combination of mass wood, concrete, and steel components. All of prefebricated timber components were supplied by Penticton, Canadabased Structurlam. The tower is topped by a roof comprising steel beams and decking, and clad in prefabricated wall panels, 70% of which is made from a wood-fiber high-pressure laminate.

Figure 2.26: Steel connector at floor-and-column intersection by Acton Ostry Architects

The hybrid structural system is used for a first floor concrete podium, two concrete cores and 17 stories of mass timber topped with a prefabricated steel beam and metal deck roof. Also the vertical loads are carried by the timber structure while the two concrete cores provide lateral stability. Glulam columns with steel connectors provide a direct load transfer between the columns and support 5-ply cross laminated timber (CLT) panels on a 2.85 meters by 4 meters grid that acts as a two-way slab diaphragm, similar to a concrete flatplate slab.

2.5.3 Solar Leaf - the bioreactor facade

The pilot project was shown at the International Building Exhibition (IBA) in Hamburg in 2013, as the worlds first bio-reactive facade generates renewable energy from algal biomass and solar thermal heat. The integrated system, which is suitable for both new and existing

Figure 2.27: SolarLeaf bioreactor facade by ARUP

buildings, was developed collaboratively by Strategic Science Consult of Germany (SSC), Colt International and Arup[29].

The biomass and heat generated by the facade are transported by a closed loop system to the buildings energy management centre, where the biomass is harvested through floatation and the heat by a heat exchanger. Since the system is fully integrated with the building services, the excess heat from the photobioreactors (PBRs) can be used to help supply hot water or heat the building, or stored for later use.

The advantage of biomass is that it can be used flexibly for power and heat generation, and it can be stored with virtually no energy loss. Moreover, cultivating microalgae in flat panel PBRs requires no additional land-use and isnt unduly affected by weather conditions.

29. *Solarleaf - bioreactor facade.* http://www.arup.com/projects/solarleaf.

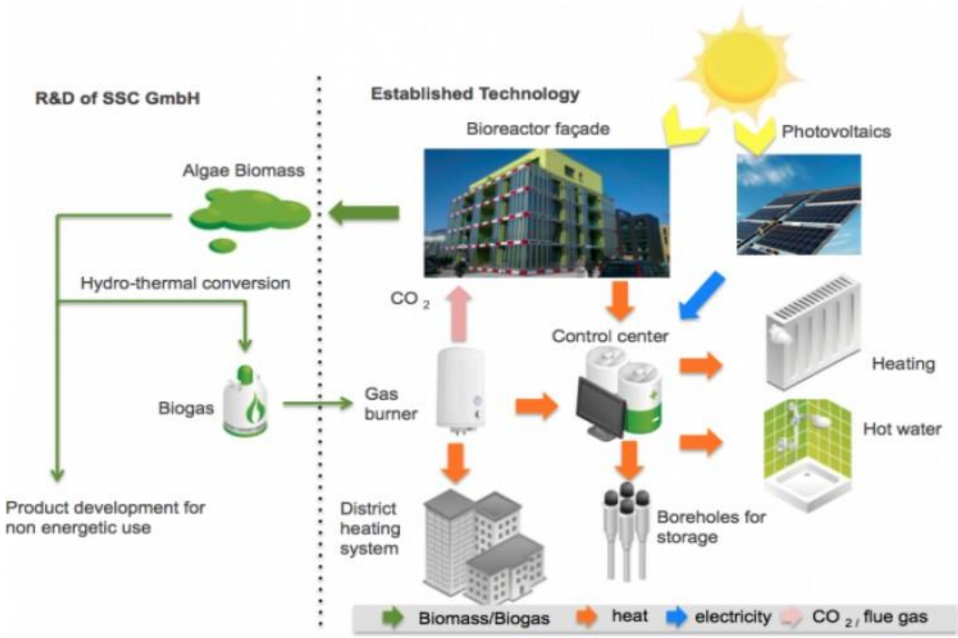

Figure 2.28: BIQ house and Bioreactor diagram

In addition, the carbon required to feed the algae can be taken from any nearby combustion process (such as a boiler in a nearby building. This implements a short carbon cycle and prevents carbon emissions entering the atmosphere and contributing to climate change.

Because microalgae absorb daylight, bioreactors can also be used as dynamic shading devices. The cell density inside the bioreactors depends on available light and the harvesting regime. When there is more daylight available, more algae grows providing more shading for the building[30].

2.5.4 Algae as Food for Humans

Algae can be a formidable environmental foe for the same reason that farming them seems so attractivebecause they can prosper with so little. Warmth, sunlight, and nutrient-tainted

30. *Solarleaf - bioreactor facade.* http://www.arup.com/projects/solarleaf.

waters are all they need. The majority of algae that are intentionally cultivated fall into the category of microalgae. Macroalgae, commonly known as seaweed, also have many commercial and industrial uses, but due to their size and the specific requirements of the environment in which they need to grow, they do not lend themselves as readily to cultivation.

Commercial and industrial algae cultivation has numerous uses, including production of food ingredients such as omega-3 fatty acids or natural food colorants and dyes, food, fertilizer, bioplastics, chemical feedstock, pharmaceutical, and algal fuel, and can also be used as a means of pollution control.

Spirulina is a biomass of cyanobacteria (blue-green algae) that can be consumed by humans and other animals. Some of the health food supplement producers are putting it into market as juices, like Naked's popular Green Machine which has 1.3 grams in every bottle. Every bite of Spirulina contains more protein and more iron than 20% fat ground beef.

"It is clear that there is substantial evidence for algae as nutritional and functional foods, yet there remain considerable challenges in quantifying these benefits, and in assessing potential adverse effects"[31].

Although it is limited at the moment of research and technology to fully supply or substitute the human food, but it is future of food production from buildings that we use as single propose of human activity.

31. Mark L. Wells et al. 2016. Algae as nutritional and functional food sources: revisiting our understanding. *Journal of Applied Phycology.* doi:10.1007/s10811-016-0974-5.

CHAPTER 3
RESEARCH METHODOLOGY

The onset of any research project and much like planning for a road trip, one must first choose the supplies needed that will result in a successful outcome. Those supplies include the method for collecting and analyzing data that will be employed during the course of the study. There are myriad options for research methods. Quantitative, qualitative, and mixed-methods are the research methods most commonly used in the social sciences. Each of these three research methods can then be broken down further into the more specific means of investigation that fall beneath each of them. Before formal data collection can begin, decisions need to be made about what type of questions will be asked, ”close-ended versus open-ended questions”,[1] whether there will be a focus on numbers versus informal responses, and so forth because these decisions will steer the researcher towards the most appropriate research style or design to use. Informally, Yin refers to ”a research design as a logical plan for getting from here to there, where here may be defined as the initial set of questions to be answered, and there is some set of conclusions (answers) about these questions. Between ’here’ and ’there’ may be found a number of major steps, including the collection and analysis of relevant data”[2] . In simpler terms, a research design can be defined as a ”blueprint” that will guide one’s research in everything from ”what questions to study,

32. John W. Creswell. 2014. *Research design : qualitative, quantitative, and mixed methods approaches.* Thousand Oaks, California: SAGE Publications. isbn: 9781452226101.

33. Robert K. Yin. 2012. *Applications of case study research.* Thousand Oaks, California: SAGE Publications. isbn: 9781412989169.

what data are relevant, what data to collect, and how to analyze the results”[3].

3.1 Literature Review

Literature review method was used for background research for all research topics addressed within this exegesis. As far as possible I have attempted to be thoroughly conversant in all of the topics studied. For the primary topics of Climate Change and Timber Architecture, although it has not been physically possible to exhaustively research every topic due to the number of areas addressed. For example IPCC WG1 report and references, and Forestry Industries at its current state was researched in depth by The specialists of the area, it is not possible for me to become an expert in such a topic that is on the periphery of this research focus. Where such limitations existed a reasonable level of literature review has been undertaken to understand the key concepts that need to be addressed. A broad range of media has been consulted, wherever possible including scholarly journal articles, thesis, reports, books, periodical articles, newspapers, websites and audio visual material to establish the historical background and the current state thinking on the subjects being reviewed. This literature review has been extremely broad, due to the number of topics that had to be studied and synthesized to develop the hypothesis.

34. Susan G. Philliber, Mary R. Schwab, and G. S. Sloss. 1980. *Social research: (guides to a decision-making process).* Itasca, IL: Peacock.

3.2 Case Study

"The case study strategy is most appropriate for 'how' and 'why' questions" especially when those questions involve "a contemporary set of events, over which the investigator has little or no control."[4] This research focuses on asking mostly "how" and "why" questions. More specifically, this research will seek to answer 'How can timber construction improve design and construction?' If so, 'why aren't we seeing more projects that are utilizing this technology?' These questions are of particular importance to architects and engineers because their respective professions are charged with protecting the health, safety and welfare of the public. Architects want the opportunity to design affordable, high quality, well-built housing that is expected to last. Engineers see the necessity for well-designed housing that will meet the needs long-term space expedition and affordable housing on Earth. Therefore, a mixed method research design using a series of exploratory case studies has been chosen as the method of investigation for conducting this research. This research design allows for a better understanding of the research problem by converging both quantitative (broad numeric terms) and qualitative (detailed views) data. It is an appropriate research method for this study because of the pragmatic or practical consideration that the subject matter (i.e. modular design of space architecture) has multiple influences affecting when it is used or not used. The findings from the quantitative and qualitative data collection will be combined during the data analysis portion of this research and conclusions and recommendations will be drawn at that point.

35. Robert K. Yin. 2012. *Applications of case study research.* Thousand Oaks, California: SAGE Publications. isbn: 9781412989169.

3.3 Summary of Methodology

In other fields such as Extreme Environment Architecture, the definition of 'Extreme Environment' had to be shown clear for future of timber construction projects whereas inadequate to understand the implications of the built projects did not yet populated enough for analysis. The Conception method was integral to the formation of the hypothesis that resulted from the literature review and industry research, this method was also integral to the process of project development. Each of the methods discussed above were indispensable in contributing to the formation of the hypothesis and case study projects.

The hypothesis and case study projects emerged from a clear and concise motivation and central question; how can design and construction improve? From this central question new questions emerged as the research developed through literature review and field research. A hypothesis was developed from this background research, from which a new set of refined questions arose. These questions are used to define the scope of attention for the case study projects and to assess them.

CHAPTER 4
DRAWINGS AND MODEL

4.1 List of Drawings

4.1.1 Building Program Diagram

4.1.2 Corner View Rendering

4.1.3 Lobby Floor Plan

4.1.4 Lobby Floor Plan

4.1.5 Typical Commercial Floor Plan

4.1.6 Typical Community Garden Floor Plan

4.1.7 Typical Office Floor Plan

4.1.8 Typical Residential Floor Plan

4.1.9 East Elevation

4.1.10 North Elevation

4.1.11 Solar Leaf Rendering

4.1.12 Lobby Structure Rendering

4.2 List of Physical Model Photos

4.2.1 Corner View

4.2.2 Bird’s eye View

4.2.3 Garden detail

4.2.4 Roof Community Garden

4.2.5 Community Garden Between each Block 1

4.2.6 Community Garden Between each Block 2

4.2.7 Column Detail

4.2.8 Roof Garden Topdown view

4.2.9 Possible Variation of Building Orientation

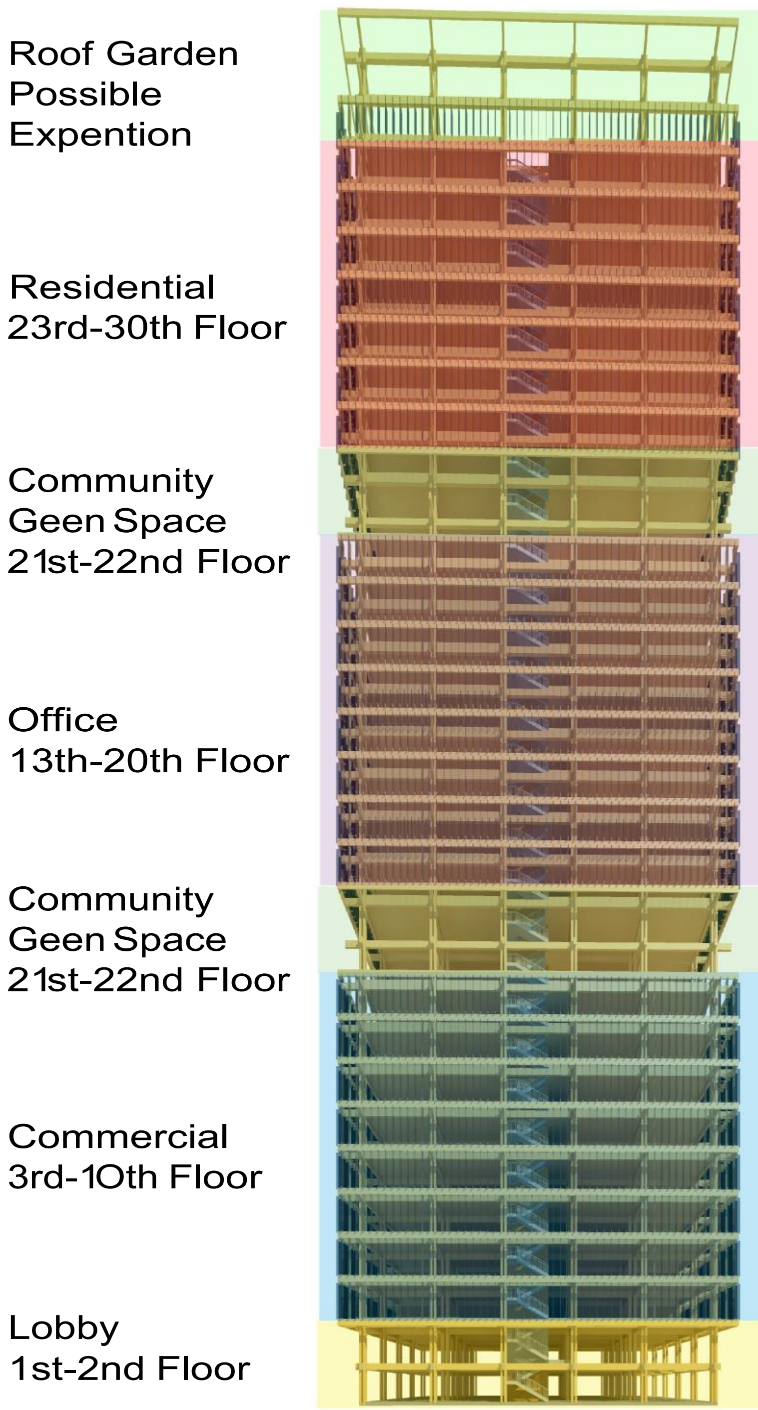

Figure 4.1: Program Diagram

Figure 4.2: Corner View Rendering

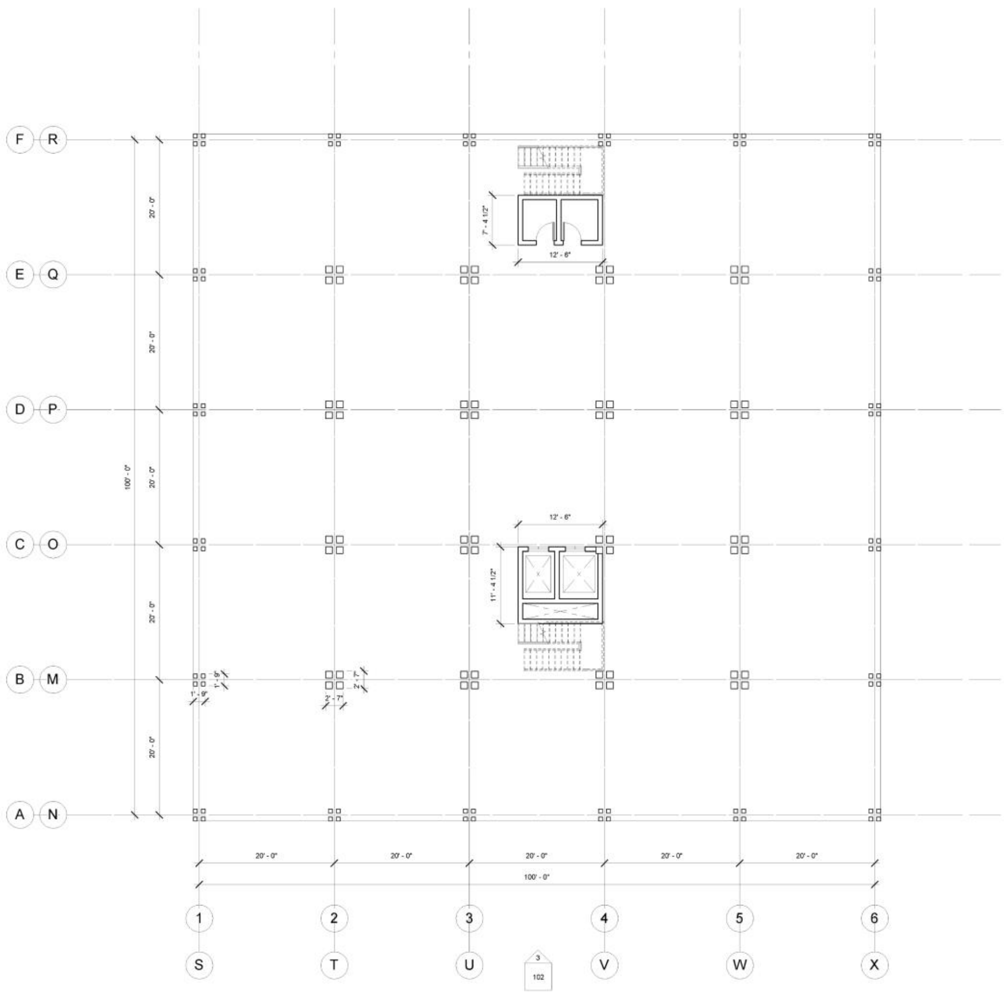

Figure 4.3: Lobby Floor Plan

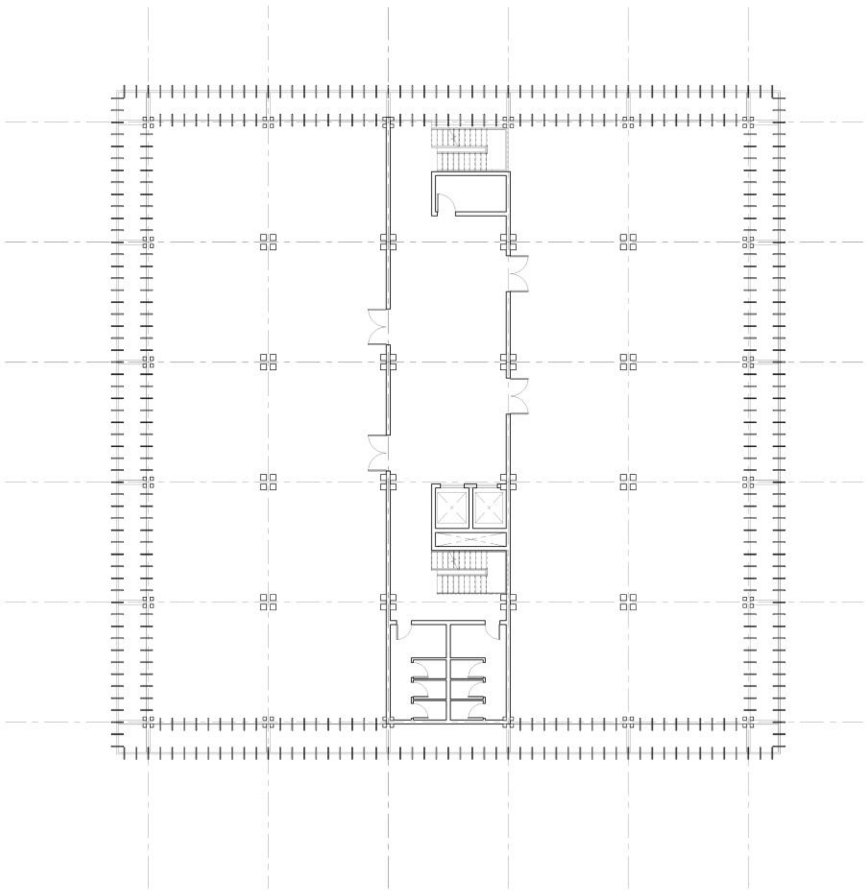

Figure 4.4: Typical Commercial Floor Plan

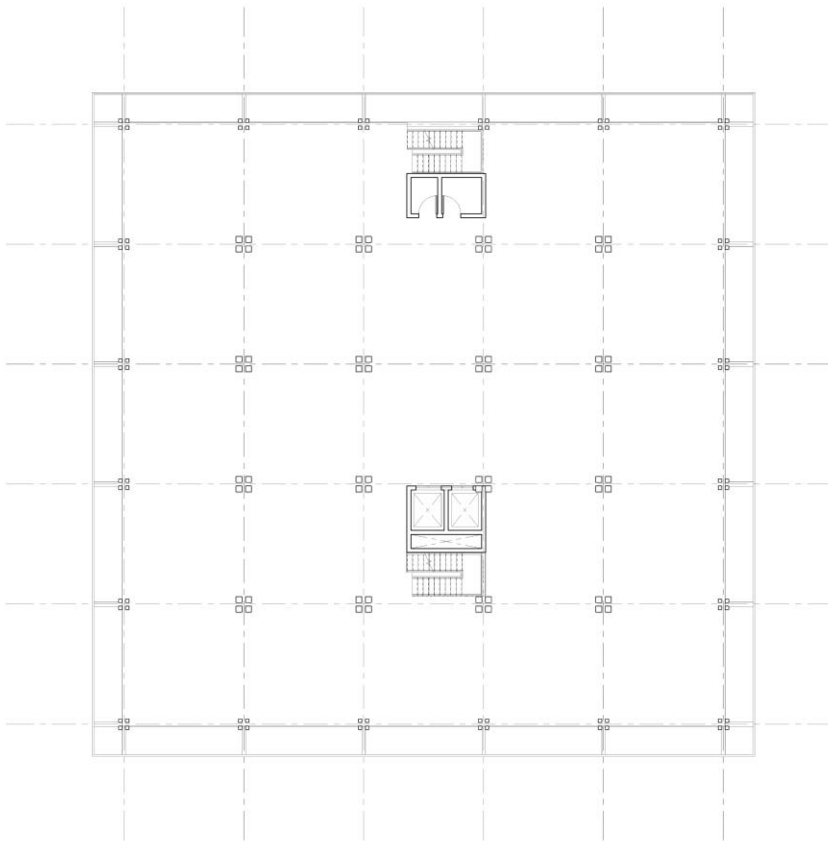

Figure 4.5: Typical Community Garden Floor Plan

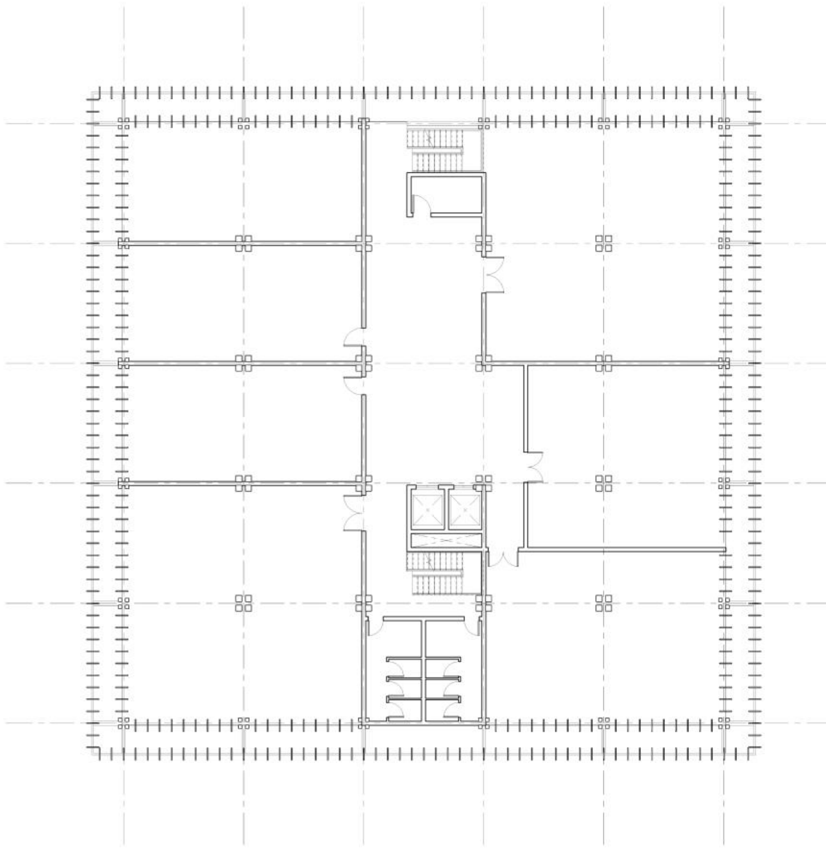

Figure 4.6: Typical Office Floor Plan

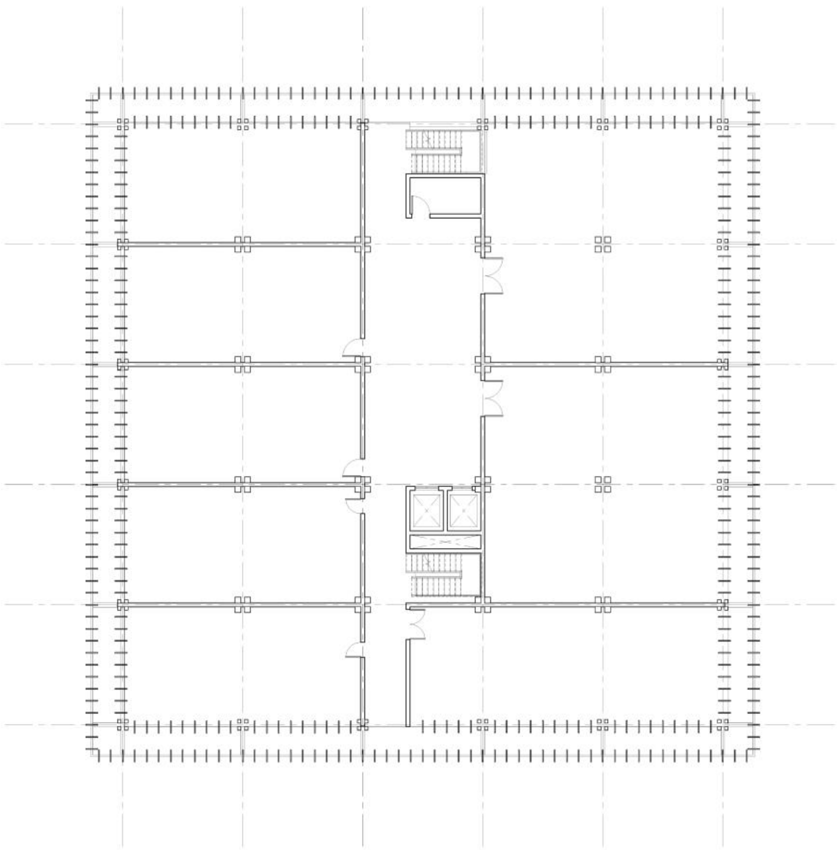

Figure 4.7: Typical Residential Floor Plan

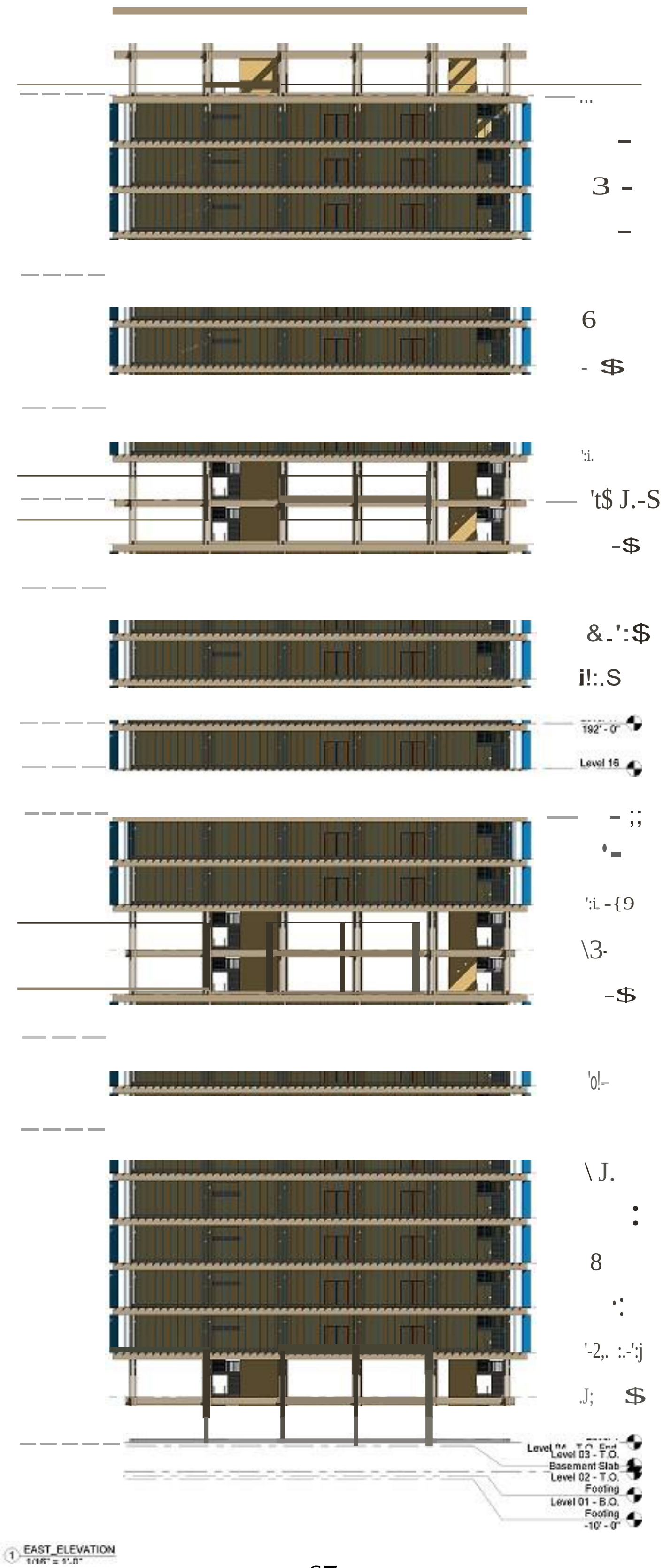

Figure 4.8: East Elevation

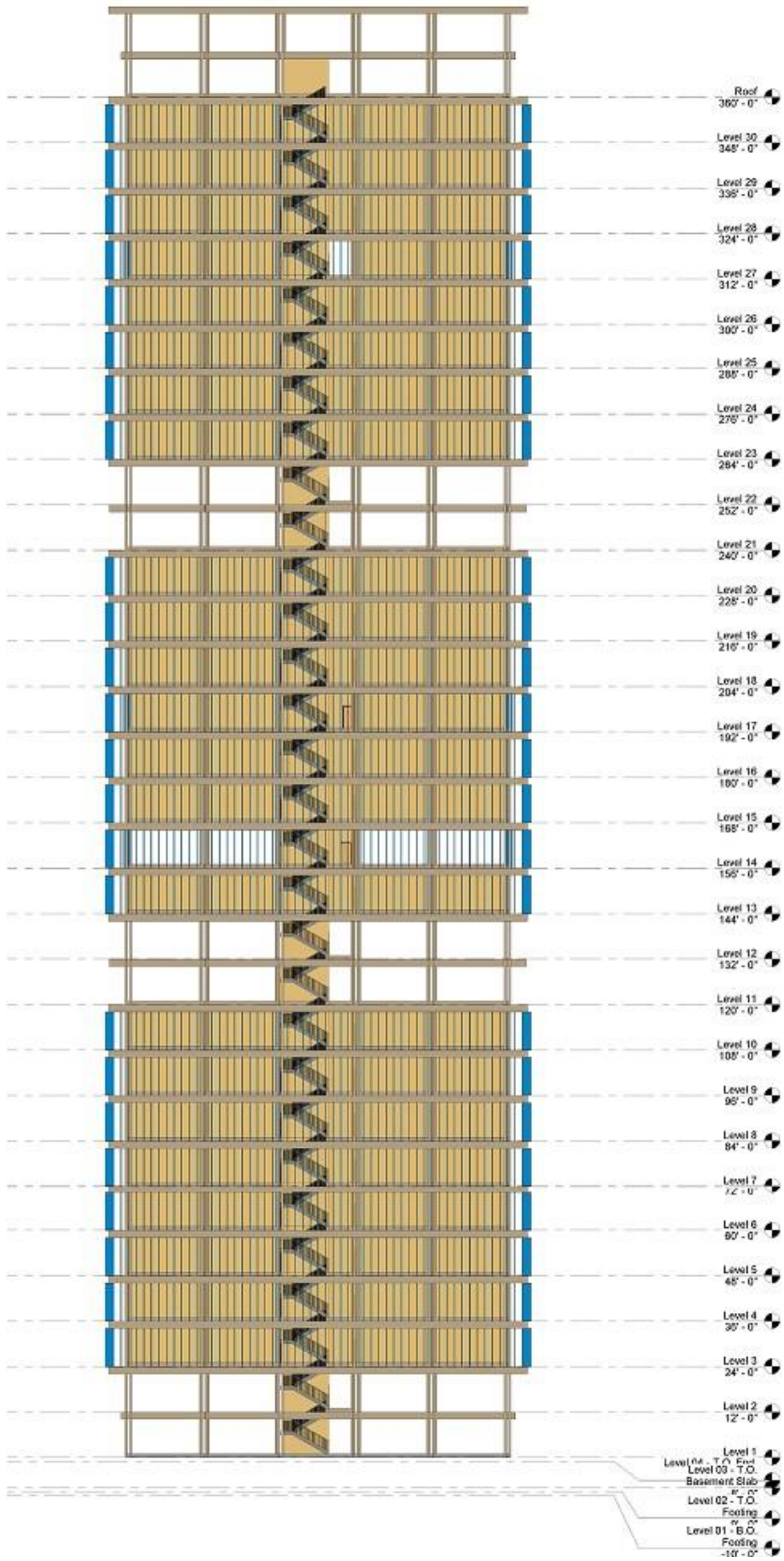

Figure 4.9: North Elevation

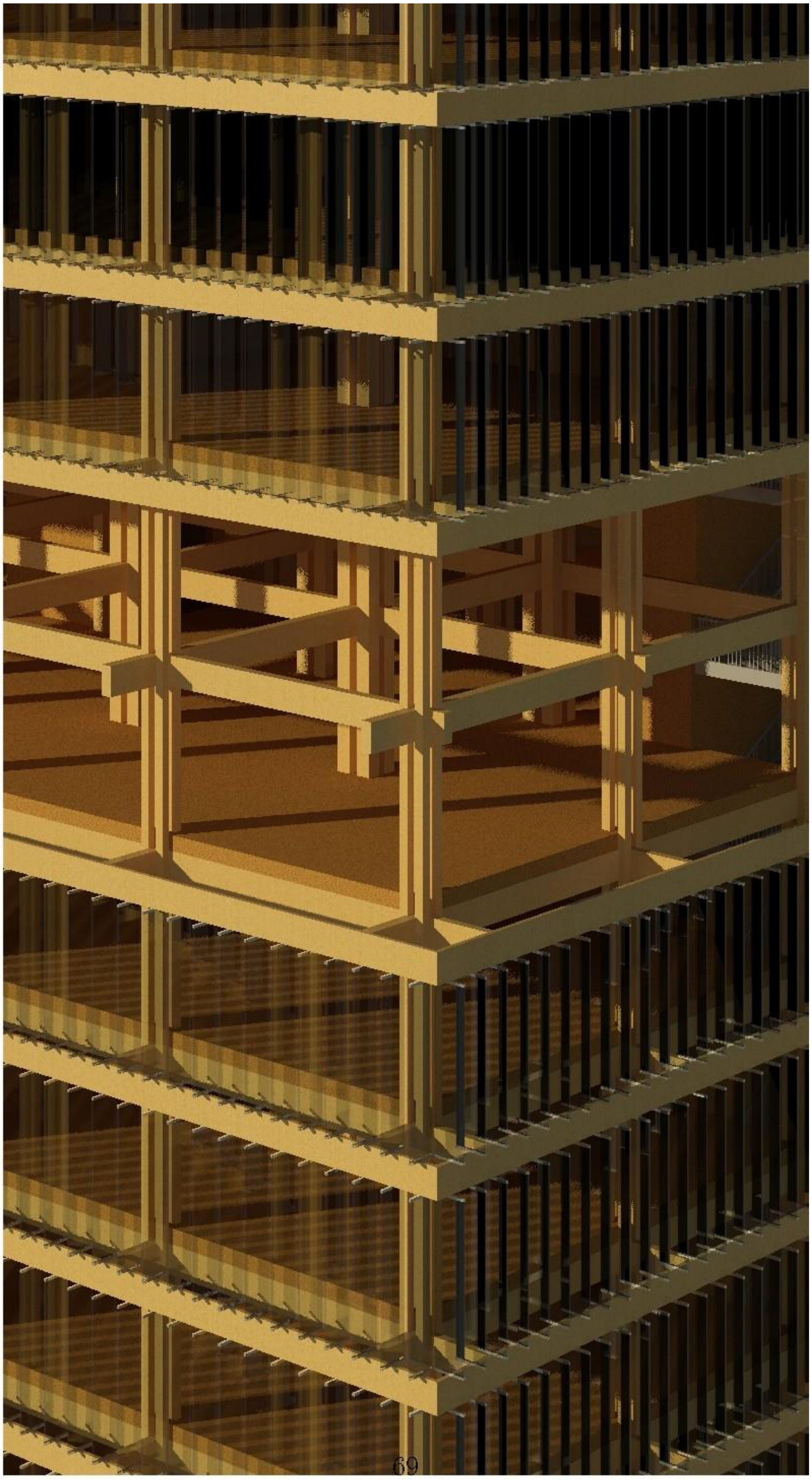

Figure 4.10: Solar Leaf Rendering

Figure 4.11: Lobby Structure Rendering

Figure 4.12: Corner View

Figure 4.13: Bird's eye View

Figure 4.14: Garden detail

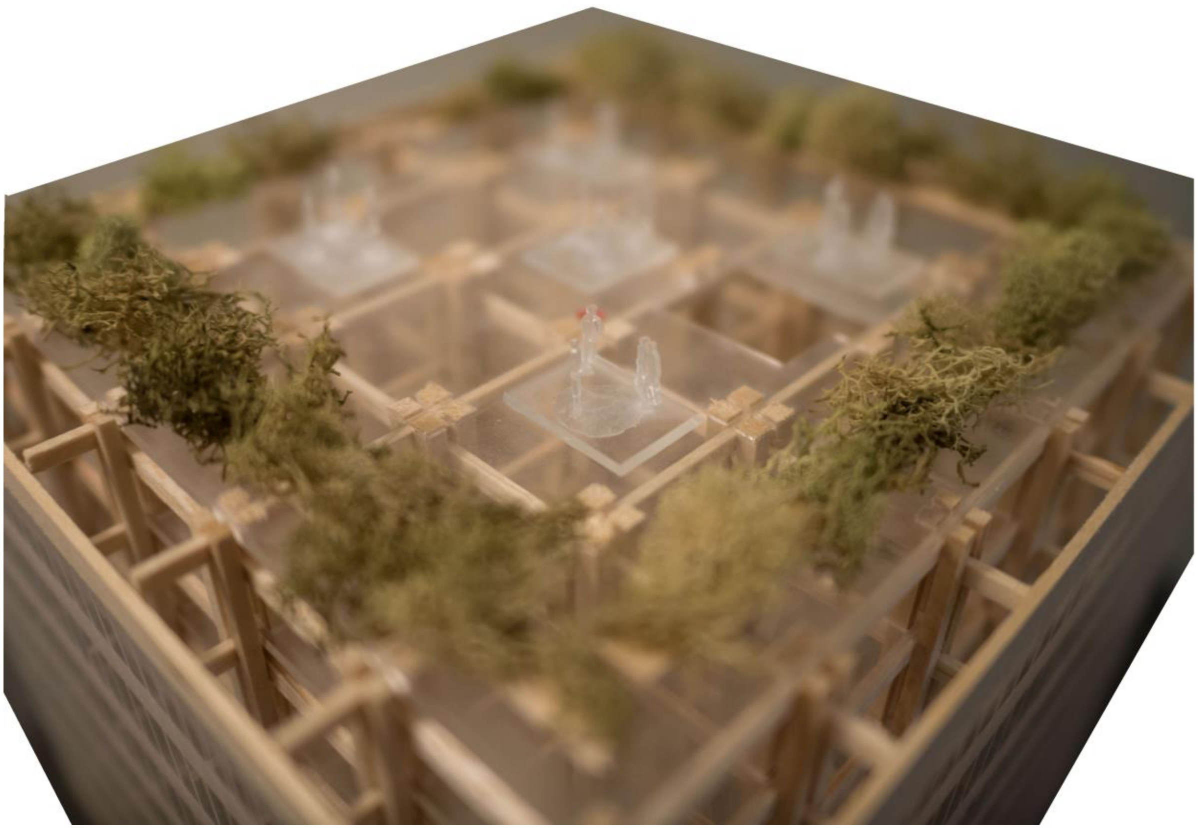

Figure 4.15: Roof Community Garden

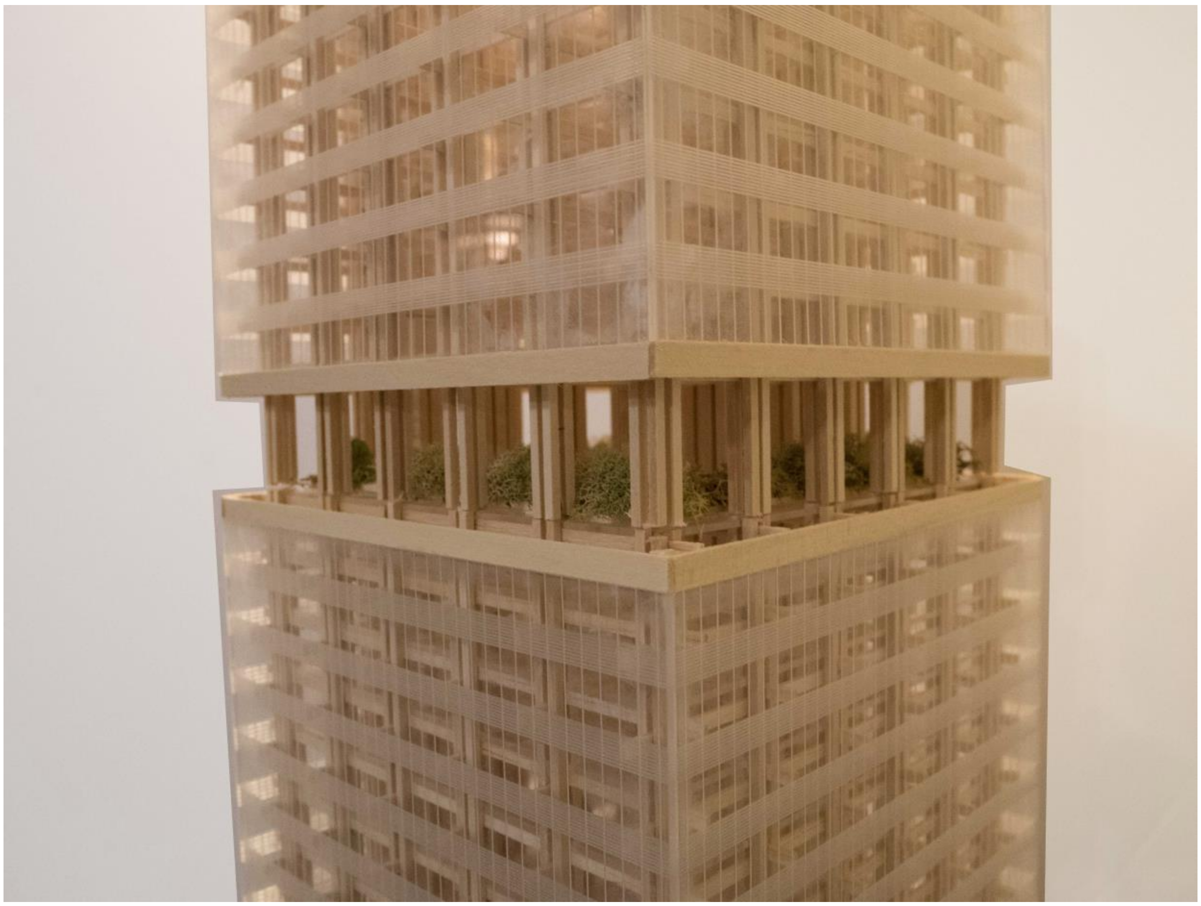
Figure 4.16: Community Garden Between each Block 1

Figure 4.17: Community Garden Between each Block 2


Figure 4.18: Column Detail

Figure 4.19: Roof Garden Topdown view

Figure 4.20: Possible Variation of Building Orientation

CHAPTER 5
CONCLUSION

Within a context of extreme risk to environmental forces, it is important to design buildings within the system that the surrounding environment has mandated. Responding to environmental conditions is not only a protective measure, but also benefits future generations. In the midst of dramatic climate shifts, housing design translates into a matter of immediate life safety for existing populations. In response to these deficiencies, the design of remote settlements in the extreme environment must be constructed in accordance with ideas of self-sufficiency and supplementary back-up energy systems. Many vernacular building traditions can serve as a reference for designing environments that are holistically sustainable within the extreme climatic conditions, challenging comfortable human habitation.

As the ending of this more timber high rises are being built among major cities, such as, Los Angeles, New York, Vancouver in North America. Due to more efficient and sustainable methods to produce timber materials, Higher tax of Carbon producing material such and cement and steel will gradually decrease. So called ”Timber Age” is coming. As I mentioned briefly about Building Codes of various climate zones around the world. It is evident that the timber can’t be the solution for every climate zones, but it’s the only sustainable and proven solution of human settlement since the beginning. Not only the governments and industries can work together to implement engineered timber more friendly to the consumer’s market, but also from school should push the boundaries construction materials. The younger generation of architects will have more freedom and conscious about coming dreadful future.

We as human kind started shelter with timber and **it** will be the last Material before we loose this beautiful planet.

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