ABSTRACT

Title of Document:	DESIGNING TO ENGAGE USERS IN SUSTAINABLE BUILDINGS
	Ashley Grzywa, Master of Architecture, 2015
Directed By:	Assistant Professor, Powell Draper, Architecture

This thesis is an investigation of how buildings can be designed to encourage pro-environmental behavior by engaging users in a sustainable built environment. By engaging users in sustainability building design can reestablish a cultural understanding of humanity's interdependence with the natural environment. The basis for investigation is a brief analysis of how cultural perceptions of the natural environment have changed over time and an understanding of what motivates pro-environmental behavior. Understanding of the types of work done and spaces used by building occupants throughout a work day informs opportunities for user engagement in the production, consumption, recycling and monitoring of energy, water and waste. Insights revealed through this research culminate in a design proposal for an office building that integrates user engagement with sustainable building performance and puts us on a path toward cultural transition to sustainable behavior and symbiosis with the natural environment.

DESIGNING TO ENGAGE USERS IN SUSTAINABLE BUILDINGS

By

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Thesis submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Master of Architecture
2015

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Preface

The title of this thesis is *Designing to Engage Users in Sustainable Buildings*. "Engage" means to 1) occupy, attract, or involve (someone's interest or attention), 2) participate or become involved in, 3) establish a meaningful contact or connection with. This is the foundation of my interest in the topic of sustainable occupancy. As an architect and a user I want the built environment to attract my attention, to interest me and to allow me to be involved and participate in shaping the built environment. I believe buildings can and should inspire people to make meaningful connections with their built and natural environment. My interest in this notion of engaging built environment arose relative to sustainability in two ways.

As a student of architecture, entering my final year of graduate school, having heard numerous lectures, read several books and taken multiple classes on the subject of sustainability, I still felt there was a hole in my education. I learned about all of the best practices, the rating systems, the criticisms and benefits, I'd visited sustainable projects and implemented sustainable design in studio projects. However, I still struggled to find a personal connection to the topic and wondered why all of the information was becoming old news and yet nothing seemed to be changing the way I or my colleagues worked or in the level of consumption and destruction around the world.

As a building user I found myself frustrated with the inconsistencies and inconveniences of so-called sustainable design. For example, moments when the low flow, automatic-flush toilet that was supposed to be more convenient and water conserving ended up flushing four and five times, triggered by the opening and closing of the stall door and using far more water than if I had been able to flush it once myself. Or when the lights flickered and turned off while I was working in a room and I had to get up to go turn them back on. Worse than that, I noticed other users becoming steadily more wasteful under the assumption that some automated system would pick up their slack. TVs and lights on manual switches were left on for hours, even days around school because people didn't think of turning them off, because they were used to things just shutting off by themselves these days. That which was supposed to be making life easier, more enjoyable and more sustainable is in fact making users lazy, irresponsible and less conscious of their behavior.

I began to realize that sustainable buildings were in fact just that, buildings. These amazing works of architecture and design achieving awards and accolades around the world championed a mixture of passive design strategies (building orientation, natural ventilation) and highly technical, sophisticated and automated thermal and lighting control systems. It seemed as though these buildings were sustainable objects, independent of users.

The work of this thesis questions the influence of users, buildings and the design process on sustainability. Extensive reading and course discussion throughout architecture school contributed to my intuition and understanding that buildings have an incredible power to shape human mood and behavior. I wanted to investigate how buildings could shape conscious, sustainable behavior of occupants, and at the same time, understand why this wasn’t being done already and what changes need to be made to better consider occupant behavior through design.

Dedication

This document is dedicated to building users. May they come to know their potential and responsibility for shaping the built and natural environments through their interactions with the places they inhabit.

Acknowledgements

As is often the case with large and lengthy endeavors such as this project, there are far more people who deserve far greater thanks than the few lines of appreciation I can offer here. That being said, the following are those whose invaluable contributions to the success of this endeavor deserve special recognition.

First, I must acknowledge my family for their physical and emotional support throughout my life and particularly during this trying year. Their encouragement was unwavering. Their love inspired me and kept me going in times of greatest stress and frustration.

Second, I extend my deepest gratitude to my friends and colleagues who, in the midst of their own struggles through the ups and downs of the thesis process, took the time to share encouragement, critique and the occasional beer. It is always a comfort to know one is not alone and I hope I have offered them at least a small measure of the support and friendship they have given me. For every day we worked together their dedication and success pushed me to be a better architect and friend.

Third, I appreciate the patience and kindness of my housemates. Three hard-working and dedicated scientists who work on very different projects at very different scales than architects. They have inspired me to see my work from different points of view, tolerated my absence during long nights and weekends spent in studio, did my share of the cooking and cleaning when I was too exhausted to do so, and listened patiently to my inspired, frustrated, angry and or stressed ranting throughout the year. These incredible individuals have shaped me in the most positive way and continue to be a joy and a comfort to come home to.

Last and certainly not least, words cannot express my appreciation for the support of faculty and staff in the School of Architecture, Planning and Preservation. Whether they were asking how thesis was going, offering a kind word, helping me accomplish one task or another or simply saying hello, they have made my time at the University of Maryland truly special. I offer a most special thanks to the members of my thesis committee for the dedication of their time, their critique, their encouragement, and especially for the inspiring and thought-provoking conversations that will continue to guide my curiosity and creation in this field.

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Chapter 1: Introduction

The past few decades have seen an increasing consensus among environmental researchers that our growing global population is and has been negatively impacting the environment and depleting resources faster than the earth can regenerate them. Words like “sustainable”, “green” and “eco-friendly” are becoming part of the global discourse in politics, culture and industry. Despite increased discussion, the notion of “sustainability” is complex and ambiguous. Terms have become overused and misused in a fad of “greenwashing”. Reports of environmental destruction beyond repair perpetuate a sense of helplessness. For many people, making positive change is perceived as an overwhelming task better left for governments and organizations than individuals.

Defining Sustainability

Although “sustainability” and related notions have been discussed and defined in many ways over the past several hundred years, two prevailing definitions have shaped the contemporary discourse, particularly as it relates to design. The first of these prevailing definitions appeared in a report titled “Our Common Future” published in 1987 by the United Nations’ World Commission on Environment and Development.[1] The report defined sustainable development in what is now known as the “Brundtland Definition”

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[1] World Commission on Environment and Development. 1987. *Our common future*. Oxford: Oxford University Press.

(named for the Commission's chairwoman, Gro Harlem Brundtland) as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[2] The second definition was popularized following the Rio de Janeiro Earth Summit of 1992 and describes sustainability as a triangle that considers economics, environment and society in equilibrium.[3] This approach to describing sustainability has also been referred to as "three Ps – people, planet and profit", or the "triple bottom line," first described by John Elkington in 1994.[4]

Beginning with the establishment of BREEAM (Building Research Establishment Environmental Assessment Methodology) in 1990,[5] building, product, infrastructure and other design rating systems have investigated the questions "what is sustainable design?" and "how can we achieve sustainable design?" Addressing the "needs of the present without compromising future generations" is often translated into the metric of reaching equilibrium or "net zero". Design industries have endeavored to achieve sustainability primarily through technological innovation and regulation. Rating systems have encouraged reduction of industrial and consumer waste, careful use and treatment of water, innovations in energy use and harvesting and the creation of high-performance products and buildings. More recently, new and revised

[2] World Commission on Environment and Development, *Our common future*
[3] Grober, Ulrich, and Ray Cunningham. 2012. *Sustainability: a cultural history*. Totnes, Devon, UK: Green Books.
[4] John Elkington, "Towards the Sustainable Corporation: Win-Win-Win Business Strategies for Sustainable Development," *California Management Review* 36, no. 2 (1994): 90–100.
[5] "What is BREEAM?", The BRE Group, accessed October 2014, http://www.breeam.org/about.jsp?id=66

rating systems have begun to call for design that surpasses net zero and achieves net positive impact on the natural environment. Philosophies such as those explained in the book *Cradle to Cradle* (2002) and the foundational documents of the Living Building Challenge (2006) rating system strive to achieve design that not only eliminates harmful impacts of development, but actually restores and improves the health of natural ecosystems.

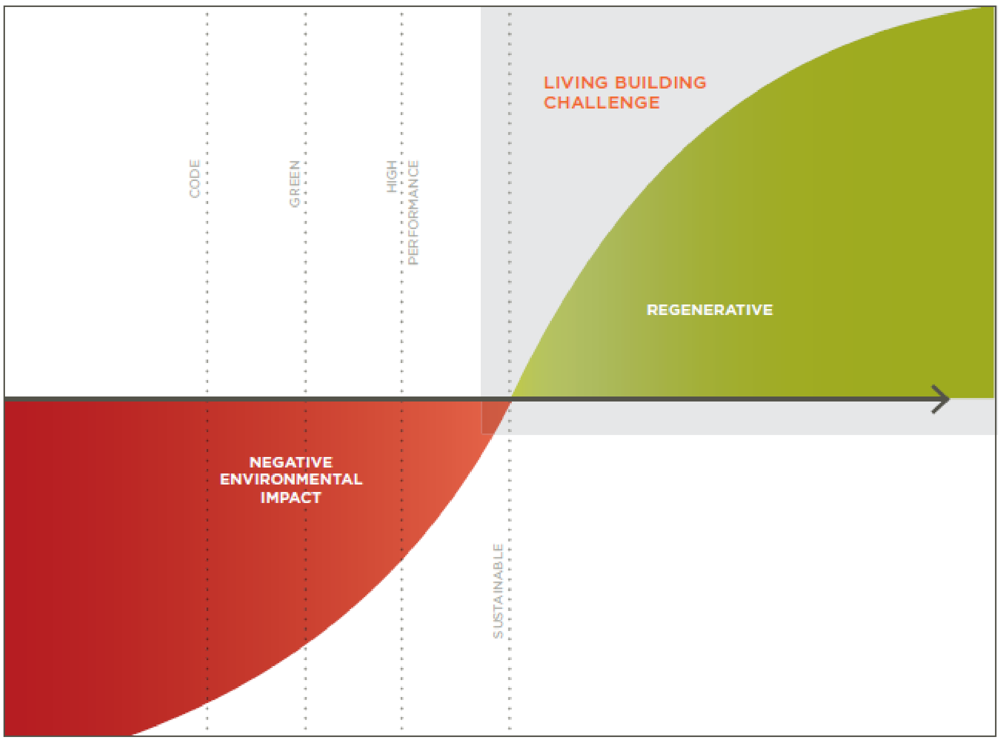

Figure 1.1 Diagram describing net positive ("regenerative") intentions of Living Building Challenge Certification, Living Building Challenge Version 3.0, 2014

Coming Up Short

Despite the achievements of sustainable design, natural resources continue to be exhausted at a dangerous rate. The Global Footprint Network (GFN) is a nonprofit organization founded in 2003 that measures human impact on the planet. Each year, continuing work began by Andrew Simms and the New Economics Foundation, GFN identifies “Earth Overshoot Day,” the date on which “humanity’s demand on nature exceeds the biosphere’s supply, or regenerative capacity”.[6] This year Earth Overshoot Day was August 19, 2014, over one month earlier than the 2008 overshoot on September 23rd and four months earlier than the first Earth Overshoot Day on December 31, 1986.[7] It is becoming increasingly clear that efficient technology and regulation alone cannot compensate for the environmental demands of our increasing global population.

Changing Our Culture (Biocentrism vs. Anthropocentrism)

Conservationist Aldo Leopold (1887-1948) observed, “We abuse land because we see it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect.” Leopold described two competing conditions of the human-natural environment relationship. The first condition, known as *anthropocentrism*, describes the notion that humans are dominant over the natural environment which they perceive to have little or no intrinsic value, existing solely to serve their own needs and desires. The second condition, known as *biocentrism*,

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[6] “Earth Overshoot Day”, Global Footprint Network, accessed October 2014, http://www.footprintnetwork.org/en/index.php/GFN/page/earth_overshoot_day/

[7] “Earth Overshoot Day: living beyond the planet’s resources,” ICLEI, accessed October 2014, http://www.breeam.org/about.jsp?id=66

describes the notion that humans have an egalitarian relationship with the natural environment which is understood to have intrinsic value.[8]

Chapter one presents evidence that biocentrism was at one point the prevailing cultural understanding of the human-natural environment relationship and identifies examples throughout history of humanity's transition to an anthropocentric attitude. Many have argued that the cultural shift to conceiving of the natural environment as a resource for the service of humankind is what started us on the path to our current situation of resource depletion and environmental degradation.[9] In a 1972 address to attendees of the United Nations' Conference on the Human Environment, then Indian Prime Minister, Indira Gandhi remarked, "This overriding concern with Self and Today is the basic cause of the ecological crisis…Modern man must again learn to invoke the energy of growing things…to recognize…that one can take from the earth and the atmosphere only so much as one puts back into it…So can man himself be vital and of good heart and conscious of his responsibility."[10] Indira Gandhi understood that returning to a biocentric way of living would require people to be "conscious of responsibility" through participation in the natural growing and energy cycles.

[8] Barr, Stewart. 2003. "Strategies for sustainability: citizens and responsible environmental behaviour". *Area.* 35 (3): 227-240.
[9] White Jr., Lynn. 1967. "The Historical Roots of Our Ecological Crisis". *Science, New Series.* 155 (3767): 1203-1207.
[10] Grober, *Sustainability: A Cultural History*, 165

Opportunities for Architecture

In many ways, the building cultures of the industrialized and industrializing world have fallen prey to the anthropocentric attitudes of our society. Over the last several decades buildings have been designed as sealed boxes, capitalizing on the availability of cheap energy to provide climate control, ventilation and artificial lighting. Although sustainable design initiatives have helped to reform some of these practices, we still conceive of buildings as mechanized systems outside of the influence of occupants. Those responsible for designing and building have relied on mechanization and automation to improve performance and make buildings more sustainable rather than designing buildings that encourage, even demand, conscious sustainable behavior of the building occupants.

Buildings provide a unique opportunity to engage users to learn about and shape their built and natural environments in a positive way. David Orr, in describing the power of building design in environmental education for students, makes a point that can easily be imagined to apply far beyond academia. “The design and operation of buildings is an opportunity to teach students [people] the basics of architecture, landscape architecture, ecological engineering for cleaning wastewater, aquaculture, gardening and solar engineering. Buildings that invite participation can help students [people] acquire knowledge, discipline, and useful skills that cannot be acquired other than by doing."[11]

If we are going to achieve a sustainable world we have to encourage sustainable behavior and cultivate, on a cultural level, biocentric thinking and living. This research examines and demonstrates, how building design can encourage *user-participation* in sustainable building performance and enhance *user-understanding* of the impact of behavior on the built and natural environment.

[11] Orr, David W. 1994. *Earth in mind: on education, environment, and the human prospect*. Washington, DC: Island Press.

Chapter 2: Evolution of Environmental Perspective and Architecture

Humankind has always looked to the natural environment for food, shelter, recreation and socialization. The degree to which the natural environment has been understood to have intrinsic value beyond meeting the needs of people varies across cultures and over time. Humanity's changing perceptions of ourselves relative to the natural environment are evident in politics, religion, science, industry and buildings. This chapter will briefly identify the prevailing perceptions of nature and related manifestations in buildings at critical periods in human history. It is important to understand that examples given do not necessarily exist solely in the category in which they are described, nor do they represent every culture within a specific era or the entire variety of attitudes across eras. The discussion aims to present a cross section of prevailing theory regarding humankind's transition to a predominantly anthropocentric culture and offers insights as to how we might best conceive of ourselves as part of the natural environment.

Nature as Gift

Studies of early civilizations around the world indicate a cultural valuing of the natural world. Many theorists speculate that the biocentric views of many early civilizations were rooted in religion. Reverence for natural cycles has been found in the mythology of cultures from the Mediterranean and the Near East all the way to the Americas, celebrating the seasons of renewal, growth, planting and harvest and expressing humility in the cold, dry, barren season.[12] Philosopher and Roman Emperor Marcus Aurelius' captured the cultural understanding of the natural world as a gift from the gods within which humankind exists when he remarked, "All that is from the gods is full of providence…From thence all things flow…All things are implicated with one another…For there is one world made up of all things."[13] Social scientist Don E. Marietta, Jr. observes, "The Pagan religions show awareness that human welfare could not be separated from the natural world."[14]

The emergence of Judeo-Christian theology saw a rejection of Pagan practices and translated the notion of the natural world from that of a gift which the gods invited humans to share, into a gift given by God to serve humankind's needs and desires.[15] Noted historian Lynn White, Jr. explains that, especially among Western cultures, Judeo-Christian doctrine supplanted the cyclical notion of time in the natural world and imposed a non-repetitive, linear notion of time (beginning with the story of creation) in which, "Our daily habits of action…are dominated by an implicit faith in perpetual progress."[16]

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[12] Marietta, Don E. 1994. *For people and the planet: holism and humanism in environmental ethics*. Philadelphia: Temple University Press.
[13] Marcus Aurelius. 1990. *Meditations of Marcus Aurelius Antoninus*. Hoboken, N.J.: Bibliobytes. http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=2008407.
[14] Marietta, *For people and Planet*, 17
[15] Grober, *Sustainability: A Cultural History*, 39
[16] White, "The Historical Roots of Our Ecological Crisis", 1205

Nature as Specimen

The notion of nature as specimen developed concurrently with the notion of nature as resource (discussed in the following section). Beginning during the Renaissance and continuing through the Enlightenment science began to supersede religion as the prevailing authority on the natural environment. Scientific investigation into how the natural world works and how the Earth exists within the larger universe was seen as necessary in order to understand how to make efficient use of natural resources to meet rising demands on these resources.[17]

Around 1730, Carl Linnaeus began to classify plant species using a nomenclature system of his own invention which today serves as the backbone of the universal taxonomic classification of all known plant and animal species around the world. His interest in classification was largely derived from an investigation into the capacity of living organisms to sustain themselves through reproduction.[18] Linnaeus' belief that the capacity for living organisms to consistently reproduce in order to "perpetuate the established course of nature in a continual series"[19] is an example of "systems thinking."[20]

Scientific investigation during this period also gave rise to a contradictory attitude defined as "atomistic thinking" in which each organism or entity is

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[17] Grober, *Sustainability: A Cultural History*, Chapter 5
[18] Ibid, 90
[19] Linnaeus, quoted from Grober, *Sustainability: A Cultural History*, 92
[20] Marietta, *For People and Planet*, 20

conceived of as separate from all other organisms. A privileging of individual things rather than whole systems in which individuals exist resulted in "little attention paid to the relationships that made nature a vast life-supporting system."[21] As a consequence, the impact of several decades, even centuries of human exploitation of natural resources on the ecological health of the planet has only recently begun to be measured and understood.

Nature as Resource

The first section in this chapter presented the theory that the fundamental shift in humanity's perception of nature as a resource to serve our needs and desires was a result of the rise of Judeo-Christian theology. While this assertion has been debated among historians and social scientists, there is a general consensus that at some point in human history we began consuming natural resources with the assumption that it was our right (divine or otherwise) to do so and that those resources would continue to be available without conflict or consequence. Rapid, large-scale mining of the Ore Mountains in the Silver Rush of 1477 and the deforestation of much of Western Europe to meet timber demands for fuel, ship building and urban construction beginning in the early Renaissance are two examples of this thinking.[22]

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[21] Ibid, 20
[22] Grober, *Sustainability: A Cultural History*, 44

At several periods during the 14th-18th century it was realized that rapid, large scale consumption was threatening continuous supply, particularly in terms of deforestation. As early as 1476 the Venetian Senate passed laws to regulate the use of forests. Similar programs were adopted in France (1600s), Germany (1760) and other areas of Europe, each with varying degrees of success.[23] Despite conservation efforts and regulations for the efficient use of timber, the growing population and development of urban areas increased demand for fuel and building material.

During the 19th and 20th centuries agrarian society gave way to urban industrialism and more and more people moved into cities. The rise of cheap fossil fuel energy and technological innovations contributed to an exponential increase in fuel consumption (Figure 2.1) and mechanization of mass production to meet the demands of a growing global population (Figure 2.2).

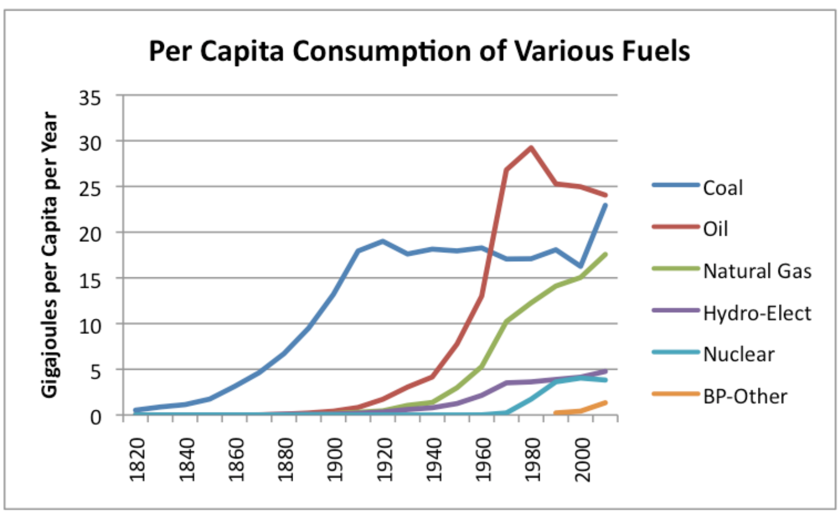

Figure 2.1: Per Capita Consumption of fuels by type

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[23] Ibid, 60, 71, 87

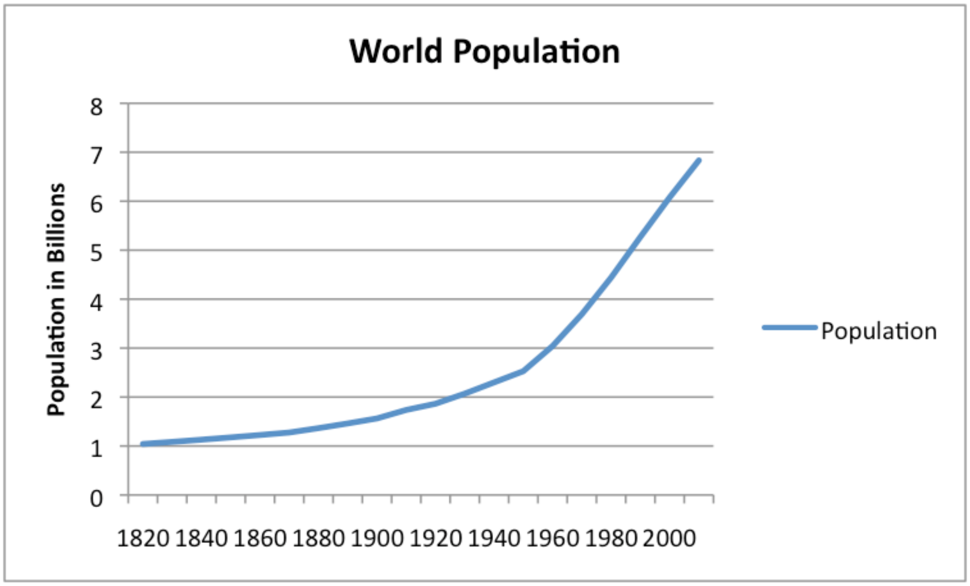

Figure 2.2: World Population Growth

In their book *Cradle to Cradle* architect William McDonough and chemist Michael Braungart identify this period as a milestone on our path to anthropocentric living. "With new technologies and brute force energy supplies (such as fossil fuels), the Industrial Revolution gave humans unprecedented power over nature…They could override nature to accomplish their goals as never before. But in the process, a massive disconnection has taken place."[24] In part the "massive disconnection" to which they refer is reflected in the overwhelming majority of buildings which are sealed, mechanically conditioned and electrically lit, physically separating occupants from contact with the processes of the natural environment. [example]

[24] McDonough, William, and Michael Braungart. 2002. *Cradle to cradle: remaking the way we make things*. New York: North Point Press.

Nature as Precious

In the 1960s and 70s people began to realize the potential environmental consequences of exploiting resources and generating waste. *Silent Spring* published in 1962 by marine biologist Rachel Carson identified DDT (a chemical insecticide used in farming in the United States beginning in the middle of the 1950s) as causing the death of numerous robins.[25] Her work presented the natural environment as something fragile that was being threatened by human activity. In subsequent years a number of publications and discoveries contributed to the idea that the earth was precious and finite. Notable among these were two photographs of the earth taken from space. The first, titled *Earthrise*, was taken by the crew of the Apollo 8 in 1968 (Figure 2.3) and the second, titled *Blue Marble*, was taken by Harrison Schmitt of Apollo 17 in 1972 (Figure 2.4)

Figure 2.3: *Earthrise*, NASA

Figure 2.4: *Blue Marble*, NASA

These images became widely published and presented the Earth as beautiful and rare. Harrison Schmitt, astronaut and photographer of *Blue Marble*, said,

[25] Grober, *Sustainability: A Cultural History*, 27-28

"The challenge for all of us, is to guard and protect that home, together, as people of Earth."[26]

The growing consensus of the natural environment as precious led to initiatives such as Earth Day. First celebrated in 1971, it endeavored to conserve and protect the environment for the environment's own sake. During this time researchers James Lovelock and Lynn Margulis developed and published the Gaia Hypothesis which conceived of Earth's biosphere, atmosphere, oceans and soil as an interconnected system, which "seeks an optimal physical and chemical environment for all life on this planet" and considered humankind as inseparable from that system.[27] At the United Nations Conference on the Human Environment in Stockholm in 1972 environmental consideration became a focus of global politics.[28]

This period inspired an investigation into alternative energies and a re-introduction of passive solar gain, daylighting and ventilation strategies in architectural design. Architects such as James Marston Fitch studied the dwellings of primitive cultures, remarking on their abilities to understand local climate conditions and respond to those conditions with locally available, renewable materials.[29] In 1979, architect Edward Mazria (who would later

[26]Quoted in Grober, *Sustainability: A Cultural History*, 26
[27] Grober, *Sustainability: A Cultural History,* 171
[28] Grober, *Sustainability: A Cultural History*, Chapter 12
[29] Fitch, James Marston and Branch, Daniel P. 1960. "Primitive Architecture and Climate." *Scientific American. 203 (6)*: 134-144.

author the Architecture 2030 challenge to reduce energy consumption) published *The Passive Solar Energy Book* as a guide for designing "an effective passive solar heated building".[30]

Nature as Broken

Throughout history humanity has debated the questions of if, how and to what extent human use of natural resources affects the overall health of the environment. In the past four decades or so we have seen an increase in research and monitoring of human impact accompanied by a growing consensus that human impact on the environment has been largely negative and will continue to have devastating consequences for human life on earth if we do not make significant, large-scale changes to the way we live.

Stephanie Mills, renowned author and lecturer in bioregionalism and ecological restoration, uses her article "Peak Nature?" to describe several of the environmental problems we are faced with today. Among these problems are climate change at a rate that exceeds organisms' abilities to adapt and evolve, consumption, pollution, waste and extinction that exceeds the natural rate of extinction by 100-10,000 times.[31] The title of the article is a play on another environmental phenomenon, "peak oil".

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[30] Mazria, Edward. 1979. *The Passive Solar Energy Book.* Emassus, PA: Rodale Press.
[31] Mills, Stephanie. "Peak Nature?," in *The post carbon reader: managing the 21st century's sustainability crises*, ed. Heinberg, Richard, and Daniel Lerch. (Healdsburg, Calif: Watershed Media, 2010), 97.

Despite recent popular use, the peak oil theory is not entirely new. The concept of peak oil, the moment in time when the extraction of petroleum reaches its maximum rate, was first introduced by M. King Hubbert in 1949. At the time, Hubbert was the Associate Director of the Exploration and Production Research Division for Shell Oil Company, Inc. In his article, "Energy from Fossil Fuels" published in 1949 in *Science*, Hubbert concludes, "The consumption of energy from fossil fuels is thus seen to be but a 'pip', rising sharply from zero to a maximum, and almost as sharply declining, and thus representing but a moment in the total of human history." [32] As can be seen in Hubbert's graph of fossil fuel consumption (Figure 2.3), Hubbert proposed two possible scenarios for the rise and fall of fossil fuel consumption, both of which reach their peak in the first half of the 21st Century.

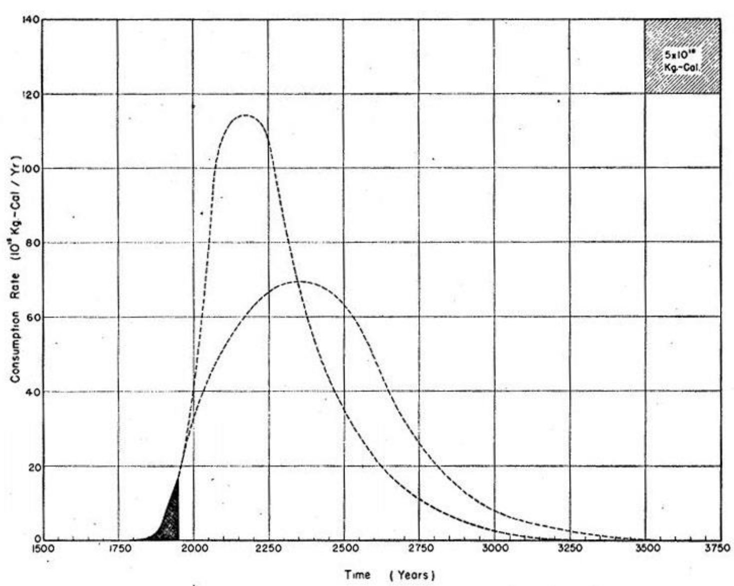

Figure 2.5: Rate of Consumption Curves for Fossil Fuels, Hubbert, 1949

[32] Hubbert, M. K. 1949. "Energy from Fossil Fuels". *Science.* 109 (2823): 103-109.

At the time of publication Hubbert's observations were shocking and may have seemed impossible in a world where fossil fuels provided abundant and cheap energy. More recently however, there is less a debate about *if* we will reach peak oil and instead researchers debate *when* we will reach peak oil (Figure 2.4). In comparing crude oil production in the United States from 1910-2010 to Hubbert's curve (Figure 2.5) it has been argued that, at least in the United States, we reached peak oil in the early 1970s.

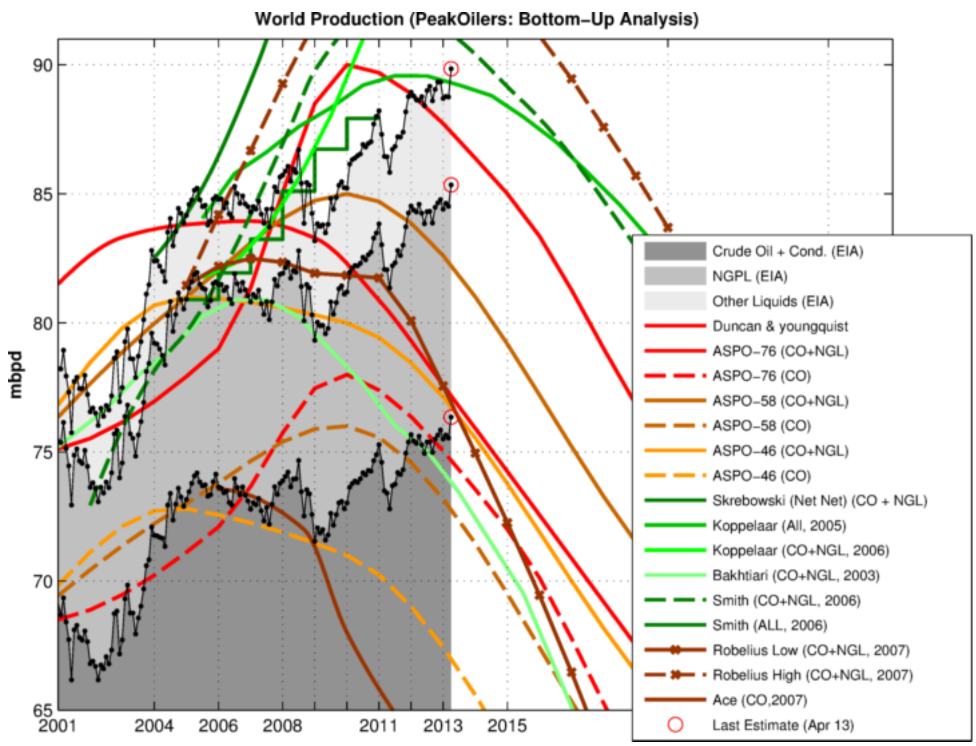

Figure 2.6: Selection of Peak Oil Models Compared to World Production

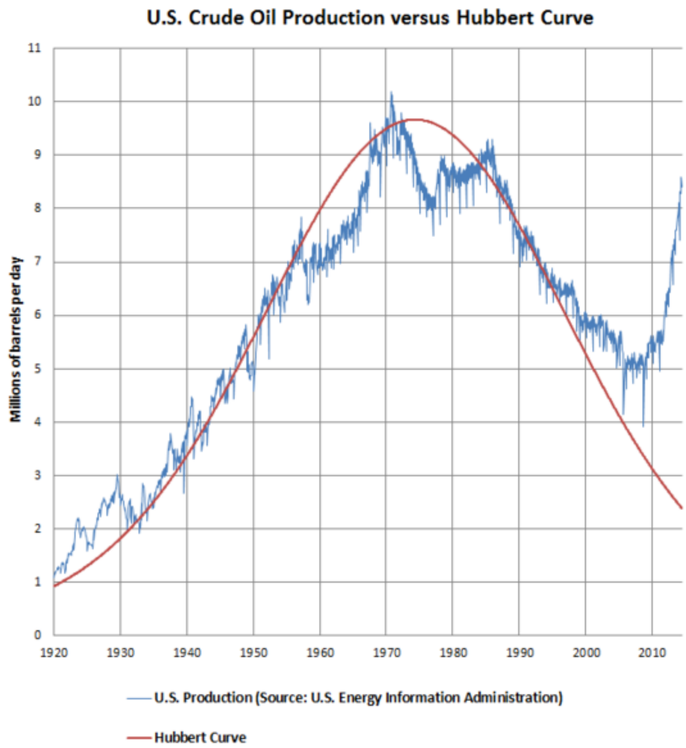

Figure 2.7: US Crude Oil Production Compared to Hubbert's Curve, 2012

In the concluding marks of his article, Hubbert comments, "Whether this possibility [peak oil] shall be realized, or whether we shall continue as at present until a succession of crisis develop – overpopulation, exhaustion of resources and eventual decline – depends largely upon whether a serious cultural lag can be overcome."[33] Already in 1949 Hubbert understood the consequences of fossil fuel consumption and identified the necessity for change on a cultural level. He finishes by stating, "However, it is upon our ability to eliminate this lag and to evolve a culture more nearly in conformity with limitations imposed upon us by the basic properties of matter and energy that the future of our civilization largely depends."[34]

[33] Ibid, 109
[34] Ibid, 109

It was not until the 1970s Energy Crisis that Hubbert's warnings, among other things, began to inspire widespread efforts to bring about change. The 1970s ushered in an era of global "earth politics" that continues today and has included such events as the Bruntland Comission of the 1980s, the Rio de Janeiro Earth Summit of 1992 and the 20 year anniversary summit in June 2012, the Earth Charter published in 2000 and others which have contributed to our definitions of sustainability and began to motivate change.[35] Advancements in science and technology have allowed us to measure and understand the impact of human processes on the natural environment as never before. The notion of "ecological footprint" debuted in the 1990s and is defined by Oxford Dictionaries as a measurement of "the impact of a person or community on the environment, expressed as the amount of land required to sustain their use."[36] Today, the Global Footprint Network (GFN) estimates, "humanity uses the equivalent of 1.5 planets to provide the resources we use and absorb our waste."[37] GFN predicts that if current population growth and consumption rates continue (based on 2008 numbers) humanity could reach resource demands as high as three times what the Earth can provide by 2050 (Figure 2.8).

[35] Grober, *Sustainability: A Cultural* History, Chapter 13
[36] Oxford Dictionary, online
[37] Global Footprint Network, online

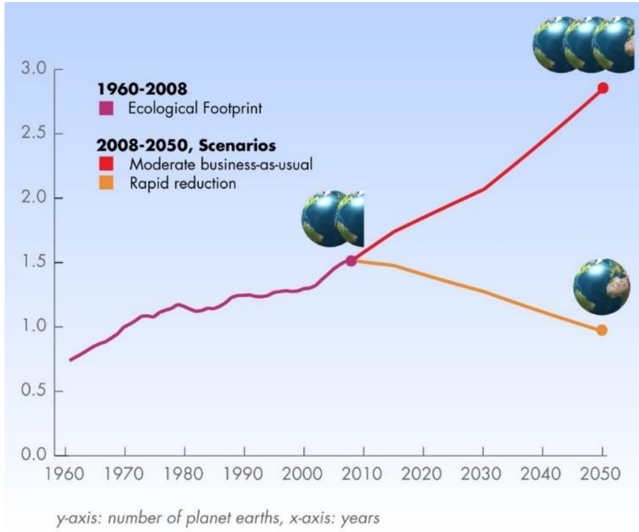

Figure 2.8: World Ecological Footprint Scenarios, 2008

With the knowledge and motivation provided by the global discourse on sustainability, architecture and design professions, among others, began to peruse sustainable design.[38]

Building design rating systems including BREEAM (1990), LEED (1998) and Living Building Challenge (2006), have taken a more holistic approach to sustainability while other initiatives such as Architecture 2030 Challenge (2006) and Passive House Institute US (2002) (began in Germany as Passivhaus in 1988) have concentrated specifically on energy consumption. In many ways these and other rating systems have inspired development and broader use of life cycle analysis, life cycle costing, energy simulation, and other analytical tools to predict and measure performance. Rating systems have continued to evolve, publishing new and more ambitious standards over

[38] Grober, *Sustainability: A Cultural History,* Chapter 13

the years; however, they are still limited by the deeply rooted anthropocentric culture in which they are conceived and in which they operate (discussed further in Chapter 2).

Nature as Community: A Model for the Future

Many conservationists, politicians, biologists, designers, psychologists and others throughout history have observed the importance and necessity of re-establishing a biocentric cultural understanding of humankind's existence within the natural environment. Journalist Ulrich Grober summarizes this line of thinking in his book *Sustainability: A Cultural History* in which he writes, "Reducing our ecological footprint means synchronizing our lifestyle and our economic cycles with natural processes once again."[39]

Returning to a biocentric way of living is not merely a matter of saving the planet. As Cindy Parker and Brian Schwartz, faculty of the Johns Hopkins Bloomberg School of Public Health, point out in their article "Human Health and Well-Being in an Era of Energy Scarcity and Climate Change", we have created "lifestyles, communities, food systems, water systems, transportation systems and health systems that are entirely reliant on cheap and plentiful oil and that assume a favorable and stable climate."[40] In a world where we spend 89% of our lives inside,[41] where food comes from the grocery store, water

[39] Grober, *Sustainability: A Cultural History,* 187
[40] Parker, Cindy L. and Schwartz, Brian S., "Human Health and Well-Being in an Era of Energy Scarcity and Climate Change," in *The post carbon reader: managing the 21st century's sustainability crises*, ed. Heinberg, Richard, and Daniel Lerch. (Healdsburg, Calif: Watershed Media, 2010), 385.
[41] "Work". *The Secret Life of Buildings.* Channel 4. Belfast, Ireland. 2011.

comes from the faucet and garbage is picked up and carried “away” on a regular basis, it is easy to forget and take for granted the delicate natural processes that sustain human life on earth.

The more we understand about the limitations to our consumption of fossil fuels and the risks of climate change the more necessary it becomes to work towards positive changes not only in environmental conditions but in human behaviors as well. For building design this means not only continuing technological and product advancements but also, focusing on the design of spaces to promote health and well-being and engage building occupants in conscious, pro-environmental behavior. As social scientist Don Marietta, Jr. recognizes, “World views can be changed, and presenting a clear and attractive new vision of the human place in nature is an urgent task.”

This thesis proposes that this “new vision” is one which thinks of the natural environment as a community to which humankind belongs, and therefore investigates the role of building design in changing the current, anthropocentric world view. To achieve this goal, the design of a building must engage users to stimulate an understanding of humanity’s place in a bio-centric world.

Chapter 3: Consideration of the User in Sustainable Architecture

Two Detrimental Assumptions

Min Kantrowitz, president of an architectural consulting and research firm, observed as early as 1984 that the proliferation of increasingly sophisticated technology has removed a majority of building users from control of the building's environmental systems. The centralization and automation of electric lighting control systems as well as heating, cooling and ventilation systems in buildings has been driven by a desire on behalf of architects and engineers to provide reliable, consistent climatic comfort to building users.[42] More recently these systems are being designed to reduce energy consumption in addition to providing environmental comfort. However, control mechanisms and the systems they oversee often exceed the knowledge or skill level of the average user, further removing them from sustainable building awareness and operation.[43]

Kantrowitz identifies two assumptions that have plagued the architecture and engineering disciplines and contributed to this divide.[44]

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[42] Kantrowitz, Min. 1984. "Energy Efficient Buildings: An Opportunity for User Participation". *Journal of Architecture Education.* 37 (3/4): 26-31.
[43] Bordass, Bill, Bromley, Ken and Leaman, Adrian. 1993. "User and Occupant Controls in Office Buildings". *Building Design, Technology and Occupant Well-Being in Temperate Climates.*
[44] Kantrowitz, "Energy Efficient Buildings: An Opportunity for User Participation," 27

> Assumption 1: “Users want ‘perfect’ environmental conditions” (where ‘perfection’ is dependent on “constancy – consistency and stability over time” and “uniformity – consistency and stability in space.”
>
> Assumption 2: “Building users ‘interfere’ with planned and proper building operation and control.”

Contrary to these assumptions, researchers often find that the opposite conditions are true. In her book *Thermal Delight in Architecture* Lisa Heschong observes that, “…in spite of the extra physiological effort required to adjust to thermal stimuli, people definitely seem to enjoy a range of temperatures.”[45] Furthermore, studies have shown that the process by which people ‘adjust to thermal stimuli’ and changes in light levels actually improves brain function, making people more productive and contributes to a greater enjoyment of the interior climatic environment.[46] Kantrowitz notes that the second assumption draws on the belief that users are unable or unwilling to participate in climate control operation and cites numerous findings that conclude, “…people are most satisfied with their environments if they have opportunities to interact with them in meaningful ways.”[47] More recent research indicates that user participation in building operation can and may

[45] Heschong, Lisa. 1979. *Thermal delight in architecture*. Cambridge, Mass: MIT Press.
[46] Find source to confirm
[47] Kantrowitz, “Energy Efficient Buildings: An Opportunity for User Participation,” 27

even be necessary to improve building performance above and beyond opportunities afforded by technology.[48]

The Language of Sustainable Design Rating Systems

With the rise of sustainable design practices architects and others have made great advances toward achieving a sustainable built environment. However, deeper investigation into the language of the rating systems by which we define our progress toward sustainability reveals that design professions continue to be hindered by the two assumptions Kantrowitz identified.

In order to better understand the degree to which sustainable design rating systems consider the important role of building users in meeting sustainable design goals I analyzed the language used to define the scoring categories of 18 building, community, infrastructure and product design rating systems from 12 rating programs around the globe (Table 3.1).
The rating programs (LEED, BREEAM, CASBEE, etc) chosen for investigation are among the most used and recognized internationally or in their country of origin. In cases where the rating program offers different rating systems for different project types (new construction, existing building, community, etc) different rating systems were only tallied separately if they had different or additional categories (Table 3.1).

[48] Janda K.B. 2011. "Buildings don't use energy: People do". *Architectural Science Review.* 54 (1): 15-22.

Table 3.1 Rating System Analysis					
Rating System/ Host Organization	Year Est.	Country of Origin	Construction Types to Which Catagories Apply	Year of most recent revision	Categories
Living Building Challenge/ International Living Future Institute	2006	US + Canada	Renovation, Infrastructure and Landscape, Building, Community	Version 3.0, 2014	**7 Petals:** Place, Water, Energy, Health and Happiness, Materials, Equity, Beauty
LEED (Leadership in Energy and Environmetnal Design)/ United States Green Building Council	1998	US - International	Building Design + Construction (BD+C), Interior Design + Construction (ID+C), Building Operations and Maintenance (O+M), and Homes	Version 4, November 2013	**9 Categories:** Integrative Process, Location and Transportation, Materials and Resources, Water Efficiency, Energyg and Atmosphere, Sustianable Sites, Indoor Environmental Quality, Innovation, Regional Proirity Credits
LEED (Leadership in Energy and Environmetnal Design)/ United States Green Building Council	1998	US - International	Neighborhood Development (ND)	Version 4, November 2013	**12 Categories:** Integrative Process, Location and Transportation, Materials and Resources, Water Efficiency, Energyg and Atmosphere, Sustianable Sites, Indoor Environmental Quality, Innovation, Regional Proirity Credits, Smart Location and Linkage, Beighborhood Pattern and Design, Green Infrastructure and Buildings.
Green Globes/ECD Energy and Environment Canada	2000	US + Canada	New Building/Significant Renovation		**7 Categories:** Project Management, Site, Energy, Water, Materials and Resources, Emissions, Indoor Environment Existing Building
Green Globes/ECD Energy and Environment Canada	2000	US + Canada	Management and Operation of Existing Buildings		**6 Categories:** Energy, Water, Resources, Emissions, Indoor Environment, Environmental Management
BREEAM (Building Research Establishment Environmental Assessment Methodology)/Building Research Establishment Group	1990	United Kingtom	UK + International New Construction, UK + International In-Use	Version 2014	**10 Categories:** Management, Health and Wellbeing, Energy, Transport, Materials, Waste, Water, Land Use and Ecology, Pollution, Innovation
Envision/ Zofnass Program for Sustainable Infrastructure + Institute for Sustainable Infrastructure		United States	Infrastructure	Envision 2.0, 2012	**5 Categories:** Quality of Life, Leadership, Resource Allocation, Natural World, and Climate and Risk.
CASBEE (Comprehensive Assessment System for Built Environment Efficiency)/ JaGBC+JSBC		Japan	New Construction	Edition 2010	**6 Categories:** Q(Quality) - indoor environment, quality of service and outdoor environment on site - and L(Load) - energy, resources and materials, off-site environment
Green Star/ Green Building Council Australia	2003	Australia	Design & As Built (Office, Retail Center, Education, Healthcare, Multi-Unit Residential, Industrial, Public Building), Performance (Operations and Maintenance)	Different Versions for different types at different years.	**9 Categories:** Management, Indoor Environmental Quality, Energy, Transport, Water, Materials, Land Use & Ecology, Emissions, Innovation
Green Star/ Green Building Council Australia	2003	Australia	Communities	Version 1.0, 2012	**6 Categories:** Governance, Design, Liveability, Economic Prosperity, Environment, Innovation
BOMA BESt (Building Environmetnal Standards)/ Building Owners and Managers Association of Canada	2005	Canada	Existing commercial buildings (office, open air retail, light industrial, shopping centers, multi-unit residential buildings, health care facilities) - building must be at least 1 year old and have had 70% minimum avg occupancy for 12 consecutive months.	Version 2, January 2012	**6 Categories:** Energy, Water, Waste Reduction and Site, Emissions and Effluents, Indoor Environment, Environmental Management System
Pearl Rating System/ Estidama Program	2008	UAE - local/regional	New Buildings	Version 1, 2010	**7 Categories**: Integrated Development Process, Natural Systems, Livable Buildings (outdoor and indoor), Precious Water, Resourceful Energy, Stewarding Materials, Innovating Practice
Pearl Rating System/ Estidama Program	2008	UAE - local/regional	Communities	Version 1, 2010	**7 Categories**: Integrated Development Process, Natural Systems, Livable Communities, Precious Water, Resourceful Energy, Stewarding Materials, Innovating Practice
BEAM Plus (Building Environmental Assessment Method)/ Hong Kong Green Building Council	2010	Hong Kong	New Buildings (NB), Existing Buildings (EB), Interiors	Version 1.2, November 2012	**6 Categories:** Site Aspects, Energy Use, Indoor Environmental Quality, Materials Aspects, Water Use, Innovations and Additions
Green Mark/ BCA (Building and Construction Authority)	2005	Singapore	Non-Res NB, Res NB, Existing Non-Res, Existing Buildings, Existing Res, Existing Schools, Healthcare, Office Interior, Landed houses, Restaurants, Supermarket, Existing Data Centers, New Data Centers, Retail	Each rating system has different version (1-4.1) and year (2008-2013)	**5 Categories:** Energy Efficiency, Water Efficiency, Environmental Protection, Indoor Environmental Quality, Other Green Features and Innovation
Green Mark/ BCA (Building and Construction Authority)	2005	Singapore	Infrastructure	Version 1, 2009	**7 Categories:** Landscape/Ecology/Land Efficiency, Energy, Renewable Energy, Water, Project Management, Waste Management and Environmental Protection, Innovation
Green Mark/ BCA (Building and Construction Authority)	2005	Singapore	District	Version 2, 2013	**6 Categories:** Energy Efficiency, Water Management, Material and Waste Management, Environmental Planning, Green Buildings and Technology, Community and Innovation
Cradle to Cradle Certified Product Standard/ Cradle to Cradle Products Innovation Institute	2005	United States	Products and Manufacturers	Version 3.0,	**5 Categories:** Material Health, Material Reutilizaiton, Renewable Energy and Carbon Management, Water Stewardship, Social Fairness

The 17 selected rating systems have collectively 126 categories. Looking at all of the categories together I identified the seven themes of (1) location, (2) natural environment, (3) resource use, (4) physical health and human comfort, (5) social, emotional and economic quality, (6) design team accountability and (7) user/operator accountability. Categories were then arranged by theme (Table 3.2). Where one category consisted of multiple words that belonged to different themes the words were separated into those themes and counted separately (i.e. the category "Health and Wellbeing" was divided such that "health" was placed under the "Physical Health and Human Comfort" theme and "Wellbeing" was placed under the "Social, Emotional and Economic Quality" theme). This was done in an effort to most accurately reflect the evaluated criteria included in each category. When it was unclear to which theme a category belonged, further investigation into the description of the category components within the rating system documents was used to determine the appropriate theme or themes. This process resulted in the 126 categories being divided into 144 words/phrases tallied.

It is acknowledged that the results of this analysis may be limited where category titles do not represent all of the themes addressed by the information within that category. Furthermore, the distribution of categories into themes does not consider the weighting of categories within the rating systems (where one category may have more scoring potential than another

Table 3.2 Category Language Analysis

Rating System	Category Topic						
	Location	Natural Environment	Resource Use	Physical Health and Human Comfort	Social, Emotional and Economic Quality	Design Accountability	User/Operator Accountability
Living Building Challenge (buildings)	Place	Water	Energy Materials	Health	Happiness Equity	Beauty	
LEED (buildings)	Location and Transportation Sustainable Sites Regional Priority Credits	Water Efficiency Atmosphere	Materials and Resources Energy	Indoor Environmental Quality		Integrative Process Innovation	
LEED (neighborhood)	Location and Transportation Sustainable Sites Regional Priority Credits Smart location and linkage	Water Efficiency Atmosphere	Materials and Resources Energy Green Infrastructure and Buildings	Indoor Environmental Quality		Integrative Process Innovation Nbhd pattern and design	
Green Globes (new building)	Site	Water Emissions	Energy Materials and Resources	Indoor Environment		Project Management	
Green Globes (existing)		Water Emissions	Energy Resources	Indoor Environment			Environmental Management
BREEAM (buildings)	Transport Land Use	Water Ecology	Energy Materials Waste Pollution	Health	Wellbeing	Innovation	Management
Envision (infrastructure)	NW: Siting	NW: Biodiversity NW: Land and Water Climate	Resource Allocation		Quality of Life	Leadership Risk: Resilience	
CASBEE	Outdoor Environment on Site	Off-Site Environment	Energy Resources and Materials	Indoor Environment	Quality of Service		
Green Star (builidngs)	Transport Land Use	Water Emissions Ecology	Energy Materials	Indoor Environmental Quality		Innovation	Management
Green Star (communities)		Environment			Livability Economic Prosperity	Design Innovation	Governance
BOMA BESt (buildings)	Site	Water Emissions and Effluents	Energy Waste Reduction	Indoor Environment			Environmental Mgmt System
Pearl (buildings)		Natural Systems Precious Water	Resourceful Energy Stewarding Materials	Livable Buildings: Indoors	Livable Buildings: Outdoors	Integrated Development Process Innovating Practice	
Pearl (communities)		Natural Systems Precious Water	Resourceful Energy Stewarding Materials		Livable Communities	Integrated Development Process Innovating Practice	
BEAM (buildings)	Site Aspects	Water Use	Energy Use Materials Aspects	Indoor Environmental Quality		Innovations	
Green Mark (buildings)		Water Efficiency Environmental Protection	Energy Efficiency Other Green Features	Indoor Environmental Quality		Innovation	
Green Mark (districts)	Environmental Planning	Water Management	Energy Efficiency Material Management Waste Management Green Buildings and Technology		Community	Innovation	
Green Mark (infrastructure)	Landscape Land Efficiency	Water Ecology Environmental Protection	Energy Renewable Energy Waste Management			Project Management Innovation	
Cradle to Cradle (products)		Carbon Management Water Stewardship	Material Reutilization Renewable Energy Material Health		Social Fairness		
Total	20	34	40	12	11	22	5

they are considered equally when grouped into themes). Despite these limitations the information presented was gathered and analyzed with the utmost attention to detail and consistency and may be considered as a reasonable and reliable overview of the language of the rating systems studied. The population of words applying to each theme is shown in Figure 3.1 as a percentage of the total 144 words tallied.

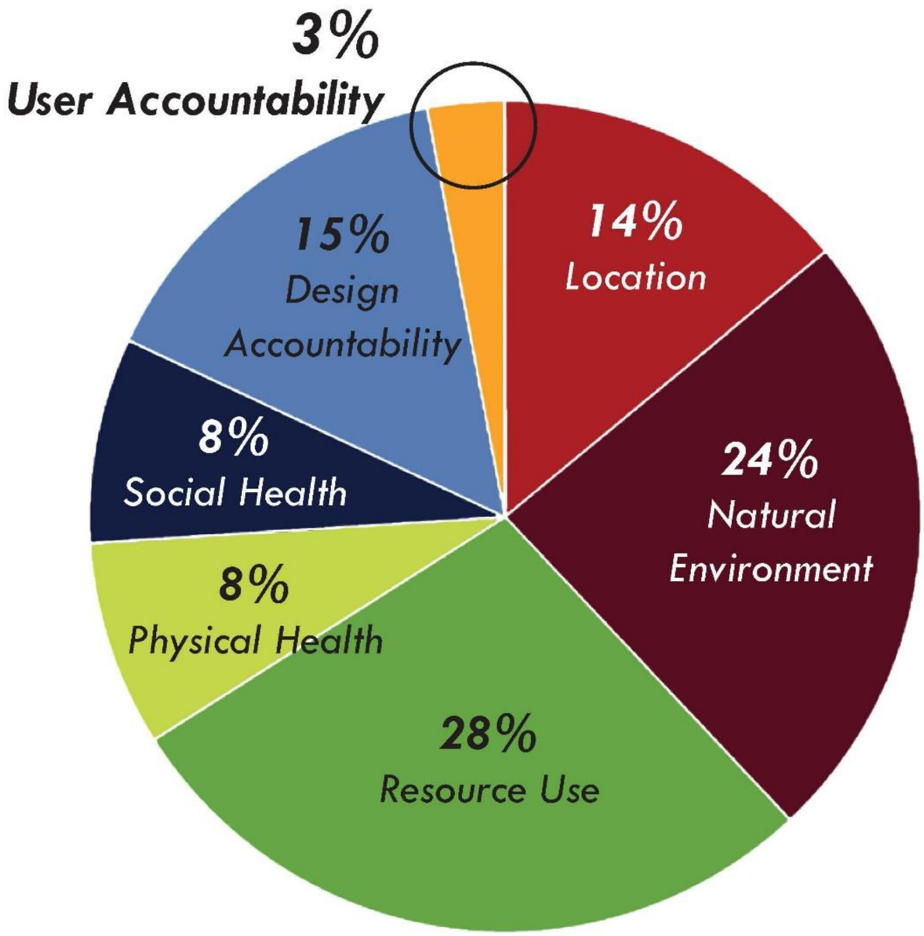

Figure 3.1: Rating System Language Analysis - Percentage of Words Identified for each Theme

The analysis revealed that 66% of words tallied address the quality and consumption of the natural environment (themes: location; natural environment; resource use) while 16% address the quality and equity of the human experience (themes: physical health and human comfort; social, emotional and economic quality) and only 3% of words address the responsibilities of users in sustainable building operation (them: user/operator accountability). This number may in fact even be too generous given that in many cases the categories address “management” which may apply to a person or group of people in charge of controlling building systems rather than an involvement of users in building operation.

While it is ultimately the accountability of the design team to achieve high performance in all of the categories, the fact that there are categories separately devoted to addressing design practice and innovation, 15% of words tallied (theme: design team accountability), is an important indication of how significant the design process is perceived to be in sustainable development. Certainly the design team plays a critical role in organizing the sustainable construction of a building; and we definitely address performance from the point of building design. However, we so far have not prioritized occupant behavior in our sustainable design considerations. It would appear from the category language analysis of our rating systems that we continue to evaluate design based on the two assumptions identified by Kantrowitz discussed earlier in this chapter. Many sustainable design efforts feed society's anthropocentric view that the natural environment and buildings *perform for people*. In contrast, this thesis builds on the arguments of many who have identified that user-participation in building operation can actually improve performance and increase user satisfaction[49] and suggests that conscious, sustainable user behavior should be a highly considered component of sustainable design in order to promote an understanding that *people perform* the healthy operation of buildings and spaces within the natural environment.

Senior researcher for the UK Energy Research Center, Kathryn Janda investigates the "social and technical dimensions of changing building practices."[50] In her article "Buildings don't use energy: people do" published in *Architectural Science Review* in 2011, Janda finds "…purely architectural solutions…to be necessary but not sufficient to achieve climate change mitigation targets." She observes, "…it can be argued that reducing energy use in buildings requires changes in the entire fabric of society, not just changing the shape and nature of buildings.", [51] Janda further argues, as David Orr does, that designing buildings as tools for informing users about their environmental impact is essential to achieve energy use reduction targets. While the article focuses on energy, Janda's comments can be

[49] Kantrowitz, "Energy Efficient Buildings: An Opportunity for User Participation"
[50] "Dr. Kathryn Janda Profile," Environmental Change Institute, accessed November 2014, http://www.eci.ox.ac.uk/people/jandakaty.php
[51] Janda, "Buildings Don't User Energy, People Do," 15

applied to all areas of building performance. Janda concludes by observing, "Some architects have the skills and experience to take on this challenge, but the field as a whole would need to develop professional expertise and seek ways of integrating user involvement in building performance to fully succeed."[52]

The extent to which design practice and "professional expertise" continues to shape and be shaped by design rating programs suggests that an important step in developing a professional expertise for "integrating user involvement" would be the reorganization of rating systems to reflect the importance of building design for sustainable user-participation.

Flowers or Sailboats?

In addition to investigating the language of rating system categories, it is necessary to consider how design professions have conceived of sustainable design through the poetics of simile and metaphor. In 1997 noted natural sciences author, Janine Benyus published the book *Biomimicry: Innovation Inspired by Nature,* which popularized the notion of "biomimicry," described by the Biomimicry Institute as "an approach to innovation that seeks sustainable solutions to human challenges by emulating nature's time-tested patterns and

[52] Ibid, 20

strategies."[53] This philosophy promotes designing buildings, vehicles and other products and human-made systems to emulate the performance of plans, animals and natural ecosystems.

In 2002 architect William McDonough and chemist Michael Braungart, authors of *Cradle to Cradle* (2002), describe the principles of the Cradle to Cradle design philosophy (which has been adapted into a product design rating system) as "illustrated by the life of a tree."[54]

In 2006 the International Living Future Institute established the Living Building Challenge philosophy and rating system based on the notion that buildings are (or should be) like flowers. A flower was chosen as the logo imagery for both the institute and the rating system and the categories are identified as "petals".[55] The aspiration that buildings should be like flowers is in part what makes Living Building Challenge the most demanding rating system to date. Like flowers, buildings that achieve the "living" certification are expected to run on renewable energy, produce no waste, be made of materials that can be safely recycled or composted at the end of life, be useful and of service to the community, and be beautiful and inspiring. Buildings are evaluated on measured performance over one year of occupancy and are among the most

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[53] "What is Biomimicry", Biomimicry Institute, accessed November 2014, http://biomimicry.org/what-is-biomimicry/

[54] McDonough, William and Braungart, Michael. 2002. "Buildings Like Trees, Cities Like Forests". *The Catalog of the Future.* Pearson Press.

[55] "Living Building Challenge," International Living Future Institute, accessed November 2014, http://living-future.org/lbc

highly performing buildings in the world, eliminating harmful impacts, improving site ecology and in some cases even producing energy and other resources.

Although Living Building Challenge is a significant step forward in the way people think about the responsibility of the built environment, the metaphor is limiting in that flowers perform their processes automatically, without human intervention. The fact is however, some buildings that have achieved the Living Building Certification have done so by relying on sustainable occupant behavior. The Bullitt Center in Seattle, Washington, designed by the Miller Hull Partnership, is a commercial office building that opened in 2013. Though it has not yet reached 100% occupancy and can therefore not begin the evaluation process, the building was designed to the standards of Living Building Challenge and was awarded full certification in April 2015. An article published about the building in the September/October 2013 issue of *Urban Land* describes the use of “performance-based design, engineering and operating strategies” to meet net zero energy and water targets.[56] It is expected that tenant behaviors will contribute 21% of the overall reduction in Energy Use Intensity (with other reductions coming from heating, cooling and lighting strategies) compared to a typical Seattle office building.[57]

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[56] Berton, Brad. 2013. “An Environmental Model for the Next 250 Years: Seattle’s Bullitt Center". *Urban Land.* 72 (9/10): 171-181.
[57] Berton, 175

With this in mind we must ask ourselves, is the flower the most appropriate metaphor for sustainable design? I argue that it is not. Whatever design achievements may come from emulating animals, plants and ecosystems, while valuable in their own right, they may in fact be perpetuating the humans vs. natural environment paradigm. We should not be thinking of ourselves as having to be *like* natural processes and should instead conceive of ourselves and our buildings as *part of* natural processes.

Janda argues that “Building users play a critical but poorly understood and often overlooked role in the built environment.”[58] Effectively, we are all custodians of environment, whether it be naturally produced or human-made, and as such I propose we transition to thinking of buildings as sailboats. Sailboats can be designed to achieve all of the same attributes that are championed in the flower metaphor with one important addition, *sailboats are designed, built, occupied and operated by people* in constant interaction with the conditions of the natural environment (Figure 3.2).

The remainder of this document is organized around investigating how building design can engage user participation and encourage conscious pro-environmental behavior. The underlying assumption is that it is environmentally necessary to pursue and advance the understanding that

[58] Janda, “Buildings Don’t Use Energy, People Do”, 20

buildings are like sailboats, that people integral to the sustainable life of buildings.

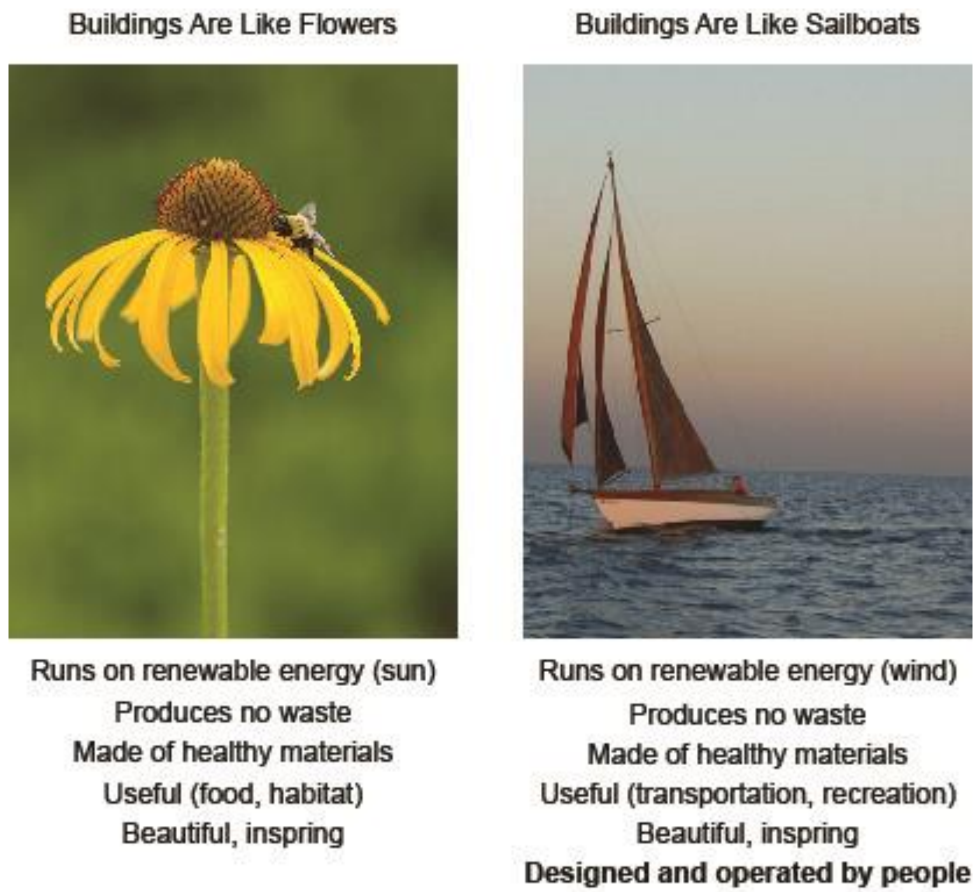

Figure 3.2: Comparing Flower and Sailboat Metaphors for Sustainable Design

Chapter 4: Motivating Pro-Environmental Behavior

In their 2002 article, “Mind the Gap: Why do people act environmentally and what are the barriers to pro-environmental behavior?” Tufts University Professor of Urban and Environmental Policy and Planning, Julian Agyeman and then Tufts Climate Initiative Project Coordinator and policy analyst, Anja Kollmuss defined “pro-environmental behavior” as “behavior that consciously seeks to minimize the negative impact of one’s actions on the natural and built world.”[59] Since the current standards, particularly Living Building Challenge and Cradle to Cradle, are introducing the idea of going beyond the reduction of negative impact and encouraging productive and positively impactful design, it is appropriate to amend the definition slightly. For the purposes of this thesis, “pro-environmental behavior” shall refer to behavior that consciously seeks not only to eliminate the negative impact on the environment but also to make positive impacts through one’s actions on the natural and built environment.

This chapter represents a literature review of social science research, particularly in the field of Environmental Psychology with the goal of better understanding the factors that influence human behavior. Developed in the United States in the 1960s as a branch of Environmental Behavior Research,

[59] Kollmuss, Aaja and Agyeman, Julian. 2002. “Mind the Gap: Why do people act environmentally and what are the barriers to pro-environmental behavior?” *Environmental Education Research.* 8 (3). 239-260.

Environmental Psychology "looks at the range of complex interactions between humans and the environment."[60]

Four Causes of Change

In his book *Treading Softly: Paths to Ecological Order* (2010) Thomas Princen identifies four causes of significant, large-scale change.[61]

1) Only when there's a crisis
2) Only when leaders muster the political will
3) Only when people are properly educated
4) Only when people's values change

Change may be caused by any one or a combination of these factors. Buildings can be designed to mitigate risk of crisis and respond to crisis with resilience and building codes can be influenced by political policies; however, building design has the greatest potential to address the final two causes of change. Investigating how building design can properly educate building users and promote placing a greater value on the natural environment in order to produce more pro-environmental behavior is an important component of this thesis. While it has been observed that individuals can be reluctant to change, behavior and social scientists Linda Steg and Charles Vlek summarize that, "Individuals seem to adapt to positive as well as to negative changes in their lives, by changing their standards, goals and expectations.

[60] Kollmuss and Agyeman, "Mind the Gap", 239
[61] Princen, Thomas. 2010. *Treading softly paths to ecological order*. Cambridge, Mass: MIT Press. http://site.ebrary.com/id/10372262.

Thus, although environmental policies may change quality of life perceptions initially, individuals may adapt soon."[62]

Closing the Gap

Many studies have identified a gap between what people are able to investigate, quantify and understand about our negative impacts on the environment and the motivation to take action to improve our impact.[63] Two of the causes for the gap between knowledge and action identified in D.W. Rajecki's book *Attitudes: Themes and Advances* (1982) summarized by Kollmuss and Agyeman are "direct vs. indirect experience" and "normative influences."[64]

1. Direct vs. indirect experience: direct experiences (i.e. walking along a riverbank littered with trash) have greater influence to motivate behavior than indirect experiences (i.e. reading about pollution in a book).
2. Normative influences: Behavior and attitude is influenced by social customs and cultural and family traditions.

Kantrowitz sites two social science theories that explain this gap. The first, "Environmental Competence," "relates to one's perceived ability to both

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[62] Steg, Linda and Vlek, Charles. 2009. "Encouraging Pro-Environmental Behavior: An integrative review and research agenda." *Journal of Environmental Psychology.* 29. 309-317.
[63] Kollmuss and Agyeman, "Mind the Gap", 239
[64] Ibid, 242

understand and negotiate the environment in meaningful ways." The second, "Learned Helplessness," "refers to one's reactions in a situation in which one is unable to control a situation in which one is involved and which one cannot avoid."[65] The way in which these theories have come to describe behavior in the built environment relates to the degree to which building systems have been automated and how directly (or indirectly) individuals have been allowed to participate in building operation. As Kantrowitz observes, "The relationship between the two [theories] is that if one has learned to be helpless in the built environment because of lack of control, it is difficult to develop and maintain a sense of environmental competence."[66]

These observations suggest that design can begin closing the gap between knowledge and action by engaging users in a more direct experience of their environment, by providing opportunities for users to operate building systems and by influencing societal customs with respect to environmental behavior. In doing so, Kantrowitz argues, "designers can support the development of competent building users."[67]

Identifying Factors of Pro-Environmental Behavior

This section identifies eight factors influencing pro-environmental behavior. The eight factors selected represent the synthesis of multiple social scientists

[65] Kantrowitz, " Energy Efficient Buildings", 28
[66] Ibid, 28
[67] Ibid, 30

and environmental psychologists' research and speculation on the factors influencing behavior. An understanding of these factors provides a necessary foundation for development and assessment of design interventions that encourage pro-environmental behavior. It should be noted that any of these factors can influence either positive or negative environmental behavior although the focus will be on how these factors can be understood to influence pro-environmental behavior.

Additionally, while these factors are all seen to influence behavior, they do not all necessarily have the same degree of influence. In general, it has been suggested that motivation is a product of an individual's egoistic, social and biospheric orientation. Egoistic or self-orientation has the strongest influence on motivation, social orientation has the second-greatest influence and biospheric orientation has the weakest influence.[68] This means the desire to serve one's own needs and wants will, for most people, be the first line of influence with regard to each of the categories.

Knowledge of Issues

Many studies have concluded that knowing what the issues are and the causes of those issues is an important first step in understanding the need for action. Kollmus and Agyeman point out that the often

[68] Stern et al, referenced in Kollmuss and Agyeman, "Mind the Gap", 245

gradual destruction of the environment makes it difficult to identify issues at their point of origin.[69]

Early models of pro-environmental behavior argued that knowledge of environmental issues was *the* factor that fostered an environmental attitude which led to action (Figure 4.1).[70] Although these models were later determined to be too limited to fully describe the motivation of pro-environmental behavior, knowledge of issues remains an important component of more comprehensive models.

Figure 4.1: Early Models of Pro-Environmental Behavior

Knowledge of Action Strategies

Related to knowledge of issues is the knowledge of action strategies. People may know about an environmental issue (air pollution, climate change, limited supply of fossil fuels) but wonder, “What can I do?” An individual has to be aware of the appropriate action to take in order to affectively reduce his or her negative environmental impact.[71]

[69] Kollmuss and Agyeman, “Mind the Gap”, 254
[70] Kollmuss and Agyeman, “Mind the Gap”, 241
[71] Kollmuss and Agyeman, “Mind the Gap”, 243

Knowledge of issues and knowledge of action strategies are especially important with regards to feedback. Research has shown that direct feedback (provided at the time and source of action) is more effective in influencing behavior than indirect feedback (provided after the fact as a collection of actions over a period of time).[72] An electric bill is a form of indirect feedback. It indicates total electricity use for a given period. It may contribute to the knowledge of an issue (that I am using too much electricity) but it does not offer specific information as to which habits or appliances are contributing the most to electricity use and does not suggest strategies for reducing use. The battery icon on a phone is a form of direct feedback. It indicates the level of charge in real time as the device is charging which allows the user to unplug the phone once it is fully charged and therefore stop drawing unneeded electrical power. Whether or not an individual actually unplugs the device when it does not need to be plugged in depends on other behavior-motivating factors addressed below.

Opportunity for and Cost of Action

The opportunity for and cost of action are influenced by what are often described as contextual factors. Contextual factors include availability,

[72] Janda, "Buildings Don't Use Energy, People Do", 18

quality, market supply, physical infrastructure and technical capabilities.[73] The Theory of Planned Behavior, introduced by Icek Ajzen in 1991, posits that people make reasoned decisions, choosing options that offer the highest benefits for the lowest cost (where cost is a measure and balance of time and effort as well as money).[74] Diekmannn and Preisendoerfer's graph in Figure 4.2 indicates that as cost increases, the likelihood that a pro-environmental attitude will influence pro-environmental behavior decreases.

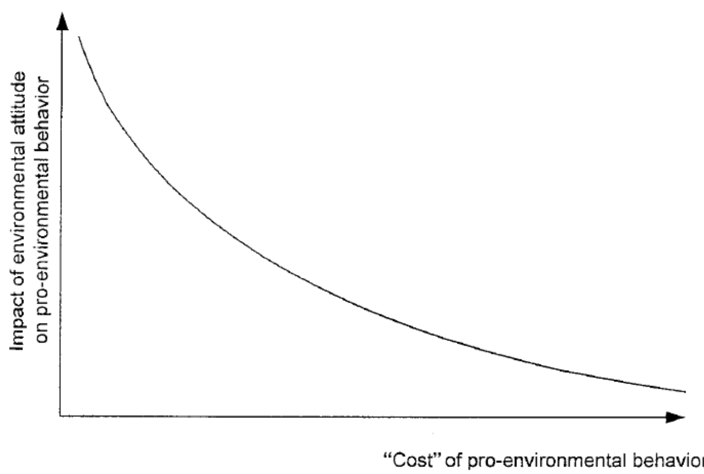

Figure 4.2: Influence of Environmental Attitude vs Cost on Pro-Environmental Behavior

Kantrowitz describes pro-environmental behavior in building operation as a product of the time, skill or money invested (cost) and the difficulty of operation (opportunity) (Figure 4.3).[75]

[73] Steg and Vlek, "Encouraging Pro-Environmental Behavior", 312
[74] Ajzen, 1991, referenced by Steg and Vlek, 311
[75] Kantrowitz, "Energy Efficient Buildings", 30

COMMITMENT OF USERS (Time, money/or skill intensive)	DIFFICULTY OF OPERATION (lack of familiarity and/or proximity; hard to operate)	
	LOW	HIGH
LOW	Operable windows. Localized light switches. Venetian blinds.	Appropriate trombe wall vent operation. Changing furnace filters.
HIGH	Relamping a building with more energy efficient bulbs.	Reprogramming a micro-processor based energy management system.

Figure 4.3: "Opportunities for User Involvement: Classification System", Kantrowitz, 1984

It has been argued that behavior models based on the Theory of Reasoned Action are limited by the assumption that people always make reasonable decisions.[76] While cost and opportunity are certainly highly influential motivators there are numerous exceptions to the Theory of Reasoned Action. People may engage in behaviors that are more expensive or difficult to execute if their values, familial or societal traditions, or sense of responsibility outweigh highest gain, lowest cost reasoning. This means that making pro-environmental behavior more accessible and affordable, though beneficial, may not automatically or completely encourage beneficial changes in behavior.

[76] Kollmuss and Agyeman, "Mind the Gap", 243

Perceived Impact of Action (Locus of Control)

The extent to which a person believes his or her actions will affect change is referred to as the "locus of control". A person with an internal locus of control believes that his or her individual behavior can result in change (positive or negative) while a person with an external locus of control finds their actions to be insignificant in causing change and believes that change only occurs by the work of powerful others.[77] Locus of control is a very important factor in determining pro-environmental behavior in two ways. First, if a person does not believe their actions are significant in doing harm because they are "just one person" or because it is "just one time" they may be more prone to environmentally harmful behaviors such as throwing away recyclable products, leaving lights on when the room is not in use or driving to places that are close and safe enough to walk to. Second, if a person understands their behavior to be harmful and perhaps even strongly values the health of the natural environment (see next section), he or she may still not engage in pro-environmental behavior because the perception is that 'it won't make a difference anyway'.[78]

It is important that design cultivate a strong internal locus of control by showing people the impact of their actions. For example, some filtered

[77] Kollmuss and Agyeman, "Mind the Gap", 243
[78] Ibid, 255

water bottle dispensers count how many disposable plastic water bottles are eliminated from use as users fill up their refillable water bottles (Figure 4.4). The count increases as each user fills a water bottle giving each individual confirmation of his or her direct effect on decreasing the use and waste of disposable water bottles.

Figure 4.4: Filtered Water Dispenser

Attitudes and Values

Research has shown that an individual's attitudes and values do indeed play a role in influencing behavior. According to Kollmuss and Agyeman, "Attitudes do not determine behavior directly, rather they influence behavioral intentions which in turn shape our actions."[79]

[79] Kollmuss and Agyeman, "Mind the Gap", 242

As summarized by Steg and Vlek, several studies have revealed that "the more strongly individuals subscribe to values beyond their immediate own interests, that is, self-transcendent, prosocial, altruistic or biospheric values, the more likely they are to engage in pro-environmental behavior."[80] Kollmuss and Agyeman confirm that the greater extent to which an individual is emotionally involved, or "has an affective relationship" with the natural environment, the more he or she will adopt pro-environmental behaviors.[81] These observations build on the idea that environmental concern is most strongly motivated by egoistic orientation (presented previously). One may infer then that a greater degree of pro-environmental behavior can result from design that succeeds in encouraging an individual's self (egoistic) concern to become, even temporarily, secondary to social and biospheric orientation.

The term "biophilia", introduced by biologist Edward Willson in 1992, is defined as "the connections that humans subconsciously seek with the rest of life."[82] As the concept of biophilia has gained popularity the notion of biophilic design has come to represent a design philosophy that integrates the natural environment with the built environment. As described in the documentary *Biophilic Design: The Architecture of*

[80] Steg and Vlek, "Encouraging Pro-Environmental Behavior," 311
[81] Kollmuss and Agyeman, "Mind the Gap", 254
[82] Willson, 350, Quoted in Orr, *Earth in Mind,* 46.

Life, allowing people to experience the natural environment (vegetation, daylighting, breeze through an open window) in their buildings responds to an innate human need for physical contact with the natural environment to maintain physical and emotional health and wellbeing.[83] The "Greenhouse" Factory and Offices project designed for Herman-Miller by William McDonough + Partners incorporates "a tree-lined interior conceived as a brightly daylit 'street'…so that even as they work indoors, employees get to participate in the cycles of day and seasons." It has been found at Herman-Miller and in other similar projects that this biophilic design approach was one factor in the factory's dramatic productivity gains and impressive employee retention rates.[84]

Values are influenced to varying degrees by social networks (family, friends, community), media and political organizations, and cultural contexts (social structure, religion, traditions, customs, etc). Though it is difficult to conclude exactly what shapes our values and how they are shaped, some studies indicate that direct experiences in nature are strong contributors to one's aptitude for pro-environmental behavior.[85] In his book *Earth in Mind*, David Orr argues that an increased valuing of nature is necessary to encourage pro-environmental behavior and

[83] *Biofilic Design: The Architecture of Life, documentary.* Online Clip. Directed by Bill Finnegan. (2011; Burlington, VT: Tamarak Media, 2011.)
[84] McDonough and Braungart, *Cradle to Cradle*, 75
[85] Kollmuss and Agyeman, "Mind the Gap", 251

that buildings provide an important setting for coming to value nature.[86] As Stephen Jay Gould observed, "We cannot win this battle to save species and environments without forging an emotional bond between ourselves and nature as well – for we will not fight to save what we do not love."[87] From this perspective, it should be the goal of building design to make social and biospheric concerns so important that they become egoistic concerns.

Perceived Reception of action/Behavioral Incentives

While behavior is motivated by our internal values and beliefs, it is also influenced by our social structure. We may be prone to exhibit more pro-environmental behavior if our cultural customs dictate that we do so because we are interested in abiding by social norms.[88] Norms, defined as "standards of proper or acceptable behavior",[89] motivate us to behave in the interest of seeking the acceptance or approval of our peers. The Theory of Normative Conduct summarized by Steg and Vlek describes the influence of two types of social norms on behavior. "Injunctive norms refer to the extent to which behavior is supposed to be commonly approved or disapproved. Descriptive norms reflect the extent to which behavior is perceived as common."[90]

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[86] Orr, *Earth in Mind*
[87] Gould, quoted in Orr, *Earth in Mind,* 43
[88] Kollmuss and Agyeman, "Mind the Gap", 249
[89] Merriam Webster Dictionary Online
[90] Steg and Vlek, "Encouraging Pro-Environmental Behavior", 311

Associate Professor in the Department of Geography at the University of Exeter, Stewart Barr, in his 2003 article, "Strategies for Sustainability: citizens and responsible environmental behaviour", observed that policymakers tend to focus on knowledge campaigns to promote environmental behavior reform and do not account for the range of factors that affect behavior, particularly social norms.[91] The same may be argued about sustainable architectural design which often provides a "dashboard" to building users that monitors energy and water use. While providing such real-time information may contribute to reductions in energy and water consumption by building users, research has shown that knowledge alone cannot promote pro-environmental behavior. Barr argues that it is necessary for policymakers (and architects) to understand the significance of normative behavior and the need for behavioral incentives in shaping human behavior.[92]

Behavior incentives can be physical incentives (awards, tax cuts, privileges) or emotional incentives such as the satisfaction of peer approval or the feeling that we did something good (opposite of guilt).[93] Incentives often result from achieving goals. Goal-framing theory proposes that goals "govern or 'frame' the way people process

[91] Barr, "Strategies for Sustainability", 288
[92] Ibid, 227
[93] Kollmuss and Agyeman, "Mind the Gap", 246

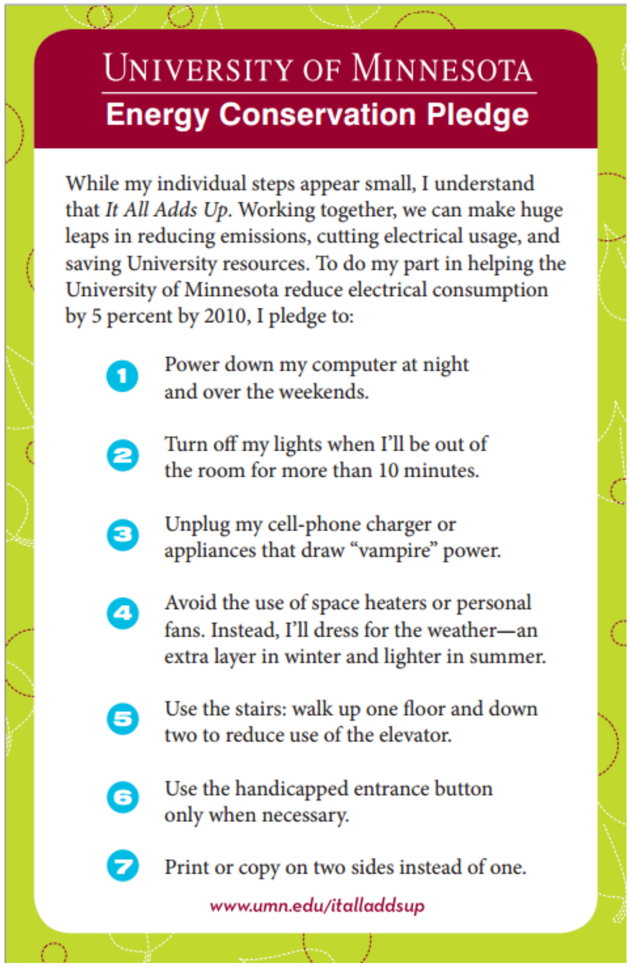
information and act upon it."[94] Steg and Vlek summarize the three types of goal-framing included in goal-framing theory: "a hedonic goal-frame 'to feel better right now', a gain goal-frame "to guard and improve one's resources", and a normative goal-frame "to act appropriately."[95]

Building design that sets and allows people to meet goals for pro-environmental behavior can accommodate all three goal types.

Commitment and Sense of Responsibility

Studies indicate that communicating a willingness to take action can be related to pro-environmental behavior.[96] Commitment may also be associated with goal-setting and incentives. For example, the University of Minnesota's "It all adds up" campaign set up tables with lap tops on campus throughout the school year and asked students walking by to take an on-line "Energy Conservation Pledge" to reduce their personal energy consumption and contribute to the University's overall goal of reducing consumption (Figure 4.4).

[94] Steg and Vlek, "Encouraging Pro-Environmental Behavior", 312
[95] Ibid, 312
[96] Kollmuss and Agyeman, "Mind the Gap", 243



UNIVERSITY OF MINNESOTA
Energy Conservation Pledge

While my individual steps appear small, I understand that *It All Adds Up*. Working together, we can make huge leaps in reducing emissions, cutting electrical usage, and saving University resources. To do my part in helping the University of Minnesota reduce electrical consumption by 5 percent by 2010, I pledge to:

1. Power down my computer at night and over the weekends.
2. Turn off my lights when I'll be out of the room for more than 10 minutes.
3. Unplug my cell-phone charger or appliances that draw "vampire" power.
4. Avoid the use of space heaters or personal fans. Instead, I'll dress for the weather—an extra layer in winter and lighter in summer.
5. Use the stairs: walk up one floor and down two to reduce use of the elevator.
6. Use the handicapped entrance button only when necessary.
7. Print or copy on two sides instead of one.

www.umn.edu/italladdsup

Figure 4.5: University of Minnesota Energy Conservation Pledge

The students who took the pledge were given a reusable shopping bag as an incentive for their commitment. Although there was no way to hold each student directly accountable for their behavior after taking the pledge, the initiative relied on the assumption that at least some of the students who took the pledge would feel compelled to engage in consumption-reducing behavior because they committed to do so.

Encouraging people to make a commitment to changing behavior is one way of fostering a sense of responsibility. Studies confirm that people having a stronger sense of personal responsibility are more likely to participate in pro-environmental behavior.[97] Sense of responsibility is also influenced by attitudes, values and locus of control.[98]

Freedom of Choice

In their article “Freedom of Choice and Behavior in a Physical Setting” Proshansky *et. al* identified that “In any situational context, the individual attempts to organize his physical environment so that it maximizes his freedom of choice.”[99] Steg and Vlek summarize, “Studies revealed…that policies are more acceptable when they are believed to be more fair, and when they do not seriously affect individual freedoms.”[100] Building design that accommodates choice and provides opportunities for users to participate in the operation and transformation of spaces to suit their needs may be more acceptable to users than design that does not.

Providing the freedom of choice in the use and control of spaces is also important for supporting permanent transition to pro-

[97] Kollmuss and Agyeman, “Mind the Gap”, 243
[98] Ibid, 256
[99] Proshansky, Harold M., Ittelson, William H., and Rivlin, Leanne G. “Freedom of Choice and Behavior in a Physical Setting,” in *Environmental Psychology: People and Their Physical Settings. Ed.* Proshansky, Harold M., Ittelson, William H., and Rivlin, Leanne G. (New York: Hold, Rinehart and Winston, Inc., 1970), 172.
[100] Steg and Vlek, “Encouraging Pro-Environmental Behavior”, 314

environmental behavior. Conscious decision-making has been predicted to be more effective because "unconscious pro-environmental behavior can easily be reversed or changed to a more unsustainable pattern because it is not based on some fundamental values."[101] An example is energy use at a rental property. People may be inclined to set the thermostat at a slightly cooler temperature (a pro-environmental behavior) if they pay for utilities but may revert back to a higher temperature setting (a negative environmental behavior) if they moved to a property where utilities are included in the price of their rent.

Someone who was conscious of the environmental impact of energy usage and committed to reducing consumption might seek alternatives for controlling environmental comfort regardless of whether or not it would decrease the cost of rent.

It is important to note that people seem to be more receptive to rewarding of pro-environmental behavior than to reprimanding environmentally harmful behavior.[102] Sustainable building design may be more effective by offering users freedom of choice and control and increasing opportunities for users to engage in more positive environmental behavior (i.e. harvesting rainwater, gardening, opening windows) rather than automating controls in a way that reprimands

[101] Kollmuss and Agyeman, "Mind the Gap", 250
[102] Steg and Vlek, "Encouraging Pro-Environmental Behavior", 314

overconsumption (i.e. faucets that turn off before one has finished washing one's hands or lights that turn off while a room is still occupied).

Behavior by Design

Many of the examples that have been described to illustrate the factors of behavior in the previous section were small scale, technological and appliance innovations that provide users with information and feedback on environmental impact. Currently, much of the design emphasis has been on employing careful combinations of these technologies and high performance building design (envelope, HVAC, daylighting) strategies to reduce negative environmental impacts. It is the argument of this thesis that important and significant changes in the way people conceive of themselves and their impact relative to the natural environment can result from employing strategies for influencing pro-environmental thinking and behavior at the scale of building design. This section will present strategies for encouraging pro-environmental behavior that have been identified in the literature review and will serve as the foundation for the discussion of building design strategies in later chapters.

Steg and Vlek offer that "Promoting behavior change is more effective when one 1) carefully selects the behaviors to be changed to improve environmental quality, 2) examines which factors cause those behaviors, 3) applies well-tuned interventions to change relevant behaviors and their antecedents, and 4) systematically evaluates the effects of these interventions on the behaviors themselves, their antecedents, and environmental quality and human quality of life."[103] They offer the outline in Figure 4.5 as a guide which will be used to support the design process in this project.

I. Which behaviours should be changed to improve environmental quality?
1. Select behaviours having significant negative environmental impacts
2. Assess the feasibility of behaviour changes
3. Assess baseline levels of target behaviours
4. Identify groups to be targeted

II. Which factors determine the relevant behaviour?

1. Perceived costs and benefits
2. Moral and normative concerns
3. Affect
4. Contextual factors
5. Habits

III. Which interventions could best be applied to encourage pro-environmental behaviour?
1. Informational strategies (information, persuasion, social support and role models, public participation)
2. Structural strategies (availability of products and services, legal regulation, financial strategies)

IV. What are the effects of interventions?

1. Changes in behavioural determinants
2. Changes in behaviours
3. Changes in environmental quality
4. Changes in individuals' quality of life

Figure 4.6: Considerations for Encouraging Pro-Environmental Behavior

[103] Steg and Velk, "Encouraging Pro-Environmental Behavior", 309

Strategies for changing behavior fall into four main categories.[104] *Antecedent strategies* attempt to change conditions that cause unwanted behavior. They tend to address an individual's knowledge of issues, knowledge of action strategies and perceived impact of action. *Consequence strategies* attempt to change consequences of unwanted behavior and often make use of incentives, penalties and feedback. *Informational strategies* attempt to change prominent motivations, perceptions and norms. Both consequence and informational strategies address the received perception of actions. Finally, structural strategies attempt to change the conditions under which choices regarding behavior are made. *Structural strategies* address attitudes and values as well as opportunities for and cost of action. Building design should employ these strategies in combination to respond to all of the different factors that determine behavior.

"Design with Intent" is an idea introduced by Daniel Lockton in 2008 as a way to describe the conclusions of a large body of research across several disciplines which recognizes "the idea of using features of a system – a physical product, built environment, computer network, or indeed any system with which a user interacts – to guide, shape or regulate the ways in which interaction occurs".[105] Lockton offers a "toolkit" for designers that summarizes this body of research into a format that can be used to foster behavior-

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[104] Ibid, 313
[105] Lockton, Dan, Harrison, David and Stanton, Neville. 2008. "Making the user more efficient: Design for sustainable behavior." Preprint. Dan Lockton webpage hyperlink, accessed November 2014, http://danlockton.co.uk/research/Making_the_user_more_efficient_Preprint_hyperlinked.pdf

shaping design of products, spaces and systems through affordances, constraints, mistake-proofing, persuasion and feedback.[106] Based on substantial environmental behavior and design research the toolkit offers suggestions for how design can achieve desired behavior. However, as the toolkit does not specifically target pro-environmental behavior some of the suggestions are potentially counter-productive in promoting the conscious and environmental value-raising user-participation this thesis finds necessary to building design.

The understanding of factors that affect behavior gained from the environmental psychology literature review allow me to evaluate those tools and strategies that will be most effective in supporting pro-environmental behavior through building design. Such an understanding will also enrich the critical evaluation of case studies presented in chapter five and inform design decisions and evaluation techniques throughout the project.

[106] Lockton et. al.

Chapter 5: Precedent Analysis

Sustainable Primitive Architecture

Primitive construction offers great insight to design for high performance buildings. These structures though simple are remarkably sophisticated. Sheltering against the environment using only the materials and construction methods that were locally available is what James Marston Fitch and Daniel P. Branch call the “one supreme and absolute limitation” of primitive architecture (architecture of “pre-literate” societies).[107] Including shelters such as igloos, sod-roofed dugouts, tent structures, mud wall buildings, and light frame structures with thatch cladding, primitive architecture “reflects a precise and detailed knowledge of local climate conditions…and a remarkable understanding of the performance characteristics of the building materials locally available.”[108]

Mud constructions for example are effective in arid dessert climates. The mass walls store heat during the hot days and reduce interior temperatures. The heat then slowly releases to warm the interior during cool nights (Figure 5.1).[109]

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[107] Fitch, et. al., 134
[108] Ibid, 134
[109] Ibid, 140

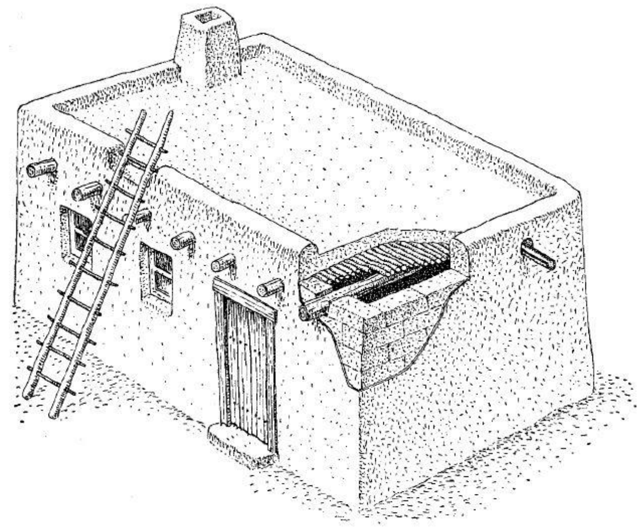

Figure 5.1: Mud brick construction, Fitch, 1960

Even by contemporary standards primitive constructions perform efficiently and effectively.[110] They do so not because of advanced technologies or carefully engineered materials, but because the builders and dwellers of these shelters were intimately aware of conditions of climate and engaged with the materials and performance. This is not to suggest contemporary society abandon advancements in sophisticated materials and technologies and revert to living in tent structures. What is important here is not that contemporary design replicate exact forms and practices of primitive architectures (although there is much to be learned from them), rather that contemporary culture adopts the principles that inform primitive architecture: understanding of environment, materials and methods.

[110] Fitch et. al., 134

High-Performance Buildings

Research shows that users have a significant impact on sustainable building performance. However, further investigation of the impact of user performance on building performance is necessary. The following precedents offer insight into how office buildings can engage occupants to improve user health and satisfaction as well as building performance.

Bullitt Center

The Bullitt Center in Seattle, Washington (Figure 5.2) was completed in 2013 and received full Living Building Certification in April 2015.

Figure 5.2: Bullitt Center, Miller Hull Partnership, 2013

The speculative office building designed by The Miller Hull Partnership has been advertised as the "most sustainable commercial building in the world" and boasts a 250-year life span.[111] The building uses an impressive combination of sustainable systems, technology and materials to achieve high-performance (Figure 5.3). Despite these sophisticated systems, construction costs were only marginally higher than a "typical" speculative office building of comparable size.[112]

[111] Berton, 172

[112] Kahn, Brad. "Living Proof: Building the Bullitt Center." *Sustainable Media Group.* 5:09. January

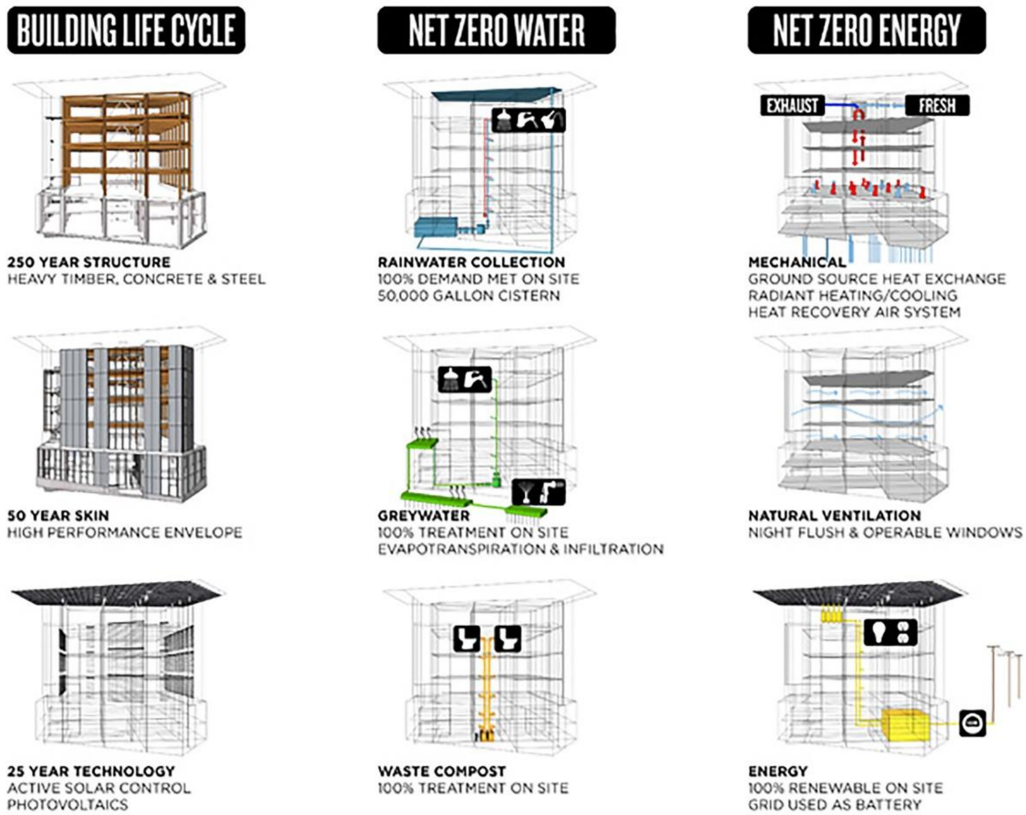

Figure 5.3: Sustainable Strategies, Miller Hull Partnership, 2013

Bullitt Foundation Presdident Denis Hayes says of the project, "We're just trying to make a building where doing the right thing, the healthy thing, the environmentally sound thing, is also the convenient thing."[113]

In order to meet net zero energy, water and waste goals set by the project and the Living Building Challenge in a cost-effective way,

11, 2013. http://www.bullittcenter.org/2013/01/11/675/

[113] Ibid.

occupant contributions to consumption were carefully considered during design (Figure 5.4).

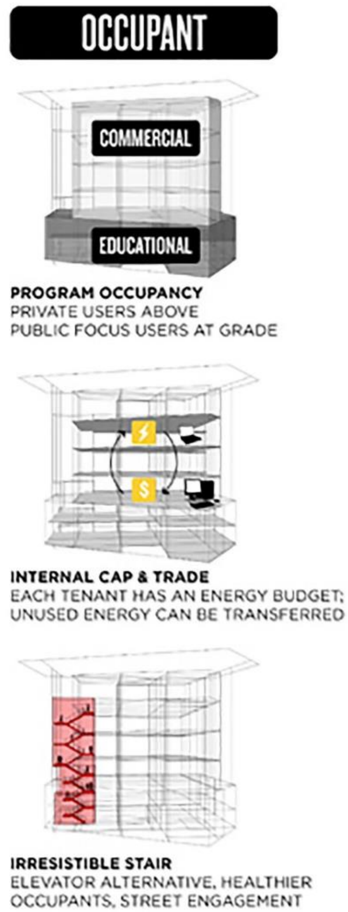

Figure 5.4: Sustainable Occupant Strategies, Miller Hull, 2013

The building accommodates public and educational spaces on the ground floor and has an informative website to educate others about sustainable design and performance features of the building. An "irresistible stair" encourages occupants to use the stairs rather than the elevator to save energy and promote physical health (Figure 5.5).

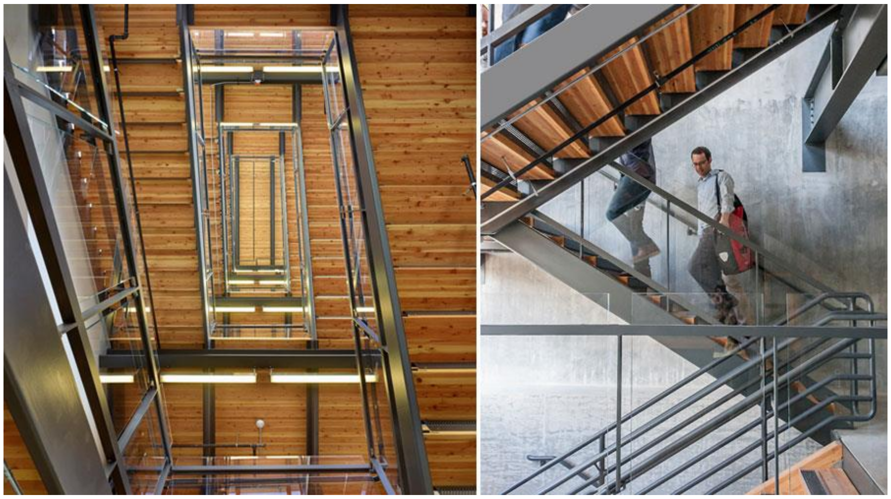

Figure 5.5: Irresistible Stair, Miller Hull Partnership, 2013

Reducing energy consumption was a top priority. To ensure that the building could operate within the energy supplied by a rooftop solar photovoltaic array, energy use intensity (EUI) had to be reduced from 72 (typical for an office building of this size) to 16. Heating and cooling design reduced EUI by 30 and lighting design further reduced EUI by 10, leaving tenant behavior responsible for the final 16 point reduction in EUI (Figure 5.6). Each tenant is expected to operate within a strict “energy budget”.

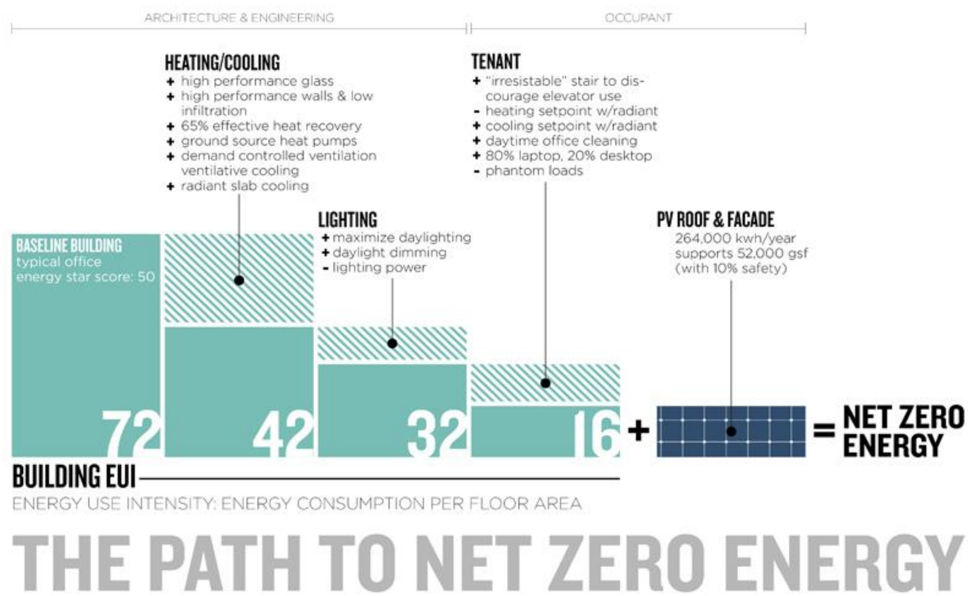

Figure 5.6: Energy Reduction Strategies, Miller Hull Partnership, 2013

So far, the building has performed even more efficiently than expected.[114] Despite debates as to the aesthetic quality of the building, the Bullitt Center is a significant example of high-performance design achieved by the vision, dedication and collaboration of building developers, designers and occupants.

David and Lucile Packard Foundation Headquarters

The David and Lucille Packard Foundation Headquarters in Los Altos, California (Figure 5.7) is an example of the opportunity and responsibility of architects, owner and occupants to work together from

[114] Kahn, Brad. "Bullitt Center Far Exceeds Energy Goals in First Year of Operations," *Living Proof Blog*, April, 22, 2014. http://www.bullittcenter.org/2014/04/22/bullitt-center-far-exceeds-energy-goals-in-first-year-of-operations/

design through commissioning to establish and achieve environmental performance goals.

Figure 5.7: David and Lucile Packard Foundation Headquarters, photos by Jeremy Bittermann, EHDD, 2012

Designed by EHDD Architects and opened in 2012 the Packard Foundation Headquarters is LEED Platinum certified and a recipient of the AIA Top 10 award for the 2014 Committee on the Environment (COTE) competition. EHDD worked with the Foundation to establish sustainability in practice. During the design phase this meant investigating and diagraming how Foundation business practices and employees affect environmental conditions (Figure 5.8). The vision for the project was "not to design a sustainable building, but to advance the Foundation's sustainability as an organization."[115]

[115] EHDD. "The David and Lucile Packard Foundation Headquarters," *The American Institute of Architects,* March 2015, www.aiatopten.org/node/403.

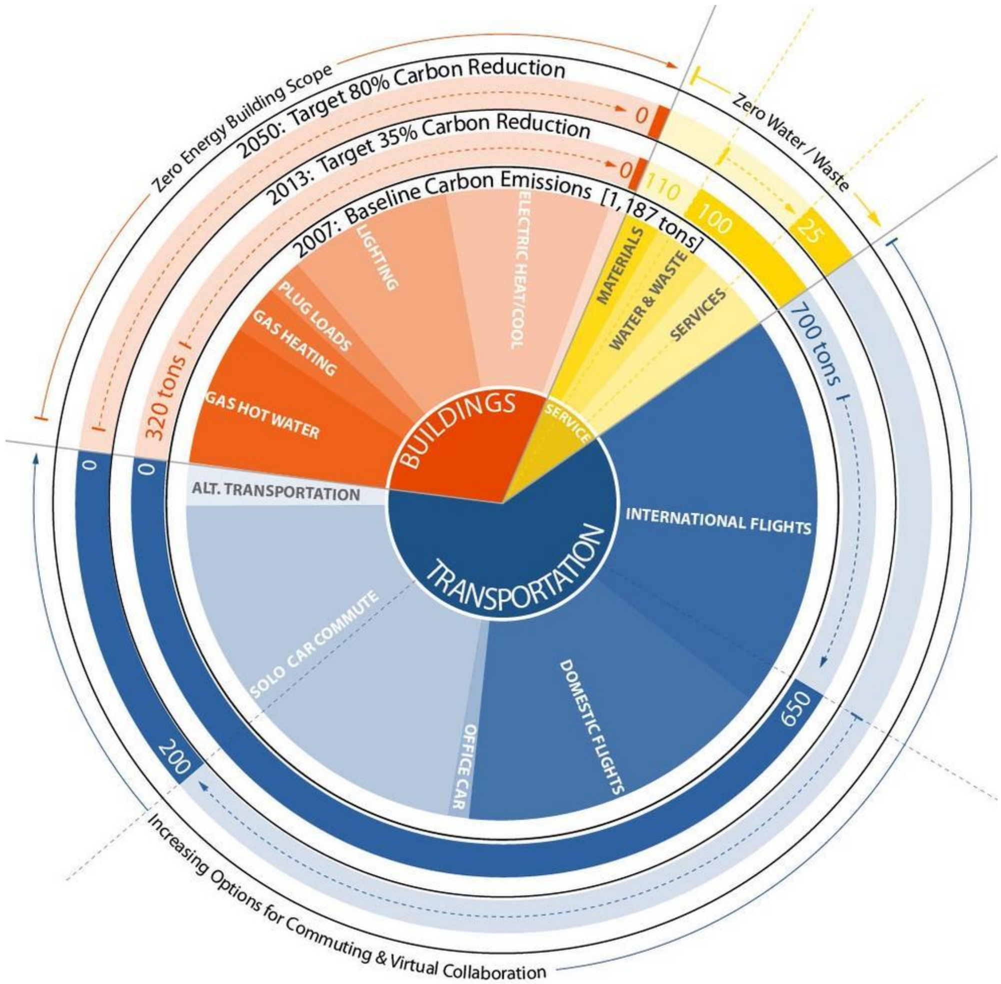

Figure 5.8: Organizational Carbon Footprint (2007), with short (2013) and long term (2050) reduction targets, EHDD, 2012

During design and construction employees formed a Sustainability Task Force to consult on design decisions and train fellow employees for high-performance occupancy.[116] Involving employees throughout the design process ensured design solutions would successfully engage occupants in building performance. "*Active* cooperation, direct

[116] Knapp, Robert H. "Sustainability in Practice: Building and Running 343 Second Street" (Physics and Sustainable Design, Evergreen State College, 2013).

contributions to the effort, however small, is far more satisfying and effective than passive cooperation, mere acceptance of conditions imposed by others."[117]

Important members of the design team stayed involved with the project through the first year of occupancy to troubleshoot issues in real time and ensure actual building performance matched intended building performance. "With just a phone call, the building operator was able to engage the post occupancy team, who could immediately access the current operation of the building and provide feedback, download information for further analysis, or schedule a site visit to investigate an issue."[118]

The design team's partnership with owners and occupants to improve sustainable practice of the Foundation and its employees is a precedent for an integrated and collaborative practice of architecture that engages occupant behavior as a tool for sustainable design. The project is also evidence of the importance of architectural services continuing throughout building commissioning to ensure occupants understand how to ensure the sustainable performance of their building.

[117] Knapp, 35

[118] EHDD. "The David and Lucile Packard Foundation Headquarters – Collective Wisdom and Feedback Loop," *The American Institute of Architects,* March 2015, www.aiatopten.org/node/403.

Interpolis Insurance Headquarters

Between 1996 and 2003 the Interpolis Insurance company worked with architecture and interior design team of Abe Bonnema, Erik Veldhoen + Co and Kho Liang IE Associates to transform their office building headquarters in Tilburg, Netherlands.[119] The company decided to eliminate personal workstations and focused on providing a variety of different types of work spaces for quiet, individual work, large and small group work, relaxation and socialization. Changes in scale, lighting levels and styles, furniture, color and enclosure provided a variety of workspaces (Figure 5.9).

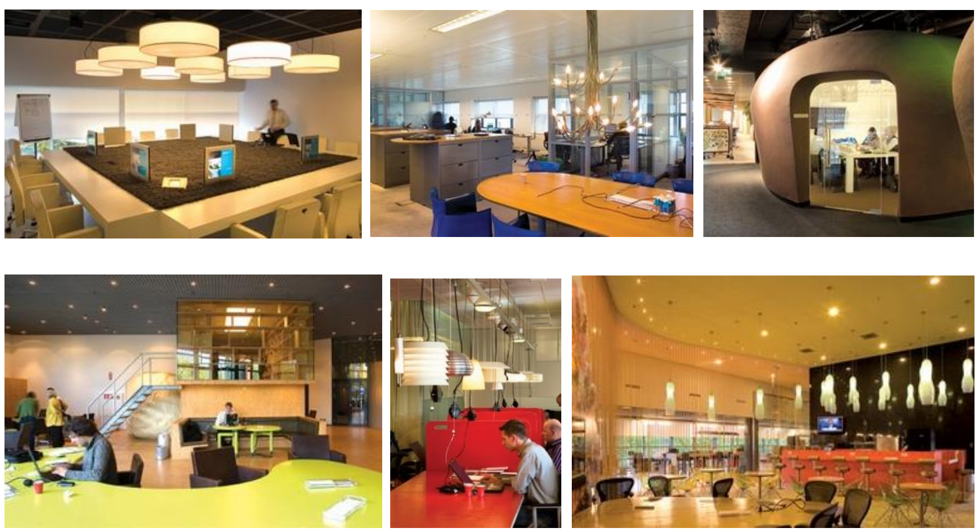

Figure 5.9: Sample of dynamic interior workspaces at Interpolis, BD Magazine, 2006

[119] Advanced Workplace Associates. *Interpolis Head Office – Tilburg, Netherlands.* London: Advanced Workplace Associates and British Council for Offices. 2006. Accessed March 2015. www.veldhoencompnay.com/workspaces/uploads/publicaties/awa_interpolis-50d33db91612e.pdf

Although sustainable design was not necessarily a driving factor in the design process, new ways of working and using spaces had an impact on building performance. (more about reduction of energy usage due to personal controls, smaller footprint for more employees because of no personal workstations, and increased employee productivity and satisfaction)[120] This precedent offers important insight to the power of design to influence how spaces are used and how user satisfaction and productivity can improve sustainable building performance.

Behavior/Action-Driven Design

The ways in which buildings influence human mood and behavior are only beginning to be tested and understood by environmental behavior research, sociology and psychology, and perhaps even less by architects. However, there is consensus across disciplines that buildings do impact, both positively and negatively, human well-being and behavior.[121] The following are examples of designs that were driven by the desire to encourage specific user behaviors and respond to the conditions of the natural environment.

Togo na of the Dogan

The Dogon people currently dwell in a region of Mali in northwestern Africa where they settled around 1300 A.D.[122] In every Dogon village

[120] Advaned Workplace Associates
[121] Clements-Croome, Derek. 2004. *Intelligent Buildings: Design, Management and Operation*. London: Thomas Telford Ltd.
[122] Lavine, Lance. 2008. *Constructing Ideas: Understanding Architecture.* Dubuque: Kendall/Huntt Publishing Company.

there is an important civic structure called a togo na (sometimes spelled toguna). This unique building is thought of as "the house of words, the men's house, or the great shelter" and is the meeting place for male village elders.[123] The building is simply constructed with "Y" branched logs supporting a thick, thatched roof structure. The mass roof provides welcome shade and the open sides of the structure allow cross breezes, creating a comfortable, cool respite from the intense heat (Figure 5.10). Perhaps more important than the provision of comfort, togo na are built to be only four to five feet tall from floor to ceiling. "This low ceiling is intentional. It forces all members of the governing council to remain seated, promotion discussion rather than physical confrontation over difficult issues."[124] The togo na is an important example of how physical spaces can shape user behavior.

Figure 5.10: Togo na, photos by John Archer, *Constructing Ideas: Understanding Architecture*, 2008

[123] Lavine, 33
[124] Ibid, 33

Oak Alley Plantation

Oak Alley Plantation in Vacherie, Louisiana was built in the 1830s. The home employs many strategies for dealing with Louisiana's hot and humid climate including responding to site conditions and engaging users. The building is situated on the site to capture summer winds (Figure 5.11). Rooms are arranged around a central open stairwell that promotes cross and stack ventilation (Figure 5.12). A deep, two story veranda surrounds the entire home, cooling incoming air and shading sixteen-inch-thick mud brick masonry walls that protect interior rooms against heat gain (Figure 5.13).

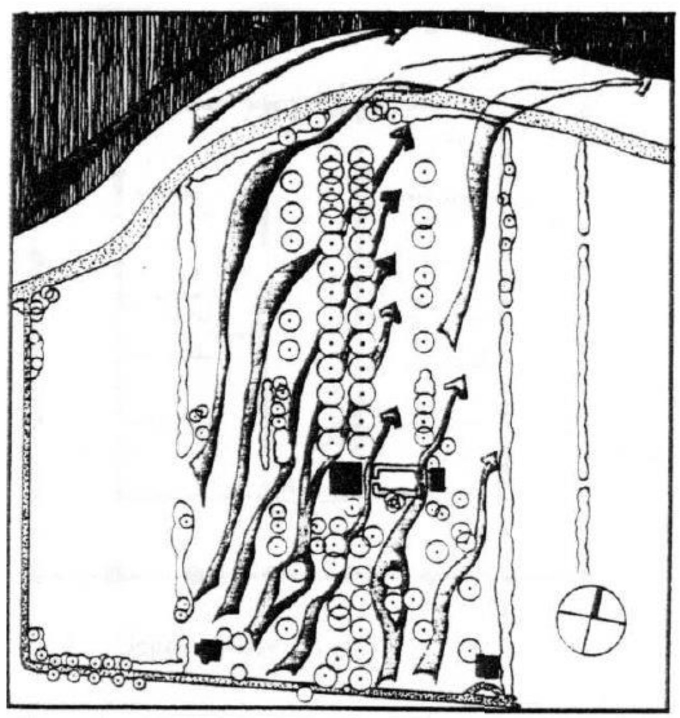

Figure 5.11: Capturing site winds, Ubbelohde

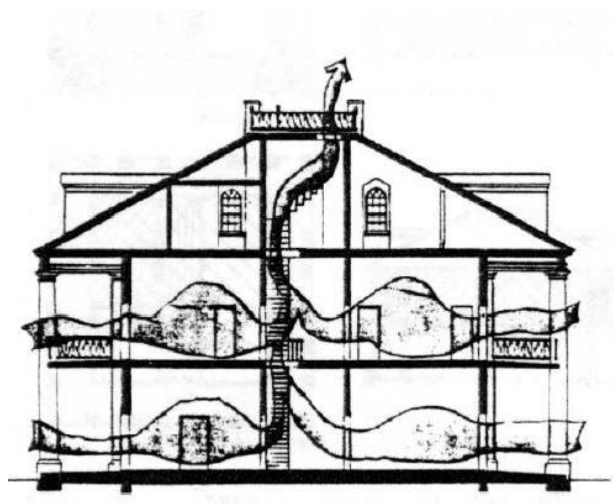

Figure 5.12: Cross and stack ventilation, Ubbelohde

Figure 5.13: Veranda, photo by Gary Saunders

Interior rooms are designed to accommodate different activities at different times of the day and year in what are described as "redundant living spaces."[125] Occupants open and close shutters to

[125] Ubbelohde, Susan. "Oak Alley: The Heavy Mass Plantation House" (School of Architecture, University of Minnesota).

control cross ventilation and daylighting and move around in the building throughout the day and year to accommodate thermal comfort (i.e. using one side of the veranda in the morning and the other side in the evening to remain cool and shaded). This building is an important example of how the arrangement of spaces can help occupants understand what areas of the building best suit their needs at specific times of the day and year and allow them to be in control of their own comfort.

WOS 8 Enclosure Design

WOS 8 is a heat transfer station on the edge of a growing neighborhood outside of Utrecht in the Netherlands. Being a heat transfer station the building is a large rectangular mass that is entirely inwardly focused and is very seldom occupied. As a result, the building became a scene for safety concerns and vandalism.[126] The building's one small window was repeatedly broken by youth throwing rocks at it and concerns were raised about youth attempting to climb up the building to access the roof.

NL Architects were asked to design a new façade for the building in 1997. The design team considered the problems of the existing building and designed a façade that would encourage positive

[126] NL Architects, "WOS 8," *NL Architects,* accessed March 2015, www.nlarchitects.nl/slideshow/133/

interaction with the building. Rather than putting screens or bars over the window the design team replaced the window glass with a transparent basketball backboard (Figure 5.14). Instead of throwing rocks, youth now throw basketballs at the window, a behavior that benefits the youth and the building. One side of the building was fitted as a rock-climbing wall rising about one third of the building height (Figure 5.15). Climbing of the building is encouraged, but only to a height which is safe for users and which does not risk unwanted roof access.

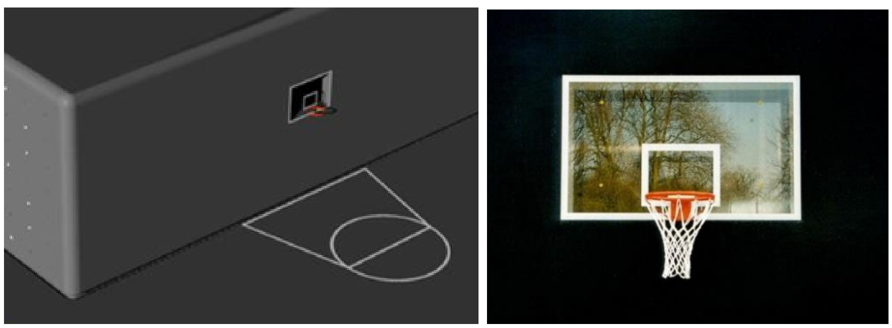

Figure 5.14: Basketball hoop backboard window, NL Architects, 1997

Figure 5.15: Climbing Wall, photo by Daria Scagliola,
NL Architects, 1997

The opposite side of the building is embedded with a series of nesting stones for the Apus Apus bird. The stones spell out the name of the building, celebrating the otherwise utilitarian energy transfer station as an important building in the community (Figure 5.16). A homogeneous polyurethane cladding provides a durable enclosure and offers an opportunity for celebrating rainwater with an exaggerated and artistic roof drain (Figure 5.17).

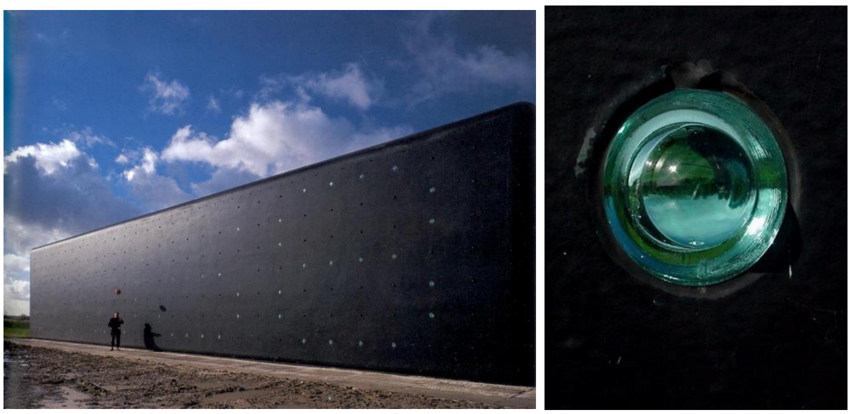

Figure 5.16: Apus apus nesting stones, NL Architects, 1997

Figure 5.17: Roof drain, NL Architects, 1997

By activating the building and calling attention to the relationship between energy production and the natural environment NL Architects have created what they describe as a "Village Square wrapped around a box".[127] This project is an example of how understanding the behavior, needs and desires of users can result in design that encourages positive interactions between people, buildings and the natural environment.

Performance Monitoring and Feedback

As discussed in chapter four, pro-environmental behavior relies on users understanding how their building is performing. Informing users about the impacts of their decisions and behaviors on energy and water usage and waste generation is an important first step toward engaging sustainable behavior of building occupants. In recent years it has become more common to have building energy performance and other overall consumption metrics displayed on TV monitors in building lobbies or on organization's websites. The Music and Science Building on the Hood River Middle School campus in Hood River, Oregon, designed by Opsis Architecture is a LEED Platinum and Living Future Institute Net Zero certified building that received an AIA Top 10 Award for the 2012 COTE competition.[128] Listed among its achievements in

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[127] NL Architects, "WOS 8," *NL Architects,* accessed March 2015, www.nlarchitects.nl/slideshow/133/

[128] Opsis Architecture. "Music and Science Building," *The American Institute of Architects,* March 2015, www.aiatopten.org/node/77.

energy use and innovation is the implementation of an energy dashboard displayed in the building and on the school's website (Figure 5.18). Although the dashboard does indeed give an account of energy and utility use and solar power generation, the abstract energy metrics of kilowatt hours (kWh) are not easily translated into single classroom or fixture usage. As with many dashboards, users are able to see the usage information but are not given enough identification about what behavior is causing high or low consumption and what can be done to improve performance.

Figure 5.18: Dashboard, photo credit Delta Controls

The following are examples of emerging technologies that are monitoring occupant behavior relative to building performance and making the results of such monitoring more accessible to building users.

LEED Dynamic Plaque

In 2014 the United States Green Building Council (USGBC) partnered with Honeywell to develop the LEED Dynamic Plaque (LDP). The design is an iteration on the LEED Certified plaques that adorn many certified buildings (Figure 5.19) and represents a USGBC initiative to encourage certified new construction projects to become re-certified as existing buildings. LDP monitors energy use, water consumption, waste output, occupant transportation and human experience and continually updates with a real-time score that reflects the LEED rating system score card (Figure 5.20).

Figure 5.19: LEED certification building plaque, USGBC, 2014

Figure 5.20: LEED Dynamic Plaque, USGBC, 2014

USGBC describes the dynamic plaque as an "appealing, easy to understand display ideal for mounting in a prominent location so tenants and guests can view and better understand the building's ongoing rating." [129] An associated app allows the building performance

[129] Long, Marisa, "USGBC and Honeywell collaborate to advance the LEED Dynamic Plaque," *USGBC,* October 21, 2014, www.usgbc.org/articles/usgbc-and-honeywell-collaborate-advance-leed-dynamic-plaque.

to be accessed anywhere by building operators and occupants. In addition to performance and scoring information, the LDP can point out potential issues and solutions for affecting building operation.

One of the first pilot locations for the LDP is the San Francisco office of DPR Construction, a national contractor specializing in technically complex sustainable construction. Eric Lamb, executive vice president of DPR says the plaque helps them better understand their building and holds them accountable for performance. "Seeing the implications of our everyday actions helps make sustainable behavior permanent, as opposed to occasional scoring, and helps us build smarter for our customers."[130]

Sid Lee Office Dashboard

Sid Lee is a marketing design and advertising firm that believes in multidisciplinary creative work and the importance of change. "We transform brands into vibrant growth platforms by crafting meaningful human experiences."[131] In their Paris office, Sid Lee has instituted a monitoring system for employee activities that affect resource consumption and building performance.

[130] Ibid

[131] "Overview," *Sid Lee*, accessed May 20, 2015, sidle.com/en/about/Overview/?slide=1.

While Sid Lee is not the first to display building performance metrics in a real-time, internet-based dashboard they are quite unique in the specificity and scale of information. The animated and interactive dashboard shows real time information such as how many cups of coffee have been poured, how many times the toilet has flushed, how many feet of paper have been printed and how many times the door has opened (Figure 5.21).[132] All of these activities are thus understood to affect the metrics for overall energy and water consumption and waste generation which are also displayed. By clicking on the individual metrics one can see aggregates of monthly and annual data (Figure 5.22).

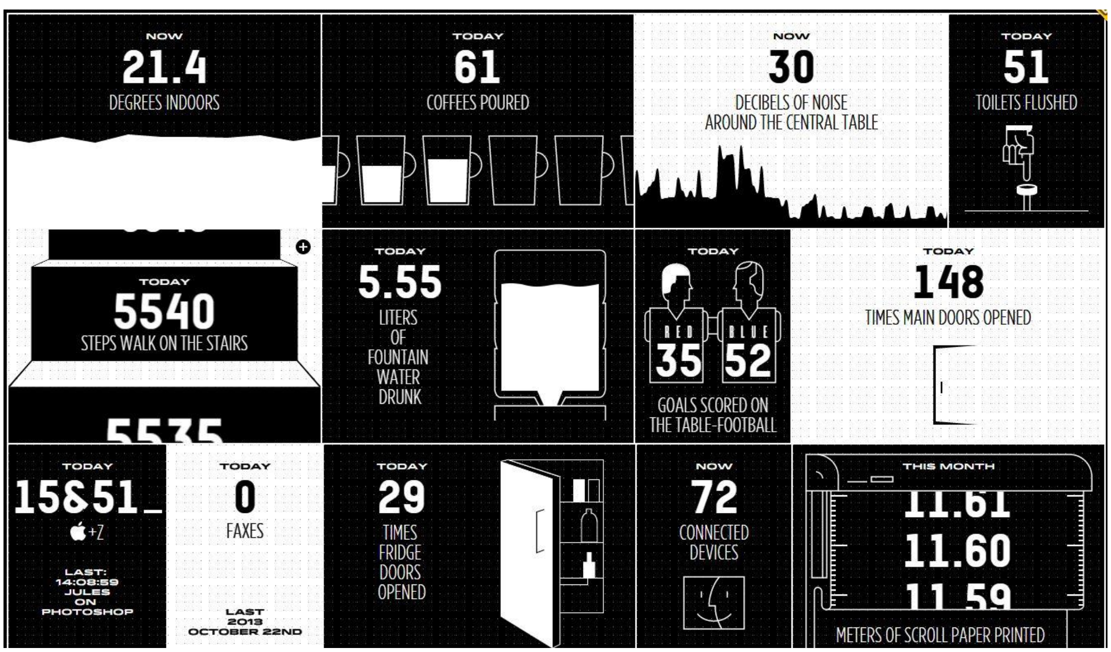

Figure 5.21: Real-time dashboard, Sid Lee Paris

[132] “Sid Lee Dashboard, Paris,” *Sid Lee*, accessed May 20, 2015, dashboard.sidlee.com.

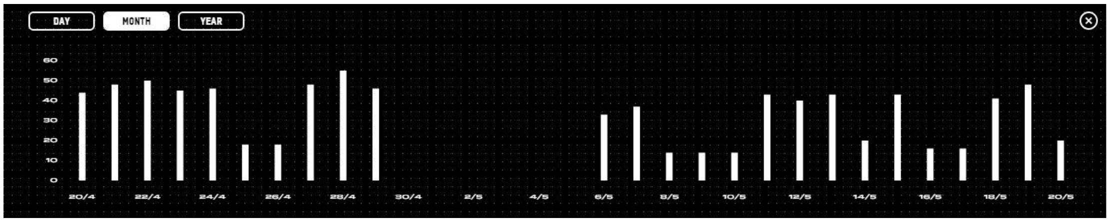

Figure 5.22: Monthly data, number of devices connected to Wi-Fi, Sid Lee Paris

Although specific strategies for improving energy, water and waste performance are not called out, this method of measuring and displaying performance is easily relatable to everyday user behavior. This is an example of human-scaled monitoring and feedback that allows users to more intuitively understand the relationship between their actions and building environmental performance.

Fitbit

Fitbit is a wearable monitoring system that allows users to track personal activity, exercise, food, weight, sleep and more. Information from the wearable syncs wirelessly and automatically with mobile devices and allows users to set goals and track their progress working toward them (Figure 5.23). [133] Fitbit advertises a variety of styles and options for wearables (Figure 5.24) that allow users to "Find Your Fit,"[134] promoting personal fitness as both trendy/stylish and catering to desires for flexibility and autonomy.

[133] *Fitbit,* accessed May 2015, https://www.fitbit.com/app
[134] Ibid

Figure 5.23: Mobile device dashboard, Fitbit, 2015

Figure 5.24: Selection of Fitbit products, Fitbit, 2015

Increasing popularity of Fitbits and similar technologies reflect the growing cultural importance of personal health and wellness and are an indication of the potential for integration of performance monitoring with personal mobile devices. This is an important time for the design and building industry to take advantage of increased public interest in performance monitoring at the level of individual users.

Fitbit and similar technologies offer an opportunity to study direct relationships between building performance and personal wellness while improving both for the benefit of the user. Imagine a total environment Fitbit where wearables and mobile devices track not only the number of steps taken and calories burned by taking the stairs, but also the energy the building saved as a result! Information about healthy eating is accompanied by local sources for fresh produce that save energy and taking public transit is represented as a metric of fresh air left untainted by reduced number of automobiles on roadways. Users and organizations able to set goals for energy, water and waste management and track their progress while being provided with strategies and information to improve. Fitbit is an important example of how to promote wellness and performance monitoring that is stylish, easy to use and understand, and takes advantage of wearables and personal mobile devices to engage behavior change for improving performance.

<u>Ecological Aesthetic: Engaging Exterior Environment</u>

"How might we develop a design aesthetic that honors basic ecological principles while celebrating the poetic and expressive qualities of the

architecture, space, materials, and design elements?"[135] Mary Guzowski, daylighting, solar design, sustainable design expert and Professor of Architecture at the University of Minnesota – Twin Cities, asks this important question in her book *Towards Zero Energy Architecture: New Solar Design.* Guzowski describes the contribution of aesthetic experiences to humankinds understanding of our place within the ecosystem and observes that, "aesthetically pleasing architecture can enhance our relationship with the environment and foster ecological awareness."[136] The following precedents are examples of buildings whose enclosure design provide opportunities for users to understand and engage with environmental forces acting on their buildings.

Sky at One Central Park

Sky at one Central Park, completed in 2014, is a mixed use high rise development comprised of two towers (one tall, one short) rising out of a connected base in Sydney, Australia. The project was a collaboration of Ateliers Jean Nouvel and PLW Architects with Patrick Blanc (hydroponic living wall design). The buildings host large vertical swatches of living walls and narrow planting boxes at spandrels bring the natural environment to building occupants. Cables stretching between planting boxes encourage vegetation to grow vertically to shade the glass façade behind (Figure 5.25).

[135] Guzowski, Mary. 2010. *Towards Zero Energy Architecture: New Solar Design.* London: Laurence King Publishing Ltd.
[136] Ibid, 163

Figure 5.25: Hydroponic growing façade, photos by Murray Fredericks (left) and Simon Wood (right), ArchDaily, 2014

The taller of the two towers sponsors an enormous cantilever from which an array of highly reflective metal panels is suspended. The reflected metal panels are intended to reflect light down to the lower floors between the two buildings (Figure 5.26).[137]

Figure 5.26: Cantilever and Heliostat, photo by Murray Fredericks, drawing by Ateliers Jean Nouvel, ArchDaily, 2014

137 "One Central Park/Ateliers Jean Nouvel," *ArchDaily*, September 25, 2014, www.archdaily.com/551329/one-central-park-jean-nouvel-patrick-blanc/.

Different people will think differently whether or not such dramatic architecture is the appropriate response to the need for buildings that connect users to their environment. The integration of living plant material provides access to vegetation for units high off the ground that wouldn't otherwise have access. However, there are a number of structural and maintenance considerations when introducing plant life, soil and water on a façade that could potentially cause damage and disruption to interior spaces. Problems associated with vegetation could cause users to become frustrated with rather than appreciative of façade vegetation. Furthermore, the large reflective array hanging over the buildings is an example of overtly ecological aesthetic. While there can be no guess what the purpose of the array is, it's size and reflectivity can be shocking and may promote skeptics to question its beauty and ask the following: Is it really working? Does it have to be that big? Could another solution have achieved the same result? Given the building is so new, only time will tell whether or not the building performs and is received successfully. In the meantime however this project is an important precedent for understanding the ways in which building performance is visible (or not) to passersby and how design decisions to engage environment can earn positive and negative reactions from users. The design resulting from this thesis project strives to adopt an ecological aesthetic that is more subtle than the strategies used at Sky at Central Park but finds value in exterior expression of responses to environmental factors such as sunlight.

La Mola Conference Center

La Mola Concerence Center in Barcelona, Spain opened in 2009 and was designed by B720 Fermín Vásquez Arquitectos. A series of narrow bar buildings are nestled into a rolling hillside with the long axes of the buildings running east-west to provide maximum north-south exposure (Figure 5.27).

Figure 5.27: Site plan showing east-west orientation of bar buildings, B720 Fermín Vásquez Architectos, ArchDaily, 2009

The thermal enclosure is clad in wood siding and clear-glazed windows that provide views of the landscape. On the south side of the buildings floor plates extend out from the thermally controlled barrier to create a narrow balcony which users can occupy (Figure 5.28).

Figure 5.28: Balcony, photo by Adria Goula, HouseVariety, 2011

The balcony hosts colored, perforated screens that slide in aluminum tracks attached at each floor plate which can be opened and closed according to sun position and occupant desire for light and views (Figure 5.29). The perforations in the screens allow filtered views between interior and exterior when the screens are closed.[138] La Mola Conference Center is an excellent example of a building responding to site conditions and providing opportunities for user operation of façade conditions to control comfort and views and increase awareness of changing environmental conditions throughout the day and year.

138 "La Mola Conference Center/b720 Fermín Vázquez Arquitectos," *ArchDaily*, December 13, 2009, www.archdaily.com/43294/la-mola-conference-centre-b720.

Figure 5.29: Perforated, operable, colored metal screens, photo by Duccio Malagamba, ArchDaily, 2009

Chapter 6: Sustainable 'Ordinary'

In a report chronicling the process of design, construction and operation of the David and Lucile Packard Foundation Headquarters, Robert H. Knapp observes, "This much-voiced, multi-faceted, contentious term refers to a pattern of living and working, not a gadget, device or trophy. Sustainability isn't something you *have*, it's something you *do.*"[139] Selecting a site and program type with which to explore the thesis question began with the realization that fostering a cultural understanding of sustainability as "a pattern of living and working" requires that sustainable design engages a wide variety of users and fosters pro-environmental behavior in everyday tasks.

Location and Site

Pro-environmental behavior begins with transportation; how a user gets to a building. The site must be in an urban area well-served by local and regional public transportation and within walking and biking distance of residential areas as well as food, retail and entertainment amenities. Downtown Silver Spring, Maryland is an excellent test case for the location of the thesis project.

Silver Spring, Maryland is an unincorporated area with an urban downtown that shares a similar history to many small to moderately-sized cities across the United States. Located on the northern edge of Washington, D.C.,

[139]Knapp, 1

present-day Downtown Silver Spring began as a series of large country homesteads. In 1873 the Baltimore and Ohio Railroad opened its Metropolitan Line which ran through Silver Spring on its way from Washington, D.C. to Point of Rocks Maryland.[140] The area began to grow in earnest in the early 20th century attracting commercial development, entertainment and retail development. The Silver Theater and the Silver Spring Shopping Center opened in 1938[141] and by the 1950s the city boasted a thriving retail market.

As was the case with many urban areas across the United States, the downtown area began to decline with the rise of suburban development. In 1960, Wheaton Plaza shopping center opened several miles north of downtown Silver Spring and eventually claimed all of the city's major retailers. The Washington Metropolitan Area Transit Authority (WMATA) opened the Silver Spring station on the Red Line Metro in 1978 connecting the city to downtown Washington, D.C. and later to Forest Glen, Wheaton and Glenmont north of Silver Spring (Figure 6.1).

[140] The Metropolitan Railroad". *The Evening Start.* April 30, 1873. p. 4. (Wikipedia)
[141] Silver Spring Shopping Center Opens Today: Comprises 19 Stores, Gas Station, Movie". *The Washington Post.* October 27, 1938. p. SS1.

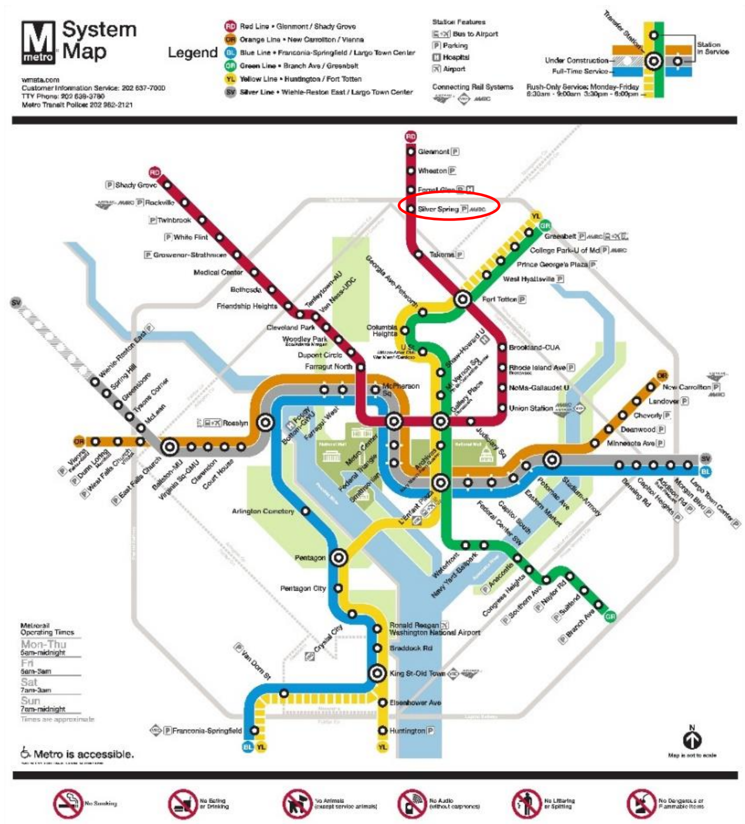

Figure 6.1: Metro Service Map, WMATA

Metro rail service sparked some slow development in the city, including the office headquarters for the National Oceanographic and Atmospheric Administration (NOAA) in the late 1980s, early 1990s. However, it wasn't until the early 21st Century that the city began its renaissance that continues today.[142]

Downtown Silver Spring, like many American downtowns, has found revival in many people's growing desire for walkable, mixed-use communities with access to public transit. Several city blocks were redeveloped as an outdoor

[142] "Silver Spring, Maryland," *Wikipedia*, accessed May 2015, en.wikipedia.org/wiki/Silver_Spring,_Maryland

shopping plaza along a pedestrian strip of Ellsworth Drive which included restaurants, shops and a movie theater. In 2003, Discovery Communications relocated its headquarters to Downtown Silver Spring and the Silver Theater was reopened as AFI Theater which attracted renewed commercial and residential development.[143] By 2005 Downtown Silver Spring's rebirth was recognized by the Rudy Bruner Award for Urban Excellence silver medal.[144] In 2011 the Civic Building and Veteran's Plaza completed the axis of the outdoor shopping street and has become a center of Downtown life with regular markets, musical performances, pubic events and a winter ice-skating rink. A new public library is under construction one block away from Veteran's Plaza and is intended to be a future stop of the Maryland Transit Authority's Purple Line light rail train providing an east-west connection between Metro Rail stations in Maryland (Figure 6.2).

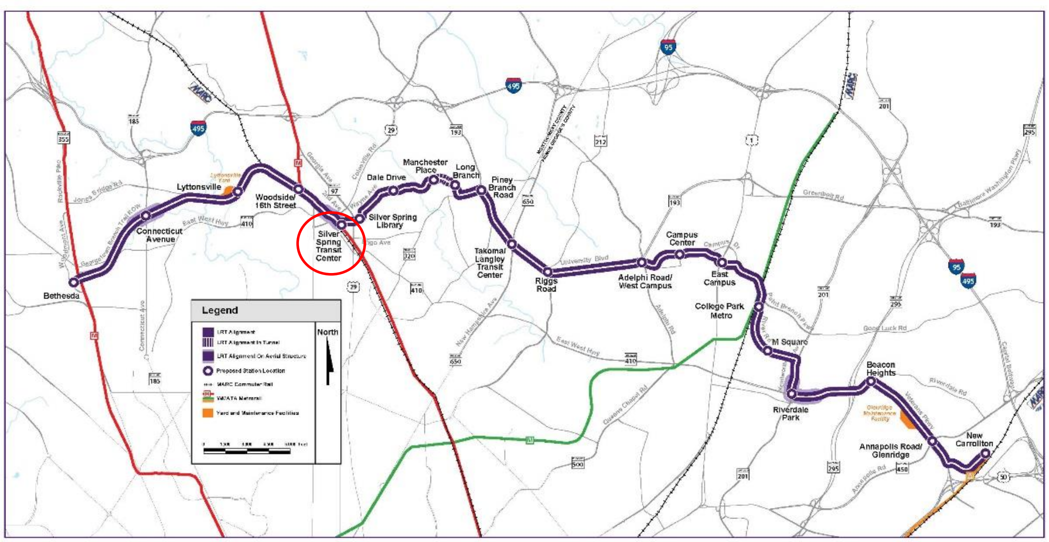

Figure 6.2: Proposed Purple Line service, Maryland Transit Authority

[143] "Silver Spring, Maryland," *Wikipedia*, accessed May 2015, en.wikipedia.org/wiki/Silver_Spring,_Maryland
[144] Ibid

Downtown Silver Spring offers a condition typical of many urban areas across the United States that are seeing or seeking urban renewal through development of mixed-use downtowns in proximity to public transit. Furthermore, Silver Spring's commitment to sustainable development is evidenced by the "Green Downtown" goals outlined in "The Vision – Silver Spring's Future" (adopted as part of the Silver Spring Central Business District Sector Plan, 2000) and a number of Energy Star and LEED Certified buildings throughout the downtown.[145]

A building site within the location of Downtown Silver Spring was chosen for its proximity to existing Metro Rail and bus transit, projected Purple Line transit and residential, retail and entertainment amenities (Figure 6.3).

145 "The Vision – Silver Spring's Future," *Montgomery Planning,* 2000, www.montgomeryplanning.org/community/plan_areas/silver_spring_takoma_park/master_plans/sscbd/sscbd_toc.shtm

Figure 6.3: Urban context map showing site proximity to transit and amenities

The site faces Georgia Avenue, an important thoroughfare connecting Downtown Silver Spring and Washington, D.C. Currently a surface parking lot, 8615 Georgia Avenue sits between the prominent Lee Building office building and a surface parking lot slated for residential development (Figure 6.4).

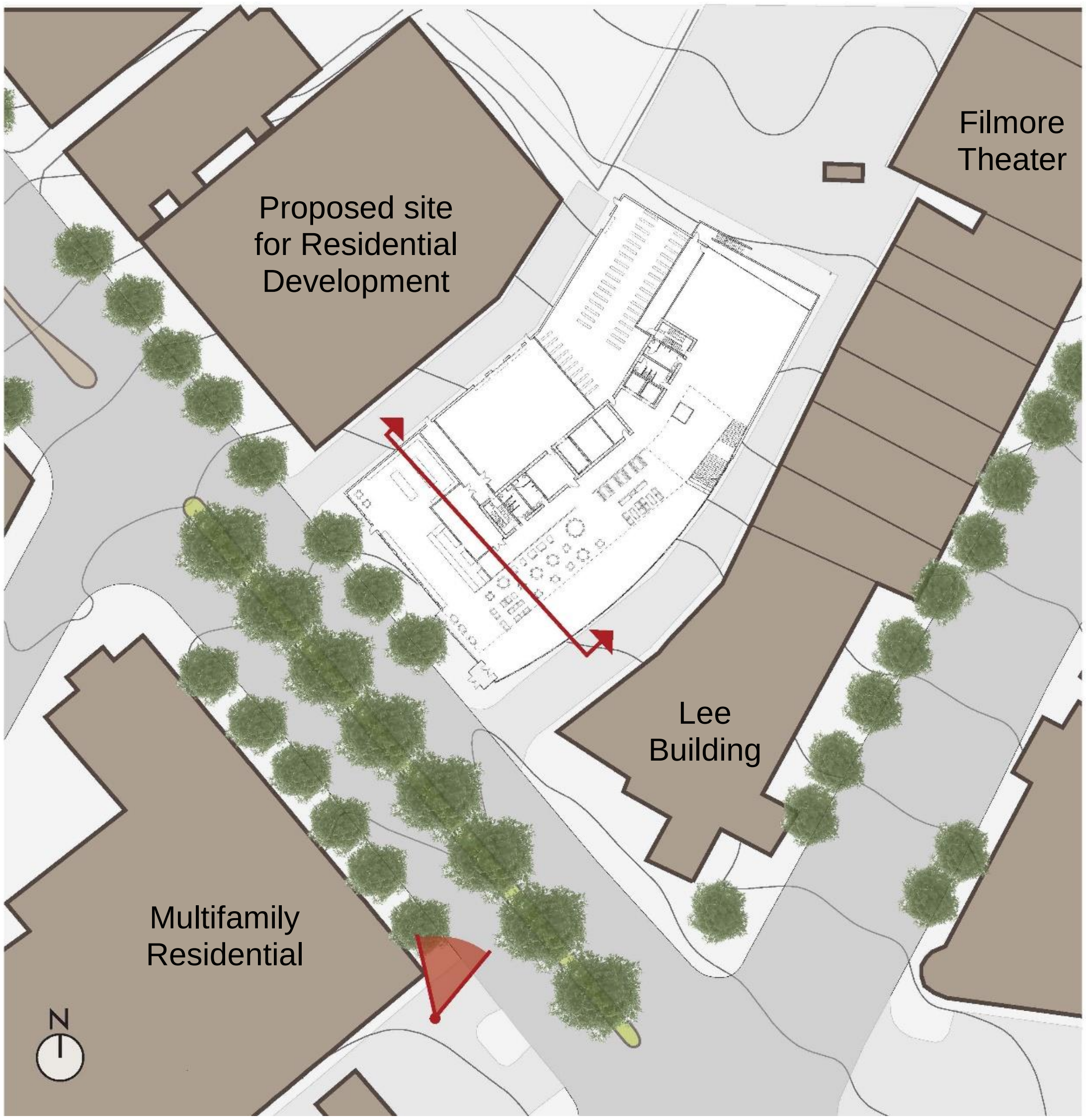

Figure 6.4: Site Plan with ground floor plan

Montgomery County zoning for the Silver Spring Central Business district identifies the site in zone CB-2 for office/commercial, with the option of retail on the ground floor. Under current zoning the building can be maximum 143' measured from the center of the property on Georgia Avenue.[146]

[146] "Montgomery County Code," *American Legal Publishing Corporation,* accessed January 2015, www.amlegal.com/nxt/gateway/dll?f=templates&fn=default.htm&vid=amlegal:montgomeryco_md_mc

Building Type and Program

In considering an appropriate building type and program with which to develop the thesis project, emphasis was placed on selecting a condition in keeping with current development in Silver Spring that engages many different types of people for prolonged periods of time. The design of a speculative office building was selected as the test case for the development of the thesis project.

The American Deep-Plan Office Building

The deep-plan, also referred to as "typical plan" and "core and shell" design for office buildings in the United States emerged in the early decades of the 20th Century. As David Arnold points out in his article "The Evolution of the Modern Office Building and Air Conditioning," the proliferation of electric lighting and air conditioning "eliminated restrictions on plan form and fenestration that architects had been constrained to work under since antiquity."[147] Narrow "U", "H" and "I", shaped buildings with access to daylight and air were no longer a necessity, as evidenced by the windowless office building built for the Hershey chocolate company in Pennsylvania (Figure 6.5) and the deep, rectangular Edison Company office building in Detroit both built in the 1930s.

[147] Arnold, David. 1999. "The Evolution of Modern Office Buildings and Air Conditioning." *ASHRAE Journal.* June 1999:40-54

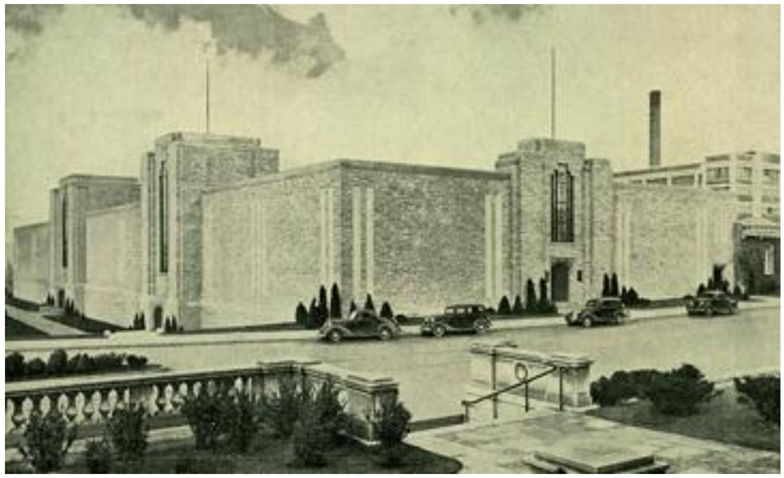

Figure 6.5: “Modern Office Building”, Hershey Chocolate Company, Hershey Archives, 1935

After World War II the notion of an entirely glazed curtain wall façade evolved alongside innovations in heating, ventilating and air conditioning to manage thermal comfort and heat gain and loss. Lever House, completed in 1952 was one of the first entirely glass curtain-walled office buildings to have sealed windows. Arnold observes, “The light, almost transparent appearance became very popular and led to similar buildings in most U.S. western cities in the 1950s and 60s.”[148] The opportunities of electric lighting and mechanical HVAC systems completely divorced buildings from their environment. The International Style saw the sealed, glazed office buildings become the standard world-wide, regardless of climate and site conditions.[149]

[148] Arnold, David. 1999. “Air Conditioning in Office Buildings After World War II.” *ASHRAE Journal.* July 1999: 33-41
[149] Hascher, Rainer, Jeska, Simone, and Klauck, Birgit. 2002. *Office Buildings: A Design Manual.* Basel: Birkhäuser. 19.

A premium amount of rentable floor area was one of the great advantages afforded by deep-plan, glass curtain-walled office buildings. Driven by the maximization of profit and efficiency, the deep-plan became the staple of American office buildings in the late 20th Century.[150] Rem Koolhaas points out in his 1995 essay, “Typical Plan”, “The ambition of the Typical Plan is to create new territories of the smooth unfolding of new processes, in this case, ideal accommodation for business…the office building represents the first totally abstract program – it does not demand a particular architecture, its only function is to let its occupants *exist.*”[151] Koolhaas goes on to criticize harshly, though perhaps not inaccurately, “Typical Plan is deep. It has evolved beyond the naïve humanist assumption that contact with the exterior – so-called reality – is a necessary condition for human happiness, for survival.”[152] Koolhaas’ critique is reflected in the rise of sustainable design rating system which, supported by environmental and human behavior research, put renewed emphasis on design that provided access to fresh air, daylight and views and sought to improve the health and wellness of occupants through design.

[150] Hascher et al., 19
[151] Koolhaas, Rem. Reprint. 2013. “Typical Plan.” *A-Typcial Plan.* Ed. Jeannette Kuo. Zurich: Park Books. 128-143.
[152] Ibid, 132

Sustainable Office Design and Retrofitting

With the attention of LEED and other sustainable design rating systems the market support for high performance office buildings has grown. Energy savings that result in cost savings support marketability of sustainable office design. As technologies continue to improve it is even becoming possible to achieve high performance with little or no additional up front cost.[153]

In the effort to mobilize the design and commercial sectors to promote sustainable new construction and retrofitting there have been a number of design guides published and formulaic strategies for "greening the workplace". One such resource, *Green Office Buildings: A Practical Guide to Development*, edited by Anne B. Feij supplies an illustrated list of strategies, "10 Ways to Green a Building." (Figure 6.6). Only two of the ten strategies make suggestions about user behavior (encouraging public transportation and recycling). The remaining eight strategies suggest that green buildings are the product of design decisions and installation of high performance and automated systems. Excepting one note about general orientation of the building mass there is no discussion of how a building should be shaped and sighted to address its environment.[154]

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[153] Freij, Anne B. 2005. *Green Office Buildings: A Practical Guide to Development.* Washington, D.C.: Urban Land Institute.
[154] Ibid, 5

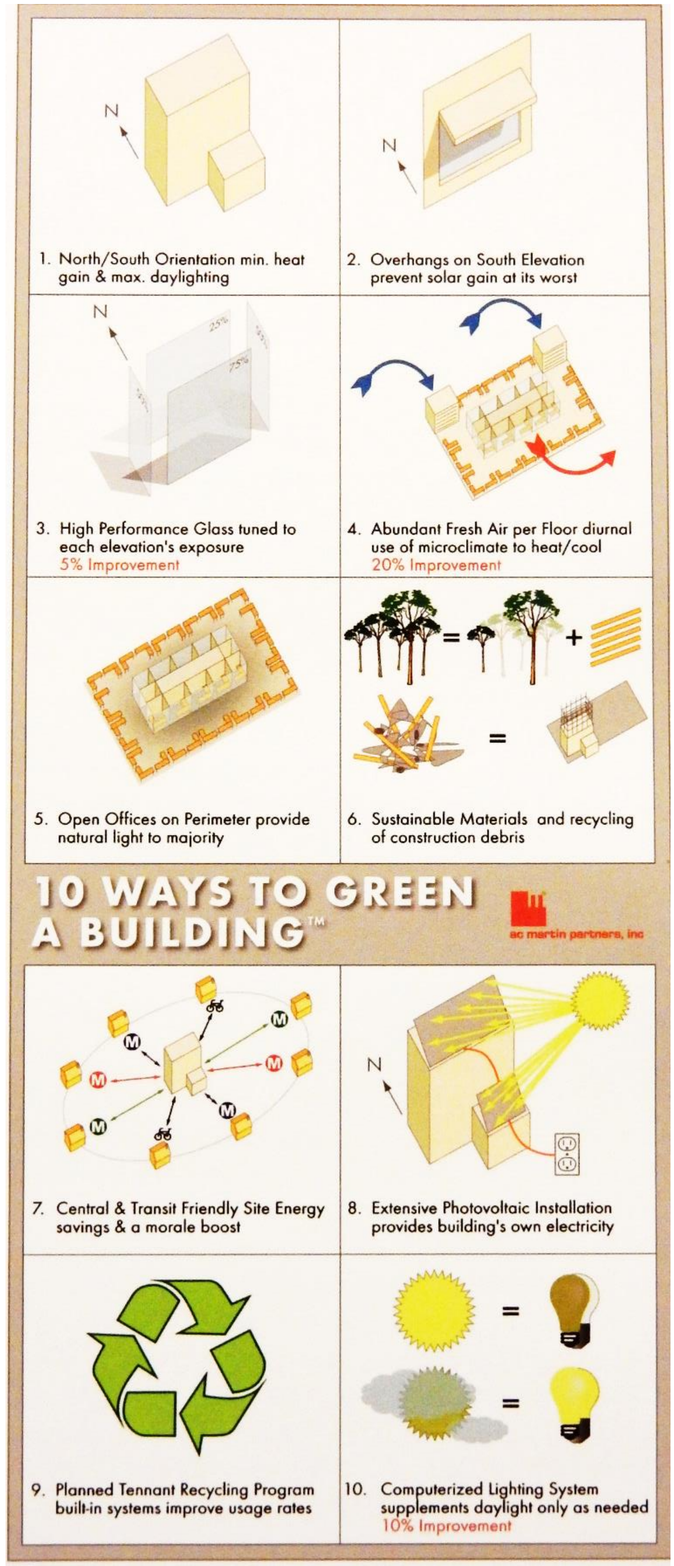


Figure 6.6: “10 ways To Green a Building”, AC Martin Partners, Inc.,
Green Office Building: A Practical Guide to Development, 2005

Through implementation of efficient mechanical systems, low-flow fixtures, automated occupancy and daylight sensors for electric lighting and energy saving technologies (LED lights, Energy Star appliances, etc) it is possible to build and retrofit high-performance, deep plan office buildings. These buildings continue to be informed by economic efficiency and tend to have a "hands off" attitude when it comes to users and building systems. However, the expansion of communication and information technologies and changing patterns of living and working require re-evaluation of the typical deep plan model.

Re-Imagining the Work Environment

In the opening chapter of the book *Intelligent Buildings: Design, Management and Operation*, editor Derek Clements-Croome writes, "Changes in society and technology are shaping our future."[155] He identifies efficiency, quality and effectiveness as drivers of office building design from the 1960s to the 1980s and observes that today buildings should act as "a milieu for human creativity."[156] In designing to nurture human creativity it is necessary to consider, 1) what kinds of work environments are needed/desired to accommodate creative work?, and 2) how is success measured and evaluated?

[155] Clements-Croome, Derek. 2004. *Intelligent Buildings: Design, Management and Operation*. London: Thomas Telford Ltd.
[156] Ibid, 9

Accommodating creative work increasingly values flexibility and collaboration. A growing emphasis is also being placed on employee well-being and work-life balance in the workplace.[157] Opportunities afforded by global economics and unprecedented access to mobile information and communication have contributed to a growing expectation for individualism and choice, particularly in in Western cultures.[158] As a result, more and more people expect to be able to make their own schedules, have a greater degree of autonomy and to be able to work when, where and how they want. Architecturally and programmatically these ideas translate to providing a variety of space and use types to accommodate different schedules, work styles and technologies. Employees desire spaces for quiet individual work but also benefit from areas for small and large group discussion, workshops, informal conversation, relaxation, and entertainment.[159]

The winning submission for a 2012 national competition to conceive of the Office Building of the Future for 2030 identified several trends that will inform the office building of the future including distributed work (working in multiple locations with the assistance of mobile technology), optimizing floor plates (designing for maximum flexibility,

[157] Strelitz, *Intelligent Buildings,* 344
[158] Ibid, 339
[159] Ibid, 343

efficiency, access to daylight) and greater modularity in interior fit-out (allowing the building to be flexible over time).[160]

Employer support for informal, active and playful workplaces represents changing attitudes toward measuring success and productivity. Research and practice are beginning to indicate the positive influence of health and well-being on employee productivity. Where previous models of efficiency in office design were based on economics of rentable area and construction costs, future models of efficiency may very well be based on the cost benefit of productive employees. Companies are beginning to understand the greater benefit of making an effective building that employees enjoy working in even if the construction cost is higher than a less functional or attractive building.[161] Despite these trends, additional and more extensive research is needed to fully understand the relationship between different types of work environments and employee satisfaction and productivity.[162]

It is not a coincidence that changes in work environments emerged and have been developing at the same time as the reinvestigation and implementation of sustainable design. Human beings are beginning to

[160] Pickard, Jon and Chilton, William. "The Office Building of the Future." *DesignInelligence.* October 10, 2012. www.di.net/articles/the-office-building-of-the-future/.
[161] Clements-Croome, 342
[162] Ibid, 81

understand that we cannot separate our own health and well-being from the health of our environment. Croome predicts that buildings will be increasingly shaped by "value for money, water conservation, occupant well-being, productivity, renewable energy and energy effectiveness" and that factors driving the design and performance of such buildings will be "information and communication technologies, robotics, smart materials, sustainable issues technology and social change."[163] Successful sustainable design integrates occupant wellness and behavior with building technology and performance.

Parti as a Product of Program and Site

Organized by Activity

While flexible and various working environments are becoming more desirable, there are still those companies with individuals who need or desire individual desks and offices. Early on in the design process, research of office design trends led to an understanding of the need for balance between private, leasable tenant areas and shared workspaces. All areas should be designed to be flexible and change in accordance with changes in work culture over time. The leasable tenant areas can be built-out in accordance with each tenants needs/desires for space. Completing build-out from a series of

[163] Clements-Croome, 10-11

interchangeable options for partitions, furniture and the like allows user choices to be incorporated into the building as it is used. This idea of “loose-fit” increases the overall life span of the building by allowing tenant areas to accommodate change.[164] Additionally, by pairing private tenant areas with shared working spaces, tenants may adopt a “hoteling” strategy whereby employees share desks and work partially from other areas in the building or home[165]. This saves the company money on the amount of rentable area needed and offers an opportunity for tenants to move into the building more quickly. Shared spaces and amenities can be used by employees while the tenant area is being fit-out for the tenants needs.

The Tietgenkollegiet Dorm in Copenhagen, Denmark, (Figure 6.7) designed by Lundgaard and Tranberg Architects in 2006 is an important precedent for understanding the balance between private and shared program spaces.

[164] Clements-Croome, 345
[165] Ibid, 344

Figure 6.7: Tietgenkollegiet Dorm, photos by Ashley Grzywa, 2014

The dorm re-imagines the residential parti of the double-loaded corridor bar building as a double-loaded corridor wrapped around a circular courtyard. The exterior side of the corridor hosts individual resident rooms while the interior side of the corridor sponsors shared dining, socializing, living and study spaces (Figure 6.8).

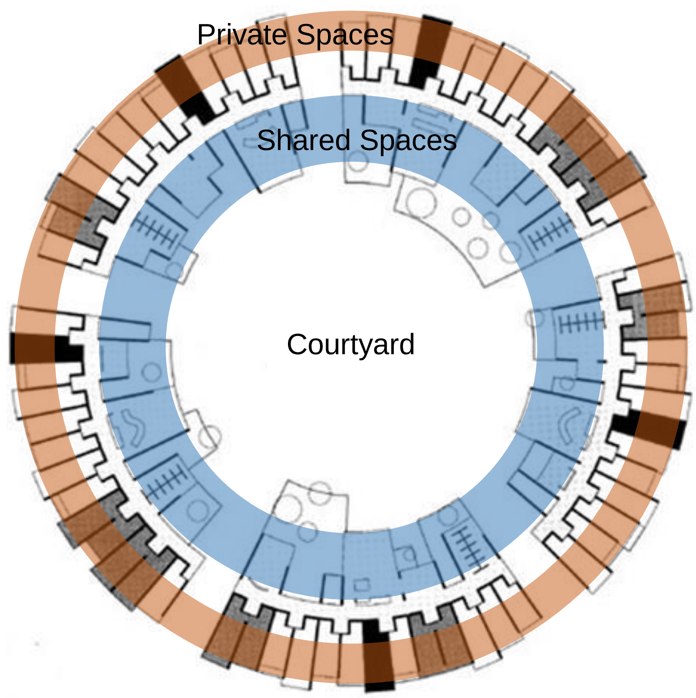


Figure 6.8: Tietgenkollegiet Dorm, plan by Lundgaard and Tranberg Architects, diagram by author

Translating the parti of the Tietgenkollegiet Dorm onto the site at 8615 Georgia Avenue was an important exercise for developing the building parti (Figure 6.9).

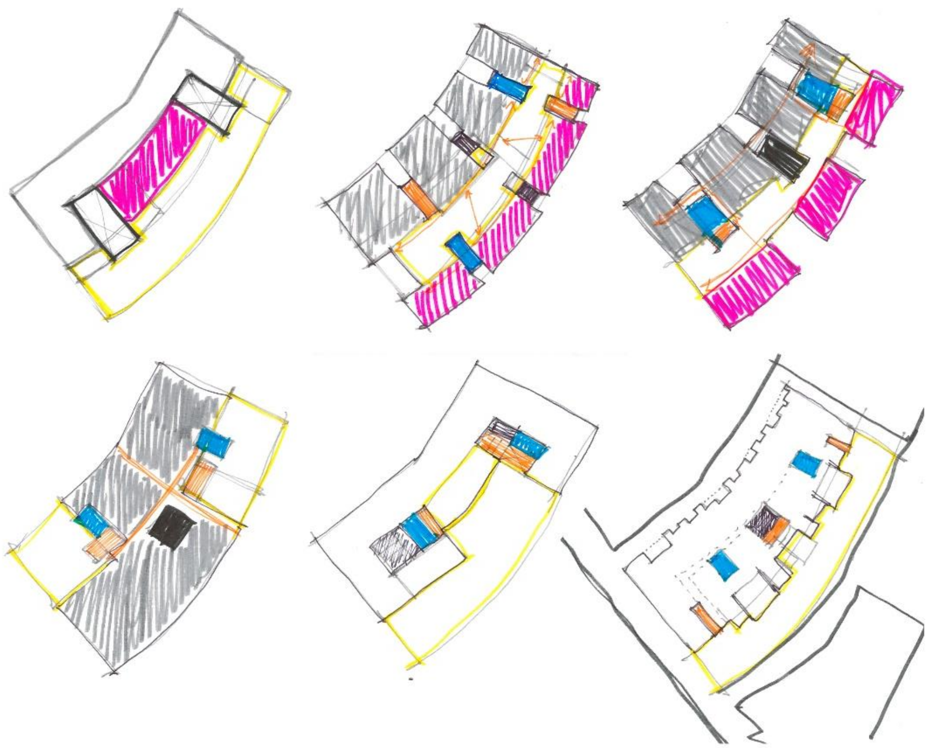


Figure 6.9: Testing relationships between private/leasable office spaces and shared work and amenity areas.

Shaped by the Sun

Sunlight, along with program, was another important factor in determining building form. In order to better understand the sun condition on site, a massing model of the site with adjacent building masses was built in Rhinoceros 3D modeling software. Investigation of environmental modeling software led to selection of the Ladybug plug-in for Grasshopper parametric modeling with Rhinoceros (Figure 6.10).

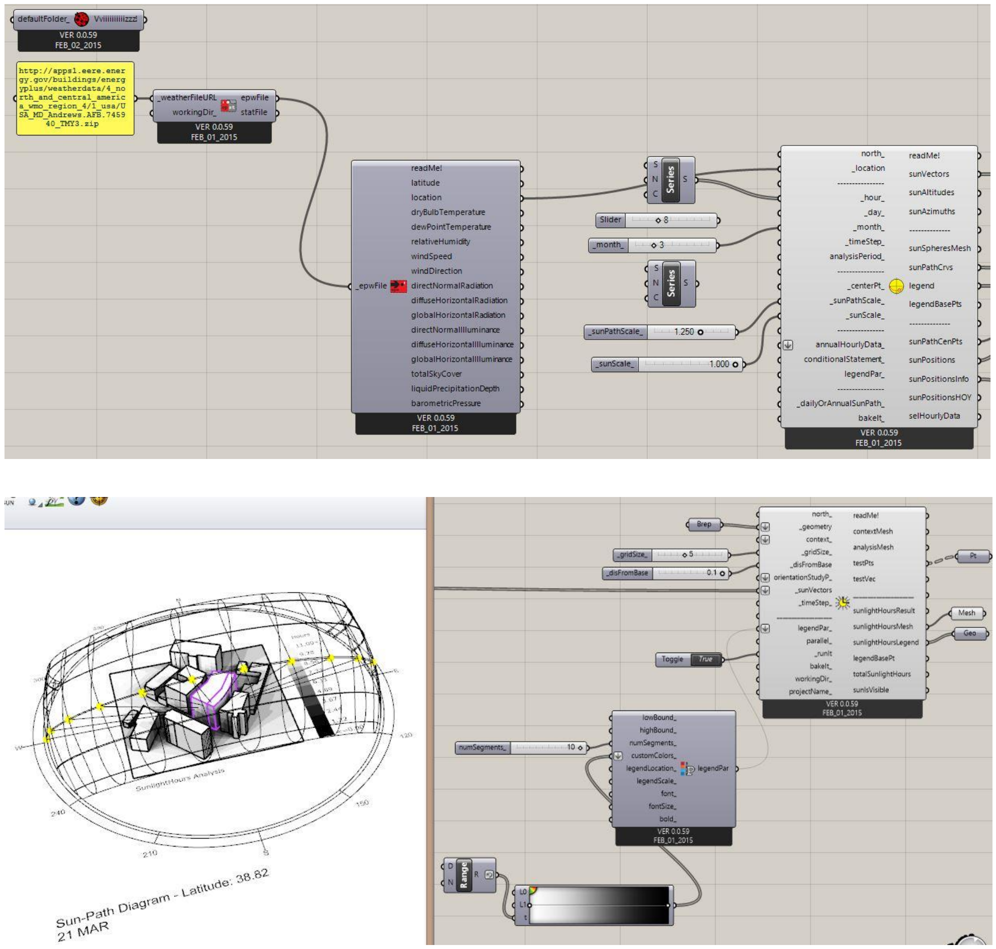


Figure 6.10: Screen Capture, Ladybug and Grasshopper script for modeling sun and shadow conditions EPW weather files

Ladybug translated EPW weather data collected from Andrews Air Force Base in Maryland into sun vectors for the appropriate latitude and longitude of the Silver Spring, site. A series of shadow studies were conducted to understand what times of the day and year the building at 8615 Georgia Avenue would be receiving sunlight (Figure 6.11-6.12).

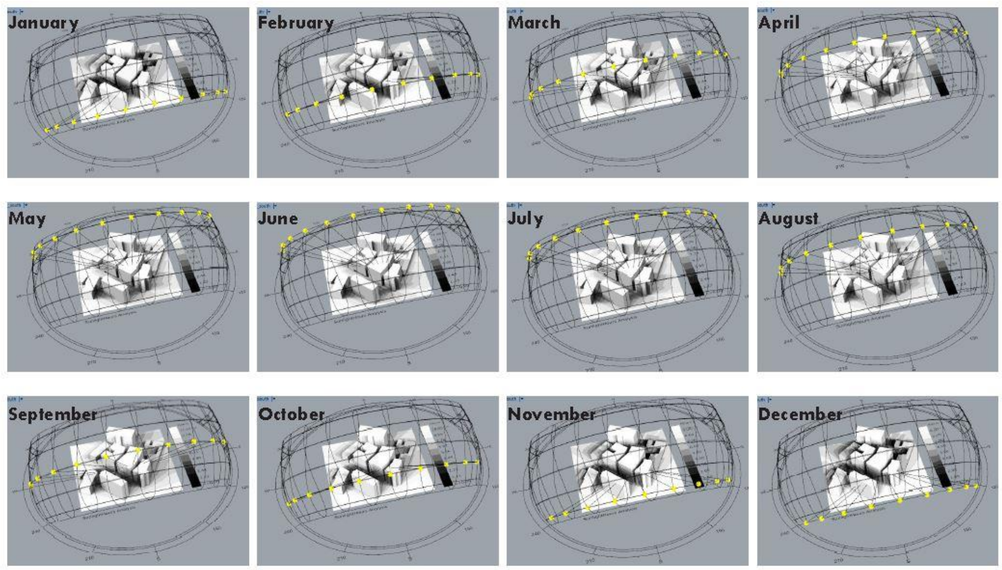


Figure 6.11: Sun studies of a day 8:00 AM – 6:00 PM for each month

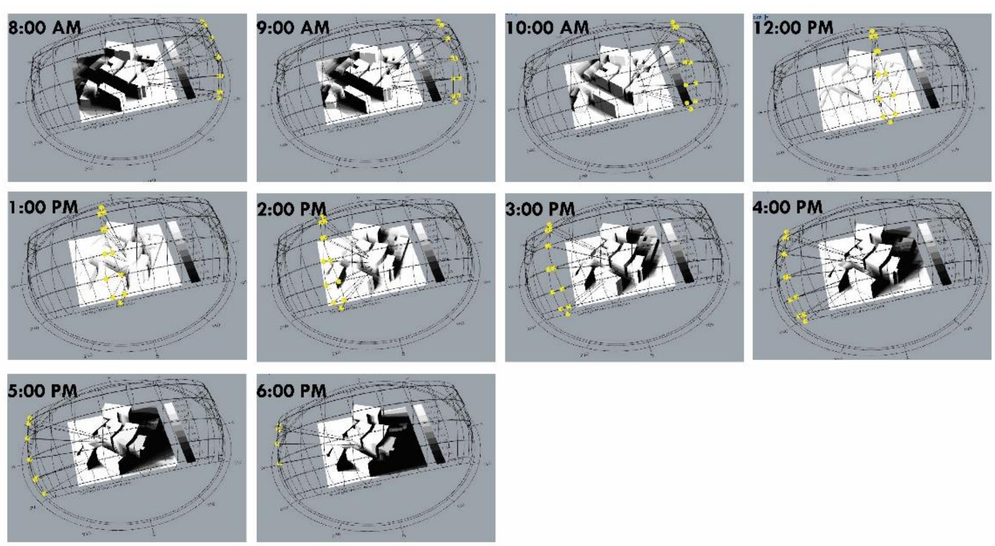
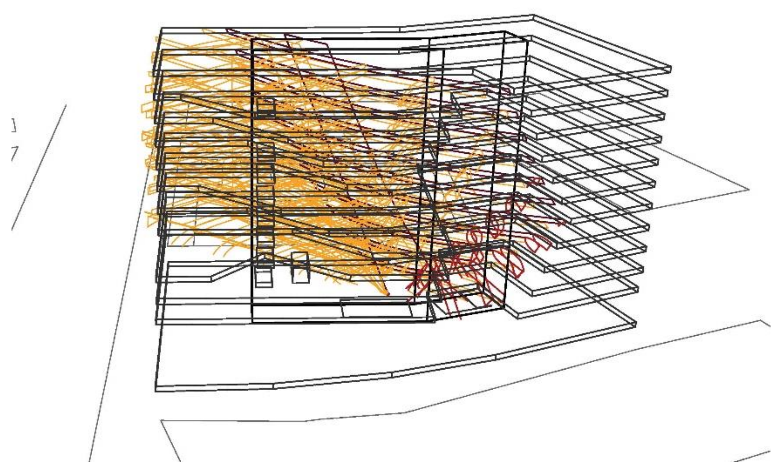


Figure 6.12: Sun studies by hour for the entire year

Conclusions draw form this study prioritized morning sun 8:00 AM – 9:00 AM and afternoon sun at 1:00 PM as important moments when the building would be most consistently receiving sunlight throughout the year. Other times of day the building is often in shade of a neighboring building for a significant part of the year.

Hourly sun vectors from 8 AM – 6 PM (work day hours) for each month of the year and monthly sun vectors for each hour of the year were mapped onto a “typical” core and shell form built up in accordance with zoning code heights and setbacks (Figure 6.13). A series of digital and physical model iterations (Figure 6.14) tested carving the building parti into specific floor plates with the goal of allowing as much sunlight as deep into the building as possible. Special attention was paid to the 8:00-9:00 AM and 1:00 PM sun vectors throughout the year.



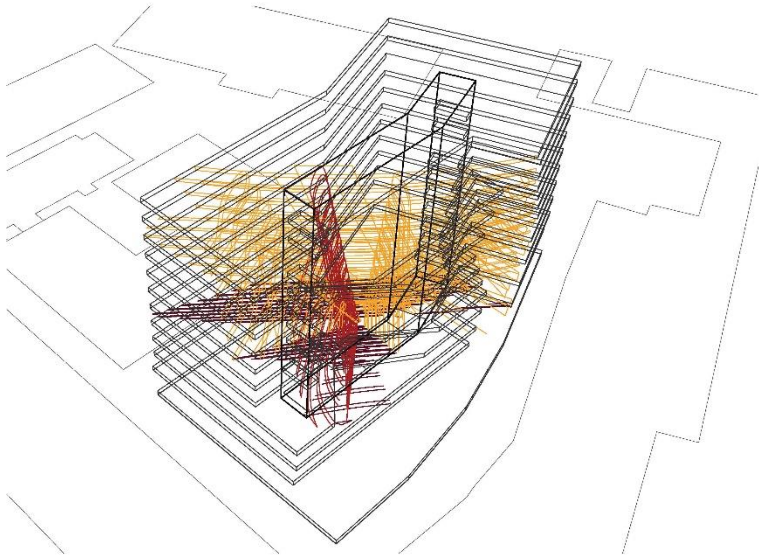
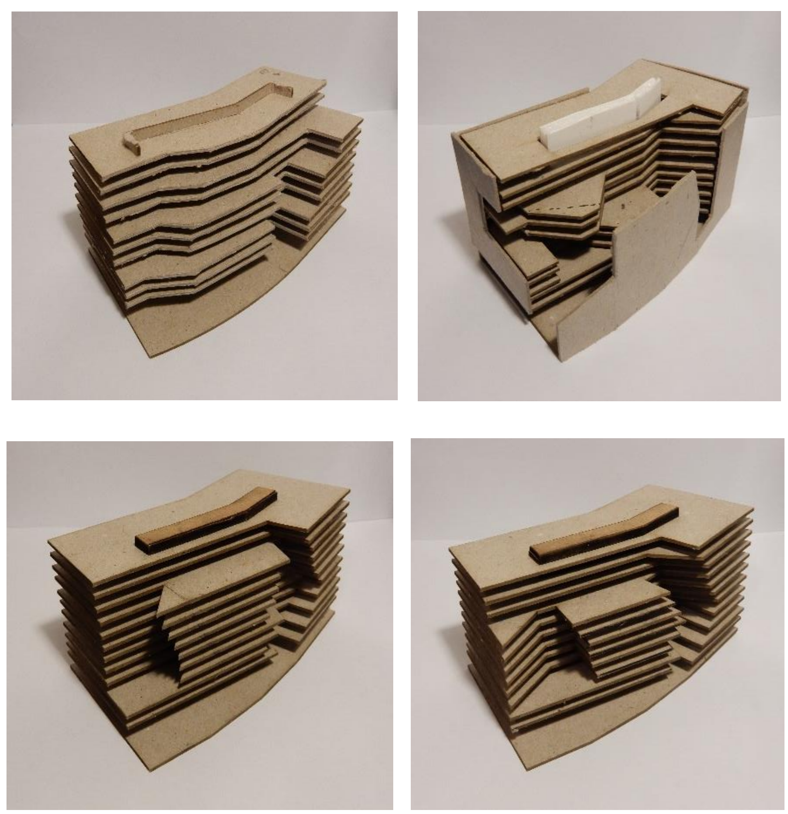


Figure 6.13: Sun path vectors projected onto building floor plates



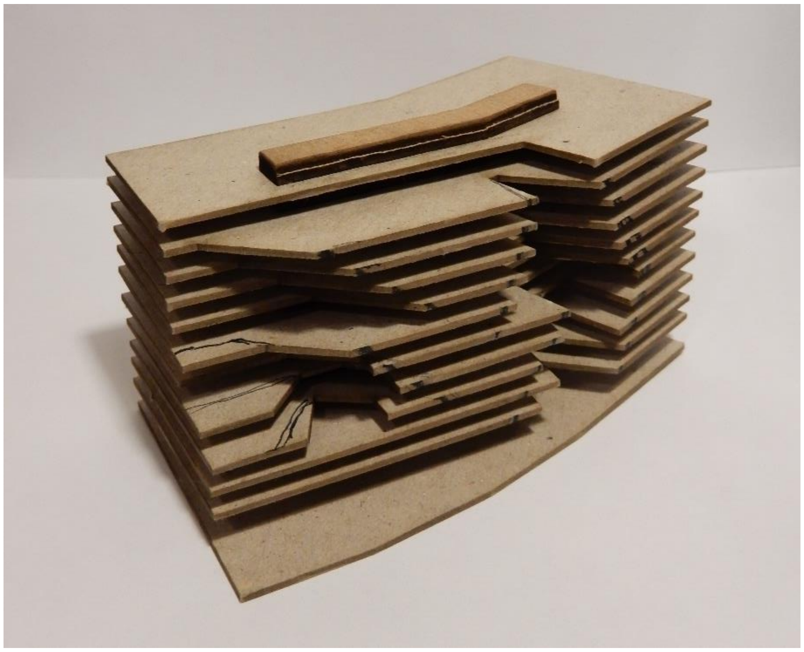


Figure 6.14: Physical study models of building floor plates shaped for sunlight penetration

Considering the needs and strategies for accommodating shared program spaces along with the findings from significant sun studies, resulted in a building form that organizes the leasable tenant areas along the northwest and northeast perimeter of the building and accommodates shared spaces in a light filled atrium space between the floor areas carved out by the 8:00-9:00 AM sun and 1:00 PM sun (Figure 6.15).

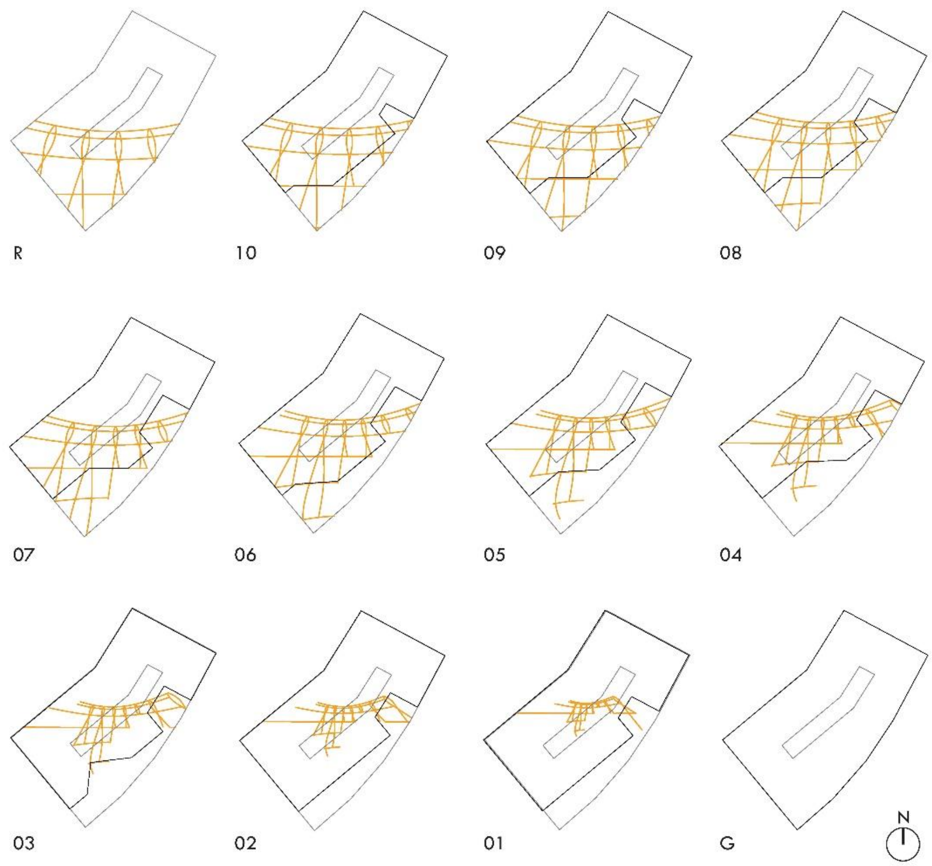


Figure 6.15: Final iteration of floor plans shaped according to sun path

Atrium as Marketplace

As more and more office building design has adopted sustainable design principles, atriums and courtyards have become important features for increasing access to daylight. Often these atria accommodate circulation at their edges and boast active, communal event space on the ground floor. While this practice is important and can have great value, the design of the building at 8615 Georgia Avenue seeks to further exploit the benefits of the light-filled atrium. Rather than simply a place to provide daylight into closed, interior rooms, the atrium is reimagined as the marketplace for sustainable living and working. Shared amenity and work spaces cantilever out from the core and occupy the atrium at every level of the building. The opaque portion of the atrium's cable net enclosure provides opportunities for projecting building and user performance metrics so users can continue to monitor performance as they move from space to space and activity to activity throughout the day. The atrium is the heart of activity; a place where users return time and again on different floors and in different spaces to truly participate in and understand the variety of ways the building can be used to improve performance and user satisfaction (Figure 6.16).

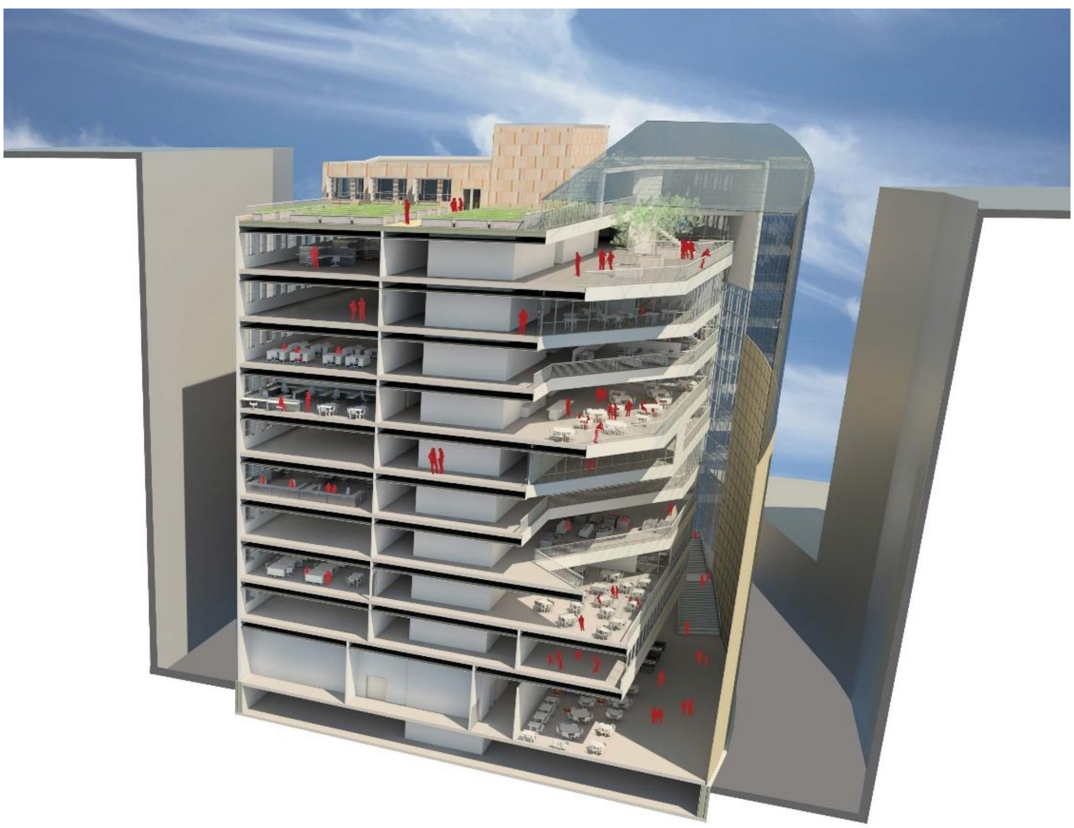


Figure 6.16: Section perspective, atrium as marketplace

Chapter 7: Building Systems

Energy, Water and Waste Systems

Environmental design literature review indicates that important factors to consider in building design are “low energy and water consumption, production and utilization of waste and reduction of environmental pollution.”[166] The three areas of focus, energy, water and waste, informed the design of whole building systems (Figure 7.1) as well as user technologies and activities (discussed in Chapter 8).

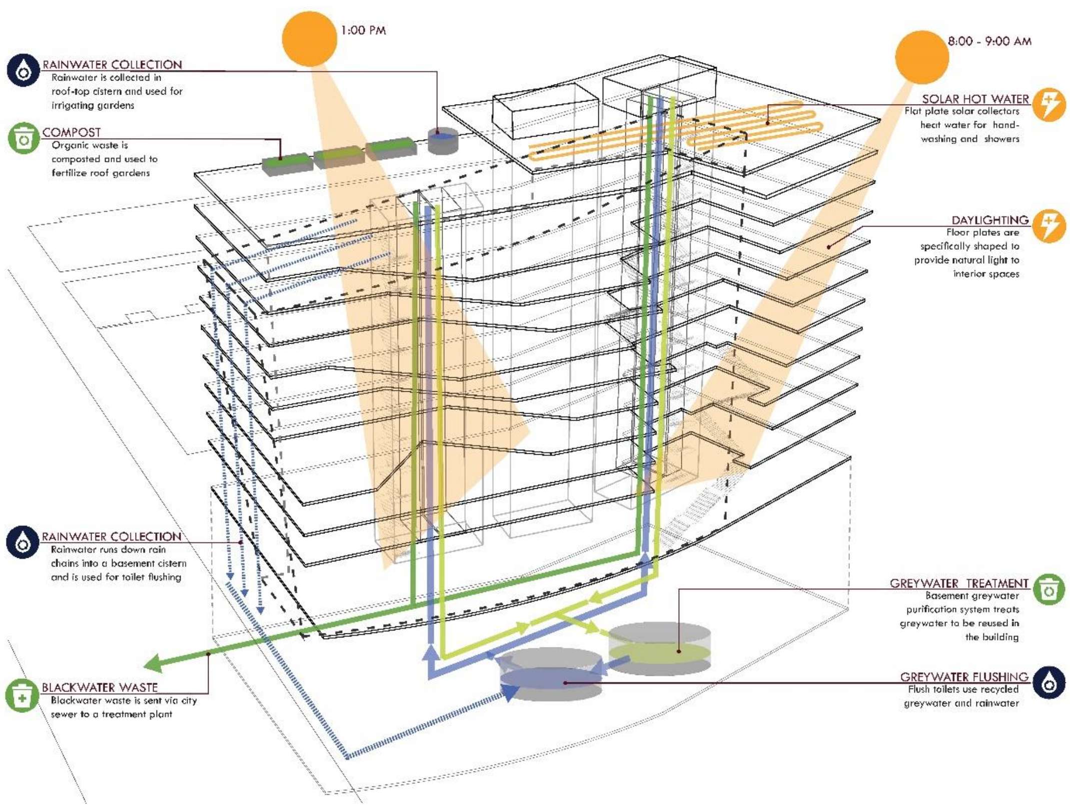


Figure 7.1: Building systems for energy, water and waste

[166] Clements-Croome, 374

Energy from the Sun

The main energy provided by the sun at 8615 Georgia Avenue comes in the form of daylight. Carving the atrium to accommodate sunlight penetration deep into the lower levels and interior of the building significantly reduces the need for electric lighting during many times of the day and year. Additionally, flat plate solar collectors on the roof heat water for hand washing and locker room showers.

Collecting Rainwater

Rainwater collected on the flat roof surfaces is collected in a storage cistern on the roof garden where it is used for irrigating garden planters. Rainwater washes down the sloped atrium roof where a series of rain chains and gutters celebrates rainwater collection in view of users and passersby. Then the rainwater is collected and filtered in a gravel trench and stored in a basement cistern where it can be recycled to supplement greywater supply for toilet flushing.

Greywater Cycling

Greywater collected from hand-wash sinks and showers is filtered and sterilized in basement treatment tanks then supplied for use in toilet flushing. Some estimates say greywater cycling can reduce water consumption by up to 30%.[167] Further investigation is necessary to implement exposed, biological water treatment systems.

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[167] Clements-Croome, 391

Potential sites for exposed wastewater treatment in the building include the ground floor of the atrium as well as the winter garden on the ninth floor. In both areas users would have the opportunity to enjoy interior vegetation in lounge work areas as well as learn about wastewater treatment in the building.

Black Water Waste

Black water from flushed toilets and kitchen sinks is sent directly into the city sewer system. Further investigation into composting toilet systems and on site treatment systems for black water is necessary to achieve net zero water and waste at 8615 Georgia Avenue. Changes in building code and legislation is also required to allow full recycling and reuse of waste in this way.

Waste Recycling and Composting

Reducing overall waste generation and especially reducing landfill waste influences building design and user behavior. One copy/print center within the building reduces the accessibility of printing services in individual workspaces and forces users to think more carefully whether or not and how many prints/copies are needed. Providing trash bins that separate landfill trash, paper recyclables, glass, plastic and metal recyclables and compostable waste in each workspace emphasizes the importance of waste management. Composting bins on the roof provide on-site composting for organic waste. Fully composted waste is used to fertilize roof top gardens, a visible and tangible example of the sustainable process of turning waste into resource.

Circulation

The building has two egress stairwells within the core as well as two elevators with roof access and a freight elevator for moving equipment and furnishings. In addition to the necessary core circulation, an inviting open stair and glass elevator occupy the void carved out for morning daylight (Figure 7.2). Users have views of the atrium activities, the city and the sky as they move vertically throughout the building.

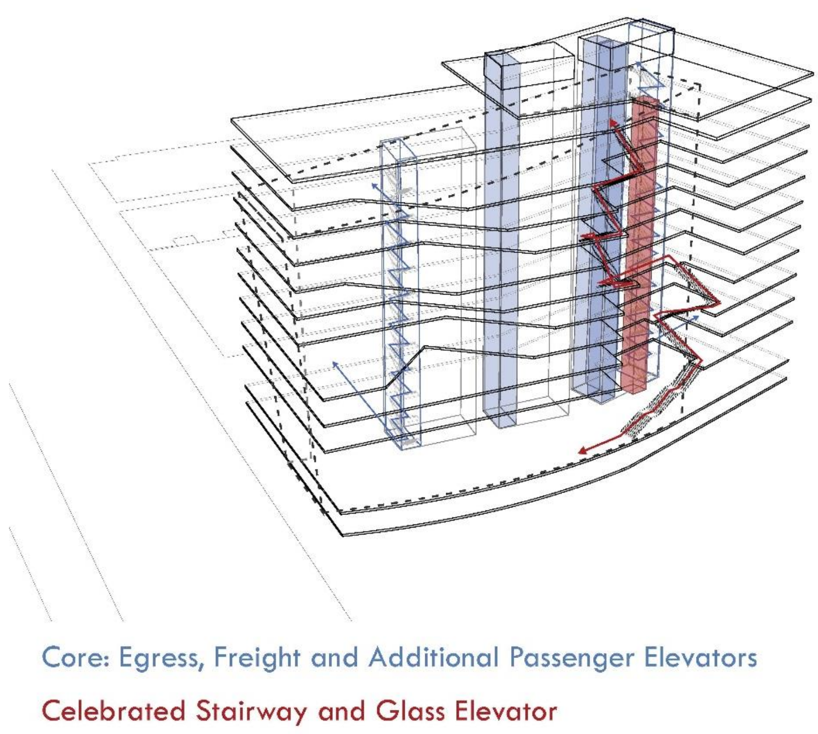

Figure 7.2: Circulation diagram

Designed in accordance with the Center for Active Design checklist the size, location and visibility of the staircase all lend increase opportunity and appeal of daily use.[168] The path of the stairwell takes inspiration from the series of ramps and stairs used in the central atrium circulation in the University of Baltimore Law Center designed by Behnisch Architekten (Figure 7.3).

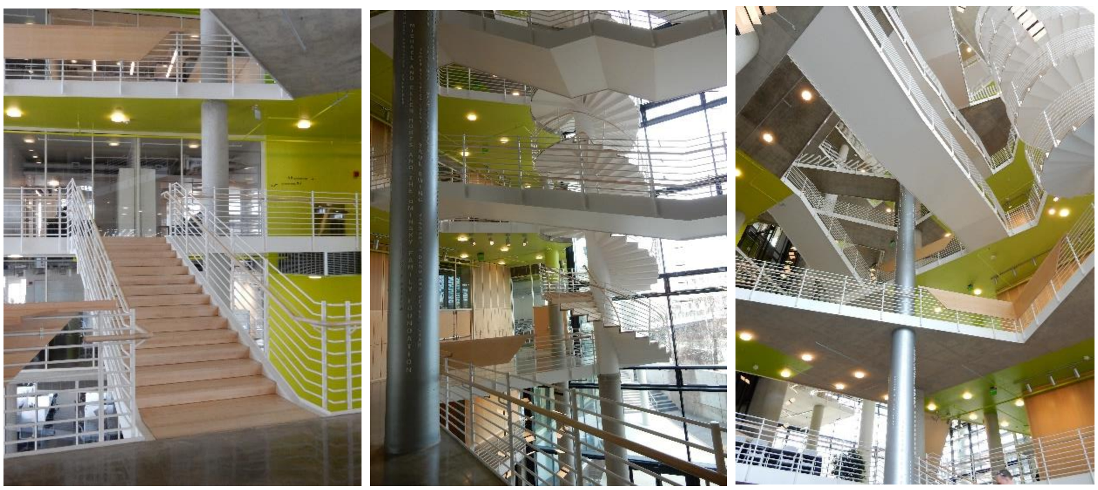

Figure 7.3: University of Baltimore Law Center atrium,
photos by Ashley Grzywa, 2015

The series of ramps and stairs appear to the user to be very dynamic and constantly changing, however, careful study of the circulation revealed a series of patterns and only a few importantly placed changes (Figure 7.4).

[168] "Building Design Checklist," *Center for Active Design,* accessed April 2015, centerforactivedesign.org/guidelines/.

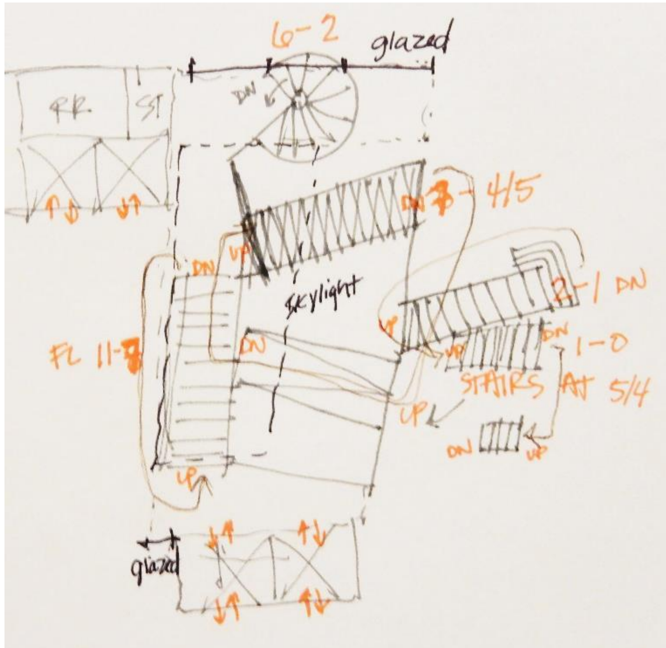

Figure 7.4: Sketching organization of stair and ramp system

Inspired by this method, the open staircase designed for 8615 Georgia Avenue achieves dynamic simplicity in its winding path from the ground floor to the tenth floor/roof garden. All along the path the stairs are wide enough for people to pass comfortably in opposite directions, however, the stairs are their narrowest width on the top floors, become wider at the middle floors and are widest at the ground floor. In this way the stairs are a physical indicator of the flow of users starting out as a large group at the ground floor and slowly shrinking in size as users climb up and arrive at their respective floors. The same is true at the end of the day where the number of people on the stairs is smallest on the top few floors and grows steadily as people join from lower floors to exit the building at the end of the day. Although it is not expected that everyone will arrive or leave at the exact same time or that the stairs will be flooded with herds of users, it is reasonable to assume that the stairs would be in greater demand at the times of day when work is beginning and ending and the design of the stairs considers these flow patterns to ensure comfortable daily use of the stairs.

The idea of placing a glass elevator adjacent to the stairs has potentially positive and negative consequences. The stairs are already located near the core elevators to encourage more people to use the stairs because they are just as convenient to get to as the elevators, if not more. Adding a third glass elevator in the atrium space provides a unique and attractive circulation experience which may tempt stair users to use the elevator which may be seen as a negative contribution to user health and building performance. However, the glass elevator was included as part of the grand staircase in the atrium to provide the same dynamic and beautiful circulation experience to those with different abilities who are unable to take the stairs. The glass elevator is also an energy generating elevator like those used in Seattle's Bullitt Center (double check). Energy generating elevators use sophisticated technologies to capture energy generated by elevator operation that would otherwise be lost.[169] The intention is not to punish users for using the elevator rather than the stairs, rather to incentivize stair usage by making the stairs

[169] "Power-Generating Elevator," *Shanghai Scientific Energy Conservation Museum*, accessed May 2015, www.ssecm-en.org/commercial/exhibits/elevator-power_generating.htm.

attractive and provide the opportunity for those using the elevator to positively contribute to building energy performance.

Mechanical and Lighting Systems

Floor-to-floor heights in the building are twelve feet, allowing a three foot ceiling plenum for mechanical, lighting and structural systems accommodation and a nine foot floor-to-ceiling height. Large windows in office areas with a three-foot sill height that extend to the ceilings provide generous daylight at task height that penetrates deep into the office space. Electric lighting is zoned parallel to the windows so unneeded electric lights near the window can be turned off independently of lights near the interior (Figure 7.5). Occupants operate interior blinds to control sunlight and glare in office areas and enclosed, shared meeting and work rooms.

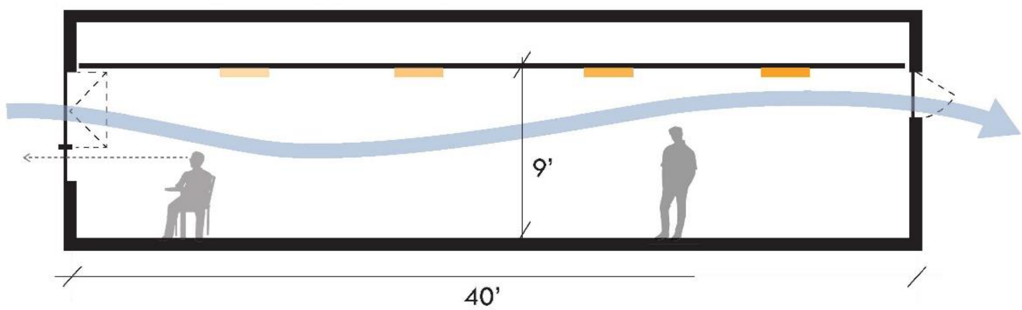

Figure 7.5: Section through typical office, natural ventilation and lighting

Mechanical ventilation is zoned in two rings parallel to the core. The interior ring handles almost exclusively cooling load (due to high heat gain from occupants, lighting, computers and other electronic office equipment) while the exterior ring adjusts for heating or cooling as needed based on exterior temperature. An independent mandated outside air system pulls fresh air from the exterior and distributes it throughout the building. Operable windows also provide natural ventilation and fresh air exchanges during favorable climate times of the year. Occupants are alerted via desktop and mobile device notification from the building management application when exterior conditions are optimal for opening and closing windows to improve comfort and performance.

A long-standing response to heating and cooling office buildings is via a variable air volume (VAV) control system. This system has been redesigned over the years to improve efficiency and save energy. However, the forced air delivery system still requires a significant amount of energy and space to move heated and cooled air throughout the building. Alternative systems were considered, including chilled beams, which move heating and cooling energy in the form of water, taking up far less space and requiring far less energy to transport. However, the chilled beam system is sensitive to changes in humidity and does not work well in a building with operable windows. Since user participation was a driving factor in the design considerations for 8615 Georgia Avenue, a VAV system was chosen over chilled beams for heating and cooling. The VAV system would employ air handlers on every floor to reduce the volume of vertical air movement in the core mechanical shaft. Further investigation is necessary to explore high-performance heating and cooling options that work well with operable windows and provide opportunities for controlling thermal comfort at the level of individual users and spaces.

Structural Systems

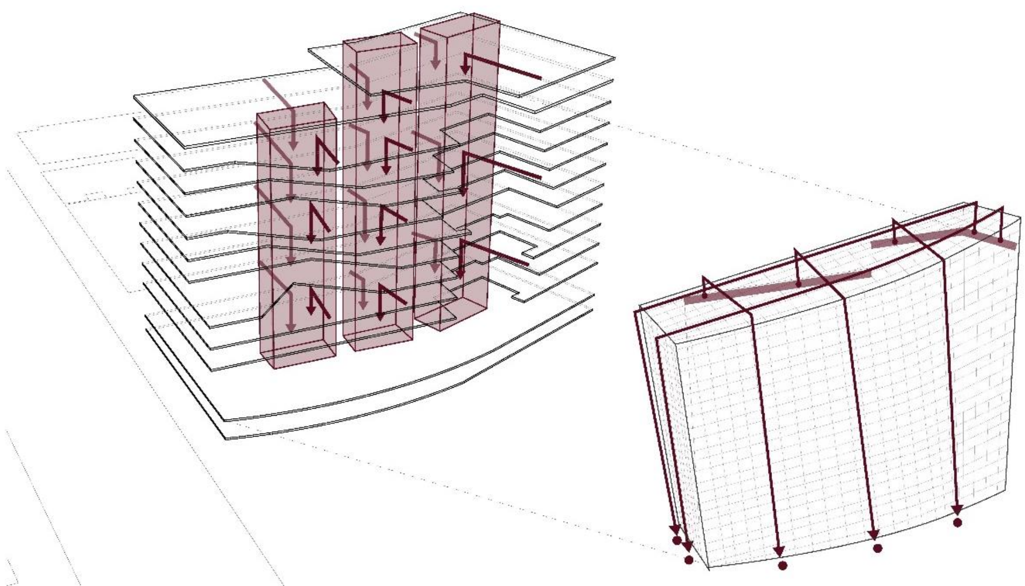

Figure 7.6: Structural systems axon

Core and Shell

The scale and height of the office building along with the desire to have flexible, column-free floor plans supported the decision for a post-tensioned concrete floor plate system cantilevered off of a concrete core. This system allows floor plates to remain relatively narrow, affording higher floor to ceiling heights. This structural system was also chosen because it is an efficient, widely-known and utilized system in office building design and contributes to the project goals of making realistic, appropriately scaled interventions to the “typical” condition to improve user and building sustainable performance without compromising the affordability and marketability of speculative office building development. By working within some of the limits of this type of design this project is able to be translated across a number of locations and building types.

Atrium

Where the load paths of the floor plates are carried from the exterior back to the core, the atrium inverts these load baths and distributes load into the ground and floor plates along the exterior edges of the system. A two-way cable net structural system was designed to achieve the maximum amount of sunlight and minimum amount of material use in the atrium. Triple-glazed structural glass panels act in compression and are attached with metal fasteners to steel cables which act in tension (Figure 7.7). This coupling of materials effectively creates a beam condition which acts as a frame allowing the large glass volume to support itself without additional steel support. Where the cable net wall is opaque, insulated, fiberglass-reinforced concrete panels replace glazed panels as the compression-bearing members of the system.

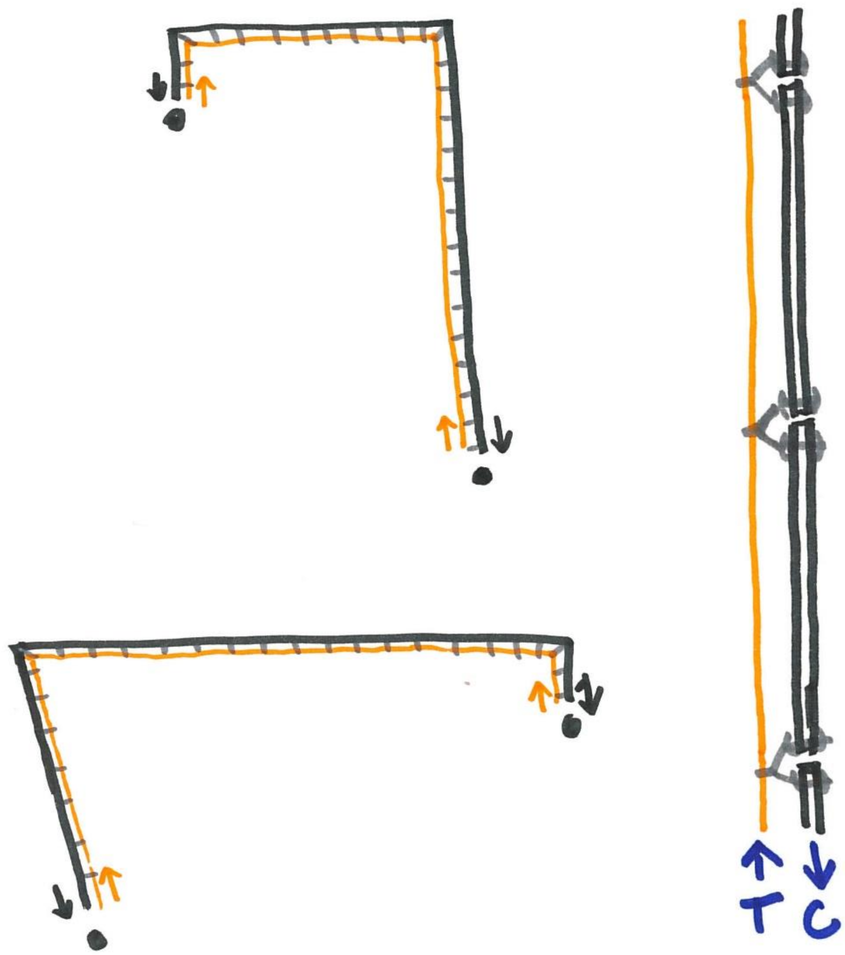

Figure 7.7: Sketches of cable net wall structural performance

Additional strategies for transitioning from glazed to solid panels were considered. The option of having the solid portion of the wall be a self-supporting masonry or frame structure was ruled out because it did not provide the desired level of tectonic cohesion across the entire atrium construction system (Figure 7.8). A double skin system was considered whereby the glass would continue as the thermal and moisture barrier all the way to the ground with a second cable system supporting a perforated metal panel outside of the glazing (Figure 7.9). While this system offered more opportunity to investigate ambient light patterns the additional layer of materials complicated the cable net system and did not provide insulation to the large portion of the wall constantly in shadow throughout the year. A third option considered changing the material performance in the solid part of the system to emphasize the intentional change in materiality and thermal performance between the glass and the opaque panels. This strategy proposed replacing the tension cables with compression rods and the compressive structural glass panels with metal panels acting in tension (Figure 7.10). Time limited the exploration of this method but the opportunity for greater tectonic expression is desirable for both the aesthetic and educational quality of the building. Future iterations should investigate and test this idea in greater detail.

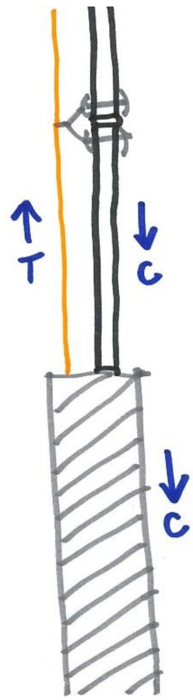

Figure 7.8: Concept Sketch - load-bearing opaque wall and cable net glazing

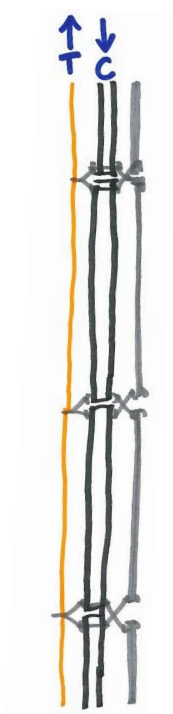

Figure 7.9: Concept sketch- double-skin cable net system

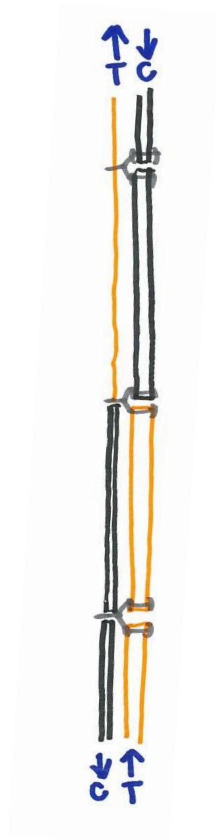

Figure 7.10: Concept sketch – inverting structural performance of cable and panel components

Enclosure Design

Primary motivators for enclosure design were 1) optimizing thermal performance by replacing a common office building model of entirely glass curtain wall enclosure with a light steel-framed opaque wall assembly to enclose the majority of the office spaces, and 2) considering opportunities to reduce heat gain and loss in the glass roof and atrium.

Primary Enclosure System

The primary enclosure system for the office areas of the building is a light steel-framed opaque wall assembly clad in fiberglass-reinforced concrete rain screen panels. A ventilated rainscreen system is low-maintenance and durable and provides ventilation to the façade, reducing heat gain. Reinforced fiberglass concrete panels are made with the natural materials of sand and cement, recalling materiality of the largely stone and brick building stock of Silver Spring, and are produced in environmentally friendly manufacturing processes. Modularized construction decreases waste and increases productivity to reduce overall construction time.

Openings in the form of aluminum-framed, double-glazed low-e windows are placed at regular intervals along the walls providing the necessary and desired amount of daylight without overwhelming heating, cooling and ventilation systems.

Exterior fixed vertical fins and horizontal fixed louvers at each window unit on the east and southwest facades provide shade from harsh, early- morning and late-afternoon sun (Figure 7.11). Windows on the north and northwest-facing windows have interior light shelves to bounce ambient light deeper into the workspaces.

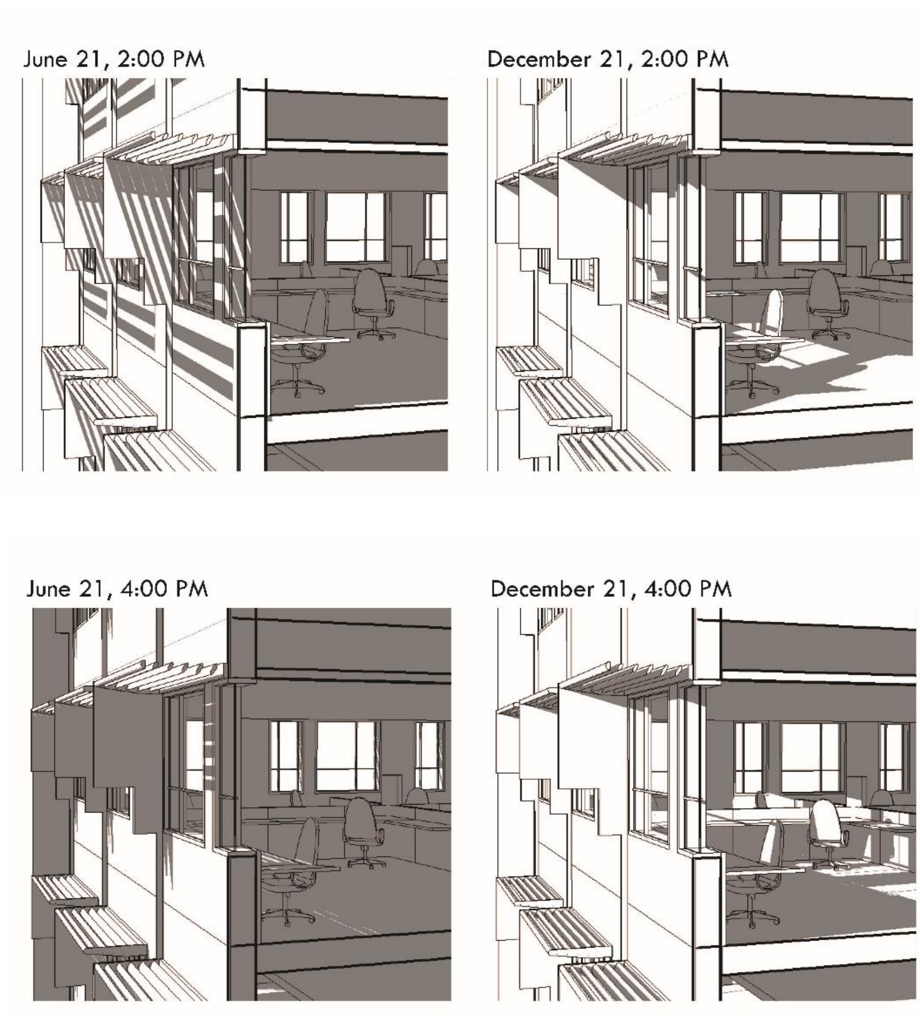

Figure 7.11: Sun studies of office spaces on southwest facade

Atrium Enclosure System

As mentioned, the atrium cable net system is made up of triple-glazed, laminated structural glass and insulated fiberglass-reinforced concrete panels. The triple-glazed systems improves thermal performance and sound transmittance and laminates between the layers of glazing offer a canvas for low-e coating, fritting and tinting to reduce heat gain and glare in the atrium. Further analysis is required to design exactly which films to use and where. The expectation is that such investigation and analysis of thermal performance would result in a visible transition across the glass walls and especially the roof from clear to tinted glass or glass fritted in a range of densities. Such transformation would improve thermal performance of the atrium and also provide another opportunity for educating users about building performance.

Chapter 8: Occupancy-Driven Design

In a 2003 survey about workspace satisfaction by *Management Today,* in association with Stanhope and ICM Research, only 39% of the more than 500 respondents believed that their place of work was designed with people in mind.[170] This number is unsettlingly low when considering how much impact buildings have on occupants and vice versa. As Derek Clements-Croome points out, “The starting point for establishing a model of an intelligent building is *people*, because they determine the mind force of the building. People are not passive recipients of their environment but adapt psychologically and behaviorally.”[171]

Research is quickly realizing that the physical and mental health and productivity of employees is worth far more than a few dollars saved or extra square feet gross rentable area. “In new office environments one encounters a strain between efficiency and individuality, where people should be the focus.”[172]

In order to make people the focus it is necessary to understand how people work. What are the tasks they do throughout the day? What kinds of spaces are needed/desired? Furthermore, engaging users in sustainable buildings and encouraging pro-environmental behavior requires a careful

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[170] Clements-Croome, 90
[171] Ibid, 8
[172] Hescher et. al., 71

understanding of how building users generate energy, collect rainwater, recycle water and waste, produce waste and use energy and water. The following questions offer an important starting point for evaluation and assessment of design ideas.

1. How does the building design help occupants understand how energy and water are supplied to and used in the building and where water and waste go?
2. How are strategies for adapting behaviors to improve impact incorporated into building design?
3. How and to what extent do occupants control or adjust electric lighting, sun shading devices, daylight levels and glare, thermal omfort and ventilation?
4. How can occupants participate in harvesting/producing energy and water and recycling water and waste?
5. How are occupants involved in the shaping and use of spaces to reduce energy and water use and eliminate waste?

To answer these questions a number of scenarios were brainstormed for different types of people who work in or visit the building. Some researchers think that this type of “scenario planning” results in a more versatile building because it takes greater advantage of programming information and resists over-specification inconsistent with user needs.[173] Thinking through users' actions and work through the course of the day helped to draw conclusions about what kinds of spaces should be included in the building, where they should be, what kinds of spatial quality they offer. Research conducted in this subject area provided insight (Figure 8.1) as well as personal experience and first-hand accounts.

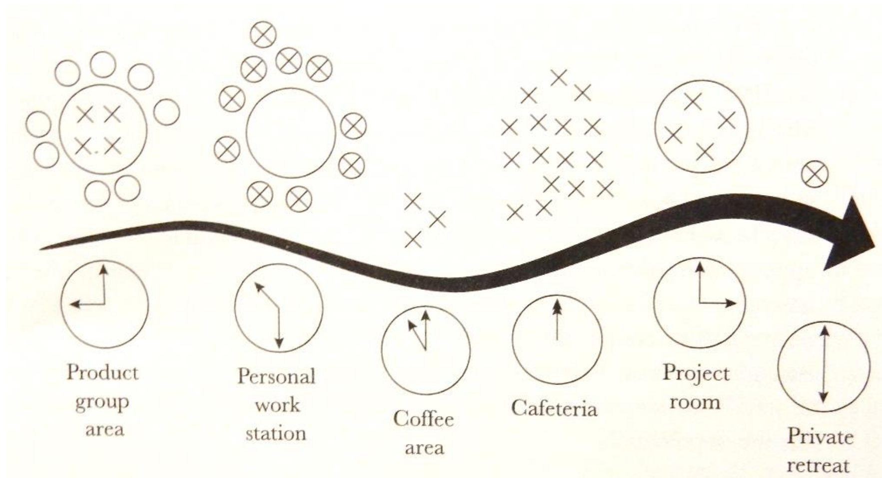


Figure 8.1: "A Variety of Settings for a Variety of Tasks", Choosing space to work in based on work type, team members, etc, *Offices at Work, 2004*

A New Design Exercise: Diagram of a Day

The exercise of graphically representing the scenario planning became incredibly important to understanding and communicating the user experience and opportunities for user engagement. It began with understanding what the diagram of a day would be for a typical office building. I collaborated with an architect working in office space in one such building to diagram her experience of the building throughout a day (Figure 8.2). Each of the spaces

[173] Clements-Croome, 353

were drawn along a linear path and were scaled relative to each other to give a general sense of the proportions of spaces. The type of enclosure (opaque, transparent, etc) was also considered, specifically for how much light (daylight) enters the spaces. Views to the exterior were marked along the route. After understanding the spatial and light sequence of the user's movement through the building, it was important to follow the path again and identify where the user was interacting with energy and water use and waste production, identified by colored dots in spaces along the path.

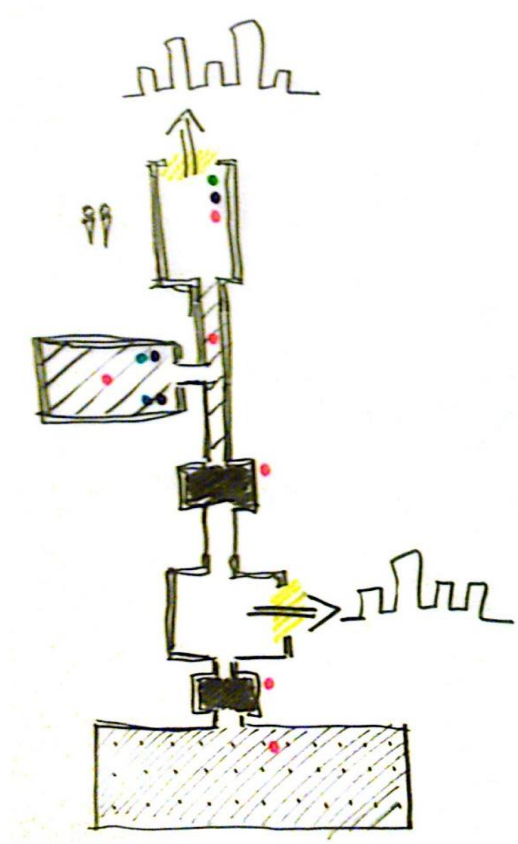


Figure 8.2: Diagram of a Day, typical office building

These strategies for representing spaces and activities related to energy, water and waste were expanded upon in several iterations of the diagram of the day for the new work and sustainability experience intended for 8615 Georgia Avenue (Figure 8.3). Comparatively it was important to see an increased number of spaces of different qualities and new opportunities for user participation in and awareness of sustainable building performance.

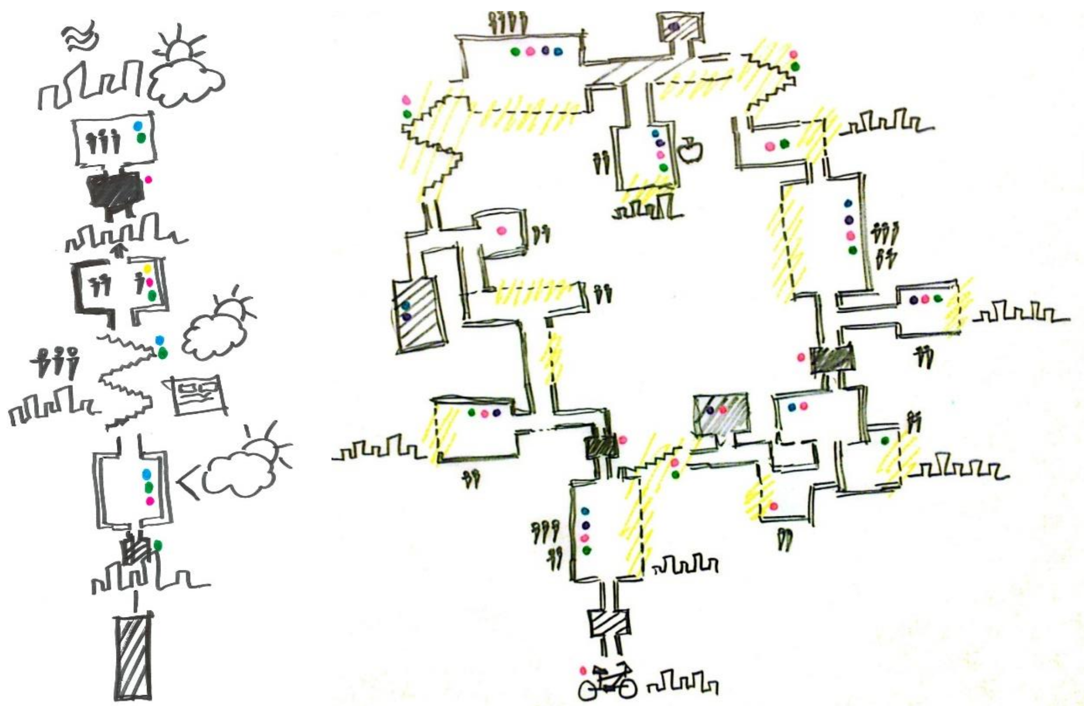


Figure 8.3: Diagram of a day iterations

May 15, 2015: Today at Work I…

While any given building would have an infinite number of diagrams relating to the different daily activities of all of the different users, an effective and concise way to demonstrate the design exercise and resultant building was representing the diagram of one day, May 15, 2015 (the day of public thesis defense). Spaces enclosed by opaque walls are identified with a thick black line, spaces open to adjacent spaces are identified with dashed lines and spaces enclosed by transparent or translucent walls are marked by a thin black line. Each space is shaded according to the level of natural daylight it receives relative to other spaces (Figure 8.4).

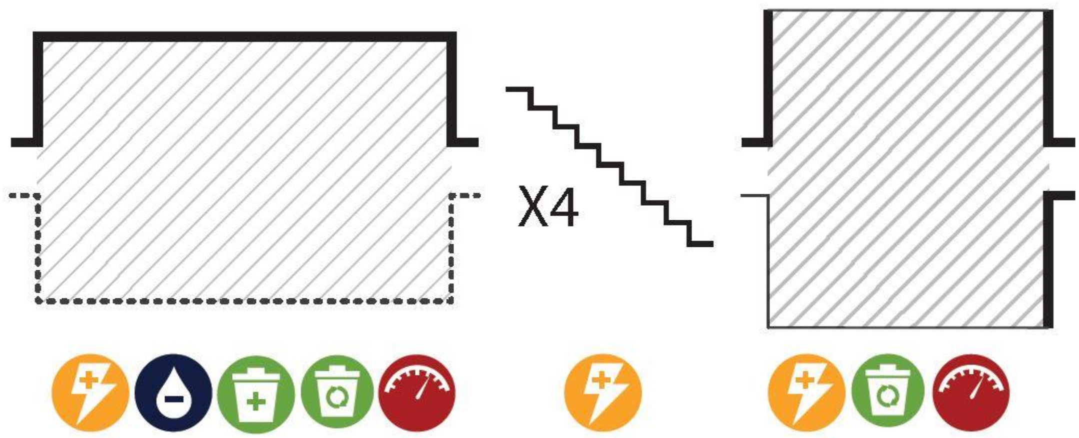


Figure 8.4: Diagram of a day, segment

A series of dots mark the opportunities for engaging users in energy water and waste performance (Figure 8.5).

Figure 8.5: Diagram of a Day icons

The complete diagram of a day (Figure 8.6) included a number of spaces and experiences, from which six moments are called out and expanded upon (The complete diagram is shown below. Sections appear larger as they are discussed later in this chapter).

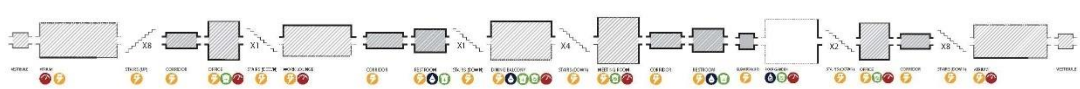


Figure 8.6: Diagram of a Day for May 15, 2015

8:30 AM – Arrive, Atrium

A user entering the building from the front entrance, having taken public transit to work, would enter an active atrium the far end of which would be filled with natural morning light washing over an inviting staircase. Users have an opportunity to grab a coffee or light breakfast from the Co-Op on the ground floor and socialize with other users before being drawn along a path of piezoelectric floor tiles (which generate energy when walked on) up the grand staircase too their first work destination in the building (Figure 8.7).

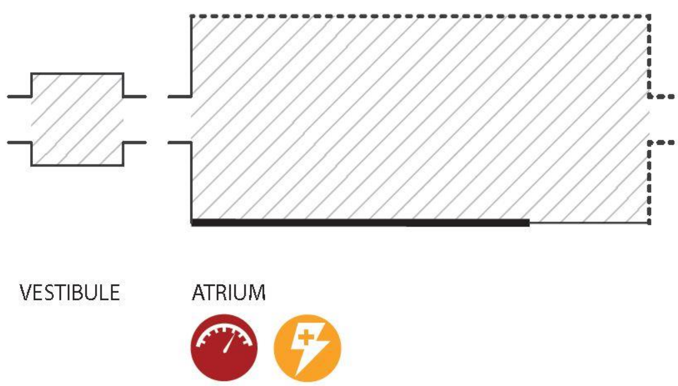


Figure 8.7: View of atrium from entry, ground level

10:00 AM – Working, Office

By 10:00 AM the hypothetical user whose day is described by this diagram is working comfortably in his or her office space. The office is on the south side of the building and will not receive direct sunlight until later in the afternoon but the ambient light is pleasant for working (Figure 8.8).

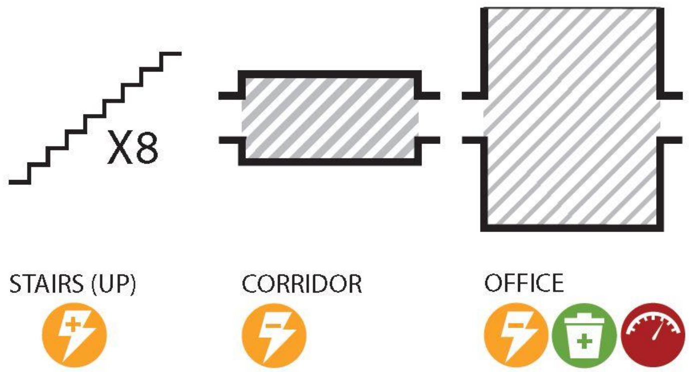


Figure 8.8: View of office area, level 8

Users have control of electric lighting which operates on switches in zones parallel to the windows; only as much light as is needed for tasks is turned on at any given time. Operable windows on the façade and awning windows that open into the hallway allow for cross ventilation of office space.

The “Power Tower” organizes a cluster of users around a power source which offers desk top outlets for convenient unplugging of equipment not in use. The Power Towers are also an opportunity for users to monitor plug load energy use, monitor lighting and ideally, operate local climate controls (though further investigation is needed in this area). A QR code on the Power Towers brings users to an online resource and dashboard for building performance where they can chat with the building manager, find tips for improving energy performance in their offices and compare their performance with other tenants (Figure 8.9).

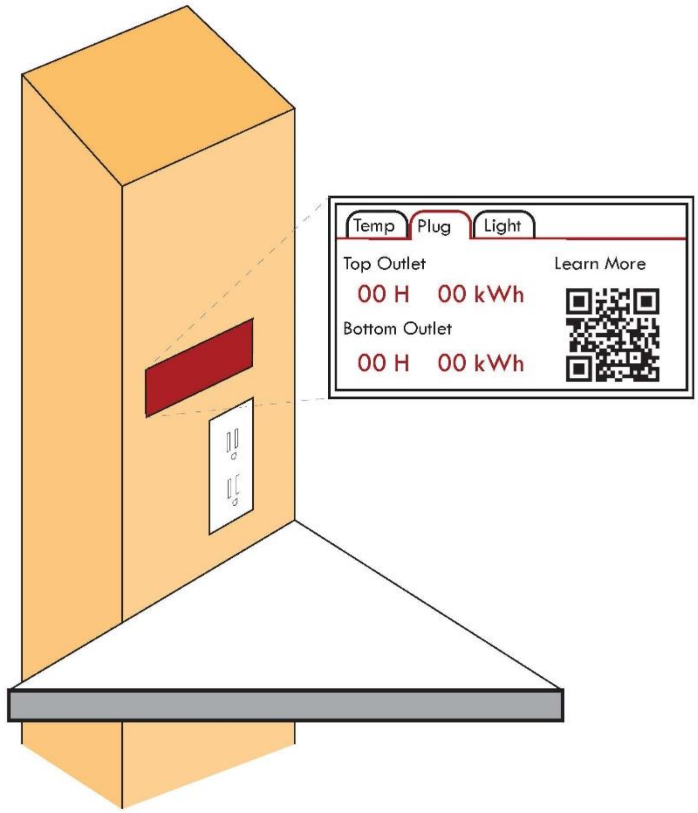


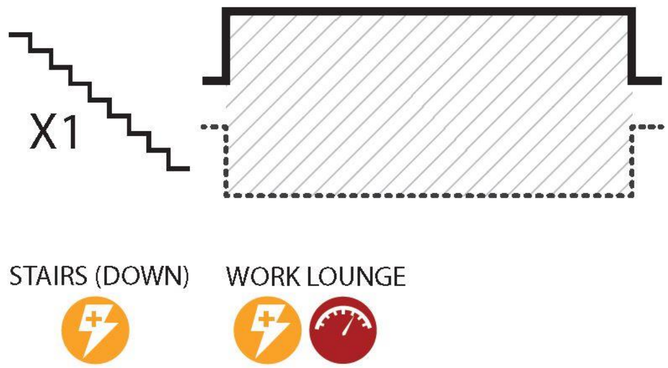
Figure 8.9: Power Tower design and monitoring concept

The Power Tower is a preliminary design idea in response to findings that personalized controls of lighting and thermal comfort provided at employee workstations can improve comfort and productivity as well as save construction and energy costs.[174]

A while after working in the office a user may decide to go to take his or her laptop and work in one of the lounge balconies in the atrium (Figure 8.10). Today the user stops at the restroom to wash his/her

[174] Lisa Napoli, New York Times article, cited in Design Intelligence article about OBF

hands on the way to lunch and is reminded that humans share our clean water supply with other living things (Figure 8.11)



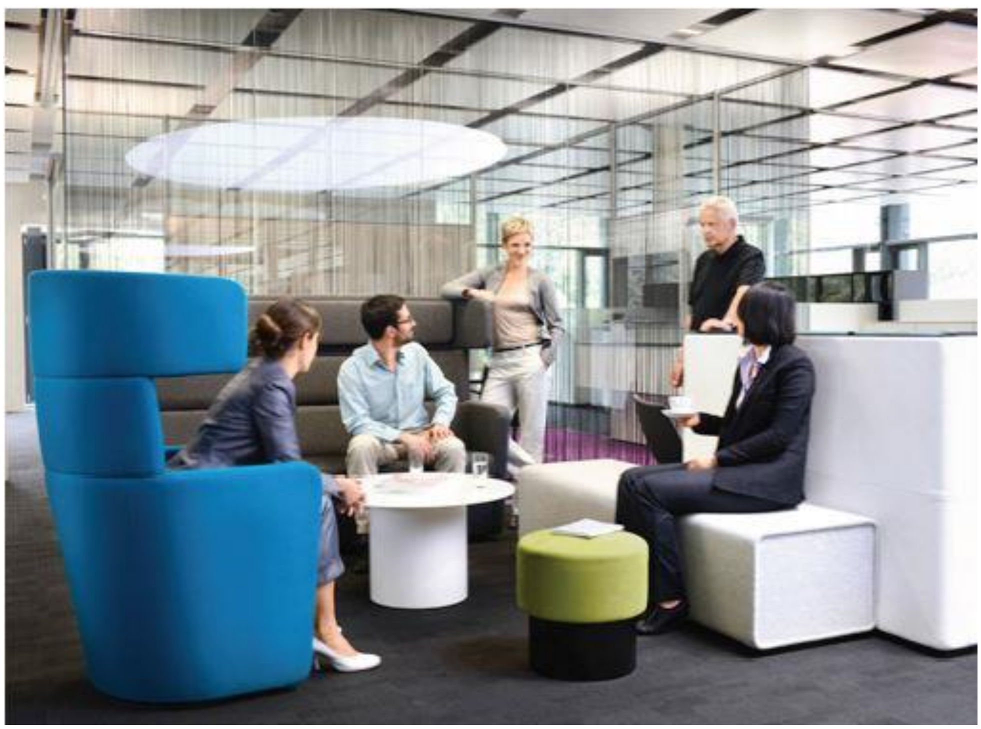


Figure 8.10: Diagram of a day, work lounge

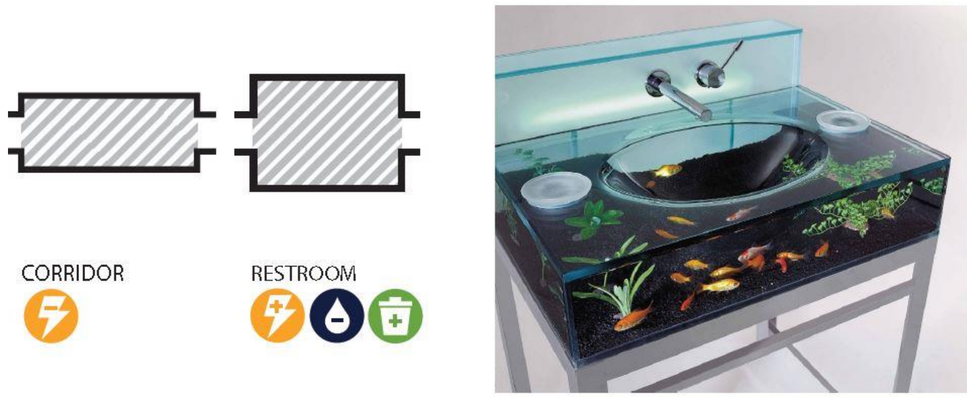


Figure 8.11: Diagram of a day, restroom

1:00 PM – Lunch, Dining Balcony

About 1:00 PM users end up in one of two dining balconies with kitchens for food preparation and clean-up. These dining areas are open to the atrium and have views of the sky out of the atrium roof. They are located in the part of the building that receives sun during lunch time year-round (Figure 8.12). By centralizing kitchen and dining areas each tenant need not have kitchens in their tenant suite which improves collaboration and socialization between tenants and reduces the overall energy and water use in the building. In addition to eating and socializing, users engage with water use and waste management in the dining area.

Figure 8.12: Dining balcony, level 6

The faucet counter counts in real time the number of ounces used each time the faucet turns on. Live measuring in ounces and daily use display in gallons can be helpful for users needing a specific amount of water to use in meal preparation or wanting to know how much water they are drinking by filling a glass or bottle at the sink (Figure 8.13). It is also important for helping users be aware of how much water they use in the kitchen sinks to improve water use performance in the building. This kind of monitoring is an important example of the way in which monitoring technology can and should be thought of as a way to improve building performance as well as occupants' individual health and satisfaction.

Figure 8.13: Faucet water monitoring design concept

Waste management is especially important in the dining areas because food and food packaging waste is a direct product of individual users. While companies can commit to going paperless and the print center can use water-based inks and recycled paper, users will continue to need to eat lunch and will continue bringing in food and packaging from off site. This means that monitoring how much of which types of waste are being produced in dining areas is important, as is educating users on where that waste goes and how they can reduce food packaging waste. Waste receptacles in the dining areas have bins for landfill waste, paper recyclables, plastic, glass and metal recyclables and compost. Each bin sits on a sensitive scale so when waste is added to the bin the weight increases (Figure 8.14). There is a direct relationship between the action of throwing something away and the waste performance improving (by recycling or composting) and declining (by adding to landfill waste). Scanning the QR code on the waste bin will show the user where that type of waste is processed and disposed of (whether a landfill in a nearby area or the composing bins on the roof).

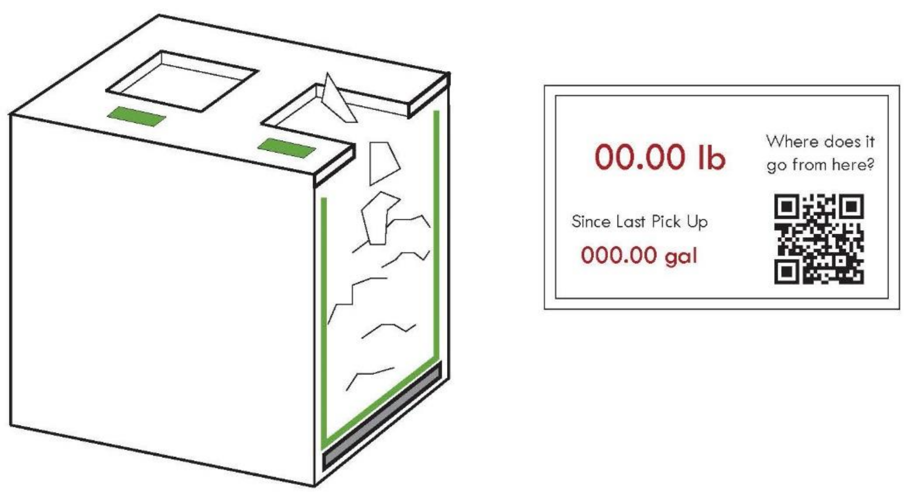


Figure 8.14: Waste receptacles design concept, weighing landfill waste, recyclables and compost

2:30 PM – Presentation, Meeting Room

In the mid-afternoon a group of users needs to give a presentation to clients and needs a quiet place where they will not be interrupted or distracted. The users reserve one of the shared meeting rooms in the building, specifically choosing one they know will have great ambient light from the adjacent atrium but will not be receiving direct sunlight at the time of their meeting (Figure 8.15). They choose the "Green Room" meeting room, so named for the green patterned translucent resin panels made of 40% pre-consumer recycled content that demonstrate the importance of sustainable building materials (Figure 8.16).

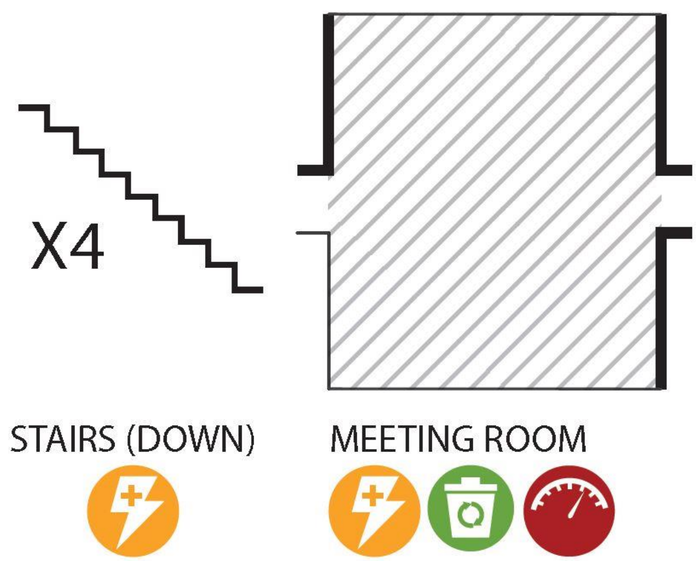


Figure 8.15: Meeting room, level 2

Figure 8.16: Varia Ecoresin wall panel, 3form

4:00 PM – Working, Relaxing, Roof Garden

Near the end of the workday a user may have a little work left to do that can be done on a lap top or tablet and the user looks forward to spending time in the roof garden to relax and finish out the work day. From the meeting room on Level 2 the user takes the elevator up to the roof garden on Level 10. The roof garden is the site of rainwater collection for irrigation, organic waste composting for fertilizer, produce production and working/relaxing/enjoying the outdoors (Figure 8.17).

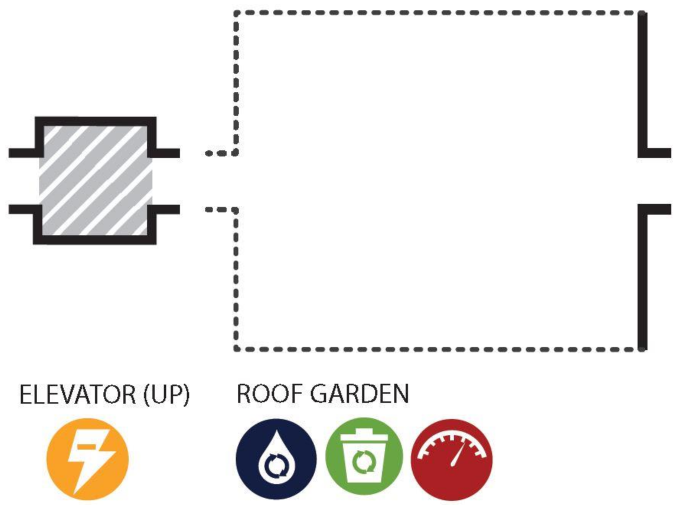


Figure 8.17: Roof garden, level 10

Users may encounter groups of children from the day care in the building tending the gardens and learning about the importance of cultivation and caring for the earth. Users are informed about crops being grown in the garden (managed by the Co-Op on site) and the harvest period for each crop (Figure 8.18). Users are invited to tend and take from the gardens as they wish. A few months from now users may be enjoying a handful of blueberries while finishing up the day’s work in the shade of a patio umbrella on the roof garden.

Figure 8.18: Maryland harvest seasons for selection of roof garden crops

Users also have the opportunity to participate in the human sun dial laid out in the patio paving for the seating area. The user stands on the current month on the center rectangle and finds his or her shadow as it is cast on one of the time stones to know the time of day (Figure 8.19). The layout of the stones has calibrated the solar time with Eastern Standard Time so that the time read in the shadow will match the users watch throughout the year.

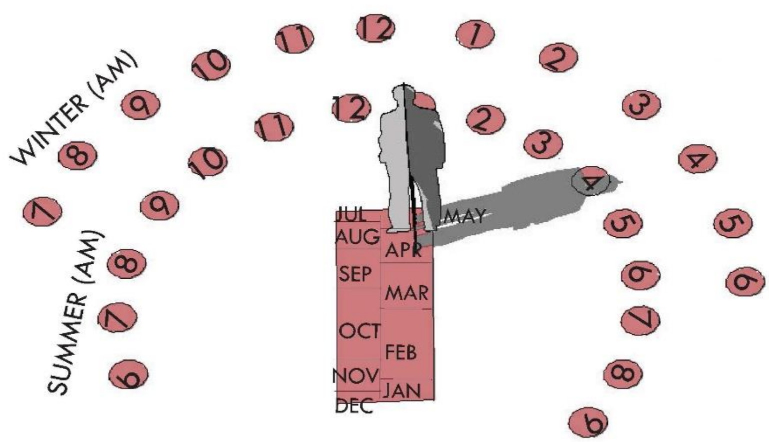
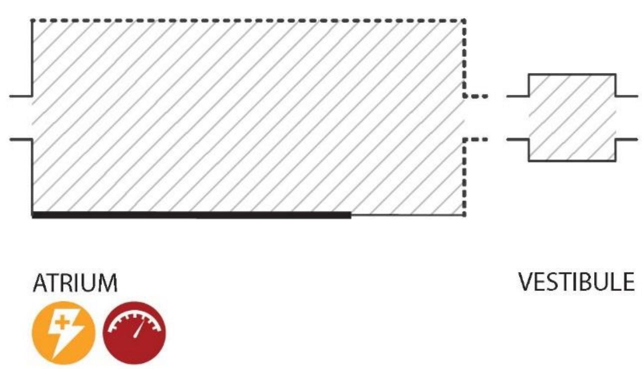


Figure 8.19: Human sun dial design concept

Giving users the opportunity to participate in this solar clock may, over time, improve user understanding of and value for the influence of sunlight on the human perception of time. Users can observe the ways in which sunlight shapes our spaces by transforming length and sequence of light and shadow relative to their own bodies.

5:45 PM – Depart, Atrium

At the end of the work day, the user descends the grand staircase, and looks out to the sunlit street (Figure 8.20). The recognition of the sun lighting the stairway on the path into the building and now lighting the street upon exiting the building allows users to intuit the path of the sun around the building throughout the day. Users can begin to better understand how to use different spaces in their building as they want to engage with or avoid direct sunlight throughout the day.



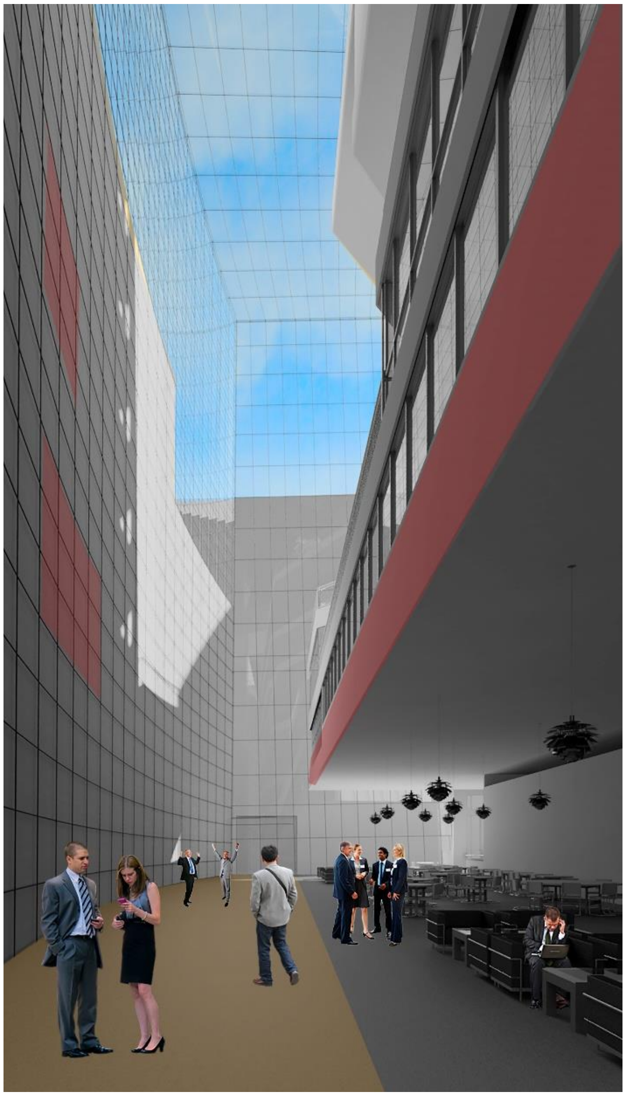


Figure 8.20: View of atrium from bottom of grand staircase, ground level

Before departing, users have the opportunity to see their daily performance projected along the opaque atrium wall and scrolling along the marquee powered by traffic on the piezoelectric floor. The values displayed here are carefully chosen to be a measure of *user* activity. It is not the building performance in terms of total energy used in kilowatt hours or the total water usage in gallons (though that information is also available in the building dashboard on users' mobile devices). Much like the daily news scrolls on the marquee of the Good Morning America studios in Times Square, users see their own daily behavior projected back to them in cups of coffee poured, sheets of paper printed, ounces of filtered water used, elevator rides taken, plug load demand on electricity, pounds of waste composted and other metrics (Figure 8.21).

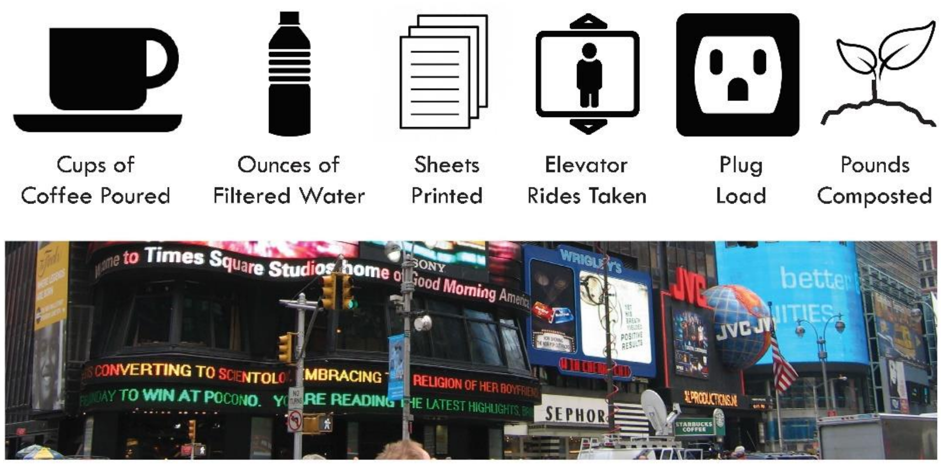


Figure 8.21: Daily report of user behavior, sample

The scrolling daily totals activate this atrium marketplace and insight a moment of reflection as users compare today's experience with other days and consider their own contribution to those numbers. What was the number in that category yesterday? Did we do better or worse today? How many of those cups of coffee or elevator rides did I add to the count? Suddenly users find opportunity to consider their own impact on overall performance and begin to understand their own responsibility for improving that impact.

Chapter 9: Defense Responses and Reflections

In addition to faculty and students of the University of Maryland, five jurors were present for the public defense of this thesis. Visiting jurors were Stephen Quick, Jeana Ripple, Nea Maloo, Antonio Rebelo and Gary Bowdon. The comments from the jurors following the presentation were largely positive and complementary. The work was commended for taking on the subject of social behavior which is often “untouched”. I was pleased that the presentation sparked interesting and inventive conversation.

One juror, Antonio Rebelo, recalled a project he knew of in Dallas, Texas, Ladybird Middle School, which evoked strong responses and interaction from users (students) who were monitoring building performance on iPads and competing with and encouraging each other to improve building performance. It was a project which, making the appropriate kind of information available to the students in an accessible and fun way, allowed them to find and create their own motivations for sustainable behavior. It is encouraging to know there are examples of users being so excited by and responsible for their building and this is definitely a precedent I will look into in greater detail.

Further along in the conversation jurors were starting to imagine and discuss new wearable technologies and floor tiles that displayed your weight as you stood on them to encourage people to take the stairs. At points the jurors were talking over each other to share ideas and wonder about the future of technology, sustainable buildings and building users. This was probably the most rewarding part of the discussion because it meant that I had truly achieved what I set out to do which was inspire discussion and exploration. In our brief discussion there was no new idea too outlandish for consideration. The conversation certainly continued my questioning and, I hope, left others questioning, how the potential for sustainable user behavior can be encouraged and utilized in buildings.

The major question of the critique was about the decision to prioritize sunlight in the atrium. The concern was raised that the atrium would effectively become a greenhouse. Admittedly, I was not able to definitively describe evidence to the contrary except to say that the glazing would be specially treated with low-e coatings and possibly tint or frit, and to call on further design and consultation with mechanical engineers to ensure high performance and comfort. It was suggested that I might consider prioritizing daylight rather than direct sunlight and that rather than one large atrium the building would benefit from a series of smaller punctures that let light in throughout. One juror, Gary Bowden, who has done work in the Middle East pointed out the cultural differences in response to sunlight. Here in the United States direct sunlight can be seen as advantageous and desirable, while in the Middle East it is never desirable. I was cautioned that while direct sunlight offers a number of benefits, it comes with a number of problems as well.

This critique was noted and will certainly inform future design decisions; however, for me, the most interesting observation from these comments was that in an entire semester, the professors and professionals with whom I had discussed the design never questioned my intention to shape the building to capitalize on direct sunlight. It is important to understand the ways in which different people see different decisions at different stages in a project and to note that design is never done and there is always another way to do something. That being the case, it is important to be able to support your decisions with passion and evidence and also to recognize and appreciate the critique and advice of others to consider changes to the work.

Another important point of discussion came when one juror commended the careful design and attention to the diagram of the day, today, in the present. However, he pointed out that it was important to consider how this building will work in the future. He cited his wife's situation, working three days from home and sharing a desk with two other people. This was an important question because while workplace trends had informed much of the program and ideas for spatial organization of the building, I did not discuss many of those ideas in my presentation and retrospectively, I did not push those boundaries as much as I could have. His comments made me realize an important consequence of the "diagram of a day" strategy which was that, the way I used it, resulting designs existed primarily in the present. Another round of scenario planning and diagraming days years in the future are necessary to understand and represent the ways in which this building will continue to transform and engage users as working styles and technologies continue to change.

Near the end of the discussion attention turned back to one of the foundation points of my investigation which was the analysis of rating systems. The research identifying the inattention to user accountability in these systems was complimented and the question was raised, how do we take the least-considered portion of the rating systems and make it one of the most important, while still achieving all of the other categories? Another juror looked to the rating systems as a point of future investigation for engaging and incentivizing and changing designers and developers' behavior the same way my design addressed user behaviors. Together these two questions were an important way to conclude, and in many ways continue the work.

Very early on in the process I had been asked by multiple faculty members, how do you prove it works? How do you measure it? Do you design a new rating system? Or an amendment to the rating systems? And while the work in these past few months did not lead entirely in that direction, it is significant that the question continues to be asked. In order to take this research and design work forward we need to set up strategies for understanding user impact, measuring performance, evaluating success and adapting strategies for continued improvement.

Chapter 10: Conclusion

The research and design work included in this thesis addresses ideas of sustainability as it relates to users, buildings and the design process. This work finds that building users have incredible impact on building performance and that carefully designed buildings can influence user behavior to encourage sustainable living and improve building performance. The future of our building culture is one designed with a complete understanding of user needs, desires and behavior. It is a building culture in which human beings come to understand their impact on the built and natural environment through the sustainable interactions they have with buildings. This future is one where humankind has found value in the natural environment and perceives itself as existing within rather than next to or opposite the natural environment.

The design ideas presented here are in no way an absolute path to this future. They are the result of exploration and informed speculation intended to inspire discussion and invention. The most important result of this work is to cause designers and users alike to question their understanding of and relationship with their built and natural environments and to consider how their decisions and behaviors impact those environments. These design ideas and methods provide a starting point for implementation, evaluation and iteration. As architects and other design professionals better understand user needs, desires and behaviors, and as users better understand their responsibility and contribution to global sustainability, humankind and our built environment will become increasingly and more truly sustainable. We will not achieve this goal in pursuit of some trophy or prize, and we will not know that we have achieved it because of some magic number or result. We will know true sustainability when we recognize it not as a word, but as a way of living in symbiosis with our ecosystem.

Figure 10.1: St. Francis of Assisi statue, patron saint of animals and ecology, photo by Lisa Thiry

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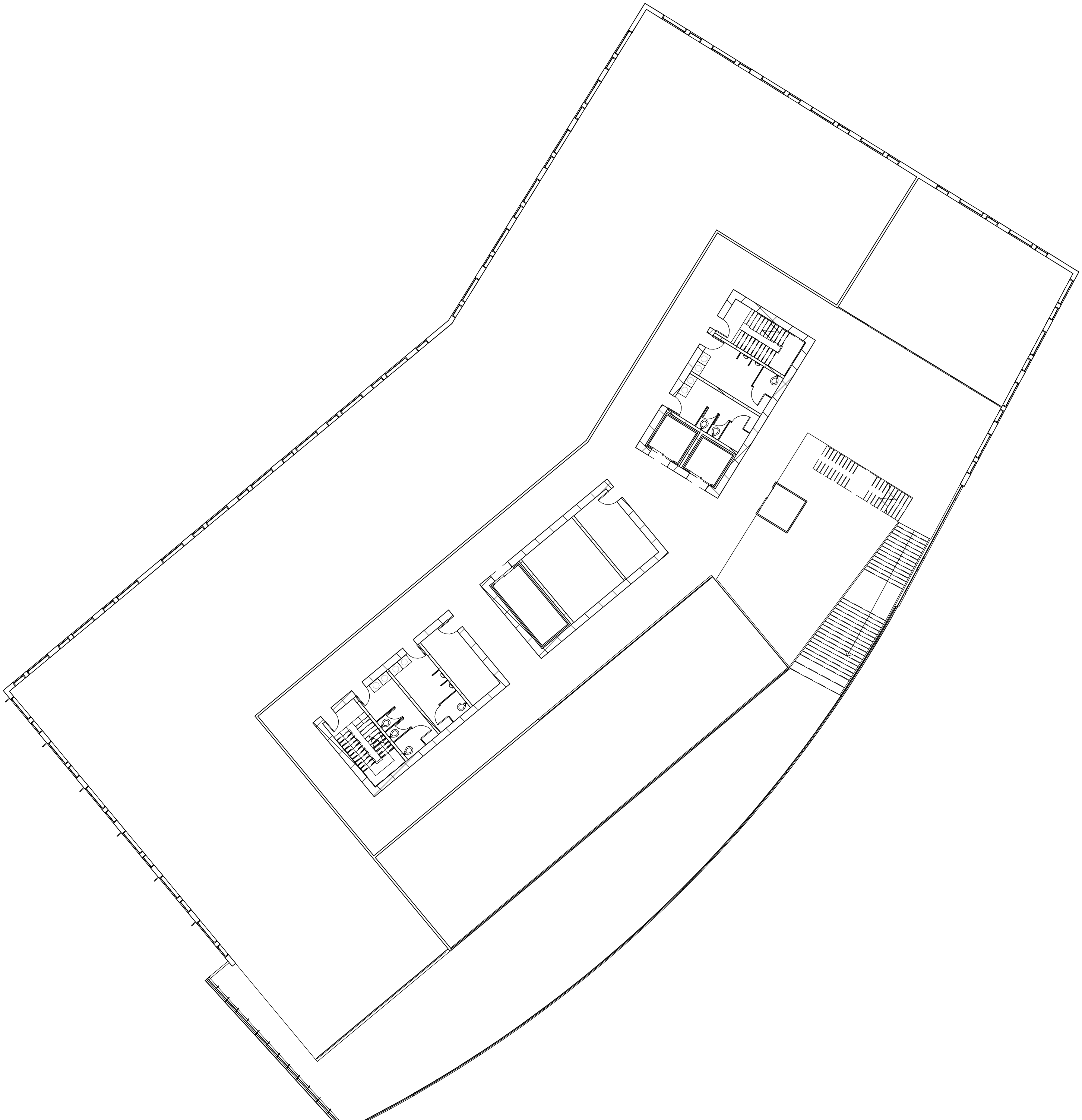

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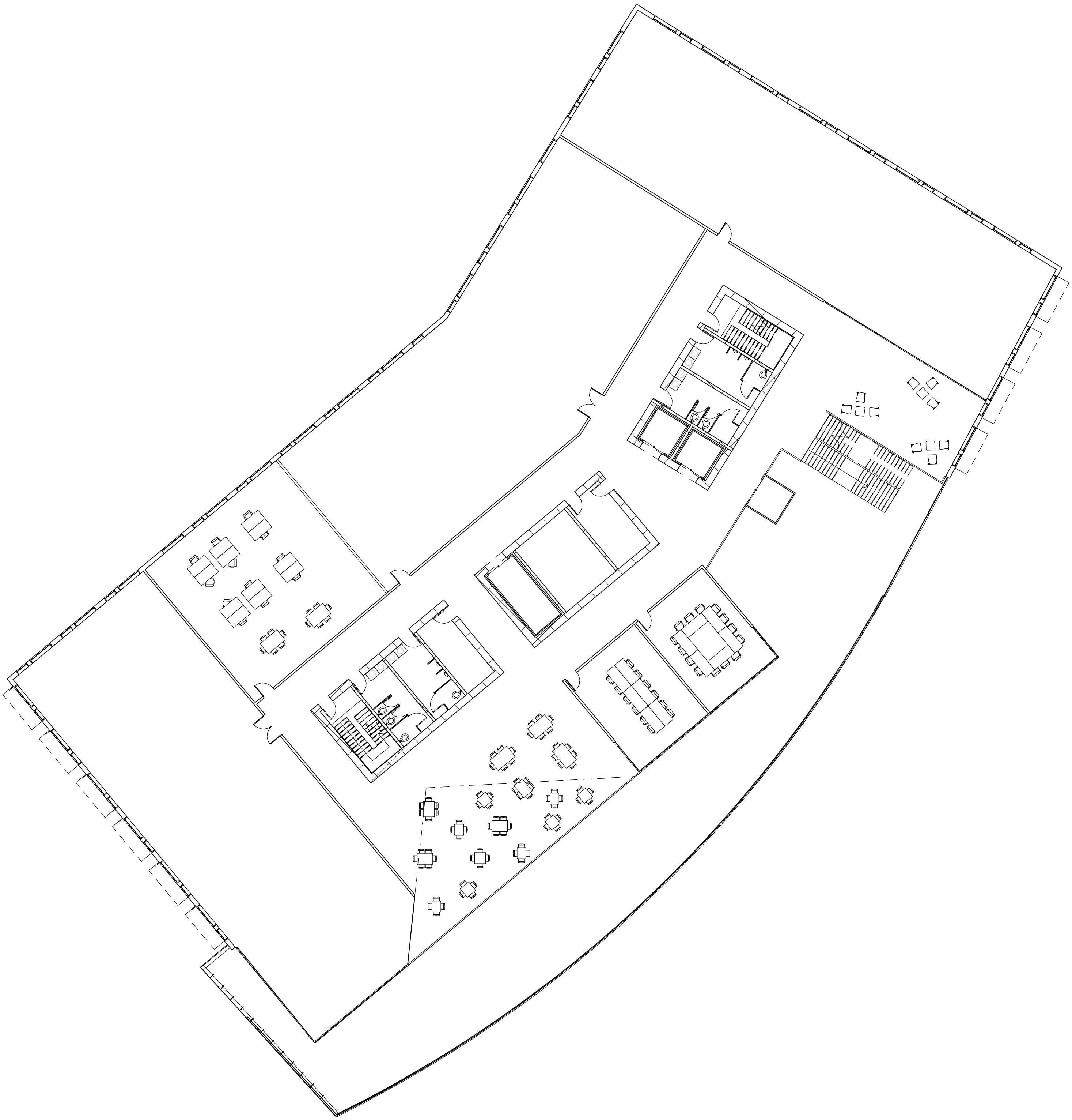

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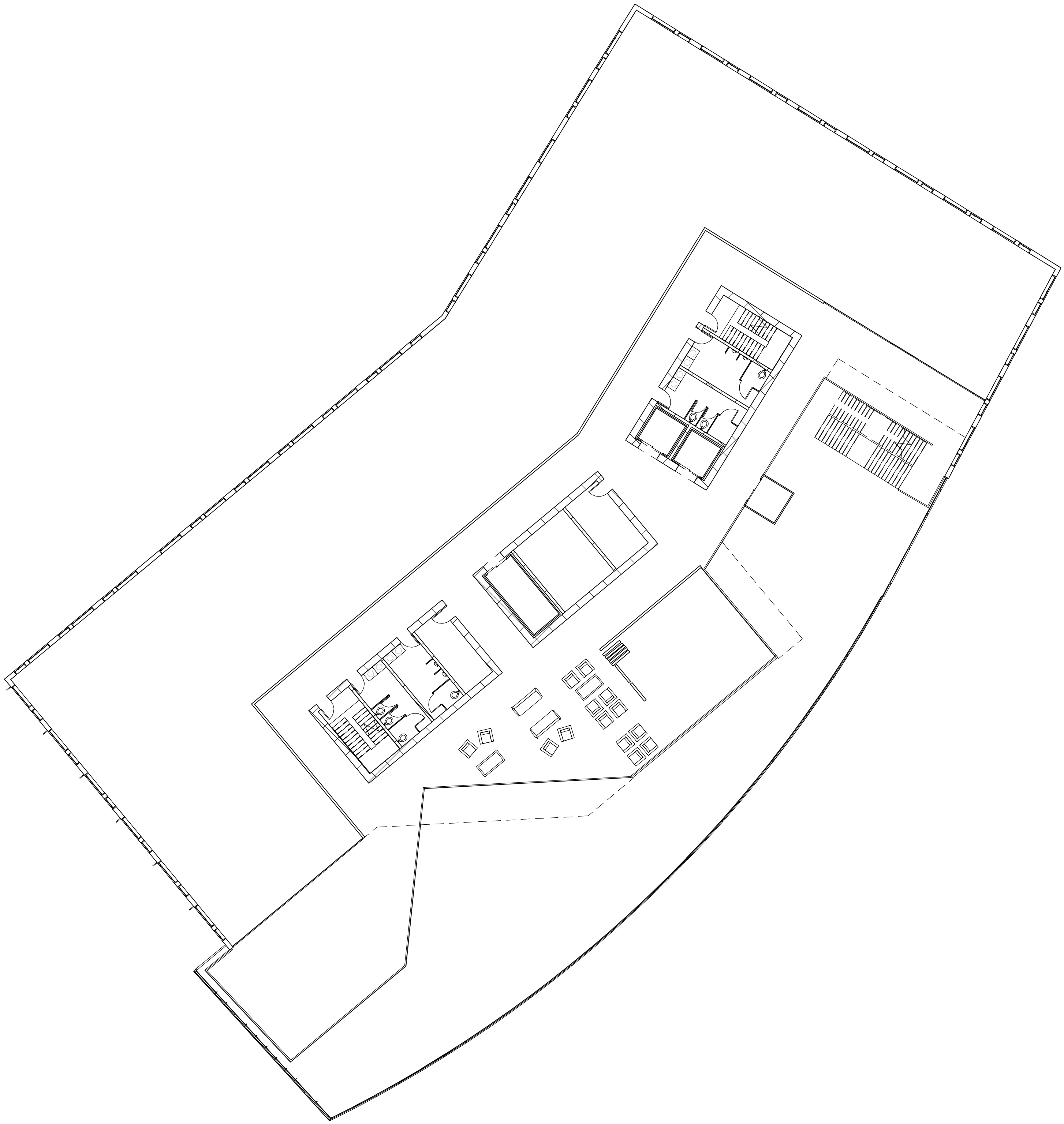

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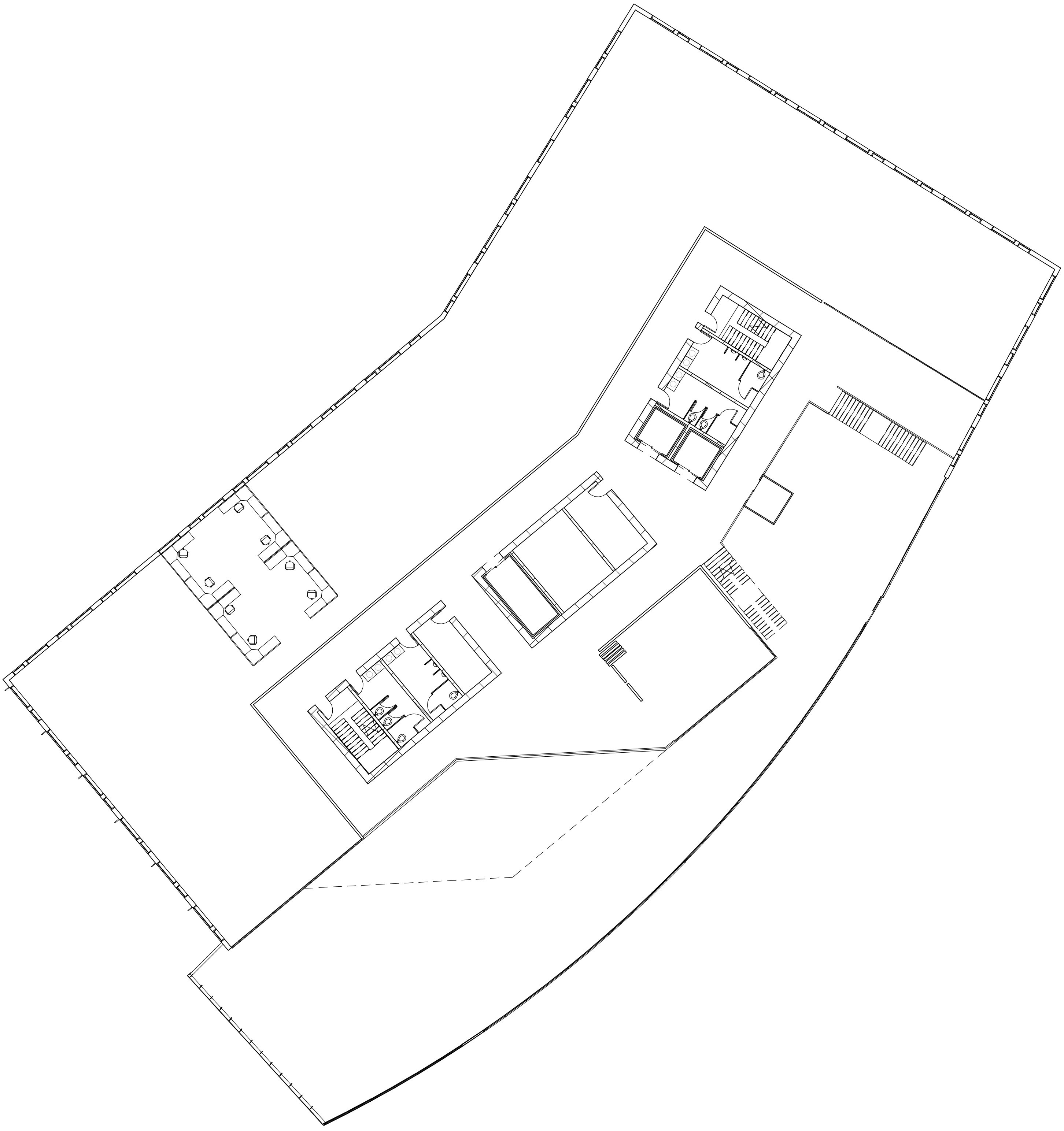

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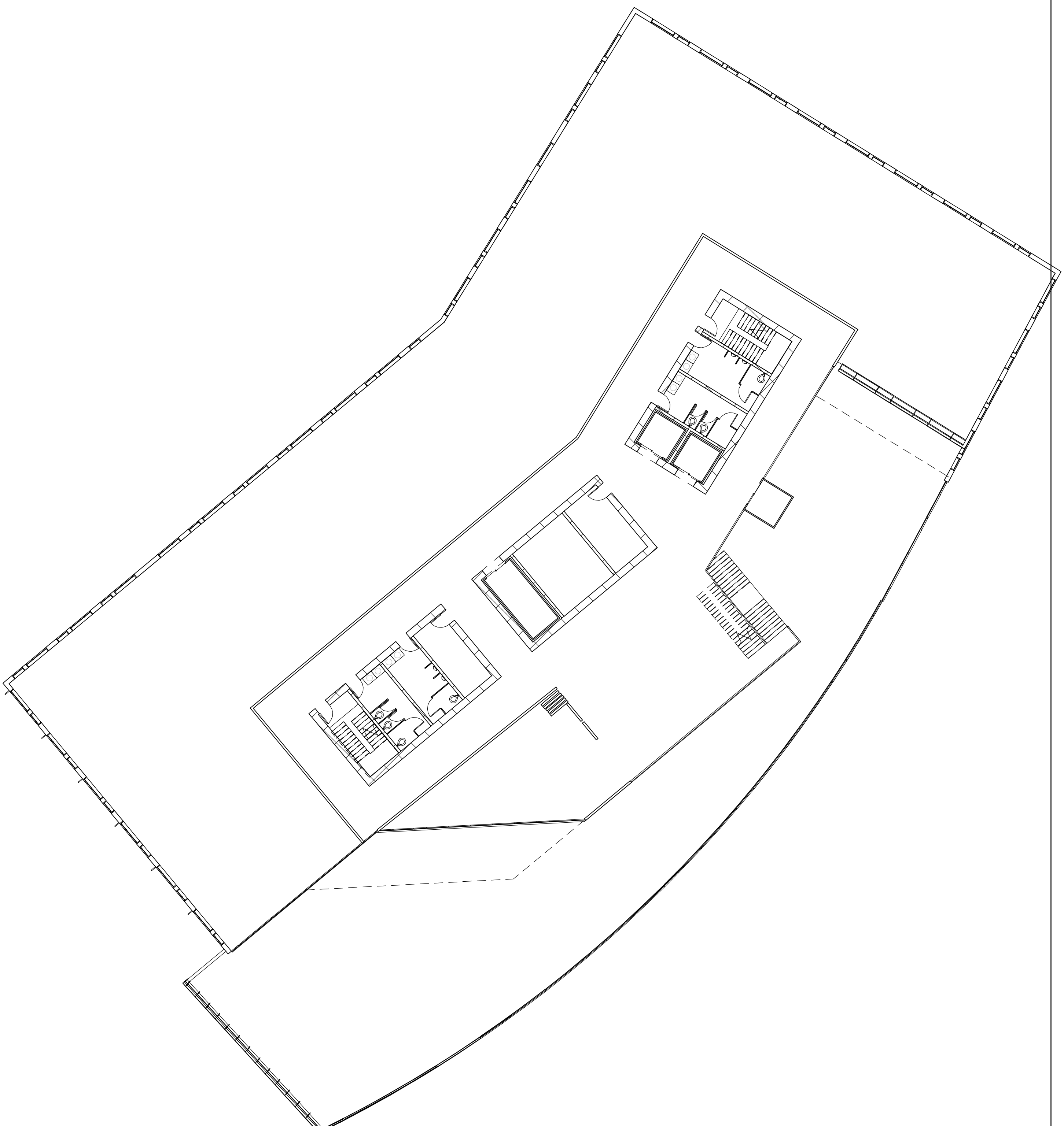

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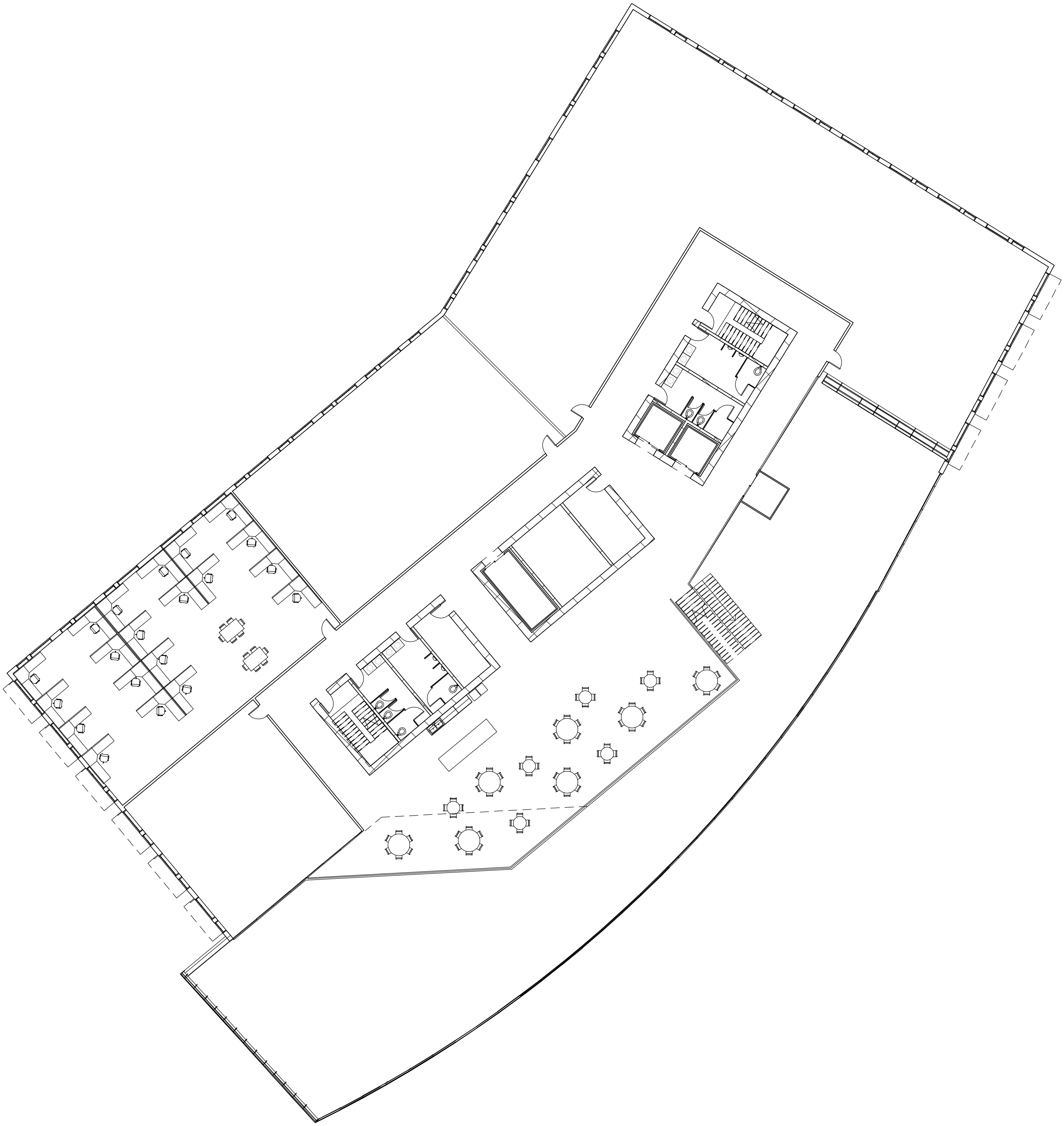

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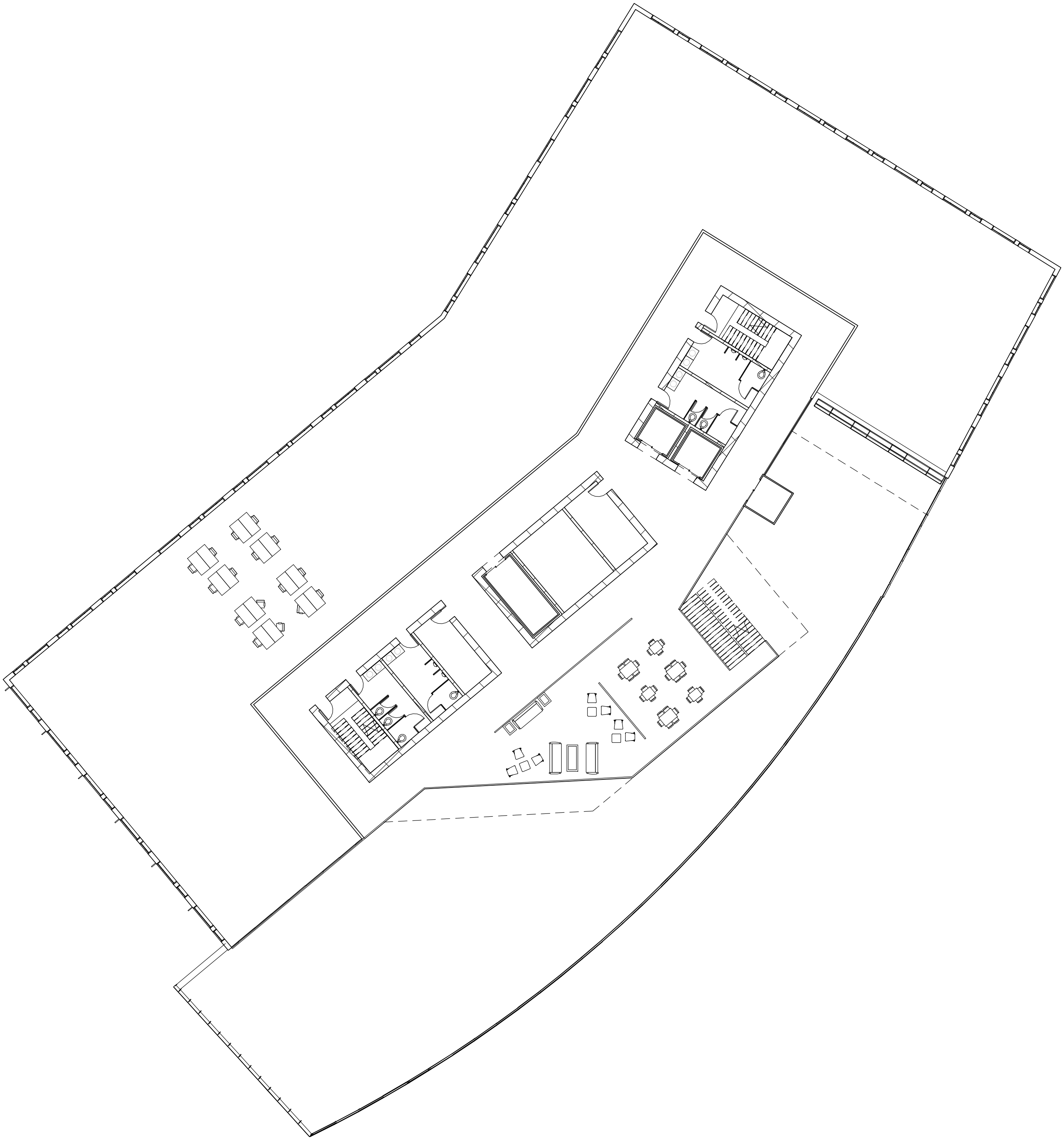

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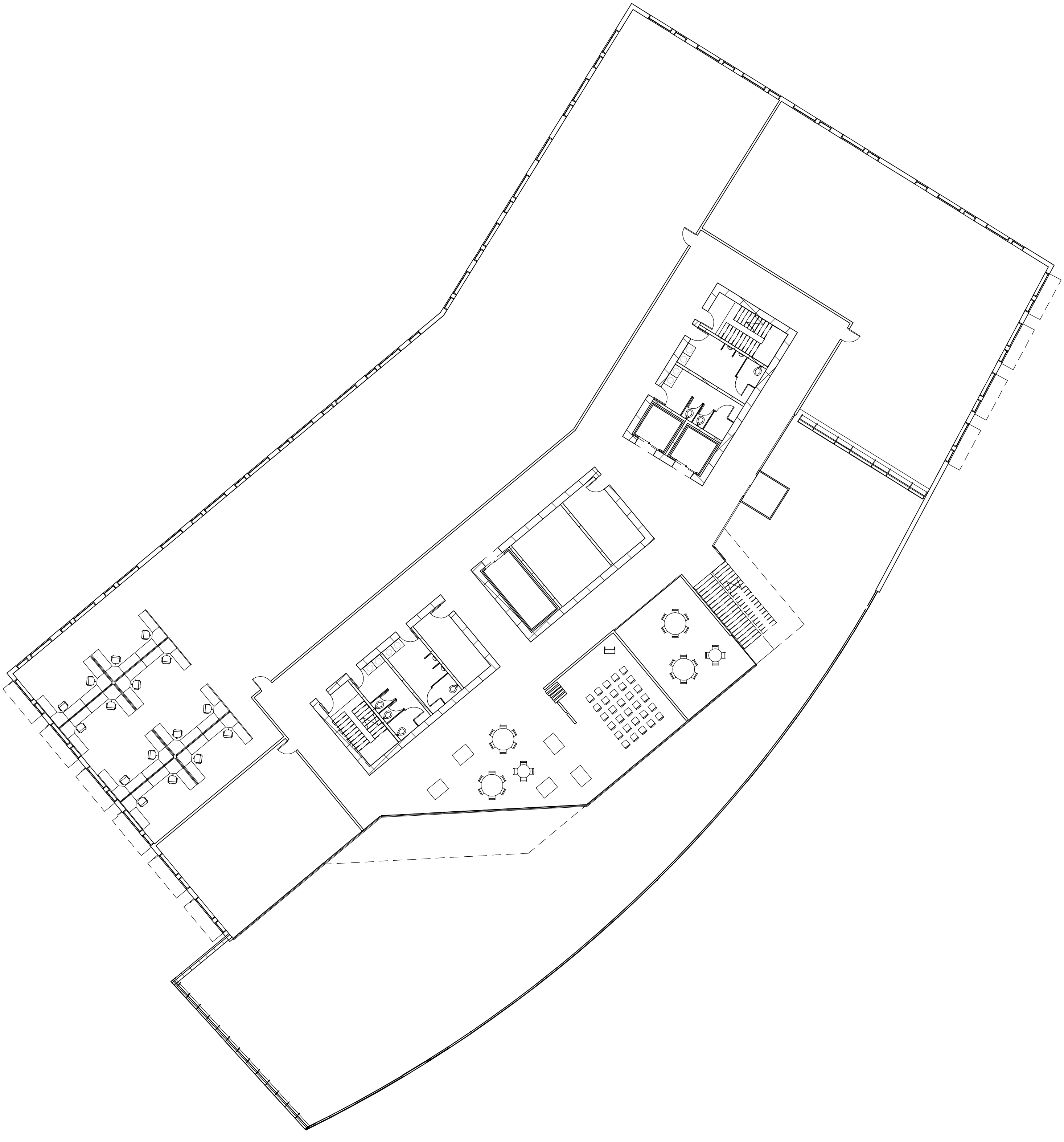

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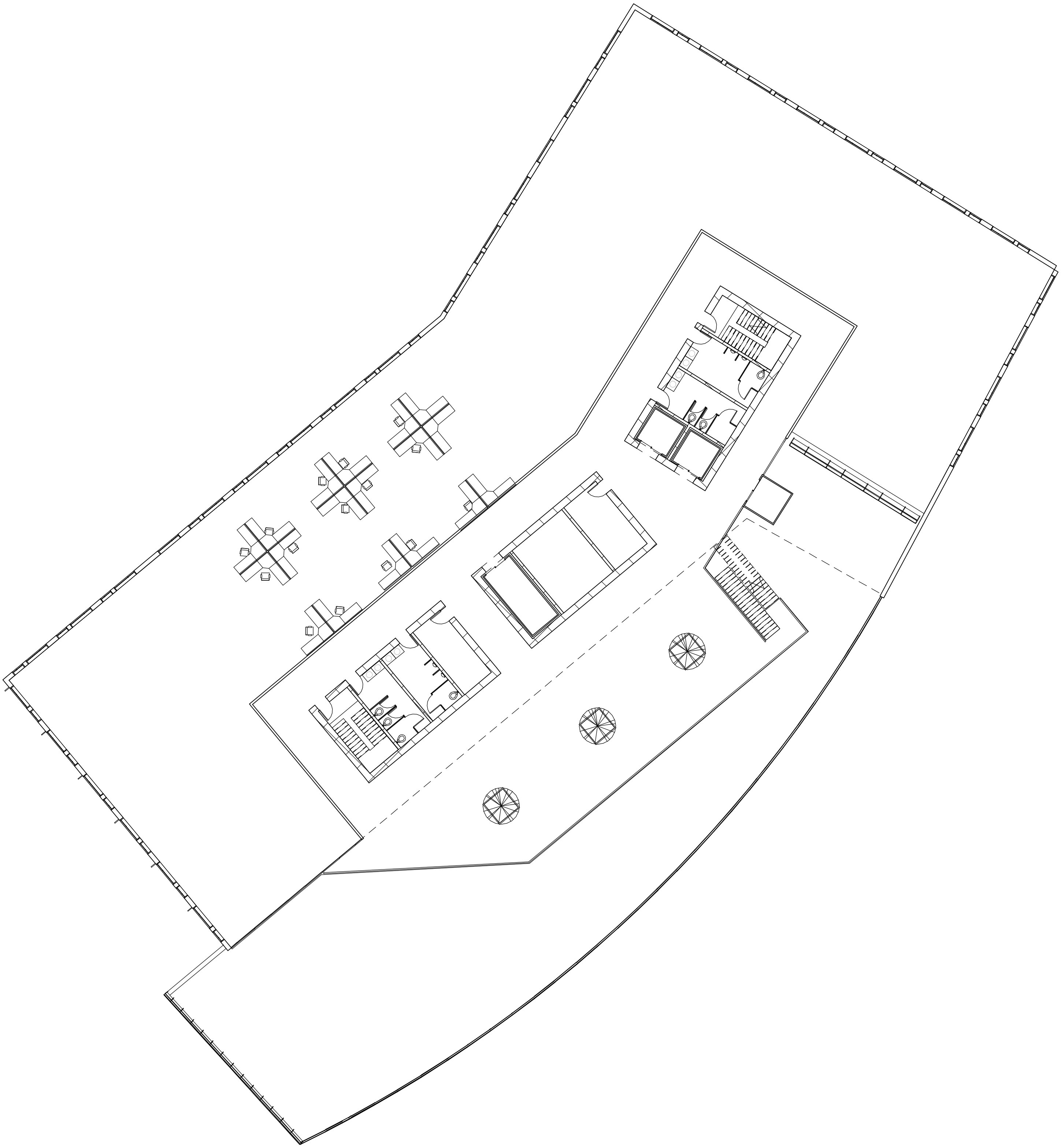

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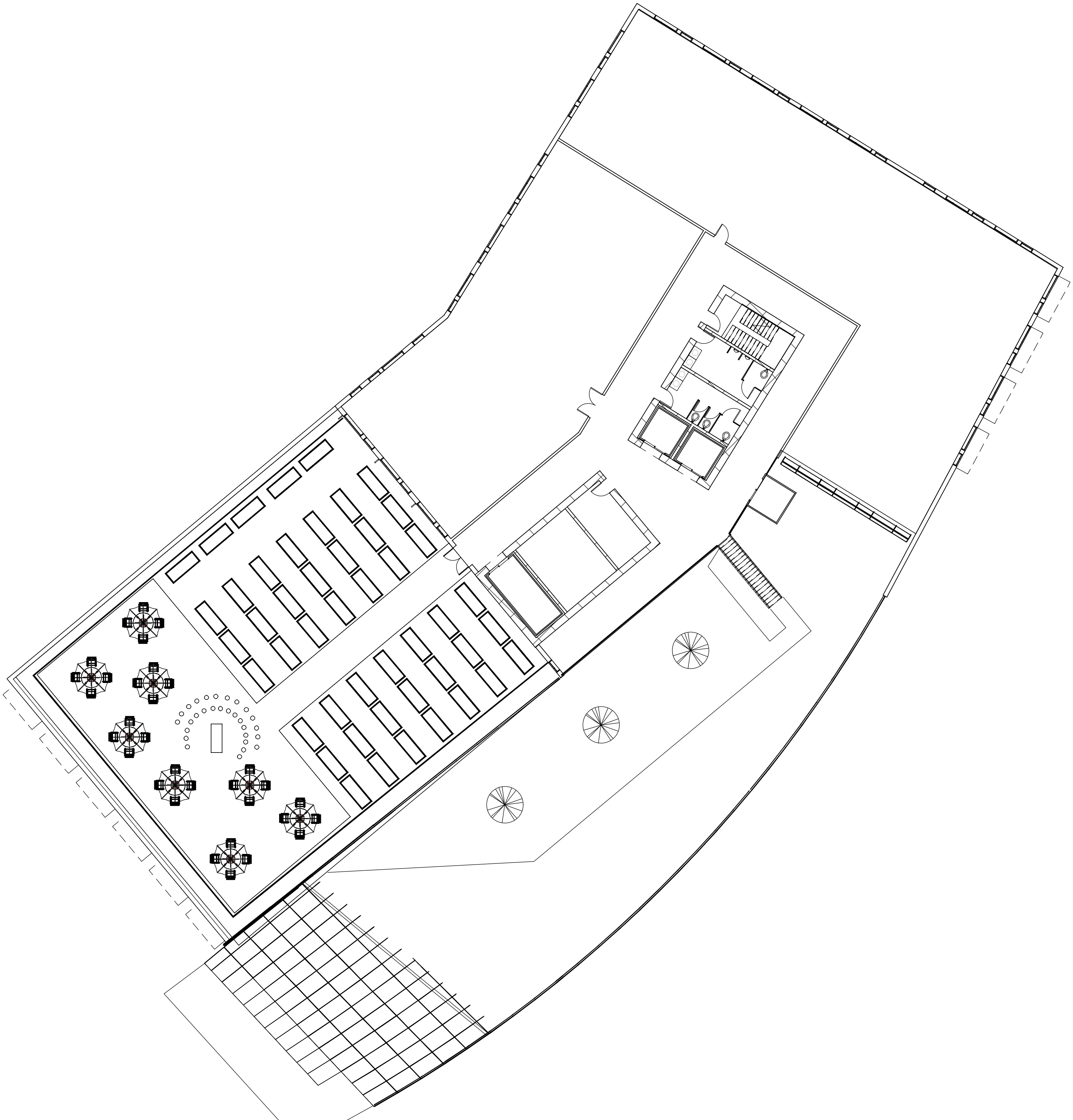

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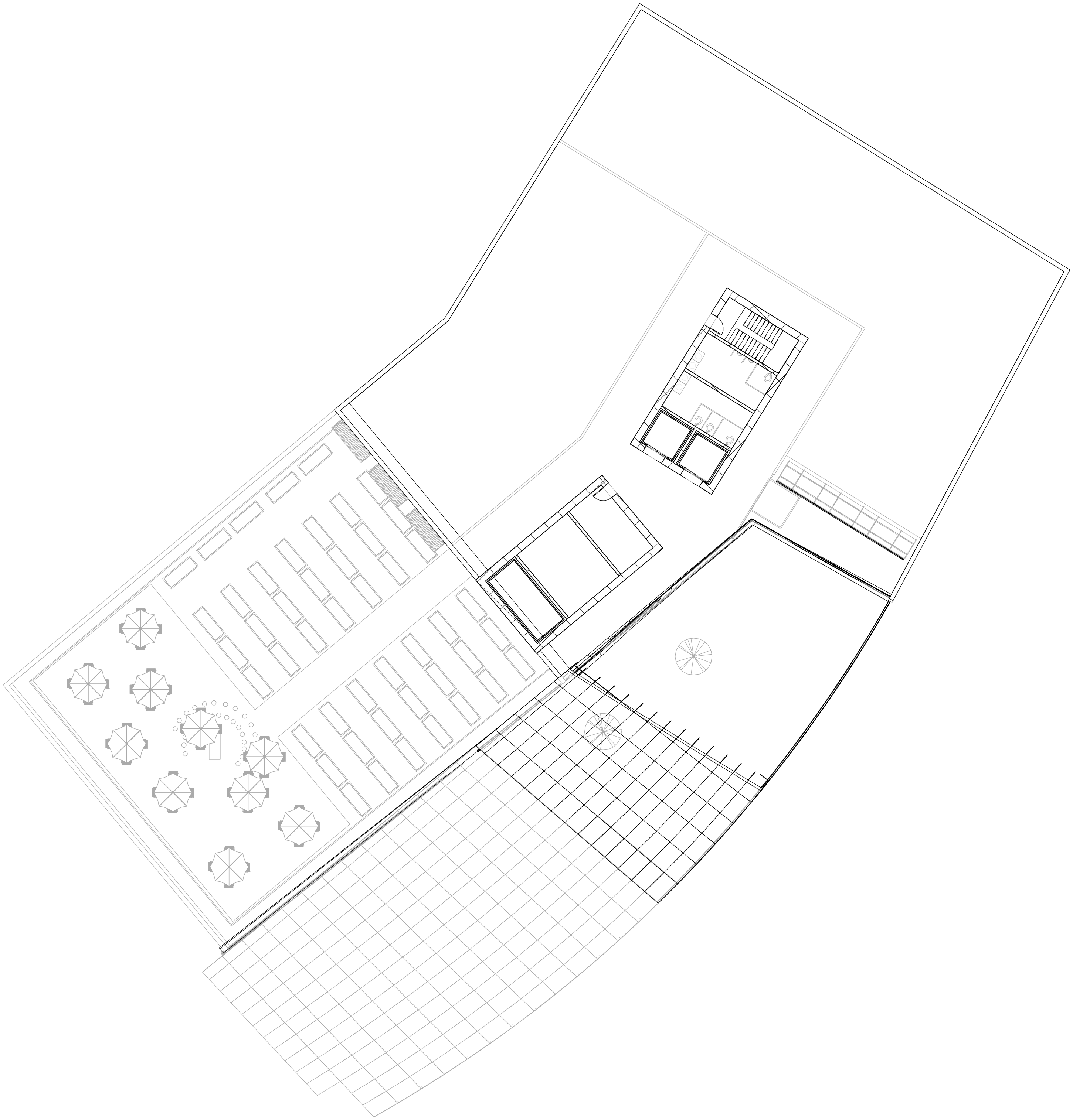

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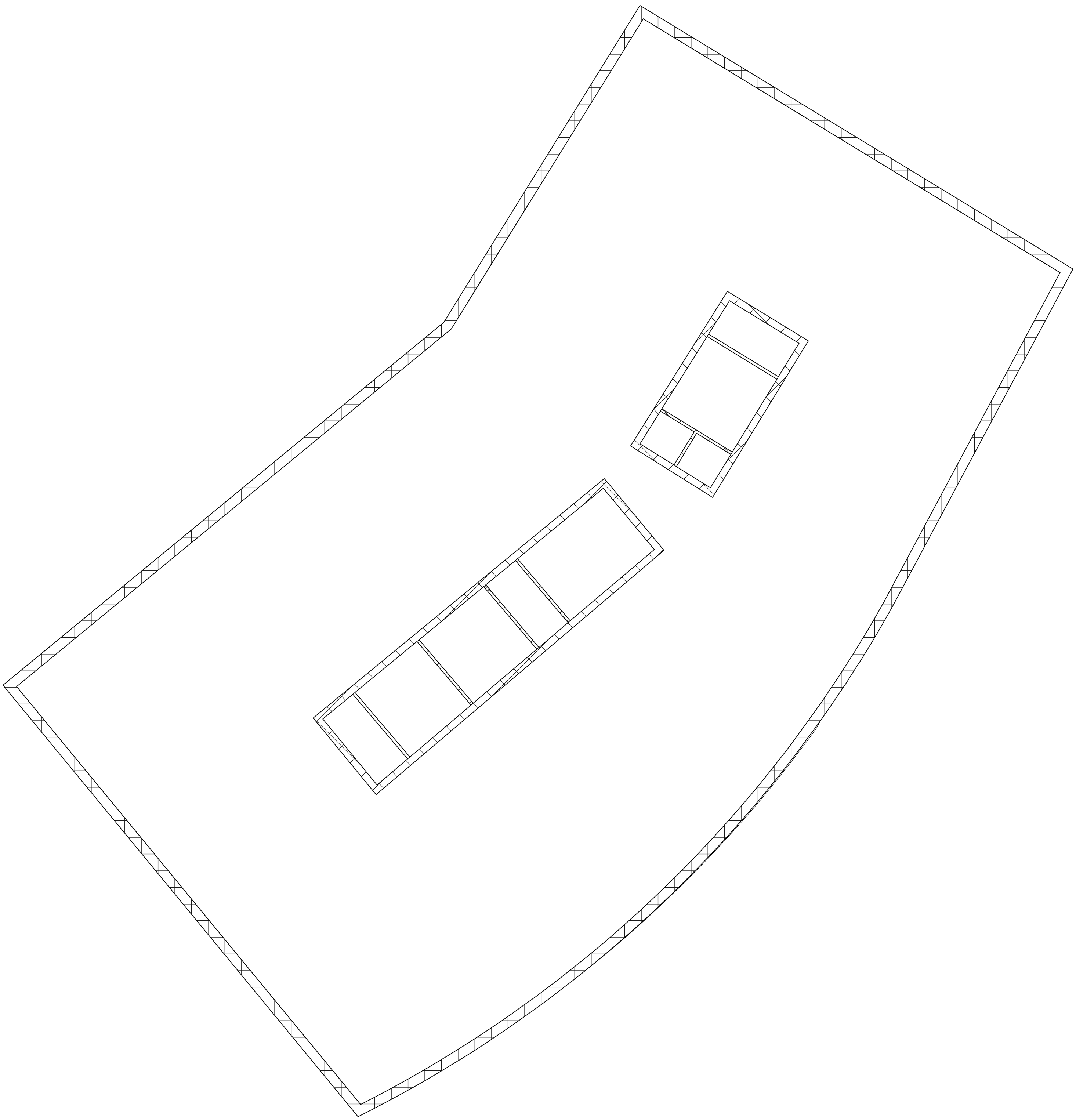

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