Niagara Escarpment II : Exploring Soleri's Arcology

by

Maryam El-Naggar

A thesis
presented to the University Of Waterloo
in fulfilment of the
thesis requirement for the degree of
Master of Architecture

Waterloo, Ontario, Canada, 2024

© Maryam El-Naggar 2024

Author‘s Declaration

I hereby declare that I am the sole author of this thesis.

This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.



Figure 0.1: Illustration of possible interior perspective of an Arcology, drawn with photoshop

Abstract

This thesis explores the ecological potential of an Arcology within a utopic and visionary context. Niagara Escarpment II is an adaptation of Paolo Soleri's Arcology with an Italian hill town aesthetic, using today's technological systems with an intent to integrate ecology and urban settlements in Niagara Falls to resolve environmental concerns. This is a rejection of the current technologically driven "Green Skyscrapers" and "Eco Towers" and proposes an alternative with an ecological inclination. The exploration of integrating ecological processes back into urban processes is historically a heavily researched theme but rarely discussed within the context of an Arcology. A close examination of Paolo Soleri's Arcology, engineered systems of megastructures, examination of indigenous architecture of the Mat Buildings, and analysis of the System's thinking details a niche for this iteration of the Arcology.

This thesis has a pragmatic approach to ecological processes and explores what architectural features work for ecology and what do not. The thesis hypothesizes that a successful Arcology must be designed on a massive scale to integrate fauna, flora, farming, living systems, aquifers, and aquaponics systems into urban settlements to improve air cycles and water cycles within the structure of the Arcology. The goal is to offer a design methodology that shows visible ecological and urban systems on multi-scales through sections within the Arcology. This is achieved by analyzing the design process into Structural organization, Human, and Ecological Processes, and integrating key interactions within the Heat, Water, Waste, and Energy System models integrated within the Arcology. The intention is to provide ecosystem services to the social system by integrating networks with low-tech biological metabolisms. The systems focus on resolving non-linear, dynamic, and cyclic within the structure.

The Niagara Escarpment II is designed for 11'000 visitors, 11'000 residents where each resident will have approximately, 2 trees, 37 plants, 56 plants for food, and Plants that recycle wastewater to deliver a water cycle of 3-5 days, depending on water use. Arcology is not only developed to improve the quality of life for individuals within but intends to increase the Niagara Escarpment's expansion and increase naturalization of the city of Niagara Falls along the peripheries by up to 17%. The Arcology in turn must be a massive structure, with substantial carbon-embodied structural systems to hold these systems. The proposal of this Arcology involves an interdisciplinary team to govern these systems within the lifetime of this Arcology and phasing for 16 years from start to finish.

This research offers a deep dive into ecological and social integration and systems analysis within a large-scale Arcology framework.

Acknowledgements

First, I would like to thank my supervisor Val Rynimmeri for your relentless guidance and positivity through out this process until the finish line. I appreciate all the knowledge that I attained from the hour long discussions we had discussing anything from sci-fi to architecture.

I would like to thank Philip Beesley for your reading suggestions and discussions regarding my thesis. I would also like to thank Tracey Winton for her deep enthusiasm and thought provoking questions that bring a grounding aspect to this thesis.

Thank you to all the University staff and students who welcomed me into the school, provided constant support and created a memorable sense of community.

Thank you to all my family for providing me with constant support, patience and positivity. Thank you Dad, for inspiring me to do more. Thank you Mom, for always listening. Thank you to my big brother, for your words, wisdom and support.

Thank you for all my friends for their support and encouragement. We finally did it!

Territorial Acknowledgement

The University of Waterloo acknowledges that much of our work takes place on the traditional territory of the Neutral, Anishinaabeg and Haudenosaunee peoples. Our main campus is situated on the Haldimand Tract, the land granted to the Six Nations that includes six miles on each side of the Grand River. It is my firm belief that reconciliation must go beyond recognition, and with that spirit I am actively participating in educational opportunities to further explore our nation's history and the rich heritage of Indigenous, First Nations, Inuit, and Métis (FNIM) peoples. I encourage all of us to do the same and a wealth of resources can be found within our Waterloo Indigenous Student Centre.

Disclaimer

Readers must note that this thesis does not associate with any political symbols or narratives in the proposal and it recognizes the importance of cultural sensitivity.

Dedication

To my Dad, Mom, Big Brother, Little Brother, Baby Sister and Family,

Table of Contents

Author's Declaration iii
Abstract v
Acknowledgments vii
Dedications ix
List of Figures xii
Quote xlvi

1. Introduction 1
    1.1 Here Be Dragons 3
    1.2 Introduction 5
    1.3 The Dream 8
    1.4 Ecological Architecture – what does not work? 10
    1.5 Ecological Architecture- what does work? 12
    1.6 Definition: from Green to Sustainable to Ecological to Arcology 14
    1.7 Vision into the Wilderness 16
    1.8 Iterative & Incremental optimization cycles is the way 19
    1.9 The Arcology Development in this thesis 21
    1.10 Thesis Structure 23

2. Literature Review, Theory to Practice and Precedents 24
    2.1 The Arcology Vision and it's Building Types 26
    2.2 Ecological Urbanism: Early Foundations and Precedents 28
    2.3 Buckminster Fuller's Technological Utopianism 34
    2.4 Integration Requires Miniaturization: From Structuralism to Ecology 42
    2.5 Precedents – The Place Bonaventure Hotel 50
    2.6 Precedents – The Barbican Center 52
    2.7 Precedents - Biosphere II 54
    2.8 Paolo Soleri's Arcology: Fusion Megastructures 56
    2.9 Lessons from Precedents 62

3. Niagara Site and Ecosystems Analysis 69
3.1 Introducing the Site 70
3.2 Introducing the Ecological Infrastructure 72
3.3 Biodiversity & Bird Migrations 74
3.4 Site Features 76

4. Systems Analysis 81
4.1 the Ecosystems Approach 84
4.2 Reframing the Problem and the Arcology Sythesis 91

5. Design Process 99
5.1 Designing the Processes of an Arcology 100
5.2 Conceptualizing the Overall Framework of an Arcology 104
5.3 Process Analysis 106
5.4 Key Interactions within the Network 150
5.5 Adaptive Governance fin an Arcology 162
5.6 Arcology Implementation Approach 174
5.7 Phasing the Arcology 176

6. Design Proposal 179
6.1 Arcology Proposal - Visualizing the Arcology 180
6.2 Arcology Proposal - Sectional Perspective & Key Interactions 188
6.3 Generating AI Images of a Megastructure 200
6.4 Generating AI Images for Arcology 206
6.5 Quantifiable Benefits: Deliverables for Arcologies 240

Conclusion 243

Back Matter 250
Bibliography 250
Glossary 256
Summary of System Principals 262
Appendices 265
Appendix A - Additional Mapping 266
Appendix B - Arcology Requirement Calculations 278
Appendix C - Arcology BEnefit Calculations 290

List of Figures

001 **Figure 0.1:** Illustration of possible interior perspective of an Arcology, drawn with photoshop.
by Author. With Photoshop.

Chapter 1

002 **Figure 1.1.1:** Here Be Dragons adapted for Urban Planning Maps - illustration of a collection of ancient maps to highlight current urban planning concerns such as zoning regulations, urban sprawl, urban growth where unknown regions in multiple scales are represented by illustrations of monsters and dragons, generated by ChatGPT and Adobe Firefly
Source: ChatGPT image generated to „create a clever image that blends current urban design issues blended with an image of ancient maps and the slogan of the page is „here be dragons" October 14, 2024, Open AI. http://chatgpt.com/c/670c8d79-1dd0-8007-9a00-f06ab97b4f60. Edited multiple images with Photoshop by Author.

003 **Figure 1.2.1:** Illustration of an Arcology, inspired by Scottish Science Fiction Writer Iain Banks' book covers, generated by Midjourney version 6.1
Source: Midjourney-version 6.1 image generated and blended to "/imagine an arcology that fits a town designed by iain m. banks, science fiction, arcology form outliner, with wild trees and plants and rivers --niji 6 --p y6lr5lq --s 999 - Upscaled (Creative)," October 06, 2024, Discord. Edited for style and content in Adobe Suite Fire Fly.

004 **Figure 1.2.2:** Author's Illustration - Fantastic history
by Author. With Illustrator.

005 **Figure 1.2.3:** Author's Illustration - FComical Projections - Pro-ecology (left), Pro-technology (right)
by Author. With Photoshop.

006 **Figure 1.3.1:** Elevations: Green Skyscrapers, Eco Towers VS Forests, Mountains & Birds
by Author. With Photoshop.

007 **Figure 1.4.1:** Bridge Towers Paris Proposal
Source: Vincent Callebaut Architectures, Bridge Towers, 2014-2015, Digital Image, Web – Paris Smart City 2050 (March 15, 2024), https://vincent.callebaut.org/object/150105_parissmartcity2050/parissmartcity2050/projects.

008 **Figure 1.4.2:** Antismog Towers
Source: Vincent Callebaut Architectures, Antismog Towers, 2014-2015, Digital Image, Web – Paris Smart City 2050 (March 15, 2024), https://vincent.callebaut.org/object/150105_parissmartcity2050/parissmartcity2050/projects.

009 **Figure 1.4.3:** Photosynthesis Towers
Source: Vincent Callebaut Architectures, Photosynthesis Towers, 2014-2015, Digital Image, Web – Paris Smart City 2050 (March 15, 2024), https://vincent.callebaut.org/object/150105_parissmartcity2050/parissmartcity2050/projects.

010 **Figure 1.4.4:** Farmer Tower Stacked Stones
Source: Vincent Callebaut Architectures, Farmscrapers Towers, 2014-2015, Digital Image, Web – Paris Smart City 2050 (March 15, 2024), https://vincent.callebaut.org/object/150105_parissmartcity2050/parissmartcity2050/projects.

011 **Figure 1.4.5:** Mountain Towers
Source: Vincent Callebaut Architectures, Mountain Towers, 2014-2015, Digital Image, Web – Paris Smart City 2050 (March 15, 2024), https://vincent.callebaut.org/object/150105_parissmartcity2050/parissmartcity2050/projects.

012 **Figure 1.4.6:** Bamboo Nest Towers
Source: Vincent Callebaut Architectures, Bamboo Nest Towers, 2014-2015, Digital Image, Web – Paris Smart City 2050 (March 15, 2024), https://vincent.callebaut.org/object/150105_parissmartcity2050/parissmartcity2050/projects.

013 **Figure 1.5.1:** Vo Trong Nghia Architects House in Coleda
Source: Hiroyuki Oki, Gallery of – House of Trees / VTN Architects-13/19, 2014-2015, Photograph, Web – Arch Daily Article (May 7, 2024), https://www.archdaily.com/518304/house-for-trees-vo-trong-nghia-architects.

014 **Figure 1.5.2:** Vertical gardens at Park Royal in Singapore
Source: Patrick Bingham-Hall, dezeen_PARKROYAL-on-Pickering-by-WOHA_20, 1 March, 2017, Photograph, Web – Forbes Article (May 10, 2024), https://www.forbes.com/sites/yjeanmundelsalle/2017/03/01/parkroyal-on-pickering-in-singapore-is-designed-as-a-hotel-and-office-in-a-garden/.

015 **Figure 1.5.3:** Ancient Khmer Temple at Angkor Wat, Cambodia
Source: Elena Frolova, Ancient Khmer temple ruins amid tree roots at Angkor Wat, Cambodia, 22 March, 2019, Photograph, Web – insight guides Article (May 6, 2024), https://www.insightguides.com/inspire-me/blog/visual/tree-roots-envelop-some-of-the-temples-in-mysterious-angkor-cambodia.

016 **Figure 1.5.4:** Alberto Kalach Casa Romany in California
Source: Yoshihiro Koitani, Casa Romany – Photo 1 by Alberto Kalach TAX, 2004, Photograph, Web – Kalach Project List (May 7, 2024), https://www.www.kalach.com/casas-jardines#/casa-romany/.

017 **Figure 1.5.5:** Luciano Pia Tree House 25 Verde
Source: Beppe Giardino, 25 Green / Luciano Pia, 13 March, 2015, Photograph, Web – Arch Daily Article (May 6, 2024), https://www.archdaily.com/609260/25-green-luciano-pia.

018 **Figure 1.8.1:** Author's illustration - as Man Thinketh - What is an architect to do??
by Author. With Illustrator.

019 **Figure 1.9.1:** Superstudio's perspective drawing of The Continuous Monument in 1969
Source: Superstudio, Continuous Monument, Manifesto New York, 1969, Digital Image, Web – ResearchGate Publication (May 7, 2024), https://www.researchgate.net/figure/Continuous-Monument-Manifesto-New-York-Superstudio-1969-URL_fig11_357681219.

020 **Figure 1.10.1:** Interior Perspective of an Ecological Megastructure generated by Midjourney v 5
Source: Midjourney-version 5.1 image generated to "/imagine ecological urban megastructure engineered with systems thinking, structure to be space frames, with flying buttress architectural feature interior perspective --ar 16:9 --style raw --s 750 --v 5.1 - Variations" January 02, 2024, Discord, http://cdn.discordapp.com/attachments/1055908341492240476/1114657679042941029/AwesomeAries_ecological_urban_megastucture_engineered_with_syst_6d1a71a6-7c96-48d8-9142-def59d3cffbf.webp?ex=6734689c&is=6733171c&hm=3e9c10dcce0cf312aa02892fbd671004b1d95a11db06dd1e38904fc1acae86c0&.

Chapter 2

021 **Figure 2.1:** Paolo Soleri - Arts and Crafts Villiage 1961 and Macro Cosanti Bowl Cut-out 1964- Sketch
Source: Paolo Soleri, Arcology, Sketchbook #2: 1959-1962 & Sketchbook #3: 1964-1968, 1970, Digital Image, Web – Pinterest (June 2, 2024), https://i.pinimg.com/564x/8c/d0/67/8cd067fa9be18600497f331822a6d7a5.jpg.

022 **Figure 2.2:** Le Corbusier's Elevation Sketch of Unite d'Habitation
Source: Le Corbusier, Unité d'habitation - Perspective de l'unité, Firminy, Digital Image, Web – Le Corbusier World Heritage (June 1, 2024), https://lecorbusier-worldheritage.org/en/1944-1965/.

023 **Figure 2.3:** Le Corbusier's Unite d'Habitation in Marsielle
Source: Le Corbusier, Unité d'Habitation in Marseilles, 1945-1952, Photograph, Web – ResearchGate (June 1, 2024), https://www.researchgate.net/profile/Gizem-Guneri/publication/333775149/figure/fig4/AS:769628577988609@1560505160067/a-The-Radiant-City-1935-241-b-Unite-dHabitation-in-Marseilles-1945-1952-242.jpg.

024 **Figure 2.4:** Geddes's Outlook Tower
Source: Patrick Geddes, Drawings of the Outlook Tower in 'Cities in Evolution', Garden Cities of Tomorrow, 1902, Digital Image, Web – Jose Farina's Blog – Urban Planning, Territory and Landscape (May 3, 2018), https://elblogdefarina.blogspot.com/2011/10/recuperando-patrick-geddes.html.

025 **Figure 2.5:** Ebenezer Howard's Garden City
Source: Sir Ebenezer Howard, an illustration of the garden city, 1917, Digital Image, Web – Word Press Article (May 3, 2018), https://littlemissurbanite.wordpress.com/2016/04/08/the-enp-board-review-series-part-6a-urban-and-regional-planning-history-and-principles/.

026 **Figure 2.6:** Tony Garnier's Cite
Source: Tony Garnier, une Cite Industrielle, 1915, Digital Image, Web – Word Press Article (May 3, 2018), https://littlemissurbanite.wordpress.com/2016/04/08/the-enp-board-review-series-part-6a-urban-and-regional-planning-history-and-principles/.

027 **Figure 2.7:** Otto Wagner's die Großstadt
Source: Otto Wagner, The Development of a Great City, Wagner's response to a competition for the general regulation of Vienna, 1911, Digital Image, Web – archimaps tumblr Article (May 4, 2018), https://tmblr.co/Z8Kftx24vmdl9.

028 **Figure 2.8:** Le Corbusier's Ville Raduise Perspective
Source: Le Corbusier, illustration of the Ville Radieuse, Architecture and Urbanism, 1925, Digital Image, Web – Word Press Article (May 4, 2018), https://inarchitectureandurbanism.wordpress.com/2013/11/10/an-architect-le-corbusier/.

029 **Figure 2.9:** Le Corbusier's Ville Raduise Elevation
Source: Le Corbusier, illustration of the Ville Radieuse, 1925, Digital Image, Web – the Charnel-House Article (May 4, 2018), https://thecharnelhouse.org/2014/06/03/le-corbusiers-contemporary-city-1925/.

030 **Figure 2.10:** Benton MacKaye in 1934 at the Appalachian Trail
Source: Appalachian Trail Conservatory, Benton Mackay at the Appalachian Trail, 1934, Digital Image, Web – Appalachian Trail Conservatory website (May 22, 2024), https://appalachiantrail.org/get-involved/volunteer/trail-management-resources/cooperative-management/.

031 **Figure 2.11:** The Tennessee Authority - Diagram of the TVA‘s water control systems
Source: Macy, Christine. Bonnemaison, Sarah, Diagram of TVA water control system, 2003. Architecture and Nature: Creating the American Landscape. London, UK: Routledge. (Also See : See Richard White, The Organic Machine: the Remaking of the Columbia River, New York: Hill and Wang, 1995.)

032 **Figure 2.12:** Paolo Soleri‘s sketch representing Doxiadis’s Ecumemopoly
Source: Paolo Soleri, Ecumenopoly, The City in the Image of Man, 1969, Digital Image, Web – Organism Earth website (May 12, 2024), https://www.organism.earth/library/document/arcology.

033 **Figure 2.13:** Fuller‘s Manhattan Dome in 1960
Source: Buckminister Fuller, Dome over Manhattan, 1960, Digital Image, Web – The estate of R. Buckminster Fuller website (June 4, 2024), https://buckminsterfuller.net/images/domes.html.

034 **Figure 2.14:** Fuller‘s Geodesic Dome in Montreal
Source: Buckminster Fuller, Biosphère Montreal, Expo ’67 Montreal, 1967, Digital Image, Web – Arch Daily website (May 22, 2024), https://www.archdaily.com/625936/the-architectural-lab-a-history-of-world-expos.

035 **Figure 2.15:** Buckminster Fuller‘s sketches
Source: Buckminster Fuller, Geodesic Dome Patent, Operating Manual for Spaceship Earth, 1969, Digital Image, Book (May 23, 2024), Fuller, R. Buckminster (Richard Buckminster). 1969. Operating Manual for Spaceship Earth. By R. Buckminster Fuller. Carbondale: Southern Illinois U. P.

036 **Figure 2.16:** Sant‘Elia‘s Axonometric illustrates his vision of the futurist city, where mechanized, monumental forms express technological progress and forward thinking, serving as a precursor to later megastructure concepts in modern architecture.
Source: Antonio Sant‘Elia, Perspective drawing from La Città Nuova, 1914, Digital Image, Web – Wikipedia website (May 5, 2018), https://en.wikipedia.org/wiki/Antonio_Sant%27Elia#/media/File:Stazione_Sant‘Elia.jpg.

037 **Figure 2.17:** Archigram‘s Plug in City launches the world into the megastructure fad of the 1960‘s with modular units are plugged into a dynamic framework, symbolizing the integration of technology, flexibility, and adaptability towards an ever changing future.
Source: Peter Cook, Plug-in City, Axonométrica, 1964, Digital Image, Web – Research Gate website (May 18, 2018), https://www.researchgate.net/figure/Figura-2-Peter-Cook-Plug-In-City-1964-Axonometrica-Fonte-Sadler-2005-p-15_fig2_265292035.

038 **Figure 2.18:** Le Corbusier‘s Emperor in Algiers
Source: Le Corbusier e Pierre Jeanneret, Perspectiva das habitações de Fort l‘Empereur, Plano Obus („ projeto A „), Argel, 1931, Digital Image, Web – Research Gate website (May 18, 2018), https://www.researchgate.net/figure/Figura-4-Le-Corbusier-e-Pierre-Jeanneret-Plano-Obus-projeto-A-Argel-1931_fig3_265292035.

039 **Figure 2.19:** Hans Hollien's Ocean Liner
Source: Hans Hollien, Aircraft Carrier City in Landscape, project, Exterior perspective, 1964, Digital Image, Web – New York, Museum of Modern Art (MoMA) website (May 22, 2024), https://www.moma.org/collection/works/634?artist_id=2705&page=1&sov_referrer=artist.

040 **Figure 2.20:** Archigram's Walking City
Source: Archigram's Herron and Harvey, a Walking City, 1964, Digital Image, Web – Arch Daily website (May 18, 2018), https://https://www.archdaily.com/974534/why-every-3d-designer-architect-can-benefit-from-the-creator-economy-in-the-metaverse/61d41da53e4b31fd0700002d-why-every-3d-designer-architect-can-benefit-from-the-creator-economy-in-the-metaverse-image.

041 **Figure 2.21:** Justus Dahinden's Radio City (1970)
Source: Justus Dahinden, Modèles transitifs pour sociétés en évolution, Radio City (Hill City), Panneau d'exposition, 1970, Digital Image, Web – FRAC Centre-val De Loire website (May 20, 2018), https://collections.frac-centre.fr/collection-art-architecture/dahinden-justus/hill-city-64.html?authID=286&ensembleID=1003

042 **Figure 2.22:** 1909 Theorem - a radicalized idea of skyscrapers. Rem Koolhaus points out the absurdity of the expectations.
Source: A B Walker, Buy a cozy cottage in our steel constructed choice lots, less than a mile above Broadway. Only ten minutes by elevator. All the comforts of the country with none of its disadvantages, Life Magazine cartoon rediscovered by Rem Koolhaus in his book Delerious New York, 1909, Digital Image, Web – Word Press website (May 20, 2018), https://porousearth.wordpress.com/2012/09/29/precedent-research-mash-up-illustration-first-iteration/.

043 **Figure 2.23:** Florence's Ponte Vecchio's midevil bridge
Source: Xavier Arnau, Dramatic sunset in Ponte Vecchio - Florence - Tuscany – Italy (Stock photo ID:155387898), Photograph, Web – iStock photo website (March 14, 2012), https://www.istockphoto.com/photo/sunset-in-ponte-vecchio-gm155387898-19547801.

044 **Figure 2.24:** Roq e Rob Project
Source: Le Corbusier, Roq and Rob, Roquebrune-Cap-Martin, Complete Works, volume 5, 1946-19521949, Digital Image, Web – Le Corbusier Foundation website (March 14, 2012), https://www.fondationlecorbusier.fr/en/work-architecture/projects-roq-and-rob-roquebrune-cap-martin-france-1949/.

045 **Figure 2.25:** Moshe Safdie's Habitat 67 in Montreal
Source: Moshe Safdie, Habitat 67 à Montréal, 2019, Digital Image, Web – a View on Cities - Habitat '67 website (January 19, 2020), https://aviewoncities.com/montreal/habitat-67.

046 **Figure 2.26:** Agricultural City
Source: Kisho Kurokawa, Agricultural City, 1959, Digital Image, Web – Research Gate website (May 19, 2019), https://www.researchgate.net/figure/Agricultural-City-1959-by-Kisho-Kurokawa_fig1_327843062.

047 **Figure 2.27:** Keller Eastling's pinup no.20 in 2016 to emphasize the landscape of infrastructure
Source: Hans und Renee Muller-Meylan Stiftung Foundation, Keller Eastling's pinup, 2016, Digital Image, Web – Research Gate website (May 21, 2024), https://www.sam-basel.org/en/events/double-lecture-superbugs-and-secret-zones-keller-easterling-and-xenia-vytuleva.

048 **Figure 2.28:** Eco-Machine in Omega Center Rhinebeck NY
Source: John Todd Eco-machine, Omega Center Eco-Machine®, Rhinebeck, New York, 2003, Digital Image, Web – John Todd website (May 21, 2024), https://www.toddecological.com/projects.

049 **Figure 2.29:** Eco-Machine in South Burlington Vermont
Source: John Todd Eco-machine, City of South Burlington Municipal Eco-Machine South Burlington, Vermont, 1995, Digital Image, Web – John Todd website (May 21, 2024), https://www.toddecological.com/projects.

050 **Figure 2.30:** Team 10's Berlin University in plan
Source: Team 10, The Free University of Berlin, Plan of Upper Level, 1963-64, Digital Image, Web – Research Gate website (Feb 19, 2024), https://www.researchgate.net/figure/The-Free-University-of-Berlin-Plan-of-Upper-Level-1963-64-Source-Free-University_fig2_342608650.

051 **Figure 2.31:** Illustration of Kawloon City
Source: Greg Girard and Ian Lambot, The Darkness City: Life in Kowloon Walled City, 1993, Digital Image, Web – South China Morning Post website (Aug 15, 2018), https://multimedia.scmp.com/culture/article/SCMP-printed-graphics-memory/lonelyGraphics/201303A106.html?src=pinterest.

052 **Figure 2.32:** The Place Bonaventure Hotel: Exterior and Interior Shots
(image: top left)
Source: placebonaventure.com, Aerial Photograph, Web (Feb 19, 2024), https://pimrc2017.ieee-pimrc.org/2017/04/01/bonaventure-nearly-50-years-of-history/index.html
(image: bottom left, right, left on the next page)
Photographs by Author, May 4, 2017.

053 **Figure 2.33:** The Barbican : Illustration, plan and interior shots
(image: top right)
Source: John Maltby / RIBA Collections, Barbican Centre by Powell & Bon Chamberlin, 1970, pencil and ink on paper, Web (May 11, 2017), http://www.themodernhouse.com/journal/beautiful-architectural-drawings-phaidon/.
(image: top left)
Source: Powell & Bonn Chamberlin, Barbican Redevelopment General Layout: Roof Plan, 1968, pencil and ink on paper, Web (May 11, 2017), http://artsandculture.google.com/asset/barbican-redevelopment-general-layout-roof-plan-chamberlin-powell-bon/kwGAMJ9LQbVU3w?hl=en.
(image: next page top)
Source: Luke Hayes, Barbican Centre, Web (May 11, 2017), photograph, https://www.arch2o.com/barbican-complex-brutalist-post-war-british-icon/.
(image: next page bottom)
Source: Luke Hayes, Barbican Centre, Web (May 11, 2017), photograph, https://www.arch2o.com/barbican-complex-brutalist-post-war-british-icon/

054 **Figure 2.34:** Biosphere II : scheme, exterior, interior shot and one of the team residences
(image: top left)
Source: Biosphere II, Schematic showing the arrangement of components of Biosphere 2, Space Biosphere Ventures, 1985, hand colored render on paper, Web – Space: Science and Technology (August 17, 2024), http://spj.science.org/doi/10.34133/2021/8067539.
(image: top left)
Source: Jasper Nance, Biosphere 2 Ocean HDR, September 11, 2010, photograph, Web – flickr website (August 17, 2024), http://www.flickr.com/photos/nebarnix/4980794834.
(image: bottom right)
Source: Luke Hayes, The Biosphere 2 sits on a sprawling 40-acre campus that is now open to the public, 2016, Web – wikiwand Website (August 17, 2024), https://www.wikiwand.com/en/articles/Biosphere_2#/media/File:Wiki_bio2_sunset_001.jpg.
(image: next page top)
Source: Biosphere II, 'Spaceship Earth', 1991, Web – USA today website (August 17, 2024), https://www.usatoday.com/story/entertainment/movies/2020/05/09/spaceship-earth-why-crazy-hulu-doc-must-watch-quarantine-viewing/3102031001/.

055 **Figure 2.35:** Paolo Soleri's Babel IIB
Source: Paolo Soleri, Babel IIB, The City in the Image of Man, 1969, Digital Image, Web – Organism Earth website (May 12, 2024), https://www.organism.earth/library/document/arcology.

056 **Figure 2.36:** Paolo Soleri‘s Novanoah I
Source: Paolo Soleri, Novanoah I, The City in the Image of Man, 1969, Digital Image, Web – Organism Earth website (May 12, 2024), https://www.organism.earth/library/document/arcology.

057 **Figure 2.37:** Paolo Soleri‘s Veladiga
Source: Paolo Soleri, Veladiga, The City in the Image of Man, 1969, Digital Image, Web – Organism Earth website (March 1, 2024), https://www.organism.earth/library/document/arcology.

058 **Figure 2.38:** Hexahedron for a population of 170,000, 1,100 meters high on a surface area of 57 hectares, 150 acres
Source: Paolo Soleri, Hexadron, The City in the Image of Man, 1969, Digital Image, Web – Organism Earth website (March 1, 2024), https://www.organism.earth/library/document/arcology.

059 **Figure 2.39:** Frank Lloyd Wright‘s Broad Acre City
Source: Frank Lloyd Write, Utopian Rendering of Broadacres City with the Mile High included, Part 4 | Masterplanning the Future of Cities, 1932, Digital Image, Web – elevatorscene website (March 8, 2024), https://www.elevatorscenestudio.com/blog/2020/6/13/broadacre-city-frank-lloyd-wright-urban-planning-illinois.

060 **Figure 2.40:** Paolo Soleri‘s Arcosanti for a population of 1,500 50 meters high on a surface area of 2.8 hectares, 7 acres
Source: Paolo Soleri, Arcosanti, The City in the Image of Man, 1969, Digital Image, Web – Organism Earth website (March 1, 2024), https://www.organism.earth/library/document/arcology.

061 **Figure 2.41:** Renzo Piano and Richard Rogers Centre George Pompidou
Source: Renzo Piano and Richard Rogers, Centre George Pompidou, 1977, Digital Image, Web – Arch Daily website (April 4, 2024), https://www.archdaily.com/64028/ad-classics-centre-georges-pompidou-renzo-piano-richard-rogers.

Chapter 3

062 **Figure 3.1:** Site of Niagara Falls - prime location due to it‘s proximity to water, US borders, tourist attraction
By Author. Image Source: Arial obtained from Google Earth.

063 **Figure 3.2:** Site of Niagara Falls - within nested loops
By Author. Image Source: Arial obtained from Google Earth.

064 **Figure 3.3:** Patches of forested lands - limited capacity to provide adequate eco-system services
By Author. Source Niagara Open Data: https://open.niagarafalls.ca/search?groupIds=7bb3d92788b845f986101a213aa1485c. Source Basemap: https://www.arcgis.com/apps/mapviewer/index.html.

065 **Figure 3.4:** Patches of agricultural lands – monocultures do not provide ecosystem services but it could be one of the contributing factors for poor quality of water.
By Author. Source Niagara Open Data: https://open.niagarafalls.ca/search?groupIds=7bb3d92788b845f986101a213aa1485c. Source Basemap: https://www.arcgis.com/apps/mapviewer/index.html.

066 **Figure 3.5:** Protected Lands in the city of Niagara
By Author. Source Niagara Open Data: https://open.niagarafalls.ca/search?groupIds=7bb3d92788b845f986101a213aa1485c. Source Basemap: https://www.arcgis.com/apps/mapviewer/index.html.

067 **Figure 3.6:** Multiple sources of water in the city of Niagara Falls, from streams, man-made canals and a lake that leads to Lake Ontario.
By Author. Source Niagara Open Data: https://open.niagarafalls.ca/search?groupIds=7bb3d92788b845f986101a213aa1485c. Source Basemap: https://www.arcgis.com/apps/mapviewer/index.html.

068 **Figure 3.7:** Active Quarries in the region, this is a prime location for construction
By Author. Source Niagara Open Data: https://open.niagarafalls.ca/search?groupIds=7bb3d92788b845f986101a213aa1485c. Source Basemap: https://www.arcgis.com/apps/mapviewer/index.html.

069 **Figure 3.8:** Biodiversity Variations in the Niagara Escarpment Region
By Author. Source Niagara Conservation Peninsula Authority: https://npca.ca/images/uploads/common/Native_Plant_Guide.pdf.

070 **Figure 3.9:** The city of Niagara Falls is one of the prime locations for bird migrations. Ecological Megastructures would benefit to be located close to natural migration paths.
Source: Kranstauber, B, R Weinzierl, M Wikelski, K Safi, Ryan Norris, Ryan Norris, and Ryan Norris, The routes with the highest survival, 2015, Digital Image, Web – UW library website (June 2, 2018), Source: "Global Aerial Flyways Allow Efficient Travelling." Ecology Letters 18 (12): 1338–45. https://doi.org/10.1111/ele.12528.

071 **Figure 3.10:** Bird migration swarms can reach up to ten million in density.
Source: Alain Delorme, Murmurations, 2013, Digital Image, Web – Wired website (May 12, 2018), https://www.wired.com/2014/05/alain-delorme-murmurations/.

072 **Figure 3.11:** Site is located close to water bodies, Sir Adams Pump Station, Butterfly Conservatory, Botanical Gardens, Waste Water Treatment Center
By Author. Image Source: Arial obtained from Google Earth.

073 **Figure 3.12:** With additional services across the border, including another Pump Generating Power Plant
By Author. Image Source: Arial obtained from Google Earth.

074 **Figure 3.13:** Site Access Points (roads) and Water Canal channel running along both sides of the project.
By Author. Image Source: Arial obtained from Google Earth.

075 **Figure 3.14:** An alternative perspective of the site showing the facilities, waterbodies and ecosystems that could be available for the megastructure.
By Author. Image Source: Arial obtained from Google Earth.

Chapter 4

076 **Figure 4.1.1:** Timothy F. H. Allen's seven types of ecosystem descriptions
Source: Timothy F. H. Allen and Thomas W. Hoekstra, Criteria for ecological sustainability, 1993, Digital Image, Web – USDA website (Feb 3, 2024), https://www.archdaily.com/64028/ad-classics-centre-georges-pompidou-renzo-piano-richard-rogers.

077 **Figure 4.1.2:** Complexity VS Complicatedness (Allen et al., 1999)
Source: Timothy F. H. Allen and Thomas W. Hoekstra, Complexity VS Complicatedness, 1999, Digital Image, Web – Jstor website (Feb 3, 2024), https://www.fs.usda.gov/rm/pubs_rm/rm_gtr247/rm_gtr247_098_107.pdf.

078 **Figure 4.1.3:** Conceptual Model of the socio-ecological system on a holarchy level (Kay et al. 1996)
Source: James J. Kay, Henry A Regier, Michelle Boyle, and George Francis, A conceptual model for self-organizing systems as dissipative structures, 1999, Digital Image, Web – Elsevier Science Direct website (Feb 4, 2024), https://www-sciencedirect-com.proxy.lib.uwaterloo.ca/science/article/pii/S0016328799000294.

079 **Figure 4.1.4:** The nested hierarchical conceptual model of the Socio-Ecological System (Kay et al. 1996)
Source: James J. Kay and Michelle Boyle, The nested hierarchical conceptual model of the Socio-Ecological System, Columbia University Press, 2008, Digital Image, Web – Jstor website (Feb 3, 2024), https://www.jstor.org/stable/10.7312/walt13250.7.

080 **Figure 4.1.5:** Holling's figure 8 adaptive cycles (Holling, 2001)
Source: Lance Gunderson and C. S. Holling, Panarchy Figure 8: stylized representation of the four ecosystem functions, Island Press, Washington, DC, 2001, Digital Image, Web – Jstore website (Feb 4, 2024), https://www-jstor-org.proxy.lib.uwaterloo.ca/stable/3658800?sid=primo&seq=5.

081 **Figure 4.1.6:** An Adaptive Ecosystems Approach for Sustainability (Kay et al, 1999)
Kay and Boyle, heuristic of the ecosystem approach, 1999, Digital Image, Web – Research Gate website (Feb 4, 2024), https://www.researchgate.net/figure/Adaptive-cycle-The-tail-labeled-x-indicates-the-potential-for-the-system-to-undergo-a_fig3_277907433.

Chapter 5

082 **Figure 5.1.1:** Illustration to visualize the Zones of the Arcology before breaking down each individual process within.
By Author. With Illustrator.

083 **Figure 5.2.1:** Illustration to visualize the Residential Zone Breakdown to conceptualize the human density required. Growth limits are very important to manage in an Arcology.
By Author. With Illustrator, Rhino and AutoCAD.

084 **Figure 5.3.0.1:** Illustration demonstrating shared accomodations is required in the Arcology with approximately 15% under 18 and approximately 5% seniors.
By Author. With Illustrator.
Source: Statistics Canada. 2023. (table). Census Profile. 2021 Census of Population. Statistics Canada Catalogue no. 98-316-X2021001. Ottawa. Released November 15, 2023. https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/index.cfm?Lang=E (accessed January 5, 2024).

085 **Figure 5.3.0.2:** The average household in Canada has to reduce by approximately 40% in the Arcology.
By Author. With Illustrator.
Source: Statistics Canada. 2023. (table). Census Profile. 2021 Census of Population. Statistics Canada Catalogue no. 98-316-X2021001. Ottawa. Released November 15, 2023. https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/index.cfm?Lang=E (accessed January 5, 2024).

086 **Figure 5.3.0.3:** Illustration indicating the average house hold in Niagara Falls has to be re-calibrated to the following to accomodate all it's residences. There will have to be 20% range for people who want more space.
By Author. With Illustrator.
Source: Statistics Canada, 2009, Survey of Drinking Water Plants, 2005 to 2007 , Catalogue no. 16-403-X. Statistics Canada, 2009, "Agricultural Water Use Survey 2007, Methodology Report," Environment Accounts and Statistics Analytical and Technical Paper Series , Catalogue no. 16-001-M2009008. https://www.statcan.gc.ca/pub/16-201-x/2010000/t233-eng.html(accessed January 5, 2024).

087 **Figure 5.3.0.4:** Illustration to visualize the Residential Zone Breakdown to conceptualize the human density required. Growth limits are very important to manage in an Arcology.
By Author. With Illustrator.
Source: Health Canada. https://www.canada.ca/en/health-canada/services/food-nutrition/canada-food-guide/food-guide-basics/estimated-energy-requirements.html(accessed January 5, 2024).

088 **Figure 5.3.0.5:** Illustrations to visualize the Arcology Residential Breakdown program to accomodate it's residences.
By Author. With Illustrator.

089 **Figure 5.3.0.6:** Illustrations on the left showing typical canadian water use in the household and for farming. The advantage of an Arcology is the ability to easily adapt new technologies and infrastructures. Arcology will be adopting water waste management system and vertical farming into it's infrastructure that will easily reduce the average water usage per person by 43%.
By Author. With Illustrator.
Source: Statistics Canada. http://www150.statcan.gc.ca/n1/pub/16-402-x/2013001/part-partie1-eng.htm(accessed January 5, 2024).

090 **Figure 5.3.0.7:** Illustrations on the left showing recommended calorie (men and women) by the Institute of Medicine, dietary Reference Intake for Energy, Carbohydrate, Fiber, Fatty Acids. Washington(DC): The National Academics Press, 2002 for both active and sedimentary lifestyles. The top three illustrations on the right show Canada's Obesity was reported by Stat Canada to be 30% above average in 2022 and the average Canadian walks an average of 2.4 miles per day. Canadian lifestyle is evidently sedimentary - a walking Arcology has health benefits.
By Author. With Illustrator.
Source: Health Canada. https://www.canada.ca/en/health-canada/services/food-nutrition/canada-food-guide/food-guide-basics/estimated-energy-requirements.html(accessed January 5, 2024).

091 **Figure 5.3.1.1:** Illustration to represent cycles within an Arcology that provides the greatest ecological potential and benefits.
By Author. With Illustrator.

092 **Figure 5.3.1.2:** Illustration to represent rainfall is not suffecient to sustain daily human use. Water collection for the entire site would sustain one resident for 11 - 15 days every month.
By Author. With Illustrator.
Source: Eldorado Weather – Niagara Falls, Canada. http://eldoradoweather.com/canada/climate2/Niagara%20Falls.html (accessed January 5, 2024).

093 **Figure 5.3.2.1:** List of Trees Selected from the Niagara Escarpment Region to attract local biodiversity. Rules of thumb on how to calculate tree height, and tree spacing.
By Author. With Illustrator.
Source: Hough, Michael. 1995. Cities and Natural Process. London ; Routledge.

094 **Figure 5.3.2.2:** Visualization to understand the scale of the soil required to sustain the height of the trees and the spaces this can provide.
By Author. With Illustrator.
Source: Hough, Michael. 1995. Cities and Natural Process. London ; Routledge.

095 **Figure 5.3.2.3:** List of Plants Selection from American enviornmental scientist and principal investigator of NASA's Clean Air Study, Bill Wolverton's Air Filtration Plants. Rules of thumb on how to calculate tree height, and tree spacing.
By Author. With Illustrator.
Source: Hough, Michael. 1995. Cities and Natural Process. London ; Routledge.

096 **Figure 5.3.2.4:** American enviornmental scientist and principal investigator of NASA's Clean Air Study, Bill Wolverton, the best plants from a global study for air filtration. Listed above are the top 12 plants that vary in height for the Arcology where biodiversity is discouraged.
By Author. With Illustrator.
Source: Hough, Wolverton, B. C. 1997. How to Grow Fresh Air : 50 Houseplants That Purify Your Home or Office. New York, N.Y: Penguin Books.

097 **Figure 5.3.2.5:** The average household requires 15 plants for air filtration inside the home. Hydroculture for indoor plants is the preferable soil type due to it's multiple advantages and it's resistance against biodiversity.
By Author. With Illustrator and Photoshop.
Source: Hough, Wolverton, B. C. 1997. How to Grow Fresh Air : 50 Houseplants That Purify Your Home or Office. New York, N.Y: Penguin Books.

098 **Figure 5.3.2.6:** The impact of tree and plant transpiration helps maintain local humidity and cools surrounding areas, creating a comfortable microclimate within the Arcology. Once an ecological infrastructure is set, the ecosystems it provides is minimally maintained for noticable benefits.
By Author. With Illustrator.
Source: Hough, Michael. 1995. Cities and Natural Process. London ; Routledge.

099 **Figure 5.3.3.1:** Vertical farming distinguishes itself from typical farming by keeping it in an isolated controlled enviornment. This keeps farming from pests, weed and pathogens.
By Author. With Illustrator.
Source: Graff, Gordon James, University of Waterloo. School of Architecture., and University of Waterloo. School of Architecture. 2011. “Skyfarming.” Waterloo, Ont: University of Waterloo.

100 **Figure 5.3.3.2:** Vertical farming vary into three categories: Aeroponics uses the least amount of water by spraying water at the root of the plants. Hydroponics is the most popular and it requires some additional considerations such as air pumps and filtrations. Aquaponics is a holistic approach, which includes an ecosystem that provides all the required nutrients to help the plants grow.
By Author. With Illustrator.

101 **Figure 5.3.3.3:** Hydroponic system variations: over the years, hydroponic systems has a lower start up cost than aquaponics. Therefore, the literature is extensive and technological innovations have caried over the years. As they become more popular, the technologies will continue to vary.
By Author. With Illustrator.
Source: Ampim, Peter & Obeng, Eric & Olvera-Gonzalez, Ernesto. (2022). Indoor Vegetable Production: An Alternative Approach to Increasing Cultivation. Plants. 11. 2843. 10.3390/plants11212843. http://www.researchgate.net/figure/Common-hydroponic-systems-a-aeroponics-b-drip-system-c-nutrient-film-technique_fig1_364742785.

102 **Figure 5.3.3.4:** Vertical farming requirements depend on many factors that are controlled. Controlling temperature, light, irrigation, humidity, ventillation and nutrients are the more prominent ways of ensuring plant growth and health. The field remains in a state of constant development, where incremental advancements and testing several experimental systems yield variable results over time.
By Author. With Illustrator.
Source: Graff, Gordon James, University of Waterloo. School of Architecture., and University of Waterloo. School of Architecture. 2011. “Skyfarming.” Waterloo, Ont: University of Waterloo.

103 **Figure5.3.3.5:** Stacking beds may use a variety of hydroponic system technoologies to improve plant growth. As technology continued to innovate, considerations such as types of substrates and soiless soil used will be studied case by case basis.
By Author. With Illustrator.
Source: Graff, Gordon James, University of Waterloo. School of Architecture., and University of Waterloo. School of Architecture. 2011. “Skyfarming.” Waterloo, Ont: University of Waterloo.

104 **Figure 5.3.3.6:** The suggested soil pH level is 6.2 - 7.3 because it allows all the macronutrients and micronutrients to be absorbed by the plants. If the soil acidity exceeds 6.0, essential macronutrients will not be absorbed by the plants. If the plant lacks nutrients, the consumers will lack nutrients triggering a health crisis and an expensive associated cost.Although aquaponic systems do not need to worry about adding nutrients, they do have to measure them and ensure they are suffecient.
By Author. With Illustrator.
Source: Bhardwaj, Ajay & Arya, Geeta & Kumar, Raj & Hamed, Lamy & Pirasteh-Anosheh, Hadi & Jasrotia, Poonam & Kashyap, Prem & Singh, Gyanendra. (2022). Switching to nanonutrients for sustaining agroecosystems and environment: the challenges and benefits in moving up from ionic to particle feeding. Journal of Nanobiotechnology. 20. 19. 10.1186/s12951-021-01177-9. http://www.researchgate.net/figure/Essential-plant-nutrients-and-their-availability-based-on-the-soil-reaction-pH_fig3_357570522.

105 **Figure 5.3.3.7:** The USDA provided a suggested Crop Selection for vertical farming that are popular in the global market and provide the hieghest yield.
By Author. With Illustrator.
Source: Graff, Gordon James, University of Waterloo. School of Architecture., and University of Waterloo. School of Architecture. 2011. “Skyfarming.” Waterloo, Ont: University of Waterloo.

106 **Figure 5.3.3.8:** Diagram to illustrate the rule of thumb for space allocation required for conventional farming and unconventional farming.
By Author. With Illustrator.
Source: Miedema, Kassandra Rose, University of Waterloo. School of Architecture., and University of Waterloo. School of Architecture. 2015. “Urban Agriculture as an Agent for Social Change in London, Ontario.” Waterloo, Ontario, Canada: University of Waterloo.

107 **Figure 5.3.3.9:** Diagram to illustrate the area required if the floors were stacked for farm use. Conventional farming will require 8 floors with a 2.2 kilometer site while Vertical Farming will require 2 floors and 16 stacks. Vertical farming will require additional mechanical systems to manage all it‘s systems.
By Author. With AutoCAD and Illustrator.

108 **Figure 5.3.3.10:** Diagram to visualize the farming and it‘s facilities required (2 floors) alone. The mechanical systems (grey) are as significant as the farming area (green).
By Author. With Rhino, AutoCAD and Illustrator.
Source: Graff, Gordon James, University of Waterloo. School of Architecture., and University of Waterloo. School of Architecture. 2011. “Skyfarming.” Waterloo, Ont: University of Waterloo.

109 **Figure 5.3.3.11:** Diagram to visualize the farming and it's facilities required (2 floors) alone. The mechanical systems (grey) are as significant as the farming area (green).
By Author. With Rhino, AutoCAD and Illustrator.
Source: Graff, Gordon James, University of Waterloo. School of Architecture., and University of Waterloo. School of Architecture. 2011. "Skyfarming." Waterloo, Ont: University of Waterloo.

110 **Figure 5.3.4.1:** Aquaponics systems are designed to house living organisms and rely on mechanical filtration to maintain healthy water quality. However, researchers including American enviornmental scientist and principal investigator of NASA's Clean Air Study, Bill Wolverton, have found that certain plants can provide ecosystem services that enhance water quality. These plants however, require up to 6.0 meters to filter the water. The Arcology has substantial horizontal distance of the Arcology serves as a valuable asset for enhancing water quality management.
By Author. With Illustrator and Photoshop.
Source: Hough, Michael. 1995. Cities and Natural Process. London ; Routledge.

111 **Figure 5.3.4.2:** Diagram to illustrate proposed plant selection suggested by American enviornmental scientist and principal investigator of NASA Clean Air Study, Bill Wolverton. Other interesting plant selections could be found in Todd and Todd's Living Machine that suggested cammomile, papyrus and ginger to mask odour.
By Author. With Illustrator and Photoshop.
Source: Wolverton, B. C, and John D Wolverton. 2001. Growing Clean Water : Nature's Solution to Water Pollution. Picayune, Miss: WES, Inc.

112 **Figure 5.3.4.3:** Diagram to illustrate water and fish density for every resident in the Arcology
By Author. With Illustrator.
Source: http://practicalaquaponics.com/blog/learn-about-aquaponics/how-to-get-started-in-aquaponics-%E2%80%93-rules-of-thumb/ (accessed July 24, 2024).

113 **Figure 5.3.4.4:** Diagram to illustrate that fish density will vary if the Arcology limits the use of mechanical filtration. The ratios calculated show the possible ranges of fish population. If the population increases, all residences can enjoy fresh fish dinner or consider adding mechanical filtration - depending on how healthy the plants in the vertical farm are frowing.
By Author. With Illustrator.
Source: http://practicalaquaponics.com/blog/learn-about-aquaponics/how-to-get-started-in-aquaponics-%E2%80%93-rules-of-thumb/.

114 **Figure 5.3.4.5:** Illustration to visualize zoning the Centralized Aquatic Waterway required for every floor for the Aquatic Waterway. The Basement has the Water Waste Management Facilities, and the Aquatic Water Way requires indirect natural lighting.
By Author. With Rhino, AutoCAD and Illustrator.

115 **Figure 4.3.5.6:** Illustration to visualize in section, the Aquatic Waterway where the channels are sloped at 2 % minimum to reduce the use of mechanical pumps.
By Author. With Rhino, AutoCAD and Illustrator.
Source: Hough, Michael. 1995. Cities and Natural Process. London ; Routledge.

116 **Figure 5.3.4.7:** Illustration to visualize the calculated water volume required in the megastucture. This water will water the plants, and to be filtered and used for it's residences and visitors. The intent is to indicate it occupies large mass in the structure. The water system will be monitered and may require additional natural filters (such as cammomile, ginger, papyrus plants) to mask odor or artificial filters, depending on the population of fish in the system. This system is an imitation of Todd & Todd's Living Machine which provided an eviornment that processed sewage water.
By Author. With Rhino, AutoCAD and Illustrator.
Source: John Todd Ecological Design. http:www.toddecological.com/projects.

117 **Figure 5.3.5.1:** Cost Comparison of "Living Machines®" and Conventional Systems, from a US EPA Report in 2001.
Source: Environmental Protection Agency, Table 2: Present Worth Comparison of "Living Machines" and conventional systems, Environmental Protection Agency, 2001 - 2002, Digital Image, Web – EPA website (August 2, 2024), https://www3.epa.gov/npdes/pubs/living_machine.pdf.

118 **Figure 5.3.5.2:** Illustration to represent Eco-Machine Systems that show capacity, space required and time for water circulation.
By Author. With Illustrator.
Source: John Todd Ecological Design. http:www.toddecological.com/projects.

119 **Figure 5.3.5.3:** Illustration to represent the waste water system to breakdown wastes, inspired by Todd & Todd's Eco-Machine. This will produce greywater at a high standard, if drinking water is required, then additional treatment processes have to be incorporated into the system.
By Author. With Rhino, AutoCAD and Illustrator.
Source: John Todd Ecological Design. http:www.toddecological.com/projects.

120 **Figure 5.3.5.4:** Illustration to represent the waste water system spatially in the Arcology.
By Author. With Rhino, AutoCAD and Illustrator.

121 **Figure 5.4.1.1:** Illustration to represent the Heat System Flow Chart. There are multiple natural systems to consider : the thermal mass of building materials have the ability to store heat, and mechanical systems that have the ability to generate heat. If close consideration is placed recovering heat inside a building as large as possible, has great benefits in colder climates.
By Author. With Illustrator.

122 **Figure 5.4.2.1:** Illustration to represent the Water system to breakdown wastes, (inspired by Todd & Todd's Eco-Machine), grow food and improve building air quality.. This will produce greywater at a high standard, if drinking water is required, then additional treatment processes have to be incorporated into the system. Water is an important leverage point in an Arcology.
By Author. With Illustrator.

123 **Figure 5.4.3.1:** Illustration of Systems Flow Chart of Waste Systems that could be expected in the Arcology. It is important to note that energy is a cyclic process and it becomes much more effecient, with additional processes. The most important cyclic system, is the water waste management system and the filtration from trees and plants.
By Author. With Illustrator.

124 **Figure 5.4.4.1:** Illustration (left) of photovoltaic infographics and rules of thumb to estimate how much energy is the Arcology expected to produce and how much is emergy is expected to get from the grid. Systems Flow Chart of Energy Systems that could be expected in the Arcology. It is important to note that energy is a linear process and battery storage units is an important to consider.
By Author. With Rhino and AutoCAD.

125 **Figure 5.4.4.2:** Illustration to represent complexity required to combine multiple systems.
By Author. With Rhino and AutoCAD.

126 **Figure 5.5.1:** Illustration to represent the flow required for Adaptive Governance - to show the iterative process between stakeholders, decision makers and learning process.
By Author. With Illustrator.

127 **Figure 5.5.2:** Adaptive management for a turbulent future - Craig R Allen et all 2011
Source: Allen, Craig R, and Lance H Gunderson. 2011. "Pathology and Failure in the Design and Implementation of Adaptive Management." Journal of Environmental Management 92 (5): 1379–84. https://doi.org/10.1016/j.jenvman.2010.10.063.

128 **Figure 5.5.3:** Different management approaches according to levels of system uncertainty and availability (from Allen et al., 2011), originally adapted from Peterson et al., 2003).
Source: Peterson, Garry D, Graeme S Cumming, and Stephen R Carpenter. 2003. "Scenario Planning: A Tool for Conservation in an Uncertain World." Conservation Biology 17 (2): 358–66. https://doi.org/10.1046/j.1523-1739.2003.01491.x.

129 **Figure 5.5.4:** Schematic Diagram to show Lake Ecosystem Management - used from Peterson et al (2003).
Source: Peterson et al. “Uncertainty and the Management of Multistate Ecosystems: An Apparently Rationale Route to Collapse. Ecology 84: 1406-1411.” n.d. 2003. Ecology 84: 1406-1411 - NCEAS Working Group. (Accessed August 3, 2024). https://groups.nceas.ucsb.edu/sustainability-science/2010%20weekly-sessions/session-102013-11.01.2010-emergent-properties-of-coupled-human-environment-systems/supplemental-readings-from-moderator-discussant-jim-heffernan/Peterson%20et%20al%202003%20Ratio.html.

130 **Figure 5.5.5:** A hypothetical example of realigning the merging roles in urban governance and adaptive management for an Arcology. These roles will continue to change depending on the details of the complex issue – one solution will perpetuate the failure of its components.
By Author. With Illustrator.
Source: Meadows, Donella H, and Diana Wright. 2008. Thinking in Systems: A Primer. White River Junction, Vt: Chelsea Green Pub.

131 **Figure 5.5.6:** A conceptual diagram of merging these three factors should focus on achieving defined empirical goals set by the management team, which provide actors with actionable objectives. These empirical goals will be refined in every iterative process.
By Author. With Illustrator.

132 **Figure 5.5.7:** A hypothetical example of realigning the merging roles in urban governance and adaptive management for an Arcology. These roles will continue to change depending on the details of the complex issue – one solution will perpetuate the failure of its components.
By Author. With Illustrator and Photoshop.
Source: Allen, Craig R, and Lance H Gunderson. 2011. “Pathology and Failure in the Design and Implementation of Adaptive Management.” Journal of Environmental Management 92 (5): 1379–84. https://doi.org/10.1016/j.jenvman.2010.10.063.

133 **Figure 5.6.1:** Proposed Arcology Implimintation Approach to reduce urban sprawl.
By Author. With Illustrator and Photoshop.
Source Niagara Open Data: https://open.niagarafalls.ca/search?groupIds=7bb3d92788b845f986101a213aa1485c. Source Basemap: https://www.arcgis.com/apps/mapviewer/index.html.

134 **Figure 5.7.1 :** Arcology‘s intentional External Phasing exhibits intentional growth.
By Author. With Rhino and AutoCAD.

Chapter 6

135 **Figure 6.1.1:** Arcology's Volume Breakdown - part 1
By Author. With Rhino, AutoCAD, Illustrator and Excel.

136 **Figure 6.1.2:** Arcology's Volume Breakdown - part 2
By Author. With Rhino, AutoCAD, Illustrator and Excel.

137 **Figure 6.1.3:** Arcology's Volume Breakdown - part 3
By Author. With Rhino, AutoCAD, Illustrator and Excel.

138 **Figure 6.1.4:** Arcology's Volume Breakdown - part 4
By Author. With Rhino, AutoCAD, Illustrator and Excel.

139 **Figure 6.1.5:** Arcology's Volume Breakdown - part 5
By Author. With Rhino, AutoCAD, Illustrator and Excel.

140 **Figure 6.1.6:** Arcology's Overall Volume – Potential
By Author. With Rhino, AutoCAD and Illustrator.

141 **Figure 6.1.7:** Arcology's Overall Longitudinal Section – Potential
By Author. With Rhino, AutoCAD and Illustrator.

142 **Figure 6.2.1:** Author's illustration of section indicating program and zoning for Section A.
By Author. With Rhino, AutoCAD and Photoshop.

143 **Figure 6.2.2 :** Author's illustration of section highlighting key interactions for Section A.
By Author. With Rhino, AutoCAD, Illustrator and Photoshop.

144 **Figure 6.2.3:** Author's illustration of section indicating program and zoning for Section B.
By Author. With Rhino, AutoCAD and Photoshop.

145 **Figure 6.2.4:** Author's illustration of section highlighting key interactions for Section B.
By Author. With Rhino, AutoCAD, Illustrator and Photoshop.

146 **Figure 6.2.5:** Author's illustration of section indicating program and zoning for Section C.
By Author. With Rhino, AutoCAD and Photoshop.

147 **Figure 6.2.6:** Author's illustration of section highlighting key interactions for Section C.
By Author. With Rhino, AutoCAD, Illustrator and Photoshop.

148 **Figure 6.3.1:** Artificial Intelligence and its subsets (inspired by Goodfellow et al, 2016, p.9; Janiesch et al., 2021, p. 687; Banh & Strobel, 2023)
By Author. With Photoshop to include "A.G.I.".
Source: Banh, Leonardo, and Gero Strobel. 2023. "Generative Artificial Intelligence." Electronic Markets 33 (1): 63-. https://doi.org/10.1007/s12525-023-00680-1.

149 **Figure 6.3.2:** The evolutionary tree of modern LLMs highlighting their rapid development. The Transformer-based models colors indicate the following: blue branch indicates decoder-only models, pink branch indicates encoder-only models and green indicates encoder-decoder branch models (by Jingfeng et al, 2023, p.3)
Source: Yang, Jingfeng, Hongye Jin, Ruixiang Tang, Xiaotian Han, Qizhang Feng, Haoming Jiang, Bing Yin, and Xia Hu. 2023. "Harnessing the Power of LLMs in Practice: A Survey on ChatGPT and Beyond." https://doi.org/10.48550/arxiv.2304.13712.

150 **Figure 6.4.1:** Arcology - Niagara Escarpment II - Exterior Perspective - one variation representing the Arcology's entrance - illustration by Imagen 3 by Gemini
Source: Imagen 3 image generated to "show me 22 stories and 2.2 km long and 350 m wide with a form that looks like a ship," "show me a street view of the megastructure and an interior shot and a shot of the vertical farming" September 07, 2024, Gemini, http://gemini.google.com/app/fe029feeb66a269d.

151 **Figure 6.4.2:** Arcology - Niagara Escarpment II - Exterior Perspective - Ocean Liner Form - a dense massive slabbed structure that resembles the scale of a small hill - illustration by Imagen 3 by Gemini with skylight added in Adobe Fire Fly
Source: Imagen 3 image generated to "show me 22 stories and 2.2 km long and 350 m wide with a form that looks like a ship," "show me a megastructure for Canadian climate," "the building must be porous," "show me more options like these , exterior and interior" September 07, 2024, Gemini, http://gemini.google.com/app/fe029feeb66a269d.

152 **Figure 6.4.3:** Arcology - Niagara Escarpment II - Exterior Perspective - Ocean Liner Form - a variation with skylight - illustration by Imagen 3 by Gemini with skylight added in Adobe Fire Fly
Source: Imagen 3 image generated to "show me 22 stories and 2.2 km long and 350 m wide with a form that looks like a ship," "show me a megastructure for Canadian climate," "the building must be porous," "show me more options like these , exterior and interior" September 07, 2024, Gemini, http://gemini.google.com/app/fe029feeb66a269d.
Edited for style and content in Adobe Suite Fire Fly.

153 **Figure 6.4.4:** Arcology - Niagara Escarpment II - Commercial Zone - Sectional Perspective - a variation of public spaces showing conceptual commercial configuration - illustration by Midjourney with color added, thicker slabs, altering tree sizes and bushes added in Adobe Fire Fly
Source: Midjourney-version 6.0 image generated to "/imagine isometric cross-section of ecological megastructures showing alot of natural light and healthy human interactions with multiple levels of multiple floor scale of interactions showing piazzas, shops, playground parks, festival streets and fairs, dancing festivals, small theater performances, details interactions between several human interactions including a variety of trees, clear isometric drawing, black and white, vector lines, design showing natural light,--sref 8425981 1741244 --v 6.0 --s 750 --ar 16:9" September 07, 2024, Discord, http://cdn.discordapp.com/attachments/941582479117127680/1246198918816202812/awesomearies_isometric_cross-section_of_ecological_megastructur_bda38259-ec33-4f6b-914e-d2af8d333ae8.png?ex=6733baaf&is=6732692f&hm=a9c7a733dee7b6b086e8810e730d8367c79d2f04e14acd43c4bb511d258c50fc&.
Edited for style and content in Adobe Suite Fire Fly.

154 **Figure 6.4.5:** Arcology - Niagara Escarpment II - Commercial Zone - Sectional Perspective - a denser variation of public spaces showing conceptual commercial configuration - illustration by Midjourney with color added, thicker slabs, altering tree sizes and bushes added in Adobe Fire Fly
Source: Midjourney-version 6.0 image generated to "/imagine isometric cross-section of ecological megastructures showing a lot of natural light and hierarchy and healthy human interactions with multiple levels of multiple floor scale of interactions showing piazzas, shops, playground parks, festival streets and fairs, dancing festivals, small theater performances, details interactions between several human interactions including a variety of trees, clear isometric drawing, black and white, vector lines, design showing natural light, --sref 8425981 1741244 --v 6.0 --s 750 --ar 16:9 - Variations (Strong)" September 05, 2024, Discord, http://cdn.discordapp.com/attachments/941582479117127680/1246199438418907217/awesomearies_isometric_cross-section_of_ecological_megastructur_9665976e-857e-417a-93ce-3df71370703e.png?ex=6733bb2b&is=673269ab&hm=6a45b7bcfd699fdcebe99c79b0bfe16841abdae58d93880d7306f4d78c8410d2&.

155 **Figure 6.4.6:** Arcology - Niagara Escarpment II - Commercial Zone - Sectional Perspective - a contemporary aesthetic showing conceptual commercial configuration showing the thicker slabs for commercial use and green infrastructure- illustration by Midjourney with color added, thicker slabs, altering tree sizes and bushes added in Adobe Fire Fly
Source: Midjourney-version 6.0 image generated to "/imagine isometric cross-section of ecological megastructures showing a lot of natural light and hierarchy and healthy human interactions with multiple levels of multiple floor scale of interactions showing piazzas, shops, playground parks, festival streets and fairs, dancing festivals, small theater performances, details interactions between several human interactions including a variety of trees, clear isometric drawing, black and white, vector lines, design showing natural light, --v 6.0 --s 750 --ar 16:9" September 05, 2024, Discord, http://cdn.discordapp.com/attachments/941582479117127680/1246331279947862056/awesomearies_isometric_cross-section_of_ecological_megastructur_779cbec5-a81f-457a-83c8-adb5211fbcad.png?ex=673435f4&is=6732e474&hm=b8824b87d2bb6b75ebc6d94900dc2259924b2a50af46f1e22c6cc6619c7f5410&.
Edited for style and content in Adobe Suite Fire Fly.

156 **Figure 6.4.7:** Arcology - Niagara Escarpment II - Commercial Zone - Perspective - showing a compact variation of commercial area with large slabs for green infrastructure - illustration by Midjourney
Source: Midjourney-version 6.0 image generated to "/imagine isometric cross-section of ecological megastructures showing alot of natural light and healthy human interactions with multiple levels of multiple floor scale of interactions showing piazzas, shops, playground parks, festival streets and fairs, dancing festivals, small theater performances, details interactions between several human interactions including a variety of trees, clear isometric drawing, black and white, vector lines, design showing natural light, --v 6.0 --s 750 --ar 16:9" September 05, 2024, Discord, http://cdn.discordapp.com/attachments/941582479117127680/1246199438418907217/awesomearies_isometric_cross-section_of_ecological_megastructur_9665976e-857e-417a-93ce-3df71370703e.png?ex=6733bb2b&is=673269ab&hm=6a45b7bcfd699fdcebe99c79b0bfe16841abdae58d93880d7306f4d78c8410d2&.

157 **Figure 6.4.8:** Arcology - Niagara Escarpment II - Commercial Zone - Perspective - showing a dense and futuristic variation for multiple floor store fronts and green roofs - illustration by Promo AI, colors added in Adobe Fire Fly
Source: Promo AI image generated with create model to "commercial zone for arcology," "ecological megastructure using systems thinking," "ecological systems thinking arcology, "October 10, 2024, http://imagef2.promeai.pro/process/do?sourceUrl=/g/i/forever/promeai/consistent_model/2024/10/31/607294627846661_0.jpg&x-oss-process=image/resize,w_500,h_500/format,webp&sign=e0a77728c9ecbea21fde631d336021ad.
Edited for style and content in Adobe Suite Fire Fly.

158 **Figure 6.4.9:** Arcology - Niagara Escarpment II - Commercial Zone - Perspective - showing an internal variation with multiple floor store fronts and a skylight - illustration by Midjourney with water features added in Adobe Fire Fly and plants and trees added with first generation Promo AI
Source: Midjourney-version 6.0 image generated to "/imagine ecological urban megastructure engineered with systems thinking, structure to be space frames, black and white, with flying buttress architectural feature interior perspective --ar 16:9 --style raw --s 750 --v 5.1"October 10, 2024, Discord, http://Midjourney-version 6.0 image generated to "/imagine isometric cross-section of ecological megastructures showing alot of natural light and healthy human interactions with multiple levels of multiple floor scale of interactions showing piazzas, shops, playground parks, festival streets and fairs, dancing festivals, small theater performances, details interactions between several human interactions including a variety of trees, clear isometric drawing, black and white, vector lines, design showing natural light, --v 6.0 --s 750 --ar 16:9" September 05, 2024, Discord, http://cdn.discordapp.com/attachments/1055908341492240476/1114657479889002567/AwesomeAries_ecological_urban_megastucture_engineered_with_syst_91397ec9-a822-42b4-8a6d-764e6b9b72ef.png?ex=6734686c&is=673316ec&hm=7ce0e26738fa33cde4aeda20637e4326fb74e1e1deba88c53d39c8c143e74331&.
Edited for style and content in Adobe Suite Fire Fly and first generation Promo AI.

159 **Figure 6.4.10:** Arcology - Niagara Escarpment II - Farming Zone - Perspective -a variation showing the potential height and scale of a vertical farming facility - illustration by Midjourney
Source: Midjourney-version 6.0 image generated to "/imagine vertical faming and aquaponics and hydroponics 17 meters high, growing fruits and vegetables, clear isometric drawing, with railings and machines to climb up the racks design showing natural light, https://s.mj.run/VeF7UMJk9Xs , --v 6.0 --s 750 --ar 16:9" September 16, 2024, Discord, http://cdn.discordapp.com/attachments/989274712590917653/1248478690048868403/awesomearies_vertical_faming_and_aquaponics_and_hydroponics_17__4734856b-52fc-4532-9398-8c6fe42c383b.png?ex=67341ce3&is=6732cb63&hm=36aedf9561191502fd639af9e31838dc1405149fd0460b3a7118e74fbb350cb9&.

160 **Figure 6.4.11:** Arcology - Niagara Escarpment II - Farming Zone - Perspective -a variation showing a variety of plants that can be grown in a vertical farming facility - illustration by Midjourney
Source: Midjourney-version 6.0 image generated to "/imagine vertical faming like aero farms efficient design built 17 meters high, growing fruits and vegetables, clear isometric drawing, design showing natural light, https://s.mj.run/VeF7UMJk9Xs , --v 6.0 --s 750 --ar 16:9, Variation (Strong)" September 16, 2024, Discord, http://media.discordapp.net/attachments/989274712590917653/1248479205537349632/awesomearies_vertical_faming_and_aquaponics_and_hydroponics_17__a2c12998-c20b-4585-b6bd-83a2c4967581.png?ex=67341d5e&is=6732cbde&hm=8a587b390bba0e9b00b4f3214b38c1429835aae9a5bd66b587ec5be85d76c708&=&format=webp&quality=lossless&width=1197&height=671.

161 **Figure 6.4.12:** Arcology - Niagara Escarpment II - Train Zone - Sectional Perspective - a traditional train station showing conceptual variation that highlights the structure's heavy form and it's capacity to hold green infrastructure - illustration by Midjourney
Source: Midjourney-version 6.0 image generated to "/imagine isometric cross-section of ecological megastructures showing train passing through the width of the intersection with a platform of people getting on and off, with roman arches, people on the platforms, details interactions between several human interactions including a variety of trees, clear isometric drawing, black and white, vector lines, design showing natural light, --v 6.0 --s 750 --ar 16:9" July 04, 2024, Discord, http://cdn.discordapp.com/attachments/989274712590917653/1247628559984492735/awesomearies_sometric_cross-section_of_ecological_megastructure_3856831f-2378-4f8a-b92b-e55d3d0f63d0.png?ex=6733a824&is=673256a4&hm=d2d3c1ab3327c4400365f0b487ae8596a65ae0e43b199b3f1a1578cb729c2bef&.
Edited for style and content in Adobe Suite Fire Fly.

162 **Figure 6.4.13:** Arcology - Niagara Escarpment II - Train Zone - Sectional Perspective - a alternative showing conceptual Train Station that highlights the flexibility of concrete - illustration by Midjourney with arches variations added in Adobe Fire Fly
Source: Midjourney-version 6.0 image generated to "/imagine perpendicular section of ecological megastructures showing train passing through the width of the intersection with a platform of people getting on and off, details interactions between several human interactions including a variety of trees, clear isometric drawing, black and white, vector lines, design showing natural light, --sref 8425255 1741258--v 6.0 --s 750 --ar 16:9 - Variations (Strong)" September 06, 2024, Discord, http://cdn.discordapp.com/attachments/989274712590917653/1247639095245799544/awesomearies_perpendicular_section_of_ecological_megastructures_c2be88aa-52a7-4ec1-baa1-4b050ca650f0.png?ex=67345ab4&is=67330934&hm=dc80adae8f2e8048d486678fc382064726c7760739f7ff601c5833a81c2808ec&.
Edited for style and content in Adobe Suite Fire Fly.

163 **Figure 6.4.14:** Arcology - Niagara Escarpment II - Train Zone - Sectional Perspective - a variation showing conceptual Train Station with multiple public and private spaces with a green roof - illustration by Midjourney with color added, and a variety of size spaces added in Adobe Fire Fly
Source: Midjourney-version 6.0 image generated to "/imagine perpendicular section of ecological megastructures showing train passing through the width of the intersection with a platform of people getting on and off, details interactions between several human interactions including a variety of trees, clear isometric drawing, black and white, vector lines, design showing natural light, --sref 8428246 1748523--v 6.0 --s 750 --ar 16:9 - Variations (Strong)" September 06, 2024, Discord, http://media.discordapp.net/attachments/989274712590917653/1247638081834713211/awesomearies_perpendicular_section_of_ecological_megastructures_f008ea35-2b8b-4c14-8dda-52aa80439af5.png?ex=673459c2&is=67330842&hm=70b1c03bf0b656d8d37724bcc4b346ad7803d84c031453aecd720b99571a5140&=&format=webp&quality=lossless&width=1197&height=671.
Edited for style and content in Adobe Suite Fire Fly.

164 **Figure 6.4.15:** Arcology - Niagara Escarpment II - Train Zone - Sectional Perspective - an alternative showing conceptual Train Station showing the thicker slabs required to hold multiple uses - illustration by Midjourney
Source: Midjourney-version 6.0 image generated to "/imagine isometric cross-section of ecological megastructures showing train passing through the width of the intersection with a platform of people getting on and off, details interactions between several human interactions including a variety of trees, clear isometric drawing, black and white, vector lines, design showing natural light, --v 6.0 --s 750 --ar 16:9" July 04, 2024, Discord, http://http://cdn.discordapp.com/attachments/989274712590917653/1247628146333974639/awesomearies_sometric_cross-section_of_ecological_megastructure_cc0e6b3f-5c08-4780-9867-afeda82d6974.png?ex=6733a7c1&is=67325641&hm=b77dda6068dc63712b9abdead88d1ba4ff173926c7f0e46d3162bc8f31d5ee94&.

165 **Figure 6.4.16:** Arcology - Niagara Escarpment II - Amenities and Services - Sectional Perspective - a different style showing conceptual semi-public space showing the thicker slabs required to hold green infrastructure - illustration by Midjourney with color added, thicker slabs, altering tree sizes and bushes added in Adobe Fire Fly
Source: Midjourney-version 6.0 image generated to "/imagine isometric cross-section of ecological megastructures showing a lot of natural light hierarchy showing large landscape and community housing and healthy human interactions with multiple levels of multiple floor scale of interactions showing community piazzas, shops, playground parks, details interactions between several human interactions including a variety of trees, clear isometric drawing, black and white, vector lines, design showing natural light, --v 6.0 --s 750 --ar 16:9" September 12, 2024, Discord, http://media.discordapp.net/attachments/941582479117127680/1246199434518331513/awesomearies_isometric_cross-section_of_ecological_megastructur_112a59aa-6bc9-4523-a2b1-86c026b15790.png?ex=673463ea&is=6733126a&hm=f7d8a94cdfcfca4b015c568d61f62fdf9e5fce50a571a9f05424d9e2f325267f&=&format=webp&quality=lossless&width=1197&height=671.
Edited for style and content in Adobe Suite Fire Fly.

166 **Figure 6.4.17:** Arcology - Niagara Escarpment II - Amenities and Services - Sectional Perspective - an alternative showing conceptual semi-public space showing the thicker slabs required to hold green infrastructure in comparison to slabs required commercial use - illustration by Midjourney with color added, thicker slabs, stepped concrete slabs, altering tree sizes and bushes added in Adobe Fire Fly
Source: Midjourney-version 6.0 image generated to "/imagine isometric cross-section of ecological megastructures showing a lot of natural light hierarchy showing large landscape and community housing and healthy human interactions with multiple levels of multiple floor scale of interactions showing community piazzas, shops, playground parks, details interactions between several human interactions including a variety of trees, clear isometric drawing, black and white, vector lines, design showing natural light, --v 6.0 --s 750 --ar 16:9" September 12, 2024, Discord, http://media.discordapp.net/attachments/941582479117127680/1246199434518331513/awesomearies_isometric_cross-section_of_ecological_megastructur_112a59aa-6bc9-4523-a2b1-86c026b15790.png?ex=673463ea&is=6733126a&hm=f7d8a94cdfcfca4b015c568d61f62fdf9e5fce50a571a9f05424d9e2f325267f&=&format=webp&quality=lossless&width=1197&height=671.
Edited for style and content in Adobe Suite Fire Fly.

167 **Figure 6.4.18 :** Arcology - Niagara Escarpment II - Amenities and Services - Perspective - a variation showing a community roof garden and cafe with seating area - illustration by Midjourney and trees altered and thicker slabs added in Adobe Fire Fly
Source: Midjourney-version 5.2 image generated to "/imagine unexpected intricately detailed roof top, visible systems within systems, designed in an arcology by Paolo Soleri with many indoor plants and trees,, high detail, tensegrity, wooden structures, stairs, tree house patios, volumetric lighting in the style of Terrence malick, cinematic --ar 5:3 --stylize 1000 --v 5.2" October 05, 2024, Discord, http://cdn.discordapp.com/attachments/945077390839787570/1292329435302989865/awesomearies_unexpected_intricately_detailed_schematics_of_the__ea9997b0-bfdd-4c74-926f-969931121330.png?ex=67341e93&is=6732cd13&hm=aff32423584dce5faf370a5c29e789122f447641d3827e4dbed8ce7579ee3499&.
Edited for style and content in Adobe Suite Fire Fly.

168 **Figure 6.4.19:** Arcology - Niagara Escarpment II - Amenities and Services - Perspective - a variation showing a conceptual of a community market with skylight - illustration by Imagen 3 by Gemini and community interactions, skylights, bushes, cafe on 2nd floor added in Adobe Fire Fly
Source: Imagen 3 image generated to “show me 22 stories and 2.2 km long and 350 m wide with a form that looks like a ship,” “show me a megastructure for Canadian climate,” “the building must be porous,“ “show me more options like these , exterior and interior,” “Interior Views,“ “More please“ September 07, 2024, Gemini, http://gemini.google.com/app/fe029feeb66a269d.
Edited for style and content in Adobe Suite Fire Fly.

169 **Figure 6.4.20:** Arcology - Niagara Escarpment II - Water way - Perspective - a variation showing a conceptual of an open space configuration with community spaces and cafes to integrate bushes in internal spaces showing the variation of fish to clean the water and potential filtered water - illustration by Midjourney with cafe, plants, opening in the concrete, removal of fish in the aquarium added in Adobe Fire Fly
Source: Midjourney-version 6.0 image generated to “/imagine perspective of ecological megastructures showing concrete structure horizontal and multiple level aquarium, with many variety of fish, showing reflection, showing natural light, --v6.0 --s 750” September16,2024,Discord,http://media.discordapp.net/attachments/989274712590917653/1248455594806083644/awesomearies_concrete_structure_mega_aquarium_fd1ca1ac-12a5-4638-9140-1b760077f0f6.png?ex=67340760&is=6732b5e0&hm=cab227b15b6e2e8f2a76c45f25b037f8ea546853883157d5c72c45f4824ea942&=&format=webp&quality=lossless&width=671&height=671.
Edited for style and content in Adobe Suite Fire Fly.

170 **Figure 6.4.21:** Arcology - Niagara Escarpment II - Water way - Perspective - a variation showing a conceptual of an intimate open space configuration with community spaces and cafes to integrate bushes in internal spaces showing the the size of the fish tank - illustration by Midjourney and community interactions, cafes, floor variation to discourage people from approaching the aquarium, opening in the concrete, creating spaces that look similar to an italian hill top town added in Adobe Fire Fly
Source: Midjourney-version 6.0 image generated to “/imagine perspective of ecological megastructures showing concrete structure horizontal and multiple level aquarium, with many variety of fish, showing reflection, showing natural light, --v 6.0 --s 750, Variation (Strong) ” September 16, 2024, Discord, http://cdn.discordapp.com/attachments/989274712590917653/1248456121937694760/awesomearies_concrete_structure_mega_aquarium_dc3af102-0d0d-419b-bda9-86083f14bbe1.png?ex=673407de&is=6732b65e&hm=7e0547debc5c0c94a535e4c6f7bf1844b964f6dc8342f2117bba7c7e462c7ba4&.
Edited for style and content in Adobe Suite Fire Fly.

171 **Figure 6.4.22:** Arcology - Niagara Escarpment II - Water way - Perspective - a variation showing a conceptual of an open space configuration with community spaces and cafes to integrate bushes in internal spaces showing the variation of fish to clean the water and potential filtered water - illustration by Midjourney with cafe, plants, opening in the concrete, removal of fish in the aquarium added in Adobe Fire Fly
Source: Midjourney-version 6.0 image generated to "/imagine perspective of ecological megastructures showing concrete structure horizontal and multiple level aquarium, with many variety of fish, showing reflection, showing natural light, --v 6.0 --s 750 " September 16, 2024, Discord, http://media.discordapp.net/attachments/989274712590917653/1248455594806083644/awesomearies_concrete_structure_mega_aquarium_fd1ca1ac-12a5-4638-9140-1b760077f0f6.png?ex=67340760&is=6732b5e0&hm=cab227b15b6e2e8f2a76c45f25b037f8ea546853883157d5c72c45f4824ea942&=&format=webp&quality=lossless&width=671&height=671.
Edited for style and content in Adobe Suite Fire Fly.

172 **Figure 6.4.23:** Arcology - Niagara Escarpment II - Water way - Perspective - a variation showing a conceptual of an intimate open space configuration with community spaces and cafes to integrate bushes in internal spaces showing the the size of the fish tank - illustration by Midjourney and community interactions, cafes, floor variation to discourage people from approaching the aquarium, opening in the concrete, creating spaces that look similar to an italian hill top town added in Adobe Fire Fly
Source: Midjourney-version 6.0 image generated to "/imagine perspective of ecological megastructures showing concrete structure horizontal and multiple level aquarium, with many variety of fish, showing reflection, showing natural light, --v 6.0 --s 750, Variation (Strong) " September 16, 2024, Discord, http://cdn.discordapp.com/attachments/989274712590917653/1248456121937694760/awesomearies_concrete_structure_mega_aquarium_dc3af102-0d0d-419b-bda9-86083f14bbe1.png?ex=673407de&is=6732b65e&hm=7e0547debc5c0c94a535e4c6f7bf1844b964f6dc8342f2117bba7c7e462c7ba4&.
Edited for style and content in Adobe Suite Fire Fly.

173 **Figure 6.4.24 :** Arcology - Niagara Escarpment II - Water way - Perspective - an aquaponic variation showing a conceptual of an open space configuration with community spaces - illustration by Midjourney with hanging plants, cafe and residential windows, change density of fish in the aquarium added in Adobe Fire Fly
Source: Midjourney-version 6.0 image generated to "/imagine perspective of ecological megastructures showing concrete structure horizontal and multiple level aquarium, with many variety of fish, showing reflection, showing natural light, --v 6.0 --s 750, Variation (Strong) " September 16, 2024, Discord, http://media.discordapp.net/attachments/989274712590917653/1248456025057656874/awesomearies_concrete_structure_mega_aquarium_c14ee8fb-fb38-46da-94a8-010620ab4b57.png?ex=673407c7&is=6732b647&hm=edc7fa27a314dee0283e7e8b01b7de769761ca8c5ea7462c99b08275b912fb36&=&format=webp&quality=lossless&width=671&height=671.
Edited for style and content in Adobe Suite Fire Fly.

174 **Figure 6.4.25:** Arcology - Niagara Escarpment II - Water way - Perspective - a variation showing a conceptual of an intimate space configuration a walk way that leads to residential spaces- illustration by Midjourney add walkway and railing, opening that leads to a residential zone, bushes added in Adobe Fire Fly
Source: Midjourney-version 6.1 image generated to "/imagine an arcology inspired by Paolo Soleri with trees and plants and aquariums, Italian hilltop town, shaded space, concrete archways, winding cobble road, in the style of futuristic brutalist architecture, solar punk, science fiction, cinematic --ar 3:2 --stylize 400 --v 6.1" October 06, 2024, Discord, http://cdn.discordapp.com/attachments/945077390839787570/1292344226750791701/awesomearies_an_arcology_inspired_by_Paolo_Soleri_with_trees_an_d08d10f4-e21e-44d3-8e44-04280be5aaab.png?ex=67342c5a&is=6732dada&hm=78e99e45ed342c9145d2eb5824f25486896cba4edb7a61aca07fdc87e45df6e4&.
Edited for style and content in Adobe Suite Fire Fly.

175 **Figure 6.4.26 :** Arcology - Niagara Escarpment II - Residential Zone - Sectional Perspective - a dense multiple floor variation showing conceptual housing configuration in tower form and the potential for green infrastructure - illustration by Midjourney with color added, thicker slabs, altering tree sizes and bushes added in Adobe Fire Fly
Source: Midjourney-version 6.0 image generated to "/imagine isometric cross-section of ecological megastructures showing a lot of natural light and healthy human interactions with multiple levels of multiple floor scale of interactions designed to deal with piazzas, shops, playground parks, festival streets and fairs, dancing festivals, small theater performances, vertical stacking, neighbourhood, detail isometric drawing of neighborhood node to show several human interactions including a variety of trees, clear isometric drawing, black and white, vector lines,--sref 841731 171244 --v 6.0 --s 750 --ar 9:16" September 30, 2024, Discord, http://cdn.discordapp.com/attachments/941582479117127680/1246198918816202812/awesomearies_isometric_cross-section_of_ecological_megastructur_bda38259-ec33-4f6b-914e-d2af8d333ae8.png?ex=6733baaf&is=6732692f&hm=a9c7a733dee7b6b086e8810e730d8367c79d2f04e14acd43c4bb511d258c50fc&.
Edited for style and content in Adobe Suite Fire Fly.

176 **Figure 6.4.27:** Arcology - Niagara Escarpment II - Residential Zone - Sectional Perspective - a dense multiple floor variation showing conceptual housing configuration in tower form and the potential for green infrastructure that begs the question where is the limit of such a structure in an Arcology- illustration by Midjourney thicker slabs, altering tree sizes and bushes added in Adobe Fire Fly
Source: Midjourney-version 6.0 image generated to "/imagine isometric cross-section of ecological megastructures showing a lot of natural light and healthy human interactions with multiple levels of multiple floor scale of interactions designed to deal with piazzas, shops, playground parks, festival streets and fairs, dancing festivals, small theater performances, vertical stacking, neighbourhood, detail isometric drawing of neighborhood node to show several human interactions including a variety of trees, clear isometric drawing, black and white, vector lines,--sref 841731 171244 --v 6.0 --s 750 --ar 9:16 – Variations (Strong)" September 30, 2024, Discord, http://cdn.discordapp.com/attachments/941582479117127680/1246193589835272414/awesomearies_isometric_cross-section_of_ecological_megastructur_2fa68fe5-18a6-4400-84ee-6743428e7d77.png?ex=6733b5b8&is=67326438&hm=a244c2e5d5024474b7d82695a141b24e56b9597dacefa0c5b63f82b3bdca0ee0&.
Edited for style and content in Adobe Suite Fire Fly.

177 **Figure 6.4.28:** Arcology - Niagara Escarpment II - Residential Zone - Sectional Perspective - a dense multiple floor variation showing conceptual housing configuration to integrate trees, bushes and grass highlighting the variety of spaces and use - illustration by Midjourney with color added, thicker slabs, altering tree sizes and bushes added in Adobe Fire Fly
Source: Midjourney-version 6.0 image generated to "/imagine isometric cross-section of ecological megastructures showing a lot of natural light and hierarchy and healthy human interactions with multiple levels of multiple floor scale of interactions showing community piazzas, shops, playground parks, stairs, varies heights, small shops, details interactions between several human interactions including a variety of trees, clear isometric drawing, black and white, vector lines, design showing natural light, --v 6.0 --s 750 --ar 16:9 – Variations (Strong)" September 04, 2024, Discord, http://cdn.discordapp.com/attachments/941582479117127680/1246330385860788274/awesomearies_isometric_cross-section_of_ecological_megastructur_8b4d19fc-addd-4671-af27-5e13c1720c78.png?ex=6734351f&is=6732e39f&hm=44d16679bc4749e25b2d99a4bcae257cace02e14d069e4eef76601c4f173c340&.
Edited for style and content in Adobe Suite Fire Fly.

178 **Figure 6.4.29:** Arcology - Niagara Escarpment II - Residential Zone - Sectional Perspective - a large variation showing conceptual housing configuration to integrate trees, bushes and grass highlighting the variety of spaces and use - illustration by Midjourney with color added, thicker slabs, altering tree sizes and bushes added in Adobe Fire Fly
Source: Midjourney-version 6.1 image generated to "/imagine isometric cross-section of ecological megastructures showing alot of natural light and healthy human interactions with multiple levels of multiple floor scale of interactions showing piazzas, shops, playground parks, festival streets and fairs, dancing festivals, small theater performances, details interactions between several human interactions including a variety of trees, clear isometric drawing, black and white, vector lines, design showing natural light, --v 6.1 --s 750 --ar 16:9 " September 04, 2024, Discord, http://cdn.discordapp.com/attachments/995431387333152778/1301653777400729610/awesomearies_isometric_cross-section_of_ecological_megastructur_0d161cf4-626d-4537-9c1a-a15c26cec641.png?ex=67346c4c&is=67331acc&hm=b2ca89c3799f27aa523d177e4d669245282eda7735408c50c092cdd0e5011475&.
Edited for style and content in Adobe Suite Fire Fly.

179 **Figure 6.4.30:** Arcology - Niagara Escarpment II - Residential Zone - Sectional Perspective - a variation showing conceptual housing configuration to integrate trees, bushes and grass highlighting the value of staircases - illustration by Midjourney with color added, thicker slabs and some bushes added in Adobe Fire Fly
Source: Midjourney-version 6.0 image generated to "/imagine section isometric of ecological megastructures showing a lot of natural light and healthy human interactions with multiple levels of multiple floor scale of interactions showing community, shops, playground parks, housing, community areas, details interactions between several human interactions including a variety of trees, clear isometric drawing, black and white, vector lines, design showing natural light, --v 6.0 --s 750 --ar 16:9 - Variations (Strong)" September 03, 2024, Discord, http://media.discordapp.net/attachments/981832774157762570/1246985529468129291/awesomearies_section_isometric_of_ecological_megastructures_sho_4d1de431-aa41-4265-b23d-2871e4102151.png?ex=6733f446&is=6732a2c6&hm=1c987f4c07b4fcbd2a4ca58f85da6ded764b744a1544d9d66e2001dadb487dbf&=&format=webp&quality=lossless&width=1197&height=671.
Edited for style and content in Adobe Suite Fire Fly.

180 **Figure 6.4.31:** Arcology - Niagara Escarpment II - Residential Zone - Sectional Perspective - a variation showing conceptual housing configuration to integrate trees, bushes and grass highlighting different spaces- illustration by Midjourney with thicker slabs and some bushes added in Adobe Fire Fly
Source: Midjourney-version 6.0 image generated to "/imagine isometric cross-section of ecological megastructures showing a lot of natural light, Italian hilltop town style housing and large green spaces and healthy human interactions with multiple levels of multiple floor scale of interactions showing piazzas, shops, playground parks, festival streets and fairs, dancing festivals, small theater performances, details interactions between several human interactions including a variety of trees, clear isometric drawing, black and white, vector lines, design showing natural light, --v 6.0 --s 750 --ar 16:9 - Variations (Strong)" September 10, 2024, Discord, http://media.discordapp.net/attachments/941582479117127680/1246333062657081364/awesomearies_isometric_cross-section_of_ecological_megastructur_fb6e8935-e99b-44de-b0c5-d31c4e1c41e4.png?ex=6734379d&is=6732e61d&hm=3231d8b46ce18e5e38cf7b91f4e278420a759c425b3a3357d4efdcf636133264&=&format=webp&quality=lossless&width=1197&height=671.
Edited for style and content in Adobe Suite Fire Fly.

181 **Figure 6.4.32:** Arcology - Niagara Escarpment II - Residential Zone - Perspective - Community Cafe in an Open Space - illustration by Midjourney with trees, skylight, background and birds added in Adobe Fire Fly
Source: Midjourney-version 6.1 image generated to "/imagine ecological arcology rectilinear forms, lots of trees and plants interior view, street perspective --ar 16:9 --v 6.1" September 1, 2024, Discord, http://cdn.discordapp.com/attachments/945077390839787570/1301683912170405898/awesomearies_ecological_arcology_rectilinear_forms_lots_of_tree_0739f3d1-ed60-4334-9f3d-8b48e42d45a6.png?ex=6734885c&is=673336dc&hm=0448d51ab932a5df0ed12ea6fce1808ff68dfe3e3e23cadb007478d72e72c797&.
Edited for style and content in Adobe Suite Fire Fly (extensively edited by Author).

182 **Figure 6.4.33:** Arcology - Niagara Escarpment II - Residential Zone - Perspective - Intimate Open Community Space with green wall - illustration by Midjourney with dome extension, some hanging plants added in Adobe Fire Fly and first generation of Promo AI
Source: Midjourney-version 5.1 image generated to "/imagine interior perspective patrick geddes ecological megastructure italian hilltop housing, space frame with hanging vines --ar 16:9 --style raw --s 750 --v 5.1" January 03, 2024, Discord, http://cdn.discordapp.com/attachments/1055908341492240476/1120870270312382494/awesomearies_interior_perspective_patrick_geddes_ecological_meg_eabd6483-173e-4a63-a30f-40450ea0cd38.png?ex=67349909&is=67334789&hm=91e8fe1621c8d3fa87599902400659e0d214b3c241666a19ed21d756d3bf71bc&.
Edited for style and content in Adobe Suite Fire Fly.

183 **Figure 6.4.34 :** Arcology - Niagara Escarpment II - Residential Zone - Perspective - Open Space with artificial lighting - illustration by Midjourney with benches and bushes added in Adobe Fire Fly
Source: Midjourney-version 6.1 image generated to "/imagine arcology full of greenery with phosphorescent lighting around the trees, phosphorescent interior design, realistic, day sky in a shaded open space covered wth a variety of trees, futuristic, street view --v 6.1 " October 20, 2024, Discord, http://cdn.discordapp.com/attachments/945077390839787570/1297687209859747981/awesomearies_arcology_full_of_greenery_with_celtic_and_tribal_p_28a3cc65-be42-4e38-909d-4f38d3ba702e.png?ex=67347ea4&is=67332d24&hm=d2bf65f7890a624d379d5520108686a81c785b68f29cd3365ab92d4ee8a051a6&.
Edited for style and content in Adobe Suite Fire Fly.

184 **Figure 6.4.35:** Arcology - Niagara Escarpment II - Residential Zone - Perspective - Night sky showing with artificial lighting in semi public space - illustration by Midjourney with benches, green lights, removal of futuristic elements and night sky added in Adobe Fire Fly
Source: Midjourney-version 6.0 image generated to "/imagine isometric cross-section of ecological megastructures showing a lot of natural light and hierarchy and healthy human interactions with multiple levels of multiple floor scale of interactions showing piazzas, shops, playground parks, festival streets and fairs, dancing festivals, small theater performances, details interactions between several human interactions including a variety of trees, clear isometric drawing, black and white, vector lines, design showing natural light, --sref 8425981 1741244 --v 6.0 --s 750 --ar 16:9 - Variations (Strong)" September 05, 2024, Discord, http://cdn.discordapp.com/attachments/941582479117127680/1246199438418907217/awesomearies_isometric_cross-section_of_ecological_megastructur_9665976e-857e-417a-93ce-3df71370703e.png?ex=6733bb2b&is=673269ab&hm=6a45b7bcfd699fdcebe99c79b0bfe16841abdae58d93880d7306f4d78c8410d2&.

185 **Figure 6.5.1:** Benefits for Niagara Escarpment II's Arcology - Quantity in Green Infrastructure
By Author. With Illustrator and Excel.

186 **Figure 6.5.2:** Quantifiable Elements of Niagara Escarpment II's Arcology - in Volume
By Author. With Illustrator and Excel.

Conclusion

187 **Figure 7.1:** Arcology's Section In Search of the Ideal - Author's first conceptual illustration inspired by Étienne-Louis Boullée's Newtonian. By Photoshop and AutoCAD.
By Author. With AutoCAD and Photoshop.

188 **Figure 7.2:**
Niagara Escarpment II's Arcology Logo - illustration by Midjourney
Midjourney-Version 6.1 image generated to "/imagine an arcology logo –v 6.1 –s 750," October 14, 2024, Discord, http://www.midjourney.com/jobs/5f3a6098-460d-4d72-a3fd-f9fa5de725e4?index=0.
Edited for style and content in Adobe Suite Fire Fly.

The Happiness of your Life,
depends on the Quality of your Thoughts.

- Marcus Aurelius



INTRODUCTION



Figure 1.1.1: Here Be Dragons adapted for Urban Planning Maps - illustration of a collection of ancient maps to highlight current urban planning concerns such as zoning regulations, urban sprawl, urban growth where unknown regions in multiple scales are represented by illustrations of monsters and dragons, generated by ChatGPT and Adobe Firefly

1.1 Here Be Dragons

Present-day urban planning approaches and architectural solutions are designed for our cities for convenience, but we did not design them for rapid economic growth; therefore, we do not know a city's growth limits. Urban sprawl is a symptom of a broader systematic failure embedded in the policies and framework that governs urban global development. Canada over ten years, like many nations that face urban sprawl, report expansions in Toronto (+29 km^2), Calgary (+21 km^2), Montréal (+16 km^2), Edmonton (+12 km^2), Winnipeg (+10 km^2), Vancouver (+10 km^2) and a 2% national built-up growth on their peripheries[1]. Prioritizing urban and economic growth without restrictions systematically reduces ecosystem services, resource depletion, and greenhouse gas emissions that exacerbate climate change, resulting in extreme weather events that cost taxpayer billions.

Current urban practices do not promote coherent, long-term environmental solutions, favoring symbolic ecological concepts over functionally integrated systems. Too often, cities pursue scattered, uncoordinated innovations without specific, measurable goals, resulting in aesthetic gestures that fail to deliver tangible or scalable outcomes. Three recurring themes cause drastic delay, compromise, backtracking, and discourse regarding sustainable urbanism planning —Brandolini's Law, the Dunning-Kruger Effect, and the misuse of architectural slogans.

Brandolini's Law states reversing misconceptions is expensive: "The amount of energy required to refute nonsense is an order of magnitude greater than to produce it." Once flawed ecological models become popular, they absorb institutional resources, are adopted by the industry, and are embedded in policy frameworks. Corrective efforts become an economic burden, causing an overwhelming waste of time and resources that could have been devoted to solutions.

The Dunning-Kruger Effect highlights the value of interdisciplinary collaboration and cautions against shallow, quick scheme trends. It states those with limited understanding overestimate their competence, frequently dominating public and policy discourse. Despite good intentions, these uninformed solutions influence decision-making, leaving cities and governments vulnerable to trendy but impractical architectural approaches. These efforts provide the illusion of progress but fail to address the systemic changes needed for sustainability and scatter innovations.

Architectural slogans' oversimplification misleads the public with the mirage of definitive solutions. Catchy phrases like *less is more* or *trees on buildings are for the elite* mask the complexity of ecological design, fostering superficial technological solutions and steering experts from providing pragmatic architectural solutions.

To get new answers, we must ask new questions: What if less is not more, and more is not more? What if ecological buildings should not be a vision of luxury for the few but instead a solution for the masses? What if sustainability does not only start at home but also on the industrial scale? What if developing a pragmatic model is the quintessential shift required to maneuver innovations toward a collaborative goal? What if we have to re-think urban planning strategies, urban policies, ownership, lifestyles, vehicular traffic, and systems?

The Arcology proposal offers pragmatic solutions against the urban normative framework and towards integrating human and ecological systems. The Niagara Escarpment II prototype explored in this thesis is located strategically in Niagara Falls. This is due to its ecological and infrastructural nexus: regional power networks (hydroelectric power plant), ecological distinctiveness (waterfalls, bird migration, geology), and major transportation routes (trade, tourism, cross-border mobility). It encourages a sustainable, scalable, and tangible solution that advocates for adaptive urban planning solutions and interdisciplinary collaboration. The intention of exploring the Arcology model is to find a solution that steers thinking outside the box.

1 Statistics Canada Government of Canada, "Canada's Large Urban Centres Continue to Grow and Spread," The Daily - , February 9, 2022, https://www150.statcan.gc.ca/n1/daily-quotidien/220209/dq220209b-eng.htm. Accessed October 10, 2024.

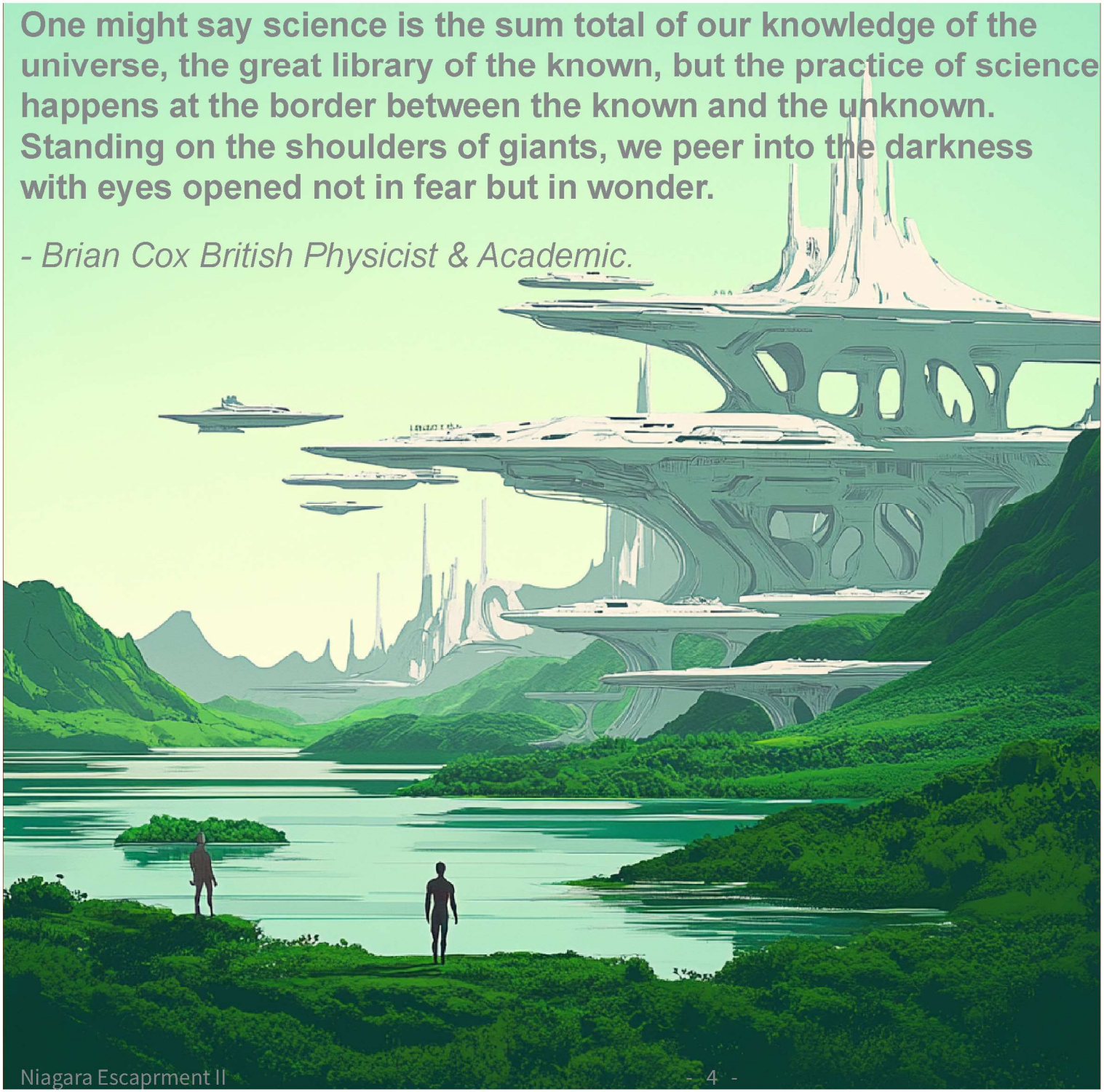


Figure 1.2.1: Illustration of an Arcology, inspired by Scottish Science Fiction Writer Iain Banks' book covers, generated by Midjourney version 6.1

1.2 Introduction

This thesis revives Paolo Soleri's late twentieth-century Arcology megastructure model to explore the potential for a systematic cohesion between human urban settlement and ecological integration through their complex processes. Paolo Soleri 's Arcology is a compelling model because it not only has the physical mass to hold massively scaled ecological processes; it possesses intriguing potential for developing complex human processes in its fabric. The Arcology concept did not manifest into mainstream architectural practice at the time of its development by Soleri because it failed to link urban processes to the construction technologies and supportive systems for human processes available at the time.

Today, any interdisciplinary team of design and building disciplines that would construct such fantastic urban settlements must see the processes and urban systems to begin the iterative and collaborative design phase to achieve defined goals. The upfront cost of such an endeavor is so significant that a clear vision must have quantifiable objectives. Soleri designed and developed such grand structures, and they potentially portrayed the illusion that these practices were resolved through drawings that alluded to variety, miniature systems, and trees with fantastically complicated detailing of entire buildings and landscape sections. Compelling as Paolo Soleri 's drawings are, and memorable iconic visions, they are to be thought of as potential for a human/nature future with a dream-like allure.

This thesis will develop an Arcology case study design for an Arcology megastructure in the Niagara Region of Canada's province of Ontario. The systems integrated into the Arcology megastructure design developed for this thesis will cycle Water, Waste, and Energy systems. The biological systems will contain water, trees, vegetation, vertical farms, and microorganisms to break down wastes. The intention is to integrate Ecology and Architecture in the Arcology to resolve ecological integration and the built urban environment of Niagara Falls to help resolve the Region's environmental concerns at the limited scale of the Arcology.

Although the ecologically based Arcology megastructure is a formidable endeavor, it has potential benefits that are significant to improve environmental impacts, urban sprawl, and resource efficiency. This is a complete contrast to our current urban planning and design practices today which build on obsolete technologies and prioritize schedule, cost, and budget. Instead, an Arcology-based approach would embrace holistic systems, to internal autonomy, energy generation, ecosystem services, and vertical farming and vastly improve the resilience and quality of urban life. These are all possible to manage, if and only if we radically re-structure the system we have established to organize our urban environment as Soleri originally proposed in the mid-20th century.

Due to the complexity of this ambition, it is notable to state that our ability to project immediate and complete concrete visions will distort the progression of such a future Arcology structure. This is because we are integrating man-made systems, and urban processes with environmental systems. Although we may regulate human processes, other biological entities may not play along. In fact, the day flora and fauna follow policies and regulations is the day they are eligible to become citizens and pay taxes. Therefore, we can perceive a reality where the complexity of the natural environment is a true test of our ability to design [2]. The immediate challenge of this venture is that it is beyond the conventional scope of architecture, however, it is scattered within other disciplines. Therefore, the Arcology model requires a collaborative process throughout multiple disciplines.

Before leaping into the abyss of unknowns, it is important to disclaim that designing an arcology is not a typical architectural design for a series of reasons. The Arcology would have complexities that are difficult to predict but can be mapped and incrementally optimized in time. The Arcology must be adaptable to modifications to ensure it meets multiple requirements of its inhabitants over time. Theoretical understanding of how these systems can merge in an Arcology alters significantly when implemented. The form of Arcologies can not be predicted because there are multiple solutions for every problem which depend on unpredictable requirements and circumstances. Therefore, the role of the Architect evolves to assume two main responsibilities. The first is to define the overall systems required and to ensure the seamless interactions

2 Maldonado, Tomás. 2019. Design, Nature, and Revolution : Toward a Critical Ecology. Translated by Mario Domandi. First University of Minnesota Press edition. Minneapolis: University of Minnesota Press, Chapter 2, p 8 – 10.

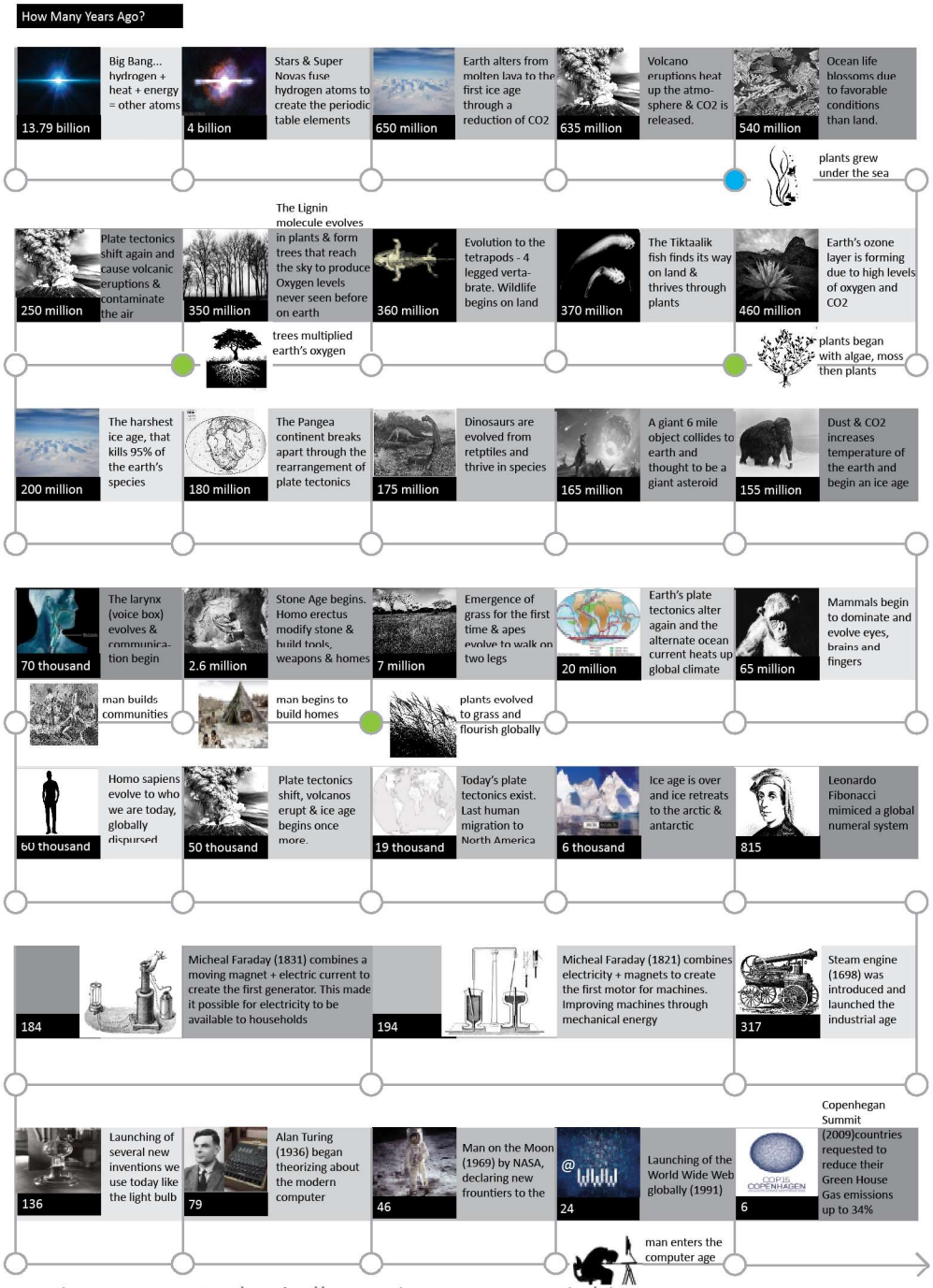


Figure 1.2.2: Author's Illustration - F Fantastic history

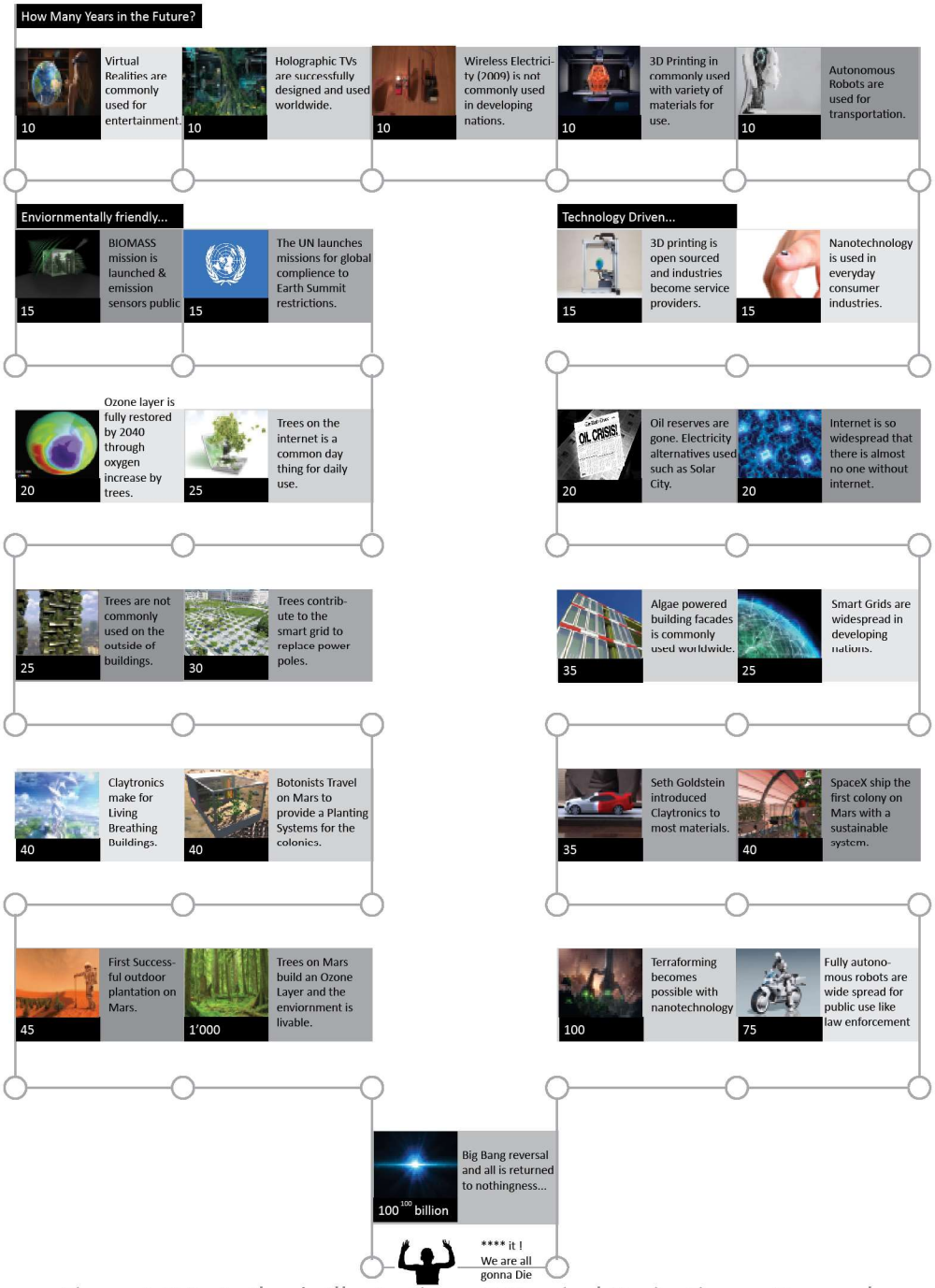


Figure 1.2.3: Author's Illustration - F Comical Projections - Pro-ecology (left), Pro-technology (right)

of the systems within the Arcology. The second is to shape a visionary design that embraces growth and change by implementing or removing specific elements while providing direction for the multi-disciplinary design team.

This peeling of complex layers leads us to a framework for architecture that can provide a solution to these ecological issues through the development of the Arcology model. The thesis will explore, elaborate, and re-develop Paolo Soleri's Arcology model through the development of a contemporary natural ecosystems approach and integrating it into the Arcology model. The thesis's main hypothesis is that a successful Arcology combining such an ecosystems-based approach and built with today 's technology, human processes, and lifestyle systems can address and resolve leading global concerns of human settlement and environmental sustainability issues. What was missing in the past, or phrased in over-generalized terms, may be echoed in lessons from natural systems thinking discussed in a later thesis chapter.

It is important to note that an arcology will fail if the quality and quantity of its resources are too small or too big and over-scaled. Such an example is Soleri 's prototype of Arcosanti, built slowly over decades in the Arizona desert and never reaching any significant scale compared to his Arcology model. This is the suggestion that Arcologies can be built very modestly and over an incremental approach of long duration. Paolo Soleri himself noted that Arcosanti is the middle step required to building an Arcology. This however begs the question that although they could be built modestly, perhaps they should not because there are preconditions that determine the success of an Arcology. Arcosanti ultimately failed due to Paolo Soleri's failure to recognize that cities are not built because cities exist. The city is a socio-economic attractor that baits people into living in it due to their interests. Consequently, building Arcosanti in the middle of the desert will not bring in people. The socio-economic attractor must have already been established before an Arcology can be built.

The second assumption in this thesis is that Arcology is a complex project comprised of multiple systems and it will fail due to a lack of developing its ongoing transformative iterations[3].

Therefore, the development of Arcology must begin with seamlessly integrating its internal and external systems. The solving of systems must begin with analyzing their processes. The analysis of natural systems and man-made systems vary in their invisible processes. Natural systems are visibly cyclic and process things slowly and man-made cycles are linear and have a quicker response. Let us take for example the flow of water within both systems. The water evaporates from bodies of water into clouds, then turns to rain and eventually to the ground, where it travels down the watershed, into more bodies of water such as rivers and lakes and repeats the process. This cycling pattern occurs after the system has refined itself over thousands of years until it has resolved a balancing act within its components. Man-made systems are visibly linear, like the twisting of tap water. Like a machine, the water flows into the sewage system, invisible to us, treated, and returned to us. Man-made processes are linear, centralized, and systematically wear down and when this system breaks down it causes chaos on multiple scales. The significant advantage of Arcologies is they have the capacity to combine both these processes to utilize the advantages of both systems.

Although slow, natural ecosystems evolve to have properties that include adaptive cycles that occur in multiple scales whereas man-made cycles must be re-designed and re-constructed to adapt. Urban processes must consider systems thinking for long-term success, especially when considering such a vast capacity of systems. This thesis will attempt to systemize and bring man-made and natural processes together into cohesive cyclic systems so each of the systems is designed to their potential. Finding a composition to bring together ecology into architecture is a search for reorganizing massive structures with processes described by complex systems, trendy buzzwords like dissipative, porosity, transparency, natural light, regenerative, holistic etc. If merging the world of megastructures and the world of miniaturization into a cohesive plan is the goal, then Paolo Soleri` s Arcology is worth re-exploration.

3 Martin, Roger L. „Strategy Is Iterative Prototyping." Harvard Business Review, June 2014, http:// hbr.org/2014/06/strategy-is-iterative-prototyping.

1.3 The Dream

Anthropocene was a term used in the late 20th Century by chemist Paul Crutzen to describe the geological epoch that was initiated during the Industrial Revolution[4]. The term identifies the geological timeline that characterizes a new era where human interactions versus natural interactions are tipped to favor the former[5]. This leads to the conclusion that human activities and human metabolisms have a significant global impact on Earth's ecosystems. Although this term is controversial and not internationally recognized, there is profound evidence that human interaction with the environment causes strain evident in environmental global patterns.

The predominant Anthropocene reality seems to be that we lack awareness of ecological processes and that we have designed man-made systems that directly clash against them, comprimise and alter them. The issues of sustainability and ecological responsibility have been a recurring theme throughout the century. The periodic waves for ecological change occurred in the 1930's, 1950's, 1960's, 1980's and 2000's. This oscillating pattern is an indication that until there is a convergence between both Nature and Society it needs to merge, or this behavior will reoccur.

4 Crutzen, Paul J. and Eugene F. Stoermer 2000. The "Anthropocene." Global Change Newsletter (41): 17–18.
5 Crutzen, Paul J. 2002. Geology of Mankind. Nature (415/51): 23.

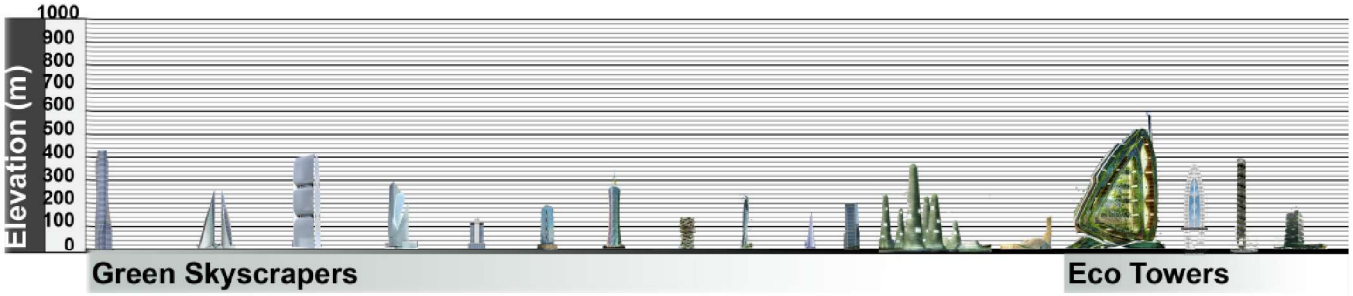
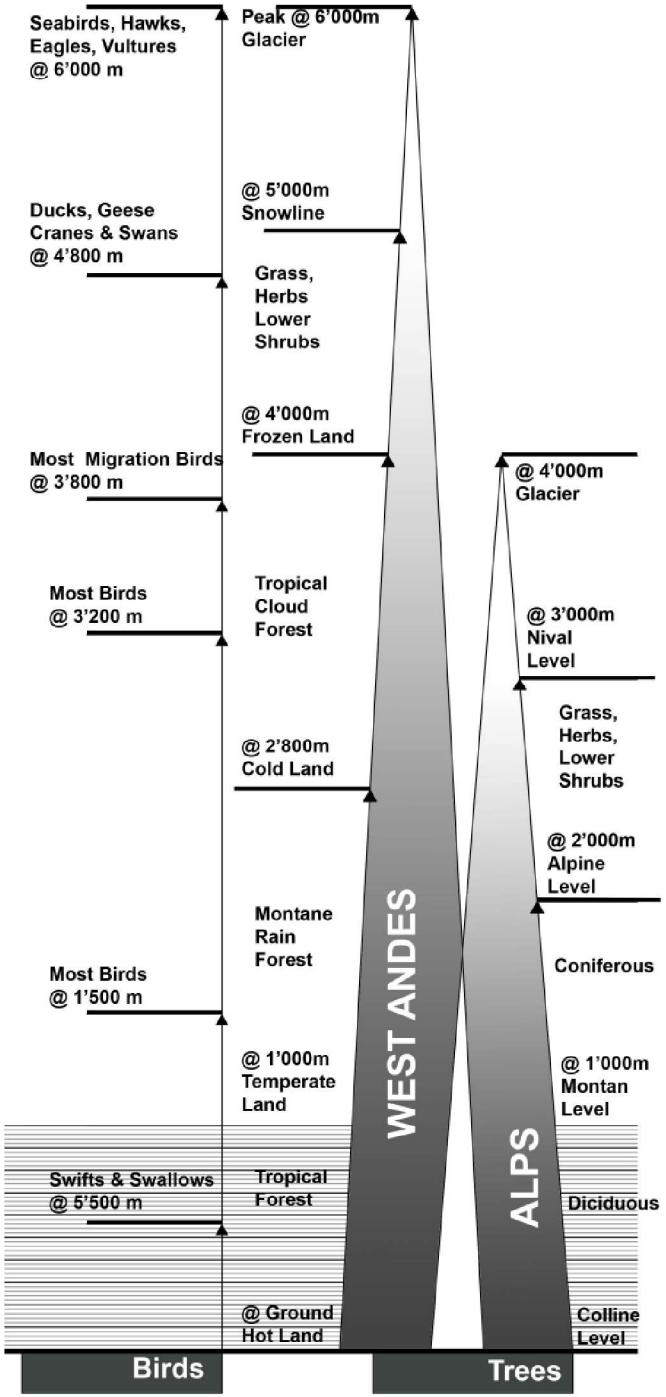


Figure 1.3.1: Elevations: Green Skyscrapers, Eco Towers VS Forests, Mountains & Birds



The architectural structures that are widespread and built today and in the recent past tend to advocate for sustainable high-rises and appear like oxymorons that visibly lack eco-literacy[6]. Contributions to this always seem to be stemming from scarcity: lack of appropriate budget allocation, technological integration, resources, research and development, and such. An alternative usual suspect is overpopulation, overcrowding, urban sprawl, and all the chaos they breed. The overall consensus is there is an evident decline in global ecological systems, and it impacts the existence of ecological functions and services and quality of life. The fear of such carelessness will ultimately result in an irreversible bifurcation of the earth as we know it. Today, evident ecological services are in decline due to the loss of ecological systems, the global rise of climate change, melting of the polar ice caps. All these narratives are designed to revolt against the existing system because images of buildings with trees, flying birds, and blue skies will continue to arise in the literature. Why do seasoned architects continue to flood our magazines with such propaganda? Via pure speculation, perhaps it could be selling features, but its repetition makes me wonder if it is a desperate hope for change.

For now, let us paint a picture of hope that resonates with Darwin's axiom "Natura non facit saltus" (Nature does not make jumps). The hope is to not only to manage Earnest Haeckel's oikos[7] but also to thrive in that household. Dutch arcchitect Lars Spuybroek presented the analogy of wandering through the forest when there is a momentary overwhelming experience that takes over you and knowing what specifically occurred. Could it be the light, the foliage, or the smell? But it is a moment where the variations, the experiential sequence, and the collection of these things unified and became sublime. These experiences do not occur within thin walls because they need to have the capacity to hold complexity, flows, and systems within systems. They can only come together within the thick of things[8]. Although pictures are very inspiring, the quality of processes that occur within the thick of things will determine a megastructure's tolerance for ecological systems.

6 Capra, Fritjof. 2007. "Sustainable Living, Ecological Literacy, and the Breath of Life." Canadian Journal of Environmental Education 12 (1): 9–9.

7 Marsden, William E. "Ecology and Nineteenth Century Urban Education." History of Education Quarterly 23, no. 1 (1983): 29–53. https://doi.org/10.2307/367968.

8 Brouwer, Joke, Lars Spuybroek, and Sjoerd van Tuinen, eds. 2016. The War of Appearances: Transparency, Opacity, Radiance. Rotterdam: V2_Publishing.

1.4 Ecological Architecture - What does not Work?

Global ecosystem instability, resource degradation, urban sprawl, and biodiversity loss are all global ecological themes that trigger urgency. With a public armed with a fragmented understanding of ecological or urban systems. How do we present the solutions to these complex systems? Cheaper and faster technological systems exasperate ecological issues. Iconic structures leave an impactful urban presence filled with mixed development and planters. Smart grid systems armed with Energy systems that might or might not align with the climate of the site.

Criticism on the matter launched a series of publications such as Archdaily's Tim De Chant[8] and Tree hugger's managing editor, Lloyd Alter[9]. The arguments are pro-plants so they may be easily manageable, but the management of trees is very complex and expensive. Soil is very heavy and thus will be very challenging to have trees in cantilevered balconies. Soil requires a mini ecosystem to thrive, every gardener knows it is essential to keep it nurtured as well. When we put trees in our buildings, we are asking for a thriving ecosystem. This did not deter the optimism of the public wanting to see trees in their architectural renders. However, this implies that the want for trees in our built environment must be studied to see further development.

8 Tim De Chant, "Can We Please Stop Drawing Trees on Top of Skyscrapers?," ArchDaily, March 21, 2013, https://www.archdaily.com/346374/can-we-please-stop-drawing-trees-on-top-of-skyscrapers. Accessed November 10, 2019.

9 Lloyd Alter, "Are Architects Going Overboard with the Trees on Buildings?," Treehugger, October 11, 2018, https://www.treehugger.com/are-architects-going-overboard-trees-buildings-4856117. Accessed November 10, 2019.

In 2015, Vincent Callebaet and his design team was comissioned by Paris City Hall, to publically introduce and promote the Climate Change Plan of Paris. His design team promoted a series of proposals (figure 1.3.1 - 1.3.6) dubbed 2050 Vision of Paris as a Smart City and was published in the ArchDaily. It was intended to spark debate regarding housing and denisty issues, integrate energy production strategies and promote eco-friendly living. They introduced a series of provocative tech-solutions, radical renders that show passive, technological and human integration, green spaces, suspended gardens with eco-friendly materials (ish).



Figure 1.4.1: Bridge Towers Paris Proposal



Figure 1.4.2: Antismog Towers



Figure 1.4.3: Photosynthesis Towers



Figure 1.4.5: Mountain Towers



Figure 1.4.4: Farmer Tower Stacked Stones



Figure 1.4.6: Bamboo Nest Towers

1.5 Ecological Architecture - What Works?

In July 2024, Buisness Insider published an article that observed that trees on tall towers were meant to express wealth, like the Guinigi Tower in Lucca, Italy built in the 1300s[10]. The want for green architecture in buildings is a subconscious want for an environment that contributes the most to human survival. Realistically, it is not a question of whether it is possible, but how the questions should begin with how. How could it be done? How long will they last? How can they be designed?

Architects have broken down these concerns by solving them in parts. Through sustainable practices, architecture has established functional building blocks and achievable milestones. Commercial products such as rooftop planters, sloped floors, vertical green walls, and vertical farms are readily available. We have extensive quantitative information about our materials to determine their thermal capacity, water tolerance, soil nutrients, etc. Future development necessitates the strategic integration of these systems by developing synergistic interactions that wouldn't emerge in isolation of its parts. Consequently, the emphasis must shift towards prioritizing system processes, iterative optimizations, and the management of the interactive dynamics that govern this merger.

The fundamental flaw is embedded in a design process that adopts a reductionist and simplistic understanding which renders the design concept reductio ad absurdum. Ecological megastructures ask for the adoption of a more scientific approach such as systems thinking where reductionism defines fixed algorithms with the intent of reconfigurations through constant iterations over time and money. To develop an Ecological Megastructure*, architects must be prepared to completely redefine the paradigm by embracing architectural elements that are flexible and adaptable. But what are we doing instead?

Global examples of ecological buildings over from past and present architectural structures (figure 1.5.1 - 1.5.5) that have trees growing on built architectural structures. What is notable in all of them is the huge mass of the structure required to hold such systems.



Figure 1.5.1: Vo Trong Nghia Architects House in Coleda



Figure 1.5.2: Vertical gardens at Park Royal in Singapore

10 Warren, Lydia. "Italian Neighbors Used to Compete by Building Tall Towers. See inside One That's Still Standing after 600 Years." Business Insider. Accessed October 15, 2024. https://www.businessinsider.com/torre-guinigi-italian-tower-photos-2024-7.

* Please note: Ecological Megastructures in the context of this thesis encompasses a generalization of the concept of an Arcology. It is intended to highlight the description and function of a building typology - a massive structure that envelopes ecosystems. While an arcology in the context of this thesis is a derivative of ecological megastructures. An Arcology describes a type of architecture that aligns with ecological principles and Paolo Soleri's concepts such as miniaturization.

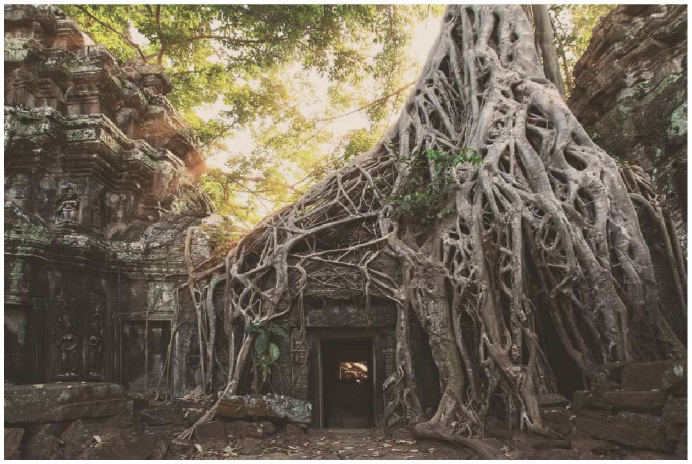


Figure 1.5.3: Ancient Khmer Temple at Angkor Wat, Cambodia



Figure 1.5.4: Alberto Kalach Casa Romany in California



Figure 1.5.5: Luciano Pia Tree House 25 Verde

1.6 Definition: from Green to Sustainable to Ecological to Arcology

The terms "green design", "sustainable design" and "ecological design" have become interchangeable terms used to indicate a shift of attitude and an expansion of scope. The three are co-relatable as they each have a strong inclination towards ecological goals, however, under critical assessment, only ecological design has specific coexistence to work with complex natural systems.

"Green design" was a term coined in the 80's to bring public awareness to spreading environmental problems, the green party was gaining traction in Europe and the flurry of products that were popularized in the media and advertisement was only opening the doors to consumerism[11]. Much like today, the term "green" would promise the potential of recyclable, environmentally friendly products without a clear standard of how much is recyclable.

"Sustainability" was first used in the 70s as an ecological term to mean "the capacity of a system to maintain a continuous flow of whatever each part of that system needs for a healthy existence"[12]. It was popularized after the United Nations of Environment called for a World Commission on Environment and Development where they produced the Brundtland Report of 1987 and by the 90's, it became the term used by mainstream media. It first coined the term sustainable development and decreed that due to an imbalance of natural resources, sustainable development requires that those societies especially technologically advanced western ones who are more affluent adopt lifestyles within the planet's ecological means[13]." However, the report also encouraged economic growth while maintaining the environment giving a loophole for businesses to shrug off the weight of environmental protection for their economic prosperity. Their slogan remained: "meets the needs of the present without compromising the ability of future generations to meet their own needs[14]". The key trigger word for architects is "producing more with less[15]", ironically, a term previously used by Buckminster Fuller[16] and in William McDonough's view meant "less bad is [still] no good[17]" . This trivialization and distortion of boundaries kept the ecological context out of the equation and kept the policies from their proper intent. The UN Environment later held many events such as Earth Summits to follow and promote global progress. The social and ethical responsibilities and the timescale of the Brundtland Report gave way to reconsider in the design process site analysis, lifecycle analysis, cradle to cradle's "eco-effectiveness", eco-efficiency, optimization of mechanical systems, longevity, and dematerialization. Over thirty years later, there has been an incremental slow but stable change, in comparison to the 1980's.

Global environmental issues today are still imminent with a growing population that is used to a high level of consumerism and an unsustainable production of waste. Architects such as Danish architect and urban design consultant, Jan Gehl advocated for an improved urban life through bicycling and improved pedestrian pathways, which seemed to have initiated a global movement. The need for more than "producing more with less" has pushed the bar to ecological design.

Although Sustainable design and Ecological design both start from the design phase, Ecological design was a movement that started much earlier. It inherently originates from the environmental movement that dates from the 60's and 70's. The most radical of those was the deep ecologists who defined ecological design as "The design of materials and products, projects and systems environments communities which are friendly to living species and planetary ecology[18]." This radical deep ecologyecological approach resembles the environmentalist's conservative approach but causes as little damage as possible, however, with a growing global community, it is difficult to apply this approach. A more comprehensive approach is better expressed by the American Institute of Architects's Committee on the Environment (AIA COTE) cited David Orr's definition which had a more scientific description: "Ecological design requires the ability to comprehend patterns that connect, which means looking beyond boxes we call disciplines to see things in their larger context. Ecological design is the careful meshing of human purposes with the larger patterns and flows of the natural world; it is the careful study of those patterns and flows to inform human purposes…[19]"

In 1988, John Button referred to more than ninety cited prefixes of the term "eco" such as ecocity, ecomanagement, ecotechnics, ecovilliage, ecotopia and eco(logical archi)tecture; but the term "ecodesign" was

referenced the name the Ecological Design Association's journal that came out in 1989[20]. The spark that set off the ecological movement was a shift of perspective from scientist's definition of ecology. The first phase of ecology-based ecosystems in a state of homeostasis and balance. By the 1960s, English botanist Arthur Tansley and American biologist Eugene Odum rejected the theory of the ecosystem being in a state of stability and emphasized the state of natural systems is in a state of constant flux[22]. Ecosystems were now linked to the theory of chaos and complexity and its potential to revolutionize made ecosystems, dynamic, self-adapting, and volatile. However, with the work of Canadian physicist and ecologist James J. Kay, ecologist Crawford Stanley Hollings, botanist Timothy F. H. Allen and more, the understanding of ecosystems was refined to ecosystems may be volatile when unmanaged, and the benefits of a self-organizing system urge for ecological management[22].

Architecture, as a discipline and a profession has developed sustainable design, to the extent that it has become acceptable in mainstream media. Therefore, to push the limits of sustainable design and perhaps instead of Buckminster Fuller's "More with Less", or Bjork Ingle's hedonistic "More is More", perhaps the ecological buildings will set up the discussion for "More is More with the use of Natural Systems" because Ecological buildings intend to be regenerative.

How do we generate this? To understand that we need to take a step into the wild side of ecology and systems thinking.

11 Madge, Pauline. "Ecological Design: A New Critique." Design Issues , Summer 1997: p 45 - 48.
12 Ibid. p 51.
13 Enviornment, UN. ur Common Future: Report of the World Commission on Environment and Development. 1987. http://www.un-documents.net/our-common-future.pdf (accessed Aug 22, 2017): p 16.
14 Ibid. p16.
15 Ibid. p21.
16 Buckminster R. Fuller, Utopia or Oblivion: The prospects for humanity (New York: Overlook Press, 1969), p265.
17 William McDonough & Micheal Braungart, "Cradle to Cradle." North Point Press, p 45.
18 Madge, Pauline. „Ecological Design: A New Critique." Design Issues , Summer 1997: p 48.
19 "Sustainable Design - Ecological Design." In Architectural Graphic Standards - Student Edition, by Ramsey, Sleeper. Hoboken, New Jersey: John Wiley & Sons, Inc., 2008, p 428.
20 John Button, A Dictionary of Green Ideas. Vocabulary for a Sane and Sustainable Future (London: Routledge, 1988), p139-142.
21 Madge, Pauline. „Ecological Design: A New Critique." Design Issues , Summer 1997: p 50.
22 Charles J. Kibert, Jan Sendzinmir, G. Bradley Guy. Construction Ecology - Nature as the basis for green buildings. Spon Press, 2002.

1.7 Vision into the Wildness

The Romantics initiated the first domino effect that steered world philosophies into considering natural systems dynamics, an initiative against overreliance on pure scientific Rationalism founded on direct lines of cause and effect. This shift was highlighted by William Blake's quote "May God keep us from single vision and Newton's sleep[23]". German Philosophers like Goethe and Kant revitalized Aristotelian traditions and recurring themes like "moving order" and "patterns coupled with elaborate illustrations of plant variations[24]." Starting with a broad mechanistic framework and process criteria influencing Russian researcher Alexander Bogdanov's Tektology, Austrian biologist Ludwig von Bertalanffy's General System's Theory, and American biologist Eugene Odum's Fundamentals of Ecology[25, 26]. This influenced the Russian chemist Ilya Prigogine, contributions to the intricate dynamics of complex systems characterized by „dissipative structures" governed by energy fluxes. Prigogine's scholarly endeavors encompassed an exhaustive examination of self-organizing systems alongside the systematic elucidation of nonlinear phenomena. German chemist, Manfred Eigen took the process past their physical and chemical compositions and introduced "hypercycles" of multiple feedback loops by exposing molecules through catalytic reactions, not only did the molecules stabilize, but they replicated and evolved[27, 28].

In light of these new scientific discoveries that adopted non-linearity and self-organization, the society awarded them as Nobel laureates and duly flooded the public media with new terms like resilience, self-sufficiency, reliance, and systems. This theoretical work validated qualitative and quantitative research which combined algorithms, data collection with diagrammatic networks to reconfigure and manage human systems. From one side of the spectrum, in 1970, American sociologist, John McHale's "Ecological Context" promoted integrating ecological systems with urban systems from resource allocation, energy distribution, growth predictions, and waste management cycles[20]. On the other hand, in 1969, Jay W. Forrester's Urban Dynamics are expressed with diagrammatic illustrations and computations introducing overpopulation and overconstruction[30, 31]. Later, American Scientist Dennis Meadows and the team at MIT published the infamous "Limits to Growth" report which introduced terms like exponential growth, overshoot, and collapse of current systems[32]. The term counterintuitive insight became synonymous with systems thinking[33]. Systems thinking ultimately became a prevalent theory when working with living and non-living systems that developed theories such as panarchies, the Figure 8 diagram for adaptive cycles, S.O.H.O. systems, ongoing adaptive management developed by scientists like ecologist C. S. Hollings[34], physicist James J. Kay[35], biologists Todd & Todd[36] to name a few who developed the original insights in the late 20th century.

As the above theories and practices evolve, their synthesis always contains three key criteria for living systems identified by Austrian American Physicist Fritjof Capra's Web of Life published in 1997: structure, pattern, and process[37]. The synthesis of these three frameworks determines the success of a system. Capra adopts Prigogine's dissipative system for the Structure which encompasses analysis such as building blocks, materials, quantitative, data collection, and physical behavior[38]. The second is the Pattern of the organization developed by Maturana and Varela which maps out the autopoiesis comprehension, relationships, qualitative behavior, and organization of the system[39]. The third, Process, is coined as cognition by Gregory Bateson[40] and later elaborated by Maturana and Varela as the Process of life. These are the networks, feedback loops, attractors, nodes, self-organizing properties, interactions, connectedness, repetition, evolution, control systems, and overall system planning. We know this dynamic works because Bertalanffy claimed that open systems maintain themselves far from equilibrium through a continual flow and change while maintaining their state of dynamic balance, directly opposing the second law of thermodynamics. Now that we know the science, we can discuss the fun, designing, part.

Ecological buildings mean something unique, as architects, to everyone. Klaus Daniels, the engineer, describes the ecological building as integrating environmental factors through form and orientation analysis to optimize the building's performance. Michael Lauring argues that Ecological buildings have a cultural identity and vary over time. Biologist Janine Benyus defines ecological design as a "place-based design", where a site's unique biotic ecology and land type are the most important considerations. At the same time, materials and components must be adaptive to the existing biodiversity. Kevin Kelly agrees but redefines it as material and technology are complex and time over time, but what is important is to

"direct innovation towards the biological". However, Simos Yannas, the Architect and Educator, with a capitalist approach, argues that ecology is never meant to be sustainable because it changes over time, and architects should focus on human users, behavior, and consumption. The public will prioritize different things, and this is good news because someone will like it and bad news because someone will not like it.

With all of the above, when trying to realize Paolo Soleri's Arcology, the architect must thread together ecology, megastructures, and it's complex processes. J. B. Jackson, landscape photographer and theorist stated: "The megastructure is prior to the individual installation and presumably, more lasting. Few of us realize that there is another kind of megastructure in terms of the whole environment… This megastructure consisting of the environment organized by man can be called the public landscape." This gives a good indication of the scale of an Arcology. It is the structure that needs to be large enough to encapsulate a landscape that has ecological processes and human processes, with internal and external processes.

Architecture is induced in the Arcology to adapt to Capra's three Criteria into the design process: structure, pattern, and process and align it to its agenda. Architecture has developed aesthetic objectives far longer than it has developed functional objectives. Integrating ecological functions is a novel concept, attempted by a few such as Lewis Mumford, Ian McHarg, and John & Nancy Todd. The emphasis is to focus on the local processes that feed the larger processes until the scale is large enough to provide self-sufficient internal processes as well as self-sufficient external processes. Only then will the two systems co-exist and provide each other with symbiotic and synergistic relationships that ultimately improve the quality of life. The structure must be a megastructure to have the capacity to handle such fluxes. This structure ultimately requires to be significantly larger than buildings built today andneed a high capacity for resilience from the macro to the micro-scale.

The foundational and theoretical issue of this thesis is this is we are dealing with non-linear entities, emergent, synergies, and surprises and we can only manage these systems through an iterative process in the design phase and in the development phase. This is the foundation of the thesis design process.

23 Blake, William. 1977. Letters from William Blake to Thomas Butts, 1800-1803. Philadelphia: R. West.
24 Capra, Fritjof. 1997. The Web of Life : A New Scientific Understanding of Living Systems. 1st Anchor Books trade paperback ed. New York, N.Y: Anchor Books: p 21-22.
25 Ibid, p 42 - 46.
26 Odum, Eugene P. (Eugene Pleasants). 1953. Fundamentals of Ecology. Philadelphia: Saunders.
27 Capra, Fritjof. 1997. The Web of Life : A New Scientific Understanding of Living Systems. 1st Anchor Books trade paperback ed. New York, N.Y: Anchor Books: p 86 - 95.
28 Eigen, Manfred. 1971. "Molecular Self-Organization and the Early Stages of Evolution." Quarterly Reviews of Biophysics 4 (2–3): 149–212. https://doi.org/10.1017/S0033583500000627.
29 McHale, John. 1970. The Ecological Context. (Rev. Ed.). New York, G. Braziller (C1970): p 107 - 174.
30 Forrester, Jay W. 1969. Urban Dynamics. Cambridge, Mass: M.I.T. Press.
31 Ulak, A., (2023) "Diagrammatic Abstractions: Jay Forrester's Urban Dynamics and Its Contribution to Architecture and Urban Planning in the Late 1960s and Early 1970s", Architectural Histories 11(1). doi: https://doi.org/10.16995/ah.8284.
32 Meadows, Donella H et al. 1972. The Limits to Growth; a Report for the Club of Rome's Project on the Predicament of Mankind. New York: New American Library.
33 Meadows, D.H. 1989. System dynamics meets the press. Syst. Dyn. Rev., 5: 69-80. https://doi-org.proxy.lib.uwaterloo.ca/10.1002/sdr.4260050106.
34 Holling, C. S. "Understanding the Complexity of Economic, Ecological, and Social Systems." Ecosystems (New York) 4, no. 5 (2001): p 390–405.
35 Kay, James J., et al. "An Ecosystem Approach for Sustainability: Addressing the Challenge of Complexity." Futures : the journal of policy, planning and futures studies 31, no. 7 (1999): p 721–742.
36 Todd, Nancy., John Todd, and Nancy. Todd. 1994. From Eco-Cities to Living Machines : Principles of Ecological Design. Berkeley, Calif: North Atlantic Books.
37 Capra, Fritjof. 1997. The Web of Life : A New Scientific Understanding of Living Systems. 1st Anchor Books trade paperback ed. New York, N.Y: Anchor Books: p 160 - 176.
38 Prigogine, I. 1975. "Dissipative Structures, Dynamics and Entropy." International Journal of Quantum Chemistry 9 (S9): 443–56. https://doi.org/10.1002/qua.560090854.
39 Maturana, Humberto, and Francisco J. Varela. 1980. Autopoiesis and Cognition : The Realization of the Living. Dordrecht, Holland ; D. Reidel Pub. Co.
40 Bateson, Gregory. 1979. Mind and Nature : A Necessary Unity. 1st ed. New York: Dutton.

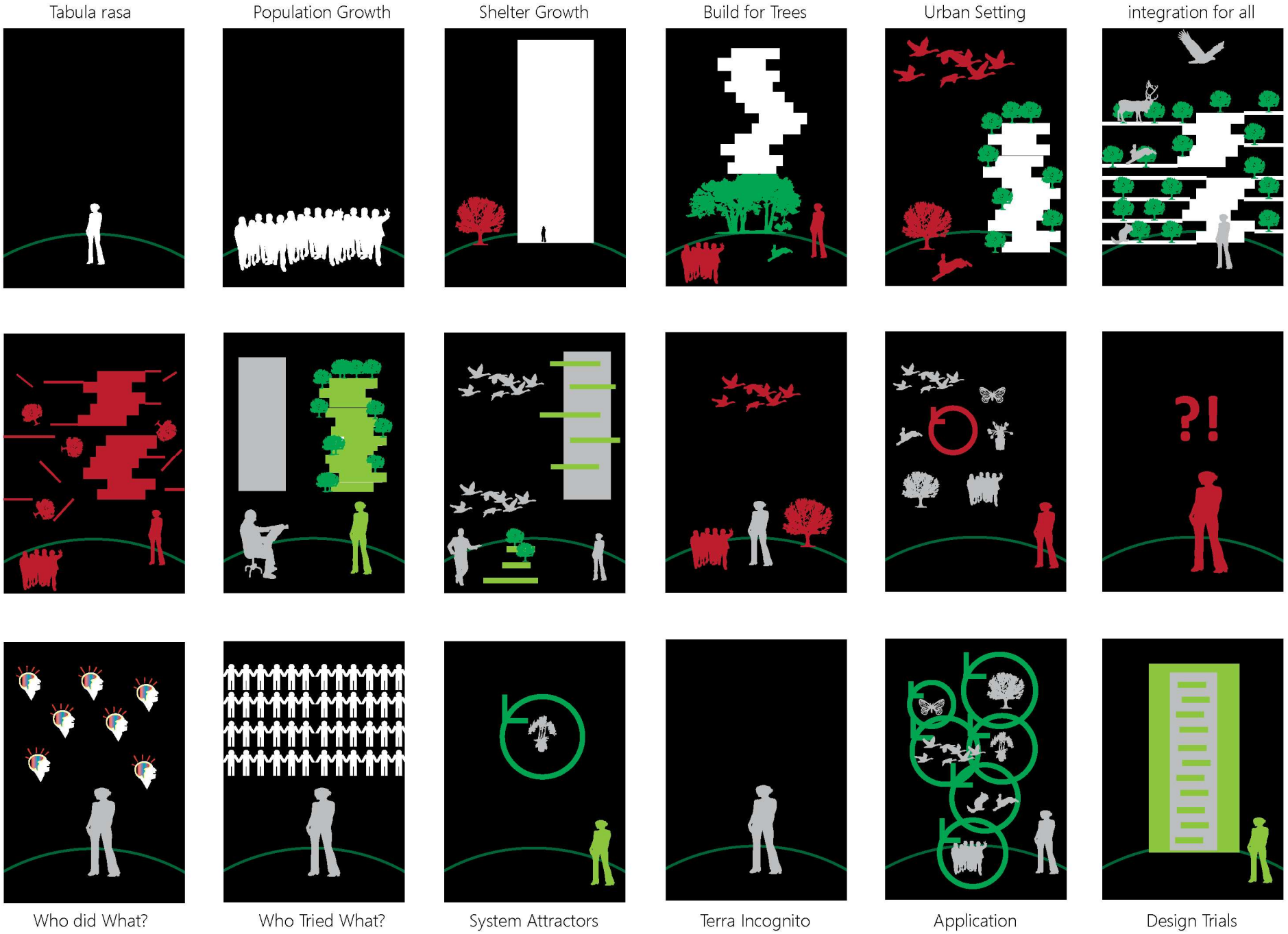


Figure 1.8.1: Author‘s illustration - as Man Thinketh - What is an architect to do??

1.8 Iterative & incremental optimization cycles is the way

Ecological megastructures like Arcologies are doomed to failure if their form always and finally dictates their function. Success in a design project hinges in an ecological design on prioritizing a system that merges several subsystems. This is a granular exercise that must precede the final design. Predicting the optimal form without a thorough investigation of complex internal interactions will fail. Instead, the merging of these systems will organically emerge over time through cycles of iterations and ongoing incremental optimization.

If at first you don't succeed, try, and try again is advice that has proved itself for generations. Could it be because we are living organisms and proof that systems thinking requires iterations? It might be when dealing with complex systems, the design "must be seen as setting in process the evolution of a built environment evolves to meet the evolving needs of users and which can adapt to fit into changing environmental conditions… [so] our construction can fit into an evolving dynamic biosphere[41]". In layman's terms, it is a moving target, and solutions must move, and architecture can not be a static icon, architecture needs to be a verb.

Systems thinking emphasizes the value of the ability to respond to feedback loops. This requires flexibility in architectural building blocks, design, and dynamic structures but more importantly, we are required to integrate adaptive architectural systems and control systems that collect feedback through constant feedback.

When the design issue is unclear and even unknown then the solution will have to be a combination of iterative and incremental solutions that evolve with a constant stream of feedback. For computing, this process is referred to as Agile software development, published in 2001[42], and in systems thinking this is called ongoing Adaptive Management a term coined by James J. Kay. To hammer the point home, today, the success of ChatGPT has been developed by a team at Google, who published the model of a transformer, this transformer is dependent on matrixes that iterate data through a focused lens, and the globalization of ChatGPT which generates constant feedback loops is key to its success[43].

Incremental optimization cycles leading to a finallized solution are ultimately detrimental in ecological megastructures and must be developed to be actively changeable. The phases of architectural design begins with the vision and design, and in this collaborative interdisciplinary process, iteration, iteration must be constant, Artificial Intelligence may be a useful tool. AI tools such as Adobe's generative AI, Midjourney, Dall-e, ChatGPT provide a constant stream of variations. The form of Architecture requires flow and collaboration with its designers and users and contains a complexity that is difficult to manage, govern, and monitor, without adopting new tools. I will explore these new AI tools in design and image generation in this thesis conclusion as a way of pointing to the future.

---

41 Kay, James J. et al. 2002. Construction Ecology: Nature as the Basis for Green Buildings. London; Spon Press: p 101 - 102.

42 Manifesto for Agile Software Development, accessed February 28, 2024, https://agilemanifesto.org/.

43 Vaswani, Ashish, Google Brain, Noam Shazeer, Niki Parmar, Jakob Uszkoreit, Llion Jones, Aidan Gomez, Łukasz Kaiser, and Illia Polosukhin. 2017. "Attention Is All You Need." https://arxiv.org/pdf/1706.03762v5.pdf.

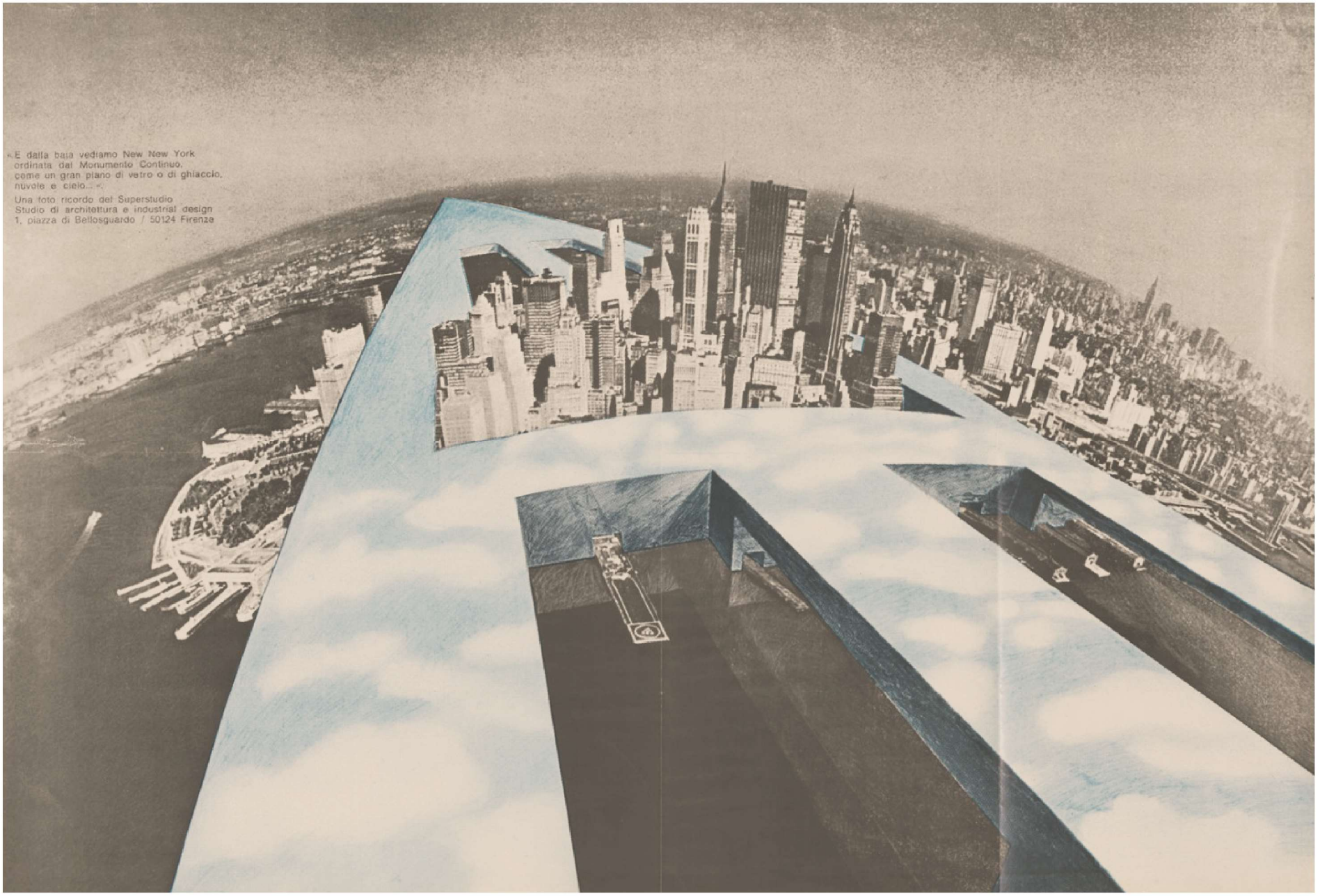


Figure 1.9.1: Superstudio‘s perspective drawing of The Continuous Monument in 1969

1.9 The Arcology Development in this thesis

The objective of this thesis is sectioned into the following:

1. Integration of complex systems and globalized solutions with the oversimplification of their systems will lead to failure in an Arcology Project. Open ended processes are the key.

The first question will be addressed in the introduction of today 's misconceptions and concerns of ecological megastructures. The comparison of Green, Sustainable, and Ecological structures is discussed to pinpoint their variances. The potential and advantages of an Arcology will then be addressed.

2. What are the concerns and challenges of megastructures and archologies? How can I integrate miniature systems and Mat Buildings? What are the lessons learned for designing an Arcology?

The Second question is a literature review of the history and beginning of Arcology. The influences that began the technological and environmental rift in the urban environment. The history, rise, and fall of the Megastructuralists in the 60's and their significant projects. The indigenous urban design of Mat Buildings and the flexibility they provide for Architecture. Finally, the history of designing an Italian Hilltown Aesthetic on a mega-scale. A conclusion that combines the lessons learned from historical analysis and case studies that attempted to merge ecological systems within the architecture.

3. What processes exist in the Niagara Falls Escarpment that can be used to flow interdependently within my Arcology?

The Third Question investigates the context of Niagara Falls on multi scales to develop reciprocal relationships and potentials for the Arcology as an interdependent structure that adds to the experience of Niagara Falls. This will explore the urban and ecological processes within Niagara Falls. This will be determined through systems thinking and existing structures and patterns will be exposed.

4. What processes do I need and what systems can be developed for a complex system for an Arcology?

The Fourth Question addresses systemizing a complex system, synthesizing the data to develop an organizational structure and rules for designing an Arcology. Defining the paradigm shift and highlighting the gap between abstraction of systems thinking and architecture. Developing systems that highlight key interactions within four prime sub-systems: Heat, Water, Waste and Energy Systems. Each of these systems has processes that must be unpacked to conceptualize the capacity of my iteration of the Arcology. The Processes have been unpacked are labeled under Structural Processes, where it analyzes the form and the limits of the structure. The second is Human processes that analyze human needs from shelter to food to the wastes they produce. The third is Ecological Processes, which in this case analyze water and plant requirements.

5. What are the potential benefits of an Arcology?

The Fifth Question will be explored in sections and in calculations of what an Arcology can provide for the individual resident and in the city. Although the synergistic relationships cannot all be predicted, the focus must be on the process. The obvious benefits will be listed for the individual and the expansion of the Niagara Escarpment will be discussed.

6. What are the limitations of an Arcology?

The sixth question focuses on the thesis' limitations: Cost, Collaboration, Commitment, Control, Communication and Coordination. To be discussed in the mplementation phase and the phasing and adaptive governance. Major limitations for megastructures that chaos are major disruptions such as war, pandemics, fire, terrorism, earthquakes, and technological failures. Paradoxically, the very feature that enables an ecological megastructure's self-sufficiency – its substantial internal water storage – may pose a greater threat to flooding than potential fire from flammable flora. While fire safety remains a crucial consideration, the risk of flooding due to the sheer volume of contained water warrants careful attention during the design & management of these structures.

7. How can Artificial Intelligence assist in the design of this Architecture?

The seventh question is a delve into generative Artificial Intelligence with a brief overview of the existing tools that could be used to assist in the development and generation of ideas. This exploration intends to determine the cons and pros of this new tool.



Figure 1.10.1: Interior Perspective of an Ecological Megastructure generated by Midjourney v 5

1.10 Thesis Structure

1. Introduction –

1.1 Here Be Dragons

Present-day urban planning issues and concerns.

1.2 Introduction

Exploring a new building typology - Paolo Soleri's Arcology.

1.3 The Dream

Rationale for the need for an ecological megastructure is a search for hope.

1.4 Ecological architecture – what does work?

1.5 Ecological Architecture- what does work?

1.6 Definition: from Green to Sustainable to Ecological to Arcology

Principles and history of terms.

1.7 Vision into the Wilderness

Brief evolutionary overview of systems thinking.
Key criteria for systems thinking.
General opinions on ecological buildings and their priorities.

1.8 Iterative & Incremental optimization cycles is the way

The intention and importance of Iterations and incremental processes, feedback loops for optimization, role of AI in enhancing the design process.

1.9 The Arcology Development in this Thesis

Questions to address in this thesis.

1.10 Thesis Structure

2. Literature Review - Ecological Megastructures

The development of an Arcology that encompasses ecosystems and urban settlement is a multidisciplinary system that was not developed to an extent that portrayed classical Arcology as a functional system. This section will integrate systems that do function: the engineered systems of Megastructure and the urban flexibility of Mat Building. This will further develop the precedents that integrate both ecology and megastructures and discuss lessons learned.

3. Niagara Site and Ecosystems Analysis

The Niagara Escarpment cycles and patterns will be identified. This will further take us down a multi-scale analysis of the Abiotic, biotic, and cultural processes to further the surrounding of Niagara Falls to develop the Arcology as an interdependent structure.

4. Systems Analysis

4.1 The Ecosystems Approach

Overview on ecosystem's approach, systems thinking & SOHO

4.2 Reframing the Problem

Synthesizing a framework, point out leverage points, etc.

5. Design Processes

5.1 Designing the Processes of an Arcology

Step-by-step procedure for the Arcology with set intent.

5.2 Conceptualizing the Overall Framework of an Arcology

5.3 Process Analysis

Rules of Thumb, Design Guidelines, Human Processes / Ecological Processes.

5.4 Key Interactions within the Network

Leverage Points within the System for Heat, Water, Waste & Energy systems.

4.5 Adaptive Governance in an Arcologies

Hypothetical analysis for Adaptive Governance.

4.6 Arcology Implementation Approach

Proposed Implementation and Naturalization in Niagara Falls.

4.7 Phasing the Arcology

Proposed Phasing and Intent.

6. Adaptive Design Proposal

6.1 Arcology Proposal - Visualizing the Arcology

Step-by-step procedure for an ecological megastructure with set intent.

6.2 Arcology Proposal - Sectional Perspective & Key Interactions

Sections & Diagramatical analysis to show Key Interactions (leverage points).

6.3 Generating AI Images of a Megastructure

History of Generative AI, AI Interpretations in 3D for quick turn arounds.

6.4 Generating AI Images for an Arcology

Generative AI's advantage for quick turn arounds.

6.5 Quantifiable Benefits: Deliverables for Arcologies

Water cycles, benefits per residence & volume estimation.

Conclusion

Overall analysis of the system will be concluded.

I would suggest all Young Architects
of the world to cultivate
an eye to see nature,
a heart to feel nature,
and I would suggest
the boldness to follow nature and all hazards.

- Frank Lloyd Wright



LITERATURE REVIEW, THEORY TO PRACTICE & PRECEDENTS

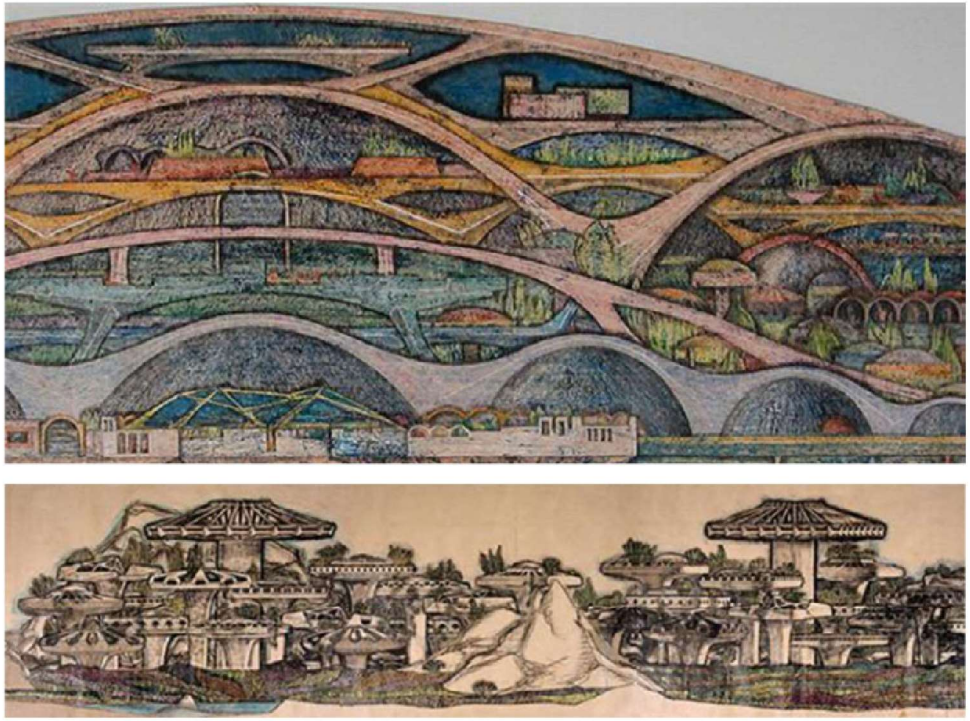


Figure 2.1: Paolo Soleri - Arts and Crafts Villiage 1961 and Macro Cosanti Bowl Cut-out 1964- Sketch

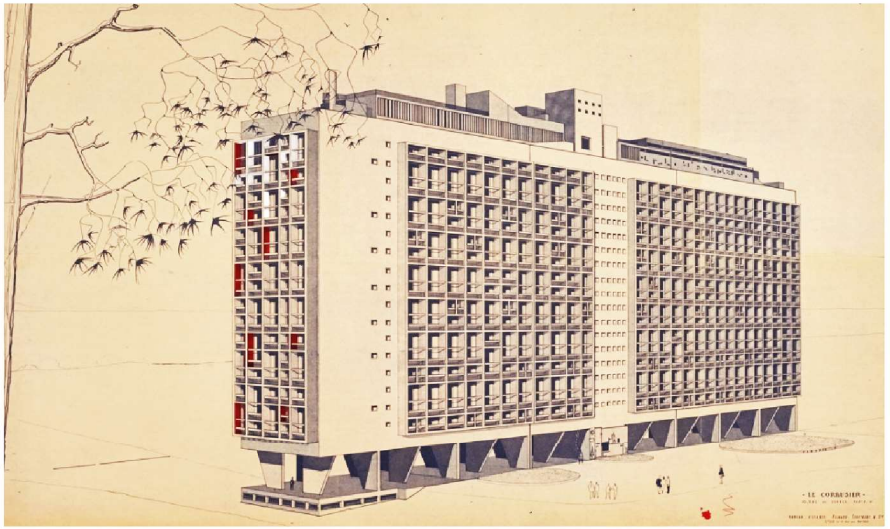


Figure 2.2: Le Corbusier‘s Elevation Sketch of Unite d‘Habitation



Figure 2.3: Le Corbusier‘s Unite d‘Habitation in Marsielle

2.1 The Arcology Vision and it's Building Types

In conceptualizing a building that seamlessly integrates natural systems, one might envision a multi-story dwelling that incorporates multi-story ecosystems to support this expansive habitat. However, the inherent layering found in the natural world, may not adapt in flat, multi-story levels structures. This inherent contradiction poses a significant challenge when attempting to harmonize natural systems with human-made structures. This approach appears to conflict with Darwin's principle of "Natura non facit saltus" (Nature does not make leaps). Unlike rigid architectural forms, natural systems thrive on gradual transitions, often utilizing natural slopes or adaptive mechanisms to foster seamless interactions. To advance ecological design, it is essential to recognize and incorporate this principle, moving beyond the constraints of rigid, layered configurations. By identifying critical leverage points, we can bridge the gap between natural and human-made systems, fostering a more integrated and sustainable approach to architecture that honors the inherent continuity of natural processes. The sublime is achieved through the gradual accumulation of experiences and subtle variations over time, after enduring hard work and dedication, creating a unified and profound moment[1].

Finding a composition to combine ecology into architecture is a search both for reorganizing massive structures and working with miniaturized subsystems. It also reorganized infrastructures, hierarchies, and synthesizing the building into something that cannot be anything less than a megastructure. To achieve a unified design that integrates the scale of megastructures and the efficiency of miniaturization, a renewed exploration of Paolo Soleri's Arcology is essential.

The development of ecological design visions initiated as early as the work of Patrick Geddes, evolved into a wide range of environmentalists, globalists, megastructurists, metabolists, structuralists, practicionists. Each emphasized the need for adaptable, evolving structures that grew in response to urban needs. It suggests that the dynamic system must be capable of supporting large populations with variable functions. Such a construction must be flexible, scalable and integrate a large environmental context, and be able to lead the way to a future and sustainable future.

Twentieth Century Architect and urbanist, Le Corbusier, built in the 1960's Unite d'Habitation[2] in Marseille accomodates a multi-family residential project for 1,600 residences. The massive eighteen-floor concrete structure accommodate both public and private spaces that include running tracks, clubs, a kindergarten, gym, pool, shops, medical facilities and even a small hotel. It was celebrated as a "city within a city" and a residential highrise with a "vertical garden city". In contrast, the concept of the Arcology, takes the Unite d'Habitation and makes it into an even larger mega project. Paolo Soleri's Arcologies visualized these variable complexities, interweaving of hierarchies, and multi-scaled indigenous architecture, with multiple functions. However, as shown by Unite d'Habitation the understanding and integration of Ecology and Architecture came well before Paolo Soleri.

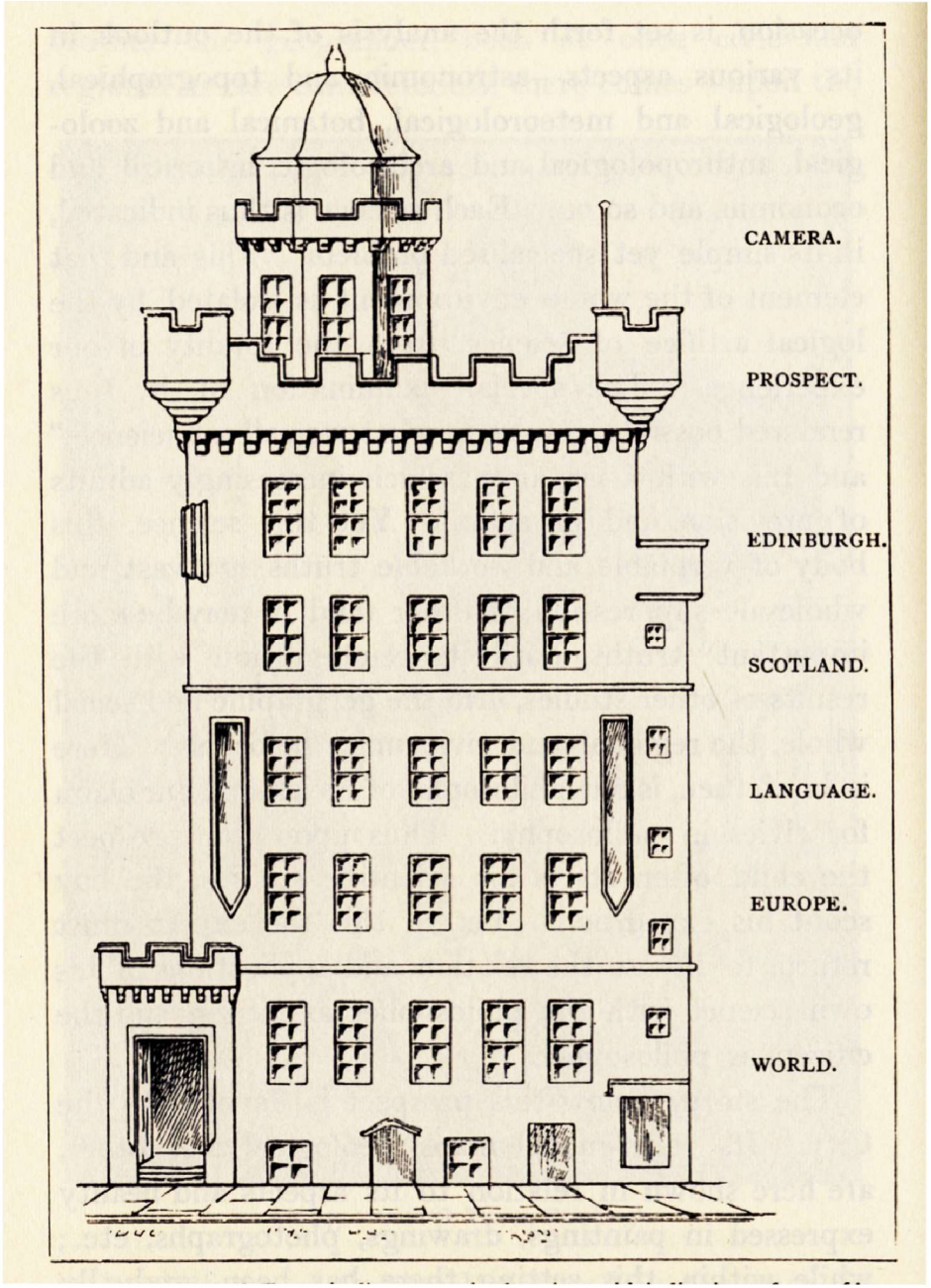


Figure 2.4: Geddes‘s Outlook Tower

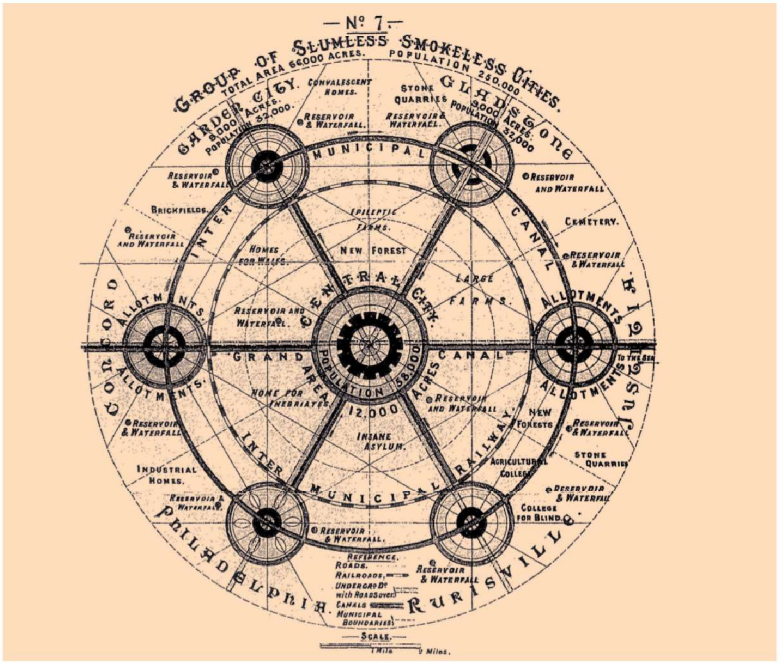


Figure 2.5: Ebenezer Howard‘s Garden City

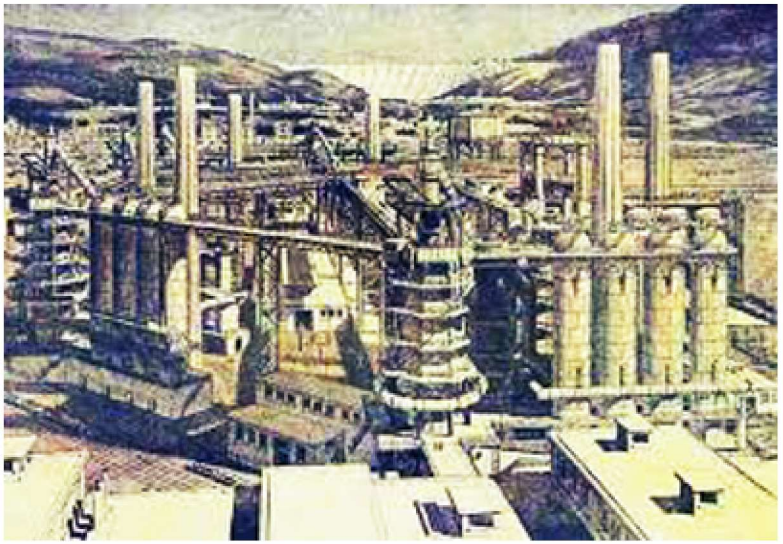


Figure 2.6: Tony Garnier‘s Cite

2.2 Ecological Urbanism: Early Foundations and Precedents

Patrick Geddes (1854 – 1932), the Scottish botanist, sociologist, educator, artist, and one of the founding fathers of modern town planning, developed a view that man should not rise above nature but work with nature[3]. Influenced by the French sociologist, Fredric Le Play, whose social philosophy centered on: lieu, travail et famille (place, work, and family). Geddes formulated his urban philosophy that revolved around: place, work, folk, environment, function, and organism[4]. In 1892, Geddes purchased a six-story building in the north of Edinburgh's Royal Mile. The lower four levels were used by Maria Short as a Public Observatory. Geddes called his tower the Edinburgh Outlook Tower. The structure was used as an exhibition where the visitor started at the top level, with an open gallery and camera obscura of Edinburgh. As the visitor climbed down a level, it would expand the visitor's perspective with views of the city of Edinburgh, then regional and geographic forms of Scotland, then cultural zones, and then Europe and the Globe[5]. The novelty of this structure brought awareness to the concept of town planning and the interactions between man and his environment. Patrick Geddes went a step further, with his proposal of the Temple of Geography, drawn by Paul Louis Albert Galeron in 1902 after Geddes`s early sketches in 1901[6]. This intended to be a two-story exhibition, where the visitor started in the basement and began his accent two stories to the top. The content included biology, anthropology, ecology, geology, astronomy, and geography[7]. The later structure was never built[8], but his contribution to integrating the city into its environment initiated many urbanistic proposals and movements such as Ebenezer Howard's Rurisville or Garden City, Tony Garnier's Cité Industrielle, Otto Wagner's die Großstadt, and Le Corbusier's Ville Radieuse[9].

In spite of sociologist, architectural and urban critic Lewis Mumford's admiration for Geddes's work, his criticism for his `closed system`, a rigid view of a dynamic system, and a proposal of a `final synthesis` was unleashed in his publication Geddesian Gambit, and Mumford hit the nail on the head in his critique.

> "Synthesis is not a goal: it is a process of organization, constantly in operation, never finished. An attempt to produce a single synthesis good for all times, all places, all cultures, all persons is to reject the very nature of organic existence… Geddes never realized how static his system had become or how limited and stultifying was his graphic vocabulary…"[10]

Mumford concept was previously suggested by Leon Battista Alberti (1404-74), who is most known for his mathematical proportion system, and the subsequent use of the module. However, Alberti is also known for his doctrine on organic unity, where he formulated that the fitness of the building is the quality of connecting its parts and mathematical module alone is not sufficient. Johann Wolfgang Von Goethe (1749-1832) playwright, poet, philosopher, and father of organic thought in Goethean science had searched for a connection between art and nature. In his study of botany, Goethe's research began with trying to formulate a law that regulates the growth in form, however, the search for this seemed impossible, and instead, Goethe pointed out the multiplicity in variations and the unity as a whole[11].

Lewis Mumford echoes the environmentalist's concerns leading to Scottish landscape architect Ian McHarg and American forester, planner, conservationist, and regional planner Benton MacKaye. These environmentalists distinguished their work by conserving and protecting ecological systems with principles that encompass a holistic perspective. Greatly influenced by Geddes, MacKaye proposed eccentric schemes, and fluid romantic undertones, with an acute atonement to regional planning. His approach to planning practices offered site modeling and special interventions with ecological solutions. He aligned the design to work with watersheds, river systems, and ecological natural infrastructures[12]. In 1928, MacKaye's compiled his prototyes of the 1910's and 1920's in his publication: The New Exploration: A Philosophy of Regional Planning. Similar to Chase's The Tragedy of Waste or Mumford's The Golden Day, MacKay attempted a holistic synthesis between trends and regional planning and ends the book discussing a "territorial lacework" with global networks[13].

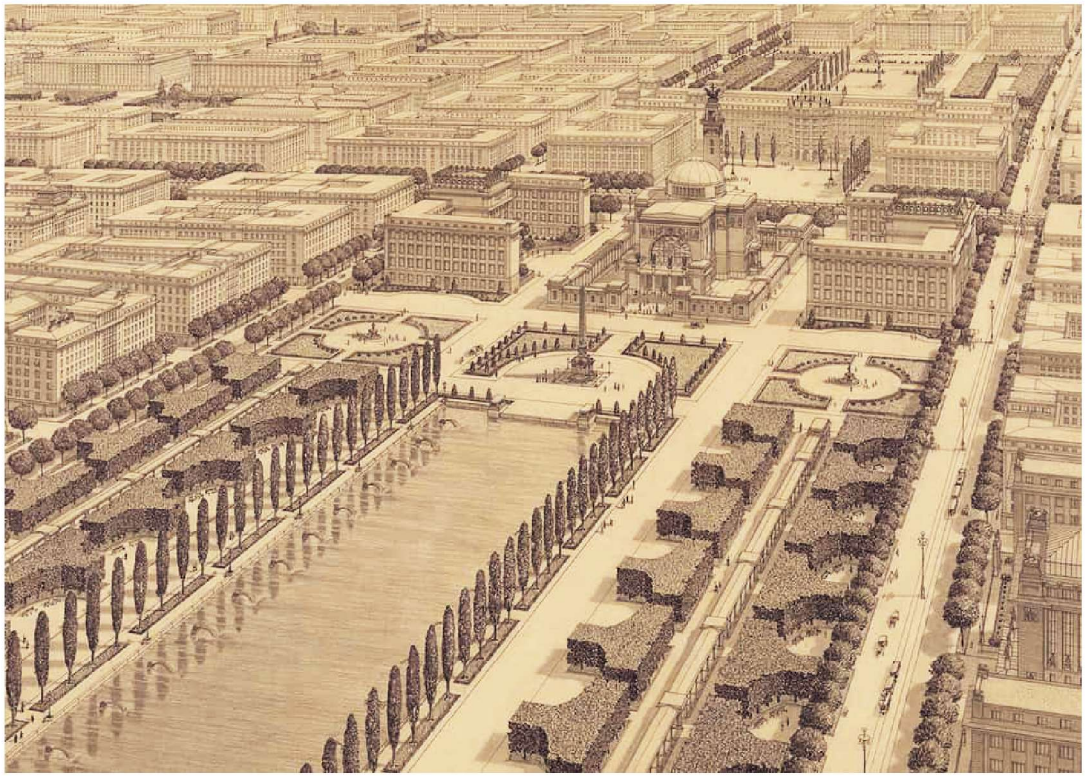


Figure 2.7: Otto Wagner‘s die Großstadt

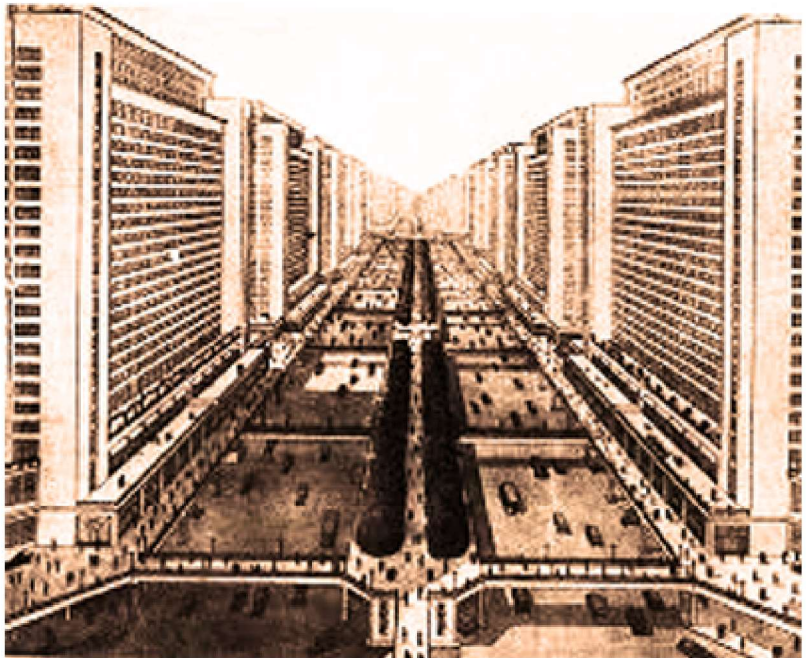


Figure 2.8: Le Corbusier‘s Ville Raduise Perspective



Figure 2.9: Le Corbusier‘s Ville Raduise Elevation



Figure 2.10:Benton-MacKaye-in-1934-at-the-Appalachian-Trail

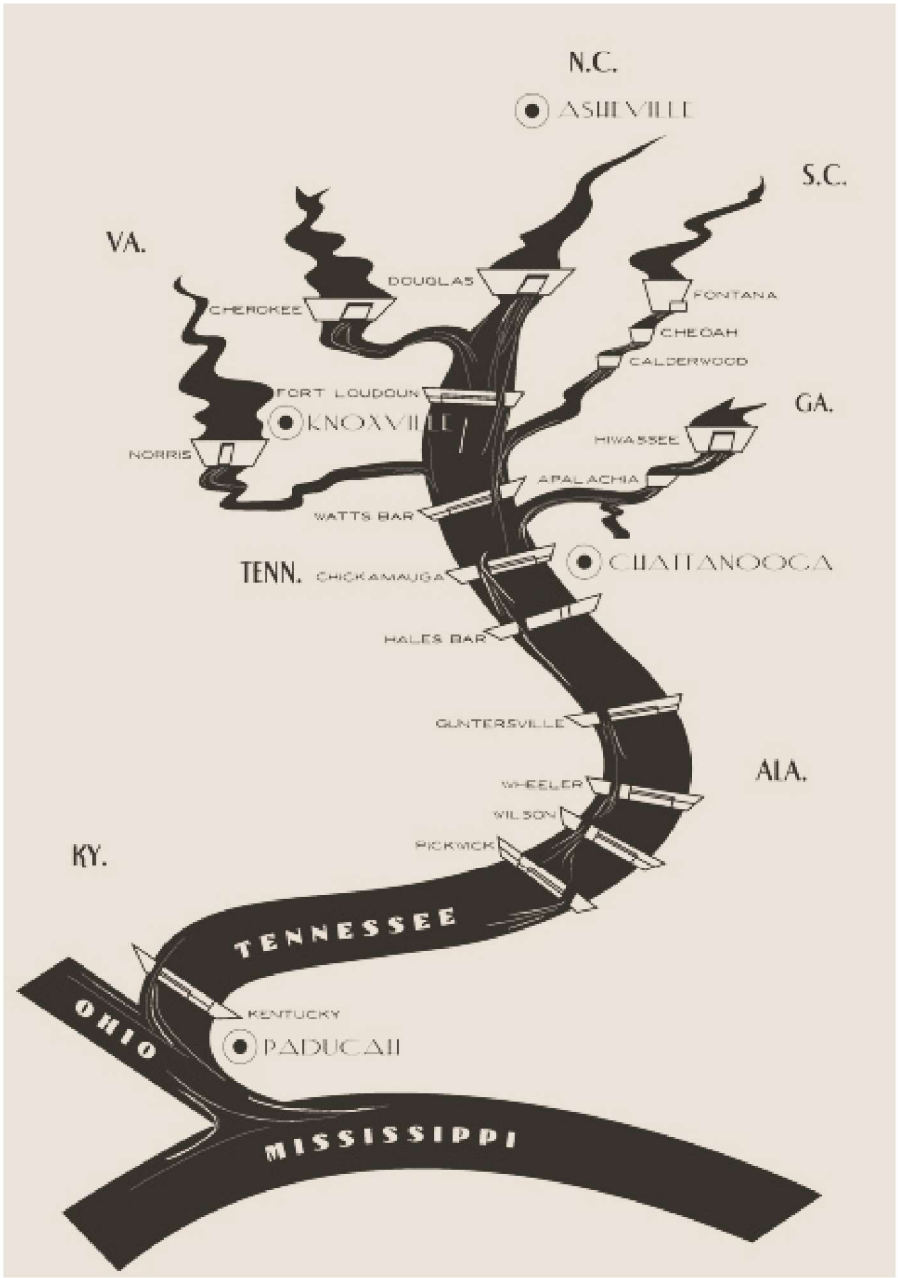


Figure 2.11: The Tennessee Authority -
Diagram of the TVA‘s water control systems

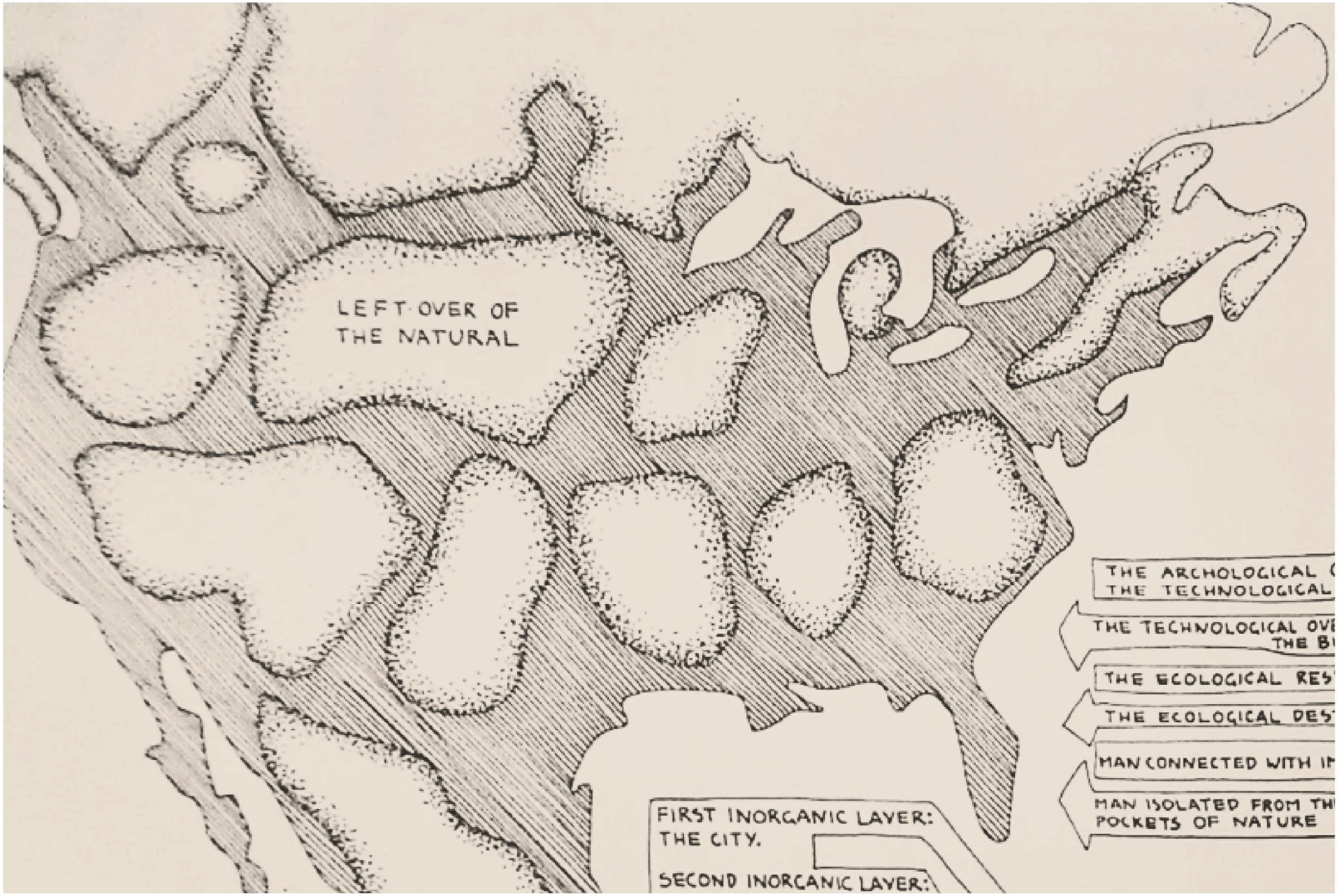


Figure 2.12: Paolo Soleri‘s sketch representing Doxiadis’s Ecumemopoly

MacKaye is best known for his work on the Appalachian Trail an initiative to resolve the flooding concerns initiated by the Tennessee Valley Authority (TVA). Depression era infrastructure work on dams and roads that was the brainchild of public administrator, lawyer and chairman of the Automic Energy Comission (AEC) David Lilienthal and supported by President Franklin Roosevelt[14]. The TVA was a series of eleven hydroelectric dams over 650 miles dubbed as "water control systems[15]". Initially, the TVA offered modern technology and its integration between natural systems which piqued the interest of conservatives, social theorists, planners, engineers, and architects. Unfortunately, the TVA took a sharp ethical turn when it was integrated into the national networks of wartime production, and David Lilienthal was promoted as head of the new Atomic Energy Commission and the vision for integrating home and region became archaic and remote[16]. This coached a movement that depended less on governmental intervention and more on collaborative social effort.

Greek Architect and city planner Constantinos Apostolou Doxiadis's Ecumenopolis[17,18]. Derived from the Greek oikumene for the world and polis for the city. With a keen interest in a global approach and integrating human settlement into the environment, Doxiadis developed major buildings, complexes, infrastructures, and regional studies in Greece, Spain, Denmark, Pakistan, India, Iran, Iraq, Ghana, Sudan, Libya, Syria, Venezuela, United States, and Australia. His journal, Ekistics, was developed with Jaqueline Tyrwhitt, and aimed to keep architects and planners in developed countries up to date with relevant global practices.

To integrate his vision with other global thinkers, in July 1963 Doxiadis organized a cruise through the Aegean to arrive in Delos for his first conference composed of leading scientists, architects, engineers, and administrators from twelve countries. This cruise was modeled after the 1933 CIAM meeting that resulted in the modern movement about city and urban planning that had traveled from Marseilles to Athens and resulted in the Charter of Athens the global manifesto of modernist urbanism. The charter of Delos was meant to replace the Charter of Athens has developed by Sigfried Giedion, and Jaqueline Tyrwhitt, with external participants such as Buckminster Fuller. With a focus on an integrated human settlement, the charter encouraged urban development, and efficient urban infrastructure, and pushed for forged urban connected networks to create global systems of urban densities. The charter's agenda emphasized on managing local materials, economical housing, and social services, and included ecological and environmental concerns. This dramatic urban explosion encouraged urban sprawl in an unprecedented wave of change. Doxiadis revised his Ecumenopolis with an interdependent network of ecologies (forests, lakes, rivers etc) which he called Ecumenokepos ["World Garden"] but with so much invested in urban development that dream dwindled without funded stewards. In 1974, Doxiadis developed his more expanded vision, Anthropocosmos ["the World of Man"] that defined "the system of our life expressed by human settlements so clearly that it can contain every part, aspect, expression or opinion, known or unknown, foreseen or unforeseen."

The implementation of such a global plan resulted in Doxiadis's continental plan of unhealthy urban patches connected by roads, Paolo Soleri's continental plan envisioned a continuous structure that seemed to contour to the topography of the terrain. This was like the megastructuralists' Comprehensive City project, proposed by Mike Mitchell and Dave Boutwell in 1969 and published in Domus magazine. The design proposed one large linear structure that stretched from New York to San Fransisco. Although Reyner Banham related this scheme to Le Corbusier's Ville Contemporaine pour trois millions d'habitant in 1922, it seems to align itself more closely to Le Corbusier's Fort l'Empereur, Algiers proposed in 1931. Mitchell and Boutwell did not assume this was an ultimate solution but suggested it may be "one of the possibilities deserving serious consideration".

Nevertheless, this did not deter Buckminster Fuller from attempting to globalize architecture with designs such as Spaceship Earth, Dymaxion world and Geodesic domes[19], taking Architecture deeper into a more engineered system approach and the realm of technocrats.



Figure 2.13: Fuller‘s Manhattan Dome in 1960

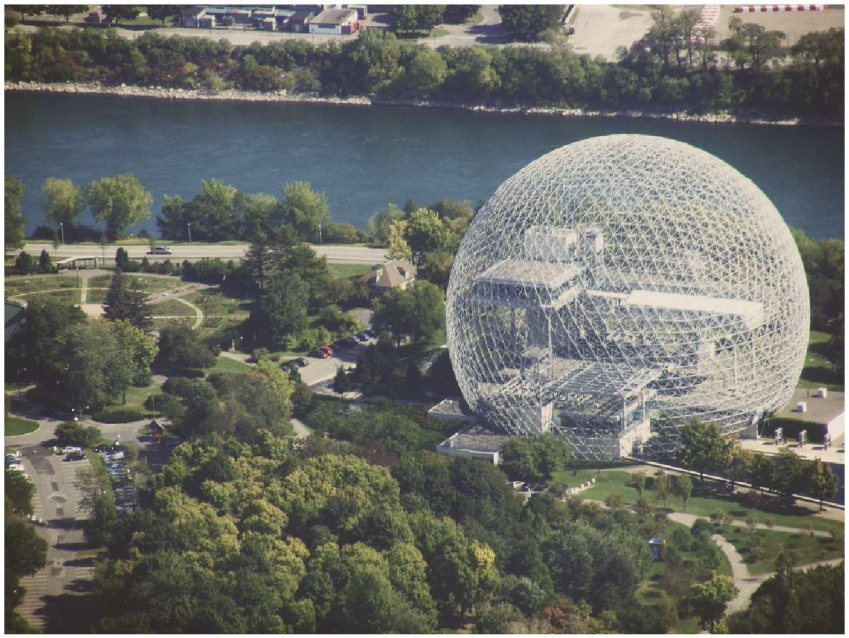


Figure 2.14: Fuller‘s Geodesic Dome in Montreal

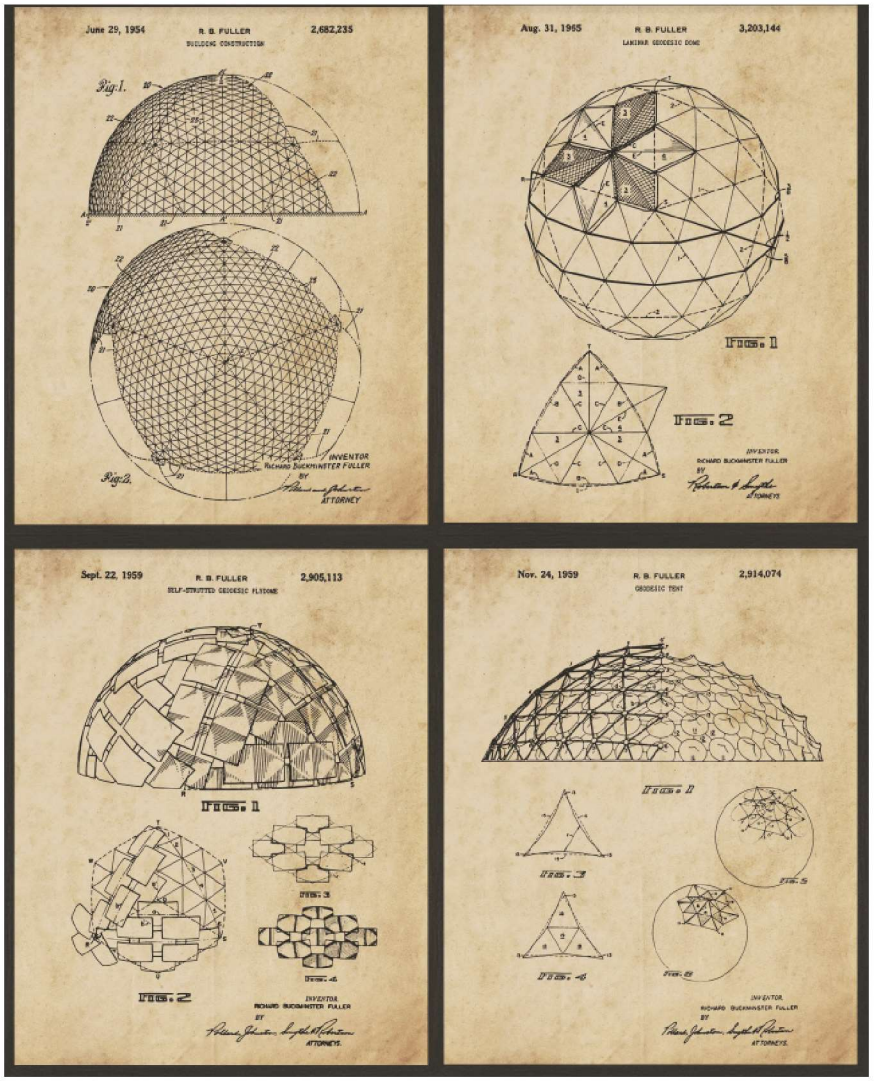


Figure 2.15: Buckminster Fuller‘s sketches

2.3 Buckminster Fuller's Technological Utopianism

With rapid population growth and economic demand for cheaper construction, Richard Buckminster Fuller developed "Manhattan Dome" in 1960. It was difficult to conceive, how this image was in an architectural magazine and not a comic book. The structure was a transparent shatterproof, glazed, wire-framed dome, over 1.8 miles in diameter, 1 mile high, imagined to be over the city of Manhattan. Fuller continues to argue that this building is ecologically and financially beneficial. As it will create a "greenhouse" effect, save on snow removal and cost of umbrellas, and help save the city money. In fact, he advocated for this design enough to claim that in ten years, the Dome would pay for itself. He further explained that this structure is best suited for colder climates. The irony is that, absurdly, he is right. If all cities in "colder climates" was magically transported to let's say, Hawaii, all its ecological and financial burdens would be resolved. What Fuller is saying is metaphorically aligned with putting Manhattan under a microscope, which in the winter shelter the city snow and rain issues, during the summer, however, Manhattan would be burned to a crisp. This proposal was never actualized but this design won the competition[20]. This was the beginning of a variation of megastructures with the intention for a globalized solution and an indication of a globalized solution. Fueled by the global distribution of photographs from Apollo 8 spacecraft[21], the Earth became an icon for an emerging ecology movement. Inspiring American biologist, Steward Brand, to create a publication with no-nonsense ecological information and do-it-yourself gadgets called Whole Earth Catalog[22].

American architect, systems theorists, writer, designer, professor, and futurist, Richard Buckminster Fuller coined with the catchphrase "think globally and act locally[23]". Fuller and his student, Shoji Sadao, designed the first geodesic dome for the United States Pavilion at the 1967 Montreal World's Fair. This iconic structure measures 250 feet (76 meters) in diameter and clad in transparent acrylic lens, served as a powerful architectural expression at the time[24]. Reynar Banham proclaimed that the gigantic geometric framed pavilions made "Montreal the capital city of megastructures in Expo Year 1967[25]". Comically, although Fuller's Bubble was virtually seen from any angle, against the backdrop of the Soviet Pavilion, the "flying roof".

Megastructures, an idea that took the world by storm in the 60's, were worlds that incorporated engineering and architectural features like space frames and systems for maximum flexibility with a futuristic sci-fi attitude. They were massive buildings with the capacity to hold multi-functions and multi-structures and so much more than sheer scale. Ralph Wilcoxen, of the Planning Librarian College of Environmental Design at Berkley categorized Megastructures with given factors. Its great size, its modular units, the capacity of great or ``unlimited expansion``, a structural framework with multi-scaled units, which can be built or plugged in or clipped on, and a structural framework that has a life cycle that is larger than its parts[26]. The description of such a megastructure was visualized by Le Corbusier, thirty years earlier, in his Fort l`Empereur, Algiers in 1931[27]. Designed as a massive, monumental, porous wall of seemingly endless structure with varying infills of two-story apartments that revealed an evolving structure with multiple variable arrangements for daily life.

The potential of a multi-level, multi-scaled megastructure, was the pursuit of the 60`s and early 70`s; it was an unprecedented epoch in Architecture. Armed with Fuller's publications such as Domebook One of 1970 and magnum opus Synergetics in 1975, the public was enamored by the possibilities of cybernetics, systems theory, intuitive mathematics, and alient structures. Swiss architect Justus Dahinden and many other megastructuralists considered it an "urban structure for the future[28]". Most of the megastructures took a machine-like aesthetic to highlight their dedication to the Future. The origional futurist manifesto itself was written in the 1920's by Filippo Tommaso Marinetti who was exhausted and exasperated in the confinement of the old way. Infamously, one night of drunkenness with his friends, lashed out speeding in his automobile towards the future where he had a moment of comical clarity after he crashed his car by swerving to avoid a pedestrian.

> "Then with my face covered in good factory mud, covered with metal scratches, useless sweat, and celestial grime, amidst the complaint of staid fishermen and angry naturalists, we dictated our first will and testament to all the living men on earth.[29]"

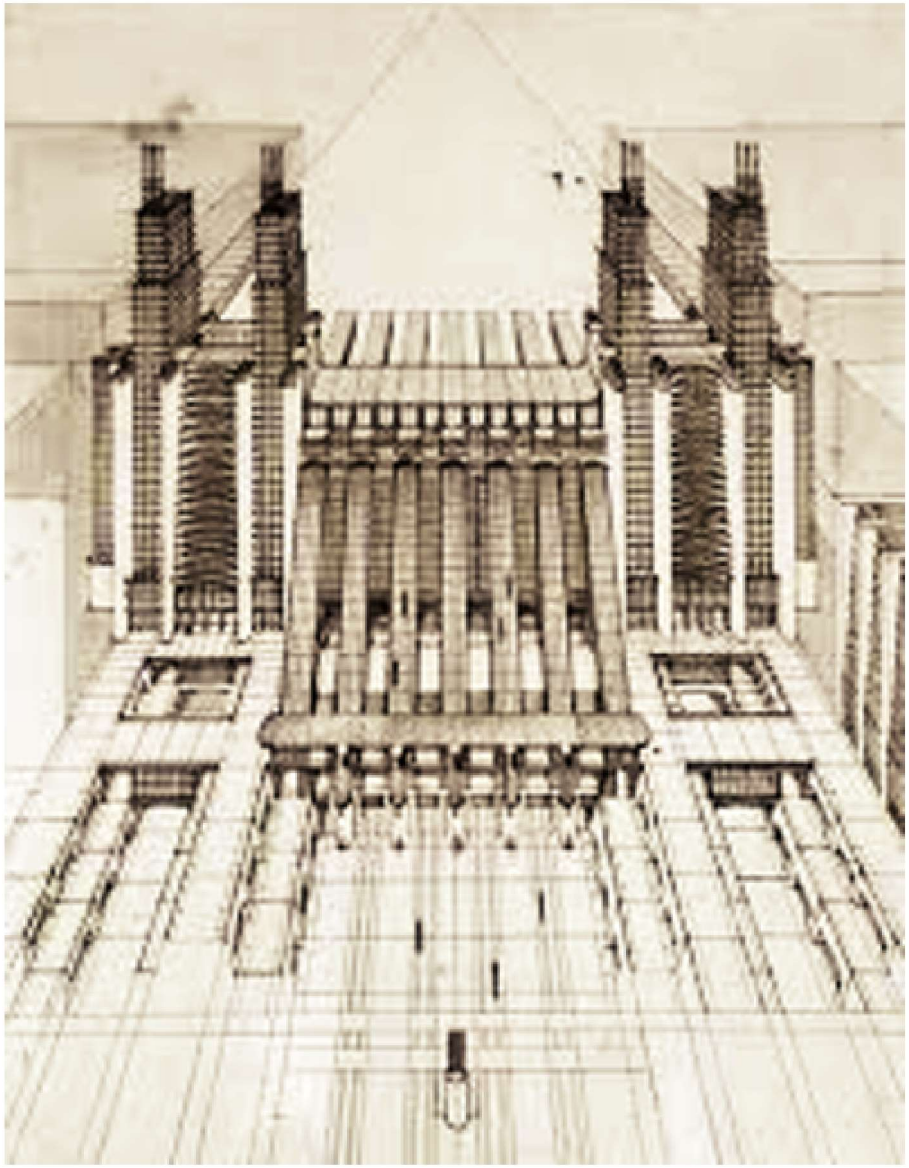


Figure 2.16: Sant'Elia's Axonometric illustrates his vision of the futurist city, where mechanized, monumental forms express technological progress and forward thinking, serving as a precursor to later megastructure concepts in modern architecture.

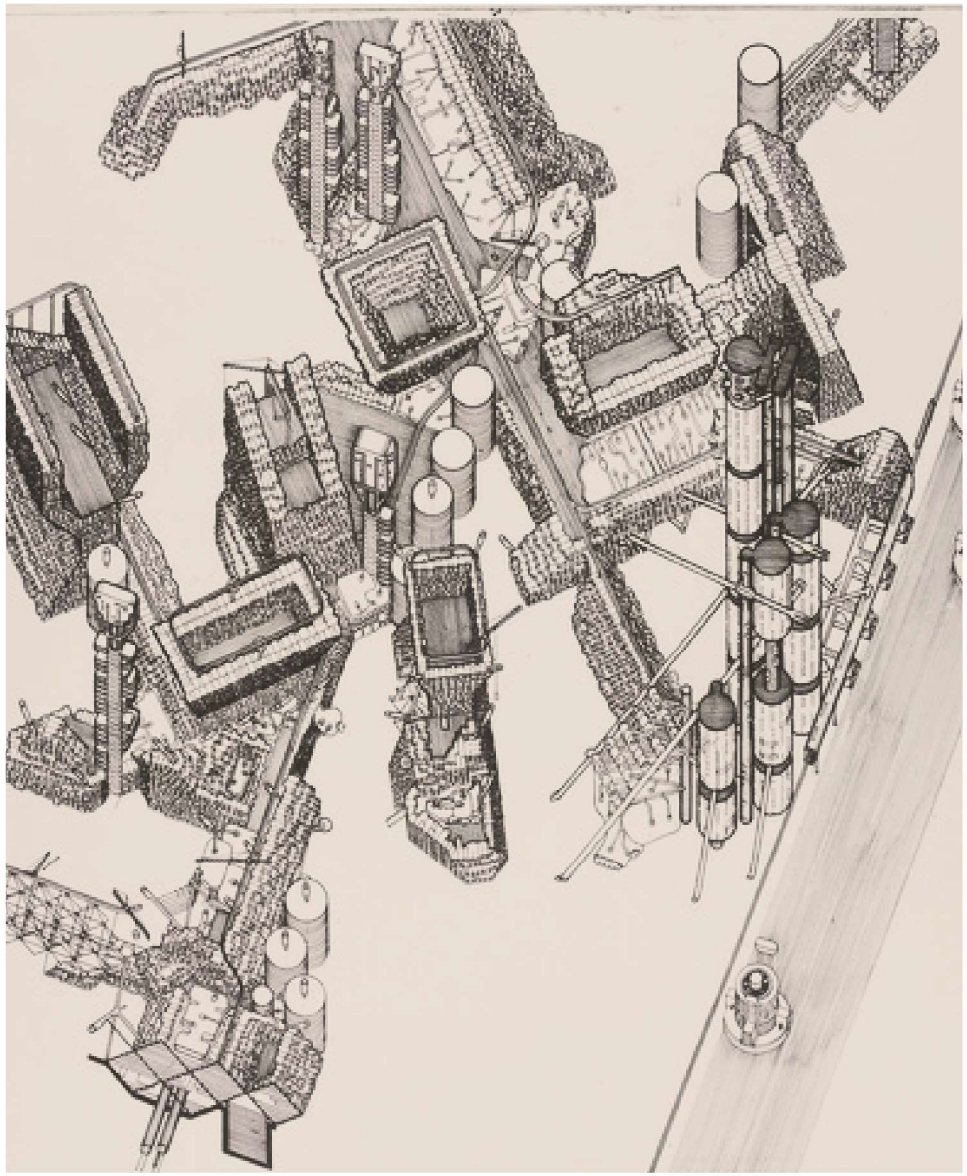


Figure 2.17: Archigram's Plug in City launches the world into the megastructure fad of the 1960's with modular units are plugged into a dynamic framework, symbolizing the integration of technology, flexibility, and adaptability towards an ever changing future.

Marinetti's exaltation of speed and the fast-paced dynamics of a machine-like city circulated in underground networks and inspired later in the 1960's the "first age of the Machine" as labeled by Reynar Banham. In the 1920's, along with Marinetti's vision of the future resonated with Antonio Sant'Elia, an Italian architect and an influential member of the futurist movement. He produced axonometric drawings of cities that reflected the future and glorified the machine age in urban form, highlighted in his writings:

> "We must invent and rebuild ex novo our modern city like an immense and tumultuous building site, active, mobile and everywhere dynamic, and the modern building like a giant machine… lifts must swarm up the facades like serpents of glass and iron… [the street must] plunge stories deep into the earth, collecting the traffic of the metropolis and connect for necessary transfers to metal cat-walks and high-speed conveyor belts"[30].

In Banham's 1960's, Archigram Group took this analogy of life in a machine literally and pushed the design to scheme a system's analysis of Sant'Elia's vision. Also in 1960's Hans Hollein's proposal for the City Interchangeable project in lower Manhattan, along with Walter Pichler, proposed a series of skyscrapers, connected by links and a mile wide turbine-like blob that unified the structure. Hollein took it a step further in his Aircraft-carrier projects. Where he revamped Le Corbusier`s 'Ocean Liner' into a machine-megastructure. His collage of the aircraft carrier, revealed a self-contained machine 'mega-silhouette' highlighted by a setting of rural rolling hills. The structure was then sunken into the ground, with only the deck used as a public space, revealing a labyrinth of modular units in the section. The section is so captivating as it exposes the inner complexities and gave the illusion of a buzzing underground life .

In the 1950's Le Corbusier's Unité d'Habitation in Marseille was designed to be like a concrete ocean liner vessel for the community that accommodated multi-uses. The building was named La Cité Radieuse, or "the radiant city" where it housed 336 apartments, a hotel, nursery, roof terrace and two shopping streets. The intension of the building was to provide relief for its inhabitants by giving them refuge from the sun, a space for green spaces and an appropriate setting for family life[31]. The 18 story structure stretched 165 meters long, 56 meters tall and 21 meters wide. The elongated wall-like structure created a two apartment layout of interlocked to form a central access corridor. Le Corbusier avoided the use of steel framing by using concrete, textured by wooden planks, giving it a more human appeal[32].

Engineered system were conceptualized in 1952 by Louis Kahn as an ideal diagram that gives a visualization of energies on a large scale for a modern city in his Traffic Circulation Project[33]. The second was the development of light weight tetrahedral lattice structures that was attributed to Alexander Graham Bell and popularized by Konard Wachsmann while working for Illinois Institute of Technology after WWII. Mies Van Rohe applied these space frame structures and created images which he called 'universal space' that can be repurposed for human use[34]. The final stage began when David Emmerich's Logemobile project in 1958 who took the Unité d'Habilitation and expressed it as a kit of parts and began arranging the apartments in different compositions. In 1958, Yona Freidman broke down the facades by using a modular, repetitive, additive approach, developed a grid network. In his project, Vue de la ville, he composed a bridge-like grid structure that towered over the city. Freedman had developed a hybrid between architecture and urban form by visualizing an algorithmic structure that accommodates the structure and its infilled parts. This design was the beginning of a new building type, described by Fumihiko Maki as a `megastructure'[35].

This vacuum of unexplored territory started a rat race between architects, where function and program were flexible and considered no longer restrictive. With the eventual launch of Cedric Price's conceptual Fun Palace project that accommodated "twenty-four hours a day for every kind of recreation and enjoyment.[36]" With its open spaces and hanging cranes that span over fixed vertical service towers and elevators, the rest of the structure was interchangeable and movable. The scale of this

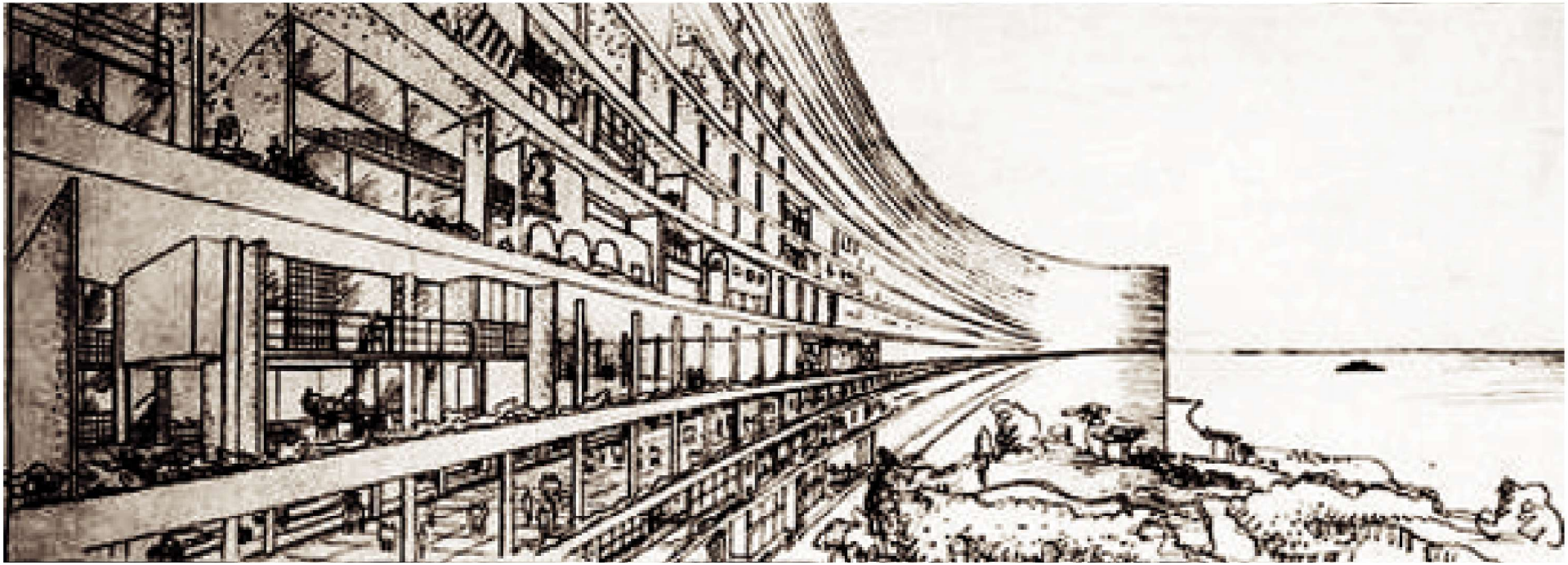


Figure 2.18: Le Corbusier‘s Emperor in Algiers

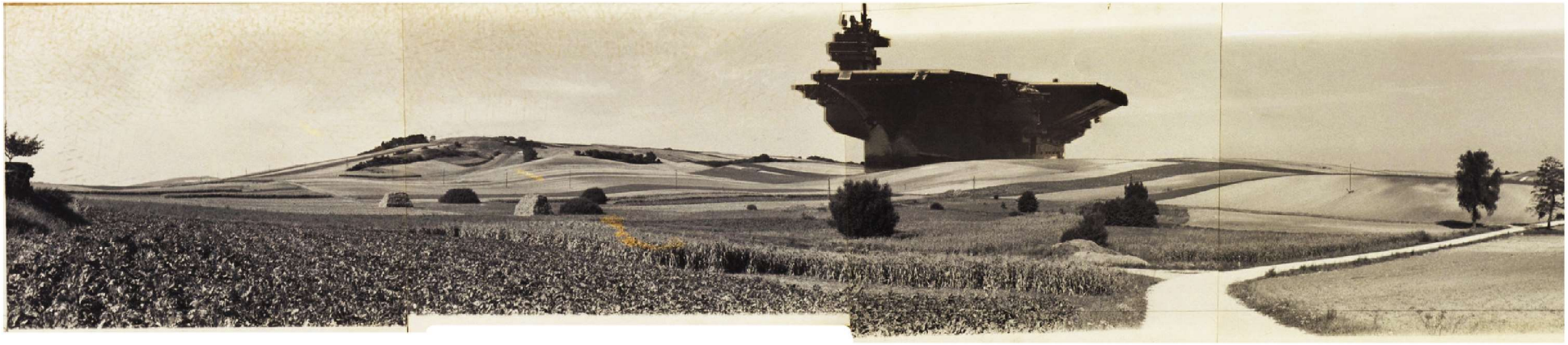


Figure 2.19: Hans Hollien‘s Ocean Liner

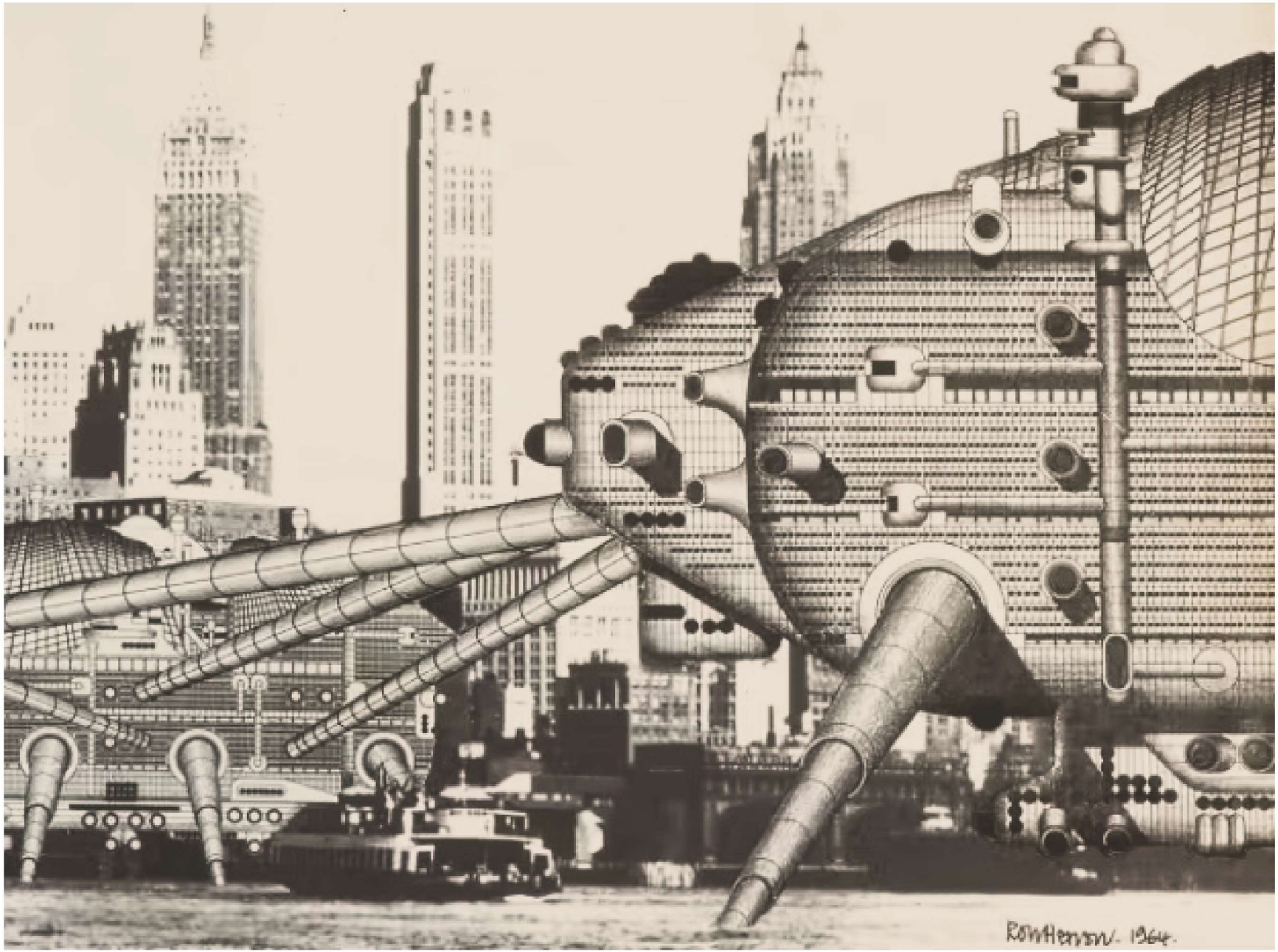


Figure 2.20: Archigram‘s Walking City

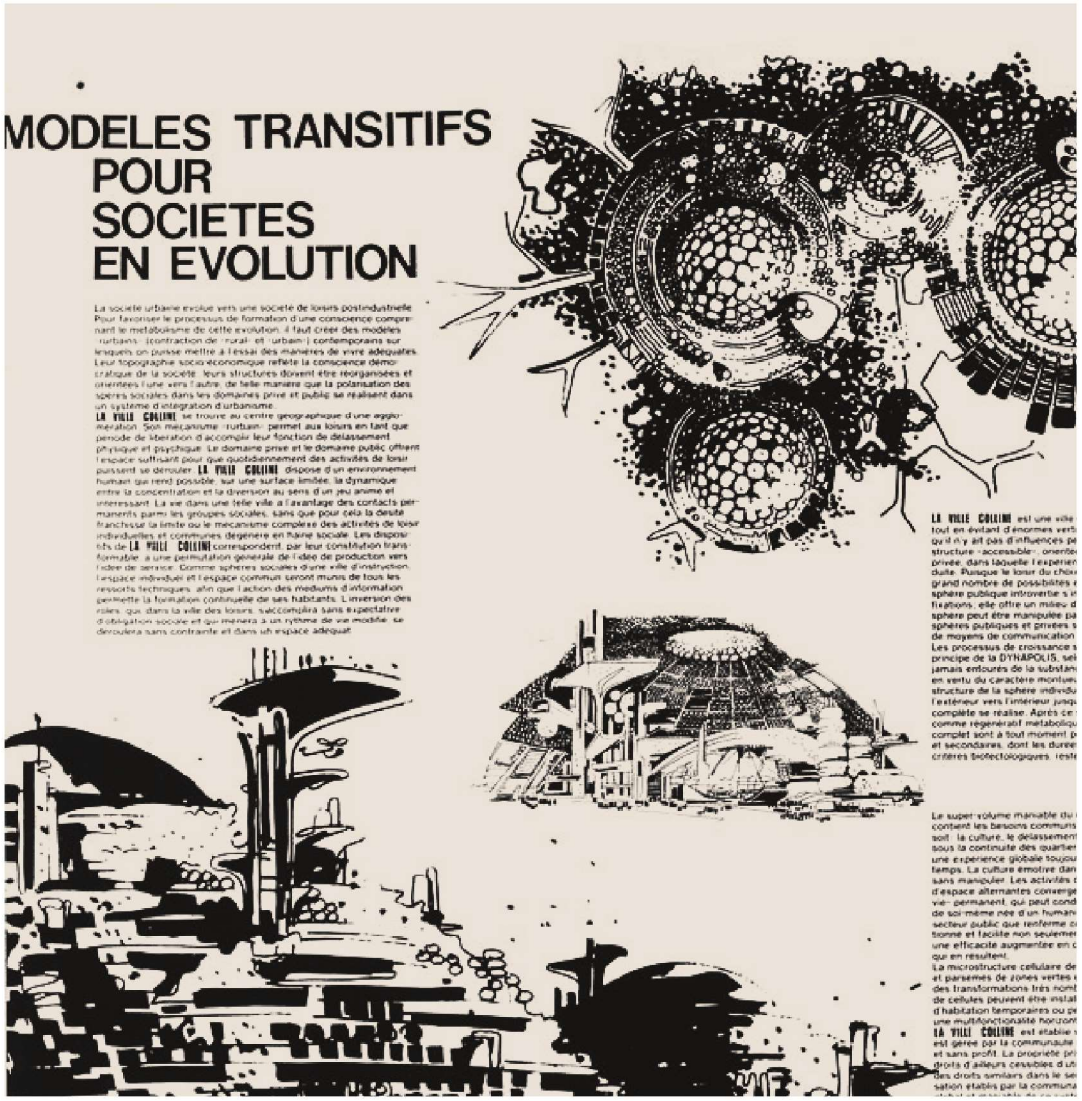


Figure 2.21: Justus Dahinden‘s Radio City (1970)

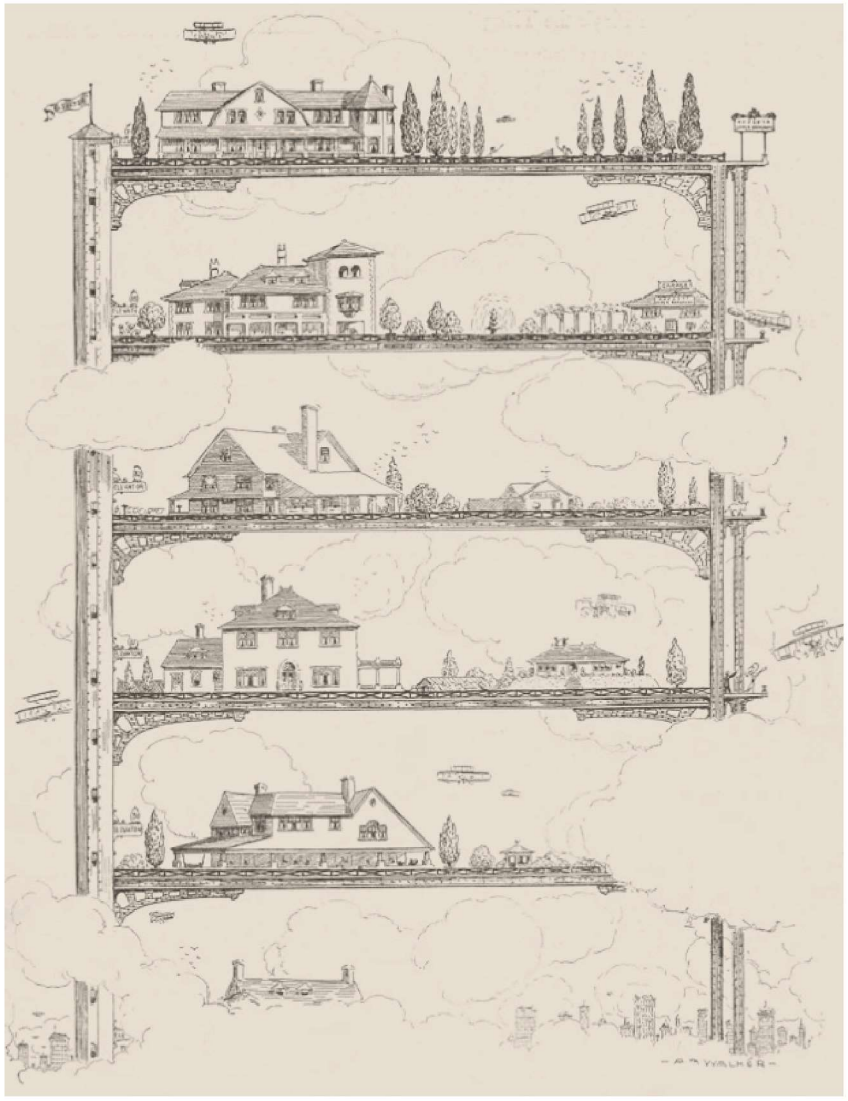


Figure 2.22: 1909 Theorem - a radicalized idea of skyscrapers. Rem Koolhaus points out the absurdity of the expectations.

structure was 855x375 feet and at that point, the possibilities of a megastructure seemed boundless[37]. This proposal was actualized in the 1970s by Renzo Piano and Richard Rogers design for the new Pompidon Centre in the Centre of Paris, one of the French capitals modern "grandes travaux".

The most shocking and "out there" of these proposals was Archigram's (Ron Heron and Brian Harvey's) Walking City project in 1963 which developed a walking-moving monumental structure that was interconnected with identical moving massive metal structures. Reyner Baham described it as the "most celebrated of early Archigram projects, largely because of the alarm caused among the older planning Establishment."[38] The image that made Archigram famous was Peter Cook's Plug-in City project developed in 1963-4. The diagonal framed lattices, with sections and axonometric drawings that visualized 'capsule' modular housing, mobile office towers, and cranes that reshuffled its 'kit of parts'. Due to the conventional Terrassenhauser scheme in its section, the design was easier to accept.[39] Archigram gave a systematic clarity that emphasized engineered systems and globally influenced architecture. Projects such as the Urban Structure project in Italy in 1966-67, designed by Leonardo Savioli's students. In 1966, Shinkenjiku magazine held a residential competition, judged by Kenzo Tange that where evidences of cranes and modular capsules were themed in most of the entries[40].

The criticism against those technologically-based types of megastructures emerged in Lewis Mumford's The Myth of the Machine in 1967 or through indirect critique such as landscape architect and University of Pensylvania professor Ian McHarg's Design with Nature which was the first book of its kind that defined the problems with modern development and present a process with ecological solutions. The first unforgiving critique was Peter Hall's article, Monumental Folly, published in New Society on the 24th of October, 1968[41]. Where Peter Hall noted the destruction of landscape due to traffic and skyscrapers since the 30's and blamed Le Corbusier's Ville Radieuse which called for the destruction of the past urban fabric because 'it is worthless'. He continued to relate megastructures as blow-ups of spaceships that could have been conjured up in a George Orwell Novel. He described megastructures as "difficult to describe, they have to be seen… they are built about a mile high. They are auto-destructive and auto-renewing, through the agency of giant machines which perpetually roll up and down within them; ultimately controlled by giant machines… the designers of course, will still be in the few remaining Victorian bits of London." He further explained that megastructure advocates had promoted three interesting hypothesis. First, the increasing use of machines can speed up the renewal process of structures. Second, prefabrication can expand to a range of structures and uses. Third, the Los Angeles freeway maybe the 20th Century source of aesthetic and the next Piazza San Marco. However, he accused the megastructuralists of failing to "fuse the propositions into a logical decision-making process." This critique triggered an avalanche of criticism against megastructures that by 1968-70, the Radio City project by Swiss academic Justus Dahinden in collaboration with Walter Stahl, echoed Paolo Soleri's need for "miniaturization" and proposed future planning synthesis and need for compactness, but the movement was already dying. A year later, Walter Stahl published his encyclopedia scholar of megastructure in 1971; however, by then, the mechanical 'dinosaurs' had already become 'fossils'[42].



Figure 2.23: Florence‘s Ponte Vecchio‘s midevil bridge

2.4 Integration Requires Miniaturization: From Structuralism to Ecology

Let's explore another mega-structural route, four years before Ralph Wilcoxon's categorization of Megastructure. Fumihiko Maki's Investigation in Collective Form in 1964, defined a more nostalgic 'Mega-Structure' as "a large frame in which all the functions of a city or part of a city are housed. It has been made possible by present-day technology. In a sense, it is a man-made feature of the landscape. It is like the great hill on which Italian towners were built."[43] This definition gives visualization opposing 'Futurism', lattices, and modular capsules with cranes. Maki went on to further explain that the "ideal is not a system…[but a master form which can move into ever new states of equilibrium and yet maintain visual consistency and a sense of continuing order in the long run." He further suggests that "several independent systems that can expand or contract with the least disturbance to others would be more preferable to the one of a rigid hieratical system." He claims that under his definition, the megastructure shows promise for environmentally engineered structures – large-scale structures with light skins, environmentally controlled, steel matrices, pressured concrete, and other engineered systems. The second is Infra-structures used for the public to enhance vertical and horizontal circulation. The third is the building type which applies to this thesis, the multi-functional structure, mega forms that retain one function such as Kurokawa's Agricultural City project[44].

The megastructure that Maki is eluding is similar to Florence's Ponte Vecchio (Old bridge), medieval bridge over the Amo River with multi-leveled 'temporary' mixed-use complex structure with protruded parts and overhangs, first recorded in 996, rebuilt in 1345[45]. Le Corbusier's Roq et Rob project, in 1948, reveals a modular, standardized version of the Italian hill-town to preserve nature is[46]. In Montreal Expo 67, Moshe Safdie's Habitat 67 was reduced from a twenty-two-story proposal to an eleven-story proposal and still it had an immediate first impression on visitors. The Mediterranean village with projecting piled-up concrete boxes, roof terracing, and rationale of the chaos was within itself a dichotomy between complexity and simplicity. The x-factor that Habitat 67 had was it was factory-built with mechanical, electrical and insulation. While the structure was arranged by cranes, connected to steel cables and brought old construction in new ways to architectural discussions[47]. Although the open boxes provided residences no enclosure against Canadian weather, the porosity of the structure, thermal mass, compositional complexity and structuralist inspired design of boxes is something to be noted. Habitat 67 was built on 354 identical prefab modules, each connected to a series of pedestrian streets, bridges and vertical circulation. Habitats was so novel that it were built in exhibitions in New York (1967), Puerto Rico (1968), Israel (1969), Rochester (1971) and Tehran (1976)[48]. The most recent adaptation of Habitat 67 is found in BIG's Mountain dwelling in Copenhagen in a much simpler form[49].

Prefab construction was also used in Kisho Kurokawa's Nakagin Capsule Tower in 1972, where massive concrete are a common theme for Japanese Metabolists. The Metabolists proposed projects like the Arato Isozaki's Space City project in 1960 and Kenzo Tange's Yamanishi Communication Centre in 1967 in Kofu, show similar concerns and ideas from Team 10. They opposed functionalism, valued compactness, formulated hierarchies in their built form and attempted allowances for change which by definition rejected "universal solutions"[50].

Megastructuralists experimented with compositions, variations and explored architecture to new heights. Team 10 distinguished themselves in developing architecture due to relations. In the seminal book, Structuralism in Literature published in 1975, Robert Scholes defined structuralism as a reaction to "modernist alienation and despair." He further explained that structuralist attempted to seek an "interactive and holistic way" as they expanded the scope of architecture into urbanism. The clear distinction between modernist attitude and structuralist attitude is modernists is modernist function is understood in plan while structuralist functions are read in section. What results in their respective analysis is modernists are dense in plan and loose in section, while structuralists tend to develop dense sections and loose in plans. Amongst the structuralist, emerged a team of young architects, reacted against the rigid "rationalized" forms of urbanism. Instead they prioritized relations "between things and within things" and their plans reformed into categories of monofunctional zones for housing, work, transport and leisure.

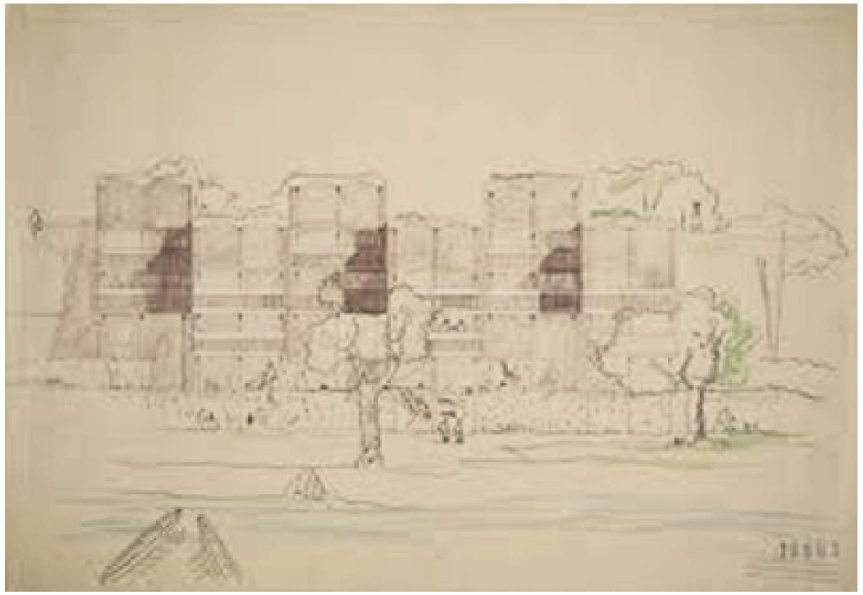


Figure 2.24: Roq e Rob Project



Figure 2.25: Moshe Safdie‘s Habitat 67 in Montreal

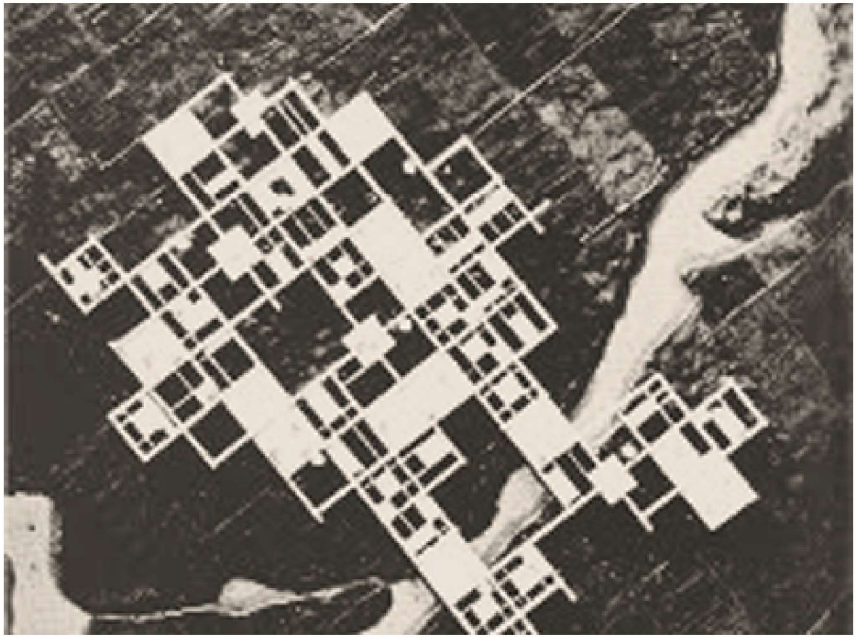


Figure 2.26: Agricultural City

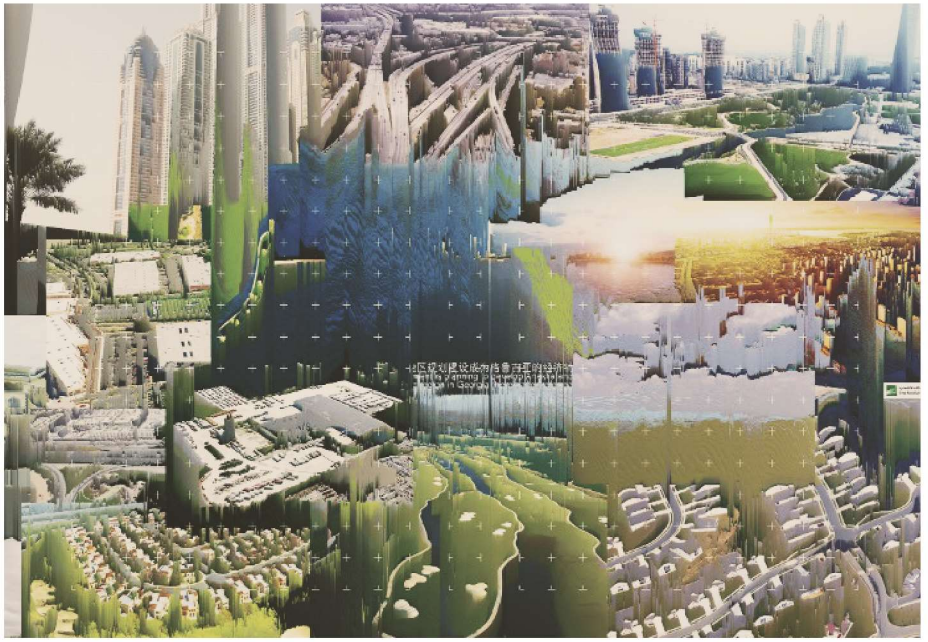


Figure 2.27: Keller Eastling‘s pinup no.20 in 2016 to emphasize the landscape of infrastructure

Aldo van Eyck, a member of Team 10 stated: "the culture of particular forms is approaching an end. The culture of determined relations has begun." Influenced by Patrick Geddes, Alison and Peter Smithson focused on the relation between social processes and spatial form. While Jacob Bakema and Aldo van Eyck were influenced by the studies of Reitveld and De Stijl.[51] Heavily influenced by African indigenous architecture, Team 10 began to frame urban form. In Architectural Design of September 1974 Alison Smithson defines this new architectural tendency of mat-building as follows: "Mat-building can be said to epitomise the anonymous collective; where the function come to enrich the fabric, and the individual against new freedom of action through a new and shuffled order, based on interconnections, close-knit patterns of association and possibilities for growth, diminution and change."[52]

In Team 10's Premier, they proposed a composition from cell to cluster, cluster to stem and stem to mat composition[53]. The cell being the smallest unit, and when composed into a cluster, it multiplies into an assortment of arrangements, with a range of relations and a formal framework of patterns of use. The composition of cluster to form is much more dynamic, where the stem is not intended to be a link but a flow which re-establishes density. Team Primer "argued that architectural order should derive from community hierarchies and contextual associations."[54] The system of relationships and patterns of encounter, which the cells and stems of the cluster generate, provide the spatial framework for these hierarchies and associations." This rational rejects new monumentality as a form and instead aims to form an infrastructure capable of growth and variance. The bringing of those two leads a building from stem to mat. From self-governing clusters to stems, then the combination of both two dimensional network organize the network of circulation. The stems can alter and grow on two dimensions, while still maintaining a coherence and interconnectedness due to its underlying modularity. The mat structure goes one step further by overlaying the patterns of use; this interweaving of the urban fabric brings out a dynamic programmatic element.

This play in circulation and interweaving of elements is visible in the Free University Berlin (1963). The design was developed by the partnership of Georges Candilis, Alexis Josic and Shadrach Woods. There were two sets of pathway hierarchies, the wider pathway, were intersected by secondary pathways. Several of these pathways are connected by elevators and ramps. Open spaces outline the interlinking between the patios and courts within the structure. This results in a dense longitudinal organization that ensures a variety of complexity, density flows, and interconnectedness through its scheme. This interlinking brings promise in an integrative, adaptive and holistic way. Its construction involved the French engineer Jean Prouvé, managed by the Berlin studio supervised by Manfred Schiedhelm along with architect Shadrach Woods. In addition, the university was reconditioned and enlarged with a library by Foster + Partners, who aligned with the Mat building process and resulted in new reviews.[55]

When discussing densifying and restructuring urban fabric as a megastructure one must consider the tragedy of Kowloon Walled City, the densest urban settlement in the world before its demolition in 1992[56]. The unmanaged, lawless densification and self-alteration of Kowloon would lead to disastrous consequences. To avoid the density inflammation, then perhaps a plan that is both dense in section and lose in plan in some parts and dense in plan and lose in section in other parts is one strategy to help keep the structure from over-densifying. The second strategy would adapt managed ecological systems to grow and change to a degree of flexibility to resist overpopulation. This begs the question, is there an invisible force that allows such structures to self-organize and self-regulate and others do not?

Most will argue that this is a matter of policies, implementation, regulations, etc. and on a surface level, this seems to be true, however, there may be a masked architectural component that could be regulated in the design phase. Writer, Architect, and Professor Keller Easterling in her book Extrastatecraft[57] argues that infrastructure—often invisible and taken for granted—plays a critical role in shaping urban environments and organizing social behavior. She introduces the concept of "disposition," which refers to the inherent potential within infrastructure systems that actively shape urban development and is not a passive





Figure 2.28: Eco-Machine in Omega Center Rhinebeck NY





Figure 2.29: Eco-Machine in South Burlington Vermont

support structure. She elaborates and discusses that our urban infrastructures prioritize car traffic and discourage pedestrian activities.

While this seems evident, perhaps there are things to consider while designing with "disposition" in mind. Such as the layout of green spaces within a city to influence its microclimates. Or the design of stormwater systems such as rain gardens, detention ponds, and green roofs to filter the water. Or the special proximity of the suburbs that discourages self-organization and emergencies. While Easterling's work is not directly focused on ecological systems, her insights into the latent power of infrastructure are essential to highlight that designing ecological infrastructure is an integral necessity for the success of ecological megastructures. By integrating both natural processes and infrastructure into a coherent system, ecological megastructures have the potential to exert influence far beyond their physical form, shaping the way people interact with their environment and organizing urban life around sustainable principles.

The transition from theory to practiced solutions is a critical step in realizing the potential of ecological structures. While the intellectual contributions of ecological designs from Geddes to Paolo Soleri to Team 10 are stimulating, the challenge is missing the biological data and solutions that sustain ecology in these structures. Canadian Biologist John Todd and Writer Nancy Jack Todd have developed such principles in their book From eco-cities to Living Machines published in 1994[58]. They delve into deep ecology and biological synthesis to ecologically redesign cities. The concept of Living Machines was later rebranded Eco-Machine is a pragmatic technological intervention presented in the form of sketches and diagrams. Eco-Machines are self-sustaining ecosystems that use natural processes to treat wastewater, recycle nutrients, and create closed-loop systems. These systems mimic natural wetlands, using plants, microorganisms, and aquatic ecosystems to purify water and process waste in a way that reduces energy use and environmental impact. This is only possible due to John Todd's research of integrating microorganisms, plants, and bacteria. The incremental improvement of each sub-system contributed to transforming waste into resources and ensuring that human activity does not strain natural systems beyond their capacity.

From early implementations such as Findhorn Ecovillage[59] in 1982 to large demanding projects such as the Omega Center Eco-Machine in New York, the Moskito Island Eco-Machine in the British Virgin Islands, the Vietnam Veteran's Memorial Rest Stop Eco-Machine, the City of South Burlington Municipal Eco-Machine in Vermont[60]. Heavily influenced by Buckminster Fuller, Todd's work extends beyond wastewater treatment and integrates his ecological design principles. Their design principles advocate for the creation of ecologically sound systems that integrate natural processes into human-made environments, essentially blending nature and technology to solve environmental problems with quantifiable results. This approach can be seen in their broader efforts toward eco-cities and permaculture. By using ecosystems to manage human waste, food production, and water treatment, the Todds' designs are one of the leading global promoters of a practical process in integrating urban and ecological processes. This kind of design exemplifies the potential of urban environments to function harmoniously with natural ecosystems, offering a future where cities can be both sustainable and resilient.

Megastructures have not only been discussed but they have also been built, ecological megastructures are less popular. In the context of this thesis, we will be elaborating on three Ecological Megastructures that have developed over decades ecosystems, horizontal structures and designed with massive concrete features. Precedents will include the Place Bonaventure Hotel in Montreal, Canada, the Barbican in London, UK, and Biosphere II in Oracle, Arizona.

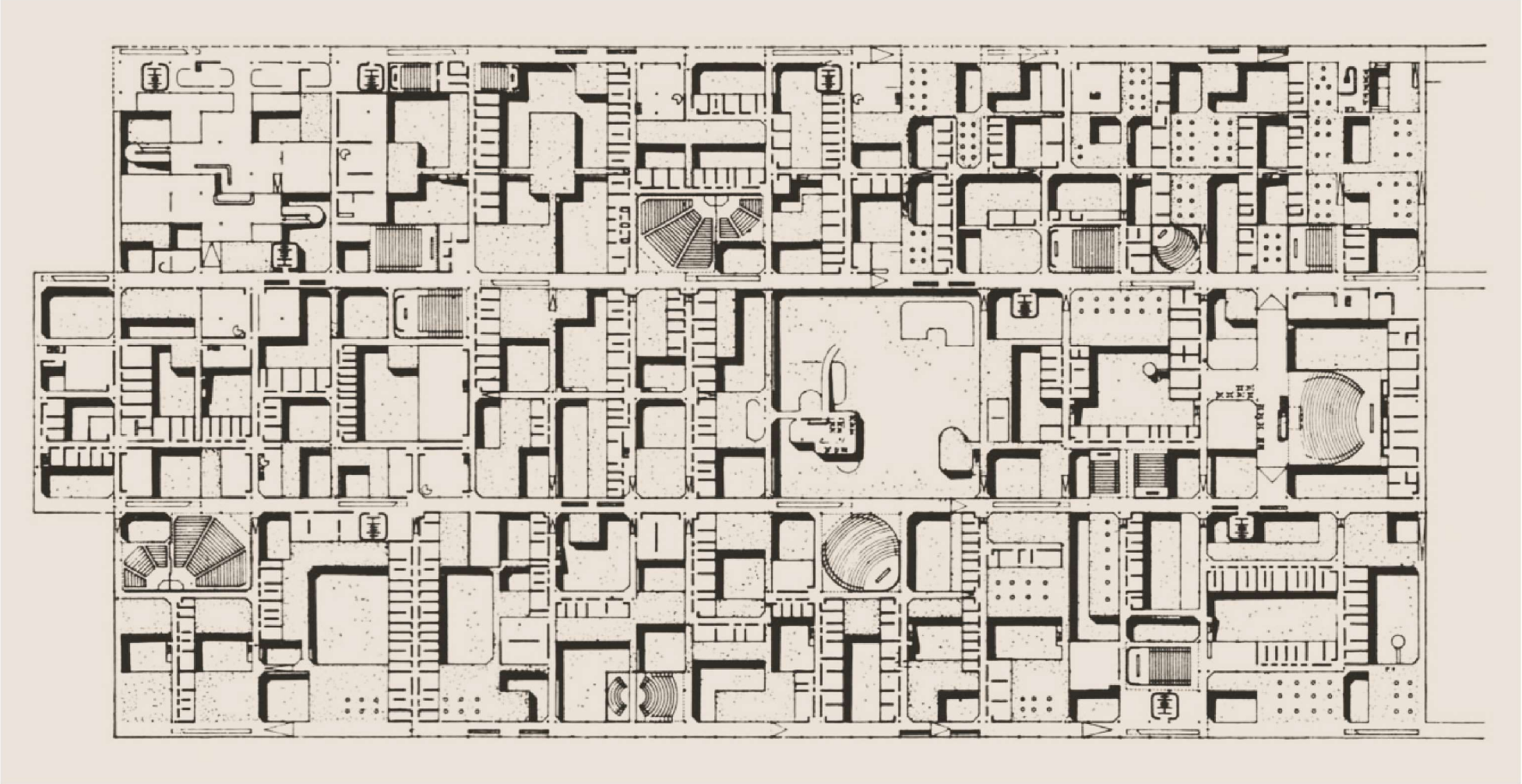


Figure 2.30: Team 10‘s Berlin University in plan

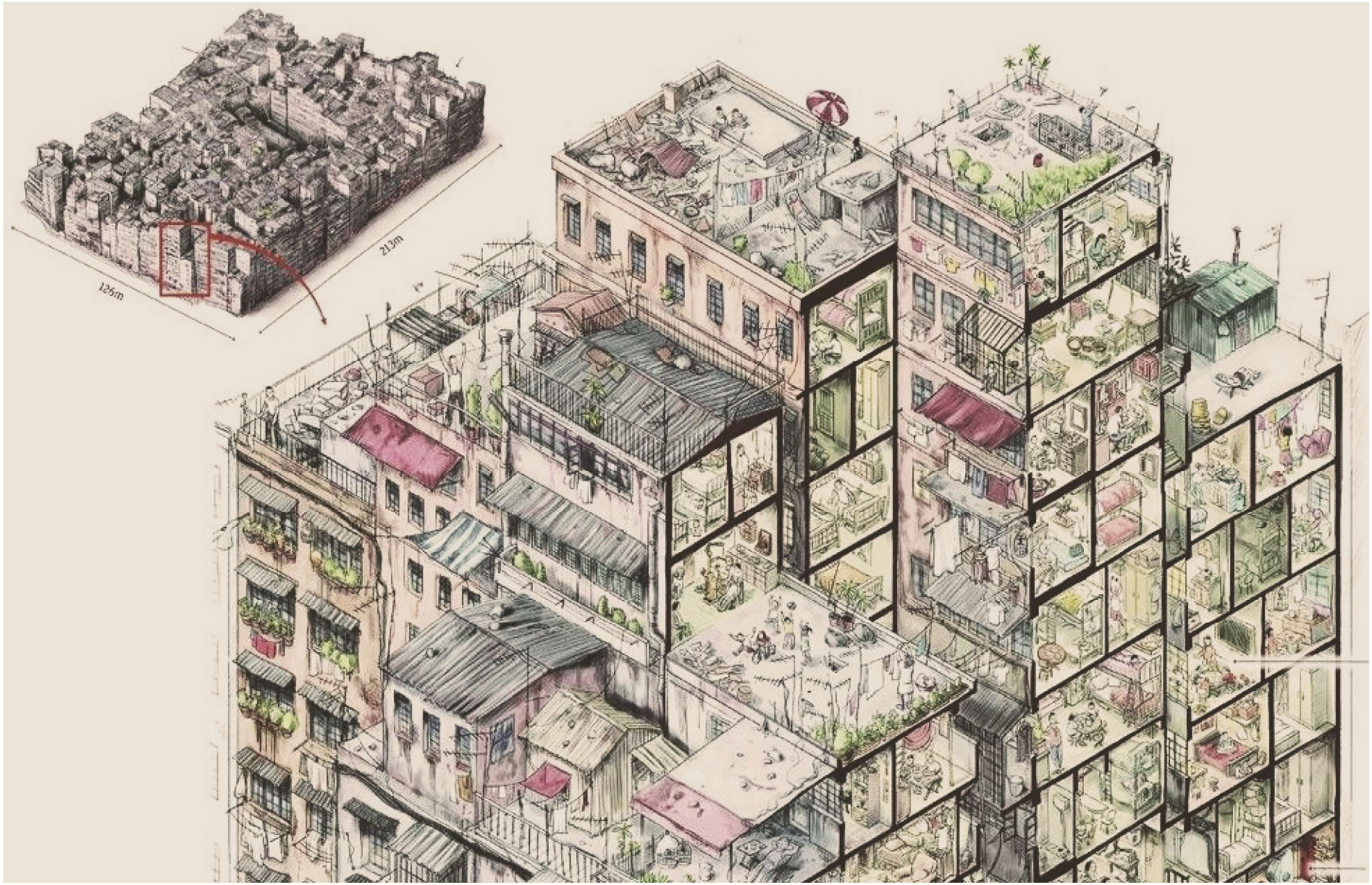


Figure 2.31: Illustration of Kawloon City

2.6 Precedents - Moving from Theory to Praxis







Figure 2.32: The Place Bonaventure Hotel: Exterior and Interior Shots

2.5 Precedents - The Place Bonaventure Hotel

Before Place Bonaventure Hotel was constructed, the Canadian National Railway tracks left a massive void space in downtown Montreal. The Bonaventure was a two million square foot complex, with a twenty-five-foot grid to accommodate the Railway train going through it. Above the train station and its proposed shopping stalls were the exhibition halls, among them was the Concordia exhibition hall which measured 250,000 square feet, and above that were the five floors of the wholesale merchandise market. The most remarkable feature is the roof garden that was designed for trees, a small river along with bridges, and natural features which attracted many of the surrounding birds.

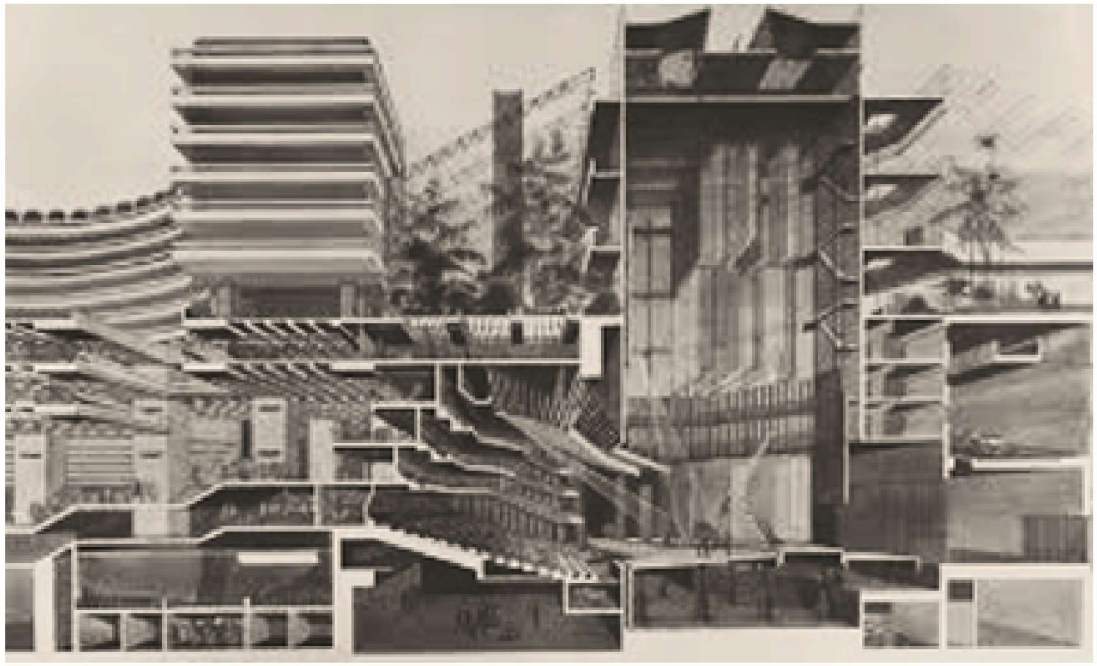


In an ecological sense, the most interesting feature of the Bonaventure Hotel in Montreal is its 2.5-acre roof garden with flowing water and bridges surrounded by 395 hotel rooms with either parametric views of the garden or Montreal's skyline. When experiencing the roof garden that supports a full ecosystem, it is difficult to remember that the experience is seventeen stories above ground level[61]. With a series of ramps and stairs leading to the hotel, the meandering experience of a horizontal hotel significantly varied from the convenience of a vertical hotel. However, this is not the only exceptional feature of Montreal's Bonaventure Hotel.

After completion, Place Bonaventure was the world's largest concrete building and the second-largest commercial building after Chicago's Merchandise Mart. During the Montreal Expo 67 excitement, Place Bonaventure's Architect heroically stated, "What Italy can do with marble and stone, we can do with wood and concrete.[62]" The megastructure's original design had an absence of windows and massive concrete exteriors. This echoed the voices of Le Corbusier and Paolo Soleri's catchphrases "A Machine for Living" and "Ocean Liner.[63]" While these colossal walls defined the boundary of the project gave Bonaventure a strong sense of presence and a sense of seclusion. The building of a massive horizontal structure requires massive density and with wild projections optimism that the placing of the railway station it will bring people to the vendors. However, those masses never came, and the Bonaventure "fortress" softened to accommodate different functions. The merchandise mart slowly transformed into offices, the enormous walls slowly opened its façade to windows, and the crumbling concrete was slowly rearranged to form different types of circulation[64].

The large trees on the roof garden grew to masses that were unaccommodating to the structure and had to be cut down and were managed to be limited to the structure. Despite the inherent previous challenges, the Bonaventure Hotel's rooftop garden demonstrates continued vitality, captivating the visitors with an auditory and visual experience that integrates birdsong, cascading water features, and flora gently brushing against the three-story window. The roof garden contrasts the exhilaration of entering the Concrete Horizontal Beast adorned with old-fashioned architectural styles.

The Place Bonaventure Hotel exemplifies miniturization and vision of structuralists with layers of multi-functional systems.



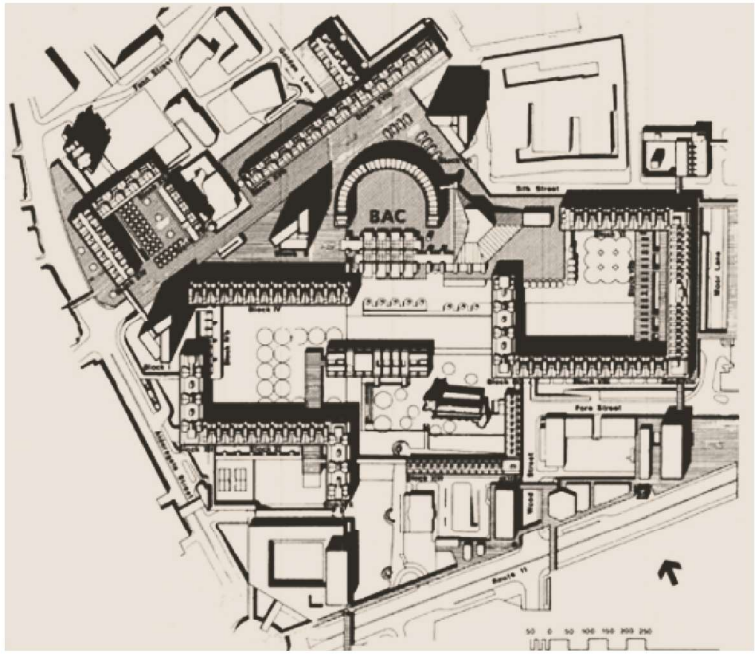


Figure 2.33: The Barbican : Illustration, plan and interior shots

2.6 Precedents - The Barbican





Although perhaps considered as "vintage[65]," The Barbican in London, UK, was even bigger. The site of the Barbican was demolished after World War II, giving parts of London a 'tabula rasa' scenario. This instigated the Town and Country Planning Act of 1947 and allowed the Corporation to buy and develop the land for multi-functional purposes. By 1959, the Corporation of London selected the scheme provided by Peter Chamberlin, Geoffry Powell, and Christoph Bon[66]. The project was fitting its name, the 'Barbican' – the outer defense walls and towers of a castle or city in the medieval era. With three towers, forty-three stories tall, nobly dubbed Shakespeare, Cromwell, and Lauderdale. The composition and Piranesi-cal arrangement of the elements gave a mixture of avant-garde and atavistic architectural qualities, leading to the polarization of reviews for the Barbican[67].

Heavily influenced by Le Corbusier, the architects decorated the monumental elements like a battleship with stairs, ramps, decks, rain gutters, railings, gates, lamps, and sheer size reflected the appearance of a concrete battleship from World War II suggesting former Guardian critic, Jonathan Glancey[68]. The Royal Shakespeare Company and London Symphony Orchestra were involved in the planning in the 1960s. Construction began in 1971, and on the 3rd of March 1982, her Majesty the Queen ceremonially opened the Barbican to the public.

It contained high-density residences with two thousand apartments supported by a multiplicity of social functions such as schools, restaurants, commercial, recreation, and an art center. Eighty percent of the Barbican apartments today are sold with a 999-year lease by the Corporation of London[69]. The ground floor is landscaped with green landscapes, water features, lakes with fish and ducks, including a waterfall. The ground floor also has brick patterned network of pedestrian walkways and cars[70]. The upper floors are decorated with plants and flowerpots. It cannot be said that Barbican was engineered to hold ecosystems in the upper floors of buildings but the size of the structure has the potential to hold these services. Despite its clear Le Corbusian Influence and Georgian planning, the Barbican even during its construction in the 70's, developed a hostile reputation as 'another bloody megastructure.'[71]

The Barbican is a precedent that revived the 1950's vision of Le Corbusier's linear city.



Figure 2.34: Biosphere II : scheme, exterior, interior shot and one of the team residences

2.7 Precedents - Biosphere II

On the morning of the 26th of September 1991, a group of eight (8) men and women smiled, waved to thousands of spectators in Oracle, Arizona, and entered the airlock in their bright red jumpsuits, to the world's largest 'closed system' space framed, engineered, greenhouse spaceship, Biosphere II[72]. It was named Biosphere II intended to mimic the self-sufficient processes of the original Biosphere I, the earth itself. This beast was the first real attempt to put all the fads and know how to figure out the limits of technology.

The space frame/geodesic dome design was developed by the Engineer Peter Pearce who worked with Buckminster Fuller. Architect Phil Hawes, trained by Frank Lloyd Wright was the primary designer. The two main volumes were designed as stepped pyramids, like a futuristic glass-covered Aztec Temple connected by sloping terrain. On both sides of the archipelago were two geodesic domes that contained the "lung," An engineered rubber-based creature that could expand and contract to adjust the air pressure of the structure in the closed system[73]. Biosphere two was a modern decomposition of the Crystal Palace with 12'000 m2, 18'000 m3, the largest fully sealed island ever created[74].

Realistically, Biosphere 2 was a 'materially closed' but 'energetically open' system. This meant it was fully enclosed but externally powered. These 'high-tech peasants' were subjected to a mixture of hard labor & specialized research. They were on a low calorie and high nutrient diet and therefore, were in a constant state of hunger[75].

The disaster struck when the oxygen was mysteriously depleted from 20 - 14%, giving the brave red jumpsuits altitude sickness. This was later explained by a chemical reaction exposed to the compound. It was evident by the residual calcium carbonate, which continued to cure using the available oxygen[76]. The carbon dioxide had to be forcibly sequestered and stored in the basement[77]. After extensive research, including the sealing of the concrete and other improvements so by March 6th, 1994, Biosphere II was revived again with a new crew and a declaration of a ten-month trial run. The second crew achieved sufficiency in food production.

However, with the project hemorrhaging money, the investor Bass was tired of Allen and his management team, the project management team was replaced by April 1st, 1994[78]. After a series of unfortunate events, including an incident of vandalism, airlock openings, and broken glass, the sealing of the Biosphere II was compromised for 15 minutes. Several of the members began to take a leave of absence that ended with the ownership and management was completely dissolved by June 1, 1994. The experiment was shut down on September 9th, 1994, which resulted in a substantial body of data, a grand structure, and a series of research papers, including one completed by H. T. Odum. The most interesting conclusions resulted in discovering the speed of fluctuations and rapid cycles from man-made ecological structures that vary from natural systems.

The project was sold to Columbia University and later the University of Arizona. Biosphere was born from the 1970s apocalyptic wave with the public wary of its catastrophic failure. The last true attempt to coincide technology with natural systems that spared no expense in construction, consultations and anointed all the greatest minds of its time, launched every engineering marvel and conducted every research to ensure the success of the Biosphere II. This failure was statement that it was abundantly clear, in spite of our collective collaboration, thirty years ago, this is our collective limitation to resolve a functional closed-loop system. We can build smaller systems but with the extensive build-up of biological matter, these systems have fluctuations and flows and we do not have the data to predict their behaviors and tolerances. This adventure will require long-term data collecting, incremental improvement, and granular mapping to ensure the growth and stability of the systems within.

Biosphere II remains to be the best example of a closed-system public simulation ever recorded.

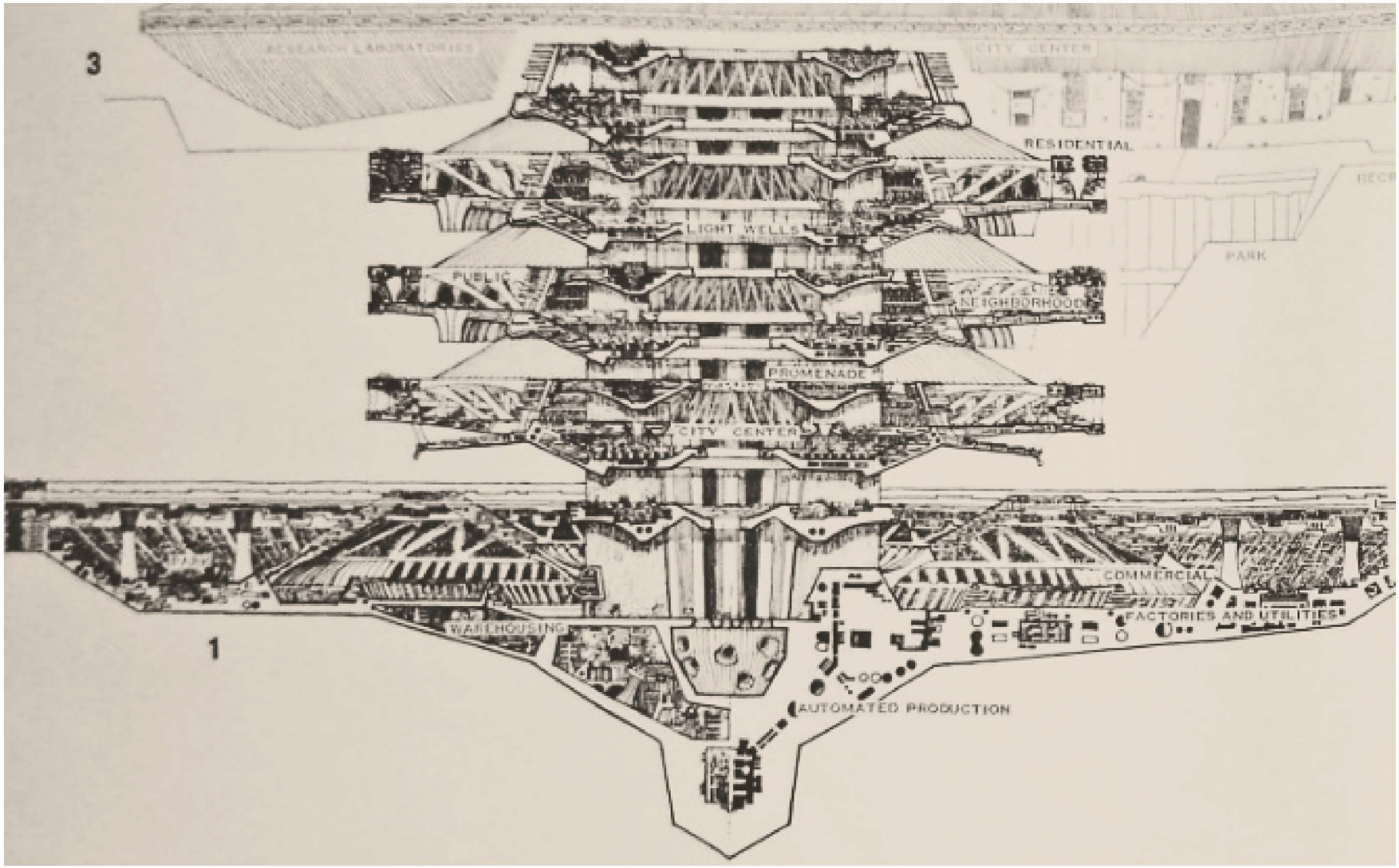


Figure 2.35: Paolo Soleri‘s Babel IIB

2.8 Paolo Soleri's Arcology: Fusion Megastructure

In stark contrast to the ephemeral, light-weight, sketched structures of the era, Soleri's arcologies were monolithic and imposing. Their dense forms, seemingly carved from solid rock, reflected a deep-seated structural introspection that challenged the prevailing emphasis on flexibility and adaptability. These massive sculptural artifacts, rooted in organic architectural principles, seemed influenced by the philosophies of Henri Bergson, Piere Teilhard e Chardin, Ilya Prigogine, and Gilles Deleuze[79]. While Arcology held the promise of harmonious human environment integration, its complex nature demanded careful study and understanding to realize it's full potential.

With the pendulum swinging towards technology-based human development on one side, Paolo Soleri presented an alternative to push it in the other direction. He urged to resist "half measures" and stated "Architecture is city planning, as it is ecology. Architecture cannot remain an atomistic phenomenon." By 1969, he presented an alternative vision that rejected the explosion of urban sprawl, the fragmentizing of architecture and processes within cities. In his Arcology, Paolo Soleri instead proposes a continuous, organized implosion of the city. It internalized all human development and needs are to be synergized in one ultra-colossal, multi-floored, multi-layered, multi-functional, mixed economies, mixed age groups, holistic, porous, dense, clustered megastructure that left natural external ecosystems to remain undisturbed a mere archaic version of Hollein's air craft carrier vision. In Soleri's vision of Arcology, he highlighted the value of structure, connections, and networks that harmonized the relationship between man-made processes , durable structures and ecological frameworks.

Although Paolo Soleri claimed to have the intention of designing "a machine for living in" where he claimed that the "passenger liner is the oldest ancestor of Arcology"[80], and the visions of his multi-scared macro-architectural designs were alluring due to their compactness, porosity, and complexity. He envisioned a massive structure that curved along structural systems that housed multi-floored urban communities and enabled a system of relationships to develop with the environment. Jeffrey Cook, one of the leading academic believers in Paolo Soleri's vision noted that "planning of economic, communication, social or even mechanical systems is hardly outlined" in Paolo Soleri's "rigid packaging" of his ideal city[81].

In comparison to the height and structures, the architecture seemed like an imploded miniaturization of urban systems. In his book Image of Man, he presented thirty-one schemes of arcologies. Each arcology varied in density, height, and functions and was designed for inhabitants ranging from 1'500 to six million[82]. The designs varied in aesthetics, from the classical like Arcvilliage I to the alien-like Mesa City project presented in 1959. His projects were represented as sketches, plans, elevations and sections with intricate elaborative substructures. The details allowed the viewers to imagine multiple scenarios occurring in each proposal. Understanding how the building functions became an exercise similar to solving a Rubik's cube because Paolo Soleri's drawings alluded to multiple functions but did not specify any specific systems even though he constantly acknowledged their significance.

Paolo Soleri's approach to systems takes that model one step further but rather than explode the model, the growth is densified and multi-leveled with all the processes internalized and imploded. Similar to the Walker Skyscraper Theorum of 1909, published by Rem Koolhaas in Delirious New York in the mid-70s, where the high-density suburbia led to a multi-leveled villa connected by elevators. Paolo Soleri's Arcology is much more elaborate, miniaturized, and entails complex processes and functions. This gave Soleri a completely different manifestation of urban form than the typical megastructure model. Although Reyner Banham celebrated Architecture Autré in his search for alternative models and futuristic attitude, he only viewed Paolo Soleri as a "kind of maniac for compactness".

Taken today, Paolo Soleri's Arcology model might be challenging to imagine in an already densified, structured urban downtown, however, it seems very feasible in suburbia or a rural setting. This model of rejecting the status quo by presenting a new scenario of living by embracing modern technology and seeking interdependence with ecology is like Garden City and Broadacre City. Ebenezer Howard's Garden City model is a step in the right direction by integrating greenery into the landscape. Frank Lloyd Wright's Broadacre City is a more ambitious model that visualizes much more elaborate landscapes, rolling agricultural hills, automobiles with flying contraptions, and dissolving suburbia further into the countryside.

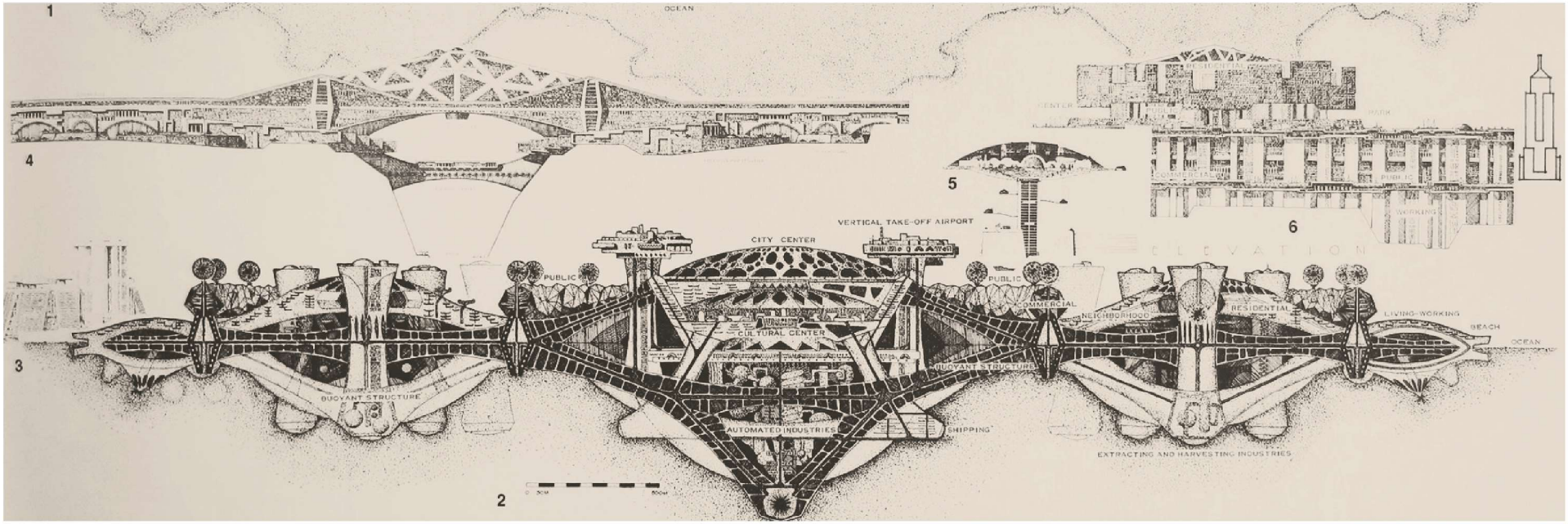


Figure 2.36: Paolo Soleri‘s Novanoah I

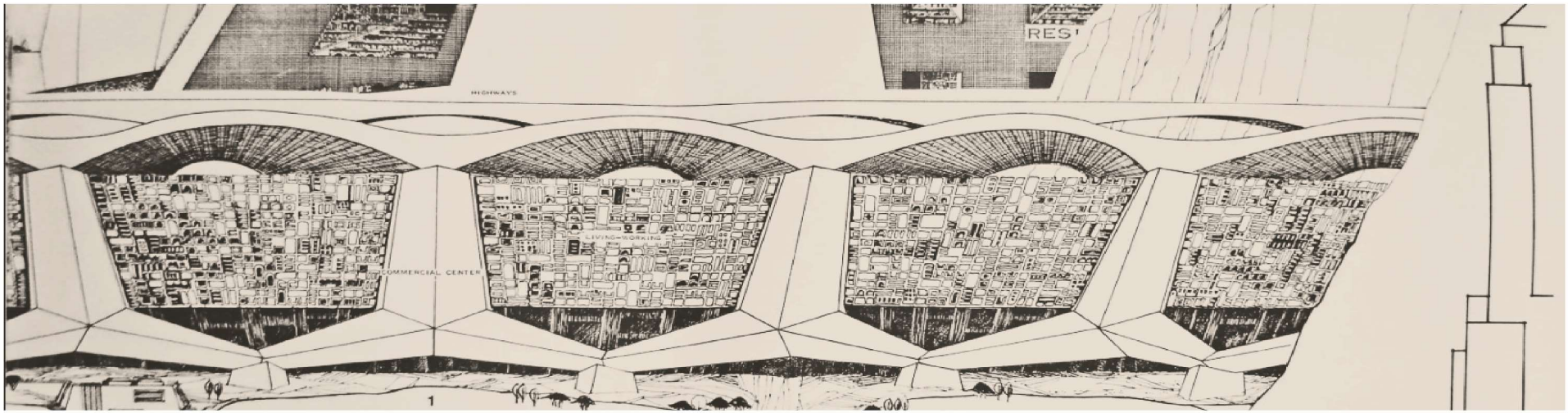


Figure 2.37: Paolo Soleri‘s Veladiga

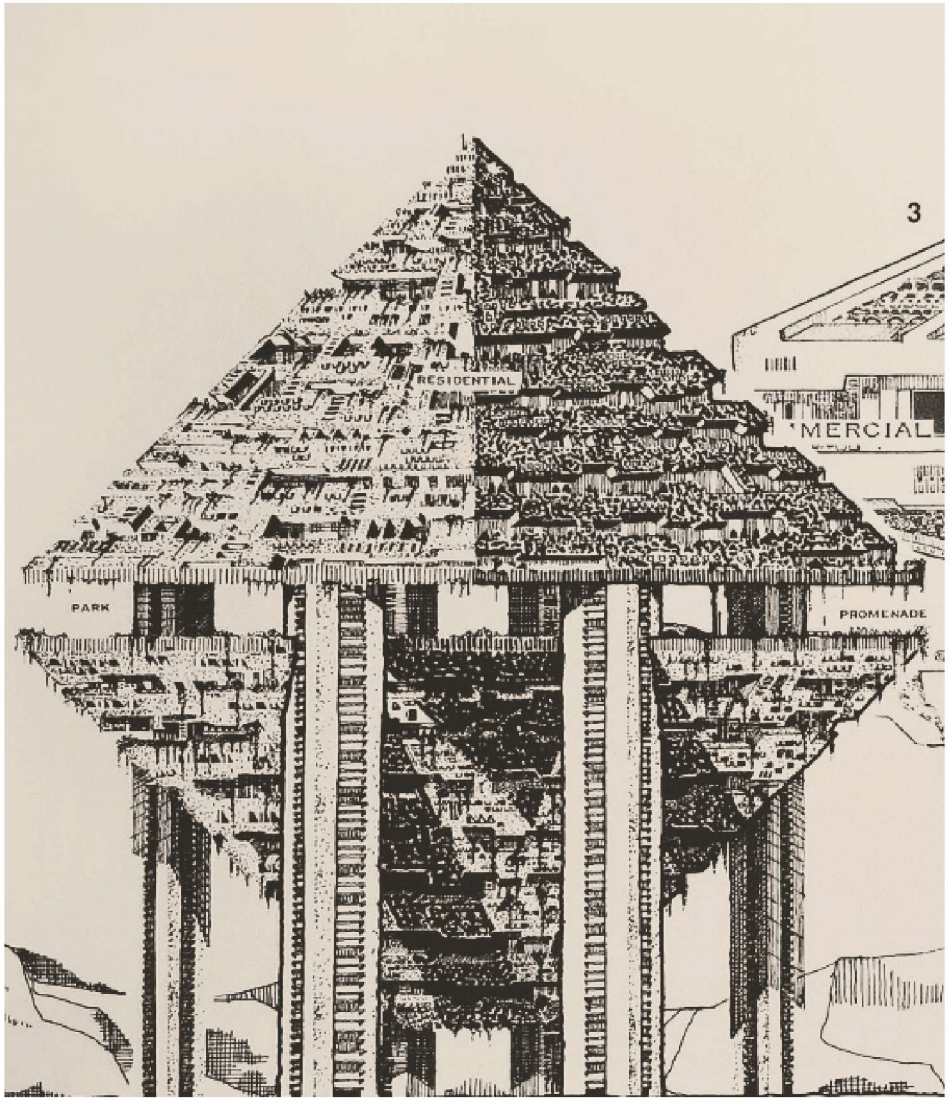


Figure 2.38: Hexahedron for a population of 170,000, 1,100 meters high on a surface area of 57 hectares, 150 acres

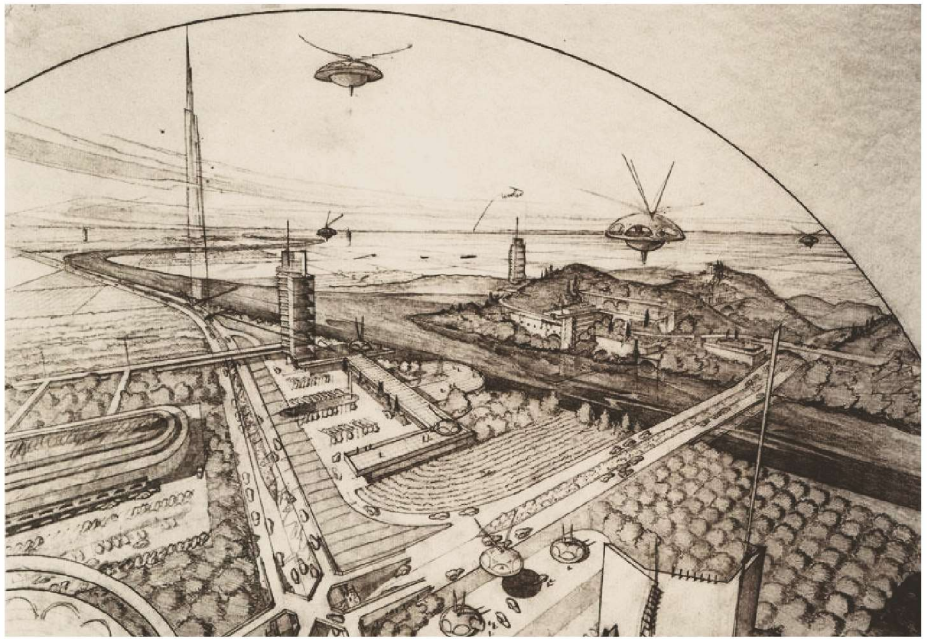


Figure 2.39: Frank Lloyd Wright‘s Broad Acre City

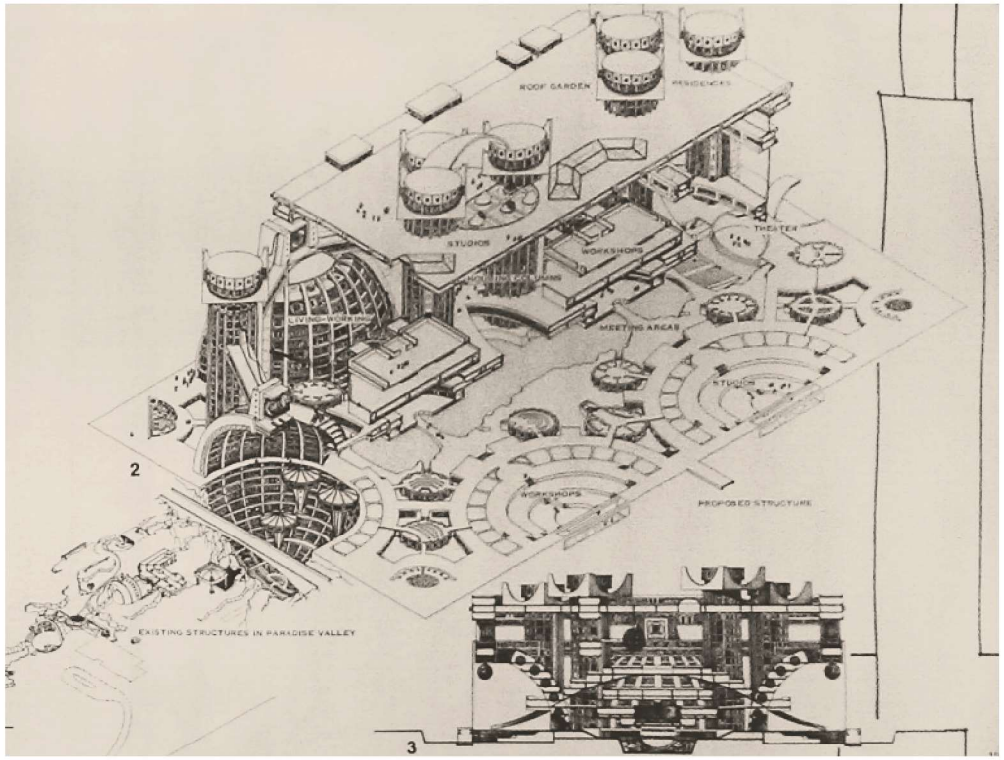
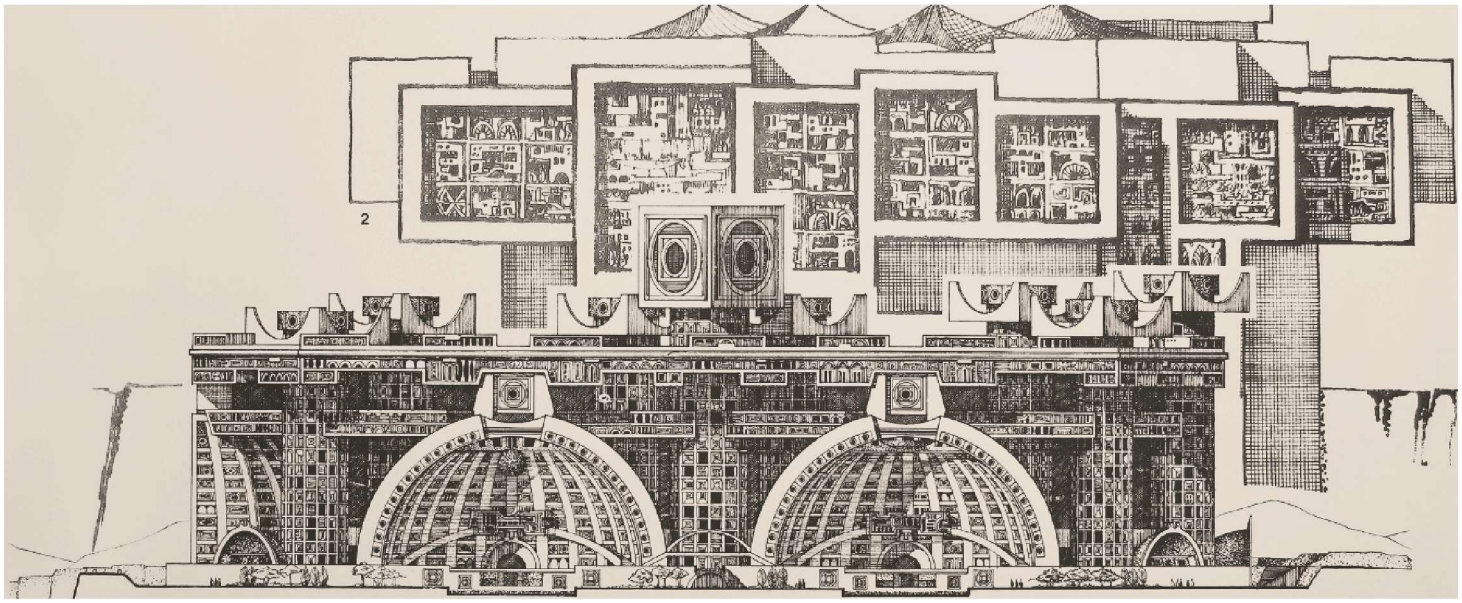


Figure 2.40: Paolo Soleri‘s Arcosanti for a population of 1,500 50 meters high on a surface area of 2.8 hectares, 7 acres



Soleri's enormous continental plan envisioned a continuous structure that seemed to contour to the topography of the vast regional terrain. This was at the scale of the mega structuralists' Comprehensive City project, proposed by Mike Mitchell and Dave Boutwell in 1969 and published in Domas magazine. The proposal proposed one large linear structure that stretched from New York to San Fransisco. Although Reyner Banham related this scheme to Le Corbusier's Ville Contemporaine pour trois millions d'habitant in 1922, it seems to align itself more closely to Le Corbusier's Fort l'Empereur, Algiers proposed in 1931. Mitchell and Boutwell did not assume this was an ultimate solution but suggested it may be one of the possibilities deserving serious consideration.

When trying to realize Paolo Soleri's Arcology, today, one must thread together ecology, megastructures, and "everything in between". J. B. Jackson, a landscape photographer and theorist stated: "The megastructure is before the individual installation and presumably, more lasting. Few of us realize that there is another kind of megastructure in terms of the whole environment… This megastructure consisting of the environment organized by man can be called the public landscape."[83]

Hence, lexicographer, author of educational and reference books, John Button defines Arcology as an architecture that is in line with ecological principles [evident in its name Arch + ecology][84]. The purpose of this structure is to develop a reciprocal relationship between human settlement and the environment in an enclosed structure. It seems like an evolution to megastructure because it propose an architectural typology that seamlessly fuses architecture and ecology on a massive scale that harmonizes human habitation with the natural environment. Soleri's vision went beyond theory as he worked to align Arcology with ecological principles. Although the idea was groundbreaking at the outset, it has become closely linked with Soleri himself and limited to the structures he created. In 1970, approximately seventy miles from Cosanti, in Cordes Junction, Arizona. The name derived loosely to mean "coming before arcology". As Soleri's prototype city, it incorporates concrete vaults, numerous innovative features, and concepts that could be further improved by integrating human-scale systems into its design.

However, the frugality of construction contrasted significantly from the grand illustrations it intended to reify, and therefore, the globe reviewed his work with skepticism. Reynar Banham contemplated "one still has to wonder if it is not the sheer physical exhaustion brought on by all the hand-labor that prevents his loyal students [from] asking themselves what they are doing working for such a thoroughly old-fashioned and establishment figure.[85]" Arcosanti was "sculptural, expressionistic, emphatically handmade ornate even[86]" and an experimental undertaking that took a lifetime to conceptualize. "If we could settle on the name Arcology, relax about the fact that Soleri originated it and we can't all agree with all that Soleri says and believes, then we could have a quickly clarifying tool of enormous and very human power in our hands. We could use it to focus and articulate notions about a meaningful and healthy future – and to build it too" (Richard Faust, Register, 1978).

2.9 Lessons from Precedents

As urbanization accelerates, cities face the dual challenges of population growth and sustainability. Ecological megastructures—large, self-sustaining urban environments—offer a promising solution by merging architectural innovation with ecological systems. These structures represent a paradigm shift, where natural processes are integrated into the built environment to reduce environmental impact and foster a harmonious relationship between human activity and ecological systems.

Historically, architectural theory and practice have been shaped by key figures such as Le Corbusier, whose Ville Radieuse and Unite d'Habitation proposed high-density, multi-purpose, vertical cities that preserved green spaces and optimized urban living. His emphasis on urban density and functionality laid the groundwork for future megastructure discussions.

Buckminster Fuller, with his geodesic domes and vision of Spaceship Earth and Universality, further developed the idea of architecture as an optimized, resource-efficient system capable of addressing the world's sustainability challenges. With light-weight geodesic domes globally bubbling up across various microclimates, Fuller's structures claimed global approval due to it's futuristic aesthetic.

On the other side of the spectrum, Paolo Soleri's arcologies envisioned cities as dense, vertical environments that consolidate human activity into closed-loop systems. His arcologies aim to create self-contained structures that recycle resources, manage waste efficiently, and reduce transportation needs by concentrating urban functions within a single megastructure. However, moving from theory to praxis has often been a stumbling block. Soleri's visions, though compelling, were admired theoretically due to the monumental scale of his proposals.

Structuralism also played a significant role in rethinking how urban spaces could be organized as interconnected systems rather than isolated buildings. Fumihiko Maki's Italian hilltop town and Team 10 introduced concepts of relational architecture, miniaturization, scalability, and adaptability. Therefore, shaping the development of megastructures that could flexibly respond to changes in urban needs.

While architectural theory and ecological processes are essential, the role of infrastructure in shaping urban environments matters. Keller Easterling highlights the latent power of infrastructure to influence how cities evolve. She introduces the concept of disposition—the hidden potential within infrastructure systems that shape urban form and behavior. While Easterling's work focuses primarily on infrastructure's political and social dimensions, her insights are valuable in understanding how megastructures can function as more than just architectural solutions. By integrating and re-imagining the infrastructure with ecological systems, megastructures can become dynamic entities that regulate urban life through ecological processes.

To make ecological megastructures a functional reality, contemporary projects must blend these visionary ideals with practical systems. This shift from theory to praxis is exemplified in the Eco-Machines concept developed by John Todd and Nancy Jack Todd. These self-sustaining ecosystems use plants, microorganisms, and aquatic systems to treat wastewater, recycle nutrients, and create closed-loop systems. Eco-machines mimic natural wetlands, using ecological processes to purify water and process waste in a way that minimizes energy consumption and environmental impact. By integrating Eco-Machines into megastructures, urban environments can actively contribute to the health of ecosystems, transforming waste into resources and ensuring that human activity does not strain natural systems beyond their capacity.

The fundamental challenge lies in accommodating a vast, dynamic biological component. Predicting the fluxes and flows of this internal ecosystem necessitates a multifaceted approach.

Firstly, funding becomes a crucial first step. Recognizing the inherently experimental nature of these projects, the initial investment will likely come from forward-thinking governmental bodies or industry leaders who understand the iterative nature of the design process and value achievements over time.

Secondly, the engineered systems – air, water, waste, nutrients, and energy flows– will require a tolerance for controlled and regulated failure. These subsystems, akin to living organisms themselves, will evolve through iterations. Engineers must be prepared to incorporate elements like air pumps and dynamic flow management systems, anticipating the need for adaptation throughout the lifetime of the megastructure.

Thirdly the success of such a system ultimately hinges on the self-regulating properties of biological living systems, and the time required for the system to mature. This means that as the megastructure‘s ecosystems mature, the intricate biochemical cycles will become self-sustaining and easier to predict. Ecologists, through data acquisition and analysis, can learn to guide future iterations, optimizing water cycles and internal food production.

Fourthly, management of the megastructure remains paramount. The delicate balance between engineered systems, ecological processes, and the social fabric of the inhabitants dictates long-term management to channel its success.

Fifth, we require data, iterations, and mapping to build tolerances to ensure the ecological megastructure does not fail. The unknown factors and uncertainties that stem from a lack of data and knowledge are significant. To bridge the gap, an ecological megastructure with open-loop systems is required to be initially constructed to collect data. Through the flow of data and a mapping of internal and iterative cycles, over time, the system will mature into a closed-ish loop system.

Finally, navigating through complexities at multiple scales commands the contribution of all parts of the interdisciplinary team. This will result in a massive external structure with intricate geometries like mat-building, with its multi-scaled, flexible approach.

The notion of ecological megastructures poses a curious paradox. While their qualities may seem intuitively appealing, a deeper examination reveals the inherent challenge of design. Unlike Edison‘s singular lightbulb, where progress could be measured by illumination, ecological megastructures demand a paradigm shift visible in its series of iterations. In this case, success hinges on embracing uncertainty that initially hinders the complete comprehension required to envelop the systems within.

Architects will experience four key design factors while designing an ecological megastructure. The first is the physical attributes which will be grand, horizontal, and porous structures that will essentially foster both living, engineered, and social systems. The second is topological variations, as the design integrates systems across multiple scales and elements such as stairs, ramps, angled terraces, and bridges, which become critical repetitive tools to bridge gaps and manage internal flows. Third is materiality and thermal mass, where concrete presents itself as a viable option due to its adaptability and capacity to store thermal energy, particularly in colder climates. Finally, it is important to note, that system integration combined with modular construction produces emergent patterns. Alternatively, experimental construction will result in additional consultants and research to identify issues which will result in costly funding. Continuous mapping of these systems therefore becomes a crucial factor for the megastructure‘s long-term success.

While integrating ecology into the urban fabric is a concept with historical roots, that range from observational purposes to regulating natural ecosystems. However, despite collaborative efforts, there is a knowledge gap between what we think we know and how to build an ecosystem. Therefore, to adapt to the unknown, the pragmatic approach proposed here goes beyond mere “kits of parts.“ It establishes the groundwork for a transformative design paradigm. Ecological megastructures push us to embrace the complexity of natural systems, fostering a holistic understanding of the intricate and “everything in between“ that sustains itself.

Therefore, the structure of holding such assemblies may come in infinite forms, this thesis will explore the following: the exterior will resemble an “Ocean Outliner“ form with a porosity like an „Italian Hill-Town“ aesthetic with features that include massive concrete forms, with scattered space frames and skins to integrate natural light within a dense complex.

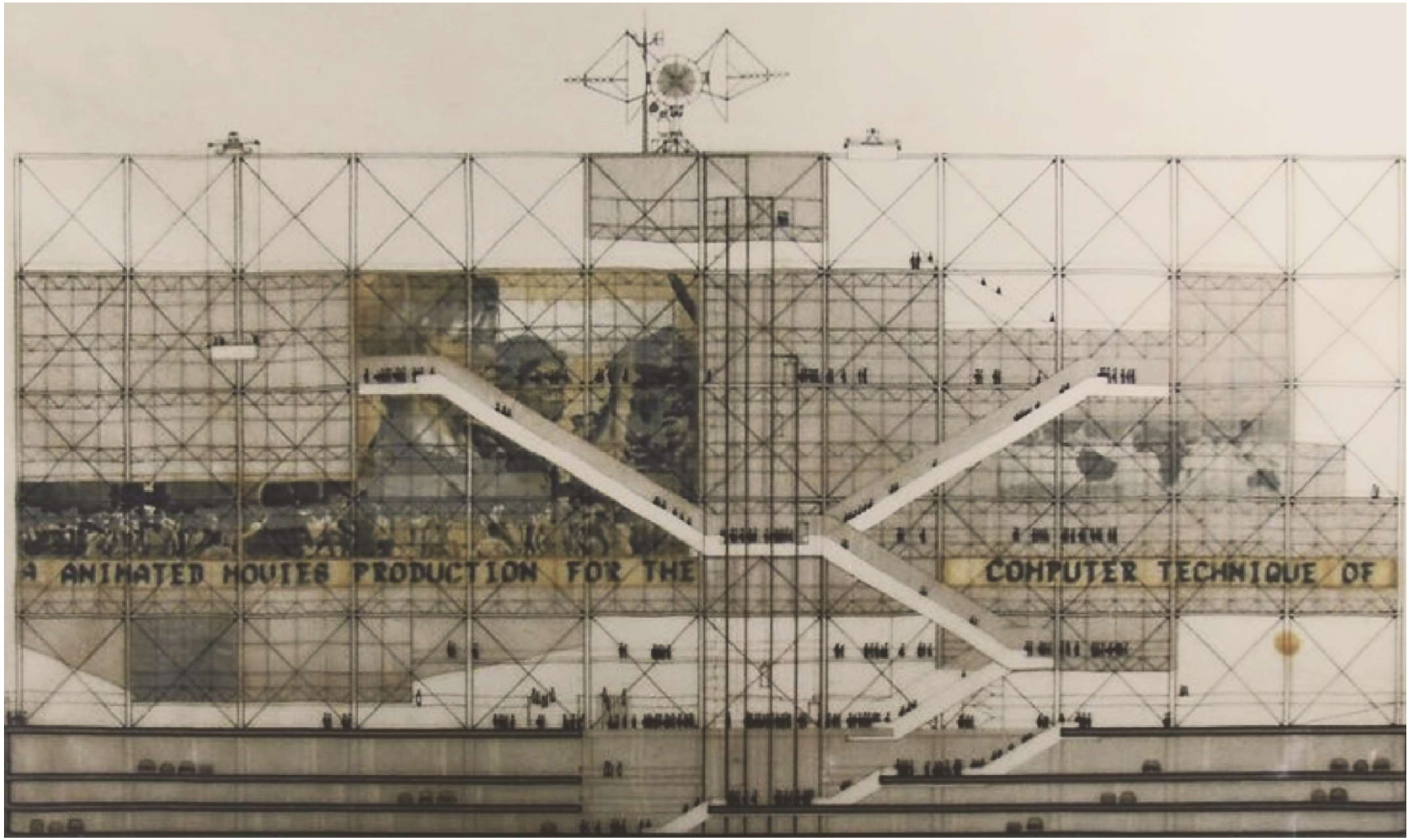


Figure 2.41: Renzo Piano and Richard Rogers Centre George Pompidou

1. Spuybroek, Lars, Joke Brouwer, and Sjoerd van Tuinen. “In the Thick of Things.” The War of Appearances: Transparency, Opacity, Radiance, 2016.
2. Kroll, Andrew. “Architecture Classics: Unite D’ Habitation / Le Corbusier.” ArchDaily, February 10, 2023. https://www.archdaily.com/85971/ad-classics-unite-d-habitation-le-corbusier (accessed Jun 22, 2024).
3. Welter, Volker. Biopolis : Patrick Geddes and the City of Life. Cambridge, Mass.: MIT Press, 2002, p 12.
4. Ibid, p 11.
5. Ibid, p 78.
6. Ibid, p 182-183
7. Ibid, p 185.
8. Ibid, p 187.
9. Ibid, p 1.
10. Mumford, Lewis, Patrick Geddes, and Frank G. Novak. Lewis Mumford and Patrick Geddes: The Correspondence. New York: Routledge, 1995, p 361.
11. Eck, Caroline. 1995. „Goethe and Alberti: Organic Unity in Nature and Architecture.“ The Structurist 0 (35): 20.
12. Benton MacKaye, “Regional Planning and Ecology,” Ecological Monographs X (July 1940), p 349.
13. Easterling, Keller. 1999. Organization Space : Landscapes, Highways, and Houses in America. Cambridge, Mass: MIT Press, p 42
14. C. Macy, S. Bonnemaison, 2003. Architecture and Nature : Creating the Ameri can Landscape. London, UK: Routledge, p 137-145.
15. Ibid.
16. Ibid, p 210 - 211.
17. Doxiadēs, Kōnstantinos Apostolou. 1968. Ecumenopolis, the Settlement of the Future. Athens: Athens Technological Organization, Athens Center of Ekistics.
18. Doxiadēs, Kōnstantinos Apostolou, and J. G Papaiōannou. 1974. Ecumenopolis : The Inevitable City of the Future. New York: Norton.
19. About Fuller: Big Ideas. n.d. https://www.bfi.org/about-fuller/big-ideas (accessed Aug 12, 2017).
20. Alter, Lloyd. A look at Bucky Fuller‘s dome over New York City. March 10, 2014. https://www.treehugger.com/urban-design/look-bucky-fullers-dome-over-new-york-city.html (accessed Aug 14, 2017).
21. Morowitz, Harold. Energy, Flow in Biology, New York: Academic Press, 1968.
22. Rheingold, Howard. “The Millennium Whole Earth Catalog” 1994, p. 383.
23. C. Macy, S. Bonnemaison, 2003. Architecture and Nature: Creating the American Landscape. London, UK: Routledge, p 293.
24. C. Macy, S. Bonnemaison, 2003. Architecture and Nature: Creating the American Landscape. London, UK: Routledge, p 293.
25. Reyner Banham, “Megacity Montreal,” Megastructures: Urban Futures of the Recent Past, New York: Harper and Row, 1976, p. 105.
26. Banham, Reyner. 1976. Megastructure : Urban Futures of the Recent Past. 1st U.S. ed. ed. London; New York; London : Thames and Hudson, 1976: Thames and Hudson; Harper & Row, p 8.
27. Ibid, p 7-8.
28. Ibid, p 9.
29. Apollonio, Umbro, 1911-1981. 1973. Futurist Manifestos. London]: Thames and Hudson, p
30. Banham, Reyner. 1976. Megastructure : Urban Futures of the Recent Past. 1st U.S. ed. ed. London; New York; London : Thames and Hudson, 1976: Thames and Hudson; Harper & Row, p 18-19.
31. Ibid, p 19-21.
32. Frearson, Amy. Brutalist buildings: Unité d‘Habitation, Marseille by Le Corbusier. Sept 15, 2014. https://www.dezeen.com/2014/09/15/le-corbusier-unite-d-habitation-cite-radieuse-marseille-brutalist-architecture/ (accessed Nov 12, 2017).
33. Ibid, p 40-41.
34. Murphy, Douglas, author. 2016. Last Futures : Nature, Technology and the End of Architecture. London: Verso, p 57-58.
35. Escher, Cornelia Regine. „Mega-Structuralism and Groupe d’Etude d’Architecture Mobile.“ In Structuralism Reloaded: Rule-Based Design in Architecture and Urbanism, by Tom Avermaete and George Vrachiliotis Thomas F. Valena, translated by Ilze Mueller, 214-216. Stuttgart/London, 2011.
36. Banham, Reyner. 1976. Megastructure : Urban Futures of the Recent Past. 1st U.S. ed. ed. London; New York; London : Thames and Hudson, 1976: Thames and Hudson; Harper & Row, p 85.
37. Ibid, p 86.
38. Banham, Reyner. 1976. Megastructure: Urban Futures of the Recent Past. 1st U.S. ed. ed. London; New York; London : Thames and Hudson, 1976: Thames and Hudson; Harper & Row, p 85.
39. Ibid, 94-97.
40. Ibid, 102-103.
41. all, Peter. “Monumental Folly.“ New Society, Oct 24, 1968, Volume 12, No 317: p 602-603.

42. Banham, Reyner. 1976. Megastructure: Urban Futures of the Recent Past. 1st U.S. ed. ed. London; New York; London : Thames and Hudson, 1976: Thames and Hudson; Harper & Row, p 201-210.
43. Busbea, Larry. 2020. The Responsive Environment : Design, Aesthetics, and the Human in the 1970s. Minneapolis, MN ; University of Minnesota Press, , p 8.
44. Ibid, 217-218.
45. "An Everlasting Symbol of Florence." Visit Florence. n.d. https://www.visitflorence.com/florence-monuments/ponte-vecchio.html (accessed Nov 13, 2017).
46. Roq et Rob, Roquebrune-Cap-Martin, France, 1949. n.d. http://www.fondationlecorbusier.fr/corbuweb/morpheus.aspx?sysId=13&IrisObjectId=6184&sysLanguage=en-en&itemPos=157&itemSort=en-en_sort_string1%20&itemCount=215&sysParentName=&sysParentId=65 (accessed Jan 12, 2018).
47. Banham, Reyner. 1976. Megastructure: Urban Futures of the Recent Past. 1st U.S. ed. ed. London; New York; London : Thames and Hudson, 1976: Thames and Hudson; Harper & Row, p 106-111.
48. Merin, Gili. AD Classics: Habitat 67 / Safdie Architects ArchDaily. Jul 21, 2013. <https://www.archdaily.com/404803/ad-classics-habitat-67-moshe-safdie> ISSN 0719-8884 (accessed Nov 16, 2017).
49. Mountain Dwellings / PLOT = BIG + JDS. ArchDaily. Mar 11, 2009. <https://www.archdaily.com/15022/mountain-dwellings-big/> ISSN 0719-8884 (accessed Nov 16, 2017).
50. Ioannidou, Ersi. "Structuralism and Metabolism." In Structuralism Reloaded: Rule-Based Design in Architecture and Urbanism, by Tom Avermaete and George Vrachiliotis Thomas F. Valena, translated by Ilze Mueller, 222-226. Stuttgart/London, 2011.
51. Avermaete, Tom. "From Deep Structure to Spatial Practice, Team 10, Structuralist Attitudes and the Influence of Antrhopology." In Structuralism Reloaded: Rule-Based Design in Architecture and Urbanism, by Tom Avermaete and George Vrachiliotis Thomas F. Valena, translated by Ilze Mueller, 124. Stuttgart/London, 2011.
52. Smithson, Alison. "How to Recognize and Read Mat-Building." Architectural Design, Sept 1974: p 573.
53. Smithson, Alison, 1928-1993. and Dendy, William, 1948-,former owner. 1974. Team 10 Primer. Cambridge: MIT Press, p 74-95.
54. Ferrer Forés, Jaime J. 2011. „Mat Urbanism: Growth and Change." Projections (10): p 73-83.
55. Avermaete, Tom. „From Deep Structure to Spatial Practice, Team 10, Structuralist Attitudes and the Influence of Antrhopology." In Structuralism Reloaded: Rule-Based Design in Architecture and Urbanism, by Tom Avermaete and George Vrachiliotis Thomas F. Valena, translated by Ilze Mueller, 129-132. Stuttgart/London, 2011.
56. Owen, Pamela. Inside the Kowloon Walled City where 50,000 residents eked out a grimy living in the most densely populated place on earth. May 5, 2012. http://www.dailymail.co.uk/news/article-2139914/A-rare-insight-Kowloon-Walled-City.html (accessed July 18, 2017).
57. Easterling, Keller. 2014. Extrastatecraft : The Power of Infrastructure Space. London ; Verso. Ch 2.
58. Todd, Nancy, John Todd, and Nancy Todd. 1994. From Eco-Cities to Living Machines : Principles of Ecological Design. Berkeley, Calif: North Atlantic Books.
59. Wikipedia contributors. 2024. "Findhorn Ecovillage." Wikipedia. April 12, 2024. https://en.wikipedia.org/wiki/Findhorn_Ecovillage (accessed Jun 16, 2024).
60. "Projects | John Todd Ecological." n.d. John Todd Ecological. https://www.toddecological.com/projects (accessed Jun 18, 2024).
61. The Bonaventure Hotel. 2015. http://hotelbonaventure.com/en/hotel/ (accessed Apr 12, 2017).
62. Southcott, Tanya. Place Bonaventure. May 1 2015. https://www.canadianarchitect.com/features/place-bonaventure/ (accessed Apr 12, 2017).
63. Banham, Reyner. 1976. Megastructure : Urban Futures of the Recent Past. 1st U.S. ed. ed. London; New York; London : Thames and Hudson, 1976: Thames and Hudson; Harper & Row, p 121-124.
64. Southcott, Tanya. Place Bonaventure. Canadian Architect. May 1 2015. https://www.canadianarchitect.com/features/place-bonaventure/ (accessed Apr 12, 2017).
65. Banham, Reyner. 1976. Megastructure : Urban Futures of the Recent Past. 1st U.S. ed. ed. London; New York; London : Thames and Hudson, 1976: Thames and Hudson; Harper & Row, p 184.
66. Our Building. https://www.barbican.org.uk/our-story/our-building/our-history (accessed Dec 21, 2017).
67. Glancey, Johnathon. A Great Place to Live. The Guardian. Sept 7 2001. https://www.theguardian.com/education/2001/sep/07/arts.highereducation (accessed Dec 21, 2017).
68. Frearson, Amy. Brutalist buildings: Barbican Estate by Chamberline, Powerll & Bon. Dezeen. Sept 13 2014. https://www.dezeen.com/2014/09/13/brutalist-buildings-barbican-estate-chamberlin-powell-bon/ (accessed Dec 21, 2017).

69. Glancey, Johnathon. A Great Place to Live. The Guardian. Sept 7 2001. https://www.theguardian.com/education/2001/sep/07/arts.highereducation (accessed Dec 21, 2017).
70. Ibid.
71. Banham, Reyner. 1976. Megastructure : Urban Futures of the Recent Past. 1st U.S. ed. ed. London; New York; London : Thames and Hudson, 1976: Thames and Hudson; Harper & Row, p 185.
72. Murphy, Douglas. 2016. Last Futures : Nature, Technology and the End of Architecture. London: Verso. 1 -16.
73. Marino, B. D. V. (Bruno D. V.), and Howard T. (Howard Thomas) Odum. 1999. Biosphere 2 : Research Past and Present. Great Britain? Elsevier Science. 32 - 63.
74. University of Arizona. “Fast Facts.” Fast Facts | Biosphere 2. Accessed June 3, 2024. https://web.archive.org/web/20180916014420/http://biosphere2.org/visit/about-biosphere2/fast-facts.
75. Marino, B. D. V. (Bruno D. V.), and Howard T. (Howard Thomas) Odum. 1999. Biosphere 2 : Research Past and Present. Great Britain? Elsevier Science. 9 - 21.
76. Marino, Bruno D.V, Tilak Ram Mahato, John W Druitt, Linda Leigh, Guanghui Lin, Robert M Russell, and Francesco N Tubiello. 1999. “The Agricultural Biome of Biosphere 2:: Structure, Composition and Function.” Ecological Engineering 13 (1): 199–234. https://doi.org/10.1016/S0925-8574(98)00100-1.
77. Poynter, Jane. 2006. The Human Experiment : Two Years and Twenty Minutes inside Biosphere 2. New York: Thunder’s Mouth Press. 157-161
78. Ibid, 323 - 329.
79. Busbea, Larry. 2020. The Responsive Environment : Design, Aesthetics, and the Human in the 1970s. Minneapolis, MN ; University of Minnesota Press. p 209 - 217.
80. Soleri, Paolo, 1919-2013. 1969. Arcology : The City in the Image of Man. Cambridge, Mass.: MIT Press, p 14.
81. Banham, Reyner. 1976. Megastructure : Urban Futures of the Recent Past. 1st U.S. ed. ed. London; New York; London : Thames and Hudson, 1976: Thames and Hudson; Harper & Row, p 200-201.
82. Soleri, Paolo, 1919-2013. 1969. Arcology : The City in the Image of Man. Cambridge, Mass.: MIT Press, p 216.
83 Pollalis, Spiro N., 1954-. 2012. Infrastructure Sustainability and Design. New York: Routledge, p 314.
84. John Button, A Dictionary of Green Ideas. Vocabulary for a Sane and Sustainable Future (London: Routledge, 1988), p????.
85. Busbea, Larry. 2020. The Responsive Environment : Design, Aesthetics, and the Human in the 1970s. Minneapolis, MN ; University of Minnesota Press, p 222.
86. Ibid, p 209 - 217.

In short, without man‘s cumulative capacity to give symbolic form to experience, to reflect upon it and re-fashion it and project it, the physical universe would be as empty of meaning as a handless clock:
its ticking would tell nothing.

The mindfulness of man makes the difference.

- Lewis Mumford - The Myth of the Machine (pg 35)



NIAGARA SITE & ECOSYSTEMS ANALYSIS

3.1 Introducing the Site

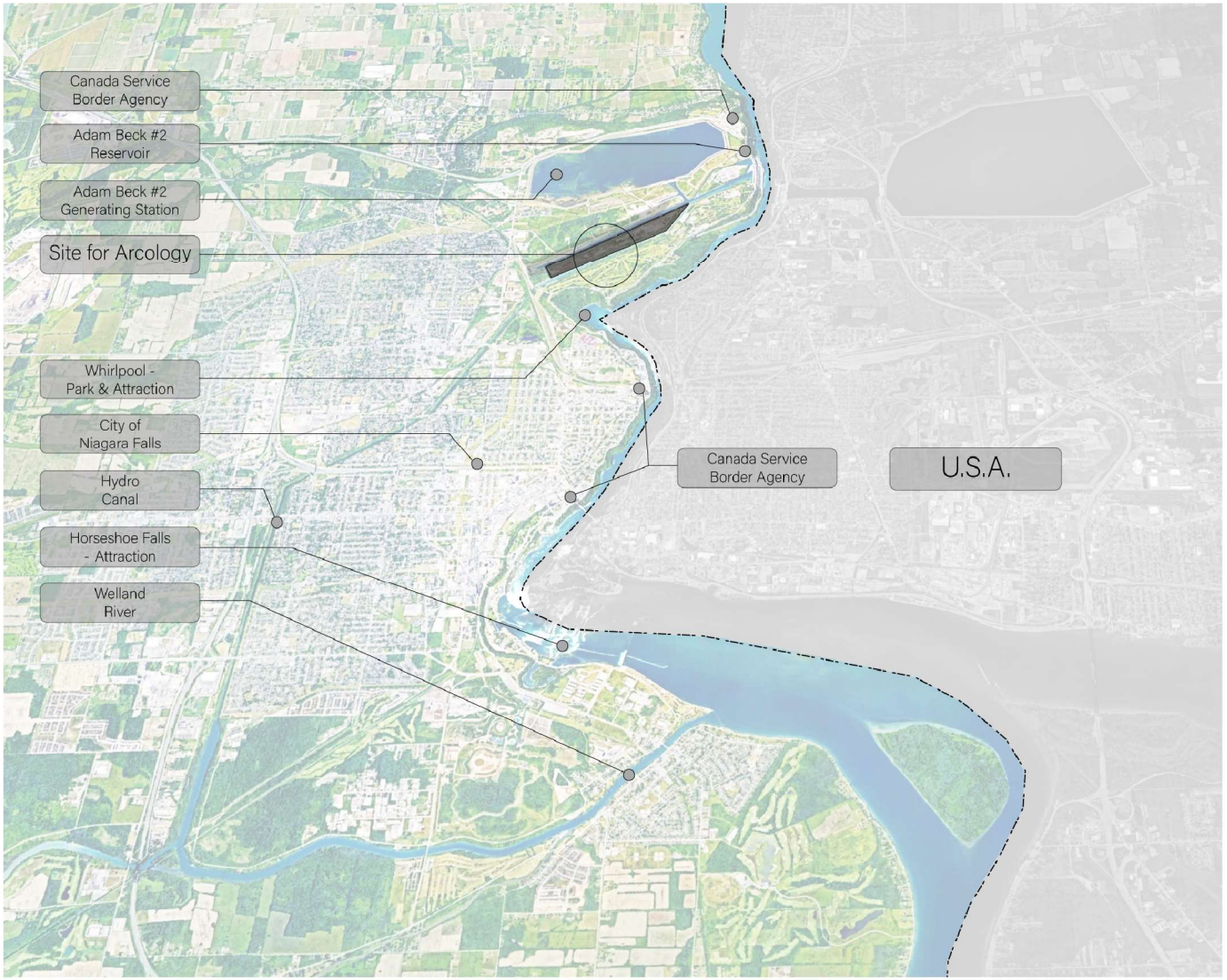


Figure 3.1: Site of Niagara Falls - prime location due to it‘s proximity to water, US borders, tourist attraction



Figure 3.2: Site of Niagara Falls - within nested loops

3.2 Introducing the Ecological Infrastructure



Figure 3.3: Patches of forested lands - limited capacity to provide adequate eco-system services

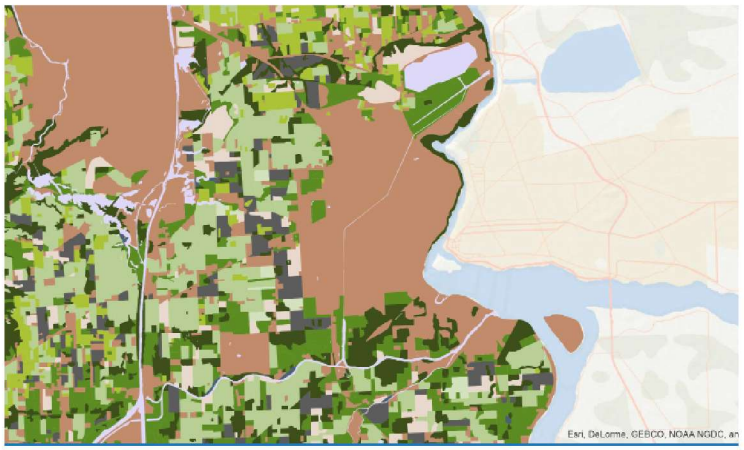


Figure 3.4: Patches of agricultural lands - monocultures do not provide ecosystem services but it could be one of the contributing factors for poor quality of water



Figure 3.7: Active Quarries in the region, this is a prime location for construction

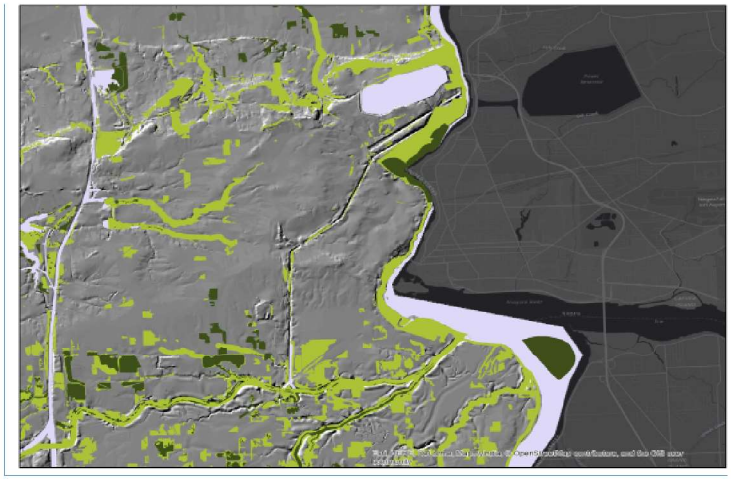


Figure 3.5: Protected Lands in the city of Niagara

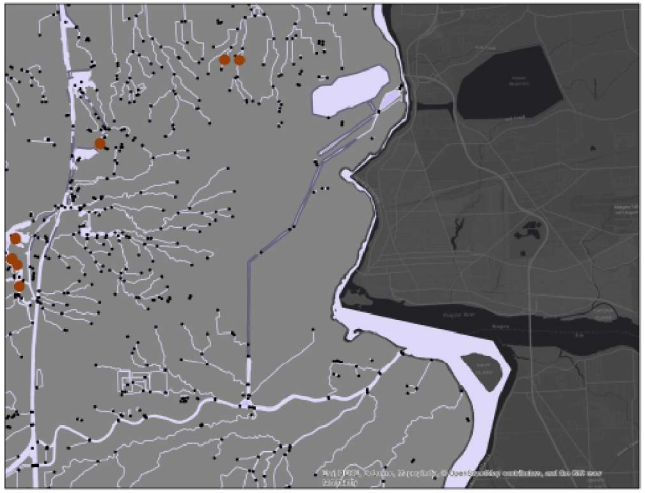


Figure 3.6: Multiple sources of water in the city of Niagara Falls, from streams, man-made canals and a lake that leads to Lake Ontario.

3.3 Biodiversity & Bird Migrations

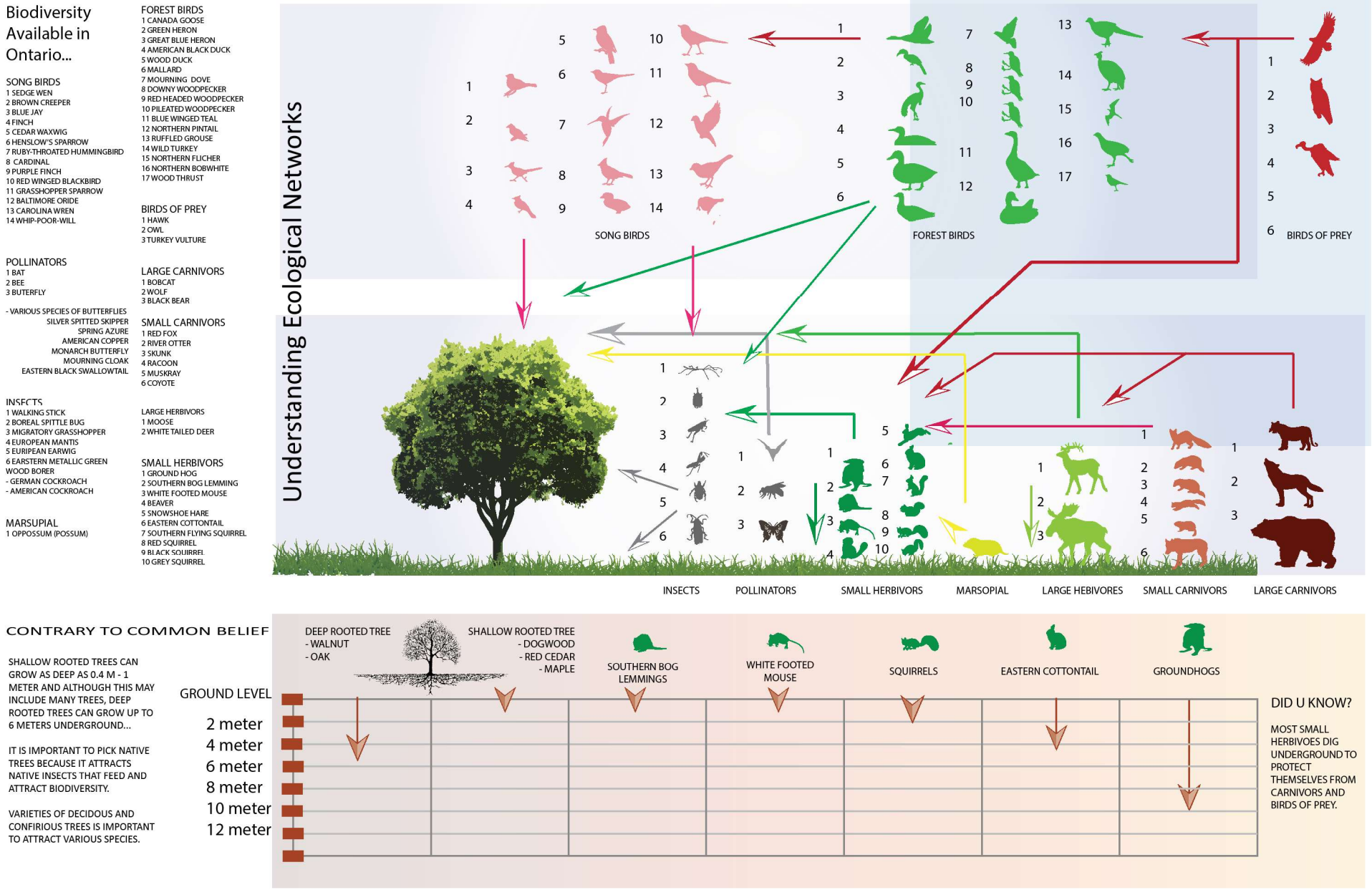
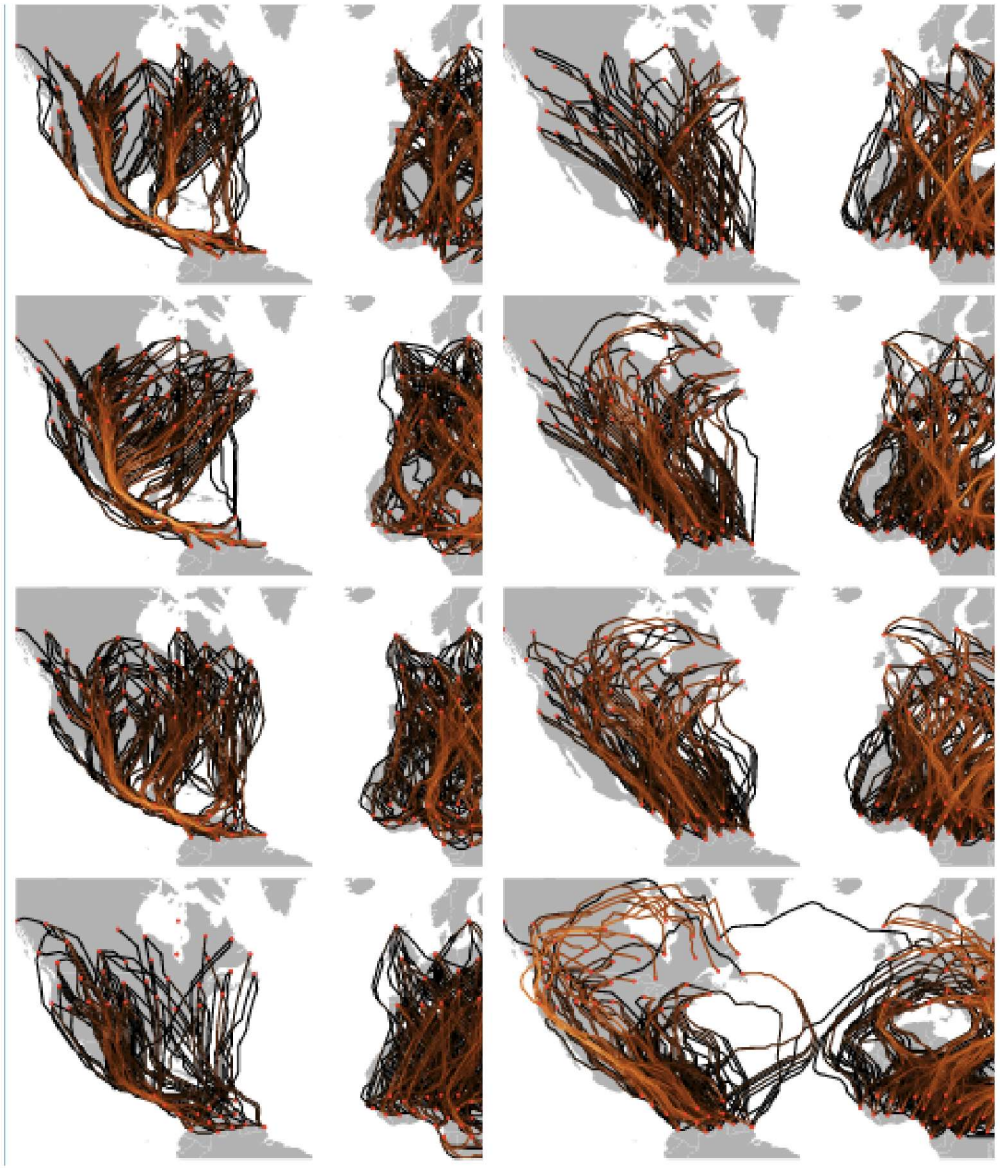


Figure 3.8: Biodiversity Variations in the Niagara Escarpment Region



April September

Figure 3.9: The city of Niagara Falls is one of the prime locations for bird migrations. Ecological Megastructures would benefit to be located close to natural migration paths.



Figure 3.10: Bird migration swarms can reach up to ten million in density.

3.4 Site Features

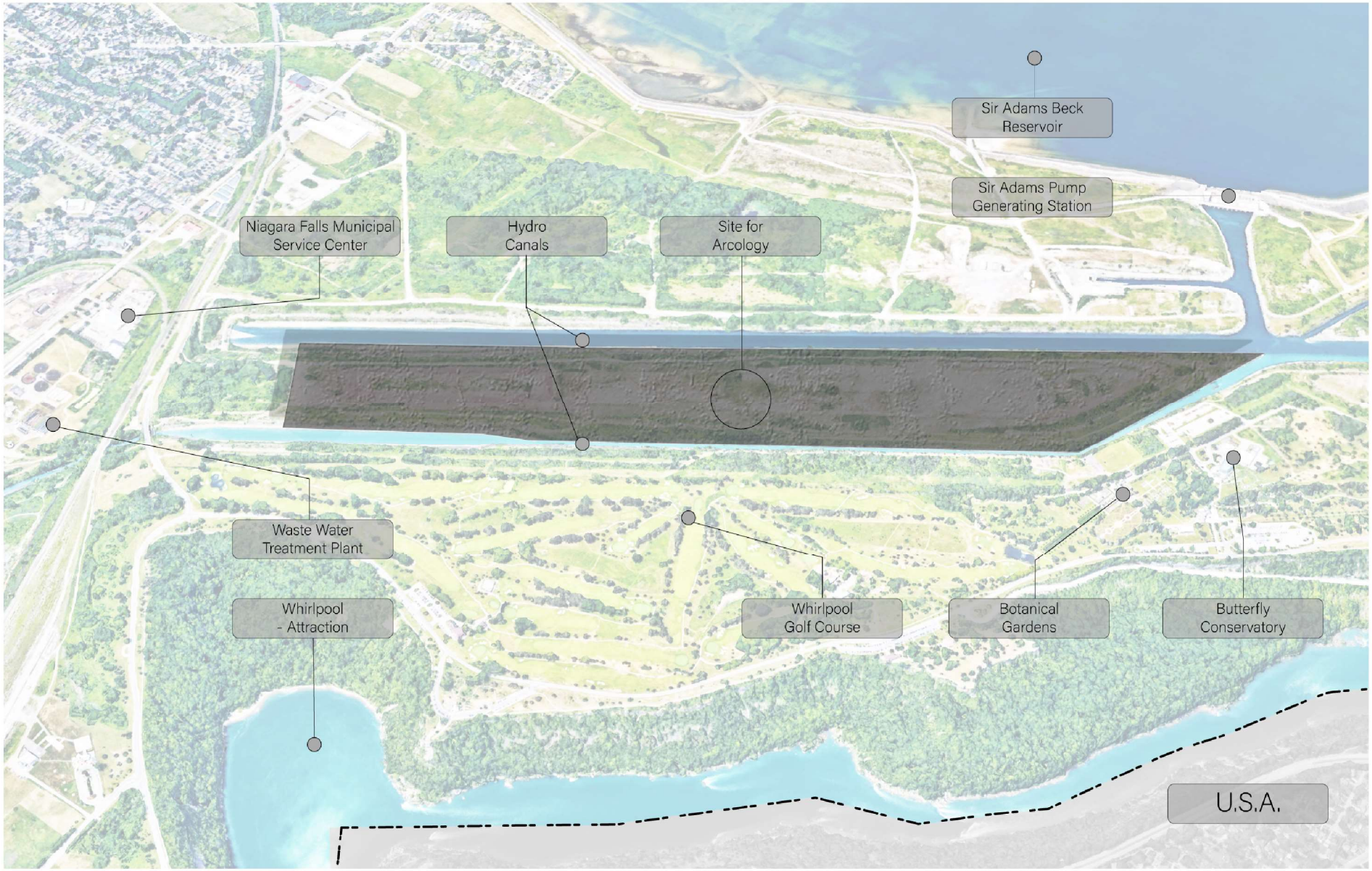


Figure 3.11: Site is located close to water bodies, Sir Adams Pump Station, Butterfly Conservatory, Botanical Gardens, Waste Water Treatment Center

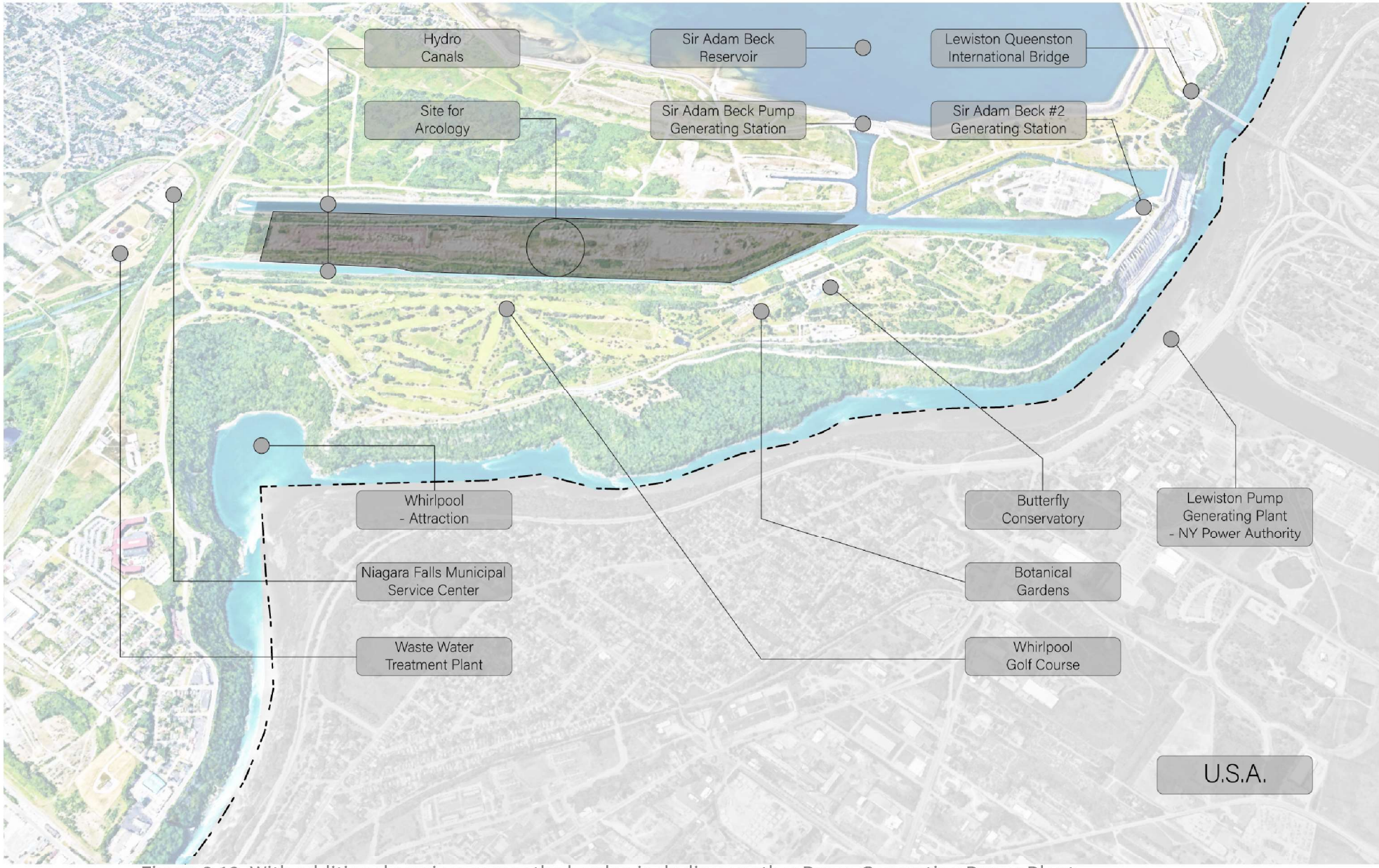


Figure 3.12: With additional services across the border, including another Pump Generating Power Plant

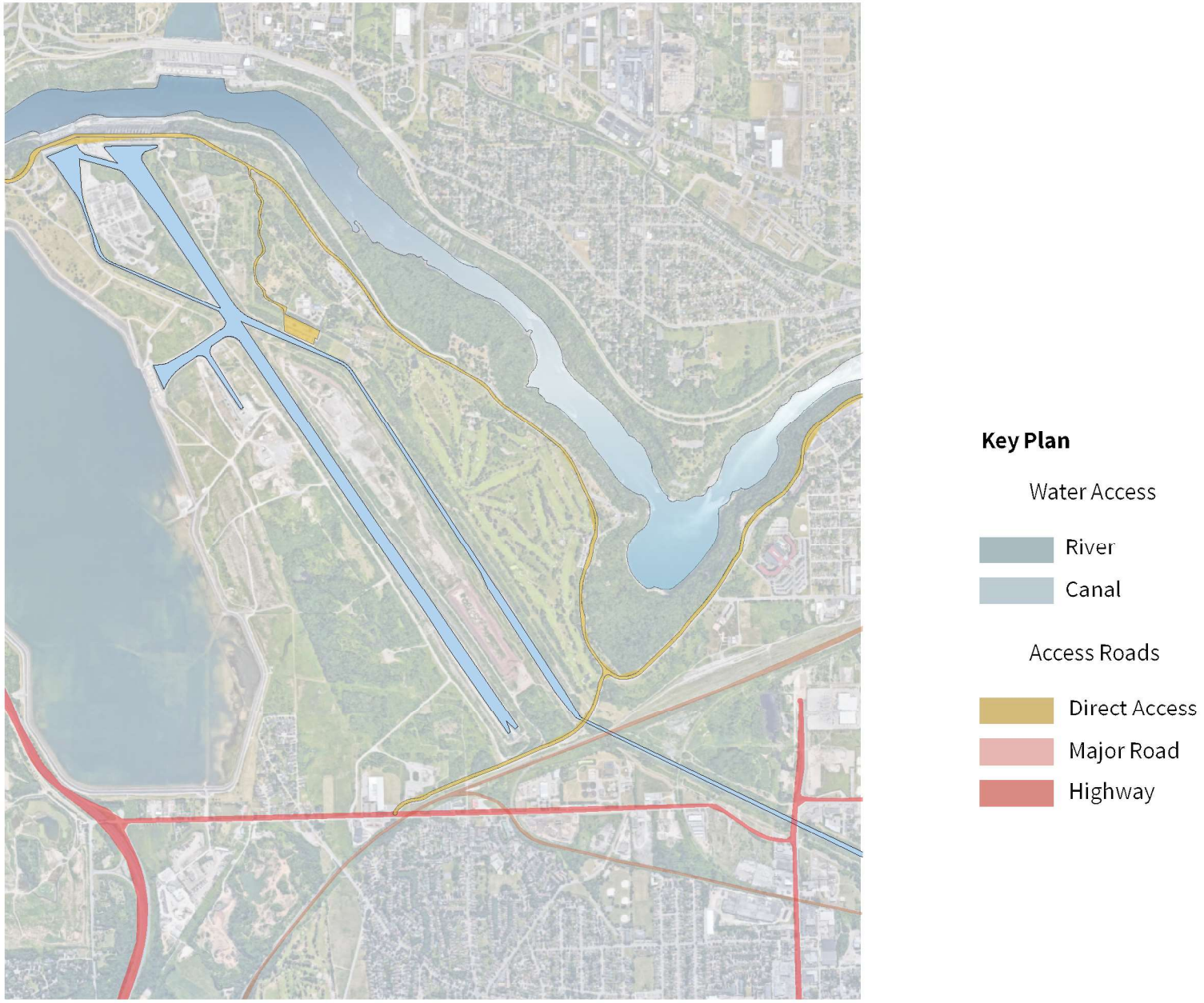


Figure 3.13: Site Access Points (roads) and Water Canal channel running along both sides of the project.

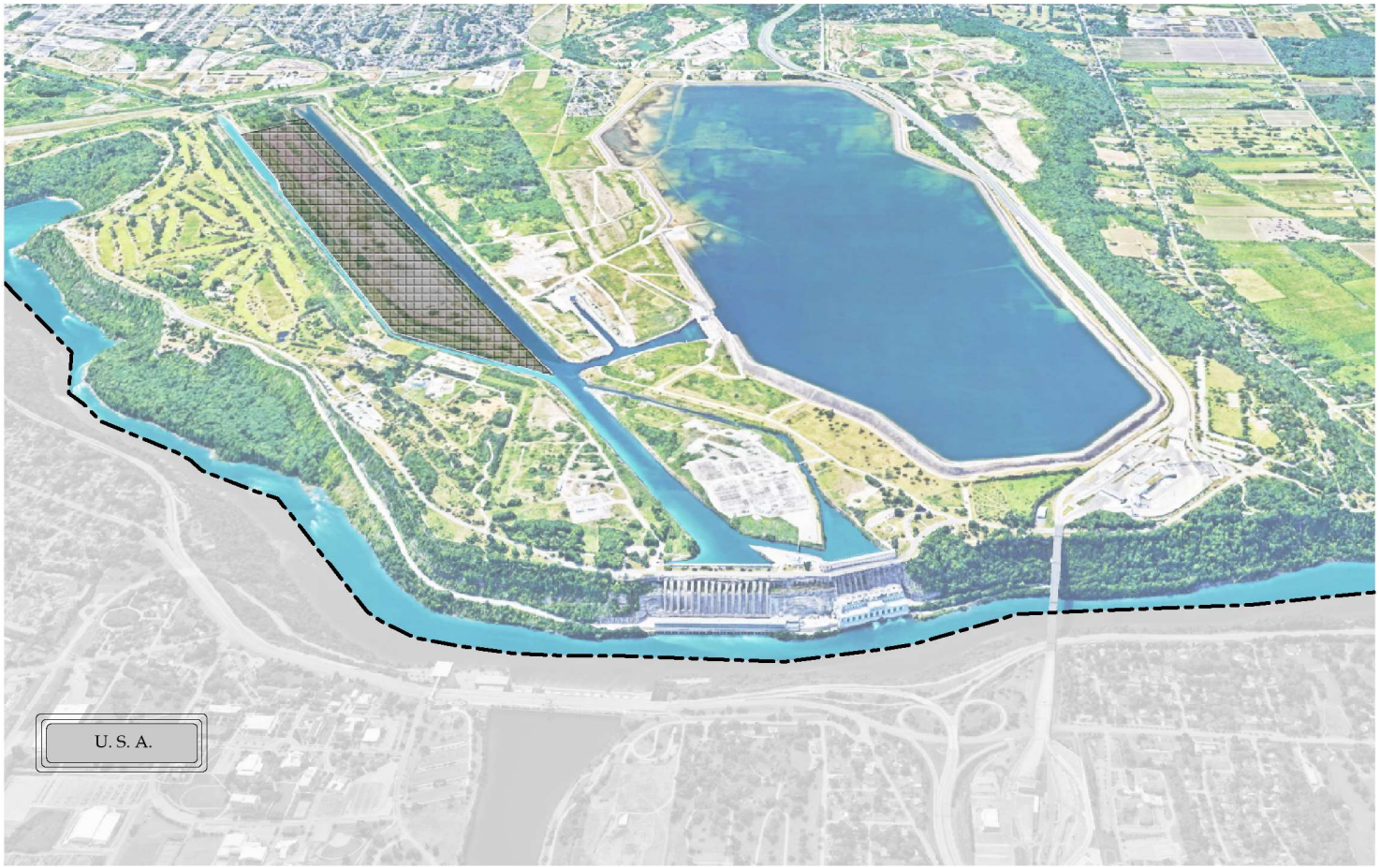


Figure 3.14: An alternative perspective of the site showing the facilities, waterbodies and ecosystems that could be available for the megastructure

There are known knowns. There are things we know that we know. There are known unknowns. This is to say, there are thinsg that we know we dont know. But there are also unknown unknowns. There are things we dont know we dont know.

- Donald Rumsfeld - United States Secretary of Defense under Gerald Ford and George W. Bush.



SYSTEMS ANALYSIS

4.0 Systems Analysis

The goals of exploring Arcology is to stop urban sprawl and encourage naturalization in the urban sector of Niagara Falls. The model is premised on the fact that people are self organizing, given the appropriate underlying conditions for all the processes. The Arcology model of my thesis is therefore, designed to provide an integrative environment for people and plants and the heighrarchies of their processes.

The model has to be designed in an integrative manner, such that human processes, the plant processes and the structural environment is synergistic. In order to deliver the synergistic goals of structure, human and plant heighrarcies, the model zones on designing the system synergies. The three key systems imployed to render the design integrative between Structure, Human and Plant processes are, the design relies on three key systems: Heat Systems, Water Systems, Waste Systems. In this particular model, the Adam Beck building provides suffecient energy for the model and supplemented in my design proposal. In order for the systems to deliver these processes synergistically, the outflow of one process leads though a cycle of natural conditioning and rendered fit to be an inflow of natural processes. Therefore, there is a codependency of processes that will provide multiple cycles in the built form.

The essential precondition for this model to enhance the energy flows for additional sustainability is natural lighting. This has been considered and explored in my sections.

The model applies a system's thinking approach to solve complex systems. System's thinking theorizes that complex issues can not be resolved through linear complicated systems. The reason is that there will always be an unpredictable outcome and the system will result in failure. System's thinking approach imploys a focus on resolving the key controling processes and managing their interative feedback loops, which over time will solve a complex problem, in a sustainable manner.

The analysis lead me to believe that the key controling processes are generated through the human and ecological processes in order to render these processes integratively. Therefore, all the system strive to be designed in a manner that it can respond to these processes at each level of their heighrarical existance.

4.1 the Ecosystem Approach

Preface to Ecosystems

Just as physicists see the chaos theory in ecosystems of the universe in a double pendulum, as an Architect, let me explain ecosystems by comparing two plants. One indoor tree, in a controlled environment, is provided sufficient sunlight, water, and daily nutrients. The second plant is a mature tree in the front yard - it is exposed to natural forces, temperature variances, seasonal cycles, animal exposure, competitive interactions under or above the soil, root systems to provide nutrition and uncontrolled sunlight exposure. It doesn't matter how much ecological theory or statistics I know or what climate condition I am in, I can not predict the behavior of one plant outside my house, because of the quantity of forces, functions, and processes the tree has been exposed to are significantly massive. However, I can predict the behavior of an indoor plant because I have full control over its interactions. Although there may be interactions I do not see in the soil, exposure to variability is minimal, and therefore, the plant's behavior is predictable. Any ecosystem predictions have an exponential percentage of error because we don't know the extent of their transactions. What we do know is ecosystems are counter-intuitive, unpredictable, complex systems. The dynamics of a complex system involve terminology such as non-linear behavior, self-organization, feedback loops, emergence, attractors, flips, nested hierarchies, typology, etc. Make sense? Not really, good, no one really gets it either, let me introduce another analogy for ecosystems theory.

Consider a series of enigmatic entities, each encapsulated within its own metaphorical "black box." These entities engage in interactions of unknown nature, receiving inputs and generating outputs, wherein the outputs of one such entity serve as the inputs for another, perpetuating a complex network of interdependencies. As we imagine this world of black boxes, consider the matrixes of these boxes as they interact with other matrixes of boxes across various scales and dimensions. Within this conceptual framework, we refer to the outputs as feedback loops, which elude to the cause-and-effect relationships governing the algorithms and networks within the black boxes. Although the inputs and outputs are observable, the underlying algorithms, interactions, processes, and functions remain mysterious. Highlighted by the random erratic responses that contradict their systematic patterns, let's call these rebellious acts "flips".

This multidisciplinary examination has prompted scholars from diverse fields to apply their unique lenses—consisting of distinct terminologies, organizational frameworks, theories, and epistemological approaches—to decipher the patterns emerging from this complexity. Such endeavors aim to predict outcomes based on causality loops and structural system patterns. This analogy aptly mirrors the predicament faced by ecologists as they study ecosystems, where each black box ranges from individual organisms to the biosphere at large. The magnitude of data required to forecast the behavior of these metaphorical black boxes is monumental. Should we endeavor to map all transactions within ecosystems, we would confront an overwhelming abyss of unknowns—a stark reminder of our epistemic limitations.

Yet, amidst this vast uncertainty, what knowledge have we accumulated? We attained a broad scale of patterns and possess an abundance of data regarding interactions at the micro and macro levels. However, the data capturing cross-sectional interactions between different scales and typologies remains elusive, primarily due to the monumental task of cataloging the myriad behaviors inherent to such complex systems. The quest to comprehensively document every conceivable aspect of these systems has not been documented. And yet, it is this very expectation that leaves us perplexed by the inherent unpredictability of complex systems. In grappling with the complexity of ecological systems, we are reminded of the profound humility required in the face of nature's vast unknown.

Introducing Ecosystems Approach

Before embarking on the Ecological Approach and its theories, three new paradigm shifts must be adopted. The first is a perception shift, due to the multi-faceted nature and levels of analysis of various types and scales within the ecosystems (figure 4.1.1). The quality of the narrative improves its resolution with the ability to consider various types and scales simultaneously. Reviewing the interactions, processes, functions, and cycles becomes part of the solution toward understanding ecosystems[1].

The second shift of perspective is to prioritize problem-solving systems by establishing hierarchies that provide a swift feedback loop referred to as complexity (figure 4.1.2). In contrast, systems get more complex when diversity is increased, providing the system with more freedom, but limited structure. Counterintuitively, complex systems are easier to control and exhibit transparent and simpler predictive behaviors. Defining the organization of a structure, once established, keeps the system focused on the quality of nutrient flows and the quality of interactions[2] . In a socio-ecological system, an example of complicatedness is twelve types of residences, complexity would be to include amenities and services within close proximity of two types of residences where the quality of flows becomes the focus of management.

The third shift is the notion that the design process should follow a problem-solving strategy. American Urban Planner Kevin Lynch and his colleague Gary Hack in their book "The Art of Site Planning", state that plans imply concreteness and strategies provide multiple solutions in response to "uncertainty, the technique of learning, the degree of participation, the linking of form and management, the use of professionals, and the relation to the client and other decision-makers[3]". These perspective shifts intend to improve the ecosystem's resolution by eliminating blind spots and prioritizing the underlying ecological processes that give a system its resilience.

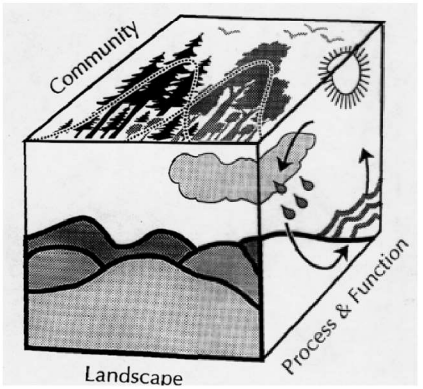


Figure 4.1.1: Timothy F. H. Allen's seven types of ecosystem descriptions

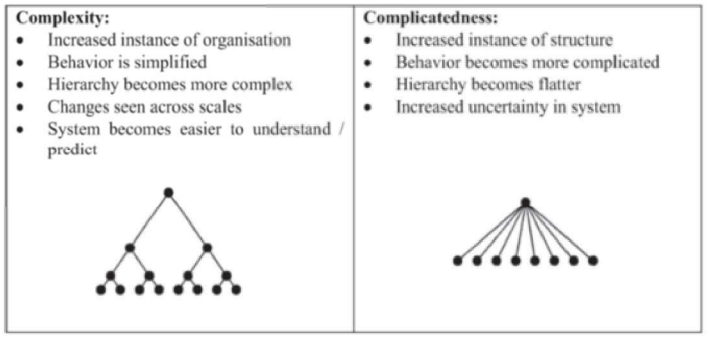


Figure 4.1.2: Complexity VS Complicatedness (Allen et al., 1999)

1 Waltner-Toews, David, James (James J.) Kay, and Nina-Marie E. Lister. The Ecosystem Approach: Complexity, Uncertainty, and Managing for Sustainability. New York: Columbia University Press, 2008. P 38 – 48.

2 Kibert, Charles J., Jan. Sendzimir, and G. Bradley. Guy. Construction Ecology: Nature as the Basis for Green Buildings. London; Spon Press, 2002. P 109 – 115.

3 Lynch, Kevin, and Gary. Hack. Site Planning. 3rd ed. Cambridge, Mass: MIT Press, 1984. P 369. Lynch, Kevin, and Gary. Hack. Site Planning. 3rd ed. Cambridge, Mass: MIT Press, 1984. P 369.

The ecosystem approach is a multi-scaled framework that considers regional analysis that maps the environmental flows to individual interactions among living organisms and details an adaptive strategy to maximize the ecosystem services provided to improve the interface and integration between manmade and natural systems. Global documented case studies include the Great Lakes Basins[4], India's Cooum River[5], Kenya's Central Highlands[6], and Toronto's Waterfront[7]. This advanced holistic methodology is backed by a system of multi-disciplinary theories and research. This approach evolved in 1972 with Prigogine and his team of researchers and the role of thermodynamics plays in explaining the behavior of complex systems through self-organizing structures. This was derived from Hatsopoulos and Keenan's Law of Stable Equilibrium and later Kestin's Unified Principle of Thermodynamics which indicates that processes have a direction and an end state. With the understanding that life can be a variable state, it launched a series of publications that reinforced the self-organizing theory by stating the system has intrinsic self-perpetuating properties that give it a semblance of order like di Castri, Jantsch, Nicolis and Prigogine, Peacocke, Wickens and Kay. Canadian physicist, ecological scientist, and policy maker, James J. Kay from 1984 to 1999, based his research on describing ecosystems as complex, adaptive, self-organizing hierarchal open systems[8].

Understanding that this is a multi-scaled and multi-layered system, there is an inherent structure to the matrixes that provides order (figure 4.1.3). The physical environment has flows that consist of three items: exergy, materials, and information. These flows are processed and structured in ecological systems and the outputs are used as inputs for social systems. Direct exposure to the physical environment and social systems leads to degradation because there is no intrinsic structure in man-made systems. Ecological systems evolved these structures and are, therefore, a necessary buffer that extends the lifespan of urban systems. Scottish landscape architect and writer, Ian McHarg's instinctive notion that human society must fit in with nature[9] was not only correct, but this model indicates urban systems are dependent on ecological processes.

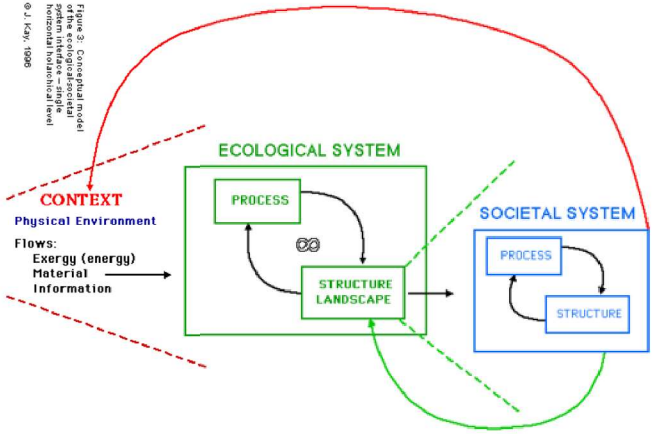


Figure 4.1.3: Conceptual Model of the socio-ecological system on a holarchy level (Kay et al. 1996)

4 Waltner-Toews, David, James (James J.) Kay, and Nina-Marie E. Lister. The Ecosystem Approach: Complexity, Uncertainty, and Managing for Sustainability. New York: Columbia University Press, 2008. P 175 – 188.
5 Ibid. P 157 – 171.
6 Ibid. 191 – 198.
7 Howell, E. T., S. C. Dahmer, K. M. Chomicki, N. Benoit, D. Boyd, and G. S. Bowen. "Monitoring Water Quality on the Central Toronto Waterfront: Perspectives on Addressing Spatiotemporal Variability." Aquatic Ecosystem Health & Management 21, no. 3 (2018): 255–67. https://doi.org/10.1080/14634988.2018.1500060.
8 Kibert, Charles J., Jan. Sendzimir, and G. Bradley. Guy. Construction Ecology: Nature as the Basis for Green Buildings. London; Spon Press, 2002. 72-74.
9 McHarg, Ian L., and Frederick R. Steiner. To Heal the Earth: Selected Writings of Ian L. McHarg. Washington, D.C: Island Press, 1998. 71.

Detailed resolution of socio-ecological systems shows they are made up of dissipative systems with complex interactions, resulting in a series of nested hierarchies and feedback loops (figure 4.1.4). This provides us with three conclusions when discussing socio-ecological systems. The first is ecological systems' outputs provide the environment for social systems. Societal systems can alter and influence ecological systems through layered transactions. Societal systems can alter the overall context of the physical environment and in turn, change the ecological system[10]. This means the changes that cascade through the nested holons through levels, processes, structures, contexts, and feedback must be identified, monitored, and governed due to their variability.

This dynamic hierarchical holon model controlled by positive and negative feedback loops is known as Self Organizing Holarchic Open (S.O.H.O.) systems. One of the properties of this system is its ability to transform and adapt to its feedback loops. The advantage of developing this structure to maturity the processes will cycle within the system, creating diversity and emergent systems, evolving the system toward attributes such as resilience. This system requires two types of cyclic loops: nested autopoietic (organized closed and self-replicating loops ie living organisms) and synoptic (open and evolving such as diversity in species)[11]. The S.O.H.O. systems have multiple steady states in such a given situation and provide specific processes and functions, known as attractors. Attractors vary from grasslands, shrublands, woodlands, and marshlands – these attractors will compete and can be re-activated within the system. These changes may have a delayed response between inputs and outputs with catastrophic behaviors such as bifurcations and flips in attractors[12]. When managing socio-ecological systems, if two or more attractors are competing over the physical environment, as environmental stewards, we design our environment by prioritizing objectives and trade-offs to determine the end goal[13]. This is in line with Canadian ecologist Holling's four-box model (figure 8 adaptive cycles) which describes a system's resilience in four cyclic stages (figure 4.1.5)[14]. This approach was elaborated by Kay and others, as an ecosystem approach for planning and decision-making for sustainability (figure 4.1.6)[15]. Developing dynamic processes requires dynamic ongoing management strategies for this evolving socio-ecological system.

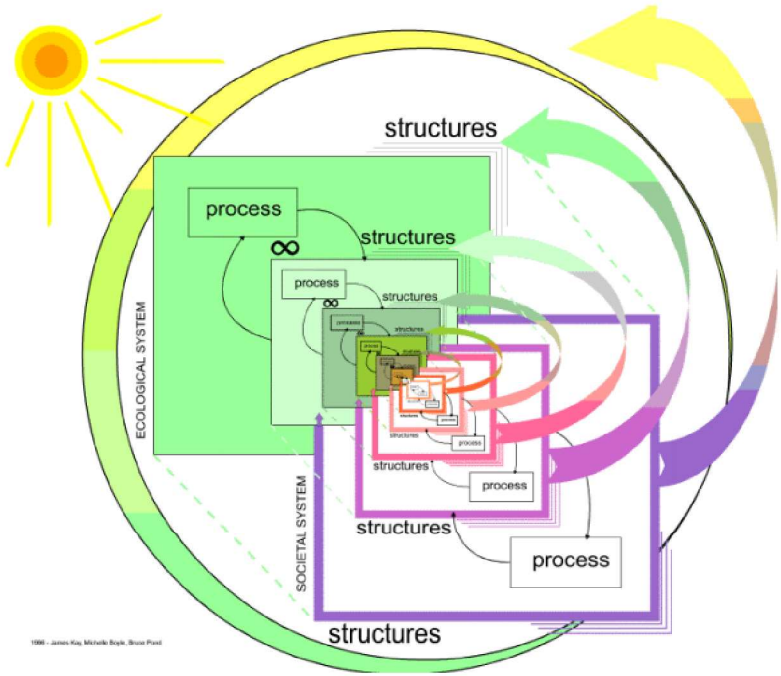


Figure 4.1.4: The nested hierarchical conceptual model of the Socio-Ecological System (Kay et al. 1996)

10 Kibert, Charles J., Jan. Sendzimir, and G. Bradley. Guy. Construction Ecology: Nature as the Basis for Green Buildings. London; Spon Press, 2002. 84-88.

11 Dempster, J. P. (Jack P.), and I. F. G. McLean, eds. Insect Populations in Theory and in Practice: 19th Symposium of the Royal Entomological Society 10-11 September 1997 at the University of Newcastle. 1st ed. 1998. Dordrecht: Springer-Science+Business Media, B.V., 1998. https://doi.org/10.1007/978-94-011-4914-3.

12 Kibert, Charles J., Jan. Sendzimir, and G. Bradley. Guy. Construction Ecology: Nature as the Basis for Green Buildings. London; Spon Press, 2002. 88 - 96.

13 Allenby, Braden R. Industrial Ecology: Policy Framework and Implementation. Upper Saddle River, N.J: Prentice Hall, 1998.

14 Holling, C. S. "Understanding the Complexity of Economic, Ecological, and Social Systems." Ecosystems (New York) 4, no. 5 (2001): 390–405. https://doi.org/10.1007/s10021-001-0101-5.

15 Kay, James J., Henry A. Regier, Michelle Boyle, and George Francis. "An Ecosystem Approach for Sustainability: Addressing the Challenge of Complexity." Futures: The Journal of Policy, Planning and Futures Studies 31, no. 7 (1999): 721–42. https://doi.org/10.1016/S0016-3287(99)00029-4.

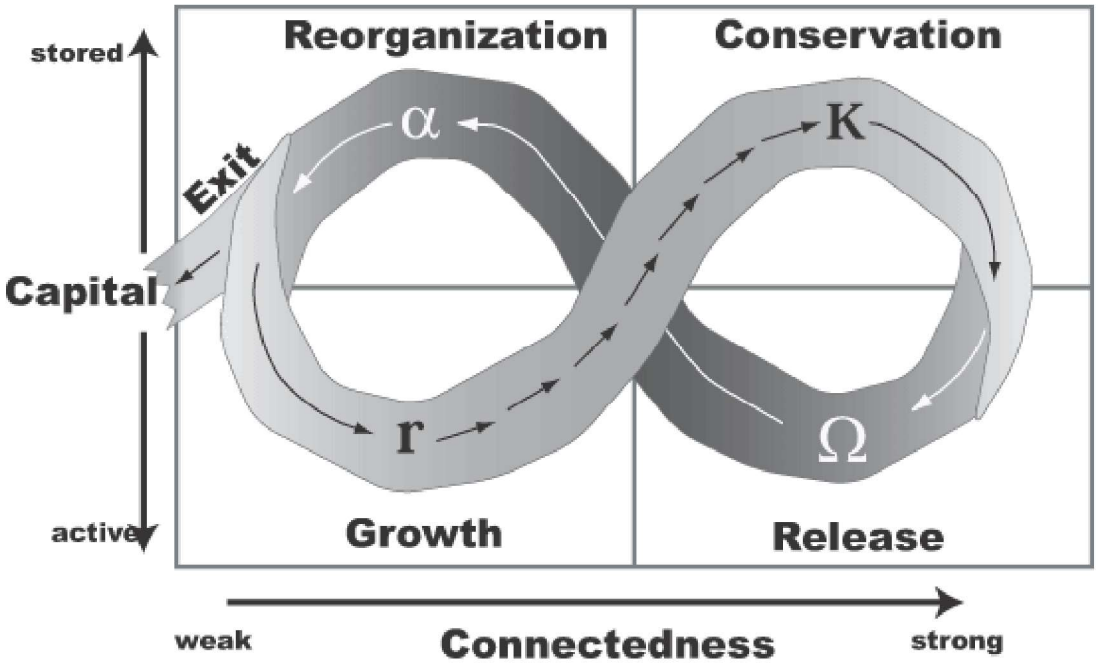


Figure 4.1.5: Holling's figure 8 adaptive cycles (Holling, 2001)

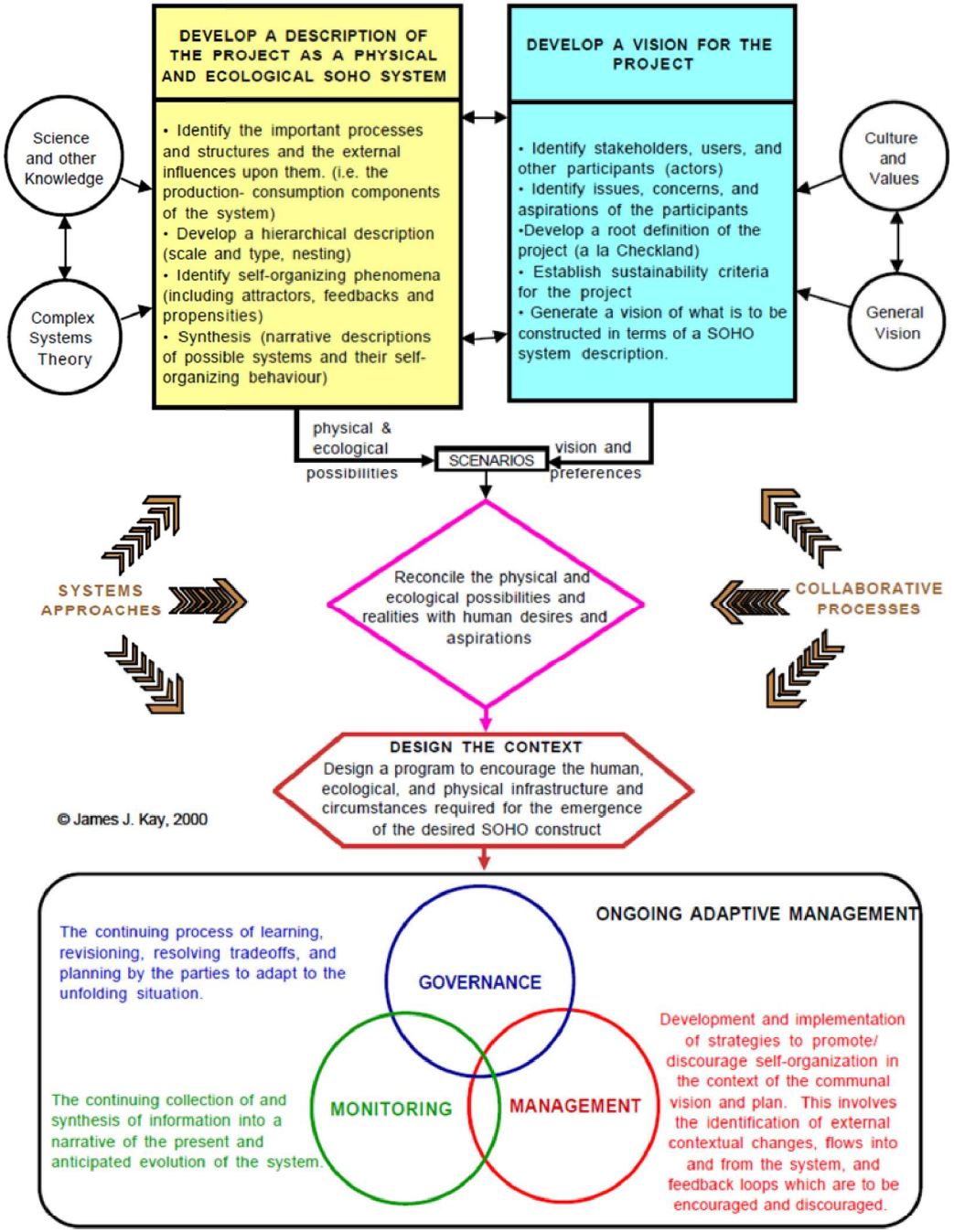


Figure 4.1.6: An Adaptive Ecosystems Approach for Sustainability (Kay et al, 1999)

Megastructures and Landscape

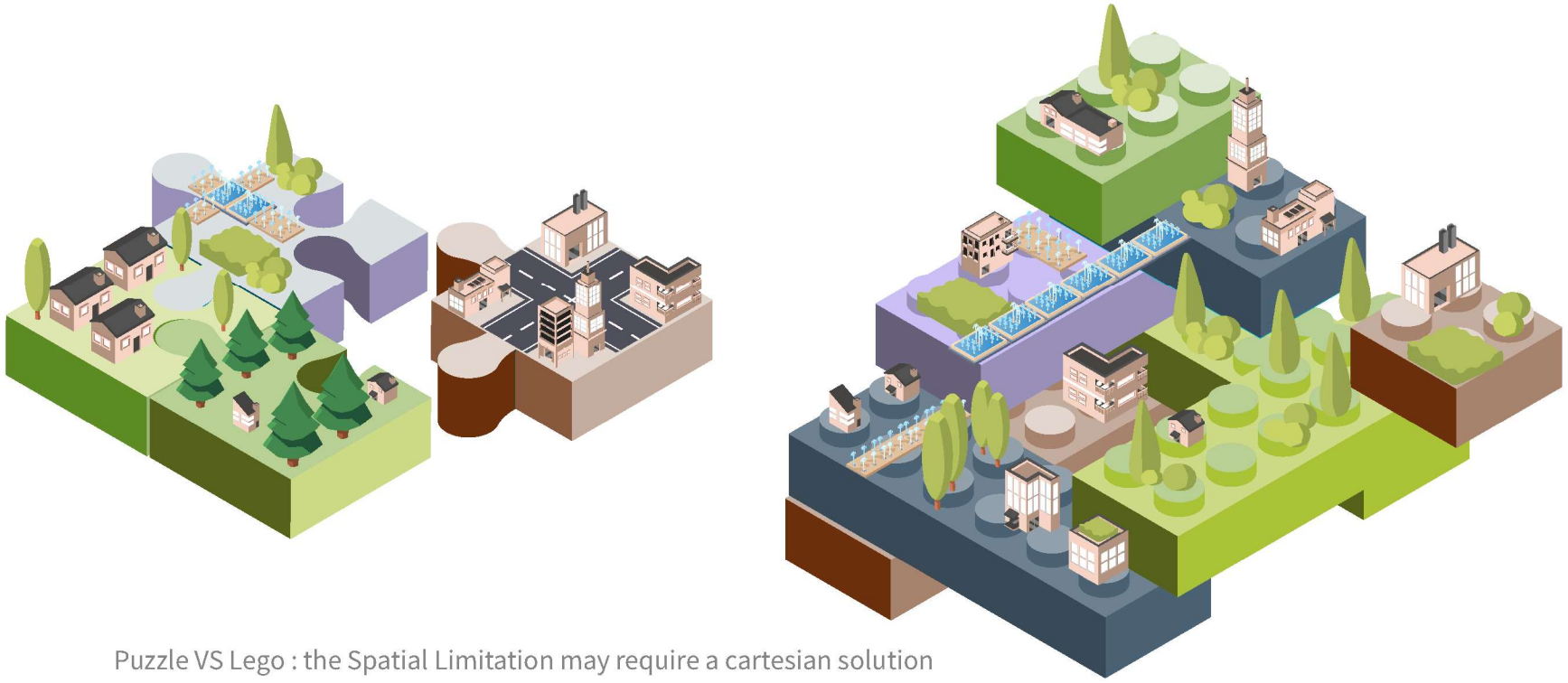
Due to the self-organizing phenomena, the resolution of Societal-Ecological Systems must become interdisciplinary to include complex interactions. This approach encourages decision-makers to illustrate a narrative as a possible future to strive for and redefine a non-traditional design framework by including strategy in the design process. The adoption of a megastructure is suited in size and scale to several types of landscapes, including its waste cycles. The combination of this new typology comes with three distinct advantages.

First, it alleviates the natural environment from urban sprawl by providing an alternative to compacted typology. This leaves the physical environment to replenish its resources and cycle at its leisure. Megastructures can be designed to be multi-leveled, scalable, and flexible to adapt to their growth and human population. The second factor is it is a man-made open system with control, monitoring, and management processes. These positive and negative feedback loops are key to understanding the limits of the growth of the system. Although it may take time for the ecological systems to mature, as soon as it does, they will have resilient attributes. The third, and perhaps most essential, is there is a profound gap in ecological research, that can be filled through data collection and observation. We have a large quantity of data at the macro level and the individual transactions, but there are many holes to be filled in the cross-sectional transactions. We can catalog socio-ecological interactions, and architectural features, technological integration, experiment with building materials, design for temporal architecture, mechanize structures in an externally controlled setting, experiment with large building models, vertical farming, etc. This Arcology would be a viable alternative, where suburbia is integrated into a multi-story man-made landscape.

4.2 Reframing the Problem and the Arcology Synthesis

There is a fundamental spatial problem with fitting living systems in current buildings and urban spaces. To clarify the issue, the issue has to be clarified on many levels. Ecosystem services have a greater return when the number of interactions is increased, and the distance are between living systems reduced. The more diversity among living systems, the more ecosystem services it can provide. Direct ecosystem services such as filtering the air, purifying the water, processing wastes, regulate climate, pollination, food, additional natural resources and providing additional indirect ecosystem services. Indirect system services such as aesthetic, cultural, and recreational benefits.

The contradiction seems most prevalent in the organizational structure of our urban design. It limits the interactions between living systems drastically with its puzzle-like plots that can only develop patches of systems. This encourages horizontal growth, and this horizontal growth creates can only create patches of green spaces and urban sprawl. Arcologies propose replacing those puzzle pieces with pieces of interlocking lego and to build megastructures that provide a more layering of functions so it can provide more adaptable and changeable building types. But to even consider this change, there must be a paradigm shift.



Puzzle VS Lego : the Spatial Limitation may require a cartesian solution

a. Paradigm of Polarities

System thinking approach and Self-Organizing Holarichal systems encourage dualities to function at various times with a variety of requirements. This paradigm shift between polarities encourages active spaces to meet the requirements of the residences. Therefore, it is less of a discussion regarding resilience vs productivity, decentralized vs centralized, slow pace vs fast pace, interdependence vs function. But rather, to have spaces that can adapt several functions to encourage movement.



If the building is centralized, the substructure must be decentralized.



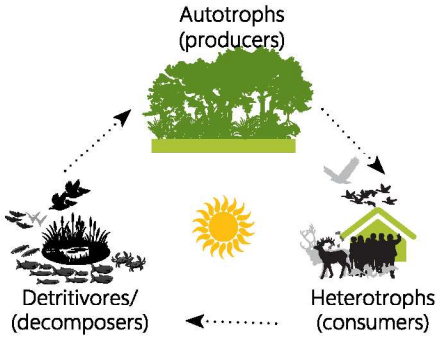
If the building is decentralized, the substructure must be centralized.



b. System Cycles

The attractive feature for arcologies is they have the capacity to withhold cyclic system cycles in their entirety. Provided they include all the resources and nutrients of the systems and process all its wastes within that cycle. This would require the systems to be granularly analyzed when placing systems to ensure that the cycle's needs and wastes are within the system. for it to be sustainable.

There are multiple systems within each system, however, with broad brush strokes, systems such as industrial facilities and farming facilities produce larger wastes compared to communities with more sedimentary cycles. This thesis will focus on residential systems with limited travel distances.





c. Limit Private Space for Larger Public Spaces

The scale of trees and plants is larger than trees and even if we limit the heights of these plants by limiting their pot sizes, we have significantly larger ecological spaces than we have living spaces for people. The private-to-public dynamic should, therefore, also be reversed. We would therefore reduce the houses from single-house dwellings to smaller compartmentalized units such as apartment-size units to limit clutter and encourage individuals to increase interactions and take advantage of public spaces for additional activities.



d. Abstraction is the Issue

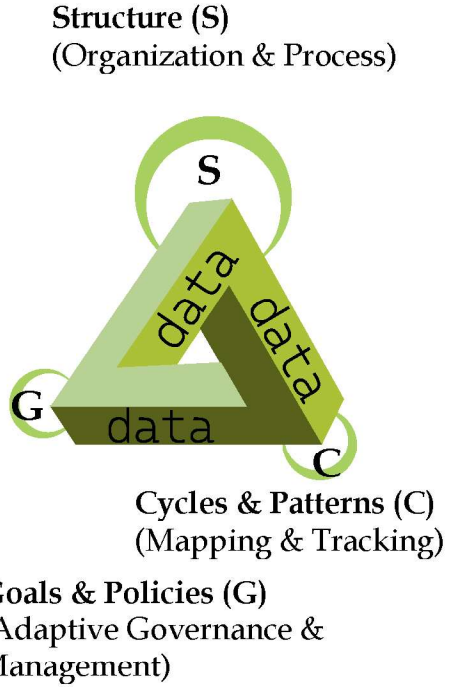
Living systems is a very complex and complicated issue because of the delayed feedback response. The feedback that we receive from the system provides data, but it requires to be analyzed and channeled into three typical categories.

The vagueness of these categories is due to the varied requirements from and for multi-disciplines. The major obstruction is understanding the structure of living systems and how it relates to architecture. Once the processes are clarified and structured, then solving the system becomes a recurring process of refining while simultaneously synthesizing the cycles and managing the goals and policies to track the system. There has been extensive research on managing goals and policies, along with cycles and patterns but the organizational structure has continued to be a vague concept.

Understanding the organizational structure of living systems will not only dictate the spatial organization but will clarify system thinking and its relationship to how to manage living systems in an architectural context.

This abstraction is a very challenging concern because the architecture in itself is intended to last a long time. This contradiction has kept architects from a pragmatic approach and has embraced artistic expression and experimental concepts.

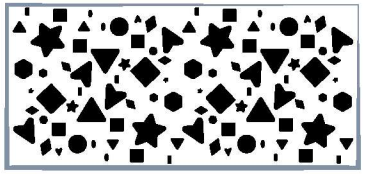
To develop a pragmatic approach, one must have a vague understanding of a variety of disciplines and piece them together but first, we must understand the structure and synthesize a procedure for living systems, this process will indicate a cause (leverage point) and conclude with visual symptoms that will indicate growth in a positive or negative direction.

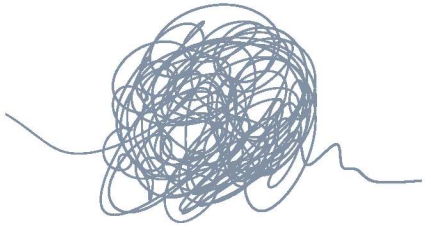


To determine the organizational structure for living systems, one must recognize the abstract thoughts on multiple scales

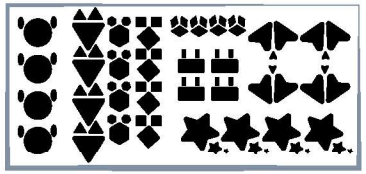
Understanding Self-Organizing Holarichal Systems - Emergence Procedure on every scale

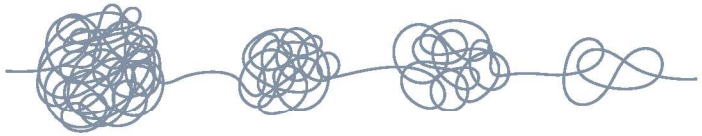
0 Chaos (Quantifiable things - Numbers)



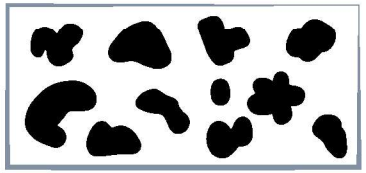


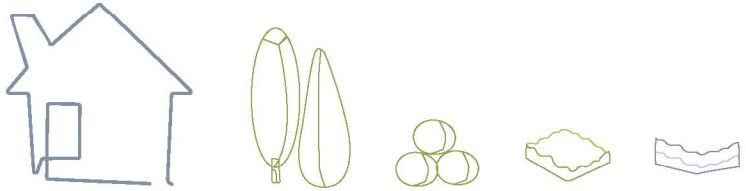
1 Clustering by Similarities (Symbioitic / Patterns)



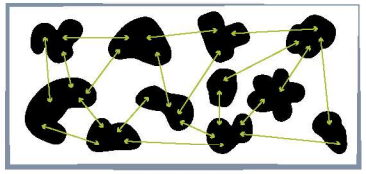


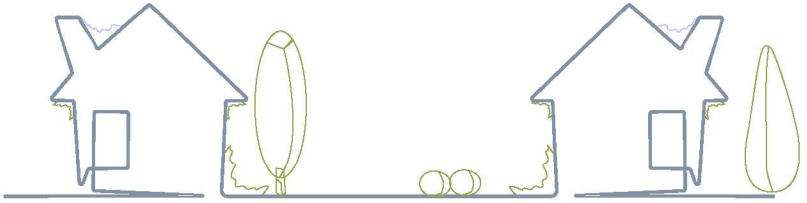
2 Emergence of Boundries (Edges)



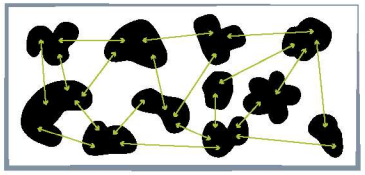


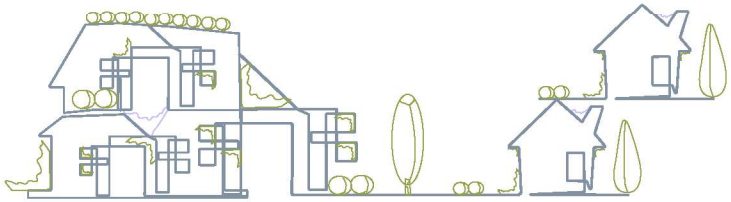
3 Interactions Between Boundries (Resillience)



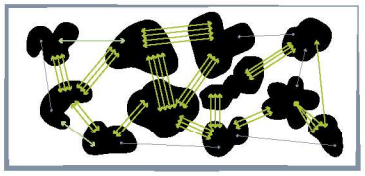


4 Development of Routines (Network Systems)



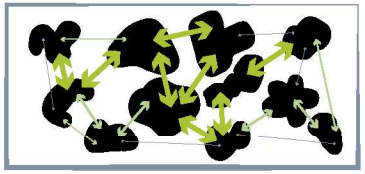


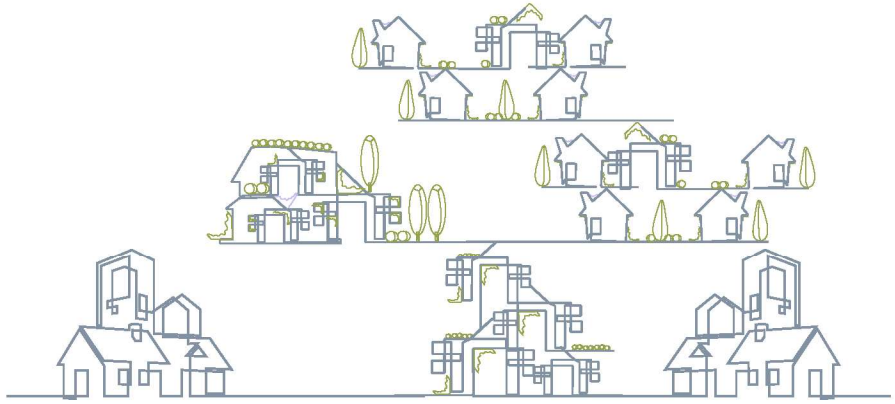
5 Development of Reactions (Feedback Loops)



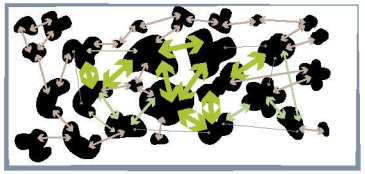


6 Recurring pathways create reinforced Structure (Heighrarchy)



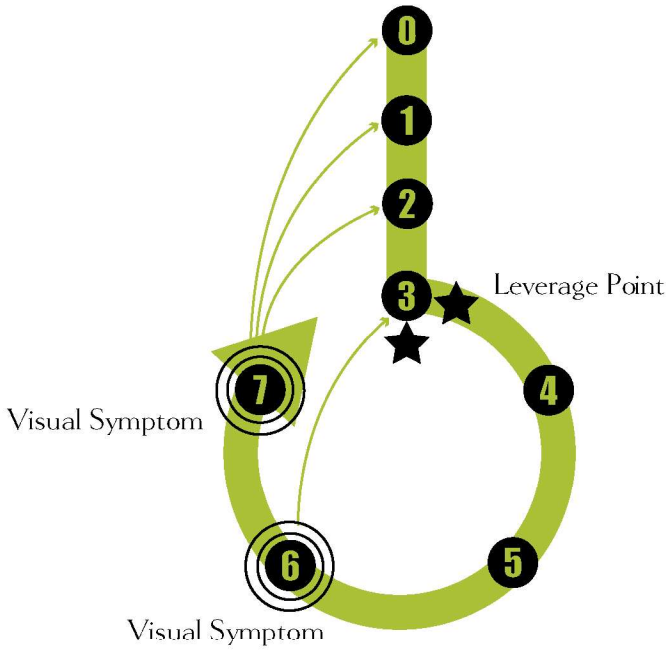


7 Evolution of Collective Behavior (Fractalization)





In a state of growth - this is the organizational flow:



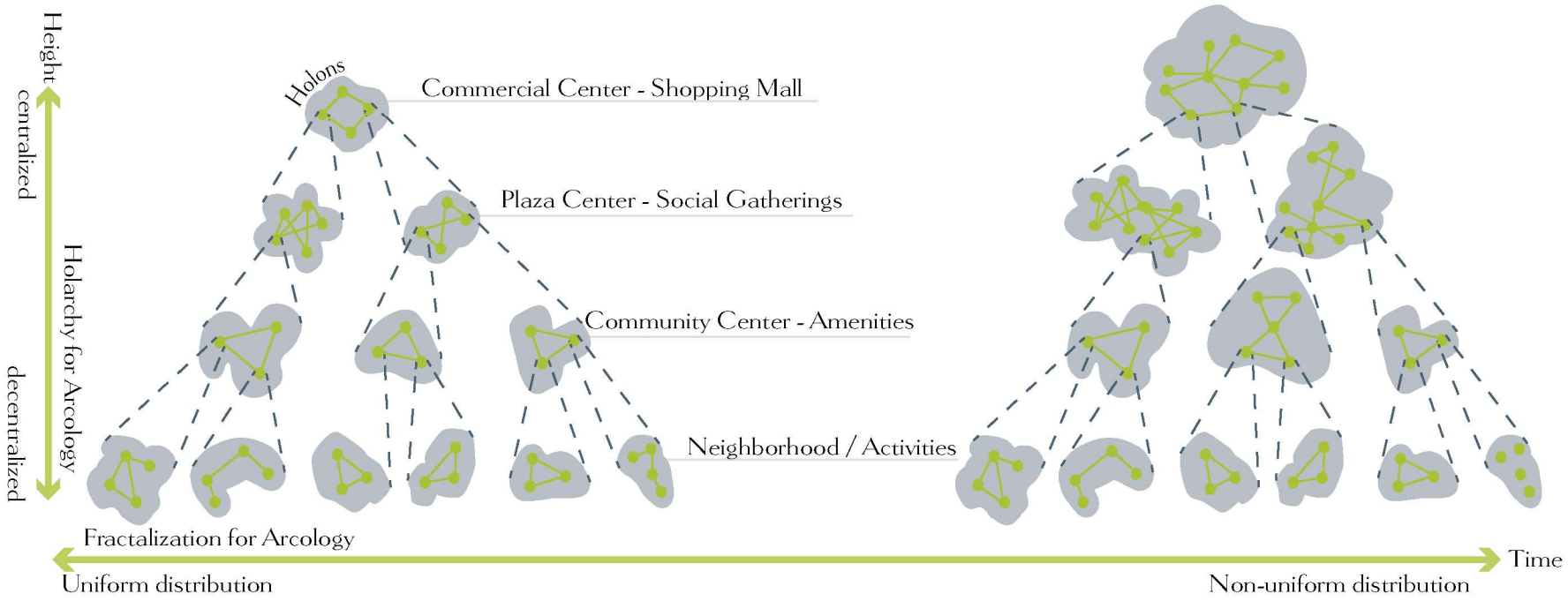
There is no consistency in leverage points. They are changable and at any point, that leverage point can vary or change if the system is not achieving its goals. However, when the system is in a state of growth, the most likely leverage point will always be the interactions between boundries. Amplifying these interactions will provide the most cyclic iterations of the system.

3 Interactions Between Boundries (Resillience)

Living systems are organic and dynamic. They will exhibit repetition and therefore, visual symptoms that is evident of that change. These changes will be visible as heighrarchies and fractalizations. This would mean, the more interactions, the more the building is subject to a height change and the it will be subjected to change. This mean the arcology would require a high level of stewardship.

6 Recurring pathways create reinforced Structure (Heighrarchy)

7 Evolution of Collective Behavior (Fractalization)



THE STOCKDALE PARADOX

You must never confuse faith that you will prevail in the end - which you can never afford to lose - with the discipline to confront the most brutal facts of your current reality, whatever they might be.

- Admiral James Stockdale - United States Navy Vice Admiral and Aviator, awarded the Medal of Honor in the Vietnam War



DESIGN PROCESSES

5.1 Designing the Processes of an Arcology

Rules for the Arcology

Form of the Arcology

Exterior : Ocean Liner
Interior : Italian Hilltop

Intent of Design

Walkable city - increase interactions - follow organizational structure - limit density - design for flexibility

Quantifiable Things

Residents : 11'000
Visitors : 11'000
Walkable distances between residences and amenities.

Rules & Programs (solvable in plan)

Walkable Limits - 1/4 of a mile or 5 minute walk
Flows on site + visible access points
Space Allocation - Stairs, Elevators and Structure
Breaking Views (for natural lighting)
Ecosystems provided by plants

Boundries - Zones for Co-existance Habitat

Urban Cores and Vegitation Buffers
Soft Topography of 2% slope for landscape
Porous internal system (for lighting)

Networks

Create height variances to signify structural heirarchy
Use different types of substrates (soil and hydroculture)
Connect boundries with bridges

Feedback loops

Initial Monitering of the system
Provide incremental adjustments
Phased Growth
Highlight key interactions
Set system goals

Systems will evolve over time

Spaces will vary over time.
Favorable systems will naturally expand.
Unfavorable systems will naturally reduce.
Emerging property is fractalization, therefore, vartaitions will appear more frequently.

Moniter the system

Moniter internal growth of the Arcology
Moniter external naturalization of Niagara Falls

Monitering fractalization and structure is key to the success and failure of the system.

How to design the processes Holons within an Archology

Rules for the Arcology

Break down Important Actors

Human Processes
Ecological Processes

Visualize the Overall Structure

Define overall form of the Structure
Priotitize Natural Light (openings)
Structural Organization

Define the Limits

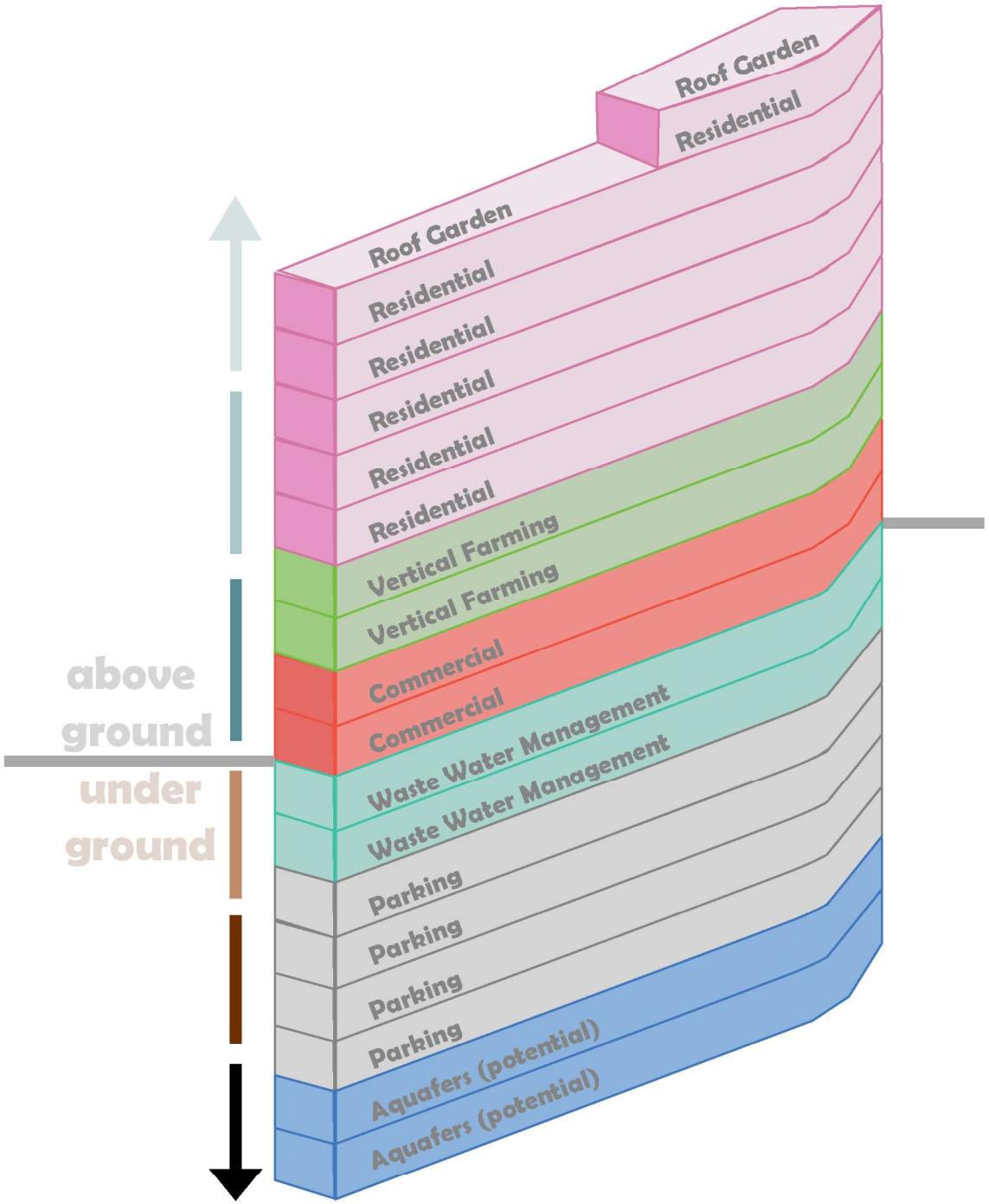
Growth Limits
Density Limits
Capacity Limits
Feedback loops (negative and positive)

Daily Water Limits

Human water use
Trees and plants water use
Transpiration and Water absorption
Breaking Views (for natural lighting)
Ecosystems provided by plants

Leverage Points

Key Interaction to Synergize the System
Mechanical Augmentation
Governance Systems



Residential Zone
x 6 Floors (3 subfloors within)
Vertical Farming Zone
x 2 Floors
Commercial Zone
x 2 Floors
Waste Water Management
x 2 Floors
Parking
x 4 - 5 Floors
Aquafers (potential)
as many floors as we want to maintain our Arcology to keep it's autonomy.

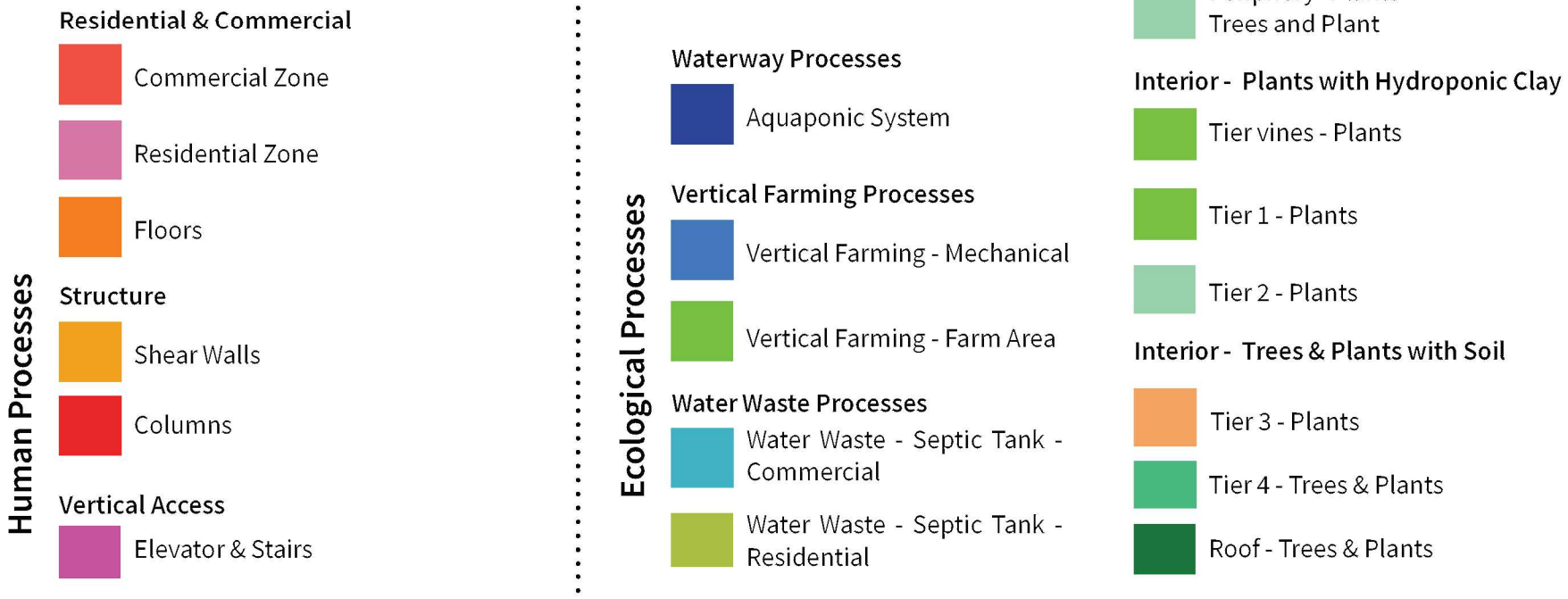
Figure 5.1.1: Illustration to visualize the Zones of the Arcology before breaking down each individual process within.

5.2 Conceptualizing the Overall Framework of an Arcology

Defined Framework for Design:

Approach :	Pragmatic
Metabolic Structure :	Cyclic
Infrastructure:	Mat Buildings
Built Form :	Megastructures
Systems Analysis :	Systems Thinking
Data :	GIS, Statistics, Rules of Thumb
Design Iteration :	Artificial Intelligence

Key Plan



Defined Form for Design:

External Form : Ocean Liner
Internal Form : Italian Hilltop Aesthetic

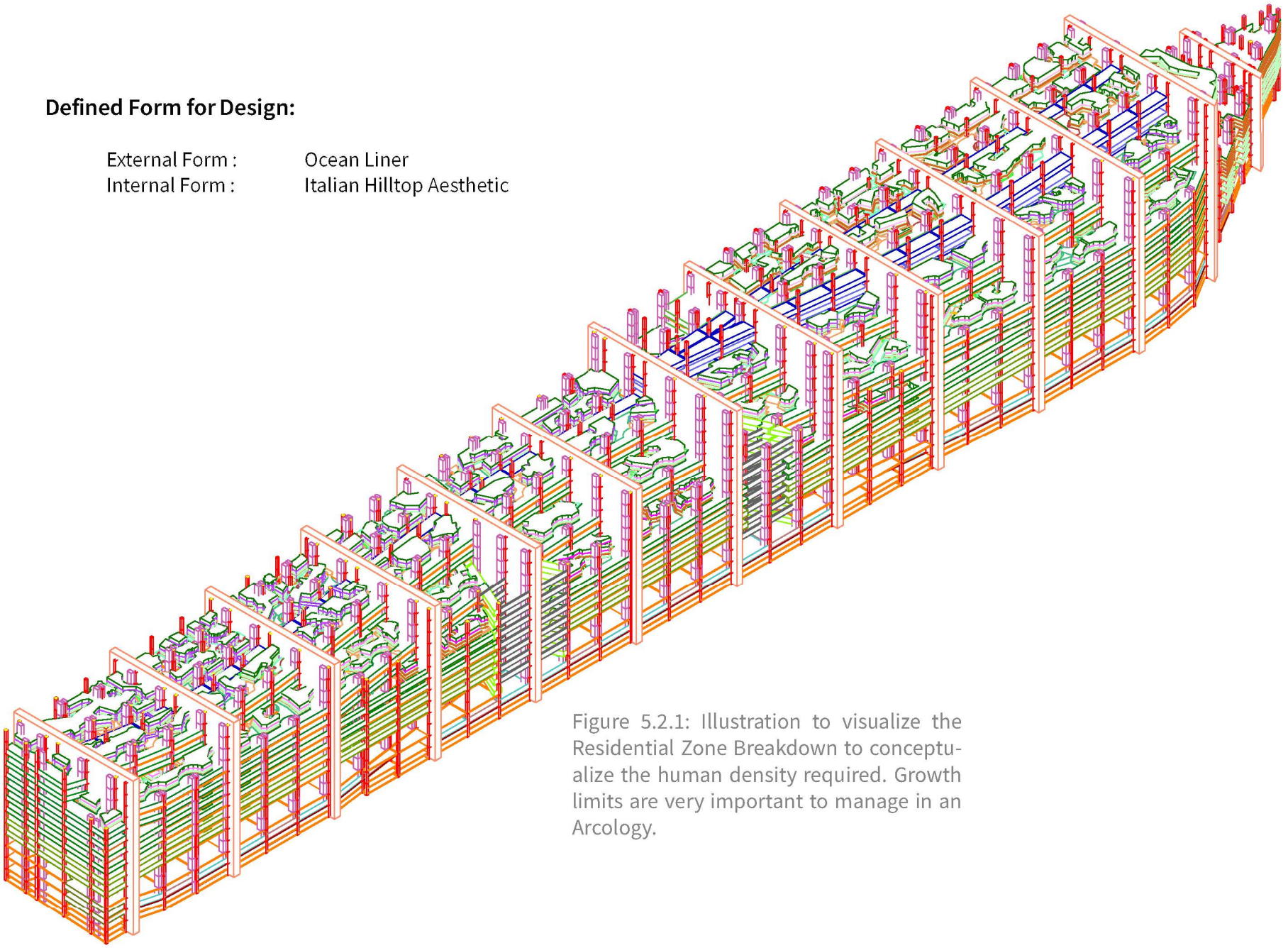


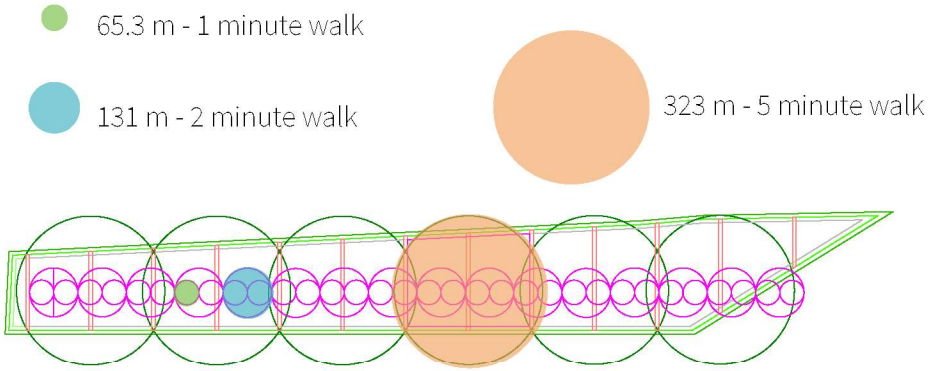
Figure 5.2.1: Illustration to visualize the Residential Zone Breakdown to conceptualize the human density required. Growth limits are very important to manage in an Arcology.

5.3 Process Analysis

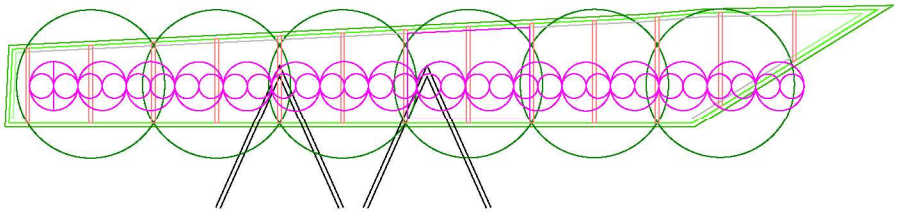
Organizational Structural Analysis

To begin designing, the capacity and the order of the structure has to be visualized and designed. The Arcology is designed in the following sequence and priorities.

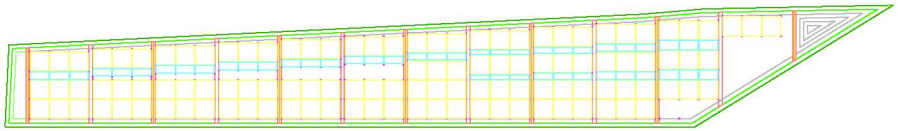
1. Proportioning & Walking Limitations



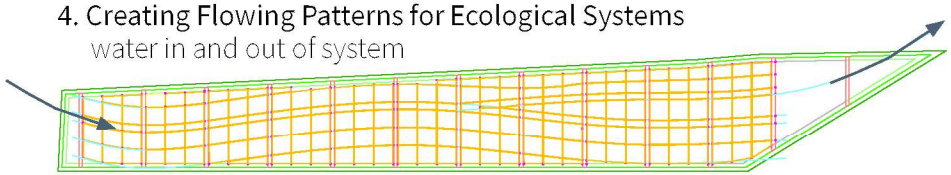
2. Breaking the Site for Views & Features



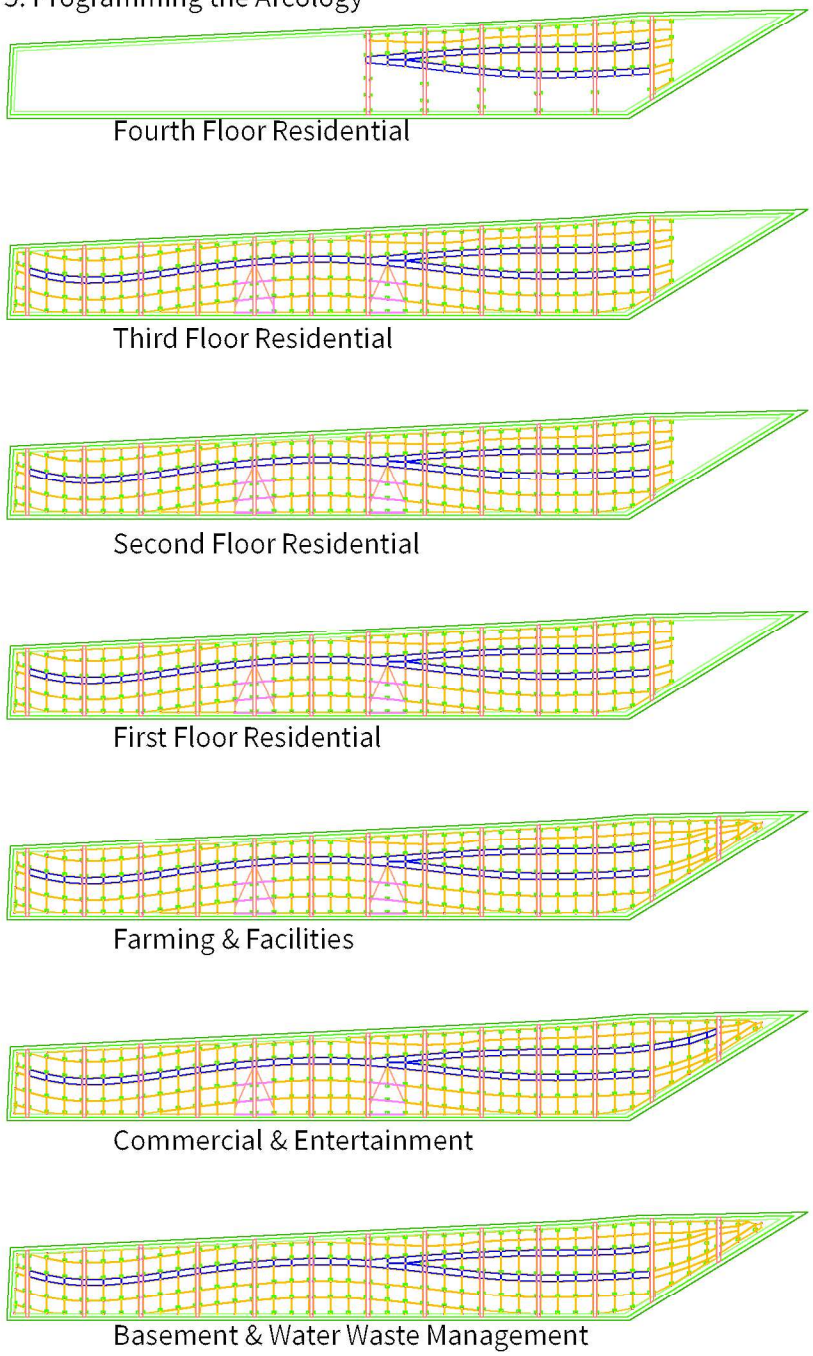
3. Sectoring and Sectioning the Site



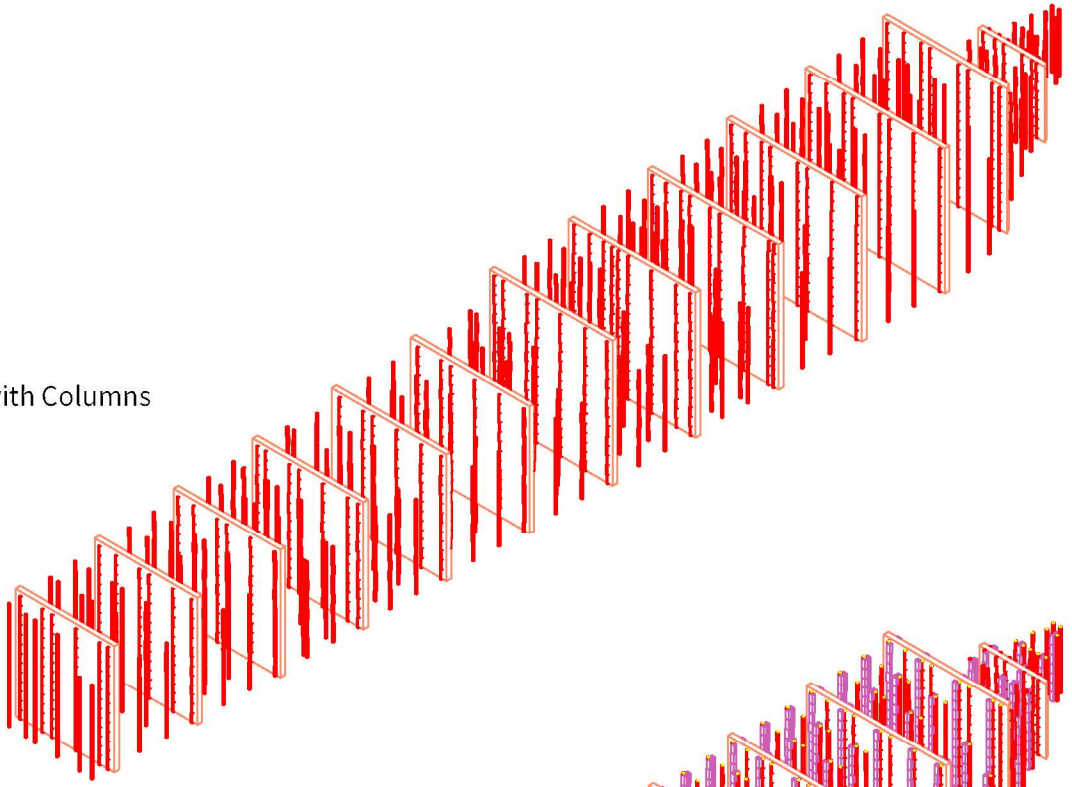
4. Creating Flowing Patterns for Ecological Systems



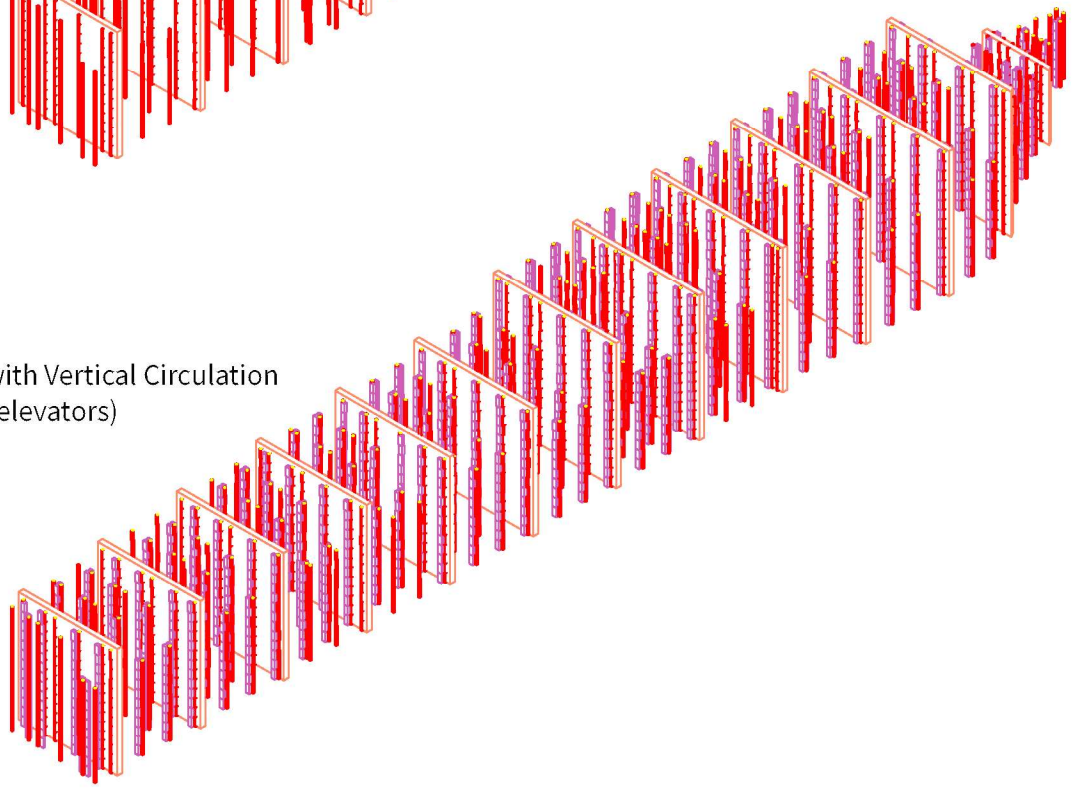
5. Programming the Arcology



Structure with Columns



Structure with Vertical Circulation
(stairs and elevators)



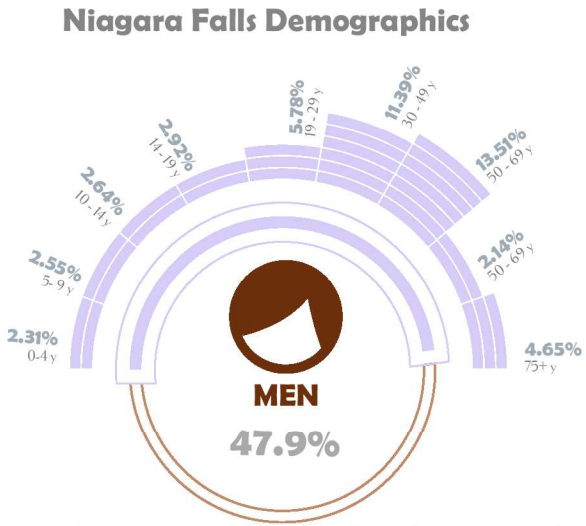


Figure 5.3.0.1: Illustration demonstrating shared accomodations is required in the Arcology with approximately 15% under 18 and approximately 5% seniors.

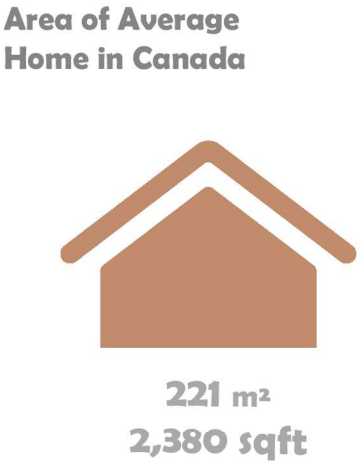


Figure 5.3.0.2: The average household in Canada has to reduce by approximately 40% in the Arcology.

Calibrating Spaces required for the Arcology

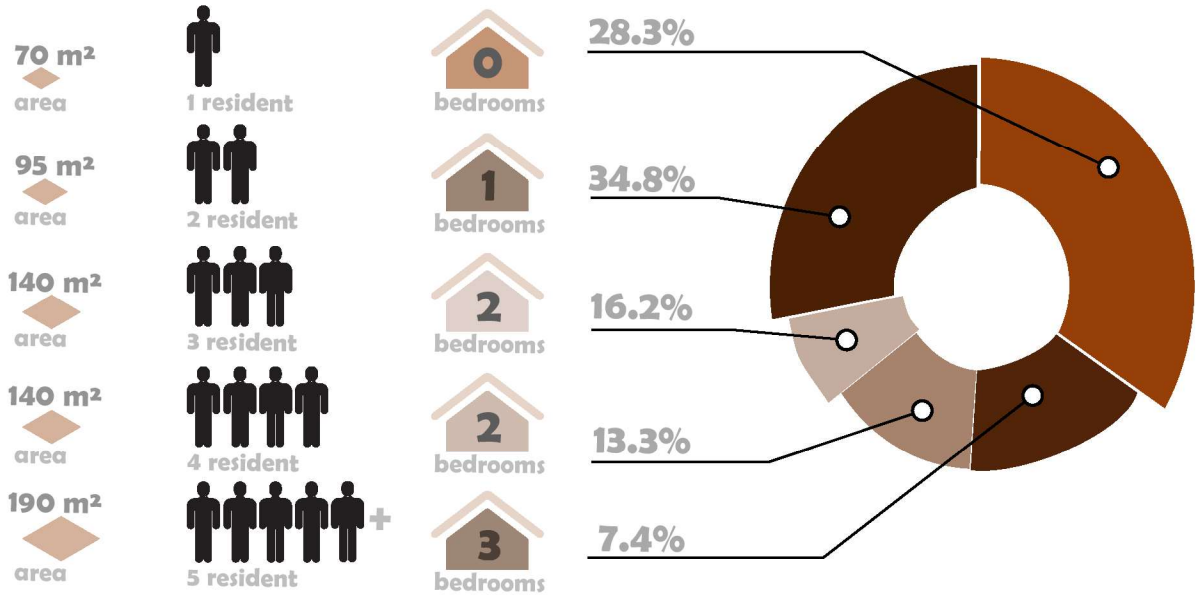
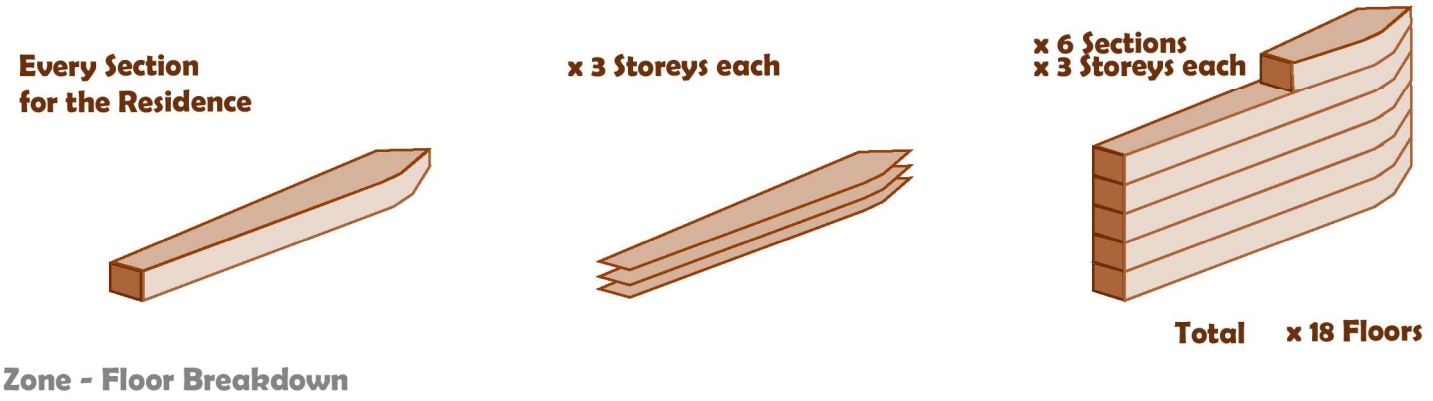
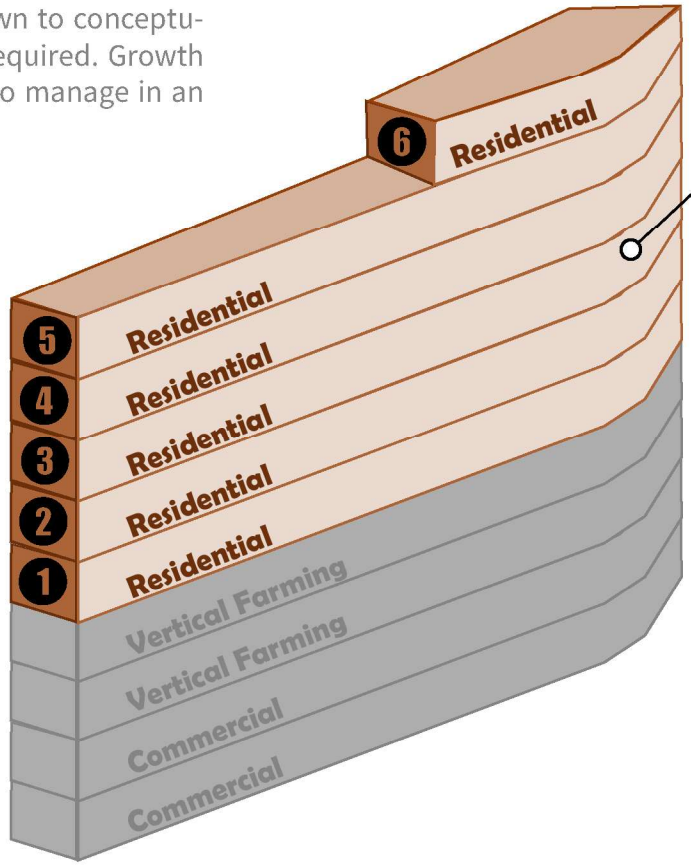


Figure 5.3.0.3: Illustration indicating the average house hold in Niagara Falls has to be re-calibrated to the following to accomodate all it‘s residences. There will have to be 20% range for people who want more space.



Residential Zone - Floor Breakdown

Figure 5.3.0.4: Illustration to visualize the Residential Zone Breakdown to conceptualize the human density required. Growth limits are very important to manage in an Arcology.



Residential Zone - Total Breakdown

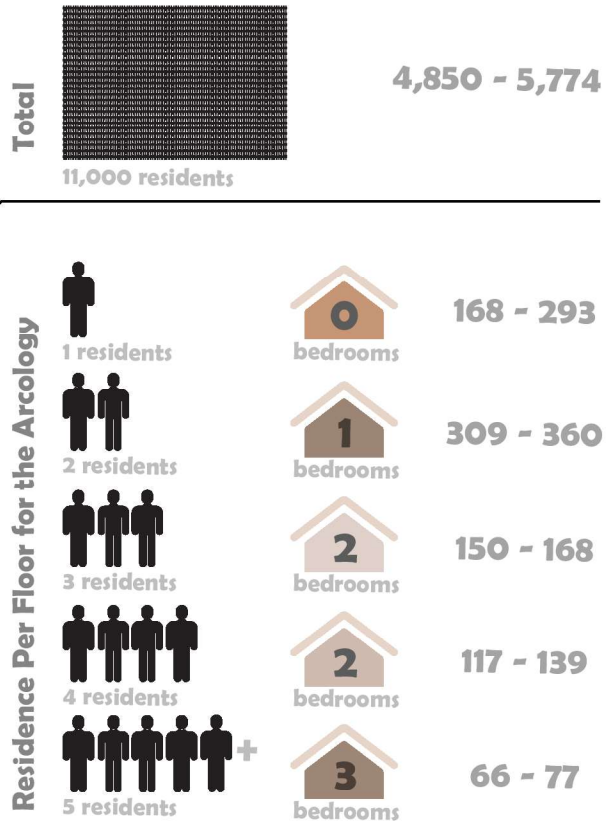


Figure 5.3.0.5: illustrations to visualize the Arcology Residential Breakdown program to accomodate it's residences.

6. Calculating Water Requirements for Each Individual

Comparing typical Average Canadian and Arcologies proposed Water Use.

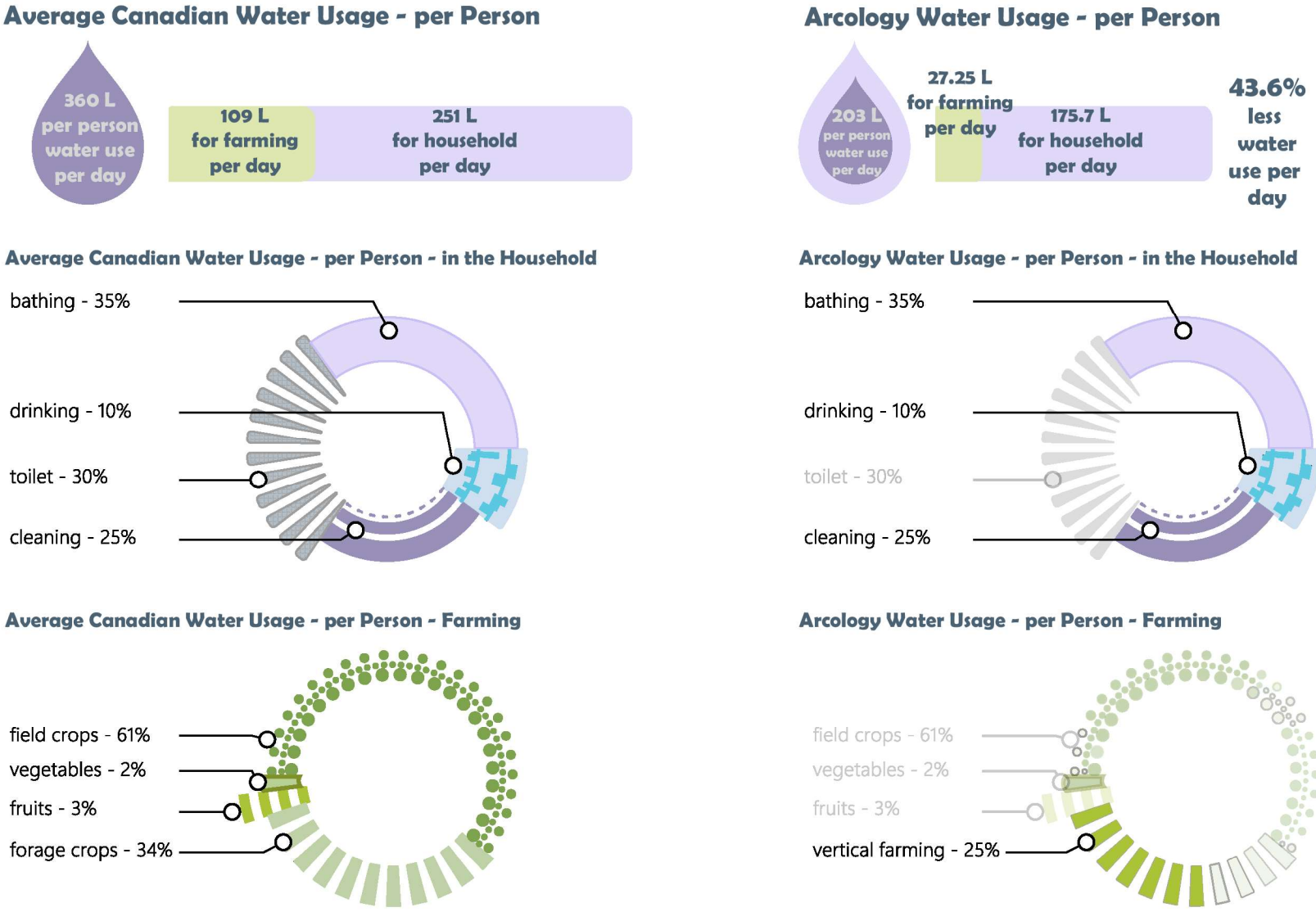


Figure 5.3.0.6: illustrations on the left showing typical canadian water use in the household and for farming. The advantage of an Arcology is the ability to easily adapt new technologies and infrastructures. Arcology will be adopting water waste management system and vertical farming into it‘s infrastructure that will easily reduce the average water usage per person by 43%.

7. Calculating Food and Activity Level Required for Each Individual

The following is an indication of the level of Activity recommended with the calorie intake for males and females and their age group. The intention of this analysis is to highlight the benefits of designing a Walkable Arcology in Northern Climates.

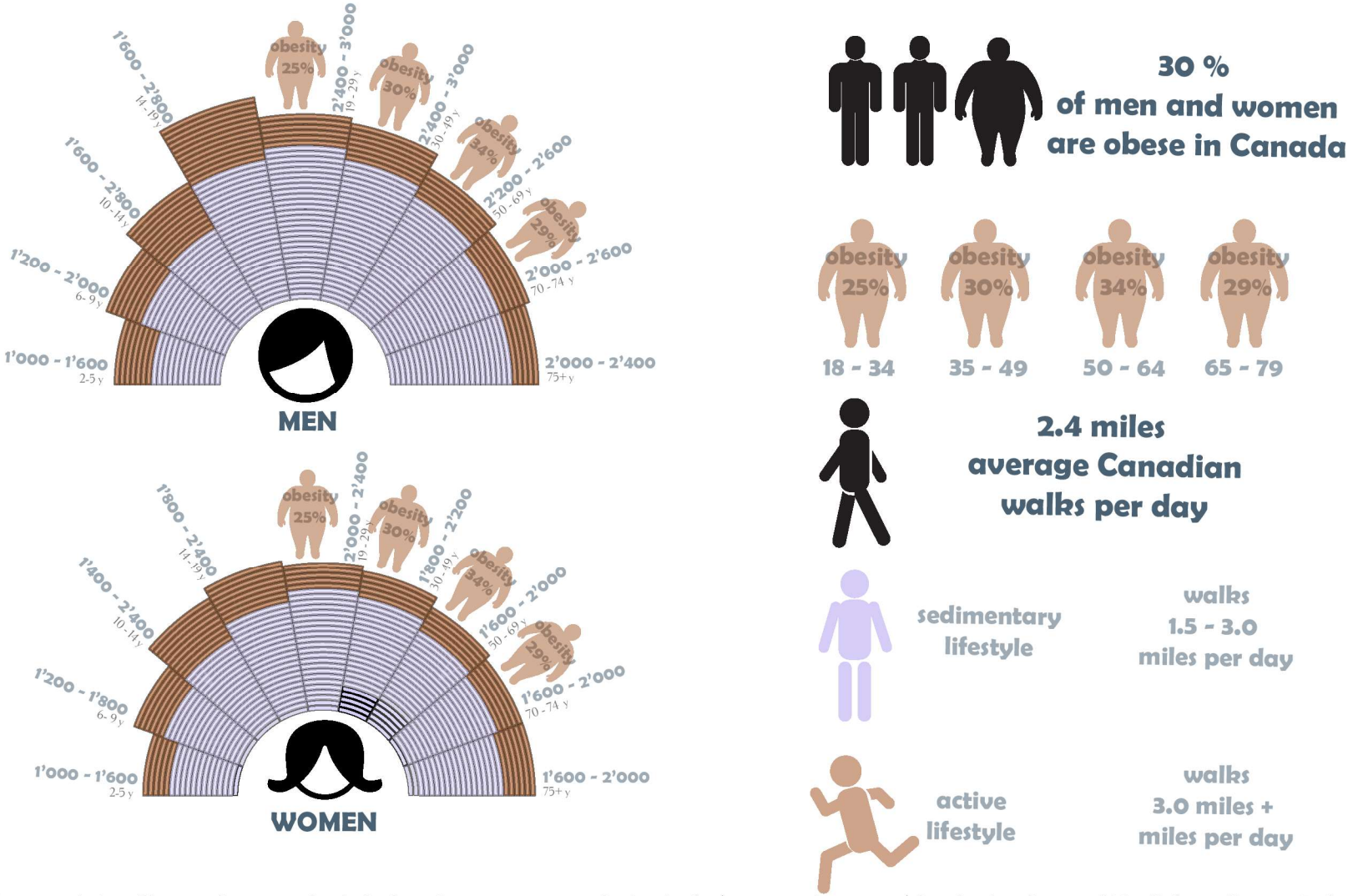
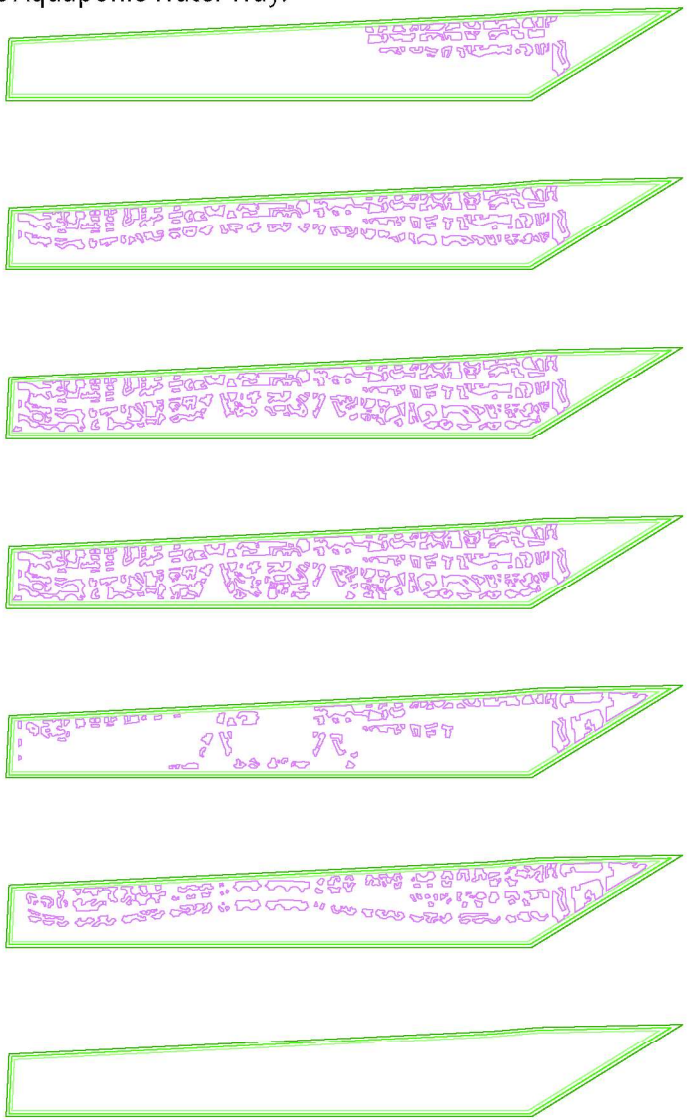
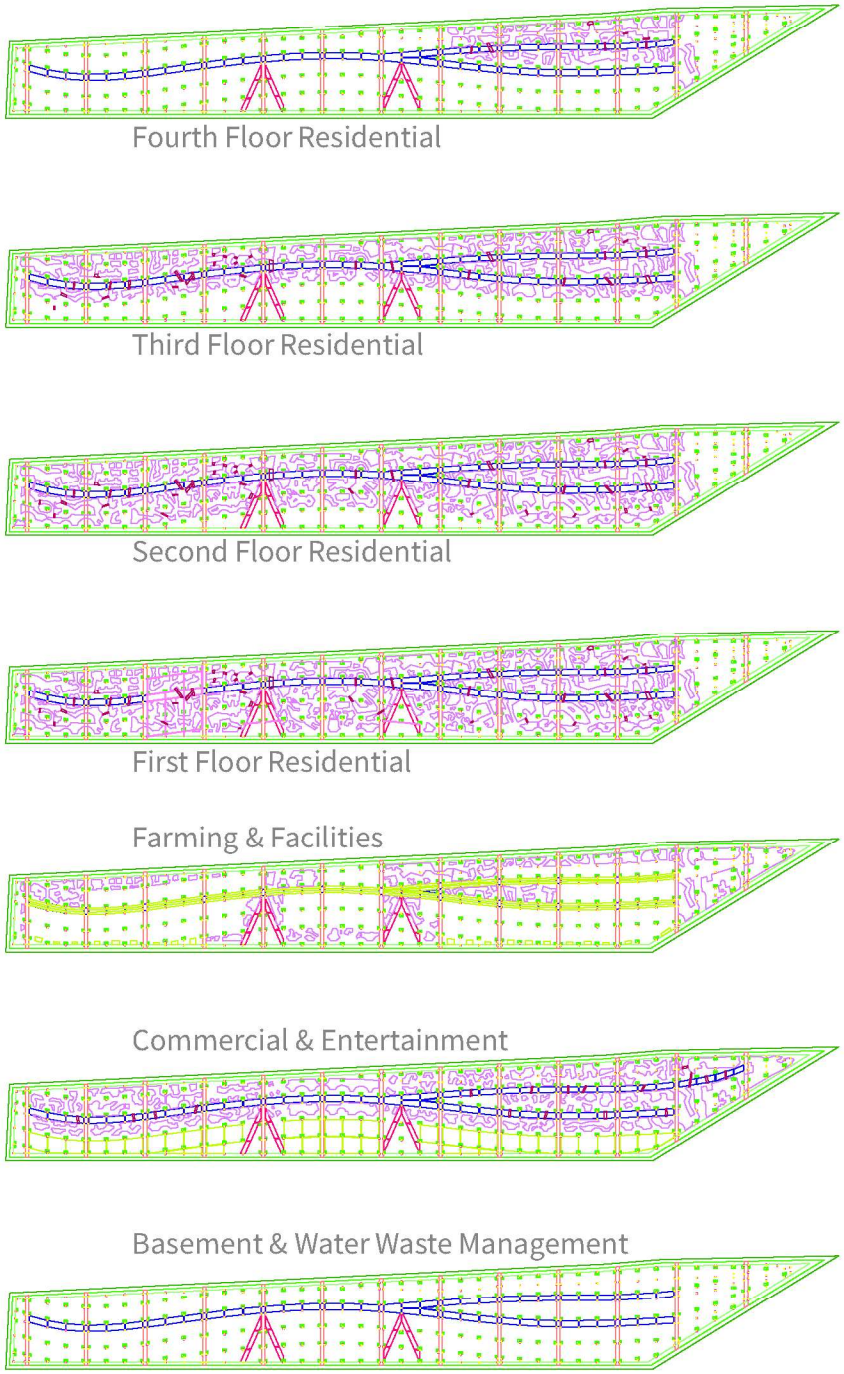


Figure 5.3.0.7: illustrations on the left showing recommended calorie (men and women) by the Institute of Medicine, dietary Reference Intake for Energy, Carbohydrate, Fiber, Fatty Acids. Washington(DC): The National Academics Press, 2002 for both active and sedimentary lifestyles. The top three illustrations on the right show Canada's Obesity was reported by Stat Canada to be 30% above average in 2022 and the average Canadian walks an average of 2.4 miles per day. Canadian lifestyle is evidently sedimentary - a walking Arcology has health benefits.

8. Designing the Arcology Inspired by Italian Hill Towns

The Arcology is inspired by cities such as Assisi and Orvieto . With it`s indigineous features and variety in patterns in each floor, that provides spaces for people and ecological systems. The flexibility of form provides spaces for multiple nodes and unique structures and future alternations when needed without comprimising the integrity of the Arcology. The variation of heights require ramps and bridges between buildings and over the Aquaponic Water Way.

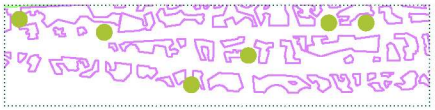




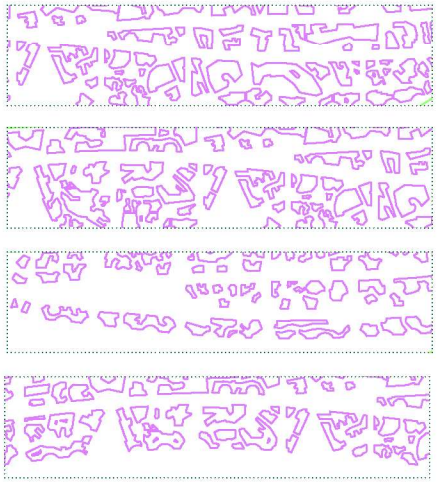
9. Advantages & Visualizing the Arcology

a. Variety of Nodes & Scale of Nodes

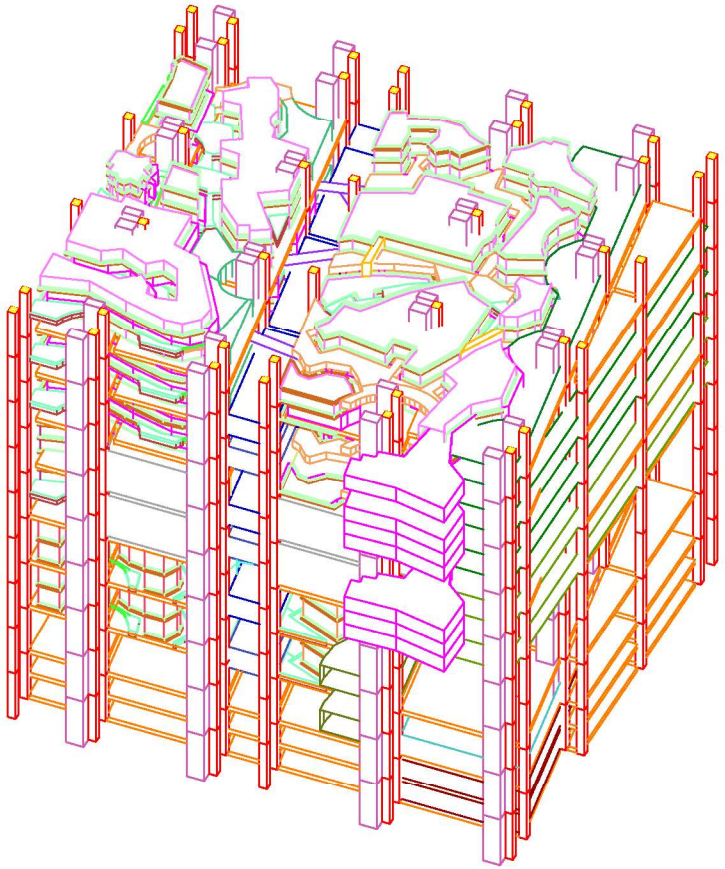
The nodes can be anything from open spaces or water fountains.



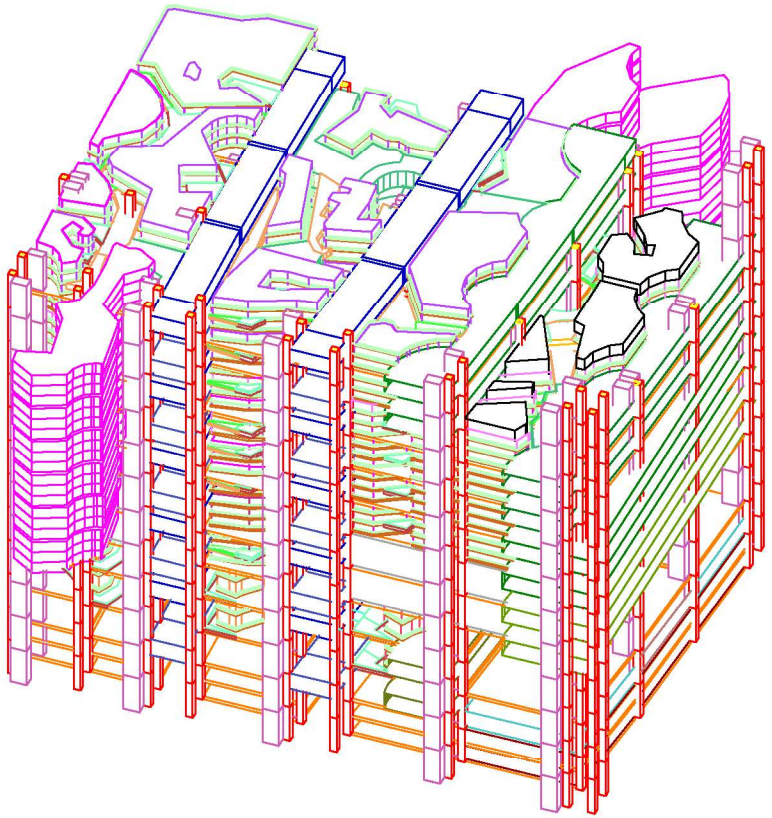
b. Flexibility of Grid



c. Varietion of Heights & Bridges



d. Varietion in Typologies & Features



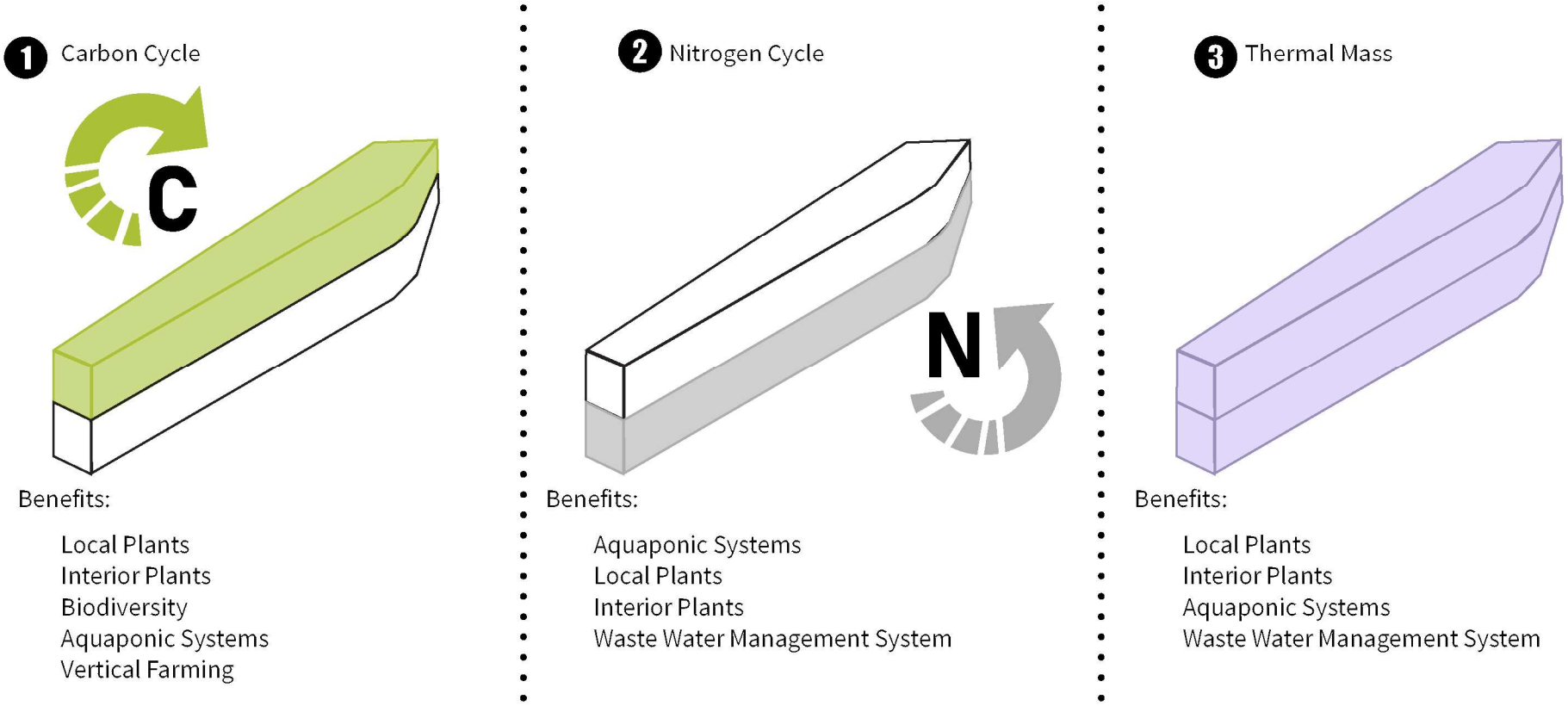


Figure 5.3.1.1: Illustration to represent cycles within an Arcology that provides the greatest ecological potential and benefits.

Ecological Processes

The Arcology's mass is it's greatest potential because of it's recyclable properties. If the Arcology does not have the capacity to withhold the following systems, the the Arcology needs to expand. The basic cycles are as follows:

1. Carbon Cycle (photosynthesis)
2. Nitrogen Cycle
3. Thermal Mass

• •

The intention of the Arcology is to ensure it's ecological processes' needs are met. This is done by metabolizing and recyling it's wastes to achieve a degree of autonomy. The goal is to incorporate four main ecological systems:

1. Local Plants, Interior Plants and biodiversity
2. Aquaponic Systems
3. Vertical Farming
4. Waste Water Management system that integrates plants to breakdown wastes.

• •

We will be showing these systems by reviewing:

1. Harvesting Water from Rain & Rivers
2. Trees, Plants and Water Requirements
3. Vertical Farming
4. Aquaponic Systems
5. Living Systems to Process Water Wastes

An Arcology's greatest asset seems to be water.
Therefore, calculating the water requirements becomes quintessential for the Arcology to function.

1. Harvesting Water

Niagara Falls rains often but on average when water harvest is calculated, my site can provide 1.65-2.44 days for one person in every sector, per month. This is not enough so we need the City Water Grid system for approximately 99% of our usage. Water in an Arcology is a vital comodity.

a. Rainfall Harvest in Niagara Falls

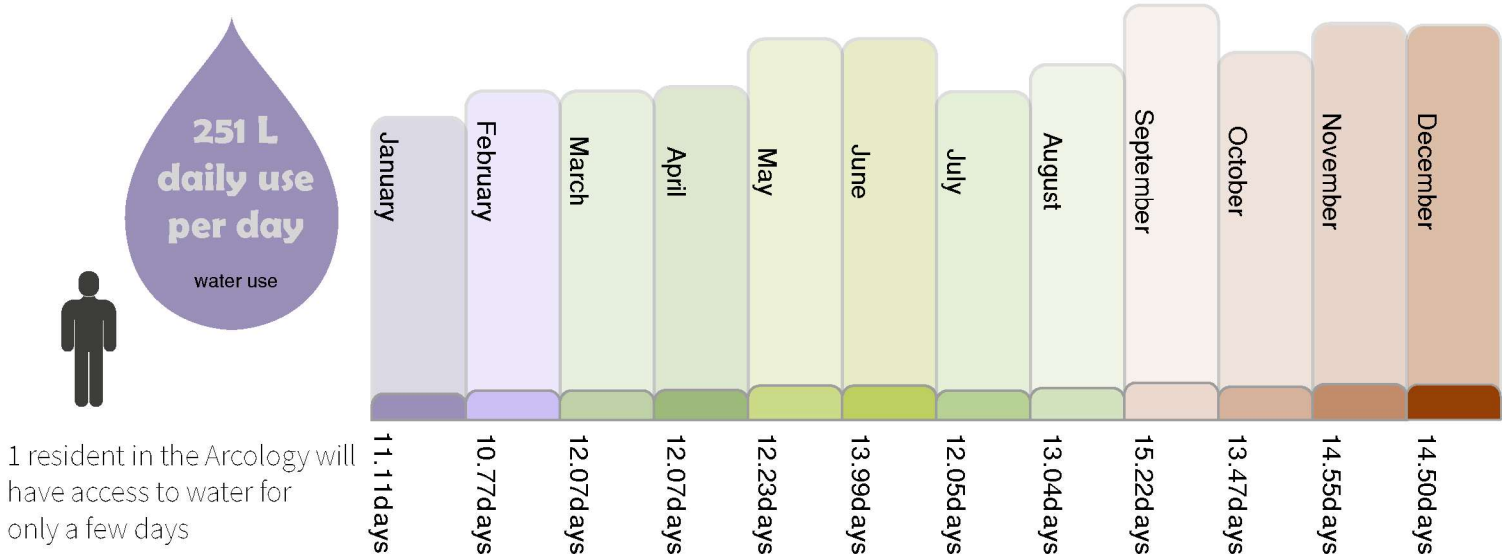
Water Harvest Monthly	Rain		Percipitation		Water Collection (1 m2 x 1 m2)
	average (mm)	extreme daily (mm)	average (mm)	extreme daily (mm)	average (L)
January	27.2	38.1	69.5	38.1	69.5
February	28.5	82.8	67.4	82.8	67.4
March	55.6	43.9	75.5	43.9	75.5
April	68.2	51.1	75.5	51.1	75.5
May	75.6	47.8	76.5	47.8	76.5
June	87.5	75.2	87.5	75.2	87.5
July	74.4	81	75.4	81	75.4
August	81.6	95.3	81.6	95.3	81.6
September	95.2	81.5	95.2	81.5	95.2
October	83.7	72.4	84.3	72.4	84.3
November	79.4	64.8	91	64.8	91
December	50.6	71.9	90.7	71.9	90.7

b. Rainfall Harvest in My Site

This provides a visualization of how much water can be harvested in Sections, Sectors and Sections per person annually.

Water Harvest Monthly	Water Collection Per Sector (2583.8m2)	Water Per Sector Per Person (420 per Ppl / month)	Water Per Sector Per Person Per Day (25l/day)
	average (L)		
January	179,574.10	427.56	1.70
February	174,148.12	414.64	1.65
March	195,076.90	464.47	1.85
April	195,076.90	464.47	1.85
May	197,660.70	470.62	1.87
June	226,082.50	538.29	2.14
July	194,818.52	463.85	1.85
August	210,838.08	502.00	2.00
September	245,977.76	585.66	2.33
October	217,814.34	518.61	2.07
November	235,125.80	559.82	2.23
December	234,350.66	557.98	2.22

c. Rainfall Harvest in My Site - continued -
This table shows the Water Collection per site and it can sustain approximately 10-15 days for one person if the daily consumption of water is 251 L per day. Therefore, highlighting the dependence we have on the City Water Grid to provide the residences with the water they need.



- Site in Reference to the Rainfall Harvest -



Figure 5.3.1.2: Illustration to represent rainfall is not suffecient to sustain daily human use. Water collection for the entire site would sustain one resident for 11 - 15 days every month.

2. Trees, Plants and Water Requirements

a. Niagara Escarpment Plants - Tree and Plant Selection



Tree Types

P

Periphery

Tree Height = 5 meters
Local Trees - from Niagara Escarpment
Attracts biodiversity
Sub-irrigation
Soil

R

Roof Gardens

Tree Height = 3 meters
Local Trees - from Niagara Escarpment
Attracts biodiversity
Sub-irrigation
Soil

4

Tier 4

Tree Height = 3 meters
Local Trees - from Niagara Escarpment
Plants for Air Filtration
Attracts biodiversity
Sub-irrigation
Soil

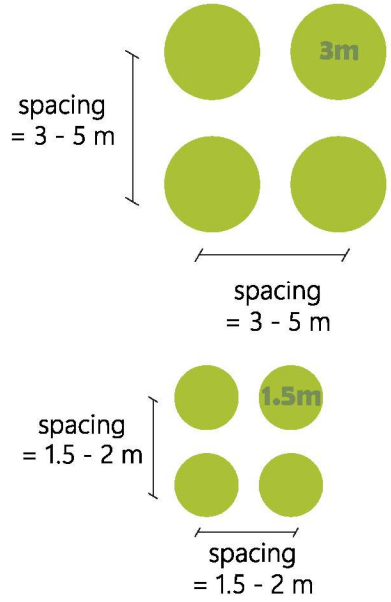


3

Tier 3

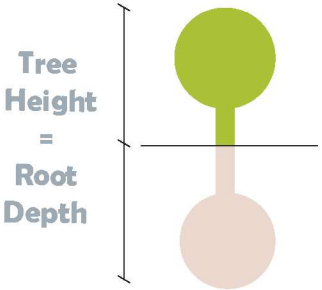
Tree Height = 1.5 meters
Local Plants - from Niagara Escarpment
Plants for Air Filtration
Attracts biodiversity
Sub-irrigation
Soil

Tree Spacing



Typical Spacing equals the Tree Span

Controling Tree Height



Tree Height = Root Depth

Limit the Soil Depth and it will limit the Tree Height

Figure 5.3.2.1: List of Trees Selected from the Niagara Escarpment Region to attract local biodiversity. Rules of thumb on how to calculate tree height, and tree spacing.

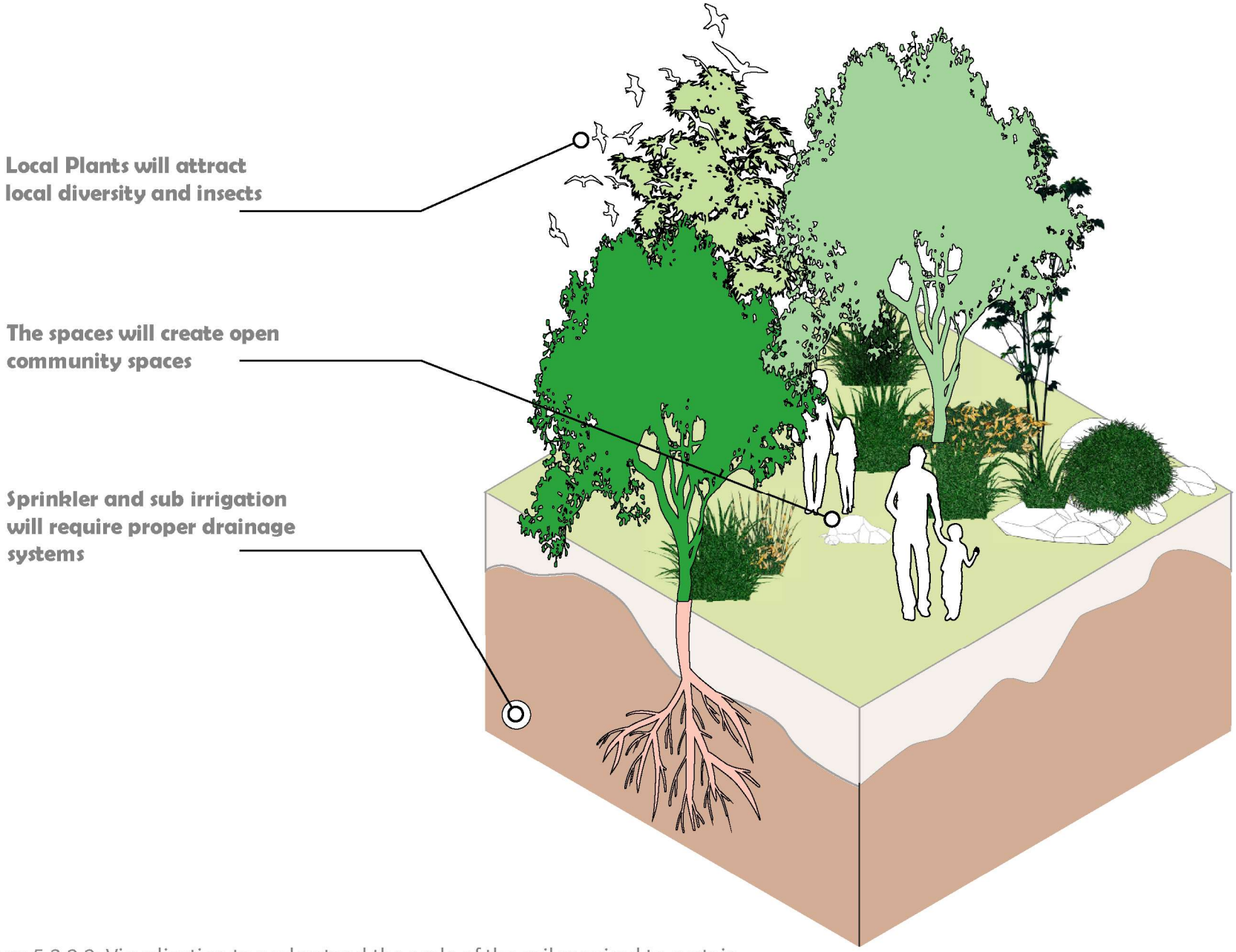


Figure 5.3.2.2: Visualization to understand the scale of the soil required to sustain the height of the trees and the spaces this can provide.

b. Air Filtration Plant Types - Plant Selection

Plant Types





Tier 2

Plant Height = 0.7 meters
Air Filtration Plants
Discourages biodiversity & Insects
Drip-irrigation
Hydroponic Clay



Tier 1

Plant Height = 0.3 meters
Air Filtration Plants
Discourages biodiversity & Insects
Drip-irrigation
Hydroponic Clay

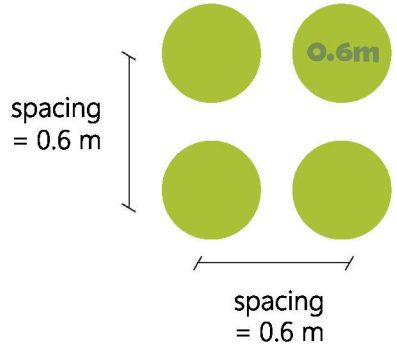




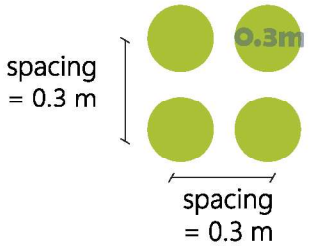
Tier Vines

Plant Height = 3-4 meters
Air Filtration Plants
Buffers Walls
Captures moisture on walls
Discourages biodiversity & Insects
Drip-irrigation
Hydroponic Clay

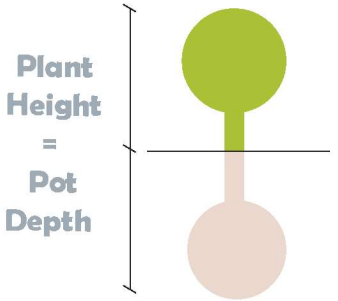
Plant Spacing



Typical Spacing equals the Tree Span



Pot Depth dependent on Plant Height



Limit the Pot Depth and it will limit the Tree Height

Figure 5.3.2.3: List of Plants Selection from American enviornmental scientist and principal investigator of NASA's Clean Air Study, Bill Wolverton's Air Filtration Plants. Rules of thumb on how to calculate tree height, and tree spacing.



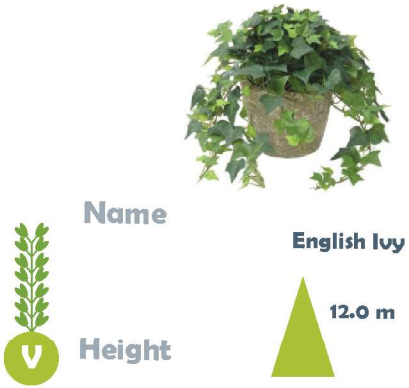


Figure 5.3.2.4: American enviornmental scientist and principal investigator of NASA‘s Clean Air Study, Bill Wolverton, the best plants from a global study for air filtration. Listed above are the top 12 plants that vary in height for the Arcology where biodiversity is discouraged.



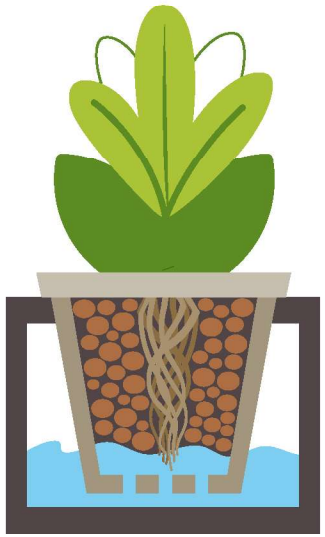
Every household requires 15 plants for Air Filtration

Ecosystem Services Provided

1. Temperature Control
2. Humidity
3. Reduce Carbon Dioxide
4. Reduce Carbon Monoxide
5. Reduce Volatile Organic Compounds

Hydroculture (no soil) and advantages

1. Reduces Over-Watering & Spillage
   - no mold
2. Reduces Risk of Growing Molds
   - no allgergies(no airborne fungus spores)
3. Plants take the Moisture they need
   - reduce use of water
4. Recude the Need to Transplant - nutrients are readily available
   so plants have a smaller root ball
5. Discourages biodiversity & insects



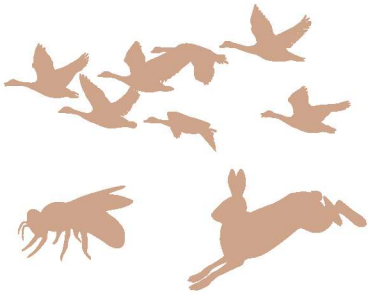


Figure 5.3.2.5: The average household requires 15 plants for air filtration inside the home. Hydroculture for indoor plants is the preferable soil type due to it‘s multiple advantages and it‘s resistance against biodiversity.

c. Expected Water absortion for trees and plants

To be able to provide water for my trees and plants, it is important to calculate the expected water absorption from trees and plants and their transpiration plant. When compared to the human consumption of water per day, watering a tree and plant is collectively less than 1% compared to human consumption.

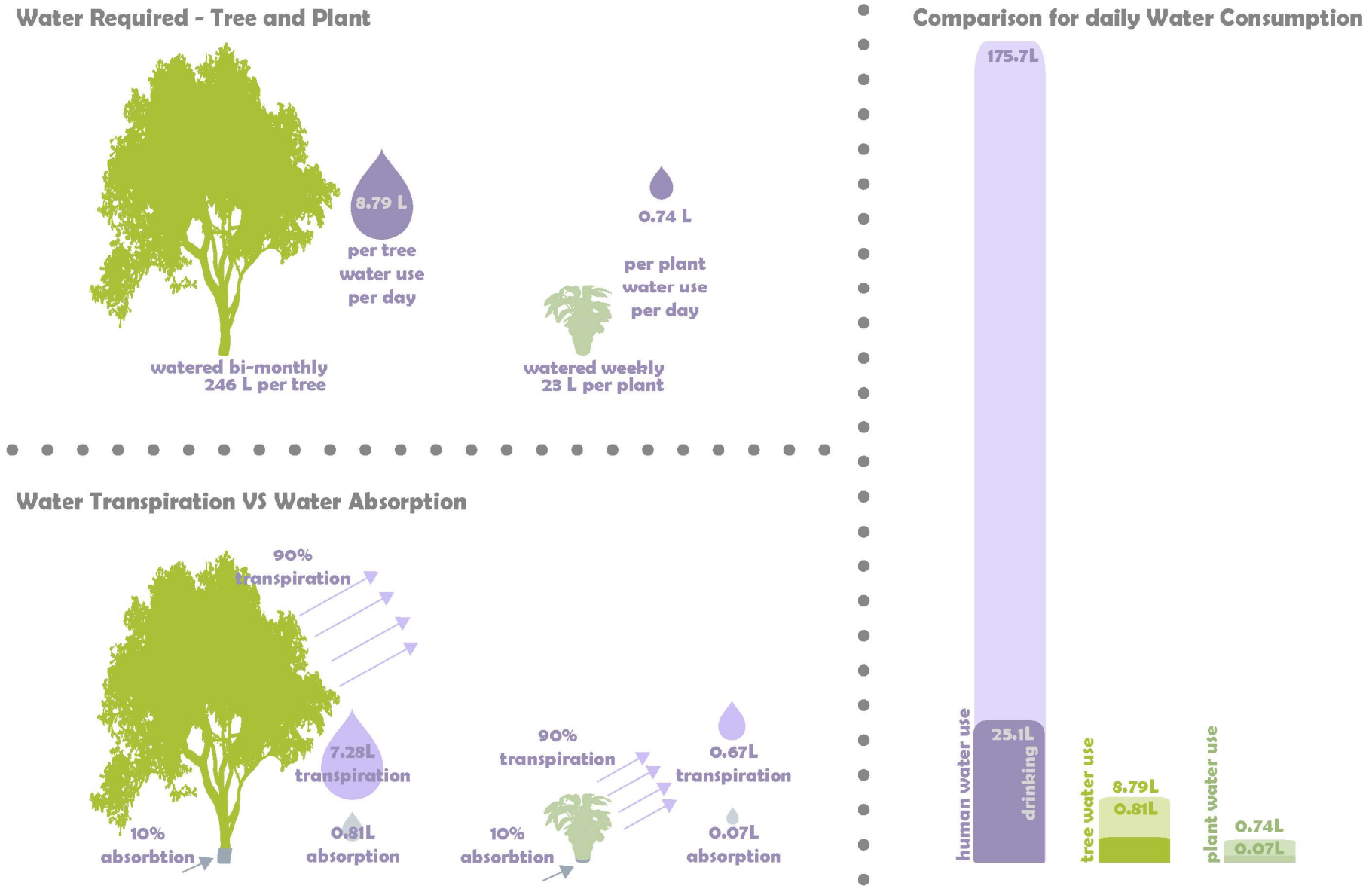
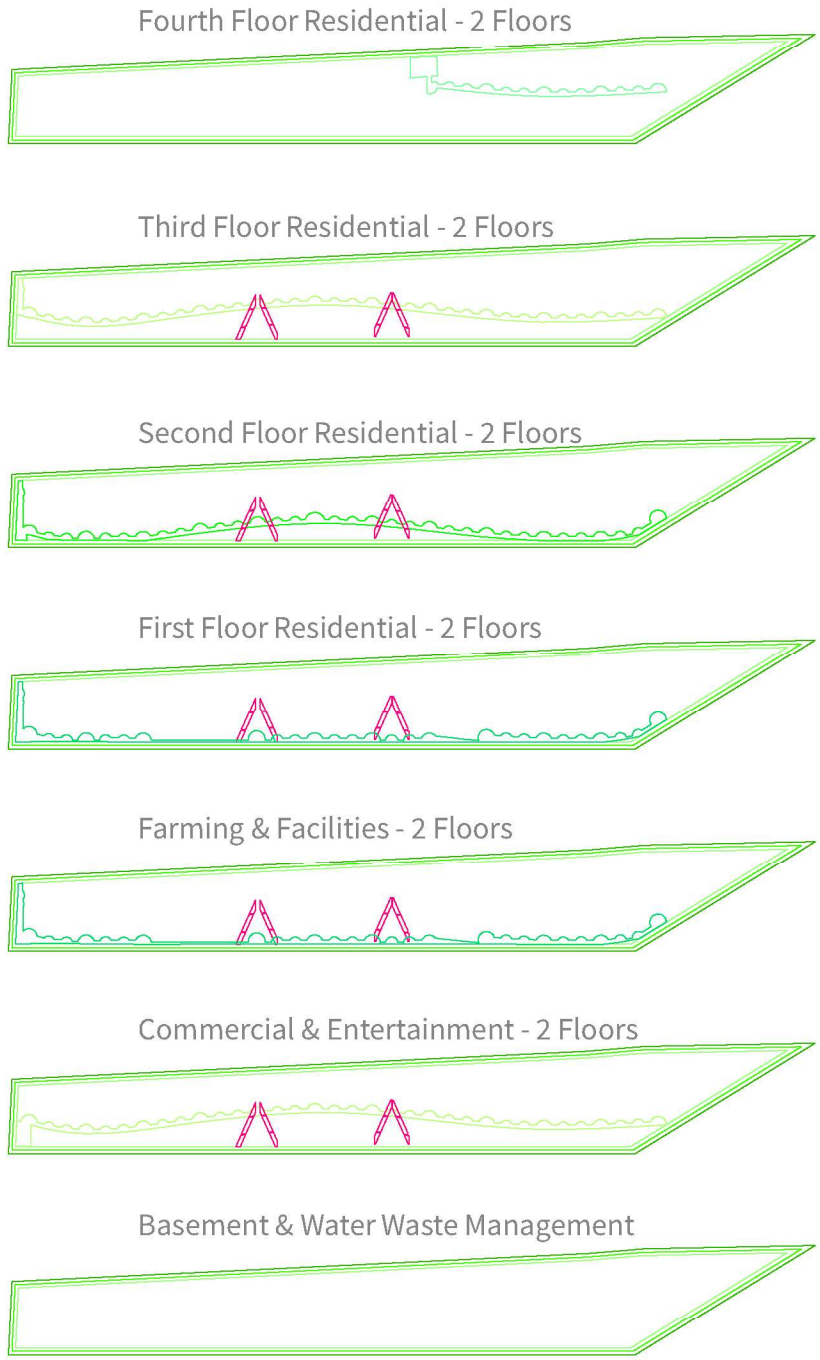


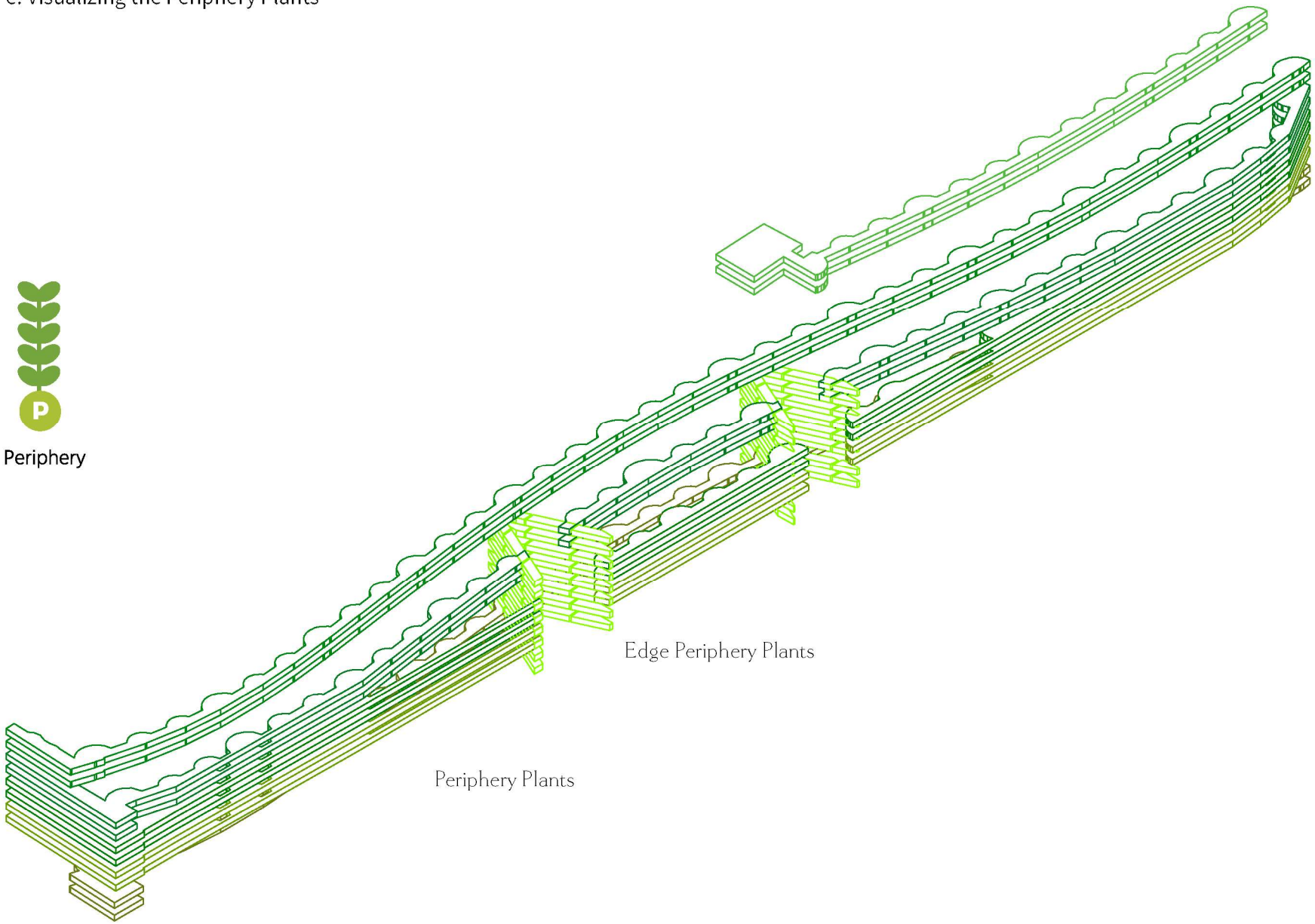
Figure 5.3.2.6: The impact of tree and plant transpiration helps maintain local humidity and cools surrounding areas, creating a comfortable micro-climate within the Arcology. Once an ecological infrastructure is set, the ecosystems it provides is minimally maintained for noticable benefits.

d. Periphery Plants Located Along the South Facade

Tree Height = 5 meters
Local Trees - from Niagara Escarpment
Attracts biodiversity
Sub-irrigation
Soil



e. Visualizing the Periphery Plants



f. Plant Corridors is designed to increase biodiversity

There are several conditions for each planters that contain local plants. However, these plants are designed to intricately connect from the south facade or the Aquatic Water Way. In some cases, they flow right through the building to encourage biodiversity. Local plants in the farming facility is restricted to only the peripheries to keep insects away from the vertical farms.



Periphery

Tree Height = 5 meters
Local Trees - from Niagara Escarpment
Attracts biodiversity
Sub-irrigation
Soil



Roof Gardens

Tree Height = 3 meters
Local Trees - from Niagara Escarpment
Attracts biodiversity
Sub-irrigation
Soil



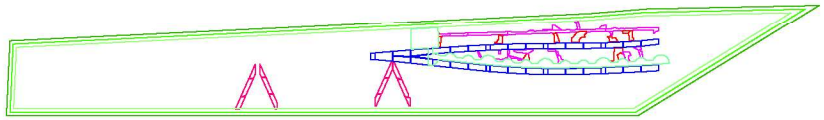
Tier 4

Tree Height = 3 meters
Local Trees - from Niagara Escarpment
Plants for Air Filtration
Attracts biodiversity
Sub-irrigation
Soil

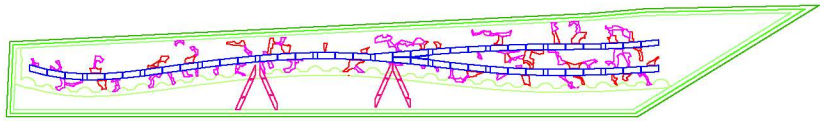


Tier 3

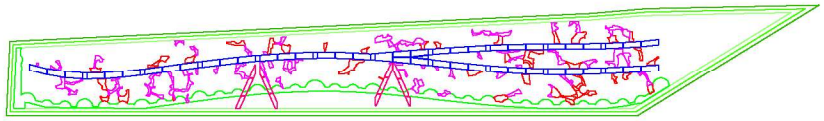
Tree Height = 1.5 meters
Local Plants - from Niagara Escarpment
Plants for Air Filtration
Attracts biodiversity
Sub-irrigation
Soil



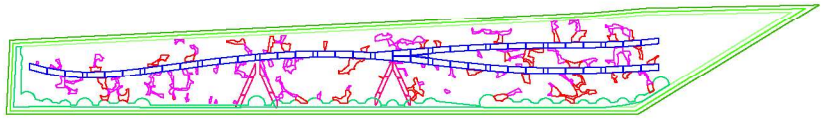
Fourth Floor Residential - 2 Floors



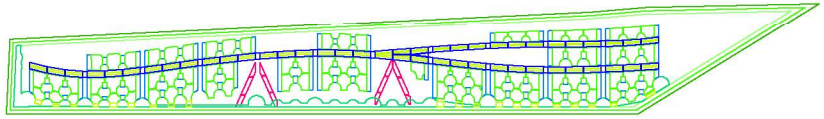
Third Floor Residential - 2 Floors



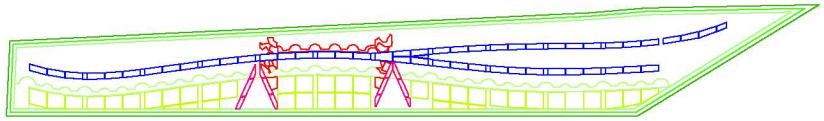
Second Floor Residential - 2 Floors



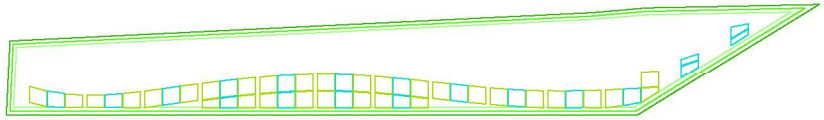
First Floor Residential - 2 Floors



Farming & Facilities - 2 Floors



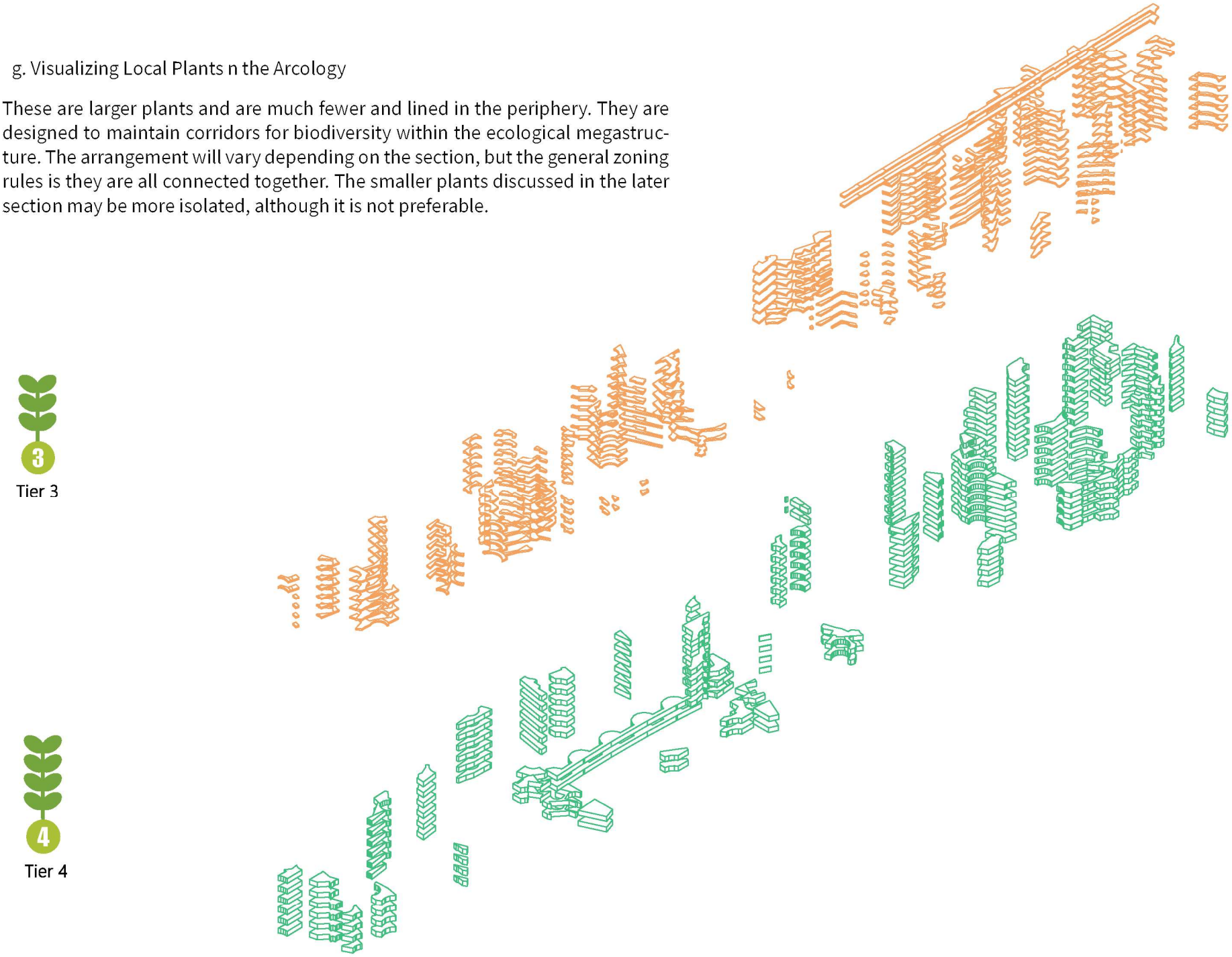
Commercial & Entertainment - 2 Floors



Basement & Water Waste Management

g. Visualizing Local Plants n the Arcology

These are larger plants and are much fewer and lined in the periphery. They are designed to maintain corridors for biodiversity within the ecological megastructure. The arrangement will vary depending on the section, but the general zoning rules is they are all connected together. The smaller plants discussed in the later section may be more isolated, although it is not preferable.



h. Smaller Interior Plants intended for Air Filtration

These plants are not local plants to discourage biodiversity and insects. They are used on the interior of the building, surrounding residences, especially along the North Facade. They are used to improve the air quality and the vines cover the structures to absorb water from the air and from walls due to condensation. They come in the following planters.



Tier 2

Plant Height = 0.7 meters
Air Filtration Plants
Discourages biodiversity & Insects
Drip-irrigation
Hydroponic Clay



Tier 1

Plant Height = 0.3 meters
Air Filtration Plants
Discourages biodiversity & Insects
Drip-irrigation
Hydroponic Clay

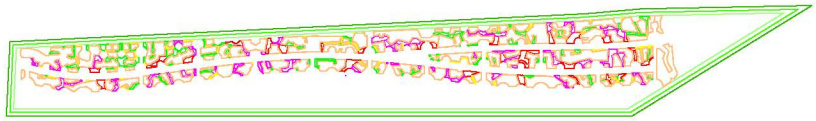


Tier Vines

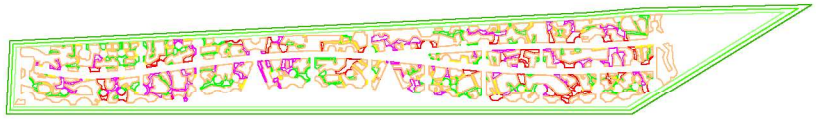
Plant Height = 3-4 meters
Air Filtration Plants
Buffers Walls
Captures moisture on walls
Discourages biodiversity & Insects
Drip-irrigation
Hydroponic Clay



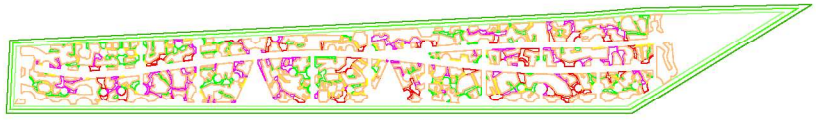
Fourth Floor Residential - 2 Floors



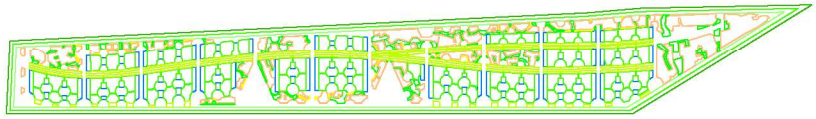
Third Floor Residential - 2 Floors



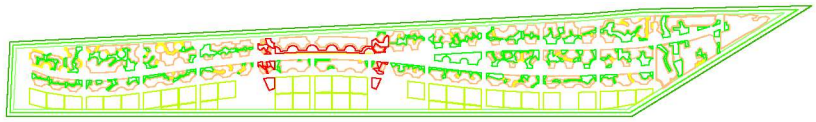
Second Floor Residential - 2 Floors



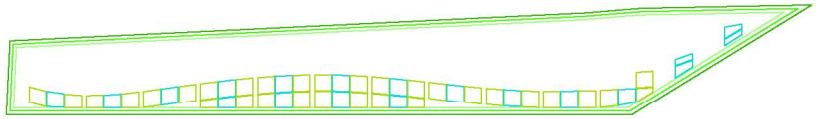
First Floor Residential - 2 Floors



Farming & Facilities - 2 Floors



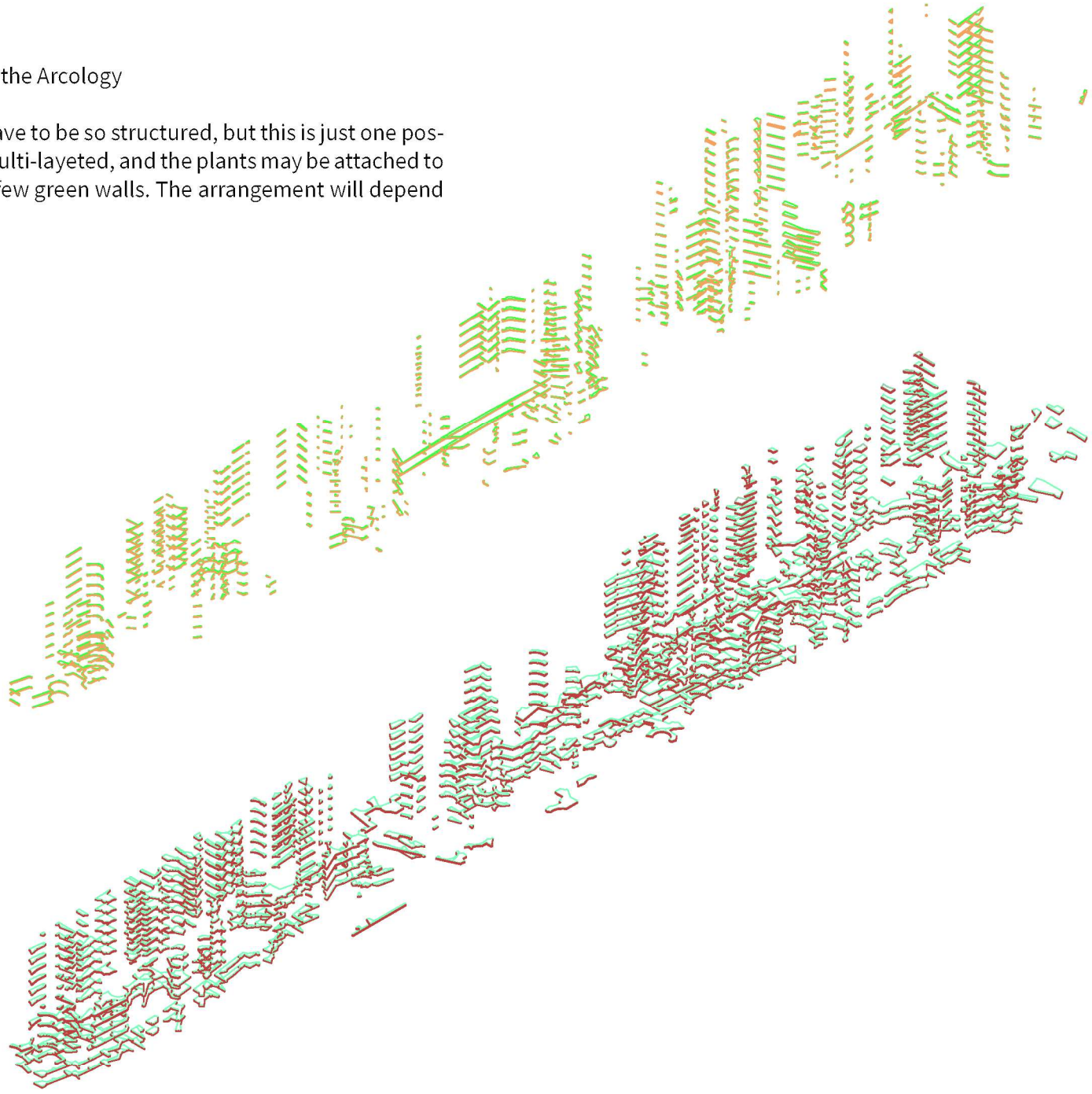
Commercial & Entertainment - 2 Floors



Basement & Water Waste Management

i. Visualizing Air Filtration Plants in the Arcology

The plant arrangement does not have to be so structured, but this is just one possible arrangement. however, it is multi-layeted, and the plants may be attached to windows, to walls, or even have a few green walls. The arrangement will depend on the design.



3. Vertical Farming

This is no longer a fad. It is now a global mandate set by the European Parliment and U.S.S.E.C.

"The United States can always be relied upon to do the right thing — having first exhausted all possible alternatives."
- Quote by William Churchill, reported on July 1980 in the pages of the Harvard Business School Bulletin.

1995	Emerging USDA Label (solution)
1997	Netherlands experienced Farming Limits and required to do more with less (demand)
1999	Cornell University promotes Hydroponic Systems that produce lettuce at extraordinary yield rates
2013	Cornell University promotes Aeroponic Systems that produce potatoes at extraordinary yield rates
2018	Nobel Laureates William D. Nordhaus wins for integrating climate change into long-run macroeconomics analysis Nobel Laureates Paul M. Romer wins for integrating technological innovation into long-run macroeconomics analysis
Nov, 2018	The Commission conducted extensive analysis and stakeholder consultation in preparation of its strategic vision for a climate-neutral EU published in November 2018. This was followed by an EU-wide debate on the vision.
2019	Triggered by the European's Parliment's decision to limit nitrogen emissions Dutch Farmers began publically protesting from October and the strikes have exponentially increasing since.
2021	the USDA label for the first time approves aeroponic, hydroponic and aquaponic systems as viable farming options.
July, 2021	The European Climate Law was published in the Official Journal on 9 July 2021 and entered into force on 29 July 2021.
Nov 30, 2021	the U.S. Securities and Exchange Comission (U.S.S.E.C.) - discusses global climate and annonces their climate proposal. and sets GHG emission reduction targets for 505 companies.
Mar 6, 2022	the U.S.S.E.C. releases Rule Proposal S7-10-22: the enhacement & standardization of Climate related disclosure for investors
May 20, 2022	The Hawaii Aquaculture and Aquaponics association, representing all aquaponic and aquaculturists of the state, object to the extensive requirements as it will cause crippling financial and operational disruption and legal liabilities. One of the major issues they were argueing is the request for day-to-day tracking and reporting to comply with scope 3 emissions. This means current means of farming is no longer viable and meet S.E.C. GHG emissions.
June 6 2022	3rd Autonomous Greenhouse Challenge at Wageningen University & Research (WUR) in Bleiswijk, Netherlands declared Dutch-American Team Koala as winners for providing autonomous algorithems to manage lettuce crops, using the lowest feasibile input of resources and growing the maximum amount of crops. The team comprised of Cornell University's CEA / GLASE program and the start-up company, Koidra.
May 28, 2024	The U.S.S.E.C. officially releases the Rule Proposal S7-10-22: and lists in it's 885 page document new rules and regulations to regulate climate change.
Summer 2024	Dutch farmers vigorously protest against new strict farming rules and regulations and reported to feel disrespected

a. Types of Vertical Farming

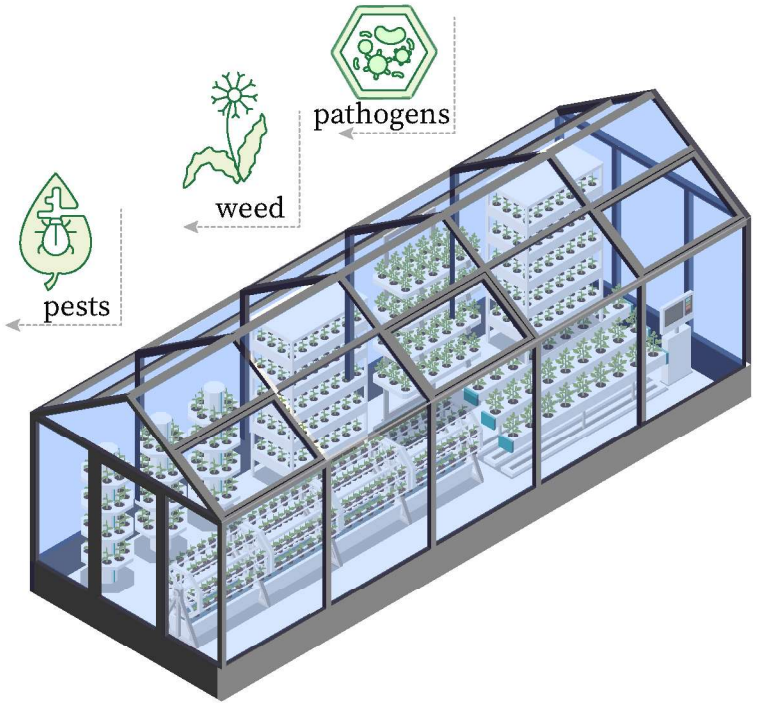


Figure 5.3.3.1: Vertical farming distinguishes itself from typical farming by keeping it in an isolated controlled enviornment. This keeps farming from pests, weed and pathogens.

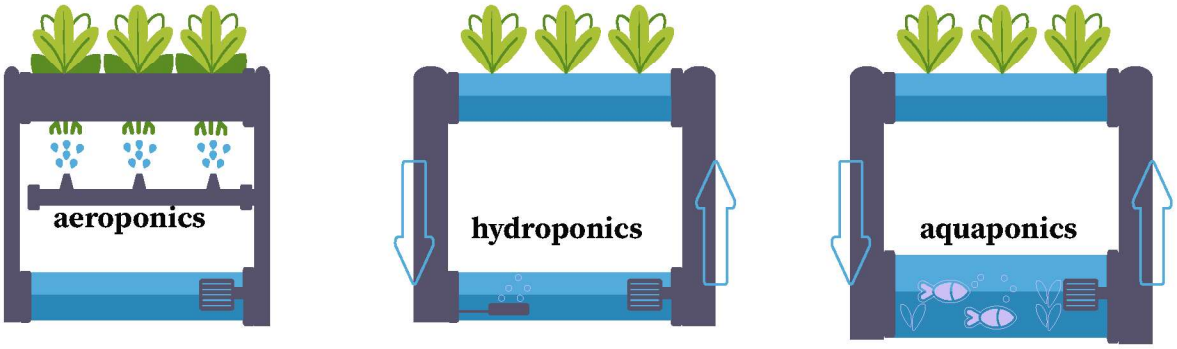


Figure 5.3.3.2: Vertical farming vary into three categories: Aeroponics uses the least amount of water by spraying water at the root of the plants. Hydroponics is the most popular and it requires some additional considerations such as air pumps and filtrations. Aquaponics is a holistic approach, which includes an ecosystem that provides all the required nutrients to help the plants grow.

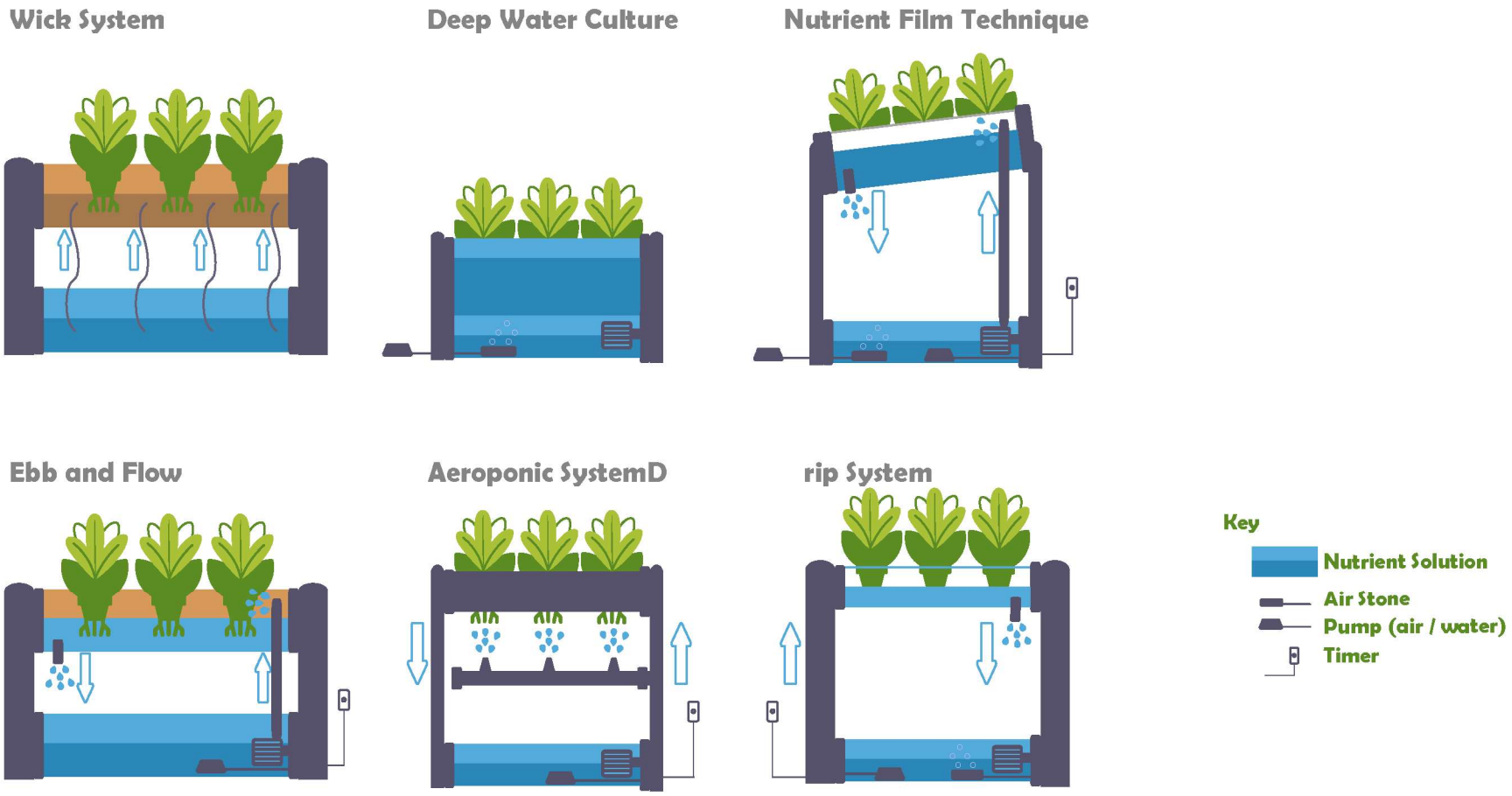


Figure 5.3.3.3: Hydroponic system variations: over the years, hydroponic systems has a lower start up cost than aquaponics. Therefore, the literature is extensive and technological innovations have caried over the years. As they become more popular, the technologies will continue to vary.

b. Vertical Farming Requirements

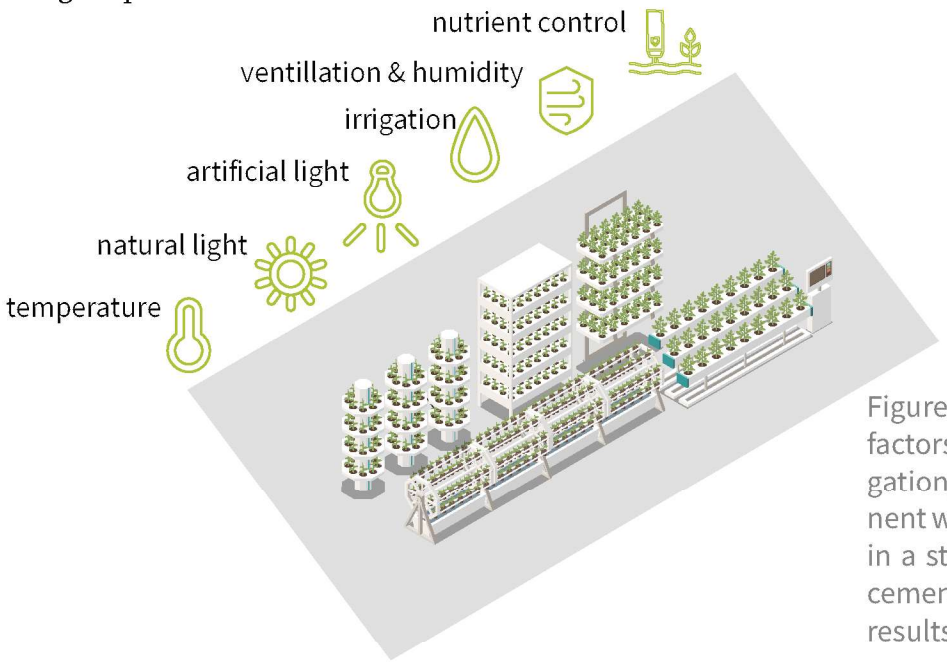
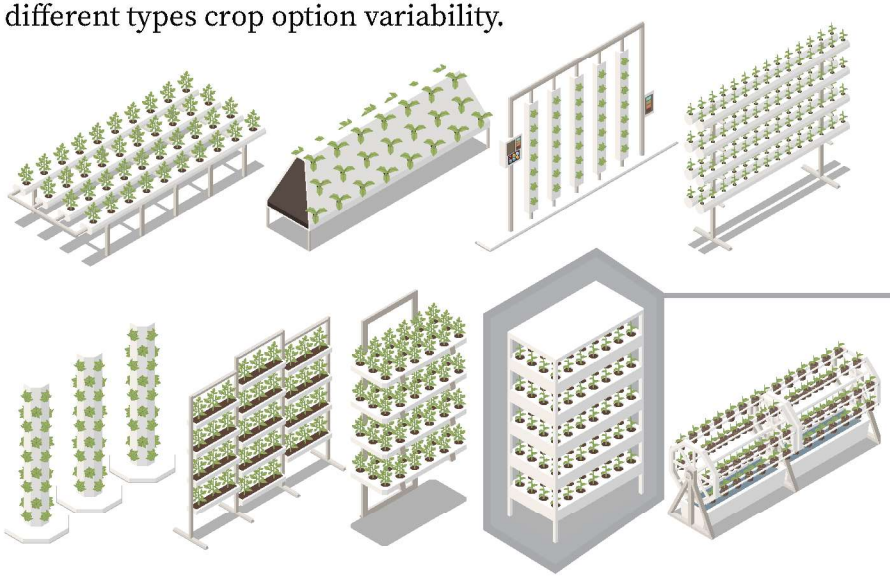


Figure 5.3.3.4: Vertical farming requirements depend on many factors that are controlled. Controlling temperature, light, irrigation, humidity, ventillation and nutrients are the more prominent ways of ensuring plant growth and health. The field remains in a state of constant development, where incremental advancements and testing several experimental systems yield variable results over time.

c. Types of Stacking

There are several types of ways to stack vertical farms, from beds to tubes. Stacking beds provide variable height options and provide different types crop option variability.





x5 productivity

Figure5.3.3.5: Stacking beds may use a variety of hydroponic system technoologies to improve plant growth. As technology continued to innovate, considerations such as types of substrates and soiless soil used will be studied case by case basis.

d. Plant Nutriant and pH Requirements

Macronutrients	**Micronutrients**
Nitrogen (N)	Iron (Fe)
Phosphorus (P)	Manganese (Mn)
Potassium (K)	Copper (Cu)
Calcium (Ca)	Zinc (Zn)
Magnesium (Mg)	Boron (B)
Sulfur (S)	Molybdenum (Mo)
	Chlorine (Cl)

Aeroponic and Hydroponic systems recieve nutrients only through ionized form. **Typical nutrients are:**

(P) Phosphate ions (PO_4^{3-})
(N) Nitrate ions (NO_3^-)
(K) Potassium ions (K^+)

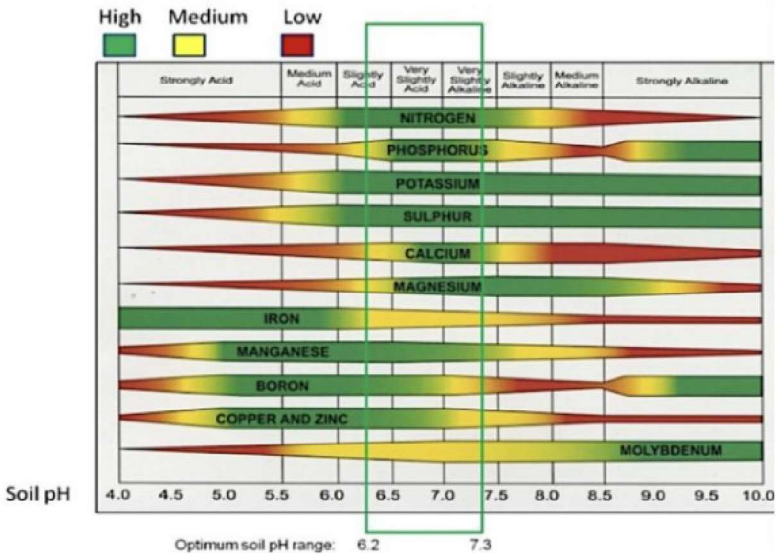


Figure 5.3.3.6: The suggested soil pH level is 6.2 - 7.3 because it allows all the macronutrients and micronutrients to be absorbed by the plants. If the soil acidity exceeds 6.0, essential macronutrients will not be absorbed by the plants. If the plant lacks nutrients, the consumers will lack nutrients triggering a health crisis and an expensive associated cost.Although aquaponic systems do not need to worry about adding nutrients, they do have to measure them and ensure they are suffecient.

e. Crop Selection for Vertical Farming

VEG. by consumption*	
~~Potatoes~~	~~35.2 lbs/pp~~
Onions	18.0 lbs/pp
Head Lettuce	15.7 lbs/pp
Tomatoes	15.7 lbs/pp
Romaine	10.3 lbs.pp
Peppers	9.1 lbs/pp
~~Sweet Corn~~	~~8.5 lbs/pp~~
Carrots	7.8 lbs/pp
Cabbage	7.6 lbs/pp
Cucumbers	6.2 lbs/pp
Celery	5.8 lbs/pp
Broccoli	5.5 lbs/pp
Sweet Potatoes	4.5 lbs/pp
~~Pumpkins~~	~~4.4 lbs/pp~~
~~Squash~~	~~3.8 lbs/pp~~
Mushrooms	2.3 lbs/pp
Garlic	2.2 lbs/pp
Snap Beans	2.0 lbs/pp
Spinach	1.4 lbs/pp
Artichokes	1.4 lbs/pp
Cauliflower	1.4 lbs/pp
Asparagus	1.1 lbs/pp
Eggplant	0.8 lbs/pp
Radishes	0.5 lbs/pp
Okra	0.4 lbs/pp
Collards	0.4 lbs/pp
Kale	0.3 lbs/pp
Brussel Sprouts	0.3 lbs/pp
Mustard Greens	0.3 lbs/pp
Turnip Greens	0.3 lbs/pp
Escarole	0.2 lbs/pp
Lima Beans	0.02 lbs/pp
TOTAL	173.42 lbs/pp

FRUIT by consumption*	
~~Orange~~	~~56.02 lbs/pp~~
~~Apples~~	~~48.62 lbs/pp~~
~~Bananas~~	~~25.06 lbs/pp~~
~~Grapes~~	~~20.72 lbs/pp~~
Watermelon	15.45 lbs/pp
~~Pineapples~~	~~13.47 lbs/pp~~
~~Peaches~~	~~9.06 lbs/pp~~
~~Canteloupe~~	~~8.88 lbs/pp~~
Strawberries	8.22 lbs/pp
~~Grapefruit~~	~~7.55 lbs/pp~~
~~Pears~~	~~5.36 lbs/pp~~
~~Lemons~~	~~5.14 lbs/pp~~
~~Tangerines~~	~~4.09 lbs/pp~~
Avacados	3.90 lbs/pp
~~Limes~~	~~3.22 lbs/pp~~
Cranberries	2.56 lbs/pp
~~Plums~~	~~2.28 lbs/pp~~
~~Mangoes~~	~~2.11 lbs/pp~~
~~Cherries~~	~~1.88 lbs/pp~~
Honeydew	1.65 lbs/pp
Blueberries	1.20 lbs/pp
~~Papayas~~	~~0.98 lbs/pp~~
~~Apricots~~	~~0.92 lbs/pp~~
~~Olives~~	~~0.87 lbs/pp~~
Raspberries	0.62 lbs/pp
~~Kiwi~~	~~0.46 lbs/pp~~
~~Figs~~	~~0.22 lbs/pp~~
~~Dates~~	~~0.20 lbs/pp~~
Blackberries	0.10 lbs/pp
TOTAL	250.81 lbs/pp

Currently suitable
Vegetables - 67.5 lbs/pp (38.9%) Fruits - 8.22 lbs/pp (3.3%)

Likely to be suitable
Vegetables - 54.02 lbs/pp (31.2%) Fruits - 25.48 lbs/pp (10.2%)

~~Req. modification for suitability~~
Vegetables - 51.90 lbs/pp (29.9%) Fruits - 217.11 lbs/pp (86.56%)

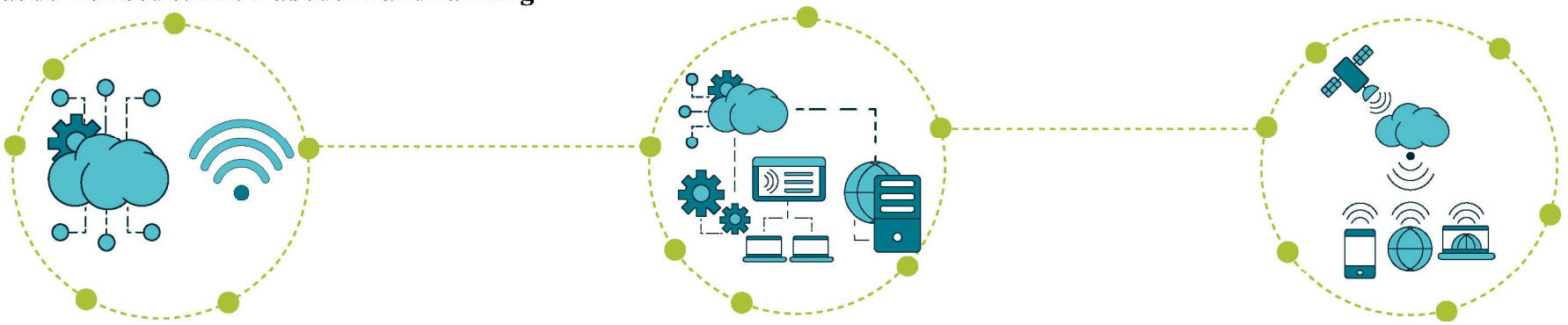
* Source: Economic Research Service, USDA

Figure 5.3.3.7: The USDA provided a suggested Crop Selection for vertical farming that are popular in the global market and provide the hieghest yield.

With the growing GHG emissions requirements set by the European Parliment and the U.S. Securities and Exchange Commission, to keep up with daily reports, This very likely means that farming facilities will all require enclosures and A.I. integrated infrastructures to keep products USDA complient and on grocery shelves for public distribution.

Due to the novalty and speed of change of the AI technology, research institutions are teaming up with start-up companies to provide the public with data, list of tested technologies, outputs, cost analysis and system variations that could help speed up the learning curve. This will continue to gain global traction, and it will affect Canadian Farmers if they wish to stay competative in the global market.

What do we need to know about AI and Farming



Input : IoT (sensors) to measure:

1. pH
2. light
3. UV
4. soil water
5. substrate water
6. plant weight
7. leaf
8. crop transpiration
9. Electrical Conductivity (EC)
10. Temperature
11. Humidity
12. Air Velocity
13. CO2
14. GHG Emissions

Processing : Machine Learning (Algorithem workflow)

With the intention of providing full autonomy of functions - A.I. has already demonstrated it's capability to predict complex problems including predicting crop yield to offsite users.

Output : Release of information

The Cloud
Apps
with multiple user access
governance program access
public announcements

What AI can predict and detect from offsite monitering?

Weather
Plant Disease
Pest / Weed Detection
Yield Predictions
Crop Selection
Plant Growth

What does this mean for Arcology and Vertical Farming?

Arcology is a built infrastructure that can integrate AI Infrastructure in it's Vertical Farms. The Arcology can begin with data collecting Vertical farm productivity in Canadian climate. The Arcology can collaborate with research institutions and Start-Up companies to innovate new technologies to improve vertical farming technologies. In the future, they can provide the option to lease spaces to farmers in the Arcology to grow their crops.

g. Vertical Farming space allocation

In Canada, the use of Agricultural land to harvest vegetables and fruits is 324 m2 per person and closed environments can downscale that into 18 m2. Vertical farming provides a less intensive comprimise between these extreme cases to 81 m2.

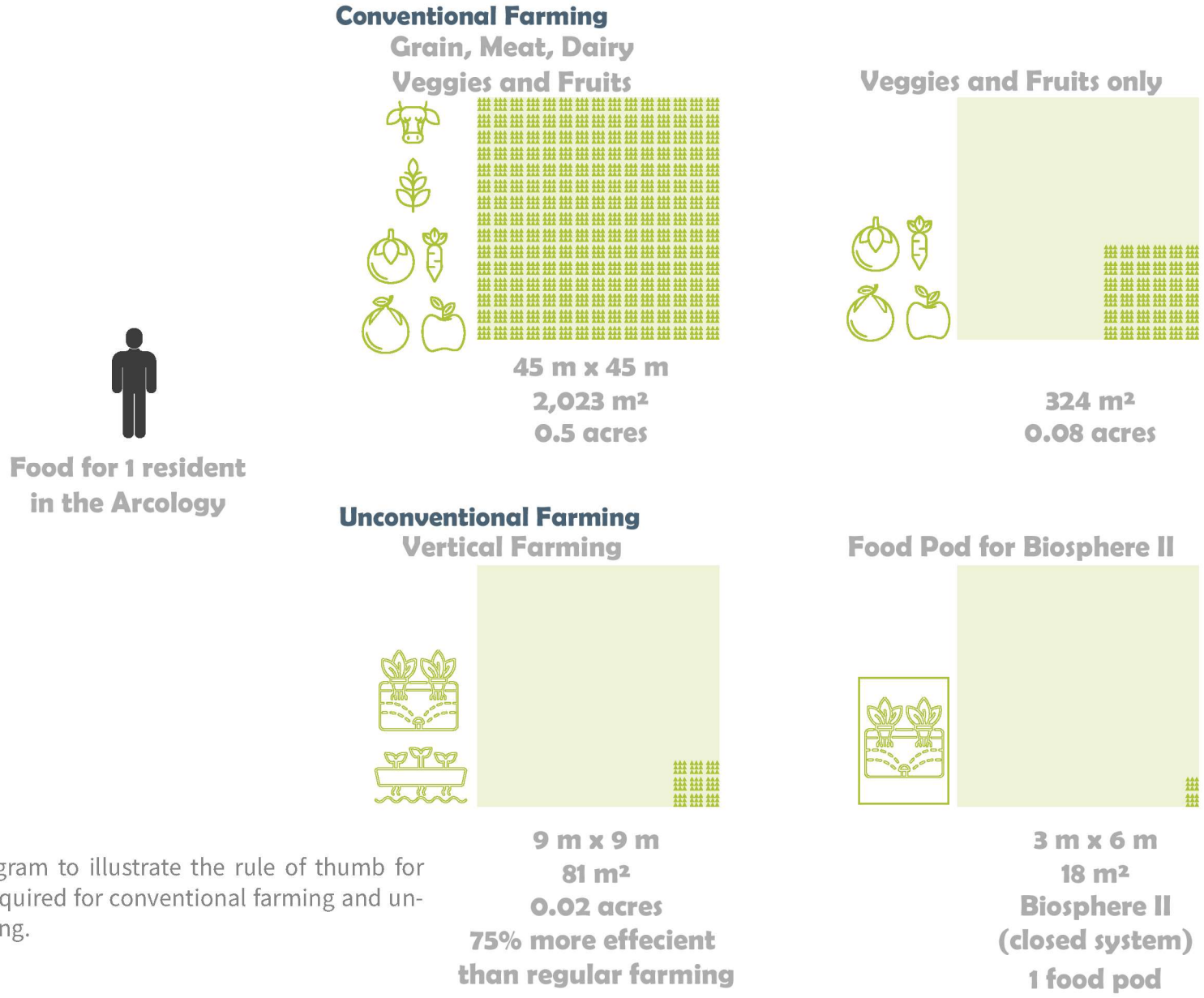


Figure 5.3.3.8: Diagram to illustrate the rule of thumb for space allocation required for conventional farming and un-conventional farming.

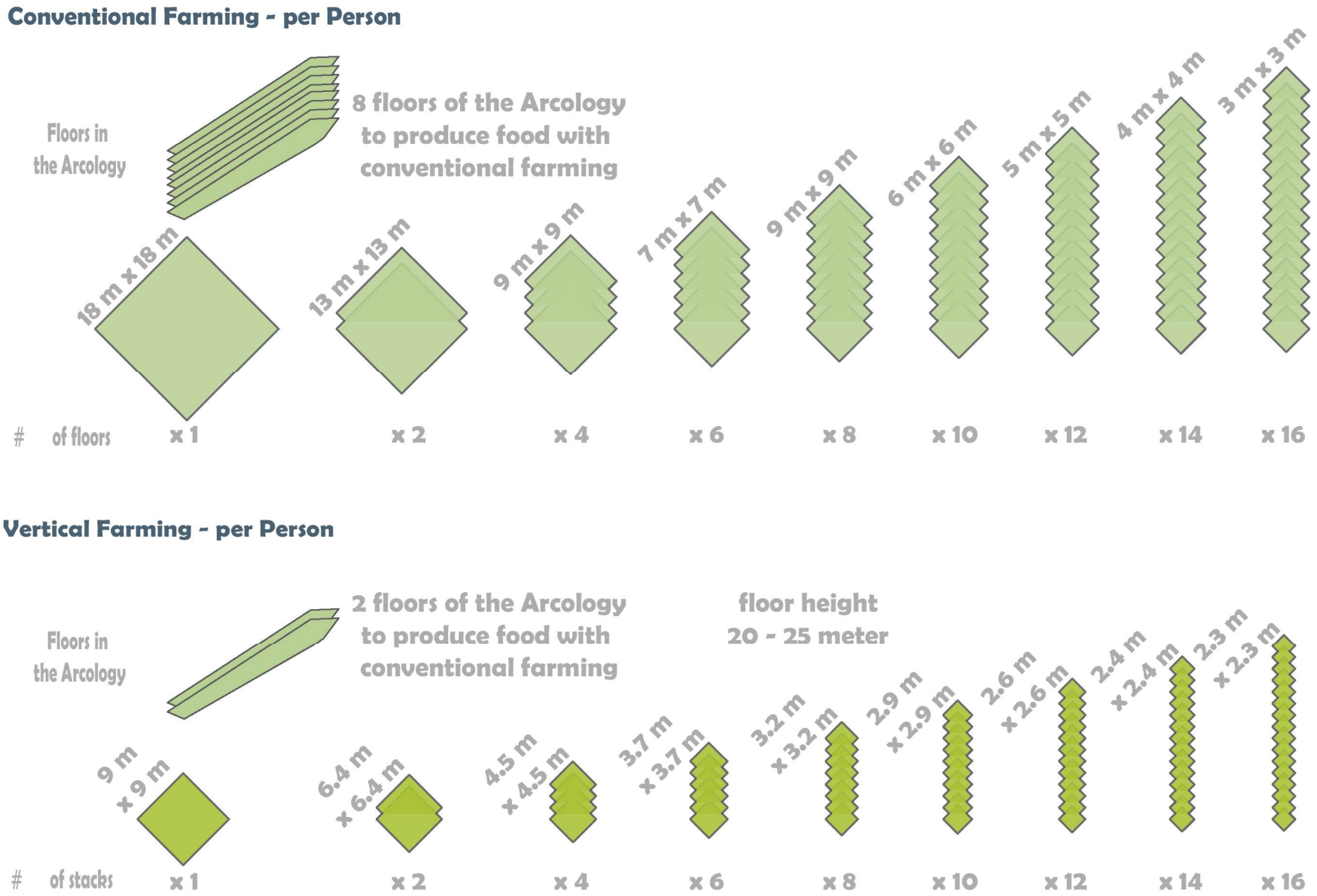


Figure 5.3.3.9: Diagram to illustrate the area required if the floors were stacked for farm use. Conventional farming will require 8 floors with a 2.2 kilometer site while Vertical Farming will require 2 floors and 16 stacks. Vertical farming will require additional mechanical systems to manage all it‘s systems.

Synergistic advantage of Vertical Farming, Aquaponics & Arcology?

Generated heat.

Vertical farming uses substantial energy to maintain and moniter plants.
Therefore, the heat emitted can be benefit the Arcology.
Placing Vertical farming between the commercial and residential zones,
will provide additional heat throughout the building.

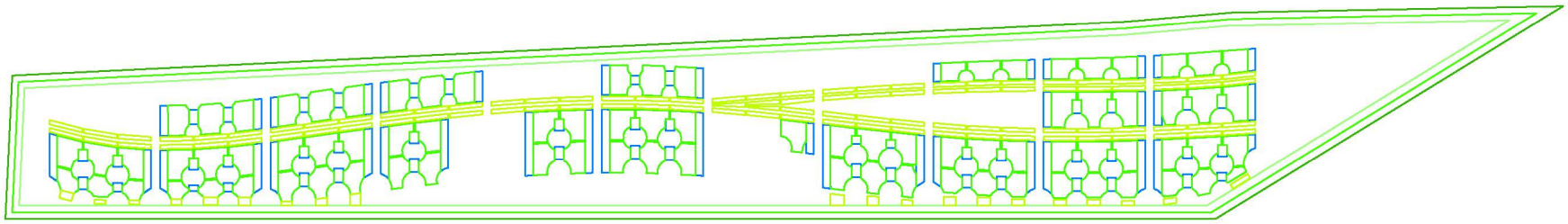
Farming Processes.

Different plants require different temperatures, grouping plants
according to their temperature requirement may reduce mechanical
redundancy and keep the arcology effecient.

Cold Plants - North Hot Plants - South

Stacked Beds - up to 16 stacks.

Different plants require different hydroponic growing options.
The arcology can accomodate all sorts and adapt accordingly.
The diagram shows 16 stack beds one of the most adaptable options.
Mechanical systems are provided on both sides of the “farm”.



Farming & Facilities - 2 Floors

Figure 5.3.3.10: Diagram to visualize the farming and it‘s facilities required (2 floors) alone. The mechanical systems (grey) are as significant as the farming area (green).

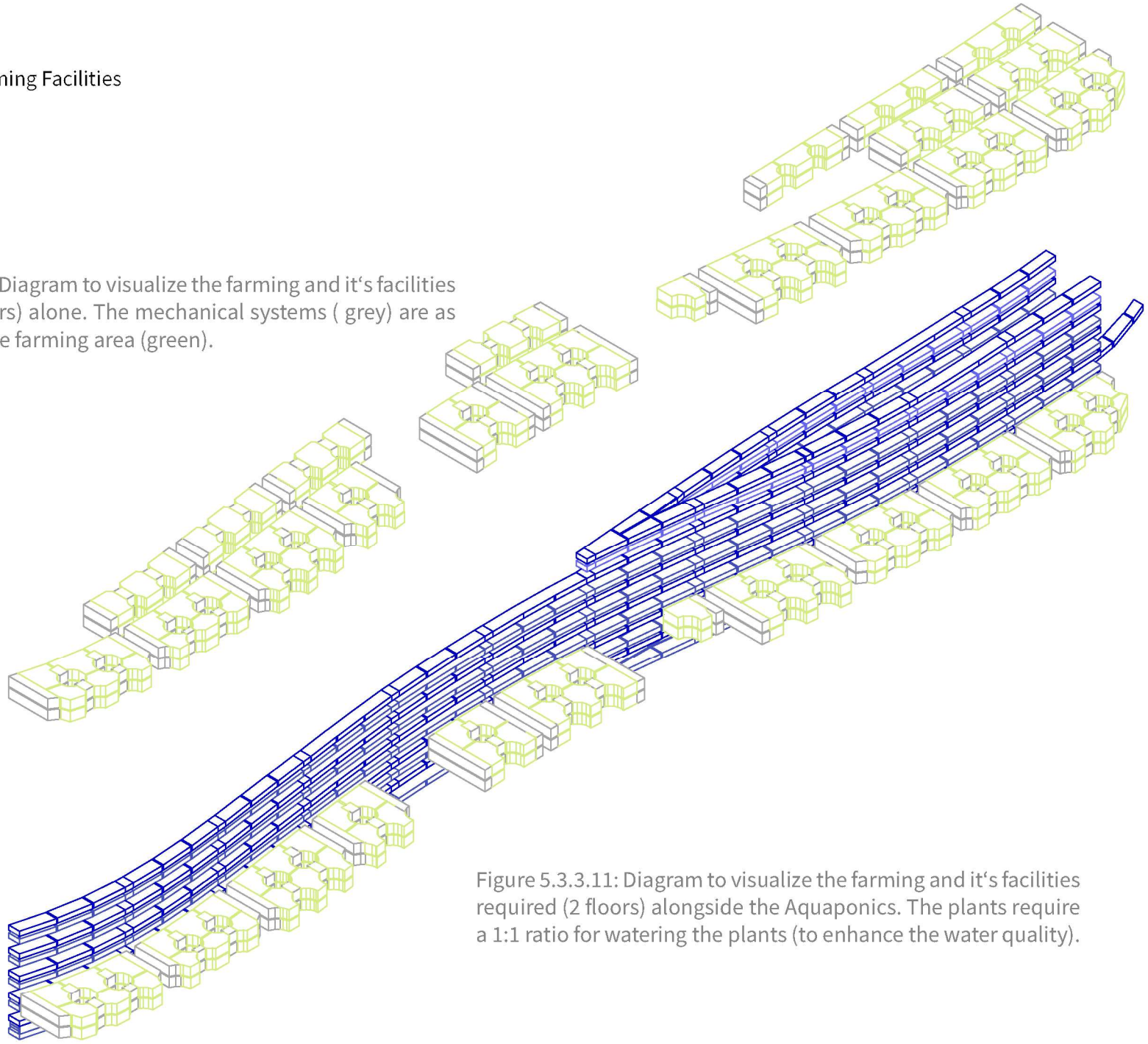


Figure 5.3.3.11: Diagram to visualize the farming and it‘s facilities required (2 floors) alongside the Aquaponics. The plants require a 1:1 ratio for watering the plants (to enhance the water quality).

4. Aquaponic Systems

a. Aquaponics - Plant Selection & Rules of Thumb

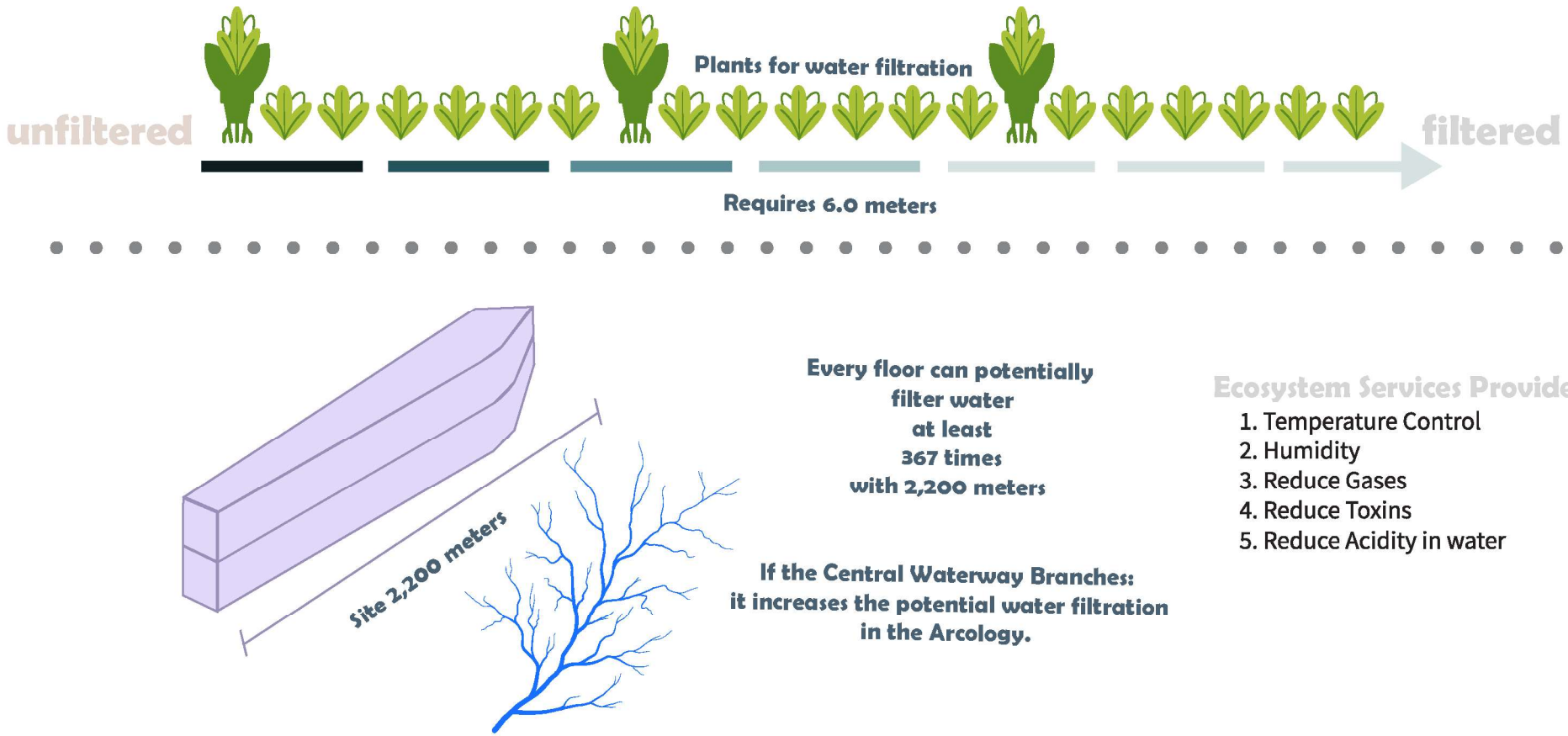


Figure 5.3.4.1: Aquaponics systems are designed to house living organisms and rely on mechanical filtration to maintain healthy water quality. However, researchers including American enviornmental scientist and principal investigator of NASA's Clean Air Study, Bill Wolverton, have found that certain plants can provide ecosystem services that enhance water quality. These plants however, require up to 6.0 meters to filter the water. The Arcology has substantial horizontal distance of the Arcology serves as a valuable asset for enhancing water quality management.

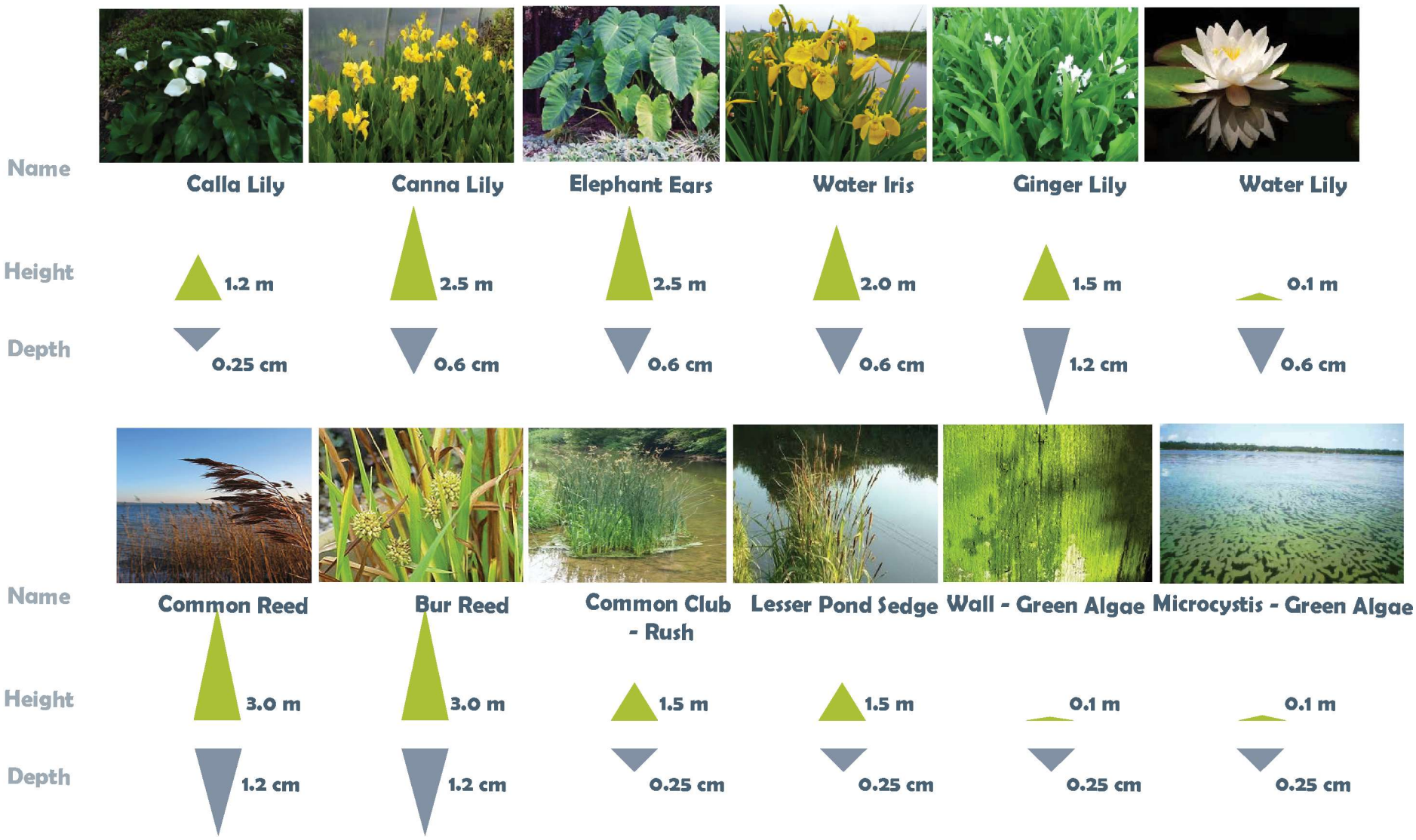


Figure 5.3.4.2: Diagram to illustrate proposed plant selection suggested by American enviornmental scientist and principal investigator of NASA Clean Air Study, Bill Wolverton. Other interesting plant selections could be found in Todd and Todd's Living Machine that suggested cammomile, papyrus and ginger to mask odour.

b. Aquaponics Water Requirements

The Aquaponic System required has a 1:1 ration with the Farming Area to provide water that provides the plants with nutients needed. This Aquaponic system has a volume and fish density that needs to be managed to provide the watering of plants and vertical farms.

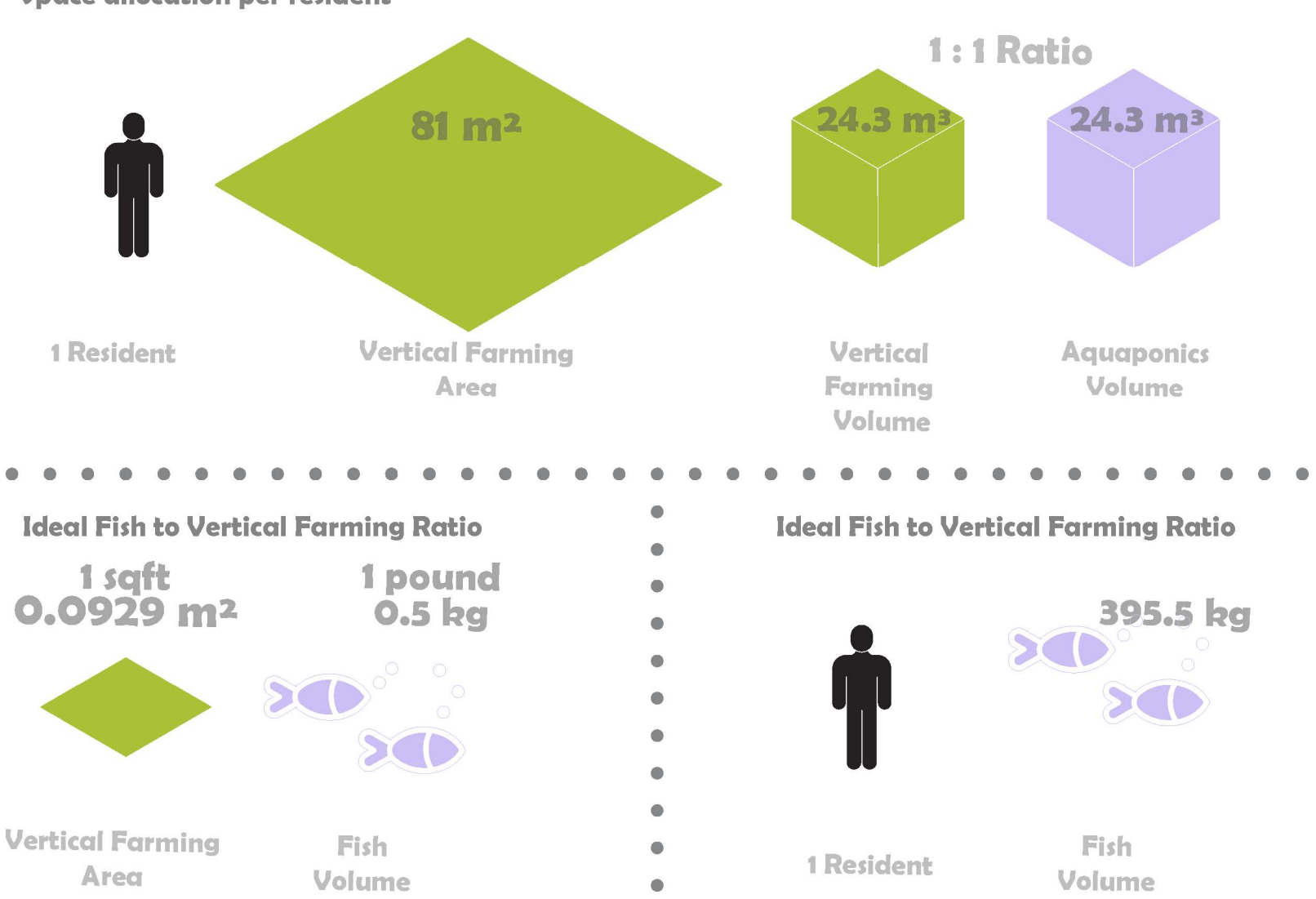


Figure 5.3.4.3 Diagram to illustrate water and fish density for every resident in the Arcology

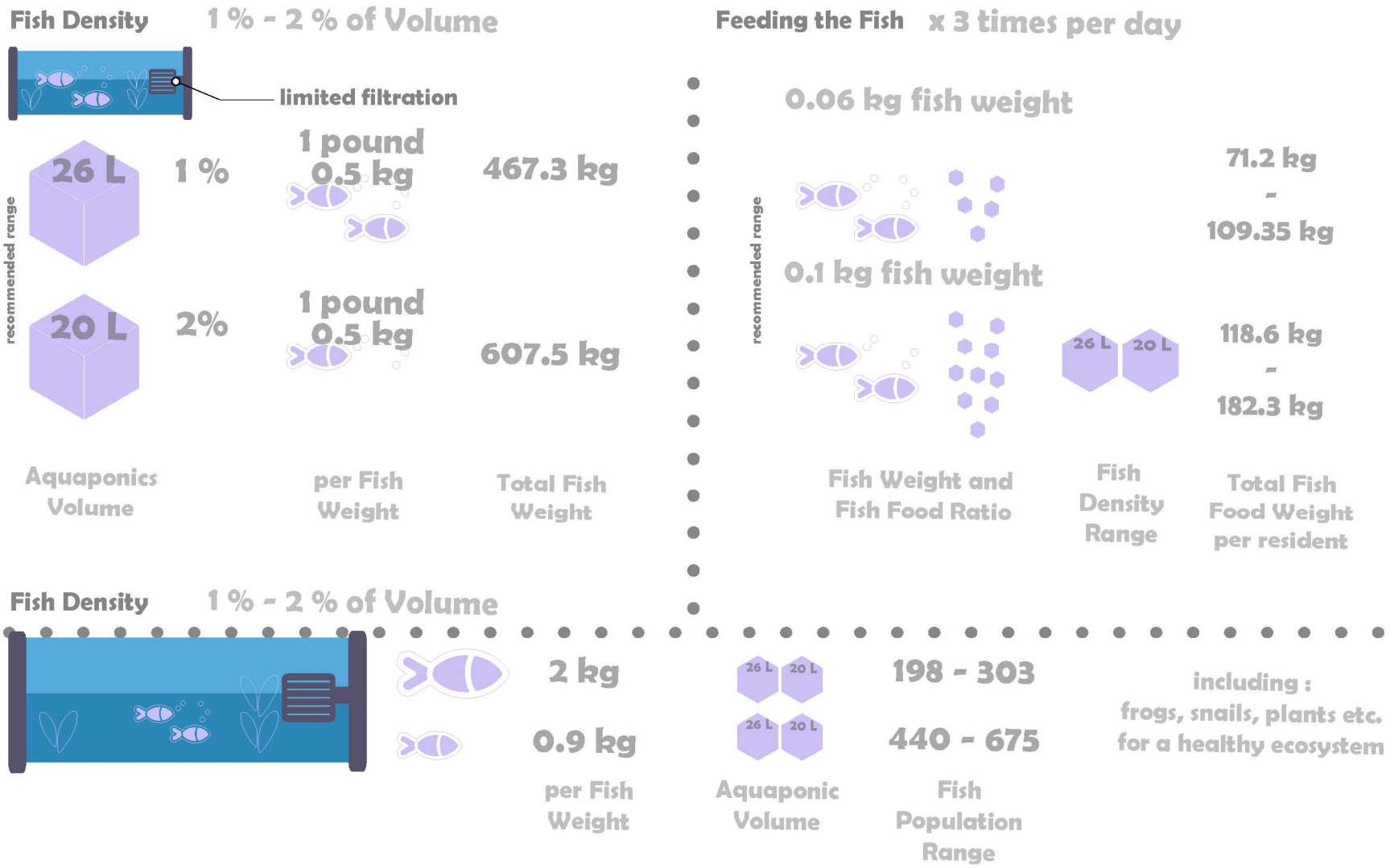


Figure 5.3.4.4: Diagram to illustrate that fish density will vary if the Arcology limits the use of mechanical filtration. The ratios calculated show the possible ranges of fish population. If the population increases, all residences can enjoy fresh fish dinner or consider adding mechanical filtration - depending on how healthy the plants in the vertical farm are frowing.

c. Aquaponic Water Way that feeds the plants

Synergistic advantage of Aquaponics & Arcology?

Thermal Mass.
Aquatic Waterways should maintain a 1:1 Ratio with the Vertical Farming System. Therefore, the thermal mass water can hold is substantial. Centralizing large water reserves in storage can offer significant thermal and enviornmental properties.

Horizontal Reach.
Although mechanical filtration is important, plants that provide water filtration benefits greatly from the horizontal layout.

Centralized Location.
Nutrients in the water should not have direct sunlight exposure, or it will reduce the quality of water.

Decentralizing Water Systems
The advantages of decentralizing water systems has multiple advantages. Local communities can manage their demands, optimize their use, local plants can help filter water channels, etc. Decentralized systems can offer greater flexibility in managing fluctuations in the water supply. This built-in tolerance range allows for dynamic balancing of water re-sources and assists in adapting during shortages.

Integration with Natural Systems
The water is cycled into the Arcology approximately multiple times, and can be returned back into the river, at a higher quality of water.

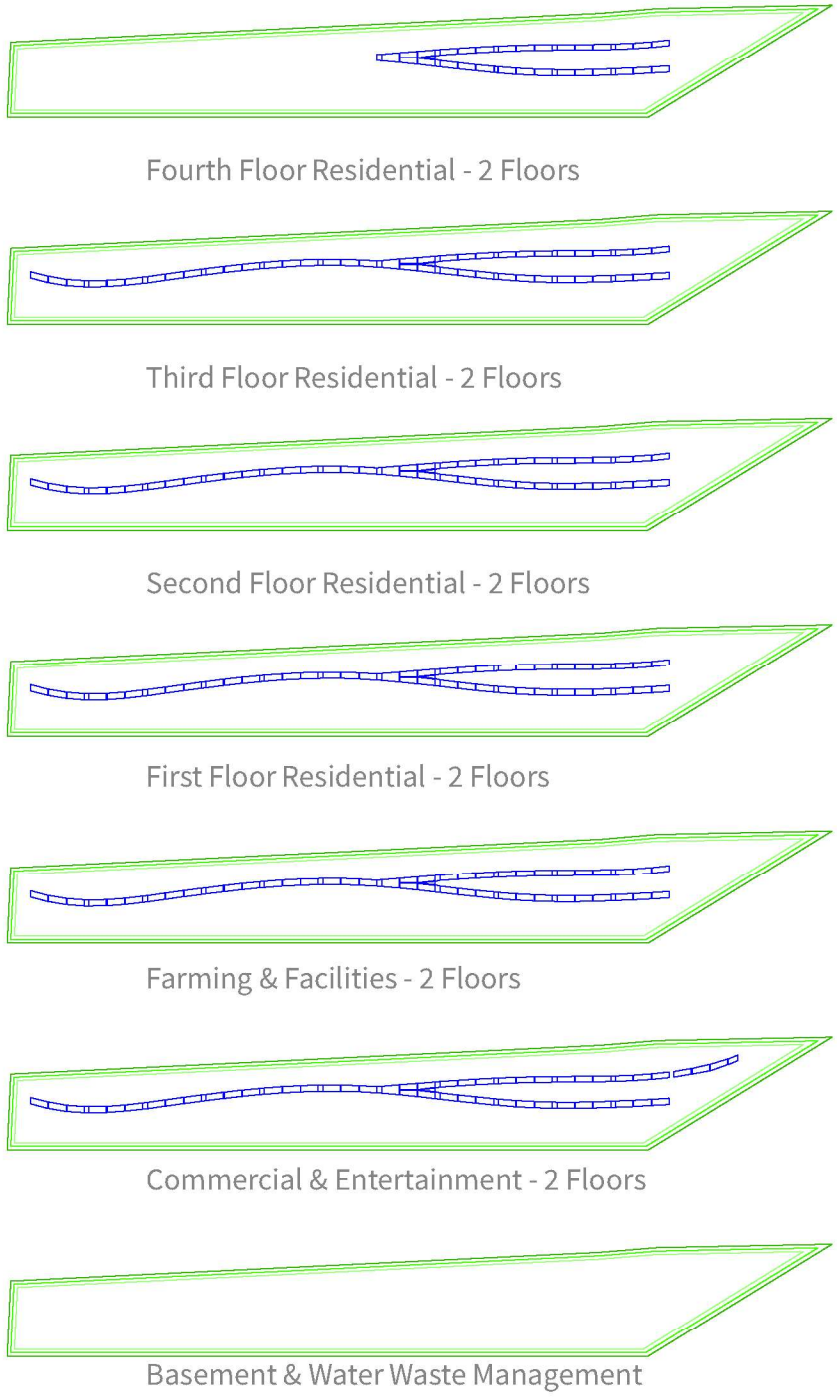


Figure 5.3.4.5: Illustration to visualize zoning the Centralized Aquatic Waterway required for every floor for the Aquatic Waterway. The Basement has the Water Waste Management Facilities, and the Aquatic Water Way requires indirect natural lighting.

d. Visualizing the Aquaponic Waterway

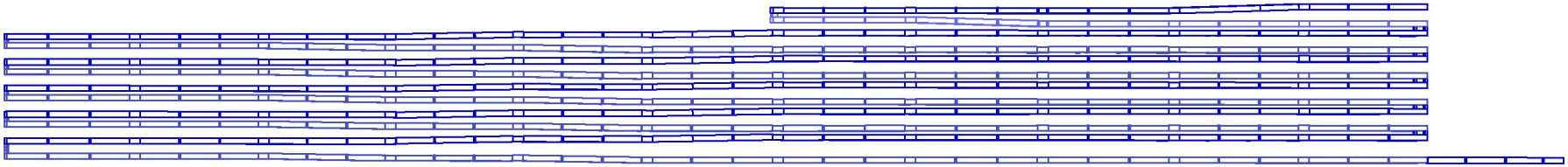


Figure 4.3.5.6: Illustration to visualize in section, the Aquatic Waterway where the channels are sloped at 2 % minimum to reduce the use of mechanical pumps.

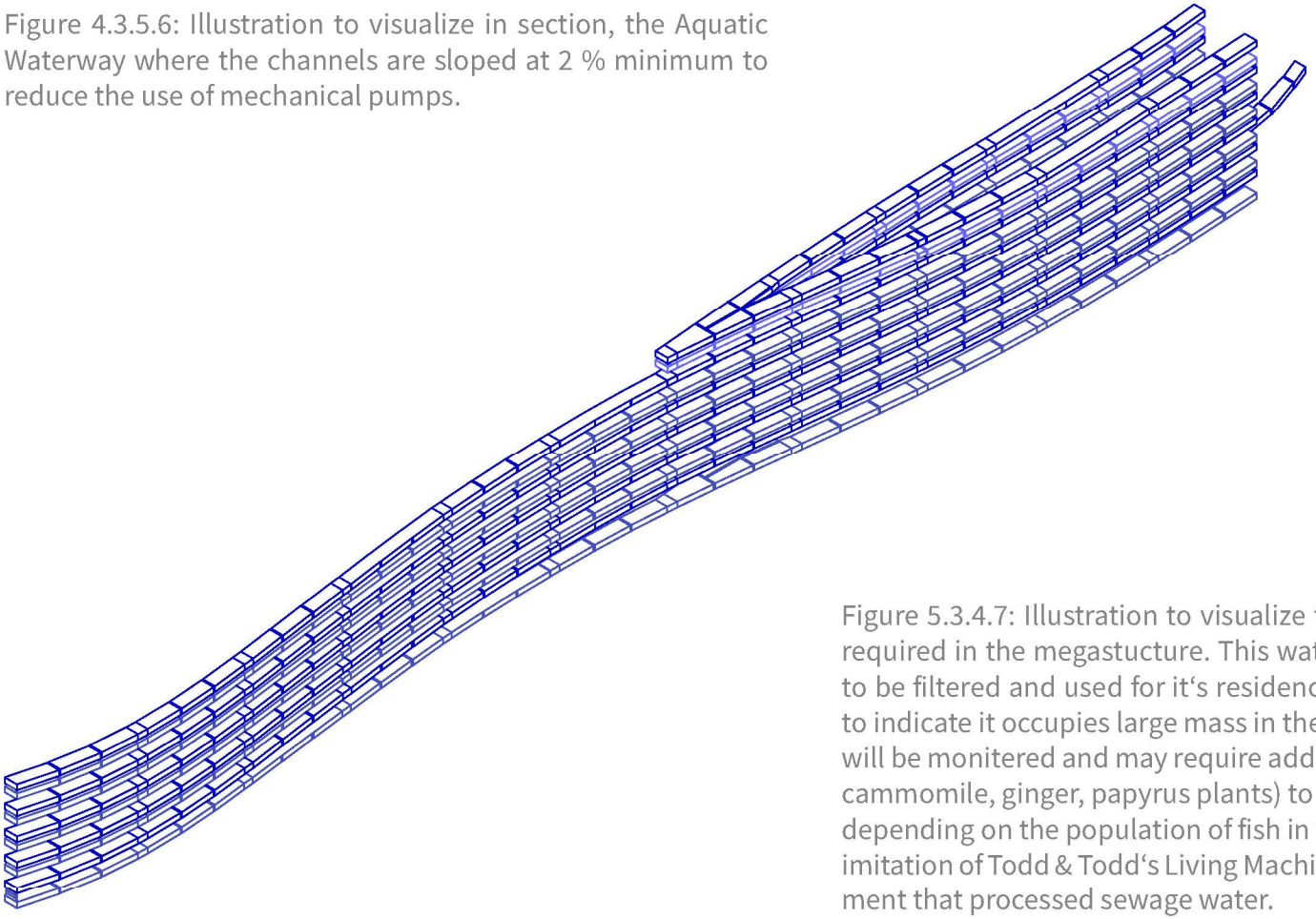


Figure 5.3.4.7: Illustration to visualize the calculated water volume required in the megastucture. This water will water the plants, and to be filtered and used for it‘s residences and visitors. The intent is to indicate it occupies large mass in the structure. The water system will be monitered and may require additional natural filters (such as cammomile, ginger, papyrus plants) to mask odor or artificial filters, depending on the population of fish in the system. This system is an imitation of Todd & Todd‘s Living Machine which provided an eviorn-ment that processed sewage water.

5. Living Systems to Process Water Wastes for the Arcology

Process	40,000 gpd	80,000 gpd	1 million gpd
"Living Machine" with greenhouse	$1,077,777[1]	$1,710,280[1]	$10,457,542[2]
"Living Machine" without greenhouse	$985,391	$1,570,246	$9,232,257
Conventional System	$1,207,036[1]	$1,903,751[1]	$8,579,978[2]

(1) Cost difference is less than 20 percent
(2) Cost difference is greater than 20 percent

Source: U.S. EPA, 2001.

Figure 5.3.5.1: Cost Comparison of "Living Machines®" and Conventional Systems, from a US EPA Report in 2001.

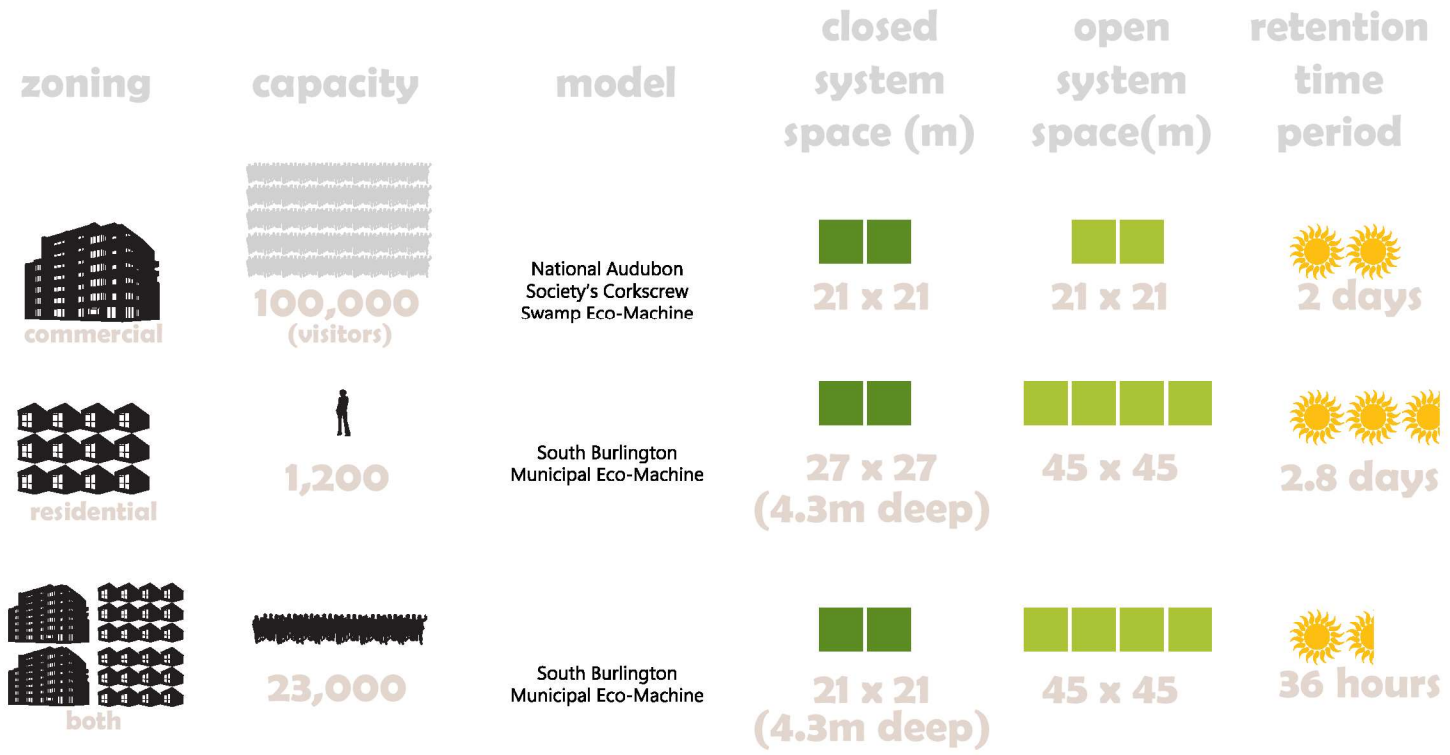


Figure 5.3.5.2: Illustration to represent Eco-Machine Systems that show capacity, space required and time for water circulation.

a. Understanding the Water Waste Management System

Inspired by the Eco-Machine©, we must comprehend its differences from other conventional systems before incorporating this emerging wastewater treatment technology in an Arcology. The technology evolved from the Living Machine TM design to the Living Machine© (sometimes referred to as Advanced Ecologically Engineered System" or AEES) and now Eco-Machine©. The process has undergone several rounds of review by the United States Environmental Protection Agency (EPA) to stay competitive with alternative wastewater management systems. This ambition reduced the academic transparency that its founder, Dr John Todd, had originally exhibited at the start of this expedition. However, we are aware of the system's broad strokes.

Conventional biological treatment systems involve basic processes such as sedimentation, filtration, clarification, absorption, nitrification, denitrification, volatilization, and anaerobic and aerobic decomposition. Eco-Machine© uses plants and animals in its treatment process as it incorporates all the treatment processes, which provides the system with an aesthetical appeal. The most evident advantage of such a system is that wastewater treatments can be allocated to populated sites. The second advantage is by using biological organisms to treat wastes, we close the loop and can potentially consistently reuse water and release high-quality water to rivers. The third is the educational benefits, data analysis, and generally raising public awareness of wastewater treatment methods.

An oversimplification of the variation process typically uses two main types of systems: closed reactors that flow into open reactors. The closed reactors use planted biofilters, and the open reactors use vegetation supported by racks for filtration. The most significant benefit of Eco-Machine© is the data collected and the know-how on microorganisms and plant selections that naturally break down wastes. A system must incorporate a food web ecosystem with plankton, algae, plants, crabs, oligochaete worms, and various invertebrates. The water is measured to see the system's capacity to treat its Ammonia, Nitrogen, Nitrate, Total Suspended Solids (TSS), Biological Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), and Phosphorus.

This would mean standard routine operation and maintenance (O&M) requirements, including vegetation and living organisms' management. Typical O&M requirements will consist of cleaning the inlet/outlet structure, cleaning the containers, removing and disposing of sludge, and machinery repair and maintenance. Vegetation management requires routine harvesting, plant growth monitoring, etc. Living organisms' management includes managing the population, controlling mosquitos and flies, etc. Waste from this system comes from plant residuals and biosolids. Plant residuals, however, can be composted and used for agricultural and horticultural purposes. The biosolids will probably require additional treatment against pathogens.

In 2001, the United States Environmental Protection Agency evaluated this system as cost-effective by 20% for flow volumes up to 100,000 gallons per day (approx. 378,000 liters per day). To reduce operations costs, they claimed that this system is most cost-competitive for warmer climates that do not require an enclosure. The Eco-Machine has been proven to recycle to high standards for greywater, which can be used for landscape irrigation, toilet flushing, pond etc. However, to achieve drinkable water, additional machines will have to be incorporated, like UV disinfection or reverse osmosis, and it is unclear how the Eco-Machine has resolved this using plants.

However, there are two main benefits to incorporating an Eco-machine© into an Arcology. First, all systems, including wastewater management, will be decentralized because living systems have limits to growth and will experience stress and collapse when overburdened. Second, this is a massive, enclosed structure in a temperate climate that shares operational costs among multiple users. Therefore, water waste management systems will only close the loop in multiple systems and provide additional benefits to the Arcology. Third, the recycling potential of this is very high due to the ecological integration of the system. One of the benefits is plant residuals can be composted throughout the building, cutting transportation costs. Another example is biogas, which could be packaged and used as a clean energy source.

b. Waste Living Systems that Process Waste for the Arcology

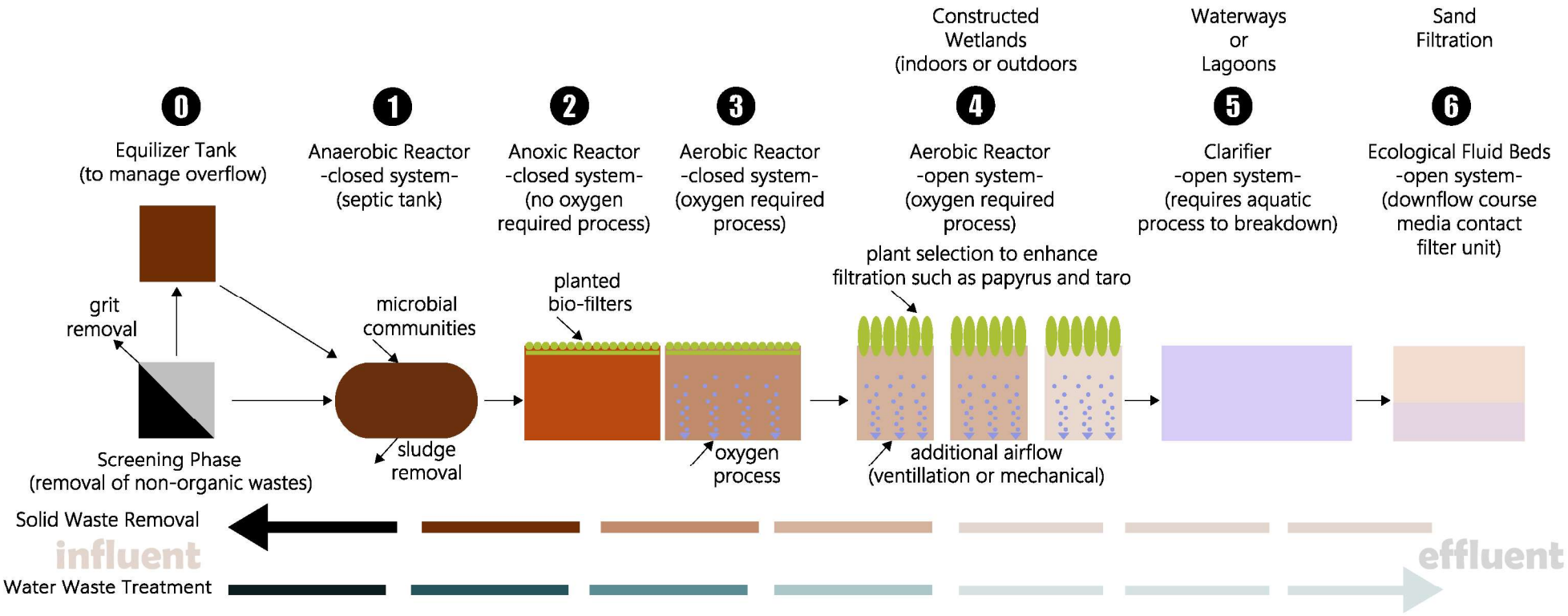
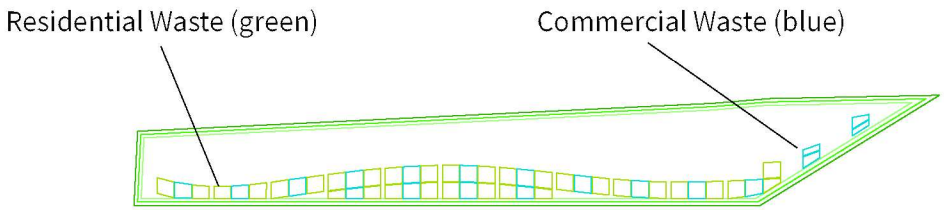


Figure 5.3.5.3: Illustration to represent the waste water system to breakdown wastes, inspired by Todd & Todd's Eco-Machine. This will produce greywater at a high standard, if drinking water is required, then additional treatment processes have to be incorporated into the system.



c. Visualizing the Waste Living Systems in the Arcology

Visible in the commercial zones and floors with vertical farming, the green below is the Aerobix reactor. In this phase, the plants have processed most of the wastes. Strong odor can be treated with strong smelling plants such as ginger or cammomile. The treated water will then move to the constructed wetlands (indoors). As required, the waste waters will be channeled into the lagoons,
and perhaps through sand filtration if used for human consumption.

Septic tanks (red) and Anoxic Reactor (blue). They require no or minimal light, they have strong odors, so these processes are kept underground under close supervision.

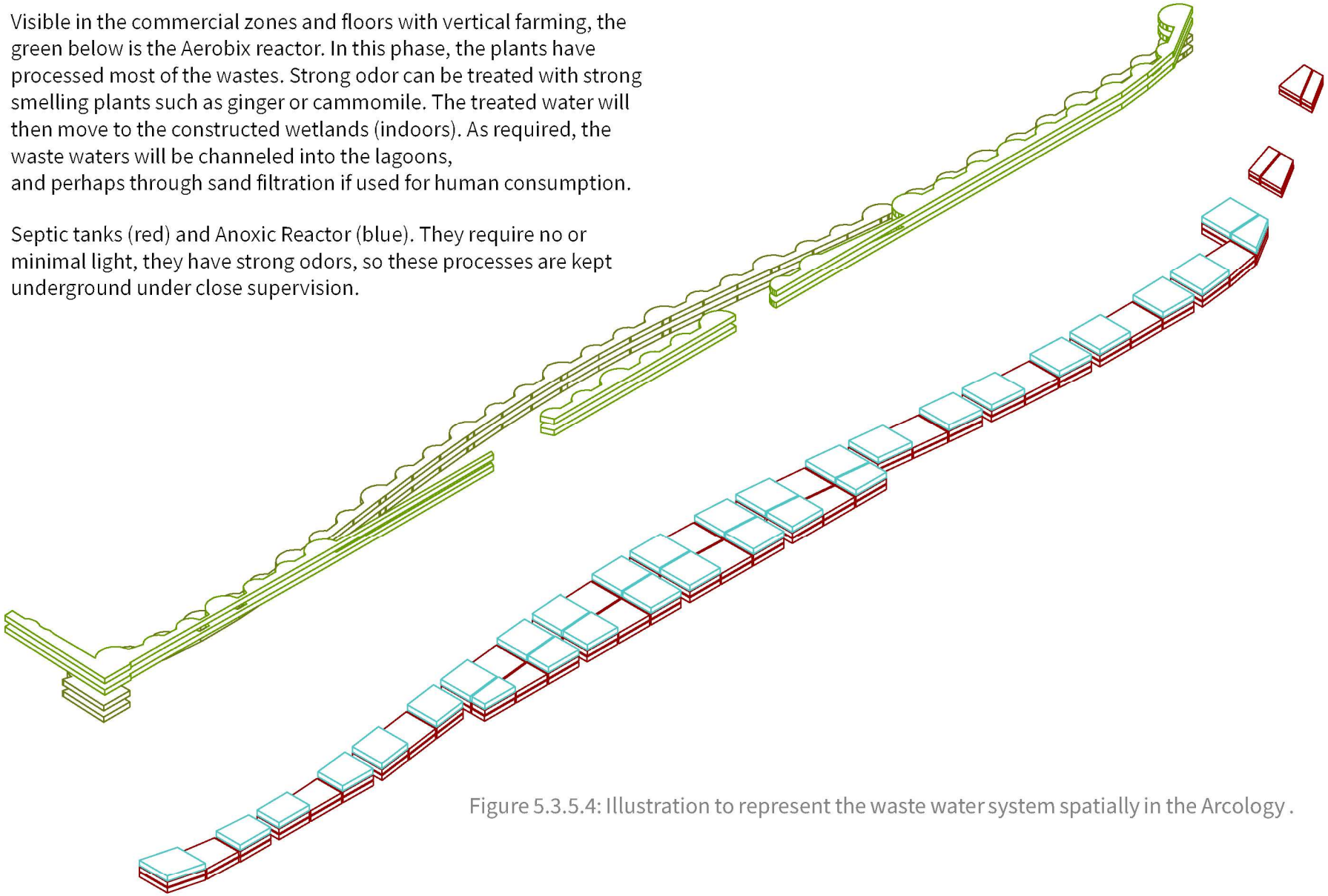


Figure 5.3.5.4: Illustration to represent the waste water system spatially in the Arcology .

Description of the Hypothesis:

The intention of this is when solving in section, due to ecological megastructure's multi-layered systems, it makes it important to review the key interactions that seem to have leverage within the system. So if something is not functioning properly, a deep dive in these interactions will provide amplified yield.



Testability is now generally accepted as the defining characteristic of the scientific method. Popper called it the *criterion of demarcation* **between science and non-science.**

- David Deutsch (2011) - British Physicist & Academic.

the criterion of the scientific status of a theory is *its falsifiability, or refutability, or testability.*

- Sir Karl R. Popper (1963) - Austrian American Philosopher & Academic.

5.4 Key Interactions within the Network

The Analysis of Systems is based on these factors. Ecological Systems will benefit manmade systems most when alayzing

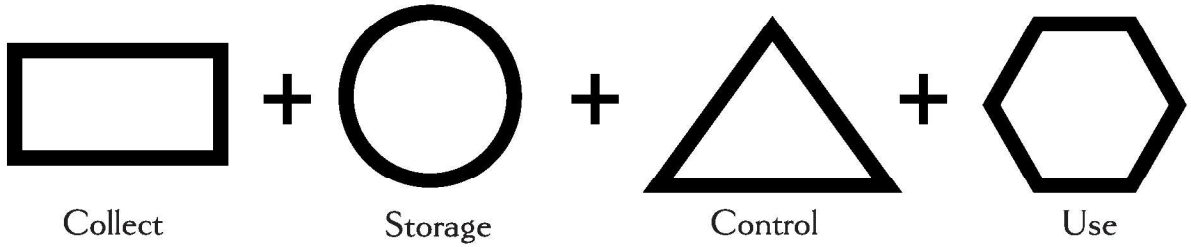
1. Heat Flow
2. Water Flow
3. Waste Flow

Ecological Systems will provide limited contribution to

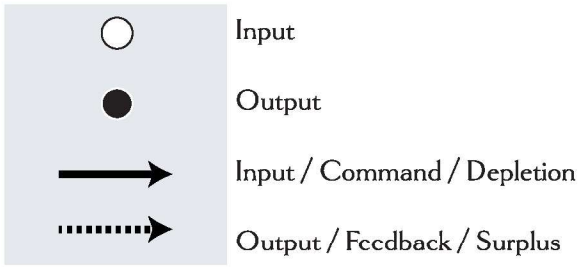
4. Energy Flow

1. Deciphering the Systems

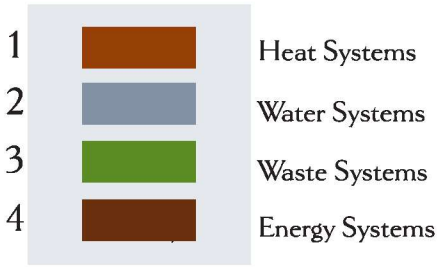
Systems in the Arcology are distributed in the following manner. Where there are ecological systems, the processes are cyclic and reciprical and the mechanical systems are linear and return to ecological systems for a synergistic exchange. These process are developed in the expanded systems.



2. Flows or Trajectories



3. Systems to be Expanded



5.4.1 Heat Systems

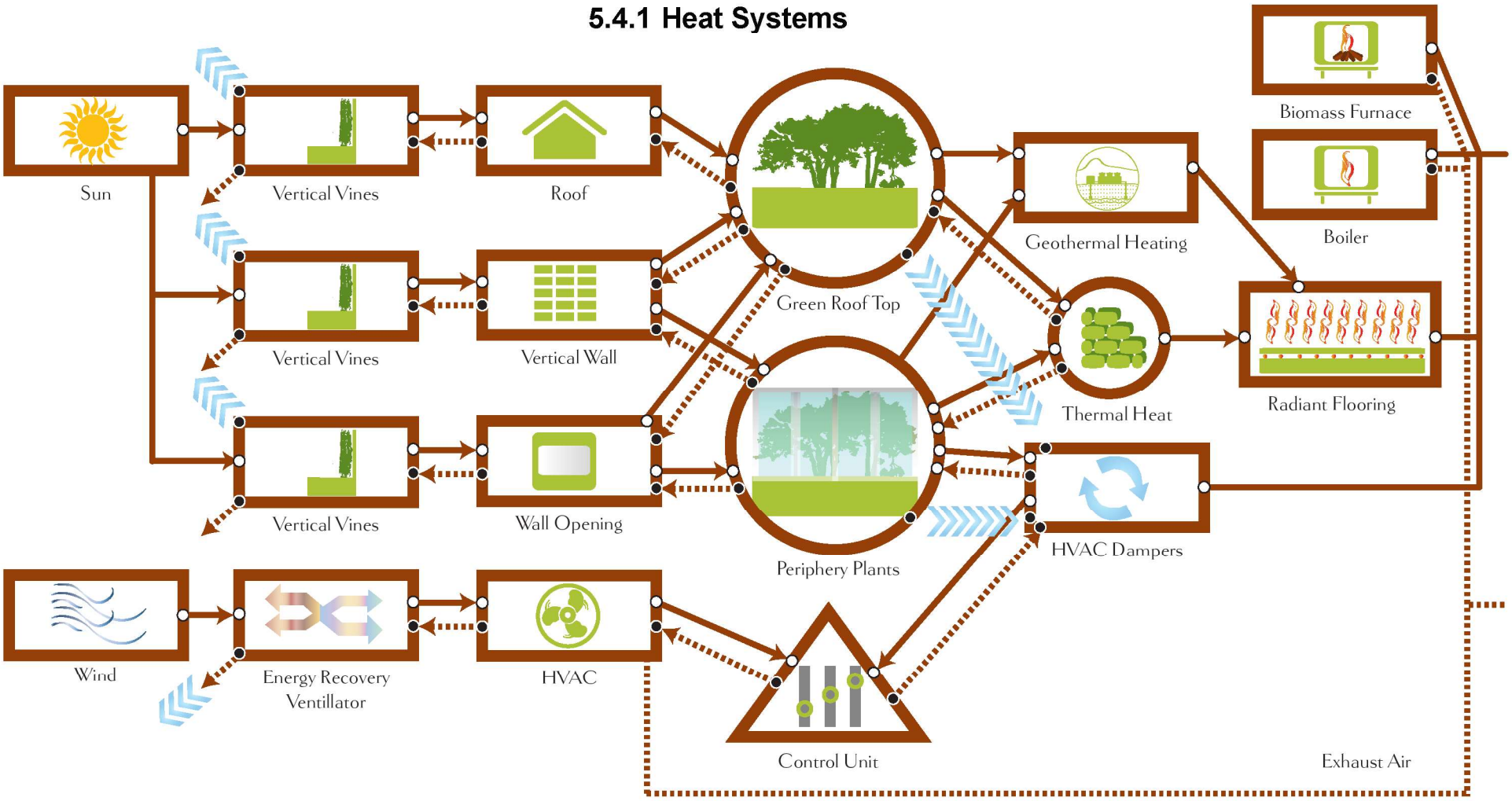
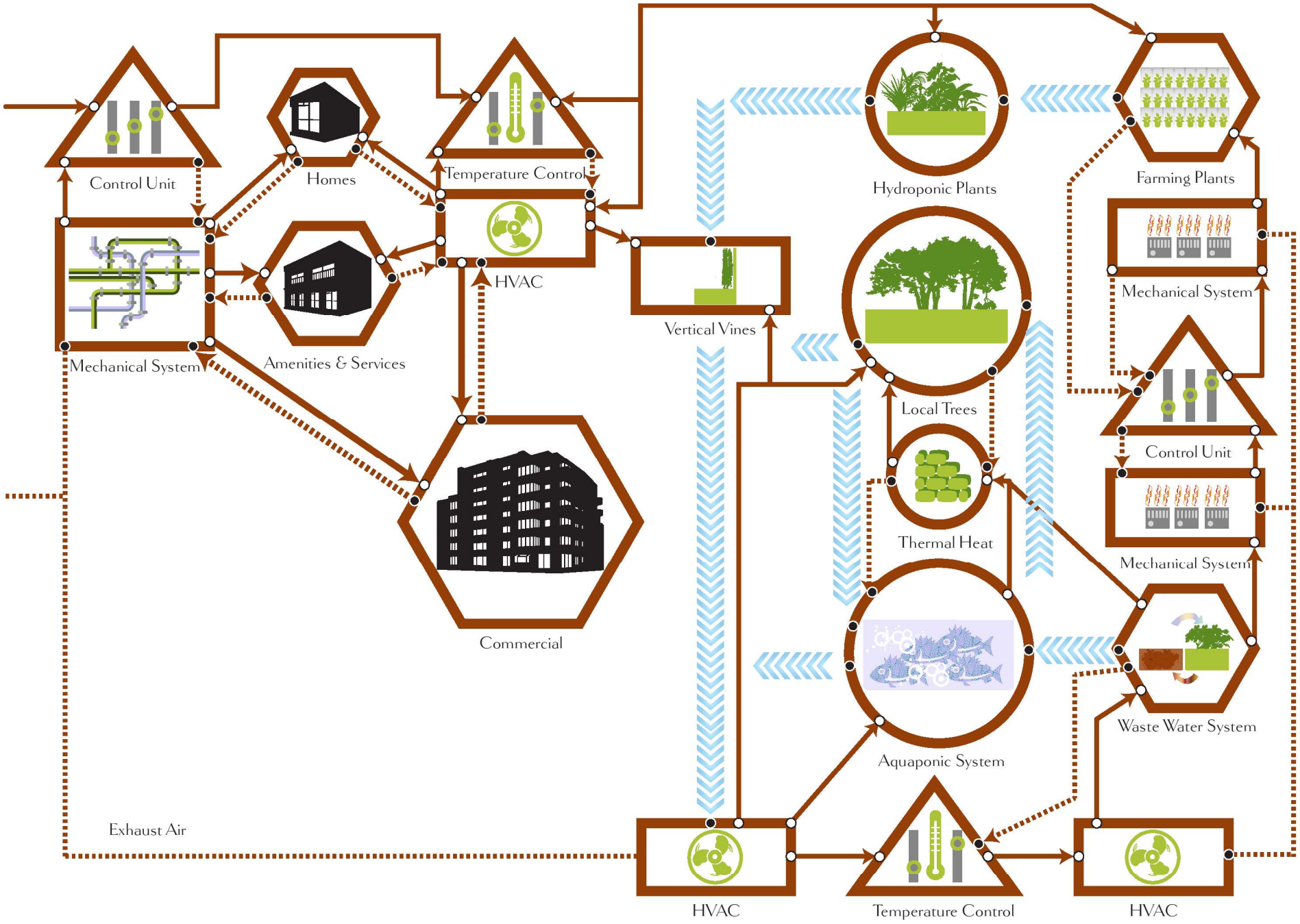


Figure 5.4.1.1: Illustration to represent the Heat System Flow Chart. There are multiple natural systems to consider : the thermal mass of building materials have the ability to store heat, and mechanical systems that have the ability to generate heat. If close consideration is placed recovering heat inside a building as large as possible, has great benefits in colder climates.


Control Unit
Homes
Temperature Control
Hydroponic Plants
Farming Plants
HVAC
Vertical Vines
Mechanical System
Amenities & Services
Mechanical System
Local Trees
Control Unit
Thermal Heat
Mechanical System
Commercial
Waste Water System
Aquaponic System
Exhaust Air
HVAC
Temperature Control
HVAC

5.4.2 Water Systems

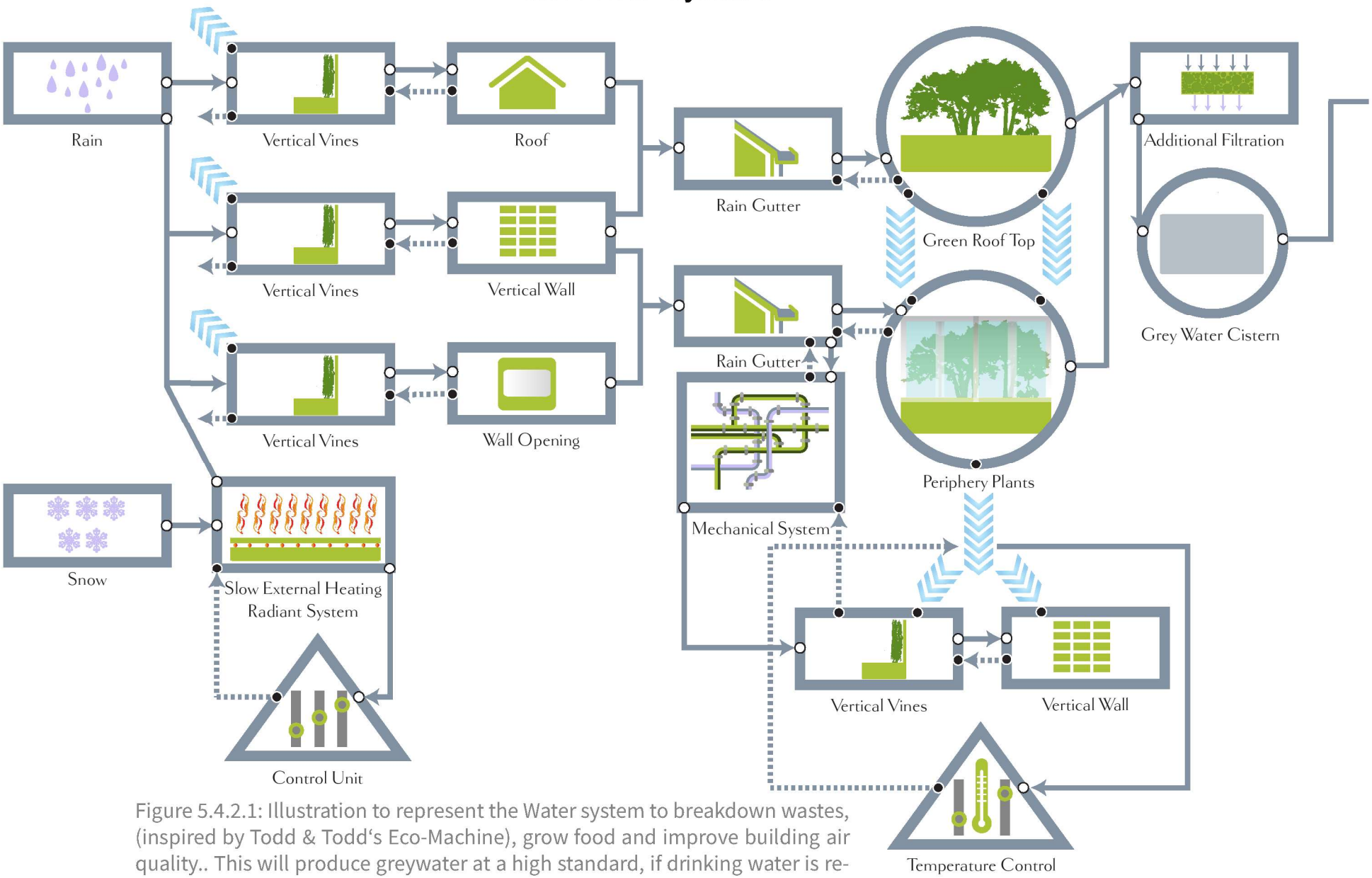
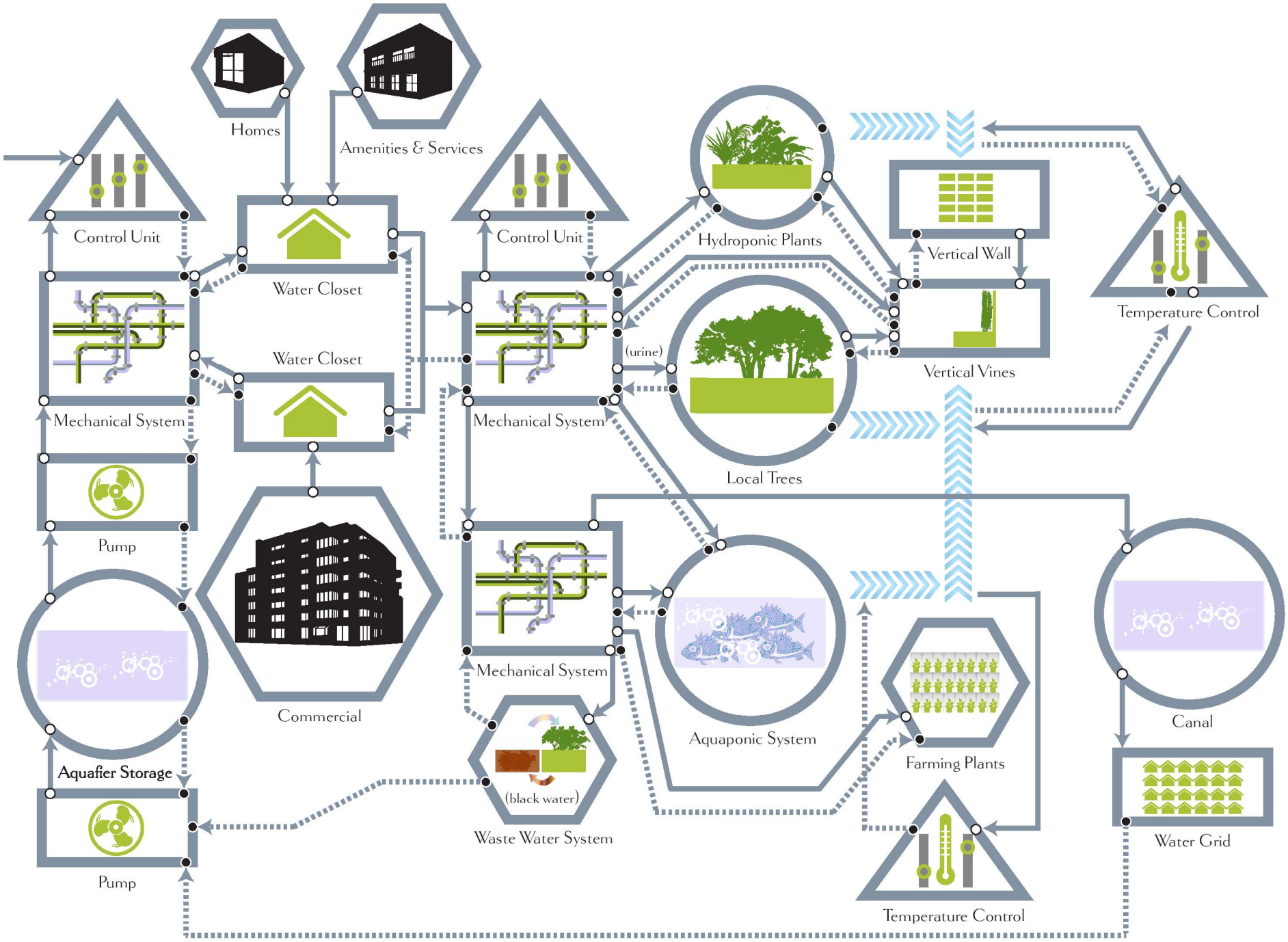
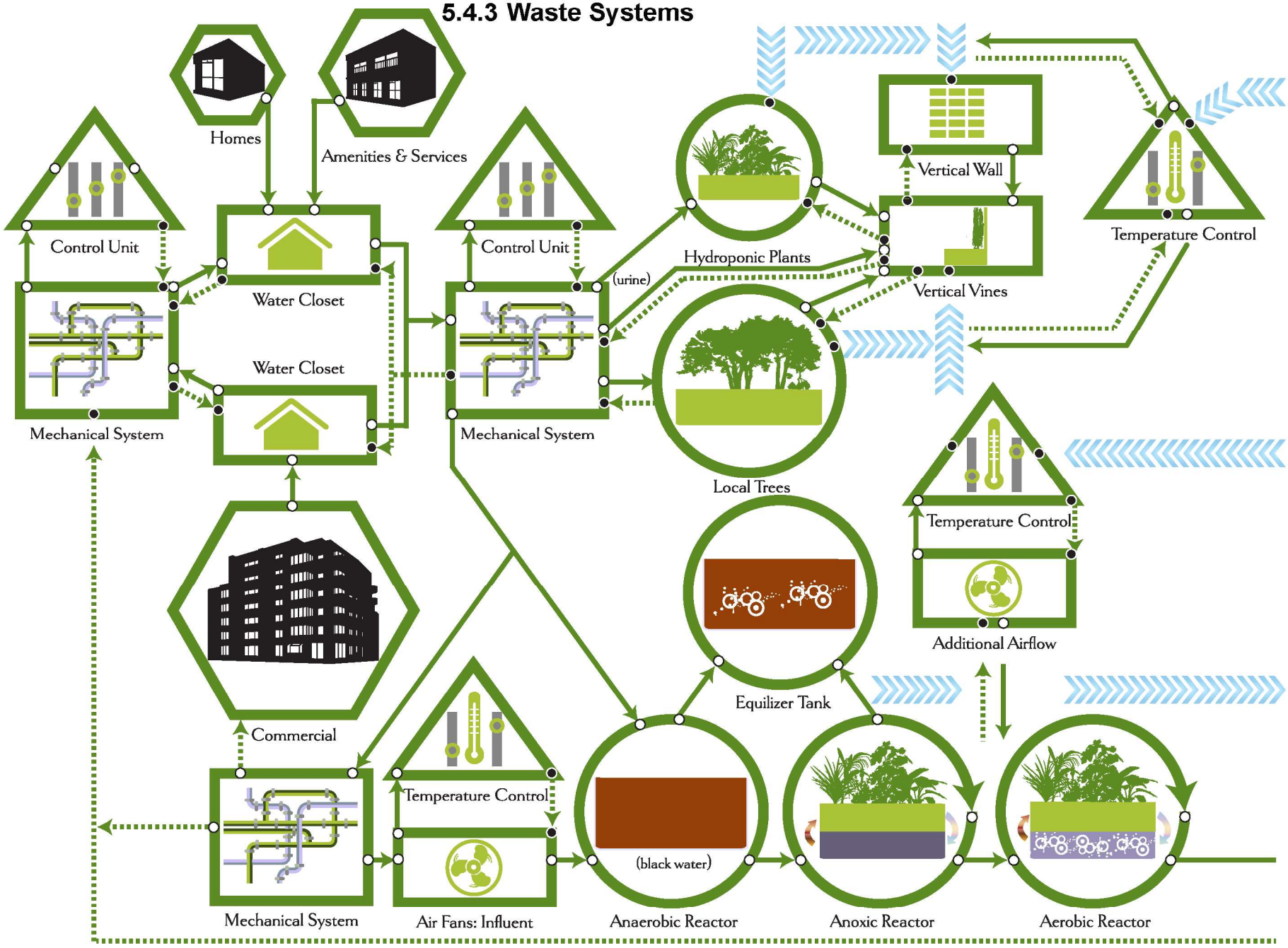


Figure 5.4.2.1: Illustration to represent the Water system to breakdown wastes, (inspired by Todd & Todd's Eco-Machine), grow food and improve building air quality.. This will produce greywater at a high standard, if drinking water is required, then additional treatment processes have to be incorporated into the system. Water is an important leverage point in an Arcology.


Homes
Amenities & Services
Control Unit
Water Closet
Water Closet
Mechanical System
Pump
Aquafier Storage
Pump
Commercial
Control Unit
Mechanical System
Mechanical System
(black water)
Waste Water System
Hydroponic Plants
(urine)
Local Trees
Aquaponic System
Vertical Wall
Vertical Vines
Temperature Control
Farming Plants
Temperature Control
Canal
Water Grid

5.4.3 Waste Systems



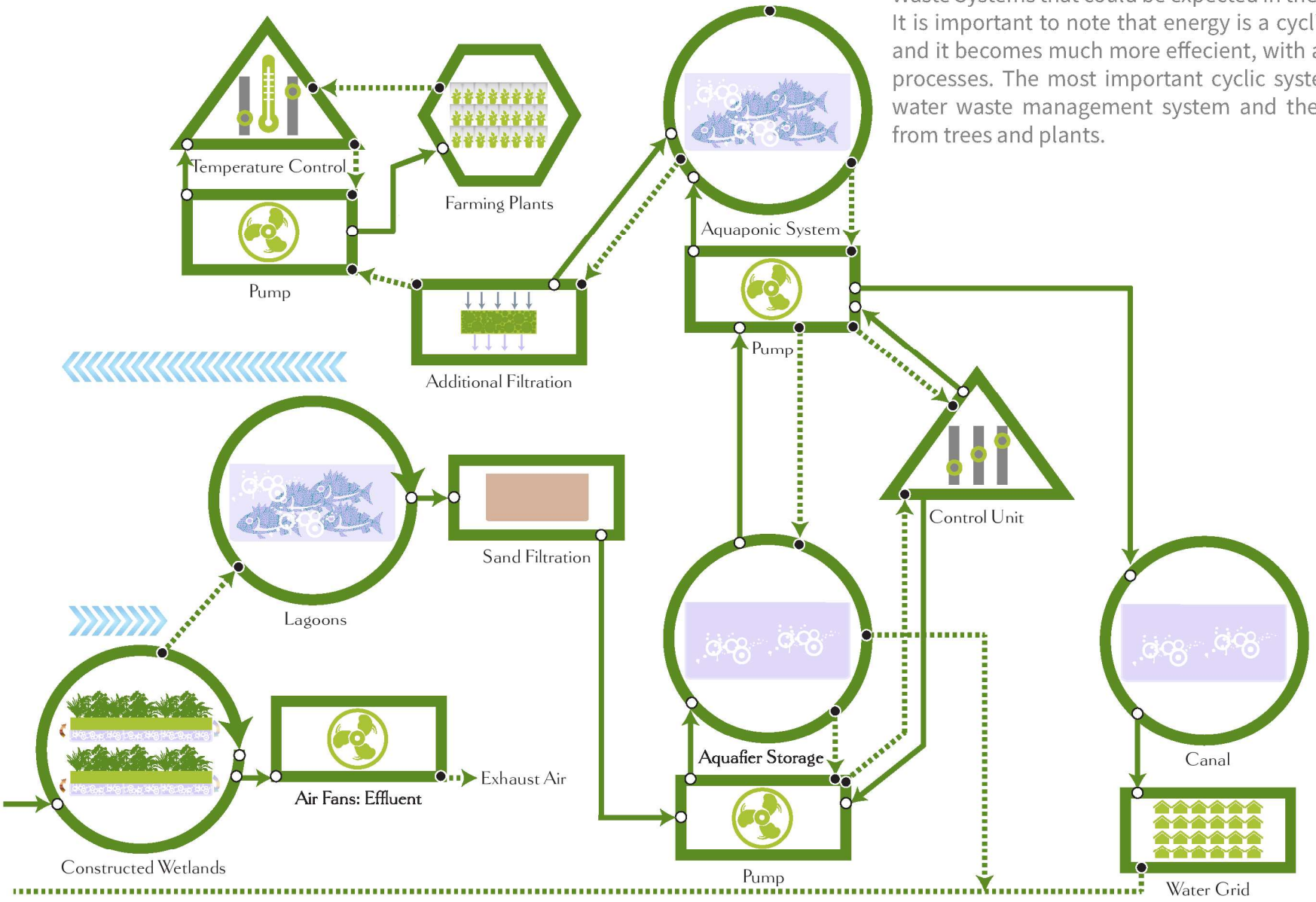
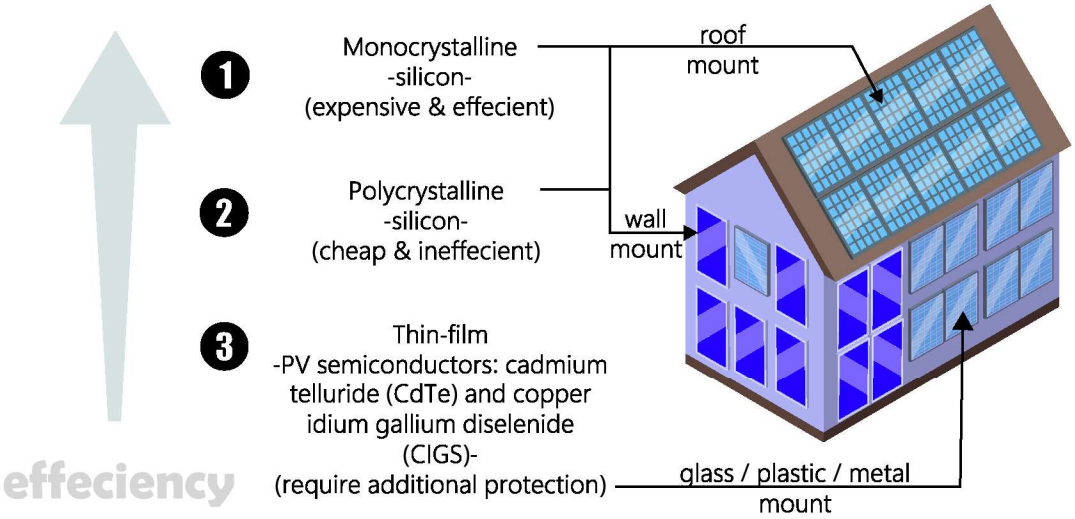


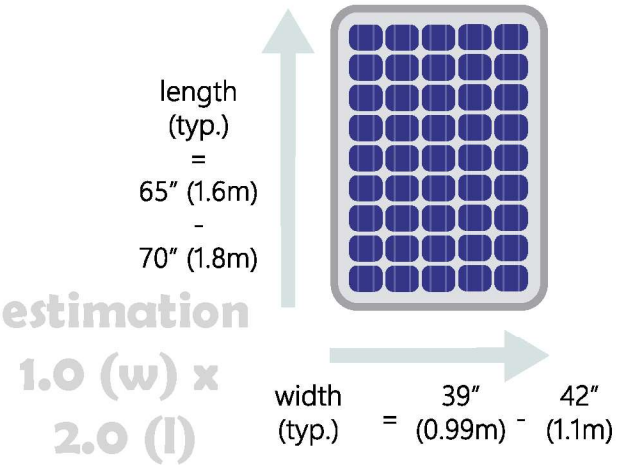
Figure 5.4.3.1: Illustration of Systems Flow Chart of Waste Systems that could be expected in the Arcology. It is important to note that energy is a cyclic process and it becomes much more effecient, with additional processes. The most important cyclic system, is the water waste management system and the filtration from trees and plants.

5.4.4 Energy Systems

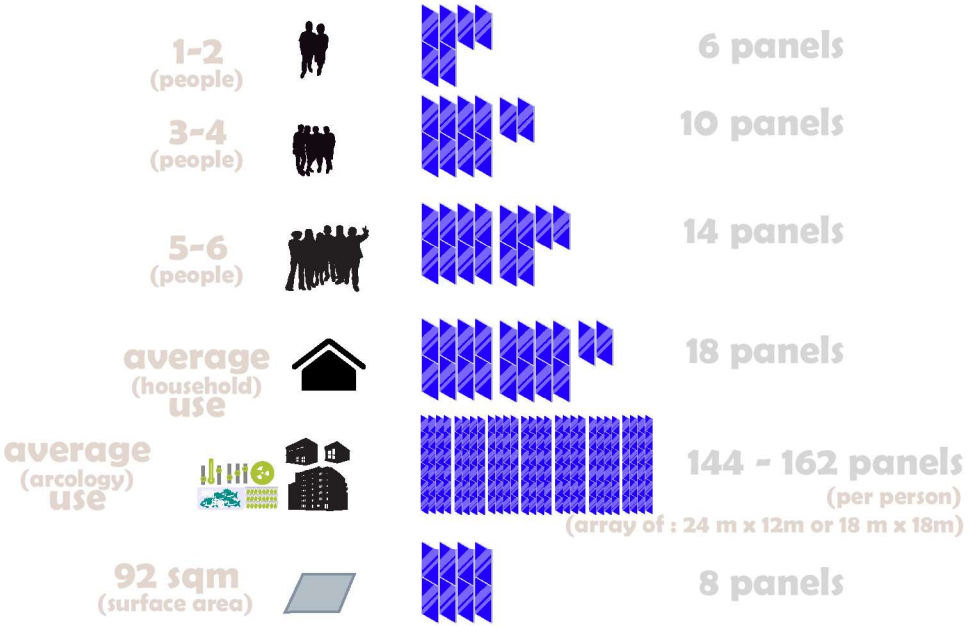
1. Solar Photovoltaic Panels - technology types & effeciency



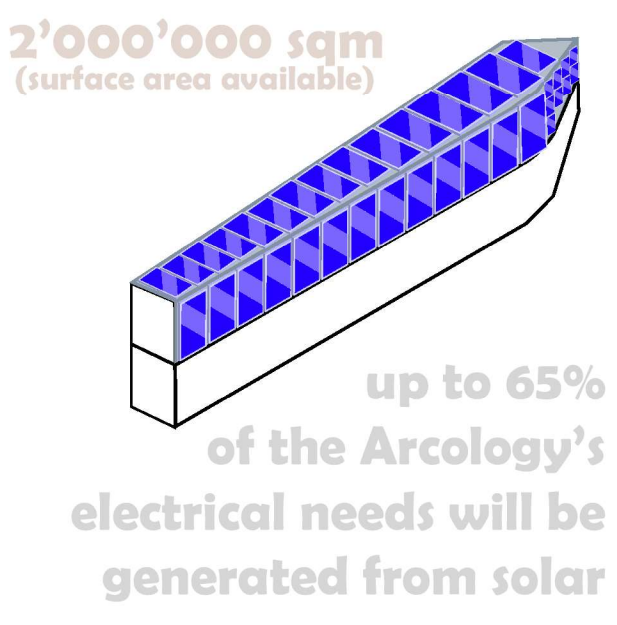
2. Solar Photovoltaic Panels - variable sizes



3. Solar Panels - Rules of Thumb (usage)



4. Arcology - solar energy is not enough



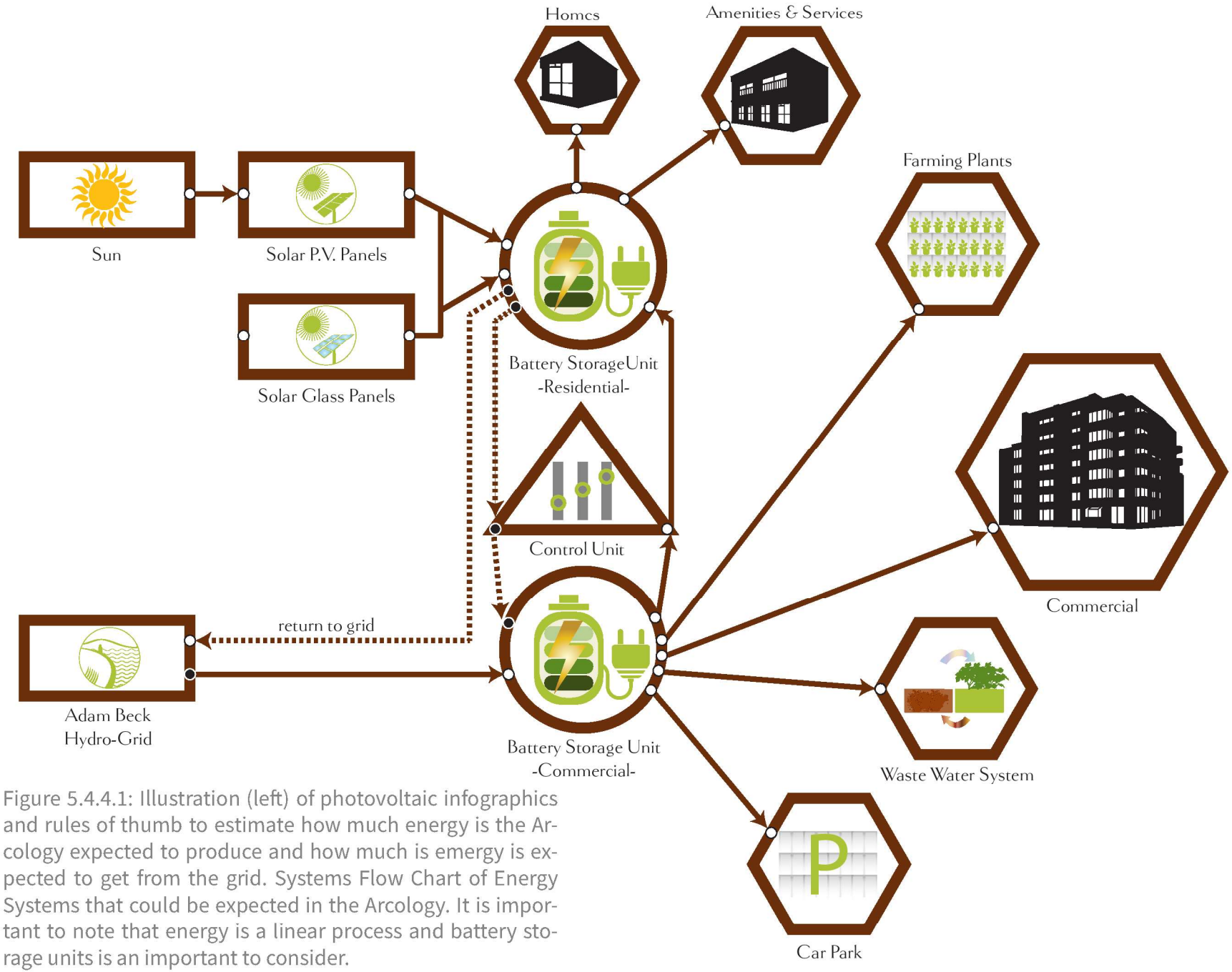


Figure 5.4.4.1: Illustration (left) of photovoltaic infographics and rules of thumb to estimate how much energy is the Arcology expected to produce and how much is emergy is expected to get from the grid. Systems Flow Chart of Energy Systems that could be expected in the Arcology. It is important to note that energy is a linear process and battery storage units is an important to consider.

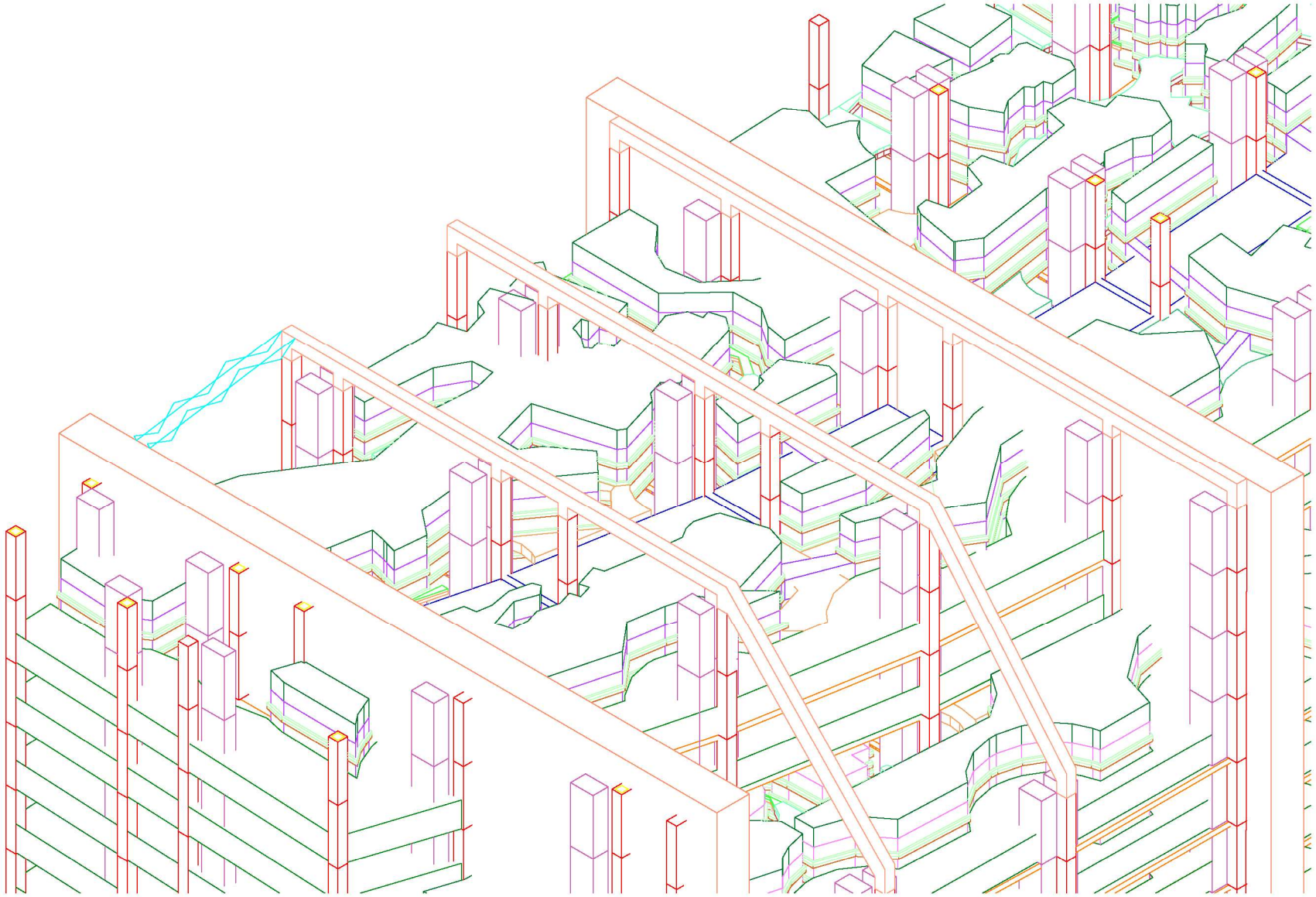


Figure 5.4.4.2: Illustration to represent complexity required to combine multiple systems.

1 Government of Canada, Statistics Canada. “Census Profile, 2021 Census of Populationprofile Table.” Profile table, Census Profile, 2021 Census of Population - Niagara Falls, City (CY) [Census subdivision], Ontario, August 2, 2024. https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/details/page.cfm?Lang=E&SearchText=niagara+falls&DGUIDlist=2021A00053526043&GENDERlist=1%2C2%2C3&STATISTIClist=1&HEADERlist=0.
2 Securities and Exchange Commission, USA. “Comments for the Enhancement and Standardization of Climate-Related Disclosures for Investors.” SEC.gov | Comments on Proposed rule S7-10-22. Accessed August 4, 2024. https://www.sec.gov/comments/s7-10-22/s71022.htm.
3 Enviornmental Protection Agency. Wastewater Technology fact sheet: The living machine. Accessed August 2, 2024. https://www3.epa.gov/npdes/pubs/living_machine.pdf.
4 Brennan, Rachel. “Home.” Brennan Research Group. Accessed July 24, 2024. https://sites.psu.edu/rachelbrennan/eco-machine/.
5 Graff, Gordon James. 2011. “Skyfarming.” Waterloo, Ont: University of Waterloo.
6 Lee, Taesoo D. and Abasifreke U. Ebong. „A Review of Thin Film Solar Cell Technologies and Challenges.“ Renewable and Sustainable Energy Reviews 70, (2017): 1286–1297. doi:10.1016/j.rser.2016.12.028. https://www.sciencedirect.com/science/article/pii/S136403211631070X.
7 Bhushan, Nitin, Linda Steg, Lise Jans, and Casper Albers. „Does Installing Photovoltaic Panels Affect Daily Electricity Usage Patterns? A Generalized Additive Model Approach.“ Energy and Climate Change 2, (2021): 100052. doi:10.1016/j.egycc.2021.100052. https://www.sciencedirect.com/science/article/pii/S2666278721000295.
8 Solar Photovoltaic Cell Basics | Department of Energy. Accessed July 10, 2024. https://www.energy.gov/eere/solar/solar-photovoltaic-cell-basics.
9 Wolverton, B. C. 1997. How to Grow Fresh Air : 50 Houseplants That Purify Your Home or Office. New York, N.Y: Penguin Books.
10 Wolverton, Bill C, and Mark Nelson. 2020. “Using Plants and Soil Microbes to Purify Indoor Air: Lessons from NASA and Biosphere 2 Experiments.” Field Actions Science Reports 2020 (21): 54–59.
11 Wolverton, B. C, and John D Wolverton. 2001. Growing Clean Water : Nature’s Solution to Water Pollution. Picayune, Miss: WES, Inc.

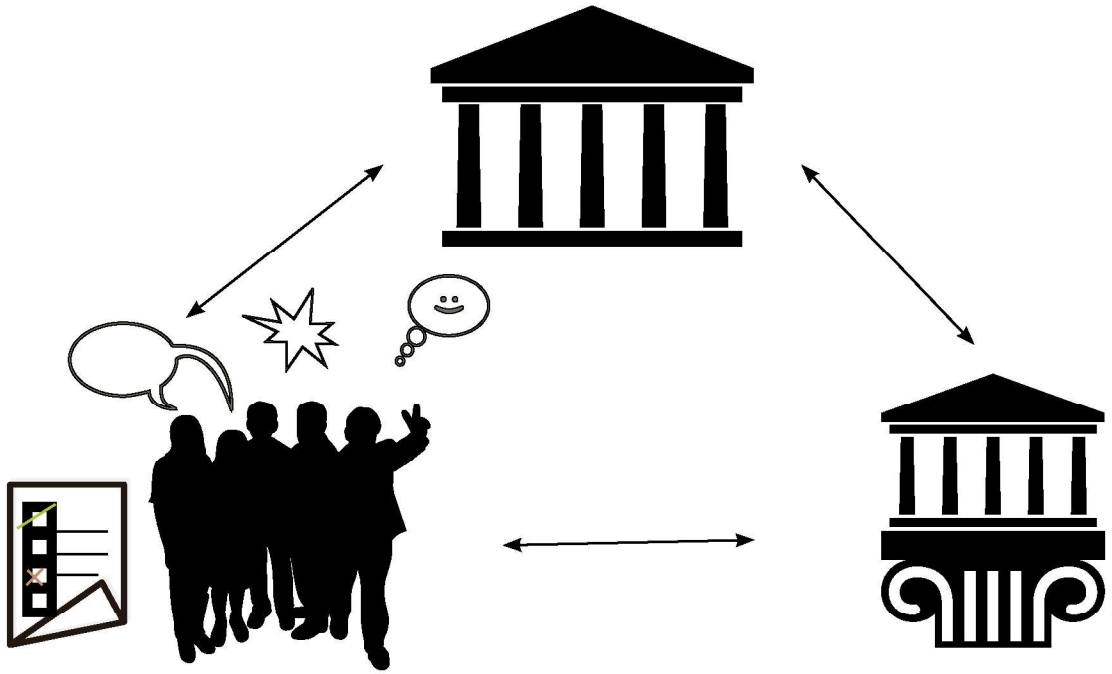


Figure 5.5.1: Illustration to represent the flow required for Adaptive Governance - to show the iterative process between stakeholders, decision makers and learning process.

5.5 Adaptive Governance in an Arcology

The Theory

Adaptive management is a systematic approach to adjusting resource and ecosystem management through a structured and iterative learning process1. This is a result of a lack of and sometimes incorrect knowledge that policymakers and stakeholders must resolve despite uncertain outcomes2. Its roots can be traced to the principles of scientific management introduced by Frederick Taylor in the early 20th century3,4. Although various adaptive management is rooted in multiple disciplines (such as business (Senge, 1990), experimental science (Popper, 1968), systems theory (Ashworth, 1982) and industrial ecology (Allenby and Richards, 1994)), C. S. Holling reintroduced the concept as "adaptive environmental assessment and management" in 1978 and later adopted by Carl Walters in 1986 as "Adaptive Management"5,6,7. Adaptive management channels policies and stakeholders to influence a system's resilience and maintain a desired state. This can be traced back to an iterative process of resource management that acknowledges uncertainty and achieves management objectives by increasing system knowledge through a structured feedback process (figure 5.5.2).

Adaptive governance extends beyond resource management to include the broader governance systems that shape decision-making processes. It encompasses the institutions, policies, legal frameworks, and social networks coordinating and overseeing adaptive management efforts. Adaptive governance's flexibility is essential when a hybrid framework is required to integrate multiple management frameworks8. In the case of Arcology, it combines adaptive management into urban governance. In managing an Arcology, adaptive governance is critical because it responds dynamically to changes in ecological variations, environmental resource availability, social needs etc. This hybrid model acknowledges the complexities of modern cities and landscapes by using real-time data to inform decision-making while fostering collaboration across disciplines like architecture, urban planning, and landscape ecology. The appropriate response to resolve uncertainty will depend on various approaches depending on the level of controllability (figure 5.5.3).

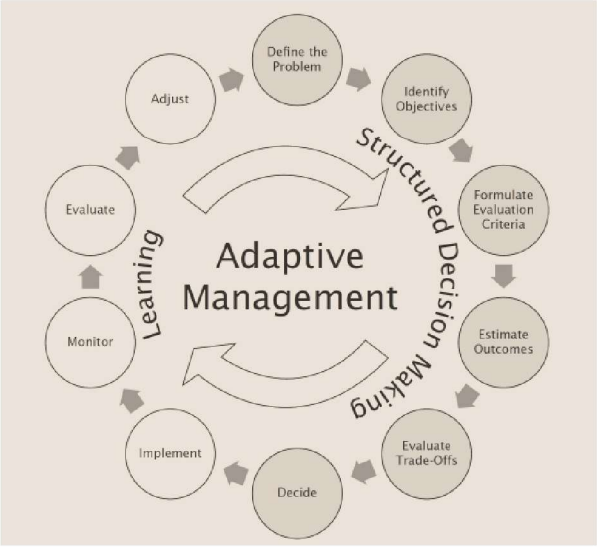


Figure 5.5.2: Adaptive management for a turbulent future - Craig R Allen et all 2011

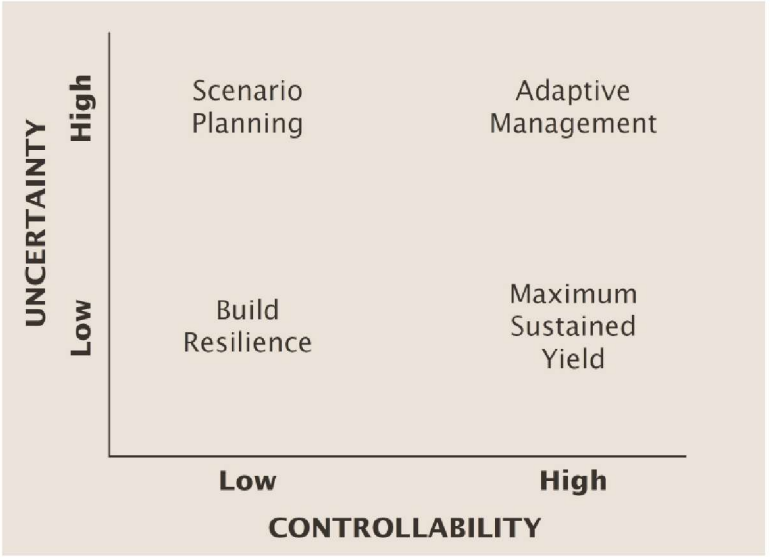


Figure 5.5.3: Different management approaches according to levels of system uncertainty and availability (from Allen et al., 2011), originally adapted from Peterson et al., 2003).

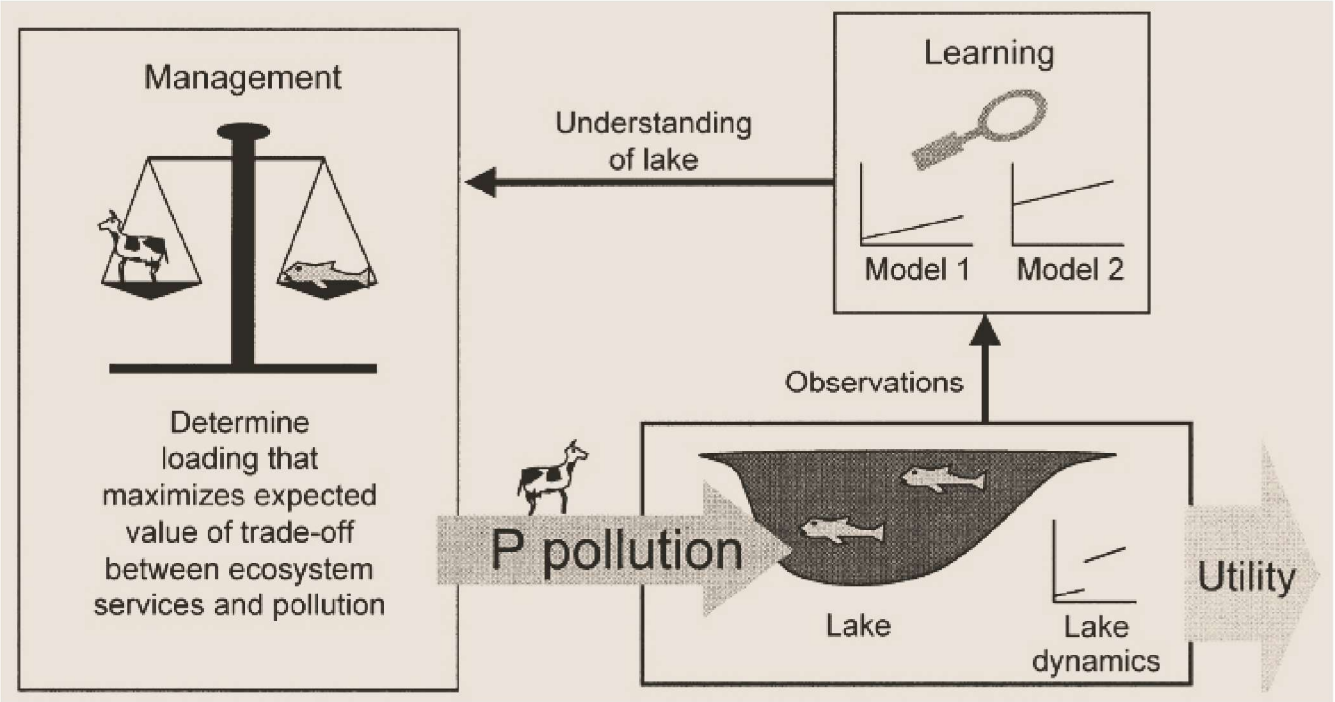


Figure 5.5.4: Schematic Diagram to show Lake Ecosystem Management - used from Peterson et al (2003).

The Arcology is intended to be a social-ecological system with interconnected human and ecological communities that must be managed together. These systems change in complex and unpredictable ways across different spatial and temporal scales. Their long-term sustainability depends on recognizing, learning from, and adapting to change rather than trying to suppress it. This represents a significant shift from traditional ecosystem and urban management, which typically aims to minimize variability and ensure a steady supply of resources to maintain the function of its components on multiple scales.

Adaptive Governance in an Arcology features adaptive spatial networks. These interconnected landscapes and urban infrastructure are spatially adaptable—provided that their components maintain their function. Adaptable infrastructure includes urban planning, water, green, and waste systems. The densification of the infrastructure increases the chances of overlapped responsibilities and shared funding resources between institutions and stakeholders. This approach prioritizes communication, collaboration, and data-driven responses.

Disclaimer :

Not all decisions could or should be adaptive. Adaptive management is reserved only for complex systems with high uncertainty and controllability. In practice, multiple factors will vary, and adaptive management should be considered on a case-by-case basis where the outcome can not be predicted. Management will require a learning curve to adapt to changing issues; this comes with certain conditions.

The successful implementation and maintenance of an adaptive program necessitates the development of sufficient institutional capacity and a sustained commitment to the process. The stakeholders or institutions require stability, essential for the long-term measurement and evaluation of outcomes. Such stability ensures that early investments in adaptive strategies yield benefits in the long-term management of resources and systems9. To clarify, this requires stakeholders to have the capacity and long-term commitment to succeed in the adaptive program.

Iterative Learning Process :

This Iterative process intends to create policies that enhance flexible governance mechanisms, prioritize iterative learning, and manage data-driven research, which will increase the system's tolerance against fluxes, ebbs, and flows. These resilient-based policies will be generated on multiple scales and in multiple categories in real-time. The hierarchal categories will include social, ecological (biotic and abiotic), economic, and urban infrastructure. The implementation of this hybrid framework is intended to manage collaboration between the actors (institutions, policymakers, decision-makers, community, entrepreneurs, etc.) so the systems holistically flow in the direction of the desired state for the Arcology and an example of this proposal will be as follows.



Figure 5.5.5: A hypothetical example of realigning the merging roles in urban governance and adaptive management for an Arcology. These roles will continue to change depending on the details of the complex issue – one solution will perpetuate the failure of its components.

The Hybridized Model for the Arcology

This model will highlight a co-production between management frameworks, integrating practical approaches that synergize gains, and a framework that shows the cyclic decision-making and learning that integrates actors and the proposed approaches.

1. Co-Production Process:
   Defenition :
      Defining and comparing management systems with opposing priorities and processes - urban governance and adaptive management.
   Intention:
      To merge with the intention of enhancing communication and collaboration among multiple actors on multiple scales.
   Conclusion:
      It will define where we are at in the “wicked problems” (Levin et al., 2012) - the data sets that emerge from the two systems will be structured and discussed among multiple actors (stakeholders, policymakers, decision-makers, entrepreneurs, community, institutions, managers, architects, engineers, landscapers, scientists, etc.)

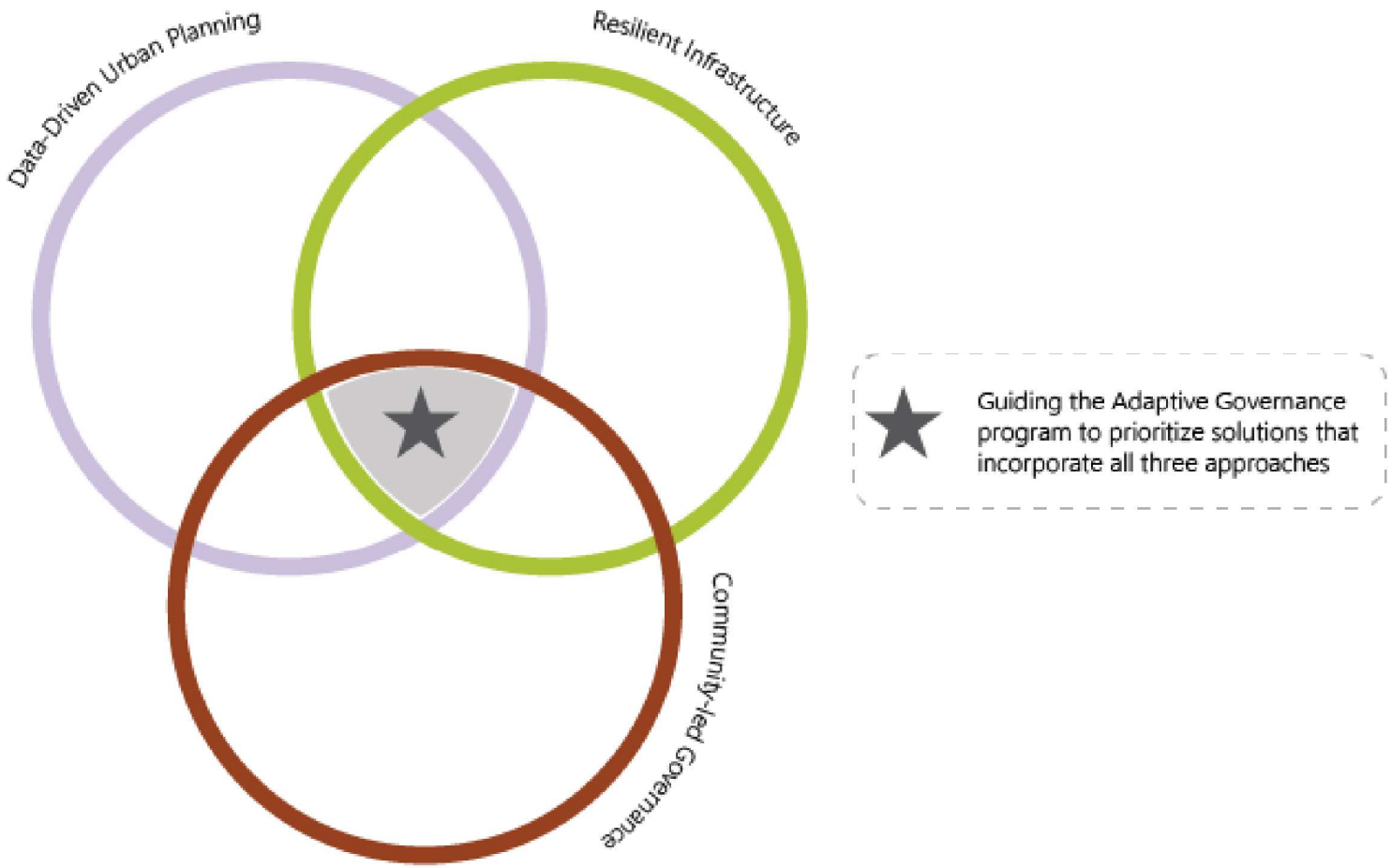


Figure 5.5.6: A conceptual diagram of merging these three factors should focus on achieving defined empirical goals set by the management team, which provide actors with actionable objectives. These empirical goals will be refined in every iterative process.

2. Identify and Integrating Practical Approaches Process:

Practical Approaches that merge from the Adaptive Management Program should focus on incorporating factors that provide the most gains. These gains are defined and learning-focused empirical goals set by the management team that provides actors with actionable objectives. Factors can include the following:

a. Data-Driven Urban Planning:

The use of machine learning to assist in managing vast data collection and analysis to identify trends, patterns, and networks, rapid prototyping, effective data collection, enhanced algorithms, and the proposal of new network patterns, etc. This is intended to be a management tool to track, report, and evaluate progress to assist actors in achieving goals set by the Arcology managing team.

b. Resilient Infrastructure:

Flexibility in urban design strategies that integrate various infrastructures such as:

Green Systems—

This includes trees, plants, grass, and biodiversity management.

Blue Systems—

This includes water channels, wetlands, and water collection management.

Waste Systems—

This includes managing the "eco-machine" systems, which include all components, from septic tanks to water quality management.

Engineered Systems—

This includes all the electrical and mechanical operational systems, including HVAC systems, Lighting Systems, Sprinkler Systems, Grids, etc.

Building Systems—

This includes all the urban planning, architectural, and structural design that collaborate to provide a cohesive environment.

Technological Systems—

As evident in smart cities, technologies (such as sensors and IoT devices) can optimize infrastructure efficiency, active energy management, passive energy tracking, rerouting, and predictive maintenance to provide a higher quality of life.

c. Community-Led Governance:

One of the indications that management decisions are working is to have a driven, self-organizing community. This communal force is the X-Factor that can help the overall Arcology function faster and last longer. Local ownership and community systems can be encouraged to attain autonomy through government incentives, programs, and constant dialogue.

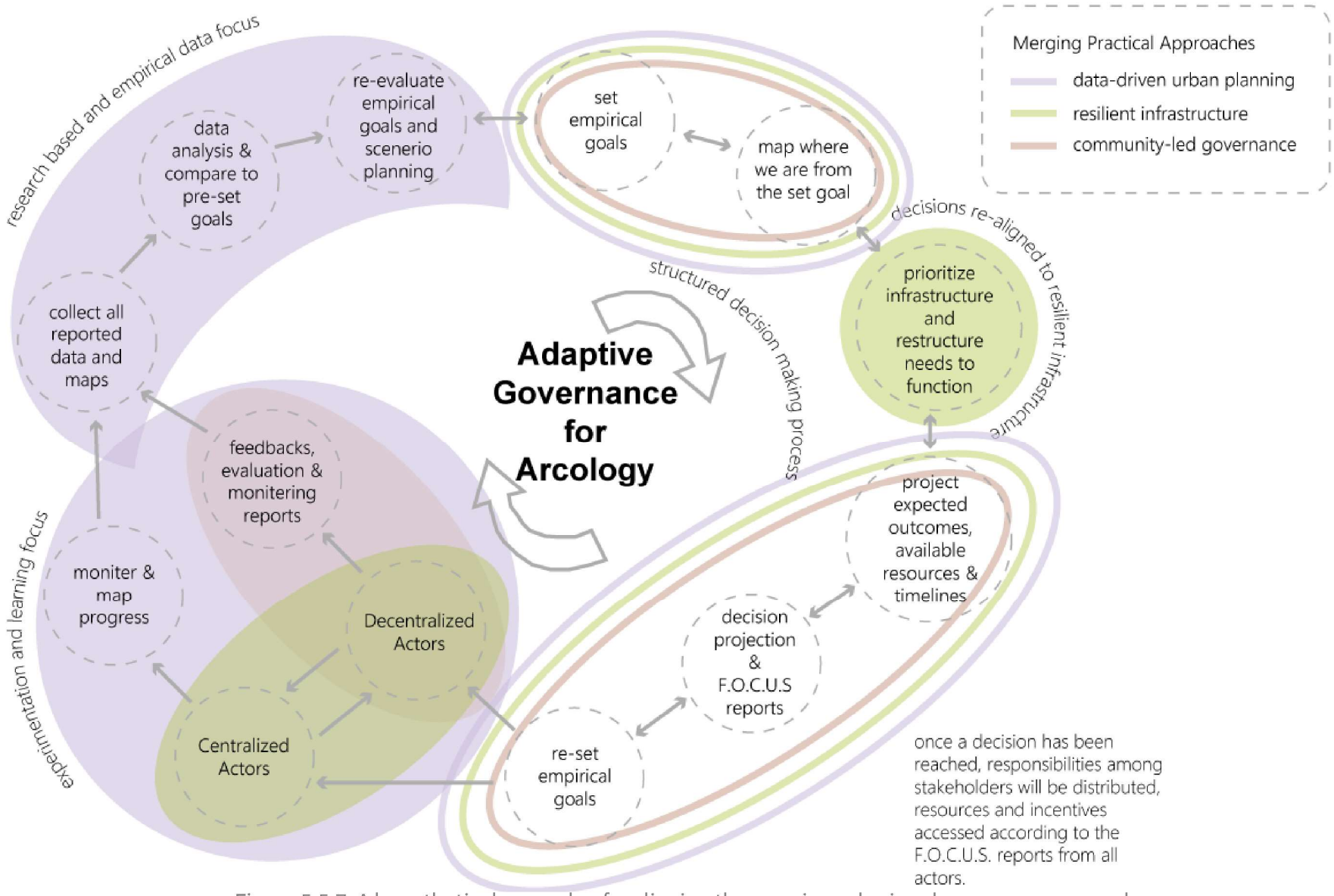


Figure 5.5.7: A hypothetical example of realigning the merging roles in urban governance and adaptive management for an Arcology. These roles will continue to change depending on the details of the complex issue – one solution will perpetuate the failure of its components.

3. The Adaptive Governance for Arcology Process:

Introducing the development of an ontological theoretical framework for Adaptive Governance of an Arcology. This model shows actionable flows, relationships, and iterative processes to refine the defined empirical goals.

Evolved from Allen's Adaptive Management Process which clearly identifies decision making processes and the learning process (figure 5.5.7).

This model requires the interconnection between roles are crucial to achieve the overall function of the Arcology.

Centralized Actors:

provide top-down coordination, strategic oversight, standard-setting, and system-wide resource allocation. Responsibilities include crisis management, risk management, strategic decision-making, standard setting, resource allocation.

Decentralized Actors:

Focus on local autonomy, local implementation, customization, innovation and feedback within the framework established by the centralized actors. Decentralized actors can influence standards settings if applicable.
Responsibilities include local implementation, resource utilization, innovation and experimentation, localized decision making, networking, report outcomes, monitoring of oddities, feedback loops, and collaborative-focused objectives.

The success of this system depends on the designation of roles, effective communication between centralized and decentralized actors, and collaboration is applicable as required.

Focusing on clear objectives between the actors involved will strongly impact the progress at this stage. One of the strategies they can implement that may prove very effective is once the decision-making process achieves the decision to proceed - each actor in the Arcology clarifies their objectives. They should be able to answer the following acronyms:

F. Function:
Specify the function they are trying to accomplish.

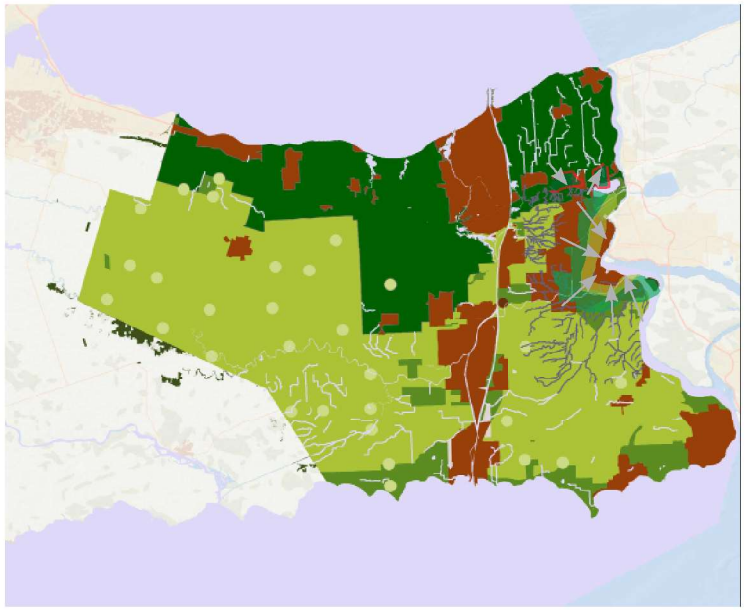
O. Outcome:
Define empirical outcomes for the function's success or failure.

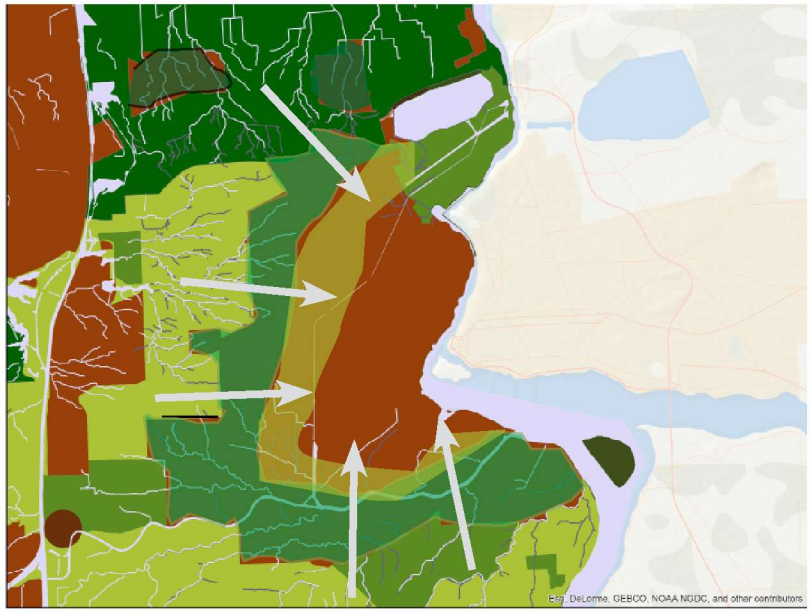
C. Connectivity:
Identify the network of actors that should collaborate or affect.

U. Utilization:
Determine resources available (data, knowledge, technology) to leverage to meet the required goals.

S. Strategy:
Strategize an action plan that identifies methods, feedback mechanisms, and timelines that achieve the defined empirical goals the managing team sets.

1. Williams, B. K., R. C. Szaro, and C. D. Shapiro, Adaptive Management Working Group, U.S., Department of the Interior W, DC. Adaptive management: The U.S. department of the interior technical guide. https://www.doi.gov/oepc/adaptive-management Web site. https://www.doi.gov/sites/doi.gov/files/migrated/ppa/upload/TechGuide.pdf. P 1. Updated 2009. Accessed 22 September, 2024.
2. Allen, Craig R, Joseph J Fontaine, Kevin L Pope, and Ahjond S Garmestani. 2011. "Adaptive Management for a Turbulent Future." Journal of Environmental Management 92 (5): 1339–45. https://doi.org/10.1016/j.jenvman.2010.11.019.
3. Taylor, Frederick W. 1975. "Scientific Management." C.P.A. Journal 45 (2): 16-70.
4. Conti, Robert F., ‚Frederick Winslow Taylor', in Morgen Witzel, and Malcolm Warner (eds), The Oxford Handbook of Management Theorists (2013; online edn, Oxford Academic, 2 Apr. 2013), https://doi-org.proxy.lib.uwaterloo.ca/10.1093/oxfordhb/9780199585762.013.0002. Accessed 28 Sept. 2024.
5. Allen, Craig R, Joseph J Fontaine, Kevin L Pope, and Ahjond S Garmestani. 2011. "Adaptive Management for a Turbulent Future." Journal of Environmental Management 92 (5): 1339–45.
6. Holling, C. S. 1978. "Adaptive Environmental Assessment and Management." In Laxenburg, Austria: International Institute for Applied Systems Analysis.
7. Walters, Carl J. 1986. Adaptive Management of Renewable Resources : An Overview of an IIASA Book Written by Carl Walters and Published by Macmillan Publishing Company. -. Laxenburg, Austria: International Institute for Applied Systems Analysis.
8. Carina Wyborn. 2015. "Co-productive governance: A relational framework for adaptive governance." Global Environmental Change, Volume 30: P 56-67.
9. Williams, B. K., R. C. Szaro, and C. D. Shapiro, Adaptive Management Working Group, U.S., Department of the Interior W, DC. Adaptive management: The U.S. department of the interior technical guide. https://www.doi.gov/oepc/adaptive-management Web site. https://www.doi.gov/sites/doi.gov/files/migrated/ppa/upload/TechGuide.pdf. P 9. Updated 2009. Accessed 22 September, 2024.





The Arcology will encourage people around the periphery of the Niagara urban form to sell or give up their property for a place in the Arcology.

Later stage of the Arcology development, if the arcology is a success, then the building can repeat along its edges, into the city of Niagara.

Established Traditional Urban Development (cities)

This Arcology implimentation approach encourages Naturalization along the peripheries of the urban form. This encourages the reduction of urban sprawl and encourages smaller towns to be incorporated into the Arcology.

Figure 5.6.1 : Proposed Arcology Implimintation Approach to reduce urban sprawl.

5.6 Arcology Implementation Approach

The Arcology has peculiar requirements and considerations, when discussing Design and Funding. The success or failure of the Arcology is dependent on the success of these two factors : Funding & Design.

Funding Explicit - Naturalization Implicit

The purpose of an arcology is to condense urban environments by integrating city functions into a more compact, vertically organized space. This approach minimizes the distances between living, working, and recreational areas, fostering a cohesive community while significantly reducing urban sprawl and promoting the naturalization of surrounding landscapes.

Funding an Arcology is one of the most important discussions and it can be compiled into three phases.

The pre-construction phase will be be heavily funded by investors, venture capitalists (a.k.a. seed funding) or public funding. All proceeds will go to the Arcology Fund. In this phase, the Arcology will be designed to ensure autonomy. All proceeds from commercial, office, vertical farming proceeds will return to the Arcology fund, to cover operational cost.

This fund will proceed to buy plots on the edge of the urban form of the City of Niagara Falls and reserve as protected plots to naturalize. To encourage social equity, the City of Niagara residence owners are encouraged to give up their land, in exchange for residence in the Arcology, or buy into the Arcology, depending on your socio-economic status.

To avoid urban or green patching in the city, the Arcology Fund will resell the land and continue to buy lands on the outskirts of the city of Niagara.

Design Implicint - Process Explicit

In the context of an arcology, design factors are inherently unpredictable and vairable. These variables lack a fixed or pre-determined outcome and are typically predicted through probability modeling. Thus, it is essential to design for adaptable and resilient frameworks that can respond dynamically to unforeseen environmental, social, and technological influences. This ensures the long-term viability of the complex urban ecosystem.

The design for an Arcology is context dependent. This requires clear programs, functions, residences - that can not be pre-determined. The design intends to re-use building materials from plots given to the Arcology Fund, where ever possible.

Naturalization Predictions

In this particular iteration of the arcology, the structure has the capacity to hold 11,000, and therefore the Arcology Fund will be able to naturalize 17.5% if the city of Niagara Falls remains as it stands today. The changes will happen over a long period of time because Arcology is very build intensive and it‘s limitations are geared towards : Cost, Collaboration, Commitment, Communication, Control and Coordination.

This Arcology Implementation Approach will encourage commitment and reduce the cost constraints on the have nots.

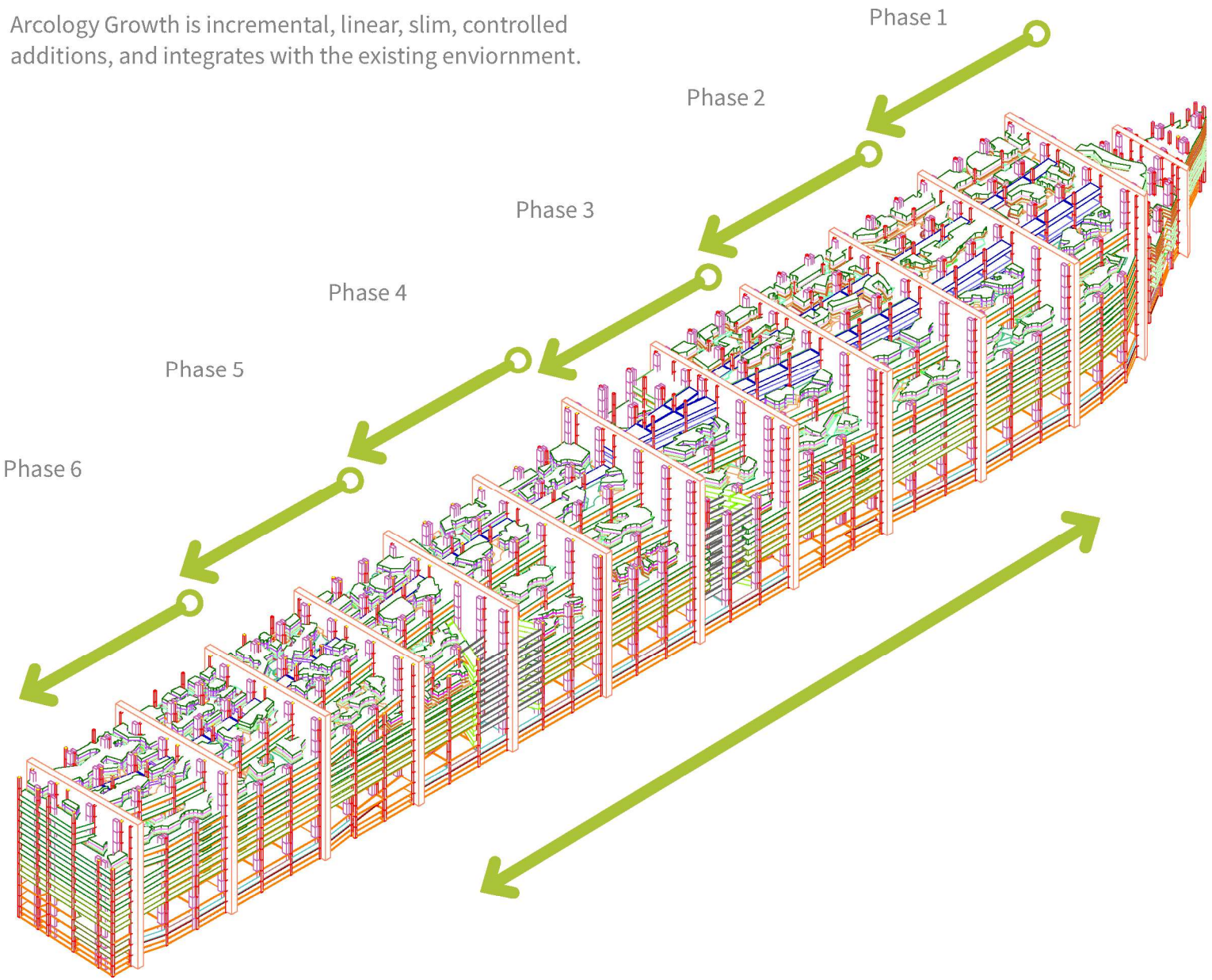


Figure 5.7.1 : Arcology‘s intentional External Phasing exhibits intentional growth.

5.7 Phasing the Arcology

Phasing of the Arcology must be wary of overdensification. Thus, the growth is to be controlled and the design is intentional.

Incremental Linear Modularity

The Arcology will be designed using an incremental linear modularity approach, where growth occurs methodically in a controlled, intentional line rather than expanding indiscriminately in all directions like a blob. The linear growth pattern supports a clear vision for future development, aligning with sustainable urban design principles by reducing congestion, promoting efficiency in land use, and enhancing livability for residents. This design also promotes to minimize residential spaces and encourage communal spaces.

Slim Design for Sunlight and Ventilation

A key element of the linear modular design is the emphasis on maintaining the Arcology's slim profile. By keeping the form elongated and streamlined, sunlight can penetrate deeper into the building, ensuring that even the interior spaces are well-lit without the need for excessive artificial lighting. The slim design also allows for better cross-ventilation, with natural airflow circulating more effectively through the structure. This passive approach to climate control reduces the need for energy-intensive engineered systems, contributing to the overall sustainability of the Arcology.

Integration with Natural Environments and Urban Infrastructure

By expanding incrementally in a controlled direction, the design can accommodate green corridors, urban agriculture, and open spaces at ground level. This integration helps foster biodiversity and promotes a stronger connection between residents and the natural world, while also ensuring the Arcology complements existing urban infrastructure. Therefore, ensuring that the Arcology evolves in harmony with its surroundings without overwhelming the natural or urban environment.

Incremental Additions via Population and Resource Triggers

The growth of the Arcology will be guided by specific population and resource triggers, ensuring that expansion occurs only when necessary and sustainable. This adaptive approach means that new modules will be added in response to growing population needs or increased resource availability. This method prevents resource strain and ensures growth dependent to needs.

Linear External Growth and Network Internal Growth

As the Arcology continues to grow externally, its internal systems and connectivity will be continually optimize it's networks. The design will centralize key amenities, such as healthcare, education, and public services, while decentralizing residential spaces along the horizontal or linear axis. This approach allows for an adaptive design process where external growth does not hinder internal functionality but enhances it. As new modules are added, they will be carefully integrated into the existing framework, ensuring that internal transportation, accessibility, and communal spaces are continuously optimized. This balance between centralization of services and decentralization of residences allows for an adaptive, fluid growth process that keeps the Arcology both efficient and livable, even as it expands.

This adaptive phasing approach results in linear-growth external expansion and network-growth internal optimization, ensuring that the Arcology remains adaptable, scalable, and intentionally designed as it grows into a sustainable, thriving urban ecosystem.

If you can dream—and not make dreams your master;
If you can think—and not make thoughts your aim;
If you can meet with Triumph and Disaster
And treat those two impostors just the same.

- Joseph Rudyard Kipling - Poem : "If-".

If you're going to try, go all the way. There is no other feeling like that. You will be alone with the gods, and the nights will flame with fire. You will ride life straight to perfect laughter. It's the only good fight there is.

- Charles Bukowski - What Matters Most is How Well you walk Through Fire.

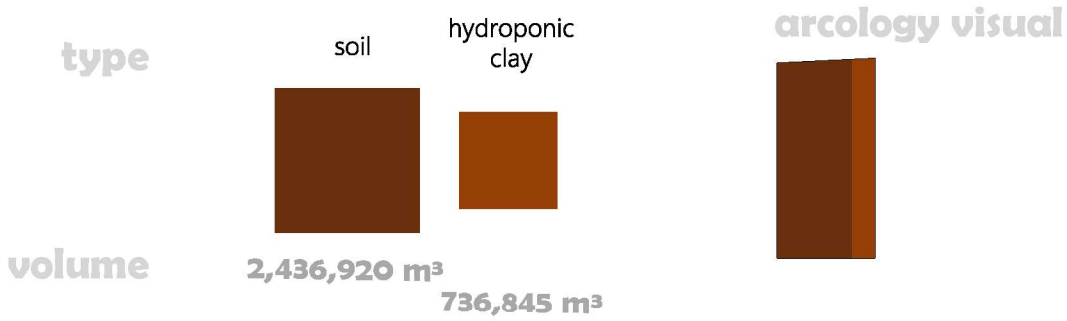
6 ADAPTIVE DESIGN PROPOSAL

6.1 Arcology Proposal - Visualizing the Arcology

This process starts with visualing the program.
There will be many interpretations to an Arcology, depending on what is considered as a priority, the Arcology's form, the method of calculations, the programs used, the systems within etc.

However, for the purpose of this thesis only :
This is a breakdown of one of many interpretations of the Arcology, named Niagara Escarpment II, in Niagara Falls. The intent is to determine the overall look of an Arcology.

1. Soil in the Arcology - Volume



2. Water in the Arcology - Volume

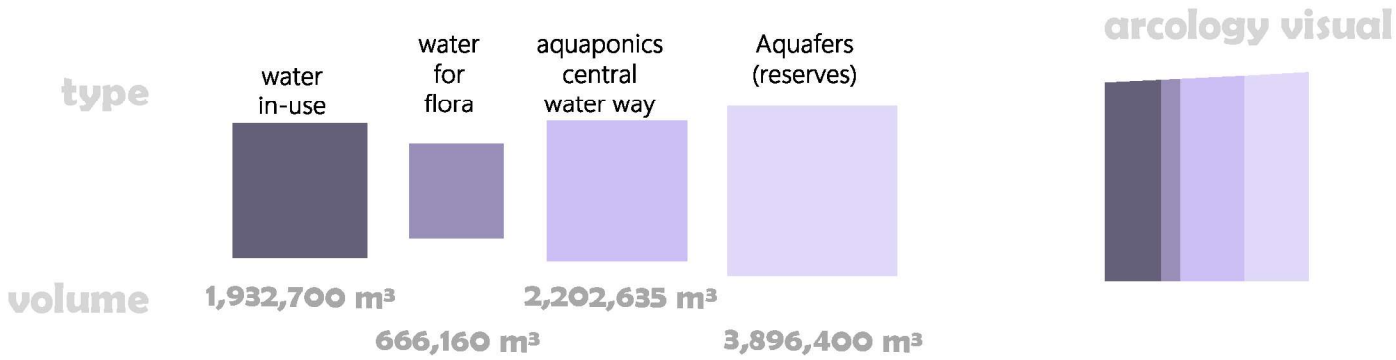


Figure 6.1.1 : Arcology's Volume Breakdown - part 1

3. Farming in the Arcology - Volume



4. Flora in the Arcology - Volume

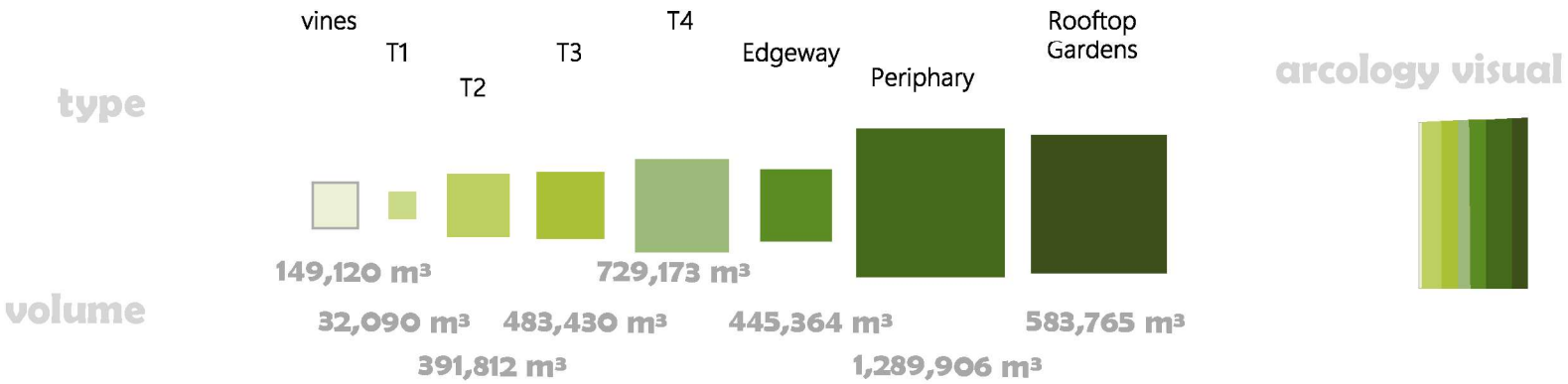
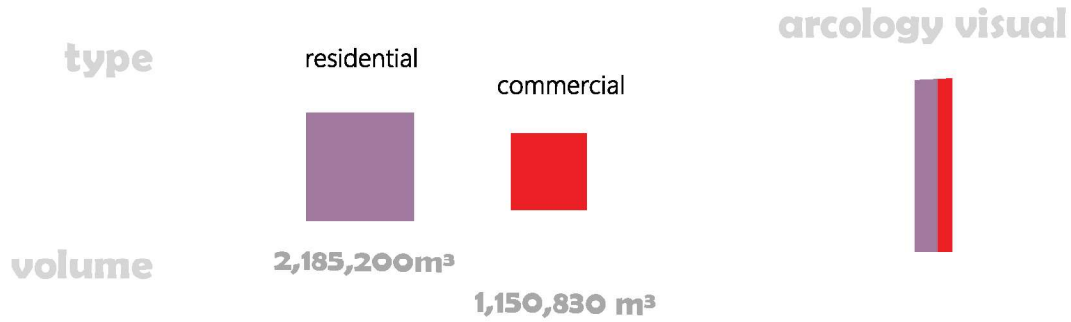


Figure 6.1.2 : Arcology‘s Volume Breakdown - part 2

5. Residential & Commercial in the Arcology - Volume



6. Organizational Structure in the Arcology - Volume

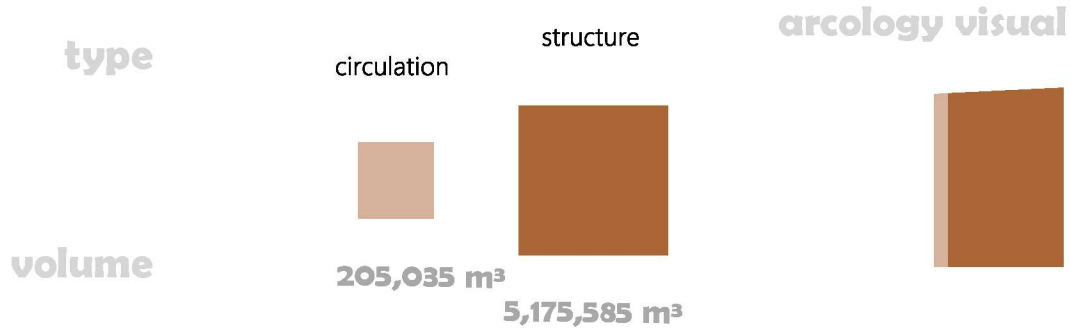
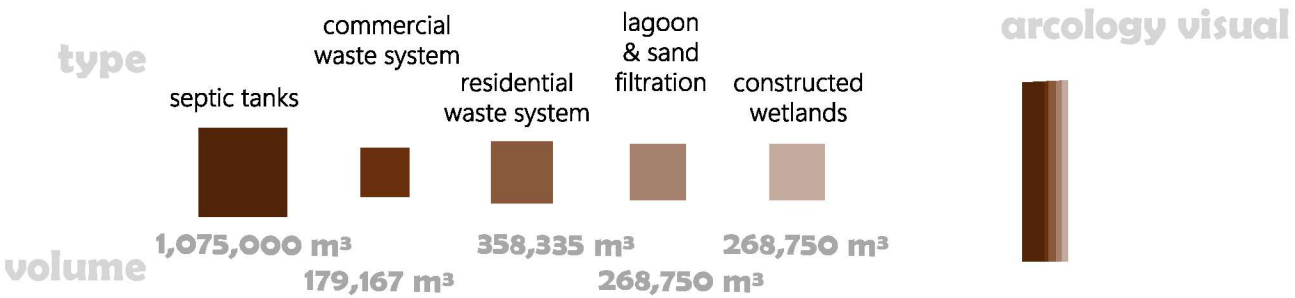
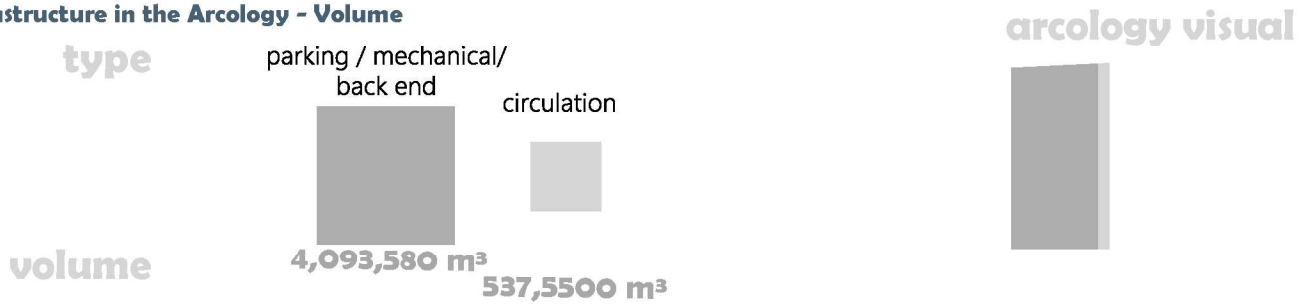


Figure 6.1.3 : Arcology‘s Volume Breakdown - part 3

7. Organizational Structure in the Arcology - Volume



8. Infrastructure in the Arcology - Volume



9. Open Space in the Arcology - Volume



Figure 6.1.4 : Arcology‘s Volume Breakdown - part 4

Visualizing the Volume of the Arcology - Elevation



Comparing the Volume of the Arcology - Percentages

total volume of the arcology

approx.

87.34 million m³

(with aquafiers that cycle for 3 days) and approx. 83.45 million m³ (without aquafiers)

Blue Mountain, Ontario
approx. 100 million (x10⁶) m³

Mount St. Helens, Washington state
approx. 82 million (x10⁶) m³



hill volume: XX million (x10⁶) m³

Mont Tremblant, Quebec
approx. 1 billion (x10⁹) m³

Castle Mountain, Alberta
approx. 3.68 billion (x10⁹) m³

Cascade Mountain, Alberta
approx. 5 billion (x10⁹) m³



mountain volume: XX billion (x10⁹) m³

Visualizing the Volume of the Arcology - Percentages

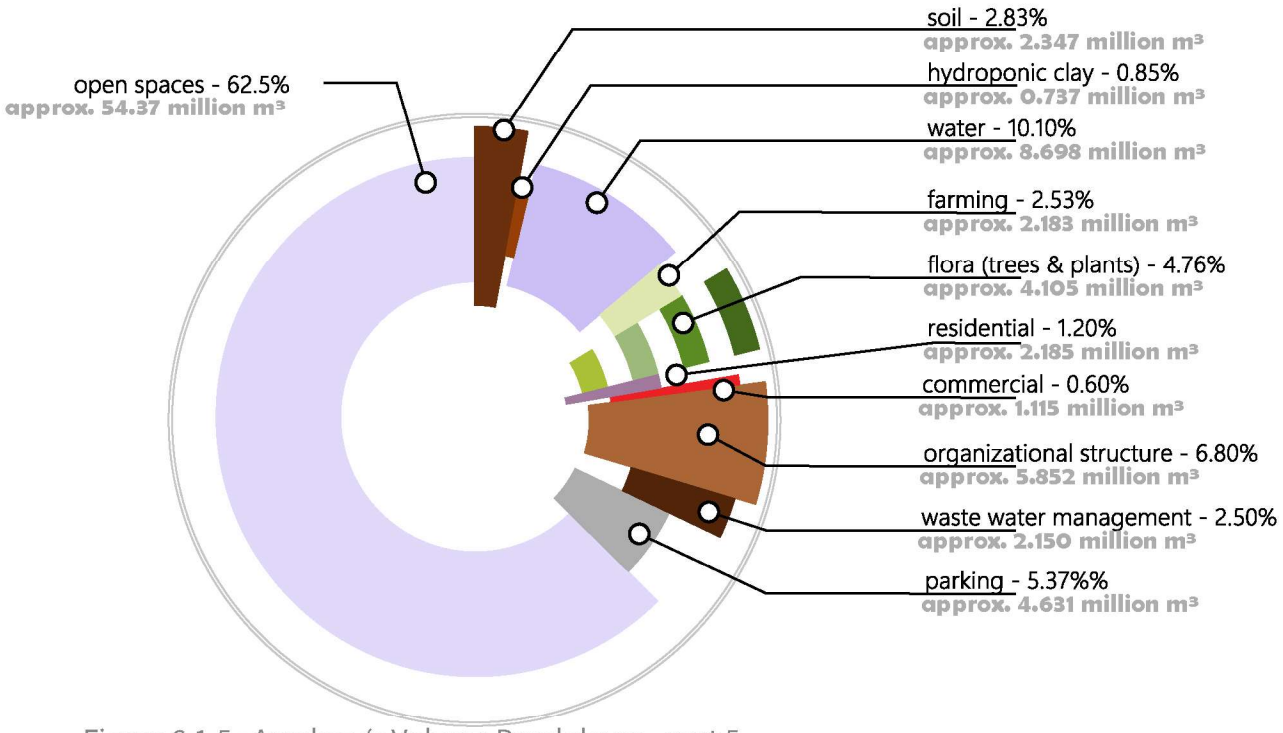
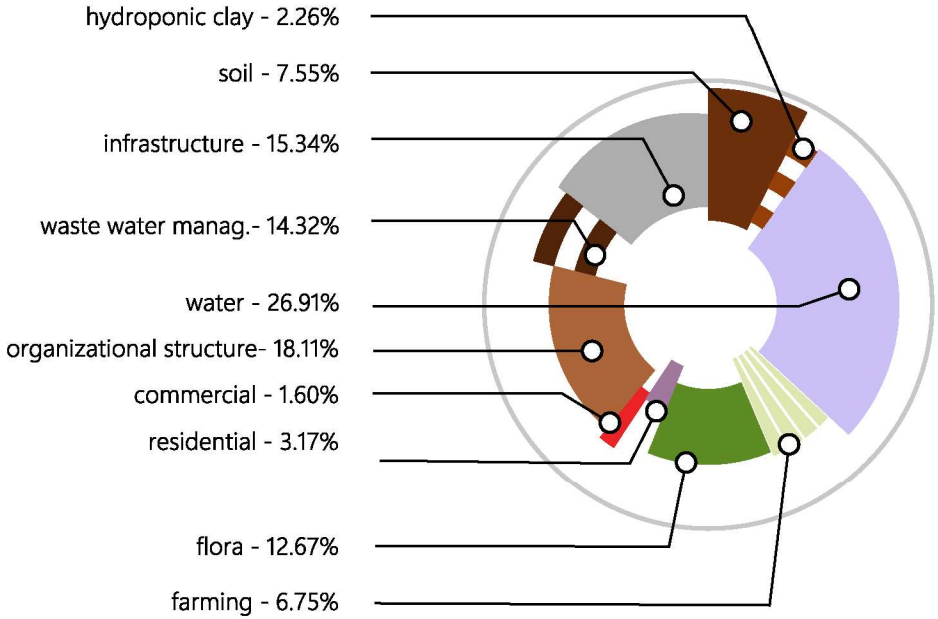
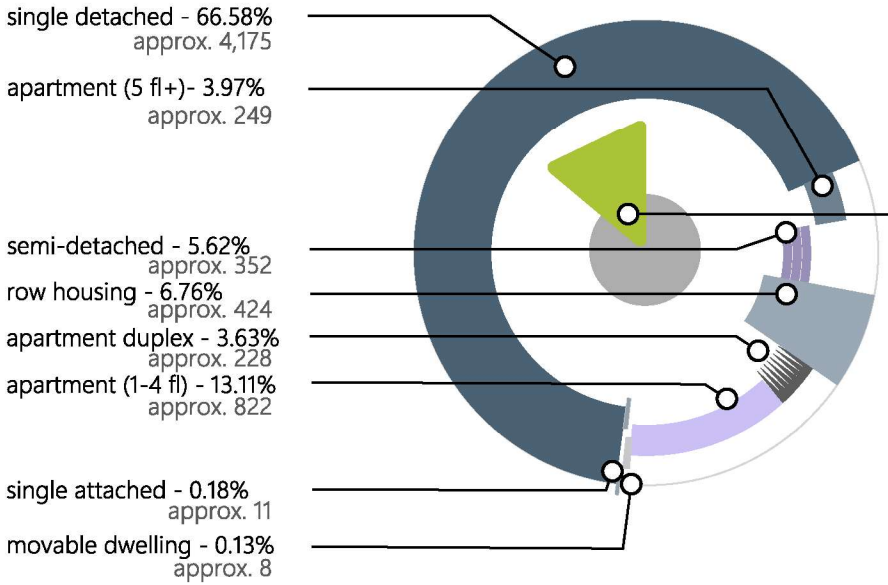


Figure 6.1.5 : Arcology‘s Volume Breakdown - part 5

Volume of Program in the Arcology



Naturalizing Areas in Niagara Falls



naturalizing areas in Niagara falls - 17.53%

approx. 6,270 homes will be naturalized



Figure 6.1.6 : Arcology‘s Overall Volume - Potential

Arcology Proposal - Overall

The process of designing an Arcology has to initiate with understanding it‘s organizational structure and grasping the magnitude of the structure. Once a structure is set then one can puncture the structure to allow natural light through. The programs and spaces that this structure can hold is so large that the design potential is infinite.

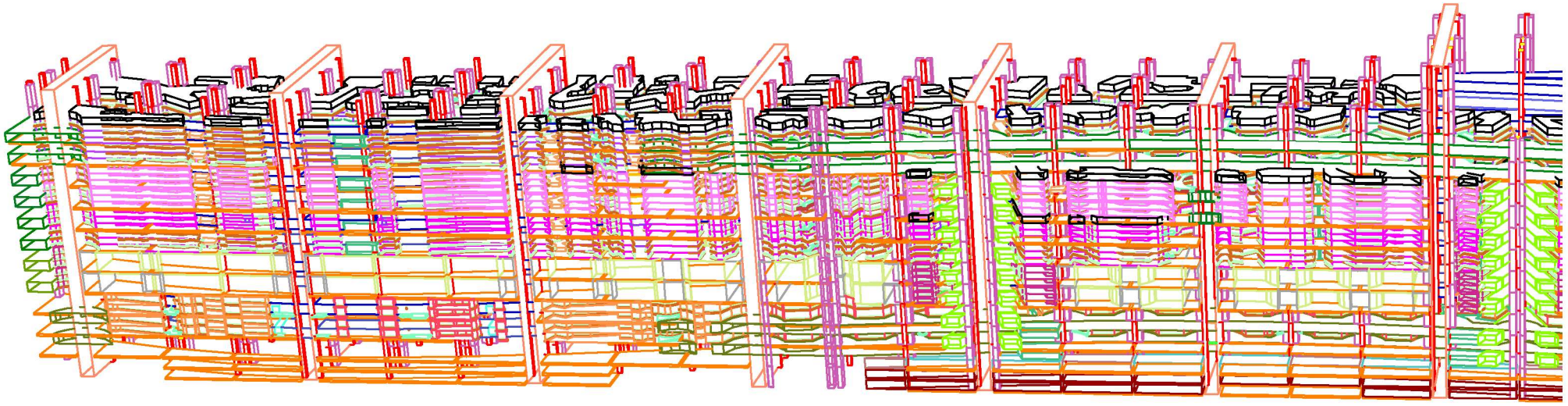


Figure 6.1.7 : Arcology‘s Overall Longitudinal Section - Potential

Key Plan

Human Processes

Residential & Commercial
- Commercial Zone
- Residential Zone
- Floors

Structure
- Shear Walls
- Columns

Vertical Access
- Elevator & Stairs

Ecological Processes

Waterway Processes
- Aquaponic System

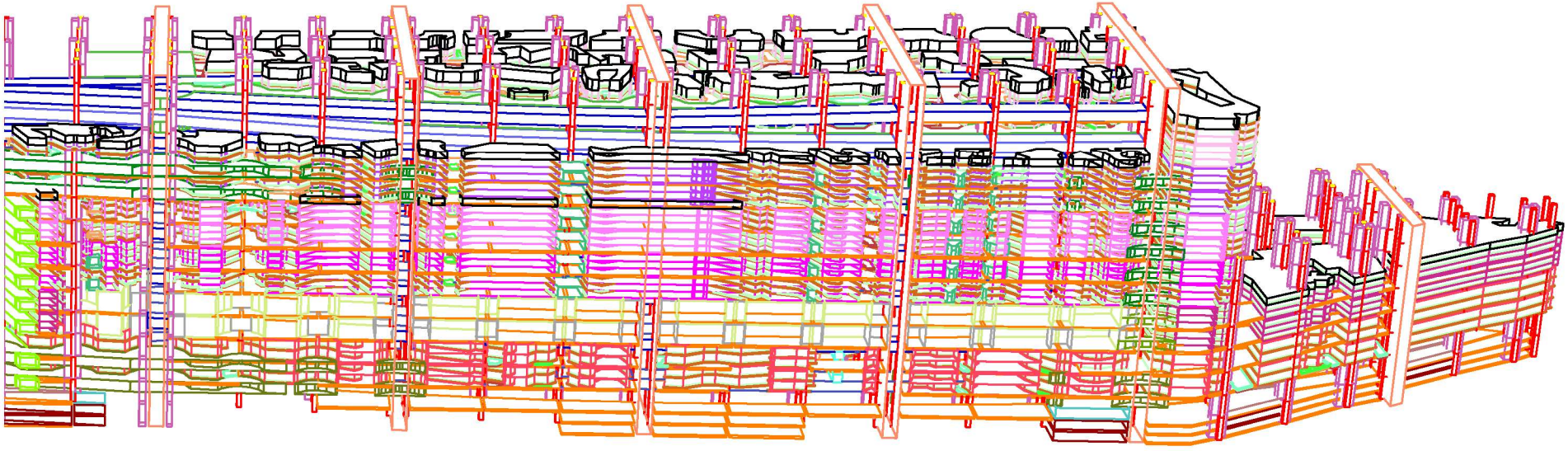
Vertical Farming Processes
- Vertical Farming - Mechanical
- Vertical Farming - Farm Area

Water Waste Processes
- Water Waste - Septic Tank - Commercial
- Water Waste - Septic Tank - Residential

Periphery - Local Trees & Plants
- Edge Periphery Plants - Trees and Plants
- Periphery Plants - Trees and Plant

Interior - Plants with Hydroponic Clay
- Tier vines - Plants
- Tier 1 - Plants
- Tier 2 - Plants

Interior - Trees & Plants with Soil
- Tier 3 - Plants
- Tier 4 - Trees & Plants
- Roof - Trees & Plants



6.2 Arcology Proposal – Sectional Perspective & Key Interactions

The Arcology thrives on the functionality of key interactions due to it‘s dynamic complexity. Consequently, the design process emphasizes the inverse relationship of plans and sections. What is loose in plan, must be dense in section and what is dense in plan, must be loose in section. Establishing an organizational framework in section enbables us to trace our key interactions, allowing for incremental optimization in the design phase. As we refine and compile additional sections, the Arcology becomes increasingly cohesive and resolved.

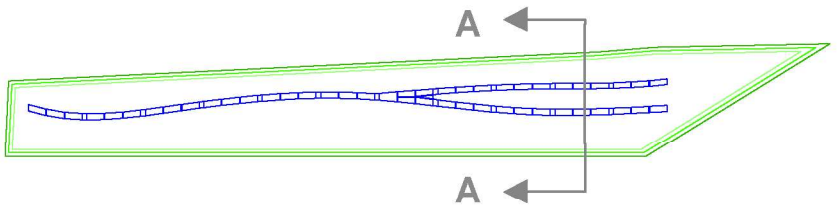
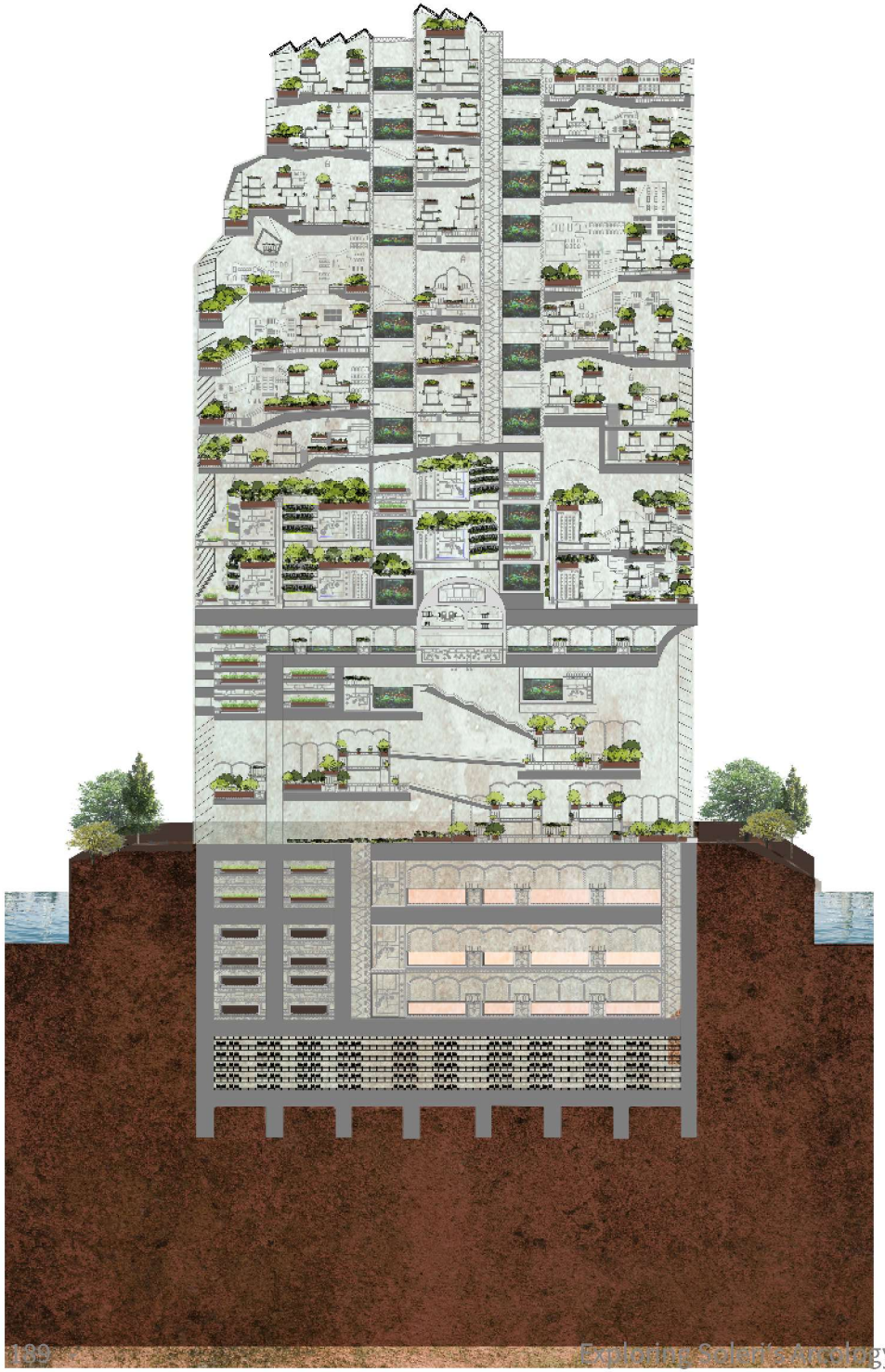


Figure 6.2.1 : Author‘s illustration of section indicating program and zoning for Section A.



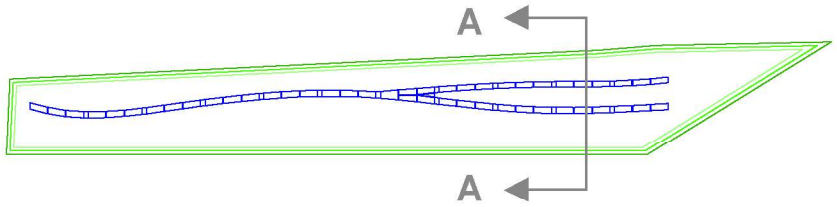
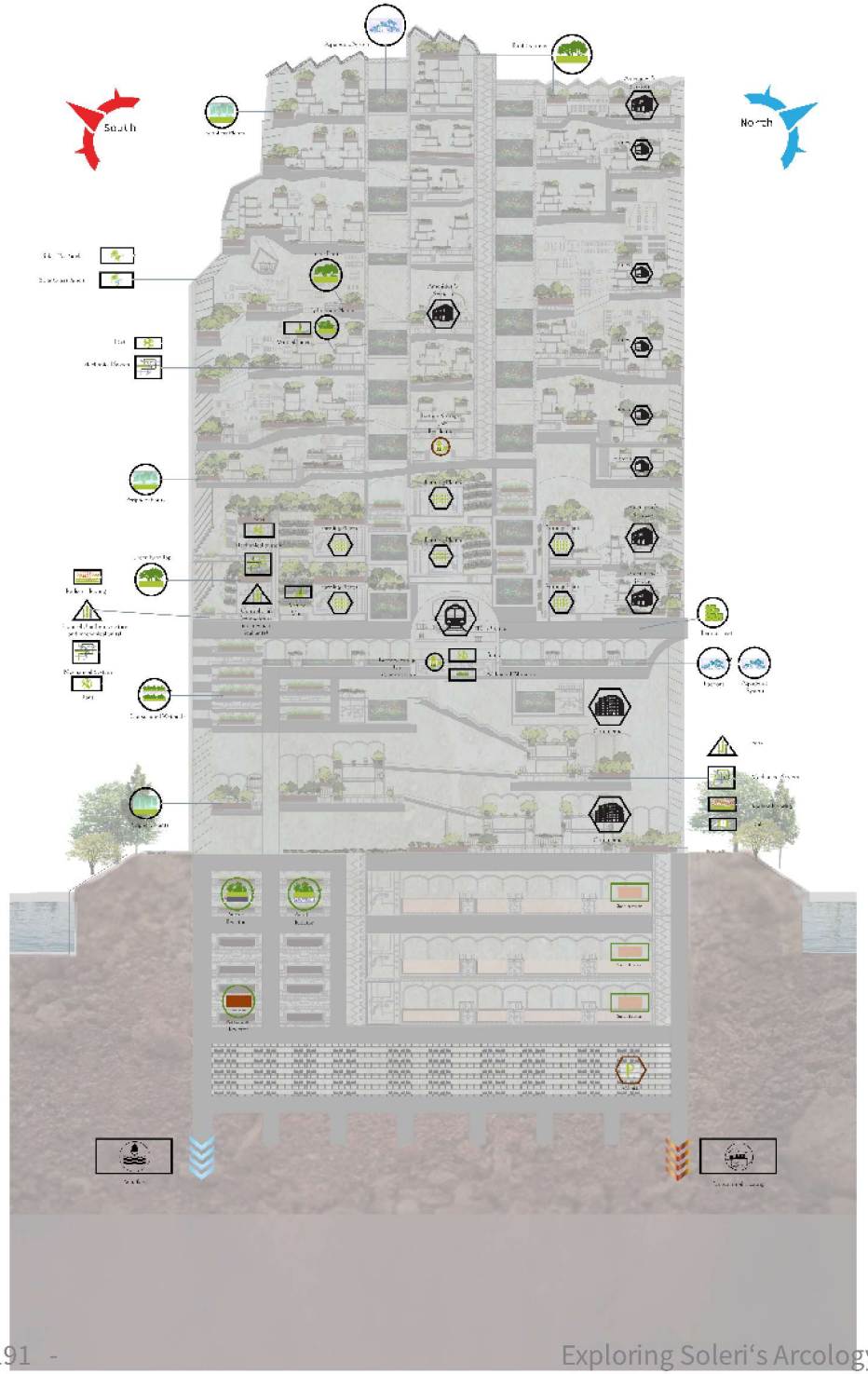


Figure 6.2.2 : Author‘s illustration of section highlighting key interactions for Section A.


South
North

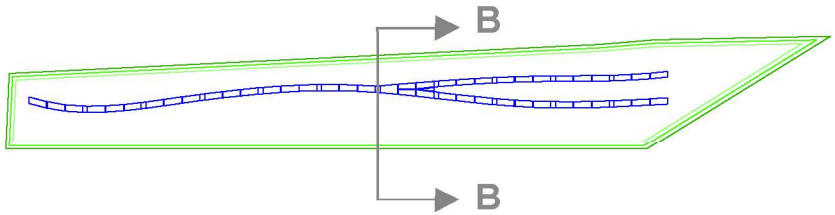


Figure 6.2.3 : Author‘s illustration of section indicating program and zoning for Section B.



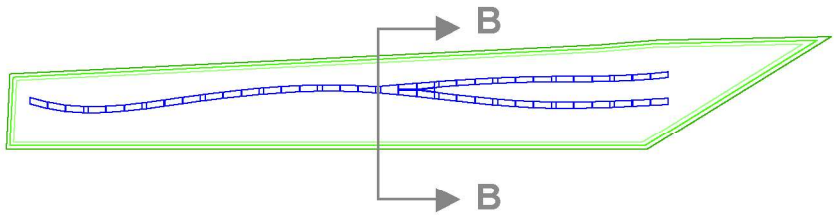
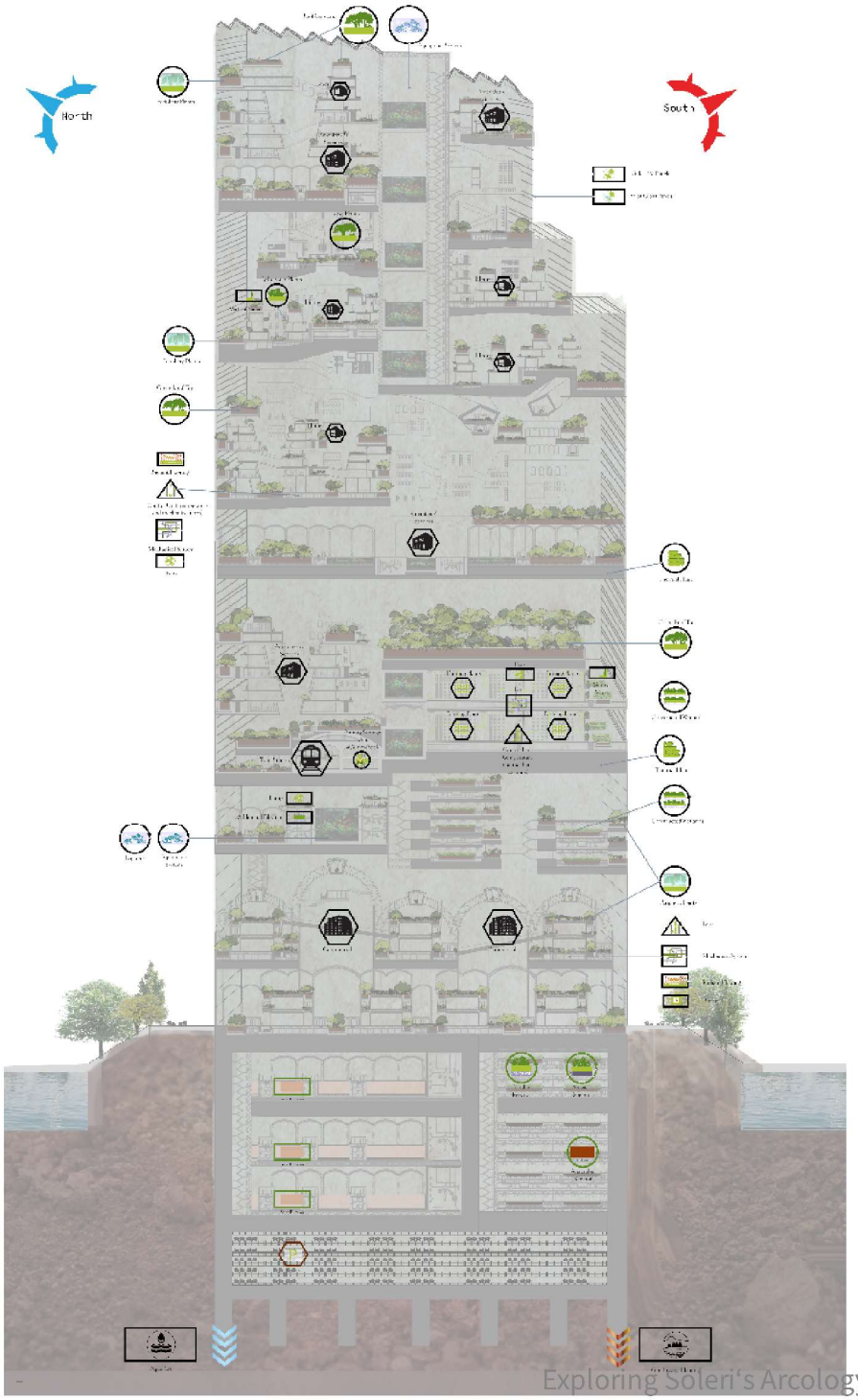


Figure 6.2.4 : Author‘s illustration of section highlighting key interactions for Section B.


North
South

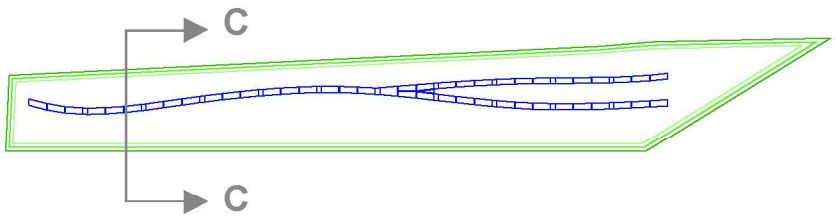
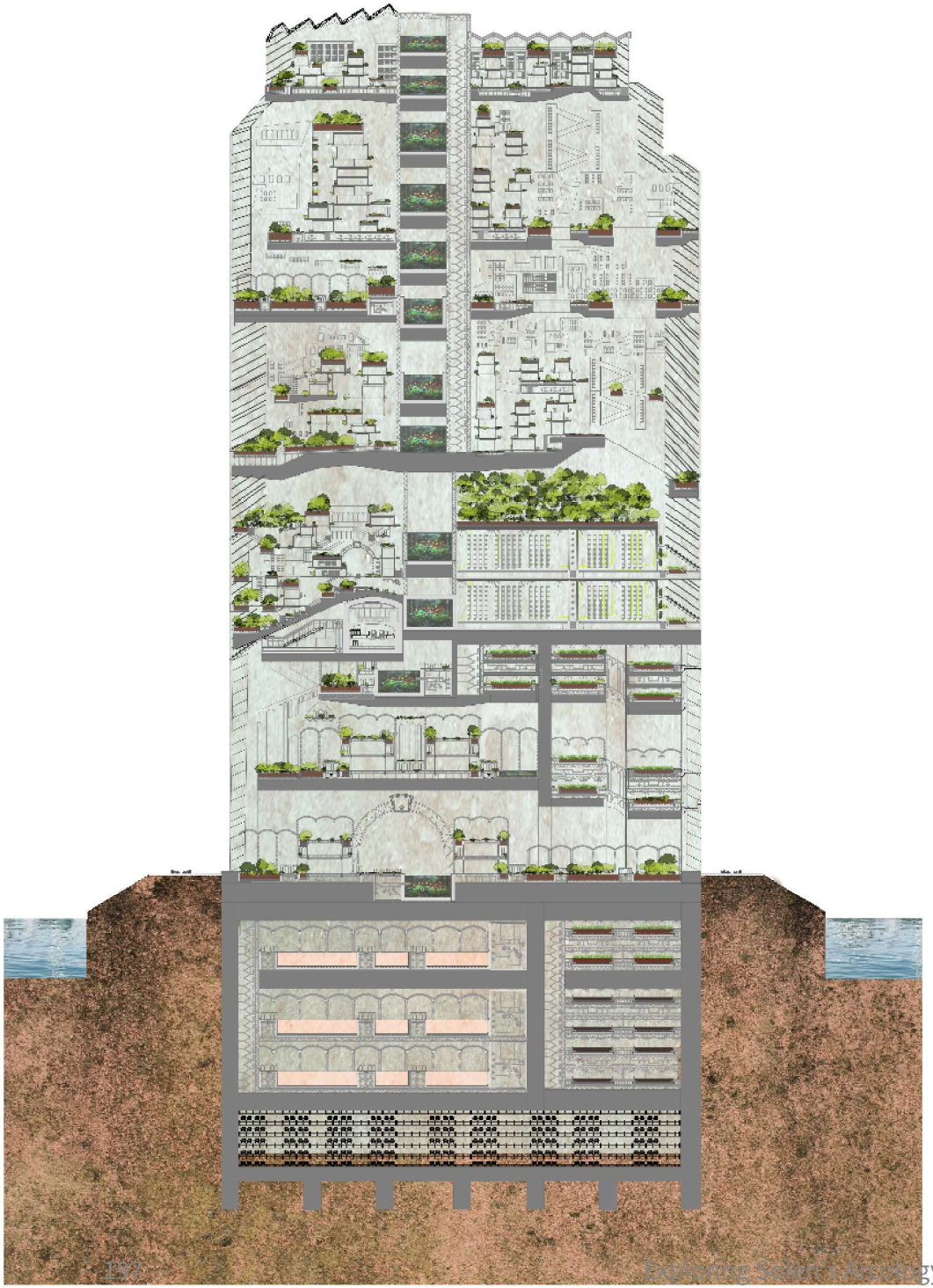


Figure 6.2.5 : Author‘s illustration of section indicating program and zoning for Section C.



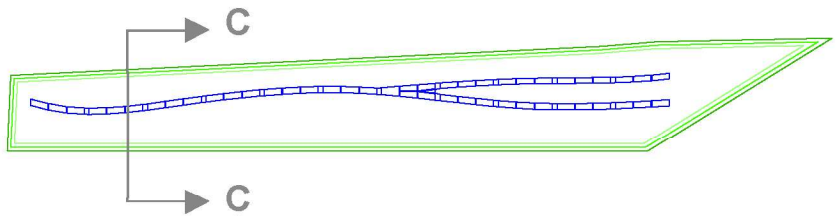
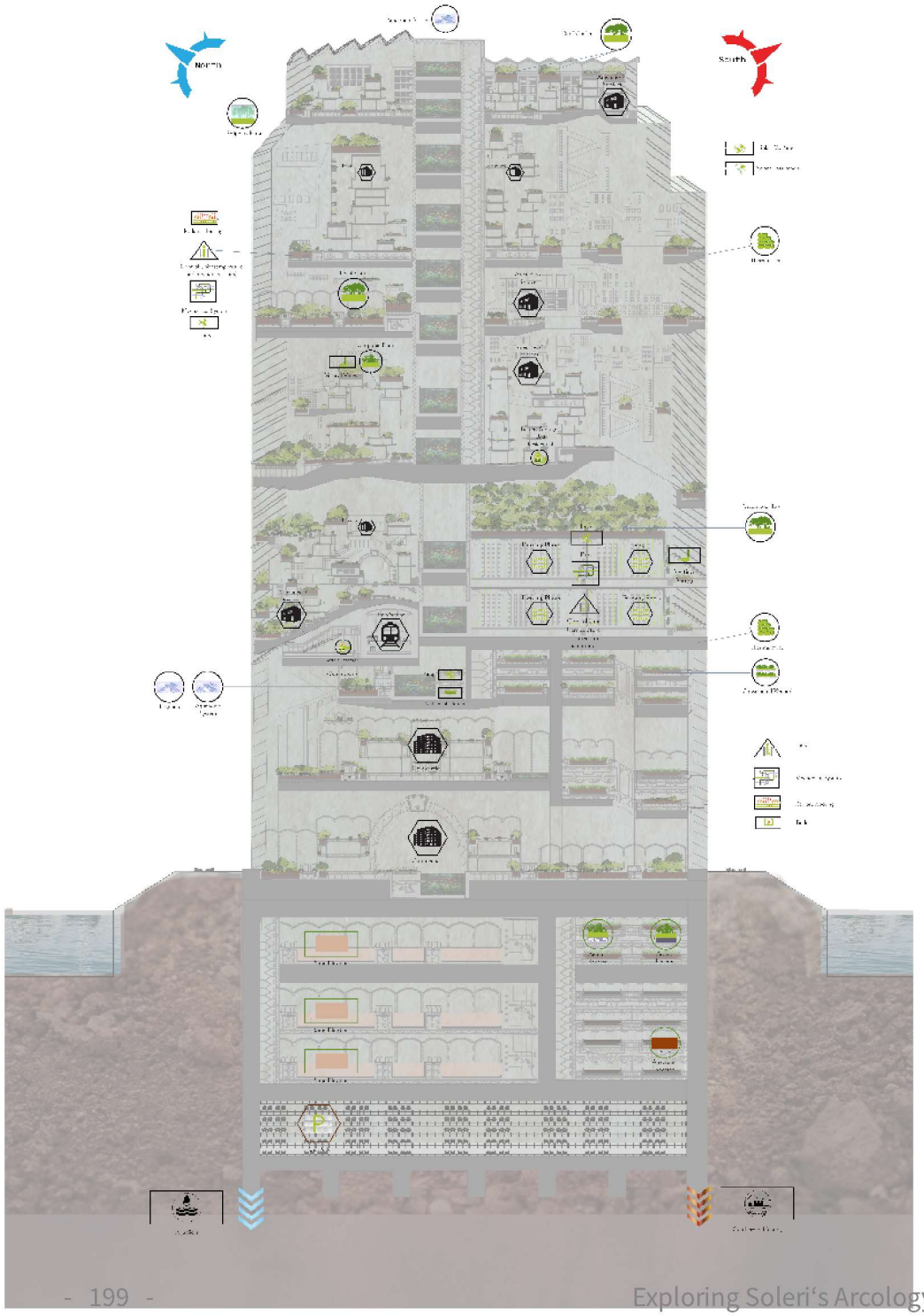


Figure 6.2.6 : Author‘s illustration of section highlighting key interactions for Section C.


North
South

6.3 Generating AI Images of a Megastructure

Artificial Intelligence Subsets and Architecture

What does this mean for Architecture? British Architect and Professor Neil Leach states that AI has capacities beyond what we have witnessed to date and predicts the unemployment of 80% of architects[1]. Just as manual drafting has become outdated with AutoCAD, with AI, Architecture, and Architects must find an alternative way to manage projects. As AGI is developing, a re-definition and adaptation of the Architect's role seems imminent[2], a collaboration between software Architects and Architects is a likely conclusion. Exploring Generative AI is a prevalent conclusion, although the images generated may not be as sophisticated as professionals, the aesthetics are comparable[3]. Generative AI may be utilized with the intention of image generators used as text-prompting tools for prototyping, elevating creativity, fast-tracking the design process, team engagement, effective communication, solutions for complexity, augmented organization, and iteration of designs. There is a learning curve to develop skills that may be required to align Architects with their vision and values[4]. One of these forms is prompt engineering. Another of these skills is a chain of thought engineering, which involves structuring prompts for the AI to follow a step-by-step reasoning process[5]. This does not eliminate the role of the Architect because Generative AI requires human expertise. This means a novel and complex design such as an ecological megastructure will still require conceptual sketches, detailed plans, and modeling using the standard software tools: AutoCAD, Revit, Rhino, Grasshopper, Adobe Suite, Lumion, Unreal Engine, etc. Multiple companies have adapted to Generative AI integration with the addition of Generative AI tools to speed up the production process. This may radically change Construction and Consultation firms which are dependent on redundancy, but will Design firms that are dependent on creativity still worry about AI's progress? If we are to understand the direction of AI, we need to know why is it successful, what AI is, and track where its progress to determine its direction. That way we may gain a better understanding of where Architects may fit into it.

Artificial Intelligence (AI) has a GDP of 19.9 Trillion USD, a higher GDP than most countries, including Canada[6]. There has never been an industry that has a faster-growing rate than Artificial intelligence in history. Public attitudes toward this exponential growth vary along a spectrum due to the paradigm shift from being a human-based knowledge economy to an economy where the value created, and the rate of its creation is dependent on Artificial Intelligence. On the left side of the spectrum, the perspective is denial and resistance to change. On the right side of the spectrum, there is panic, accompanied by the instinct that intellectual property will be eradicated due to the machine's dominance over creativity and intelligence. The middle consensus would be to perceive the benefits of Artificial Intelligence and use its tools to improve productivity at a novel growth rate. This is an urgent policy concern, and whether it is a bottom-up or top-down approach, this technology will change the management of every industry today. Instead, the focus will be on how Artificial Intelligence will contribute to designing complex systems such as an ecological megastructure. This can be answered with a diverging question that investigates the direction of growth of Artificial Intelligence towards Artificial General Intelligence (AGI). Then converge by looking into the feedback loop and tools that Artificial Intelligence can provide in the design phase and the management phase that can significantly accelerate the design process and implications for architecture.

1 Walsh, Niel Patrick. 2023. "'Ai Is Both Incredible and Terrifying'; a Conversation with Neil Leach." Archinect. June 19, 2023. https://archinect.com/features/article/150352996/ai-is-both-incredible-and-terrifying-a-conversation-with-neil-leach.

2 Leach, Niel. 2024. "Open Lecture | Neil Leach: Alien Intelligence: An Introduction to AI for Architects." YouTube. Waterloo Architecture. March 6, 2024. https://www.youtube.com/watch?v=jn1dQZ09ljk.

3 Lee, Dami. 2023. "We Tried to Compete with Ai... [Ai vs. Architect]." YouTube. Dami Lee. March 19, 2023. https://www.youtube.com/watch?v=N709ZrxoIP0. 4 Kay, James J. et al. 2002. Construction Ecology : Nature as the Basis for Green Buildings. London ; Spon Press: p 101 - 102.

4 Fisher, Joshua A. "Centering the Human: Digital Humanism and the Practice of Using Generative AI in the Authoring of Interactive Digital Narratives." In Interactive Storytelling, 73–88. Cham: Springer Nature Switzerland, n.d. https://doi.org/10.1007/978-3-031-47655-6_5.

5 Wei, Jason, Xuezhi Wang, Dale Schuurmans, Maarten Bosma, Brian Ichter, Fei Xia, Ed Chi, Quoc Le, and Denny Zhou. "Chain-of-Thought Prompting Elicits Reasoning in Large Language Models," 2023. https://doi.org/10.48550/arxiv.2201.11903

6 IDC. "Artificial Intelligence Will Contribute $19.9 Trillion to the Global Economy through 2030 and Drive 3.5% of Global GDP in 2030." Accessed November 27, 2024. https://www.idc.com/getdoc.jsp?containerId=prUS52600524#:~:text=IDC%3A%20Artificial%20Intelligence%20Will%20Contribute,of%20Global%20GDP%20in%202030.

Artificial intelligence is growing at approximately a factor of ten (10) every six (6) months[7]. This diagram above (figure 1), is already outdated because it is missing 2024's new kid on the block and future key player: Artificial General Intelligence (AGI). We will be chronologically exploring the growth of AI in three waves. The first wave of Artificial intelligence will be the growth of Machine Learning from its inception to the year 2000. The second wave will provide an overview of Deep Learning and Generative Artificial Intelligence. The third wave will cover the key developments towards Artificial General Intelligence (AGI) that open the doors to commercializing this technology, which has been repetitively predicted to affect every industry.

In 1930, Princeton Professor of Mathematics, Alonzo Church introduced lambda calculus which captured a basic functional notion of computation[8]. Church influenced his Ph.D. English student, Alan Turing[9]. In 1938, Turing, the father of artificial intelligence, captured a basic state-based model of computation and named the computational equivalent the Turning Complete or the universal computation. In World War II, the Mathematician and cipher-expert, Alan Turing played a crucial role in deciphering the top-secret German codes by improving the bomba method that could find settings for the Enigma Machine[10]. . Essentially, Turing was the first to create a correlation between computational languages and mathematical languages through algorithms and matrixes. This building block played an important role in developing the theory of programming languages. Artificial Intelligence was pre-dominantly dependent on Symbolic AI from the 1950s until the 1990s. This meant the research was dependent on the focus of logical processing and manipulating symbols and concepts rather than numerical data. This promoted arduous research and reflection to structure machine thinking processes before the prototyping was released. This prompted the public question "Can machines think?" in which Turing proposed an alternative question "Can they imitate?" In 1950, Turing outlined a game called the "Imitation Game"[11], where he proposed the question of machines a machine pretends to be a person and responds to a series of questions, can they be identified as human or not?[12]

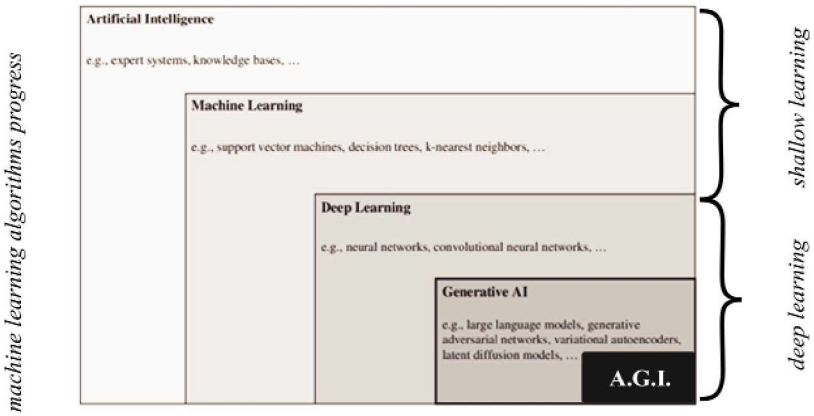


Figure 6.3.1: Artificial Intelligence and its subsets (inspired by Goodfellow et al, 2016, p.9; Janiesch et al., 2021, p. 687; Banh & Strobel, 2023)

7 "Prof. Geoffrey Hinton - 'Will Digital Intelligence Replace Biological Intelligence?' Romanes Lecture." 2024. YouTube. YouTube. February 29, 2024. https://www.youtube.com/watch?v=N1TEjTeQeg0.

8 Church, Alonzo, and C. (Clifford) Truesdell. Introduction to Mathematical Logic. New York: Kraus Reprint, 1965.

9 Copeland, B. Jack, Carl J. Posy, and Oron Shagrir, eds. Computability: Turing, Gödel, Church, and Beyond. Cambridge, Massachusetts: The MIT Press, 2013, 7-10.

10 "Alan Turing and the Beginning of Ai." 1998. Encyclopædia Britannica. Encyclopædia Britannica, inc. July 20, 1998. https://www.britannica.com/technology/artificial-intelligence/Alan-Turing-and-the-beginning-of-AI.

11 Turing, A. M. "Computing Machinery and Intelligence." Mind 59, no. 236 (1950): 433–60.

12 French, Robert M. "Dusting Off the Turing Test." Science (American Association for the Advancement of Science) 336, no. 6078 (2012): 164–65. https://doi.org/10.1126/science.1218350.

This litmus test set the basic standard for prototyping computational intelligence. From 1964 to 1966, German American Computer Scientist and MIT professor, Joseph Weisbaum, announced ELIZA, the first Rogerian psychotherapist created to explore communication between humans and machines[13]. From 1968 to 1970, an American Computer Scientist at MIT announced SHRUDLU, a virtual program that conversed with its users to organize and move virtual objects[14] within its parameters to understand and process natural language[15,16]. It was almost a public spectacle when these prototypes underwent the Turing Test and the way to Artificial Intelligence seemed unattainable[17], until the paradigm shifted towards mega data initiated by the invention of neural networks.

On September 30, 2012, AlexNet competed in the ImageNet Large Scale Visual Recognition Challenge (ILSVRCS) and proved dramatic progress in image processing through its algorithm called Convolutional Neural Network (CNN). Canadian pioneers Ph.D. Candidate Alex Krizhevsky, Ph.D. Candidate Ilya Sutskever and University of Toronto Computer Science Professor Geoffrey Hinton utilized graphics processing units (GPUs) during training[18]. Ph.D. Candidate from the University of Montreal, Ian Goodfellow and his colleagues, hypothesized a structural framework of hierarchies by analyzing metadata through a Generative Adversarial Network (GAN)[19]. Essentially, this added a layer to the deep learning process by pitting two neural networks against each other as they competed for hierarchy, and for the first time, a machine could generate new images[20]. This launched Generative AI into exponential growth[21], although AI was able to produce neural processing unit (NPU) and natural language processing (NLP) tasks such as speech recognition, photo editing, and such, this Large Language Model (LLM) seemed to have limitations by misinterpreting data, generated inaccurate responses and over analyzed patterns resulting in false information which is known as AI hallucinations. In 2017, Google Brain's "Attention is All You Need' by Vaswani and seven colleagues introduced the Transformers into the Architectural model, introducing semi-supervised learning by developing an attention mechanism by running multiple sequences in parallel from the encoder for input and decoder for output. Then the encoder's output is fed into the decoder's input along with other inputs to generate a prediction. These three sequential developments fast-tracked the AI boom of generative AI systems and are used as a series of responsive tools launched in the early 2020s by enabling a computer to be able to speak to us and generate a predictable response[22]. Midjourney, DALL-E, Stable Diffusion, and Adobe Firefly enhanced text-to-image AI Generators. Large language model chatbots became publicly available such as OpenAI's ChatGPT, Google's Gemini, and Anthropic's Claude. Generative AI can also generate text-to-audio, and text-to-video, and generate code, music, lyrics, robotics, planning, data, and automated 3D modeling and the list is expansive.

13 O'Regan, Gerard. "Eliza Program." In The Innovation in Computing Compani on, 119–22. Switzerland: Springer International Publishing AG, 2018. https://doi.org/10.1007/978-3-030-02619-6_24.

14 Deniz Yuret. (2013, Sept 13). Winograd shrudlu. www.youtube.com. https://www.youtube.com/watch?v=QAJz4YKUwqw.

15 Winograd, Terry. "Linguistics and the Computer Analysis of Tonal Harmony." Journal of Music Theory 12, no. 1 (1968): 2–49. https://doi.org/10.2307/842885.

16 Winograd, Terry. "Understanding Natural Language." Cognitive Psychology 3, no. 1 (1972): 1–191. https://doi.org/10.1016/0010-0285(72)90002-3.

17 Bits and Bytes TVO. (2012, May 18). Eliza — Please tell me your problem (Bits and Bytes, Episode 7). www.youtube.com. https://www.youtube.com/watch?v=4snglh0YJtk.

18 Krizhevsky, Alex, Ilya Sutskever, and Geoffrey Hinton. ImageNet Classification with Deep Convolutional Neural Networks. Communications of the ACM. Vol. 60. NEW YORK: ACM, 2017. https://doi.org/10.1145/3065386.

19 Goodfellow, Ian J, Jean Pouget-Abadie, Mehdi Mirza, Bing Xu, David Warde-Farley, Sherjil Ozair, Aaron Courville, and Yoshua Bengio. "Generative Adversarial Networks," 2014. https://doi.org/10.48550/arxiv.1406.2661.

20 Giles, Martin. 2020. "The Ganfather: The Man Who's given Machines the Gift of Imagination." MIT Technology Review. MIT Technology Review. April 2, 2020. https://www.technologyreview.com/2018/02/21/145289/the-ganfather-the-man-\whos-given-machines-the-gift-of-imagination/.

21 Kniberg, Henrik. 2024. "Generative AI in a Nutshell - How to Survive and Thrive in the Age of Ai." YouTube. January 20, 2024. https://www.youtube.com/watch?v=2IK3DFHRFfw.

22 Banh, Leonardo, and Gero Strobel. "Generative Artificial Intelligence." Electronic Markets 33, no. 1 (2023): 63-. https://doi.org/10.1007/s12525-023-00680-1.

Large Language Models (LLM) as self-correcting and autonomous agents are the next big thing. A series of global studies were released exploring models of a closed feedback loop that is self-organizing, autonomous, self-correcting AI with the intent of lowering the cost of human data collection and human feedback. It began in May 2022, STaR – Self-Taught Reasoner was introduced as a model that fine-tunes itself through a series of step-by-step incremental iterations as it generates rationale and responds to its output[23]. It has been proven that AI can generate human-prompted tools, AI can also use these tools and interact with other autonomous agents sequentially or in parallel. In May 2023, Large Language Models as Tool Makers (LATM) introduced two key stages: the making of tools and the using of tools in a closed-loop framework piloted by AI. Its published limitations included "a significant lack of high-quality datasets that authentically represent daily human-computer interactions"[24]. In May 2023, a study released by OpenAI's research team proposed process supervision requires intermediate revision steps and introduced active learning into AI[25]. This was reinforced in September 2023 with the publication of another approach where it is proposed that Reinforced Learning Artificial Intelligence Feedback (RLAIF) produced comparable data to Reinforced Learning Human Feedback (RLHF)[26]. Then on September 2023, a compilation of a comprehensive layout of the growth of LLM-based autonomous agents and proposed a unified architectural framework. This discusses adaptive artificial intelligent systems and proposes the following agent constructions that are composed of the four following components: profile, memory, planning, and action. This approach further develops its analysis by providing a framework for evaluating the agents[27]. November 2023, MetaGPT was introduced as a novel metal-programming framework where AI composes a group of autonomous agents that leverage role specialization, manage workflows, and communicate with its agents in a closed-loop system. It manages this through an executable feedback mechanism that self-regulates and hits multiple benchmarks. This promotes the LLM-based multi-agent framework and proposes human development is available for management[28]. In layman's terms, MetaGPT enables individuals with basic AI skills to establish a comprehensible virtual company with access to a dedicated team of AI agents that can manage, code, organize, and run a company with API keys. In January 2024, AgentBoard was introduced as an open-source analytical evaluation framework to facilitate holistic analysis for LLM's agents and a scoring system consisting of memory, planning, world modeling, self-reflection, grounding, and special navigation[29]. With the release of Google's Gemini in December 2023, Anthropic's Claude-3 in March 2024, and the future release of OpenAI's Q*, there have not been any policies outlining limitations for AGI. The capacities of AGI include self-correcting, self-regulating, collaborating with AI agents, self-synthesizing its self-generated data, it does not need human-generated testing and its growth projection is unpredictable. OpenAI's CEO, Sam Altman predicted in an interview this could mean a billion-dollar company could be run by one individual[30].

---

23 Zelikman, Eric, Yuhuai Wu, Jesse Mu, and Noah D Goodman. "STaR: Bootstrapping Reasoning With Reasoning," 2022. https://doi.org/10.48550/arxiv.2203.14465.

24 Cai, Tianle, Xuezhi Wang, Tengyu Ma, Xinyun Chen, and Denny Zhou. "Large Language Models as Tool Makers." arXiv.Org, 2023. https://doi.org/10.48550/arxiv.2305.17126.

25 Lightman, Hunter, Vineet Kosaraju, Yura Burda, Harri Edwards, Bowen Baker, Teddy Lee, Jan Leike, John Schulman, Ilya Sutskever, and Karl Cobbe. "Let's Verify Step by Step." arXiv.Org, 2023. https://doi.org/10.48550/arxiv.2305.20050.

26 Lee, Harrison, Samrat Phatale, Hassan Mansoor, Thomas Mesnard, Johan Ferret, Kellie Lu, Colton Bishop, et al. "RLAIF: Scaling Reinforcement Learning from Human Feedback with AI Feedback," 2023. https://doi.org/10.48550/arxiv.2309.00267.

27 Wang, Lei, Chen Ma, Xueyang Feng, Zeyu Zhang, Hao Yang, Jingsen Zhang, Zhiyuan Chen, et al. "A Survey on Large Language Model Based Autonomous Agents," 2023. https://doi.org/10.48550/arxiv.2308.11432.

28 Hong, Sirui, Mingchen Zhuge, Jonathan Chen, Xiawu Zheng, Yuheng Cheng, Ceyao Zhang, Jinlin Wang, et al. "MetaGPT: Meta Programming for A Multi-Agent Collaborative Framework," 2023. https://doi.org/10.48550/arxiv.2308.00352.

29 Ma, Chang, Junlei Zhang, Zhihao Zhu, Cheng Yang, Yujiu Yang, Yaohui Jin, Zhenzhong Lan, Lingpeng Kong, and Junxian He. "AgentBoard: An Analytical Evaluation Board of Multi-Turn LLM Agents," 2024. https://doi.org/10.48550/arxiv.2401.13178..

30 Sam Altman and Alexis Ohanian - We're Not far from AI Enabling a One-Person Billion Dollar Company." n.d. Www.youtube.com. Accessed March 9, 2024. https://www.youtube.com/watch?v=Q5vsEUgxt3E.

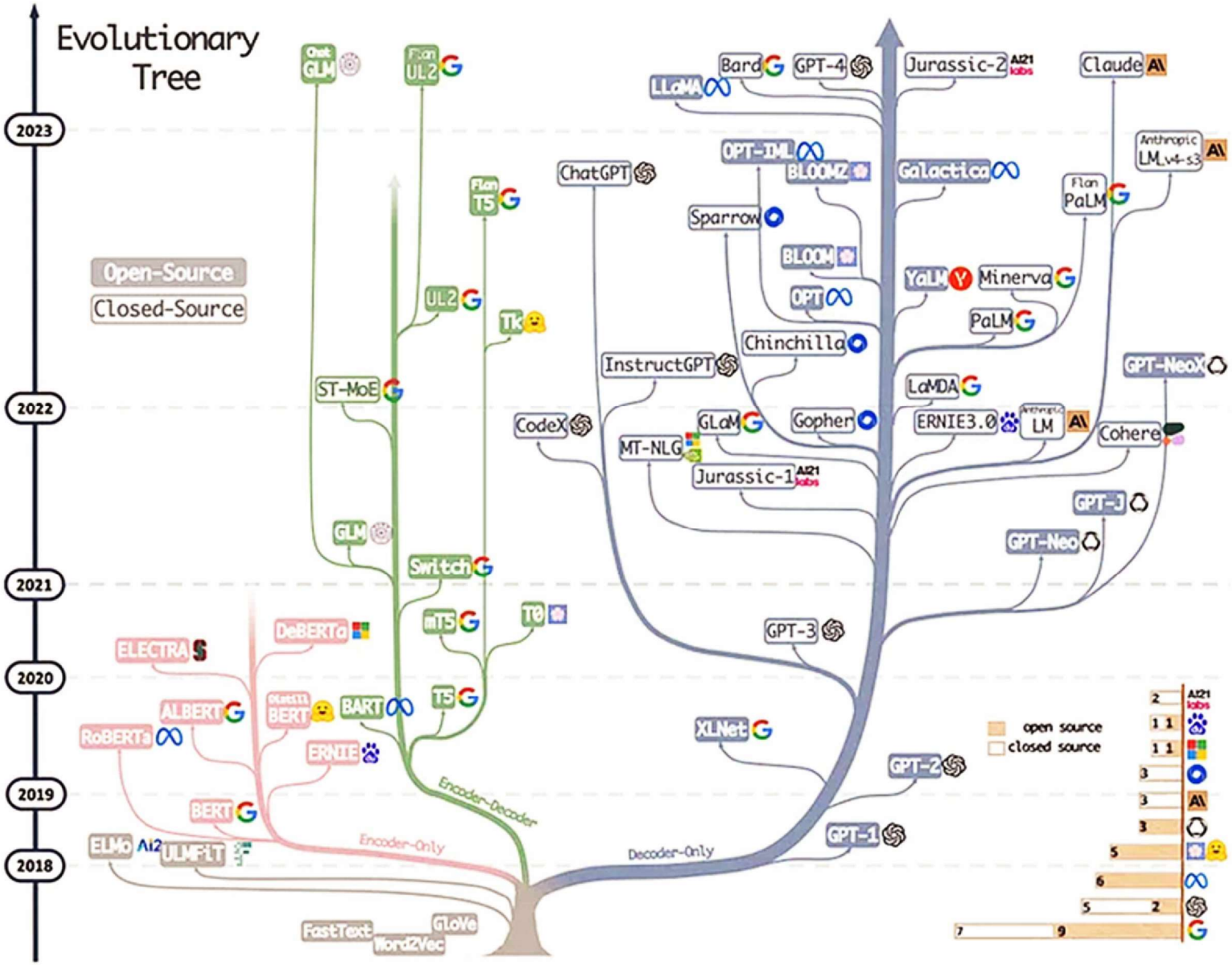


Figure 6.3.2: The evolutionary tree of modern LLMs highlighting their rapid development. The Transformer-based models colors indicate the following: blue branch indicates decoder-only models, pink branch indicates encoder-only models and green indicates encoder-decoder branch models (by Jingfeng et al, 2023, p.3)

As exciting as Artificial Intelligence is to the future, a haunting quote by George Orwell arises when considering the progress of Artificial Intelligence" "there will be no art, no literature, no science. When we are omnipotent, we shall have no more need of science[31]." With the progress of Artificial Intelligence, redundant Architect responsibilities such as project management, scheduling, and contract administration of typical construction, could be a thing of the past, which may potentially eliminate a significant number of architectural jobs over some time. A possible advantage architects might be in generating novel designs that require human monitoring by multiple disciplines. Interdisciplinary collaboration requires constant re-iteration of designs on multiple phases over time. Provided that Generative AI image generator tools can improve efficiency, creative agency [32], and communication, and provide data-driven design options. It is a tool that might be too good for architects to ignore without its iterations. The advantage is Generative AI provides a real-time feedback loop from the design to the construction phase, especially in interdisciplinary design teams.

A novel Architectural typology to explore is Ecological Megastructures which is a typology that has a significant upfront cost and high risk of failure. They produce a substantial amount of information that requires quick adaptive strategies and Artificial Intelligence can process, analyze, and provide quick feedback. This shortens the feedback loop and adjusts to emerging properties. The challenge of designing an ecological megastructure will be the integration of systems, ecological integration, and technological integration. This unknown territory is an intriguing angle to explore.

31 Orwell, George. 1984. San Diego, CA: Harcourt Brace Jovanovich, 1984, p176.

32 Wojtkiewicz, Kathryn. "How Do You Solve a Problem like DALL-E 2?" The Journal of Aesthetics and Art Criticism, 2024. https://doi.org/10.1093/jaac/kpad046.

6.4 Generating AI Image for Arcology

Generative AI is a rapidly growing field, that produces high quality renders to support multiple fields of designand addresses challenges regarding time effeciency. Traditional rendering process is time consuming and limits the capacity for conceptual exploration and iterative refinement. Given the scale and complexity of the Arcology, strategies that quickly adapts to multidisciplinary requirements becomes essential, making generative AI a useful tool that augments the design and iterative process.

This thesis will examins Generative AI Images using the following programs, Dall-e 3 by Chat GPT, Imagen 3 by Gemini, Midjourney, Adobe Fire Fly and the initial generation of Promo AI. Through prompt engineering and iterative refinement, variations in the Arcology's design (its form, shape and spatial configuration) are explored, revealing the potential of generative AI to shape such expansive architectural spaces.

This thesis will explore multiple spaces from the exterior form to public and private spaces.



Figure 6.4.1 : Arcology - Niagara Escarpment II - Exterior Perspective - one variation representing the Arcology's entrance - illustration by Imagen 3 by Gemini



Figure 6.4.2 : Arcology - Niagara Escarpment II - Exterior Perspective - Ocean Liner Form - a dense massive slabbed structure that resembles the scale of a small hill - illustration by Imagen 3 by Gemini with skylight added in Adobe Fire Fly

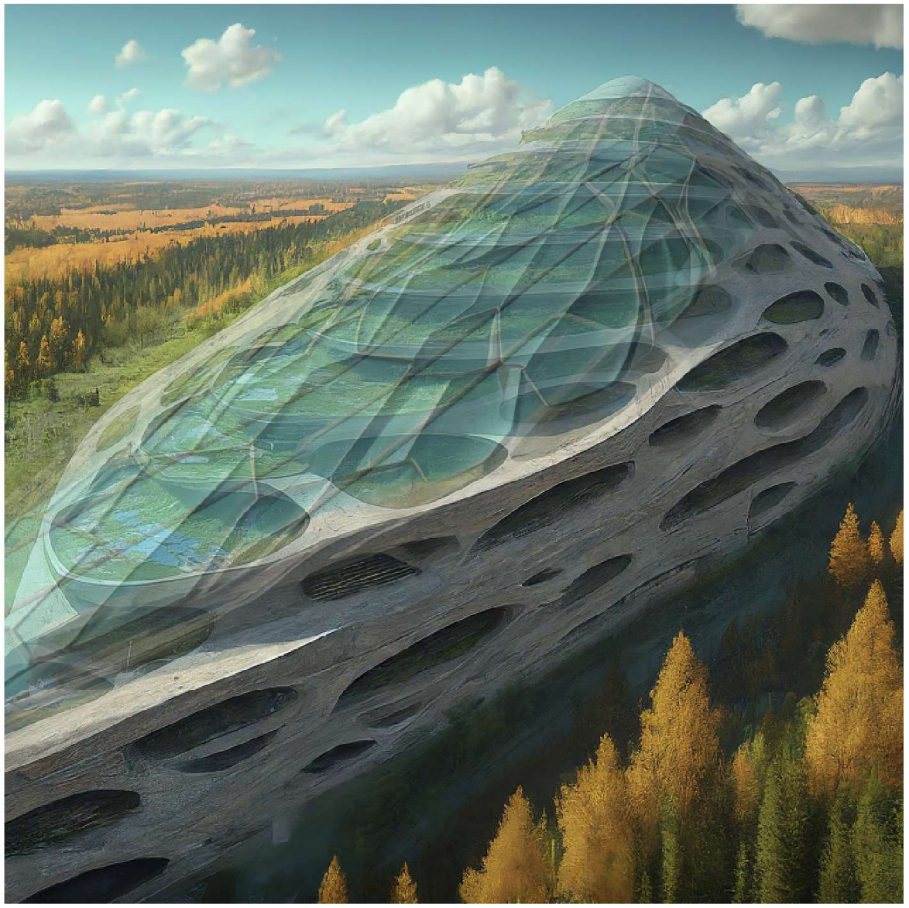


Figure 6.4.3 : Arcology - Niagara Escarpment II - Exterior Perspective - Ocean Liner Form - a variation with skylight - illustration by Imagen 3 by Gemini with skylight added in Adobe Fire Fly



Figure 6.4.4 : Arcology - Niagara Escarpment II - Commercial Zone - Sectional Perspective - a variation of public spaces showing conceptual commercial configuration - illustration by Midjourney with color added, thicker slabs, altering tree sizes and bushes added in Adobe Fire Fly



Figure 6.4.5 : Arcology - Niagara Escarpment II - Commercial Zone - Sectional Perspective - a denser variation of public spaces showing conceptual commercial configuration - illustration by Midjourney with color added, thicker slabs, altering tree sizes and bushes added in Adobe Fire Fly



Figure 6.4.6 : Arcology - Niagara Escarpment II - Commercial Zone - Sectional Perspective - a contemporary aesthetic showing conceptual commercial configuration showing the thicker slabs for commercial use and green infrastructure- illustration by Midjourney with color added, thicker slabs, altering tree sizes and bushes added in Adobe Fire Fly



Figure 6.4.7 : Arcology - Niagara Escarpment II - Commercial Zone - Perspective - showing a compact variation of commercial area with large slabs for green infrastructure - illustration by Midjourney



Figure 6.4.8 : Arcology - Niagara Escarpment II - Commercial Zone - Perspective - showing a dense and futuristic variation for multiple floor store fronts and green roofs - illustration by Promo AI colors added in Adobe Fire Fly



Figure 6.4.9 : Arcology - Niagara Escarpment II - Commercial Zone - Perspective - showing an internal variation with multiple floor store fronts and a skylight - illustration by Midjourney with water features added in Adobe Fire Fly and plants and trees added with first generation Promo AI



Figure 6.4.10 : Arcology - Niagara Escarpment II - Farming Zone - Perspective -a variation showing the potential height and scale of a vertical farming facility - illustration by Midjourney



Figure 6.4.11 : Arcology - Niagara Escarpment II - Farming Zone - Perspective -a variation showing a variety of plants that can be grown in a vertical farming facility - illustration by Midjourney



Figure 6.4.12 : Arcology - Niagara Escarpment II - Farming Zone - Perspective -a variation showing a machine-like vertical farming facility that prioritizes production - illustration by Midjourney



Figure 6.4.13: Arcology - Niagara Escarpment II - Farming Zone - Perspective -a variation of multiple stacked farming with an eco-sensative aesthetic- illustration by Midjourney



Figure 6.4.14 : Arcology - Niagara Escarpment II - Train Zone - Sectional Perspective - a traditional train station showing conceptual variation that highlights the structure‘s heavy form and it‘s capacity to hold green infrastructure - illustration by Midjourney

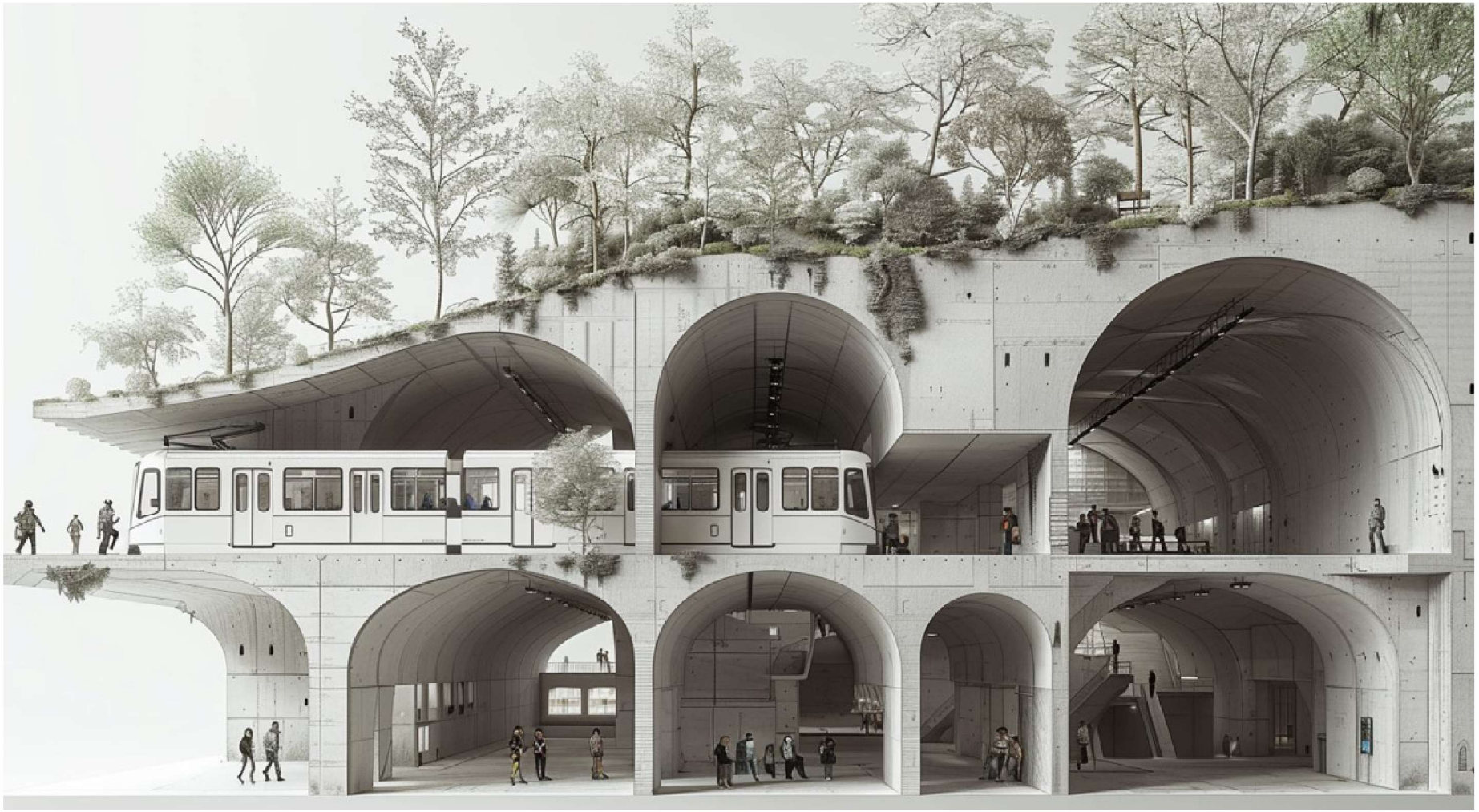


Figure 6.4.15 : Arcology - Niagara Escarpment II - Train Zone - Sectional Perspective - a alternative showing conceptual Train Station that highlights the flexibility of concrete - illustration by Midjourney with arches variations added in Adobe Fire Fly



Figure 6.4.16 : Arcology - Niagara Escarpment II - Train Zone - Sectional Perspective - a variation showing conceptual Train Station with multiple public and private spaces with a green roof - illustration by Midjourney with color added, and a variety of size spaces added in Adobe Fire Fly

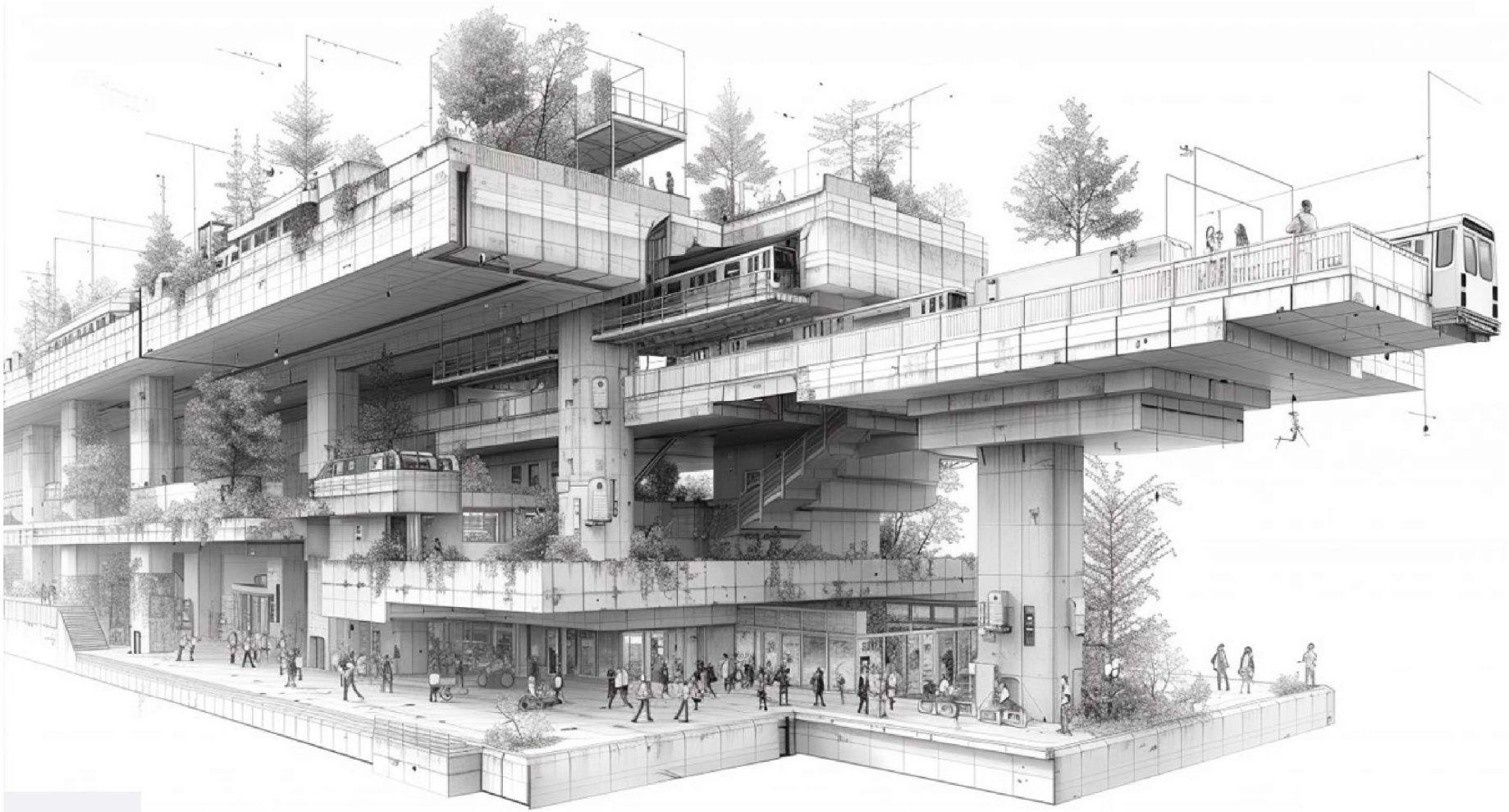


Figure 6.4.17 : Arcology - Niagara Escarpment II - Train Zone - Sectional Perspective - an alternative showing conceptual Train Station showing the thicker slabs required to hold multiple uses - illustration by Midjourney



Figure 6.4.18 : Arcology - Niagara Escarpment II - Amenities and Services - Sectional Perspective - a different style showing conceptual semi-public space showing the thicker slabs required to hold green infrastructure - illustration by Midjourney with color added, thicker slabs, altering tree sizes and bushes added in Adobe Fire Fly



Figure 6.4.19 : Arcology - Niagara Escarpment II - Amenities and Services - Sectional Perspective - an alternative showing conceptual semi-public space showing the thicker slabs required to hold green infrastructure in comparison to slabs required commercial use - illustration by Midjourney with color added, thicker slabs, stepped concrete slabs, altering tree sizes and bushes added in Adobe Fire Fly



Figure 6.4.20 : Arcology - Niagara Escarpment II - Amenities and Services - Perspective - a variation showing a community roof garden and cafe with seating area - illustration by Midjourney and trees altered and thicker slabs added in Adobe Fire Fly

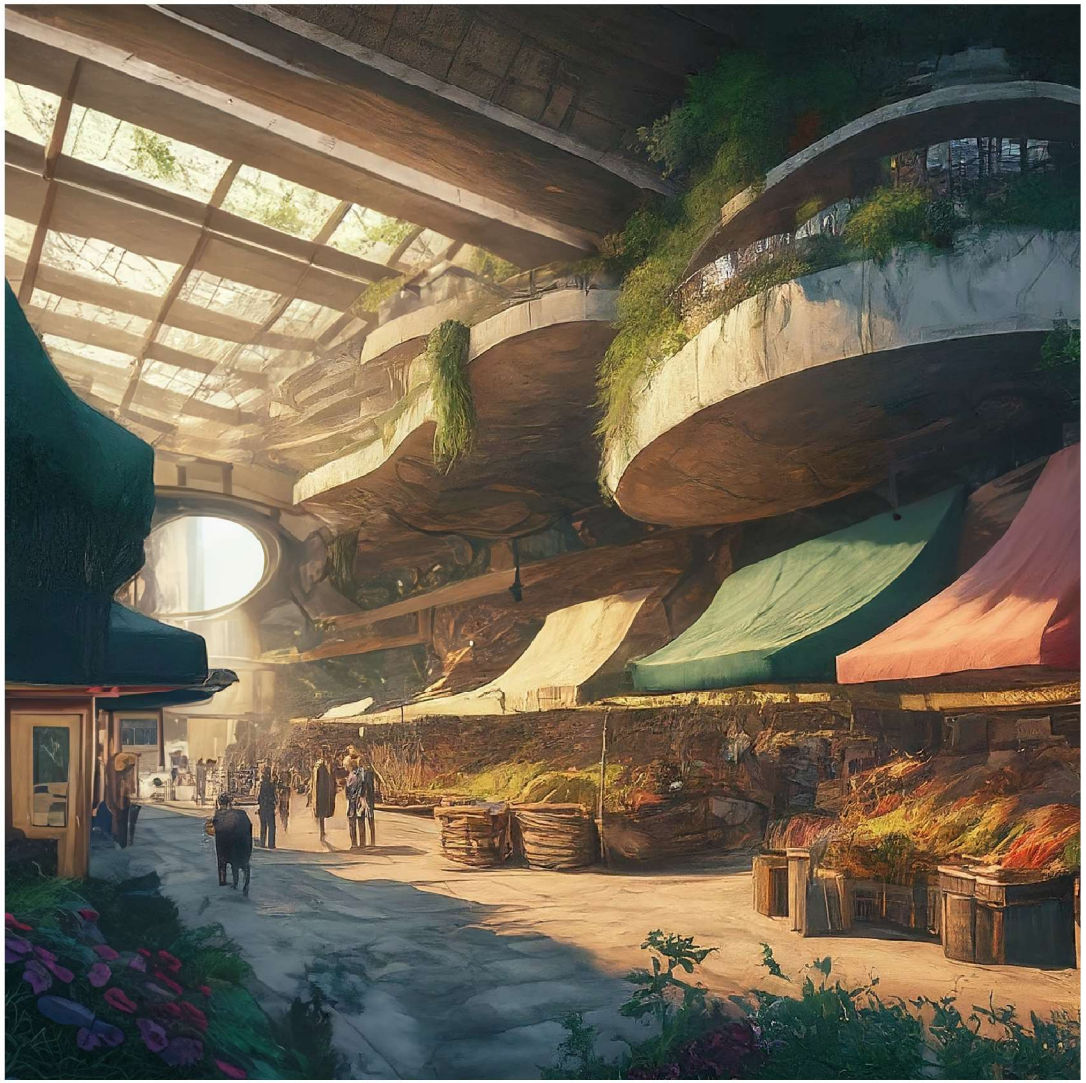


Figure 6.4.21 : Arcology - Niagara Escarpment II - Amenities and Services - Perspective - a variation showing a conceptual of a community market with skylight - illustration by Midjourney and community interactions, skylights, bushes, cafe on 2nd floor added in Adobe Fire Fly



Figure 6.4.22 : Arcology - Niagara Escarpment II - Water way - Perspective - a variation showing a conceptual of an open space configuration with community spaces and cafes to integrate bushes in internal spaces showing the variation of fish to clean the water and potential filtered water - illustration by Midjourney with cafe, plants, opening in the concrete, removal of fish in the aquarium added in Adobe Fire Fly



Figure 6.4.23 : Arcology - Niagara Escarpment II - Water way - Perspective - a variation showing a conceptual of an intimate open space configuration with community spaces and cafes to integrate bushes in internal spaces showing the the size of the fish tank - illustration by Midjourney and community interactions, cafes, floor variation to discourage people from approaching the aquarium, opening in the concrete, creating spaces that look similar to an italian hill top town added in Adobe Fire Fly



Figure 6.4.24 : Arcology - Niagara Escarpment II - Water way - Perspective - an aquaponic variation showing a conceptual of an open space configuration with community spaces - illustration by Midjourney with hanging plants, cafe and residential windows, change density of fish in the aquarium added in Adobe Fire Fly



Figure 6.4.25 : Arcology - Niagara Escarpment II - Water way - Perspective - a variation showing a conceptual of an intimate space configuration a walk way that leads to residential spaces- illustration by Midjourney add walkway and railing, opening that leads to a residential zone, bushes added in Adobe Fire Fly



Figure 6.4.26 : Arcology - Niagara Escarpment II - Residential Zone - Sectional Perspective - a dense multiple floor variation showing conceptual housing configuration in tower form and the potential for green infrastructure - illustration by Midjourney with color added, thicker slabs, altering tree sizes and bushes added in Adobe Fire Fly



Figure 6.4.27 : Arcology - Niagara Escarpment II - Residential Zone - Sectional Perspective - a dense multiple floor variation showing conceptual housing configuration in tower form and the potential for green infrastructure that begs the question where is the limit of such a structure in an Arcology- illustration by Midjourney thicker slabs, altering tree sizes and bushes added in Adobe Fire Fly



Figure 6.4.28: Arcology - Niagara Escarpment II - Residential Zone - Sectional Perspective - a dense multiple floor variation showing conceptual housing configuration to integrate trees, bushes and grass highlighting the variety of spaces and use - illustration by Midjourney with color added, thicker slabs, altering tree sizes and bushes added in Adobe Fire Fly



Figure 6.4.29 : Arcology - Niagara Escarpment II - Residential Zone - Sectional Perspective - a large variation showing conceptual housing configuration to integrate trees, bushes and grass highlighting the variety of spaces and use - illustration by Midjourney with color added, thicker slabs, altering tree sizes and bushes added in Adobe Fire Fly



Figure 6.4.30 : Arcology - Niagara Escarpment II - Residential Zone - Sectional Perspective - a variation showing conceptual housing configuration to integrate trees, bushes and grass highlighting the value of staircases - illustration by Midjourney with color added, thicker slabs and some bushes added in Adobe Fire Fly



Figure 6.4.31 : Arcology - Niagara Escarpment II - Residential Zone - Sectional Perspective - a variation showing conceptual housing configuration to integrate trees, bushes and grass highlighting different spaces- illustration by Midjourney with thicker slabs and some bushes added in Adobe Fire Fly



Figure 6.4.32 : Arcology - Niagara Escarpment II - Residential Zone - Perspective - Community Cafe in an Open Space - illustration by Midjourney with trees, skylight, background and birds added in Adobe Fire Fly



Figure 6.4.33 : Arcology - Niagara Escarpment II - Residential Zone - Perspective - Intimate Open Community Space with green wall - illustration by Midjourney with dome extension, some hanging plants added in Adobe Fire Fly and first generation of Promo AI



Figure 6.4.34 : Arcology - Niagara Escarpment II - Residential Zone - Perspective - Open Space with artificial lighting - illustration by Mid-journey with benches and bushes added in Adobe Fire Fly



Figure 6.4.35 : Arcology - Niagara Escarpment II - Residential Zone - Perspective - Night sky showing with artificial lighting in semi public space - illustration by Midjourney with benches, green lights, removal of futuristic elements and night sky added in Adobe Fire Fly

6.5 Quantifiable Benefits: Deliverables of Arcologies

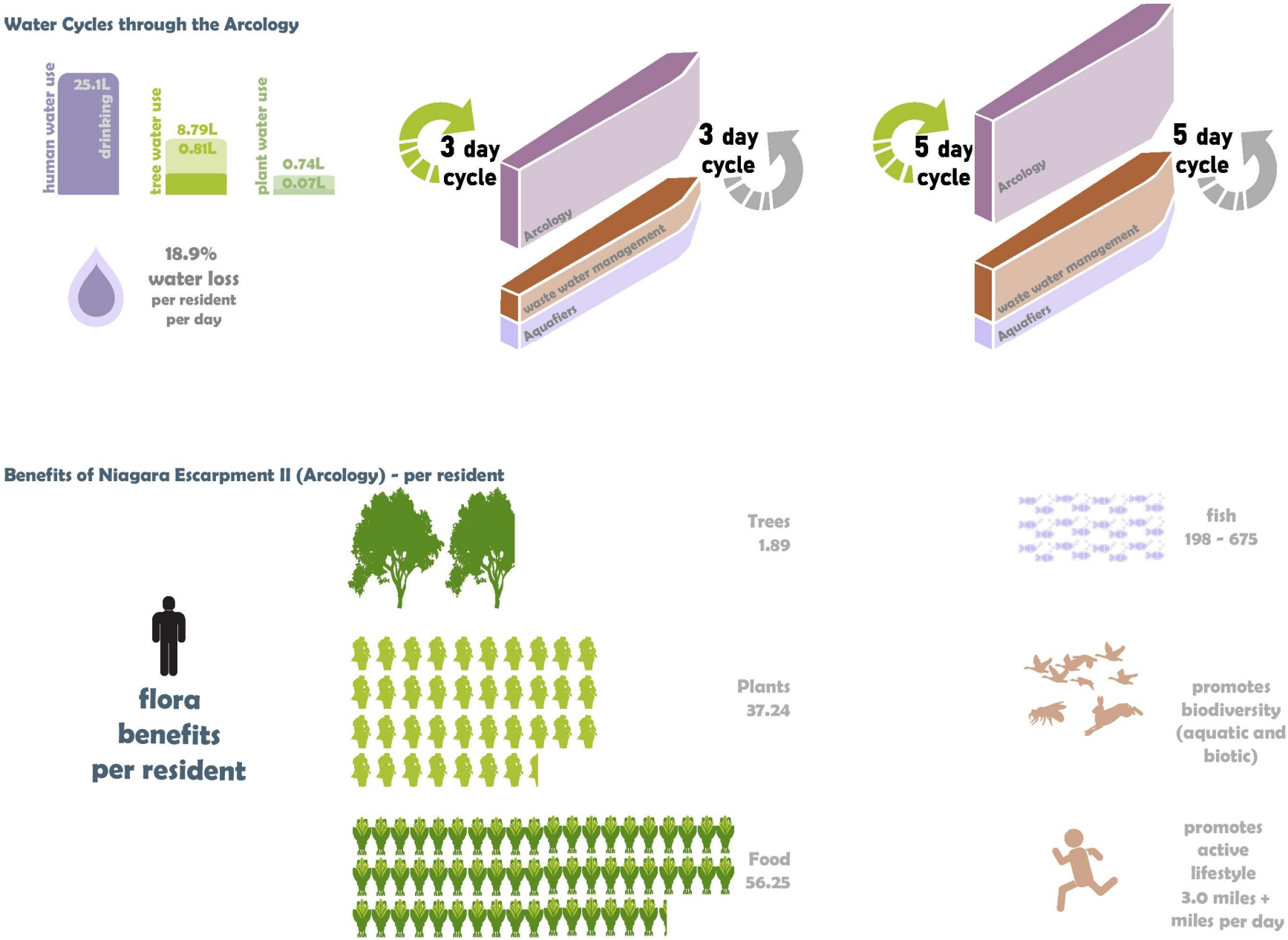


Figure 6.5.1 : Benefits for Niagara Escarpment II‘s Arcology - Quantity in Green Infrastructure

Niagara Escarpment II (Arcology) - Volume

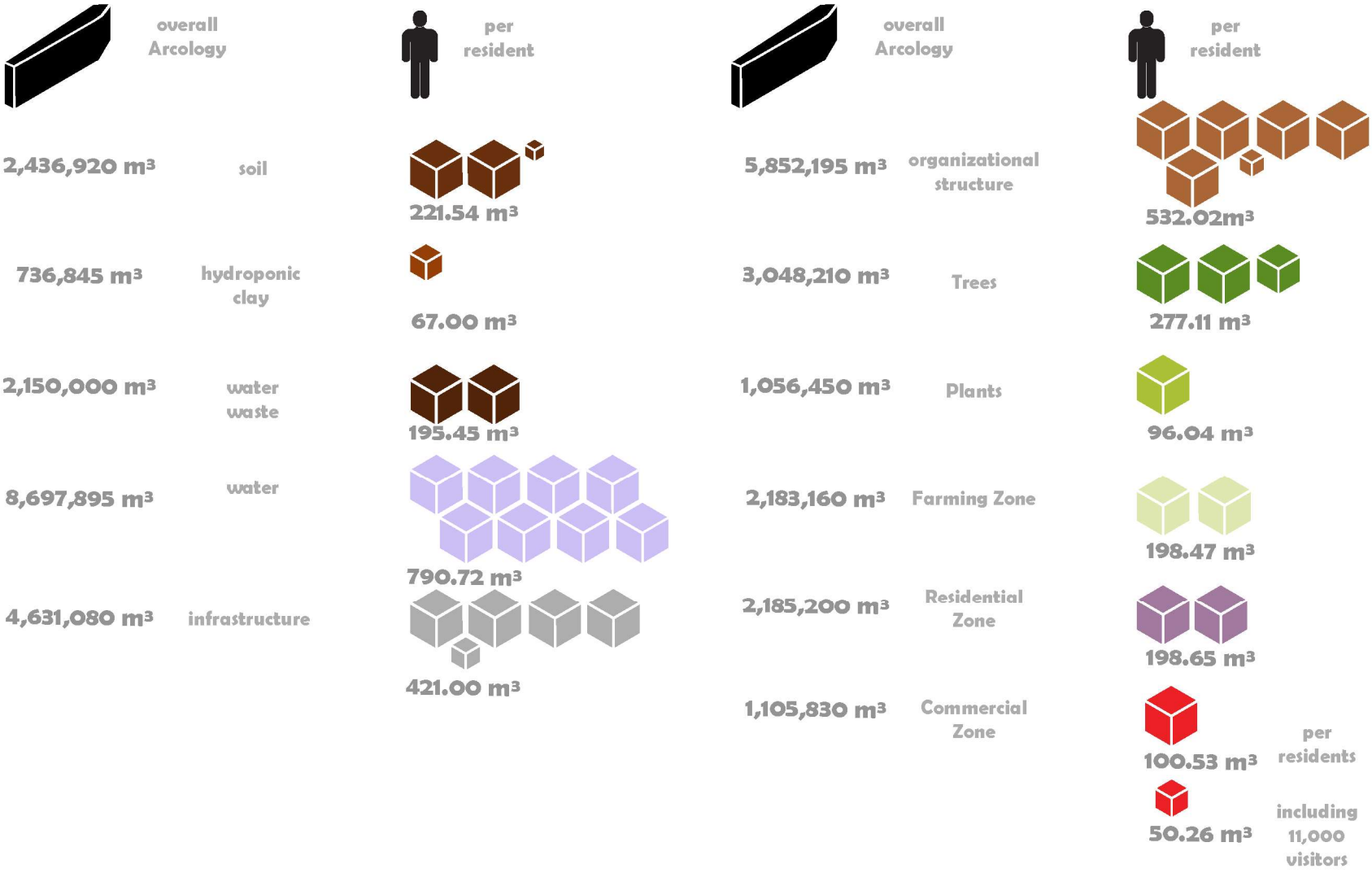


Figure 6.5.2 : Quantifiable Elements of Niagara Escarpment II‘s Arcology - in Volume

We do not claim - we prove. It is not your obedience that we seek to win, but your rational conviction. You have seen all the elements of our secret. The conclusion is now yours to draw - we can help you to name it, but not to accept it - the sight the knowledge, and the acceptance must be yours.

- John Galt, Fictional Character from Atlas Shrugged, written by Ayn Rand.



CONCLUSION



Figure 7.1 : Arcology‘s Section In Search of the Ideal - Author‘s first conceptual illustration inspired by Étienne-Louis Boullée‘s Newtonian. By Photoshop and AutoCAD

Conclusion

This overall thesis explores the potential of the Arcology, a concept first developed in the 1960s, as an updated model for achieving ecological integration within human settlements. Due to its large scale, its capacity for system interconnectedness, and its ability to integrate ecosystems with urban developments, the Arcology concept provides compelling possibility for coming to terms with the global climate change that will shape humanity's future. The design thesis itself, a proposal for the Niagara Escarpment II, is an Arcology envisioned for Niagara Falls, one that demonstrates how water, air, waste, and energy systems can co-exist with biological processes provided by developing ecosystems within urban processes. Overall, this work urges a search for a more holistic, visionary, utopic approach that aims to mitigate the environmental impact of urban development and contribute to a sustainable future.

Present-day urban planning approaches, and their accompanying architectural solutions, often offer illusory solutions that deny the big picture future reality, focusing instead on short-term economic gains at the expense of long-term sustainability. This failure to address the root causes of ecological degradation and climate change reflects a broader systemic problem embedded within the normative framework governing urban development. Arcology, as demonstrated through the Niagara Escarpment II prototype, presents not only an architectural innovation but a quintessential shift in how we integrate human and ecological systems. By embracing an interdisciplinary systems approach and incremental optimization, the Arcology model can trigger positive societal change, steering us towards a more adaptive way of living where urban settlements harmonize with the natural world.

Current urban planning practices fail to address long-term environmental consequences due to the excessive promotion of ecological architectural concepts that lack pragmatic solutions. Expansion prioritizes short-term economic benefits, leading to urban sprawl and disconnection between urban systems and ecological processes. The Arcology concept challenges this paradigm by proposing core integration between city designs and ecosystems. This shift necessitates an interdisciplinary approach where a team of architects, urban planners, engineers, ecologists, landscapists, scientists, social scientists and such collaborate to develop cohesive enclosed systems.

Arcology development challenges include planning and managing comprehensive building at massive scales, creating steady and longer-term investment, technological / engineering innovations, system integration, and long-term management. Moreover, the management of interconnected systems requires constant monitoring, control mechanisms, policies, goals, and consultations as required well into the future. It can be summarized in a series of C's: Cost, Collaboration, Control, Communication, and Coordination.

The benefits of considering an Arcology include possible solutions to global issues such as overpopulation, resource scarcity, and climate change by significantly increasing ecosystem services to urban settlements. In layman's terms, they provide the opportunity to provide self-sufficient urban environments that promote the development of ecosystem services within a denser urban context and avoiding the problems of wasteful sprawl.

The design principles explored in this thesis acknowledge that many symbols and urban forms carry underlying meanings, often influenced by historical contexts, including colonialism. While this thesis does not associate with any political symbols or narratives in the proposal, it recognizes the importance of cultural sensitivity. This allows for adjusting symbols and forms to reflect evolving societal values and cultural narratives. In Canadian history, the Wacousta Syndrome, a concept developed by Canadian historical landscape philosopher Gaile MacGregor, speaks to a colonial society initially occupying isolated fortifications in the wilderness, living in a state of anxiety not just of nature but of the country's original First Nations.

Despite the prevailing image of the colonial fort, megastructure forms can also be found in ancient First Nations precedents such as Cahokia, a thriving pre-Columbian city near modern-day St. Louis, Missouri. Built by the Mississippian culture between 1050 and 1350 CE, Cahokia was home to Monks Mound, the largest prehistoric earthwork in the Americas. This monumental city exemplified advanced urban planning, integrating complex social, political, and ceremonial systems with the surrounding natural environment. As a hub of trade and cultural exchange across North America, Cahokia demonstrates how architecture and urban systems can embody both functionality and deep symbolic meaning. The city's decline, often attributed to

environmental stress and resource depletion, serves as a cautionary tale about the fragility of human systems when disconnected from long-term ecological sustainability.

The Niagara Escarpment II Arcology seeks to address these historical lessons laid out above, the anxieties and social limitations of forts and the quick depletion of local resources in rapidly growing settlements like Cahokia. This is done by proposing a framework required to have the capacity to accommodate the evolving social complexity that would continuously drive the Arcology into a state of development and growth. With its external form initially inspired by an Ocean Liner, and an interior structure reminiscent of an Italian Hill Town, the design thesis prototype reflects the potential of Arcology to blend ecological harmony with ongoing human adaptability. The exterior and interior forms are one narrative of multiple potential narratives that can be adapted to many cultural contexts. While full-scale construction may remain a distant and never arrived at goal, the concept provides a tangible exploration of how Arcologies can reimagine urban landscapes, organizational systems, and interactions between ecological and social processes.

By learning from historical precedents like Cahokia and aligning with evolving societal narratives, modern technological, and ecological strategies, the Arcology model illustrates a new paradigm for urban development. This approach prioritizes the integration of architecture, culture, and environment, envisioning settlements that are not only functional but also highlight the value of integration, contribution, and resilience.

One must consider a multi-layered lens in all aspects to solve an Arcology. Critical analysis reveals that integrating systems requires long-term management; therefore, iterative and incremental optimization cycles are the foundation of designing arcologies. This also limits the architect‘s role from imagining a small and imagined single-function building into a system that adapts to change. This avoids static designs that do not handle the dynamic nature of complex systems for both urban and ecological processes. The corner of the design can build on Capra’s three criteria of structure, pattern, and process. This will prioritize the interconnected subsystems and embrace feedback loops to create an adaptive and long-term architectural structure that has the capacity to evolve. This is due to the non-linear nature of ecological systems that demand flexibility, buffers, and tolerances. Iterative design cycles informed by constant data analysis and feedback loops enable architects to refine their designs and accommodate unforeseen challenges. This process mirrors biological evolutions and systems thinking, where solutions organically emerge through continuous adaptation and improvement.

The complexity of such systems with conventional architectural practices requires several proposed alternatives, which can be very time-consuming. While human creativity remains essential, artificial intelligence (AI) can be an effective tool in the iterative design process. Generative AI models can facilitate the rapid exploration of design variations and a more extensive range of possibilities to consider. This paves one of the various solutions where AI can be used as a tool to augment human processes. Generative AI may also be used to monitor and control systems during the construction phase, but this portion is beyond the scope of this thesis.

Niagara Escarpment II Arcology will propose a pragmatic systems framework applied under such an updated Arcology design approach This framework prioritizes complex systems thinking and SOHO (Self-Organized Holarichal Open) Systems Analysis to map cyclic metabolic structures. It will leverage flexible and adaptable infrastructure based on Mat Building principles. The overall megastructure form will be informed by statistical analysis and general rules of thumb to set basic achievable milestones with 3D interactions rapidly generated by Artificial Intelligence (AI). This approach is intended to facilitate iterative design cycles and adaptive governance management to ensure the development of this system.

Paolo Soleri envisioned megastructures to integrate human settlements with the environment. Soleri’s Arcology designs aimed to minimize urban sprawl and promote ecological principles. Despite this large scale, he criticized overarching global solutions and blamed the wave of urban sprawl on architect’s like Constantinos Doxiadis’s Ecumenopolis model. He instead advocated for compacting urban settlements and integrating the environment. The work was illustrated with large-scale striking images that revealed overall mega structural urban forms but lacked precise information

regarding the internal systems. Reviews varied dramatically, and echoed the challenges of realizing the Arcology, particularly with social and engineering concerns.

Ironically, megastructures had been accepted as a global solution at that time with popular designs from Le Corbusier and Buckminster Fuller in circulation. While megastructures often focused on technology and a machine-like aesthetic, housing the masses, Arcology emphasized ecological harmony with human needs. Even the ecologically based criticism of Ian McHarg and Lewis Mumford was wary of the Arcology model despite the unified environmental agenda. The movement faced criticism for neglecting to exhibit practical and potential solutions to the ongoing social and environmental issues. Therefore, Arcologies remained a fantastic dream, perhaps to be resolved in the distant future, but few since had tried to revive that dream.

Fumihiko Maki offered an alternative, more pragmatic view of megastructures, one focusing on adaptability and integration with natural systems by introducing complex aesthetics such as those of Italian hilltop towns. In comparison, Dutch Structuralists like Hermann Herzberger tended to develop dense sections and looser more modular plans. These solutions were elaborated on by Team 10's overall influence, emphasizing relationships, hierarchies in spaces, and organization in the plan when embarking on grand schemes. The practicality and solution-based arguments of the structuralists steered public perception towards the possibility of such elaborate structures, but it required colossal obstacles. Specifically, ecological megastructures faced challenges like funding, managing complex systems, engineering concerns, and managing uncertainty. This concluded with passages outlining a design approach that came with pre-conditions. The ecological megastructure had to have significant initial funding from forward-thinking entities. The second was that engineered systems had to innovate and integrate systems but also had to be designed for adaptation and controlled failure. Ecologists had to be involved to ensure the reliance on self-regulating biological processes can mature over time. Undertaken today, such venture requires interdisciplinary teams for complex design considerations. Today, this highlights the necessity of long-term management to maintain social and ecological balance.

Ecological megastructures conceived today should have repetitive themes visible in their physical attributes, typology variations, materiality, and system integration. They are visible in three existing precedents analyzed in this thesis: the Place Bonaventure Hotel, Barbican Center, and Biosphere II, which exhibited successful thriving ecosystems over long periods. Their failures highlighted a lack of knowledge to merge ecosystems with social systems within ecological megastructures and we need to focus on developing long-term solutions that consist of incremental optimization. Arcologies require a transformative design paradigm for sustainable urban settlements. In the context of this thesis, we will explore the potential of an Arcology with the following features: The exterior will resemble an "Oceanliner" form with a material and typological porosity similar to an "Italian Hilltown" aesthetic, one built with massive concrete forms, frameworks and openings to enhance natural light within the structure.

The design's site analysis reflects on features of the location of the Arcology, Niagara Falls, Ontario. It highlights the region's ecological properties such as the Niagara Escarpment, watersheds, natural drainage, and the quality of existing water systems. It alludes to Niagara Falls's strategic location, being a tourist attraction, close to the US border, and connected to many natural lakes, rivers, and waterfalls. It is a natural attractor for biodiversity due to its bird migration networks. The intent of Niagara Escarpment II is to biomimic some processes from the Niagara Escarpment mainly due to its rocky soil and natural system's resilience. It can, therefore, adapt.

The intent of exploring systems thinking analysis is to synthesize a framework to enhance the incorporation of ecosystem services into megastructures. This ecosystem approach considers social and ecological systems as interconnected, with a focus on maximizing the integration of ecosystem services. It emphasizes understanding the flow of energy, materials, and information within these systems. The intention of incorporating systems thinking is because traditional approaches rely on reductionist methods which minimize systems into smaller parts and fail to design for the overall operating system. This linear reduction leads to the conclusion that environmental and urban environments should typically be separated. Although natural

(and social) ecosystems are complex and unpredictable, they are resilient and combine features that evolved positive and negative feedback loops that regulate the system. They take time to process, time to mature, time to monitor but in the end offer rewards and results in free eco-system services. Such ecosystems also involve nested hierarchies and therefore require various scalar levels of analysis. This approach requires a shift of perspective from controlled environments to open systems, from complicated to complex interactions, and from static plans to problem-solving strategies.

This situation of complex systems urges the shifting to an alternative paradigm. Architecture is a field that deals with concrete quantifiable measurements while systems thinking deals with the abstraction of ideas because the cycles are so complex and potentially massive. Therefore, it outlines the nature of ecosystems and the perceived behavior of living systems by restructuring their organization, pattern mapping, and analyzing processes. This thesis provided an example of how to adapt a system's thinking terminology to architecture to define leverage points that affect states of growth in an Arcology. In the thesis analysis, interactions between boundaries (resilience) have the highest potential for a leverage point. It is also important to define visual symptoms that indicate a specific operating state. In the case of Arcology, my analysis indicated recurring pathways (hierarchy) and collective behaviors (fractalization) are a clear indicator of growth. In layman's terms, ecosystems are complex and exhibit organic growth over time which leads to non-uniform distributions (and decisions) over time, and therefore, it is impossible to predict the Arcology's final form.

The design process for the Niagara Escarpment II therefore requires the design intent to focus on increasing interactions, shaping density, creating walkable structures, reducing living spaces, and increasing public spaces. This thesis outlines the organizational structure of these processes and guides the design process for positive and negative feedback loops. The architect can also focus on functions within the network that highlight key interactions. This Arcology investigates the Heat, Water, and Waste systems and keeps Energy Systems with a minor addition of photovoltaic cell integration due to their high return value. Through the zoning and their habitats, the Arcology becomes an exercise of restructuring systems that is resolved through iteration cycles over time.

The resolution of Arcologies is intended to integrate the various system zones together, which requires significant restructuring, which is why the analysis may best and maybe only be understood in cross-section. This design situation of open-endedness leads us to a quick historical overview of generative artificial intelligence. The intention in this thesis is to use AI as a tool to assist the designer in generating 3D design options that can further assist in the resolution of the integration of complex systems within the Arcology when dealing with multi-disciplinary teams.

As an example, by calculating a basic parameter of human processes like population size, placed inside the extensive structures of the Arcology and its integrated subsystems, which include vertical farming, living spaces, public spaces, and amenities, the Niagara Arcology can be earmarked for circa 11,000 residents and 11,000 visitors (maybe in future becoming circa 20,000 residents only). Recall that the design of the Arcology in this thesis is inspired by historical Italian hilltop towns such as Assisi and Orvieto of similar population, and integration of those ecological processes of the Italian regions inherent in historically evolved hill town life is an inspiration. Such a population structuring establishes a conceptual framework to develop Arcology building cross-sections for analysis, this resulting in a series of calculated predictions regarding water volume, soil volume, and overall volume of trees which vary in height. Lastly, hill town life is considered a very attractive lifestyle option globally, an assumption borne out by the large number of tourist visitors.

The above statistical projections, the specifics of the actual building design aside, all illustrate the ultimate potential of an Arcology. The numbers seem impressive, but these speculations, however focused in analysis, remain utopic and imagined conclusions that will vary upon construction. However, just as an example, and in one minor illustrative conclusion, two evidence points of real benefits are that the naturalization along the edges of the City of Niagara Falls will increase to up to 17% and water will be recycled to up to 300 – 500%. Water can even be returned to natural systems, therefore hypothetically improving the quality of water in Canada's lakes over long periods of time. This is the ripple effect of a complex systems approach. Although Niagara Escarpment II is a visionary and complex project, the overall notion remains that its extraordinary social and ecological magnitude can be realized in nothing less than an Arcology.



Figure 7.2 : Niagara Escarpment II‘s Arcology Logo - illustration by Midjourney

Bibliography

Aiello, Carlo, Paul Aldridge, Noemie Deville, Anna Solt, and Jung Su Lee. 2014. Evolo Skyscrapers. 2 : 150 New Projects Redefine Building High. Los Angeles: Los Angeles : eVolo.

Allen, Craig R, Joseph J Fontaine, Kevin L Pope, and Ahjond S Garmestani. 2011. "Adaptive Management for a Turbulent Future." Journal of Environmental Management 92 (5): 1339–45. https://doi.org/10.1016/j.jenvman.2010.11.019.

Allen, Craig R, Joseph J Fontaine, Kevin L Pope, and Ahjond S Garmestani.
Almerini, Ana. "Complete Guide to Solar Panel Size." Complete Guide to Solar Panel Size, November 1, 1969. https://www.solarreviews.com/blog/complete-guide-to-solar-panel-size#:~:text=72%2Dcell%20panels.-,Solar%20panel%20dimensions%20and%20weight,80%20inches%20by%2040%20inches.

Alter, Lloyd. A look at Bucky Fuller's dome over New York City. March 10, 2014. https://www.treehugger.com/urban-design/look-bucky-fullers-dome-over-new-york-city.html (accessed Aug 14, 2017).

Apollonio, Umbro, 1911-1981. 1973. Futurist Manifestos. London]: Thames and Hudson, p30. Banham, Reyner. 1976. Megastructure : Urban Futures of the Recent Past. 1st U.S. ed. ed. London; New York; London : Thames and Hudson, 1976: Thames and Hudson; Harper & Row.

Avermaete, Tom. "From Deep Structure to Spatial Practice, Team 10, Structuralist Attitudes and the Influence of Antrhopology." In Structuralism Reloaded: Rule-Based Design in Architecture and Urbanism, by Tom Avermaete and George Vrachiliotis Thomas F. Valena, translated by Ilze Mueller, 129-132. Stuttgart/London, 2011.
Babalis, Dimitra. 2006. Ecopolis : Revealing and Enhancing Sustainable Design. Firenze: Firenze : Alinea.

Banham, Reyner. 1976. Megastructure: Urban Futures of the Recent Past. 1st U.S. ed. ed. London; New York; London : Thames and Hudson, 1976: Thames and Hudson; Harper & Row.

Bateson, Gregory. 1979. Mind and Nature : A Necessary Unity. 1st ed. New York: Dutton.
Benton MacKaye, "Regional Planning and Ecology," Ecological Monographs X(July 1940).

Bhushan, Nitin, Linda Steg, Lise Jans, and Casper Albers. „Does Installing Photovoltaic Panels Affect Daily Electricity Usage Patterns? A Generalized Additive Model Approach." Energy and Climate Change 2, (2021): 100052. doi:10.1016/j.egycc.2021.100052. https://www.sciencedirect.com/science/article/pii/S2666278721000295.

Blake, Anne M. and James L. Moseley. „One Hundred Years After The Principles of Scientific Management: Frederick Taylor's Life and Impact on the Field of Human Performance Technology." Performance Improvement (International Society for Performance Improvement) 49, no. 4 (2010): 27–34. doi:10.1002/pfi.20141.

Blake, William. 1977. Letters from William Blake to Thomas Butts, 1800-1803. Philadelphia: R. West.

Brennan, Rachel. "Home." Brennan Research Group. Accessed July 24, 2024. https://sites.psu.edu/rachelbrennan/eco-machine/.

Brouwer, Joke, Lars Spuybroek, and Sjoerd van Tuinen, eds. 2016. The War of Appearances : Transparency, Opacity, Radiance. Rotterdam: V2_Publishing.

Buckminster R. Fuller, Utopia or Oblivion: The prospects for humanity (New York: Overlook Press, 1969), p265.

Busbea, Larry. 2020. The Responsive Environment : Design, Aesthetics, and the Human in the 1970s. Minneapolis, MN ; University of Minnesota Press.

C. Macy, S. Bonnemaison, 2003. Architecture and Nature: Creating the American Landscape. London, UK: Routledge.

Capra, Fritjof. 1997. The Web of Life : A New Scientific Understanding of Living Systems. 1st Anchor Books trade paperback ed. New York, N.Y: Anchor Books.

Capra, Fritjof. 2007. “Sustainable Living, Ecological Literacy, and the Breath of Life.” Canadian Journal of Environmental Education 12 (1).

Carina Wyborn. 2015. “Co-productive governance: A relational framework for Charles J. Kibert, Jan Sendzinmir, G. Bradley Guy. Construction Ecology - Nature as the basis for green buildings. Spon Press, 2002.

Conti, Robert F., ‚Frederick Winslow Taylor‘, in Morgen Witzel, and Malcolm department of the interior technical guide. https://www.doi.gov/oepc/adap department of the interior technical guide. https://www.doi.gov/oepc/adaptive-management Web site.

Doxiadēs, Kōnstantinos Apostolou, and J. G Papaiōannou. 1974. Ecumenopolis : The Inevitable City of the Future. New York: Norton.

Doxiadēs, Kōnstantinos Apostolou. 1968. Ecumenopolis, the Settlement of the Future. Athens: Athens Technological Organization, Athens Center of Ekistics.

Easterling, Keller. 1999. Organization Space : Landscapes, Highways, and Houses in America. Cambridge, Mass: MIT Press.

Easterling, Keller. 2014. Extrastatecraft : The Power of Infrastructure Space. London ; Verso. Ch 2.

Eck, Caroline. 1995. „Goethe and Alberti: Organic Unity in Nature and Architecture.“ The Structurist 0 (35).

Eigen, Manfred. 1971. “Molecular Self-Organization and the Early Stages of Evolution.” Quarterly Reviews of Biophysics 4 (2–3): 149–212. https://doi.org/10.1017/S0033583500000627.

Enviornment, UN. ur Common Future: Report of the World Commission on Environment and Development. 1987. http://www.un-documents.net/our-common-future.pdf (accessed Aug 22, 2017).

Enviornmental Protection Agency. Wastewater Technology fact sheet: The living machine. Accessed August 2, 2024. https://www3.epa.gov/npdes/pubs/living_machine.pdf.

Escher, Cornelia Regine. „Mega-Structuralism and Groupe d’Etude d’Architecture Mobile.“ In Structuralism Reloaded: Rule-Based Design in Architecture and Urbanism, by Tom Avermaete and George Vrachiliotis Thomas F. Valena, translated by Ilze Mueller, 214-216. Stuttgart/London, 2011.

Ferrer Forés, Jaime J. 2011. „Mat Urbanism: Growth and Change.“ Projections (10).
Forrester, Jay W. 1969. Urban Dynamics. Cambridge, Mass: M.I.T. Press.

Frearson, Amy. Brutalist buildings: Barbican Estate by Chamberline, Powerll & Bon. Dezeen. Sept 13 2014. https://www.dezeen.com/2014/09/13/brutalist-buildings-barbican-estate-chamberlin-powell-bon/ (accessed Dec 21, 2017).

Frearson, Amy. Brutalist buildings: Unité d‘Habitation, Marseille by Le Corbusier. Sept 15, 2014. https://www.dezeen.com/2014/09/15/le-corbusier-unite-d-habitation-cite-radieuse-marseille-brutalist-architecture/ (accessed Nov 12, 2017).

Glancey, Johnathon. A Great Place to Live. The Guardian. Sept 7 2001. https://www.theguardian.com/education/2001/sep/07/arts.highereducation (accessed Dec 21, 2017).

Government of Canada, Statistics Canada. “Census Profile, 2021 Census of Populationprofile Table.” Profile table, Census Profile, 2021 Census of Population - Niagara Falls, City (CY) [Census subdivision], Ontario, August 2, 2024. https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/details/page.cfm?Lang=E&SearchText=niagara+falls&DGUIDlist=2021A00053526043&GENDERlist=1%2C2%2C3&STATISTIClist=1&HEADERlist=0.

Graff, Gordon James. 2011. “Skyfarming.” Waterloo, Ont: University of Waterloo.

Gunnell, Kelly. 2013. Designing for Biodiversity: A Technical Guide for New and Existing Buildings, edited by Brian Murphy, Carol Williams. Second edition. ed. London: London : RIBA.

Hart, Sara. 2011. Ecoarchitecture : The Work of Ken Yeang, edited by David Littlefield. Chichester: Chichester : Wiley.

Holling, C. S. "Understanding the Complexity of Economic, Ecological, and Social Systems." Ecosystems (New York) 4, no. 5 (2001): p 390–405.

Holling, C. S. 1978. "Adaptive Environmental Assessment and Management." In https://www.doi.gov/sites/doi.gov/files/migrated/ppa/upload/TechGuide.pdf.

Ioannidou, Ersi. „Structuralism and Metabolism." In Structuralism Reloaded: Rule-Based Design in Architecture and Urbanism, by Tom Avermaete and George Vrachiliotis Thomas F. Valena, translated by Ilze Mueller, 222-226. Stuttgart/London, 2011.

John Button, A Dictionary of Green Ideas. Vocabulary for a Sane and Sustainable Future (London: Routledge, 1988),

Kay, James J. et al. 2002. Construction Ecology : Nature as the Basis for Green Buildings. London ; Spon Press.

Kay, James J., et al. "An Ecosystem Approach for Sustainability: Addressing the Challenge of Complexity." Futures : the journal of policy, planning and futures studies 31, no. 7 (1999): p 721–742.

Koolhaas, Rem. 2011. Project Japan : Metabolism Talks--, edited by Hans-Ulrich Obrist, Kayoko Ota, James Westcott and Office for Metropolitan Architecture. AMO. Köln ; London: Köln ; London : TASCHEN GmbH.

Kroll, Andrew. "Architecture Classics: Unite D' Habitation / Le Corbusier." ArchDaily, February 10, 2023. https://www.archdaily.com/85971/ad-classics-unite-d-habitation-le-corbusier (accessed Jun 22, 2024).

Lee, Taesoo D. and Abasifreke U. Ebong. „A Review of Thin Film Solar Cell Technologies and Challenges." Renewable and Sustainable Energy Reviews 70, (2017): 1286–1297. doi:10.1016/j.rser.2016.12.028. https://www.sciencedirect.com/science/article/pii/S136403211631070X.

Lynch, Kevin, A T/Jeo;y of Good City Fonn, The MIT Press, Cambridge, Massachusetts, and London, England, (1981).

Lynch, Kevin, The Image ofT/Je City, The MIT Press, Cambridge, Massachusetts, and London, England, (1960).

Madge, Pauline. „Ecological Design: "A New Critique." Design Issues , Summer 1997.

Maldonado, Tomás. 2019. Design, Nature, and Revolution : Toward a Critical Ecology. Translated by Mario Domandi. First University of Minnesota Press edition. Minneapolis: University of Minnesota Press, Chapter 2.

Manifesto for Agile Software Development, accessed February 28, 2024, https://agilemanifesto.org/.

Marino, Bruno D. V., Tilak Ram Mahato, John W. Druitt, Linda Leigh, Guanghui Lin, Robert M. Russell, and Francesco N. Tubiello. „The Agricultural Biome of Biosphere 2:: Structure, Composition and Function." Ecological Engineering 13, no. 1 (1999): 199–234. doi:10.1016/S0925-8574(98)00100-1.

Marsden, William E. "Ecology and Nineteenth Century Urban Education." History of Education Quarterly 23, no. 1 (1983). https://doi.org/10.2307/367968.

Martin, Roger L. "Strategy Is Iterative Prototyping." Harvard Business Review, June 2014, http:// hbr.org/2014/06/strategy-is-iterative-prototyping.

Maturana, Humberto, and Francisco J. Varela. 1980. Autopoiesis and Cognition : The Realization of the Living. Dordrecht, Holland ; D. Reidel Pub. Co.

McGregor, Gaile. The Wacousta Syndrome : Explorations in the Canadian Langscape. Toronto: University of Toronto Press, 1985.

McHale, John. 1970. The Ecological Context. (Rev. Ed.). New York, G. Braziller (C1970).

Meadows, D.H. 1989. System dynamics meets the press. Syst. Dyn. Rev., 5: 69-80. https://doi-org.proxy.lib.uwaterloo.ca/10.1002/sdr.4260050106

Meadows, Donella H et al. 1972. The Limits to Growth; a Report for the Club of Rome's Project on the Predicament of Mankind. New York: New American Library.

Merin, Gili. AD Classics: Habitat 67 / Safdie Architects ArchDaily. Jul 21, 2013. <https://www.archdaily.com/404803/ad-classics-habitat-67-moshe-safdie> ISSN 0719-8884 (accessed Nov 16, 2017).

Morowitz, Harold. Energy, Flow in Biology, New York: Academic Press, 1968.
Mountain Dwellings / PLOT = BIG + JDS. ArchDaily. Mar 11, 2009. <https://www.archdaily.com/15022/mountain-dwellings-big/> ISSN 0719-8884 (accessed Nov 16, 2017).

Mumford, Lewis, Patrick Geddes, and Frank G. Novak. Lewis Mumford and Patrick Geddes: The Correspondence. New York: Routledge, 1995.

Murphy, Douglas. 2016. Last Futures : Nature, Technology and the End of Architecture. London: Verso.

Odum, Eugene P. (Eugene Pleasants). 1953. Fundamentals of Ecology. Philadelphia: Saunders.

Our Building. https://www.barbican.org.uk/our-story/our-building/our-history (accessed Dec 21, 2017).

Owen, Pamela. Inside the Kowloon Walled City where 50,000 residents eked out a grimy living in the most densely populated place on earth. May 5, 2012. http://www.dailymail.co.uk/news/article-2139914/A-rare-insight-Kowloon-Walled-City.html (accessed July 18, 2017).

Pawlyn, Michael. 2011. Biomimicry in Architecture. London: London : RIBA Pub.
Pollalis, Spiro N., 1954-. 2012. Infrastructure Sustainability and Design. New York: Routledge.

Poynter, Jane. 2006. The Human Experiment : Two Years and Twenty Minutes inside Biosphere 2. New York: Thunder's Mouth Press.

Prigogine, I. 1975. "Dissipative Structures, Dynamics and Entropy." International Journal of Quantum Chemistry 9 (S9): 443–56. https://doi.org/10.1002/qua.560090854
Reyner Banham, "Megacity Montreal," Megastructures: Urban Futures of the Recent Past, New York: Harper and Row, 1976.

Rheingold, Howard. "The Millennium Whole Earth Catalog" 1994.

Roq et Rob, Roquebrune-Cap-Martin, France, 1949. n.d. http://www.fondationlecorbusier.fr/corbuweb/morpheus.aspx?sysId=13&IrisObjectId=6184&sysLanguage=en-en&itemPos=157&itemSort=en-en_sort_string1%20&itemCount=215&sysParentName=&sysParentId=65 (accessed Jan 12, 2018).

Securities and Exchange Commission, USA. "Comments for the Enhancement and Standardization of Climate-Related Disclosures for Investors." SEC.gov | Comments on Proposed rule S7-10-22. Accessed August 4, 2024. https://www.sec.gov/comments/s7-10-22/s71022.htm.

Sharma-Wallace, Lisa, Sandra J. Velarde, and Anita Wreford. „Adaptive Governance Good Practice: Show Me the Evidence." Journal of Environmental Management 222, (2018): 174–184. doi:10.1016/j.jenvman.2018.05.067.

Smithson, Alison, 1928-1993. and Dendy, William, 1948-,former owner. 1974. Team 10 Primer. Cambridge: MIT Press, p 74-95.

Smithson, Alison. "How to Recognize and Read Mat-Building." Architectural Design, Sept 1974.

Solar Photovoltaic Cell Basics | Department of Energy. Accessed July 10, 2024. https://www.energy.gov/eere/solar/solar-photovoltaic-cell-basics.

Soleri, Paolo, 1919-2013. 1969. Arcology : The City in the Image of Man. Cambridge, Mass.: MIT Press, p 14.

Soleri, Paolo. 1971. The Sketchbooks of Paolo Soleri. -. Cambridge, Mass.]; (Cambridge, Mass., Mit Press, C1971): Cambridge, Mass. : MIT Press.

Southcott, Tanya. Place Bonaventure. May 1 2015. https://www.canadianarchitect.com/features/place-bonaventure/ (accessed Apr 12, 2017).

Spuybroek, Lars, Joke Brouwer, and Sjoerd van Tuinen. "In the Thick of Things." The War of Appearances: Transparency, Opacity, Radiance, 2016.

Statistics Canada Government of Canada, "Canada's Large Urban Centres Continue to Grow and Spread," The Daily - , February 9, 2022, https://www150.statcan.gc.ca/n1/daily-quotidien/220209/dq220209b-eng.htm. Accessed October 10, 2024.

Taylor, Frederick W. 1975. "Scientific Management." C.P.A. Journal 45 (2).
The Bonaventure Hotel. 2015. http://hotelbonaventure.com/en/hotel/ (accessed Apr 12, 2017).

Todd, Nancy., John Todd, and Nancy. Todd. 1994. From Eco-Cities to Living Machines : Principles of Ecological Design. Berkeley, Calif: North Atlantic Books.

Ulak, A., (2023) "Diagrammatic Abstractions: Jay Forrester's Urban Dynamics and Its Contribution to Architecture and Urban Planning in the Late 1960s and Early 1970s", Architectural Histories 11(1). doi: https://doi.org/10.16995/ah.8284.

University of Arizona. "Fast Facts." Fast Facts | Biosphere 2. Accessed June 3, 2024. https://web.archive.org/web/20180916014420/http://biosphere2.org/visit/about-biosphere2/fast-facts.

Vaswani, Ashish, Google Brain, Noam Shazeer, Niki Parmar, Jakob Uszkoreit, Llion Jones, Aidan Gomez, Łukasz Kaiser, and Illia Polosukhin. 2017. "Attention Is All You Need." https://arxiv.org/pdf/1706.03762v5.pdf.https://www.businessinsider.com/torre-guinigi-italian-tower-photos-2024-7.

Warren, Lydia. "Italian Neighbors Used to Compete by Building Tall Towers. See inside One That's Still Standing after 600 Years." Business Insider. Accessed October 15, 2024. https://www.businessinsider.com/torre-guinigi-italian-tower-photos-2024-7.

Welter, Volker. Biopolis : Patrick Geddes and the City of Life. Cambridge, Mass.: MIT Press, 2002.

Wikipedia contributors. 2024. "Findhorn Ecovillage." Wikipedia. April 12, 2024. https://en.wikipedia.org/wiki/Findhorn_Ecovillage (accessed Jun 16, 2024).

William McDonough & Micheal Braungart, "Cradle to Cradle." North Point Press.

Williams, B. K., R. C. Szaro, and C. D. Shapiro, Adaptive Management Working Group, U.S. and Washington Department of the Interior DC. „Adaptive Management: The U.S. Department of the Interior Technical Guide." . Accessed 22 September, 2024. https://www.doi.gov/sites/doi.gov/files/migrated/ppa/upload/TechGuide.pdf.

Williams, B. K., R. C. Szaro, and C. D. Shapiro, Adaptive Management Working
Williams, Byron K. Adaptive Management Technical Guide. Accessed September 22, 2024. https://www.doi.gov/sites/doi.gov/files/migrated/ppa/upload/TechGuide.pdf.

Wolverton, B. C. and John D. Wolverton. Growing Clean Water : Nature's Solution to Water Pollution. Picayune, Miss: WES, Inc, 2001.

Wolverton, B. C. How to Grow Fresh Air : 50 Houseplants that Purify Your Home Or Office. New York, N.Y: Penguin Books, 1997.

Wolverton, Bill C. and Mark Nelson. „Using Plants and Soil Microbes to Purify Indoor Air: Lessons from NASA and Biosphere 2 Experiments." Field Actions Science Reports 2020, no. 21 (2020).

Wyborn, Carina. „Co-Productive Governance: A Relational Framework for Adaptive Governance.“ Global Environmental Change 30, (2015). doi:10.1016/j.gloenvcha.2014.10.009. https://www.sciencedirect.com/science/article/pii/S0959378014001769.

Yeang, Ken. 2006. Ecodesign : A Manual for Ecological Design. Chichester: Chichester : Wiley.

Glossary

Abiotic: Refers to a substance that is not living, in scientific terms, and is necessary for the existence of life. It was first used in the 1950s by biologists to describe basic organic and inorganic compounds forming parts of the ecosystem. In 1963, Eugene Odum provided examples such as water surface.

Arcology: Abbreviation for Architecture and Ecology. The term was coined by Paolo Soleri to describe a building typology that combines architecture with ecology. In the context of this thesis, it is a derivative of ecological megastructures. An Arcology describes an architecture that aligns with ecological principles and Paolo Soleri's concepts, such as miniaturization.

Artificial: Something that does not occur naturally, often made in imitation of a natural product. 'Artificial' is a more accurate alternative to 'man-made'.

Biome: A major ecological community extending over a large area and usually defined by its main vegetation types, such as rainforest, desert, grassland, or savannah.

Biotic: Refers to living organisms, especially in their natural environment.

Buffers: The size of stabilizing storage relative to flows – tolerances for a system from entropy.

Closed System: A self-contained enviornment that depends on internal interactions within it's boundries. It does not allow matter to enter or leave, however, it allows energy (such as heat and sunlight) to enter and leave.

Club of Rome: A small elitist group of scientists, teachers, economists, and industrialists who met regularly from April 1968 onwards to examine and report on the 'predicaments of mankind', the group initially met up in Rome. The most influential aspect of their work has been the book The Limits of Growth (1972), based on elaborate computer modeling and preliminary systems thinking analysis that concluded there are limits to growth regarding the human population, food, resources, industrial output, and pollution.

Complexity: The quality of a system that has a large magnitude of components, all intrinsically linked and intertwined with each other. The atomistic approach of scientists oversimplifies and ignores the quality of synthesis within a complex system. The alternative holistic approach accepts complexity as a valuable quality of health systems and infers with those systems as little as possible. It is well-established within ecology that complex systems are far more dynamically stable than simple ones, and this includes human systems as well.

Craft: Derived from old English to mean power or skill. A particular skill is considered to be specifically a manual or healing skill. It is distinguished from 'art', reserved for more mundane (literally 'earth-related') products and services.

Cybernetics: The theory and practice of control systems, especially self-regulating control systems, and how information is conveyed around such systems, both natural and artificial. Inspired by the earth's biosphere and recorded ability to self-regulate, man-made systems have a steep learning curve to adapt to if they are to ascertain this control. This new theory provided terminology such as 'information', 'input', 'output', and 'feedback', and proposed substituting terminology such as 'dialogue', 'knowledge', 'wisdom', 'vitality', and 'explanations'.

Cycle: A series of events that recurs regularly, returning to a similar 'starting point' after a particular length of time. The natural world works in balance and cycles and experiences flows and repetitive patterns that are structured cohesively. Artificial processes may be referred to as 'cycles' but are not true cycles. Instead, they are attempts to pretend that human beings can be the net energy principle – terms such as 'recycling' or 'energy cycle' are not cyclic. Yet the 'hydrological cycle,' 'carbon cycle,' or 'nitrogen cycle' are established cyclic flows of nutrients and elements in the biosphere.

Delays: The length of time relative to the rates of the system changes.

Dynamics: The behavior exhibits variations over time of a system or any of its components.

Ecology: Originating from the Greek term 'oikos' + logos, meaning the study of the home. The study of the interconnectedness of nature, including human beings and their activities. Purist scientists sometimes point out the technical dictionary definition: ' the study of the relationships between living organisms and their environment'. In this context, ecology refers to studying the structure and function of natural systems.

Energy: Vigor, vitality, the force underlying life and movement. The original meaning is 'force or vigor, exertion, activity liveliness, the efficient exercise of power.' In 1807, it was first used by Thomas Young to refer to the 'doing of work' by physical means and was later divided into categories overused in the field of physics: kinetic, potential, light, electricity, chemical, gravitational, electromagnetic, etc.

Entropy: A measure of the degree of disorder within a system. The second law of thermodynamics states that the entropy of a closed system must always increase or decrease over time.

Environment:	The surroundings and context of something or someone; an overused term to indicate surroundings. In this context, the human environment indicates surroundings affected by human beings and the ecological environment indicates surroundings affected by ecosystems.
Environmentalism:	Aware of and concerned for the total environment. It was originally founded in the 1950s as an unfavorable reaction against the Industrial Revolution and the exploitation of the land by unsustainable growth. In the 1960s, it evolved to encourage reform against the exploitation of environmental issues against political agendas prioritizing economic growth.
Ecological Megastructure:	In the context of this thesis, encompass a generalization of the concept of Arcology. They are intended to highlight the description and function of a building typology—a massive structure that envelopes ecosystems.
Feedback loop:	The mechanism (such as rules, information, signals) that allows a change in storage capacity to affect a flow into or out of that stock. In layman's terms, it is a reactionary mechanism that signals to a system if this is a preferable or non-preferable result.
Flow:	Interaction with specific attributes (such as materials, information, etc) that enter or leave from one stored capacity (such as container, body, etc) to another over a period of time.
Goals:	The purpose or a set of expectations for a system.
Hierarchy:	Systems organized in such a way as to create a larger system. Subsystems within systems.
Holism:	The belief that systems can only be properly understood when seen as a unified whole rather than as a sum of their separate parts
Holon:	A whole system combined of a sub-set of parts, and simultaneously, part of a larger whole.
Holarchy:	A combination of the word holon and hierarchy, coined by Arthur Koestler, to describe a semi-autonomous sub-wholes (of parts) linked in a form of hierarchy to form a whole.
Holarichal nested:	The system is nested within a system and is made up of systems. Such nesting cannot be understood by focusing on one hierarchal level alone. Understanding comes from the multiple perspectives of different types of scales.

Hydrological Cycle:	The movement of water in the biosphere from the earth's surface to the atmosphere and back through a series of complex water flows.
Hydroponics:	Growing plants without soil, usually in beds of sand saturated with nutrients in solutions. It is known to require considerable attention and care and can produce high yields, depending on the crop selection.
Ideology:	A system of beliefs about human nature and society; often used to suggest such a system is characterized by inflexibility and an unwillingness to listen to other points of view.
Integration:	Putting the parts of something together to make a unified whole.
Leverage Points:	Places in the system where small changes can lead to large shifts in behavior.
Linear relationship:	An additive relationship between two elements in a system that exhibits constant proportions between cause and effect. The relationship resembles a straight line on a graph. In the context of this thesis, it is relatable to man-made urban systems and machines.
Matrix:	The place in which something develops. A word often used by green thinkers but best avoided unless you mean a mold for casting, the rock surrounding a fossil, or a rectangular array of mathematical elements.
Non-linear relationship:	An unpredictable relationship between two elements in a system where the cause does not produce a proportional effect. In the context of this thesis, it is relatable to living organisms where multiple alternative factors may greatly vary the results due to their ability to evolve, interact, adapt, etc. Living systems have cyclic patterns due to their self-organizing property to repeat desired reactions and discontinue undesirable reactions.
Ontology:	In the context of this research, theories about the nature of being refer to meta-theories that are related and may have common origins but have their own terminologies and evolution of thought.
Open System:	An environment where external interactions are free, available, accessible, and flowing within its boundaries. It allows for matter and energy to enter and leave without limits.
Paradigm:	A model for a new system that requires different goals, organizational structures, rules, relationships, sets of behaviors, parameters etc.

Static:	The behavior exhibits very little or no variations over time of a system or any of its components.
Resilience:	The ability to recover quickly from a shock. Natural systems, being complex and having many interactions, can usually recover quickly from natural interruptions due to their variety of interactions. Therefore, in the context of this thesis, resilience highlights the value of building many interactions that increase its chances to restore, recover, repair, or bounce back after a change due to an outside force.
Resistance:	Being able to withstand the threat of danger and destruction. Ecological resistance is action from central principles of doing what is necessary in a non-violent manner.
Self-Organizing:	The ability of a system to structure, to re-structure, to learn, and to diversify and complexify. In layman's terms, the system can adapt but it has a will of its own.
System:	A set of elements or parts that is coherently organized and interconnected in a pattern or structure that produces a characteristic set of behaviors, often classified as its function or purpose.
Quality:	An essential part of the character of something or somebody to be respected. The two aspects of quality are the innate and the value-laden of something. Initially used by the British writer J.B. Priestly in 1943, the American politician Adlai Stevenson first used the contrast between Quality and Quantity of American Life in 1955.
Quantity:	An amount or number of something. A helpful strategy when granularly analyzing a process or system or measuring the flows of a system.
Symbiosis:	a close and long-term relationship between two species that is beneficial for both, by extension, any such mutually beneficial relationship.
Synergy:	Working together in an integrated way, by extension, 'synergy' is sometimes used to describe how, in an integrated system, the whole system is much more than simply the sum of its parts.
Synthesis:	Seeing the whole picture; pulling all the strands together. This is not to be linked with the term 'synthetic,' which in the nineteenth century was used to denote 'man-made' (synthesized from chemicals) and by the 1930s evolved to mean artificial.

Thermal Storage:	Way of storing low-grade energy (generated by cyclic sources such as solar or tidal) so it can be used when needed. Storage methods include 'heat sinks' or 'thermal mass.'
Thermodynamics:	The exploration of energy processes, especially those involving heat.
Thinking:	Using your intelligence to its full potential. Clear thinking is the only reliable guide to appropriate behavior and it is important to trust: "Trust your own thinking and it will work out just fine" (Harvey Jackins 1983).
Trust:	Believing that things can be how you want them to be.
Utopia:	The ideal place where everything is just how you want it.
Zoning:	The designation by a competent authority of areas of land as suitable only for certain uses, in an attempt to control undesirable development. Common practice for urban planning.

Summary of Systems Principals

Systems

- More than the sum of its parts.
- Interconnections in systems operate through flows. Many of these interactions operate through a flow of information, especially in urban environments.
- The most crucial determinant of a system's behavior is its goals (function, goals, etc). However, it is the most obscure part of the system.
- System structure controls the behavior of a system. A system's behavior can be determined through repetitive feedback over time.

Feedback loops

- The mechanism (such as rules, information, signals) that allows a change in storage capacity to affect a flow into or out of that stock. In layman's terms, it is a reactionary mechanism that signals to a system if this is a preferable (positive) and encourages the interaction or non-preferable (negative) result and discourages the interaction.
- Balancing feedback loops are the source of stability and resistance to change. This is due to their inherent organizational structure to seek goals.
- Reinforcing feedback loops is a self-enhancing behavior, that leads to exponential growth or escape from the system.
- Information delivered from a feedback loop may vary from physical quantifiable information to non-physical qualitative information. Mapping the information depending on its feedback may assist in quicker decision processes.
- Systems with similar feedback structures (organizational properties) produce similar dynamic behaviors.

Complex System Behaviors

- Arise as competitive feedback loops, where one loop dominates another loop and exhibits an alternative behavior.
- A delay in the balancing of a system's feedback loops makes a system likely to oscillate.
- Changing the length of a delay may result in a large change in the behavior or the system.
- Systems often exhibit characteristics of self-organization: the ability to structure, to re-structure, to learn, and to diversify, and complexify. In layman's terms, the system can adapt but it has a will of its own.

Limits to Systems with Resilience, Self-Organization and Hierarchy

- There are always limits to resilience. It is a characteristic, not a superpower.
- Some living systems have higher resilience than other systems.
- Systems need to be managed not only for their productivity or stability, but they also need to be managed for resilience, this includes urban environments.
- Systems often exhibit characteristics of self-organization: the ability to structure, to re-structure, to learn, and to diversify, and complexify. In layman's terms, the system can adapt but it has a will of its own.
- Hierarchical systems evolve from the bottom up. Hierarchical systems are reinforced and evolve through feedback loops. In urban organizations, the hierarchy is intended to serve and manage smaller systems.

Models:

- Everything we think we know about the world and its subparts is a model, aka narrative.
- We all have strong connections with a specified model and an inclination to defend it.
- The model could be wrong and fall short of the reality of things.
- Models are to be tested and if the pattern of responses is predictable, it is concluded to become a dependable model. If it is not, then the model may be adjusted or discarded.

Appendices

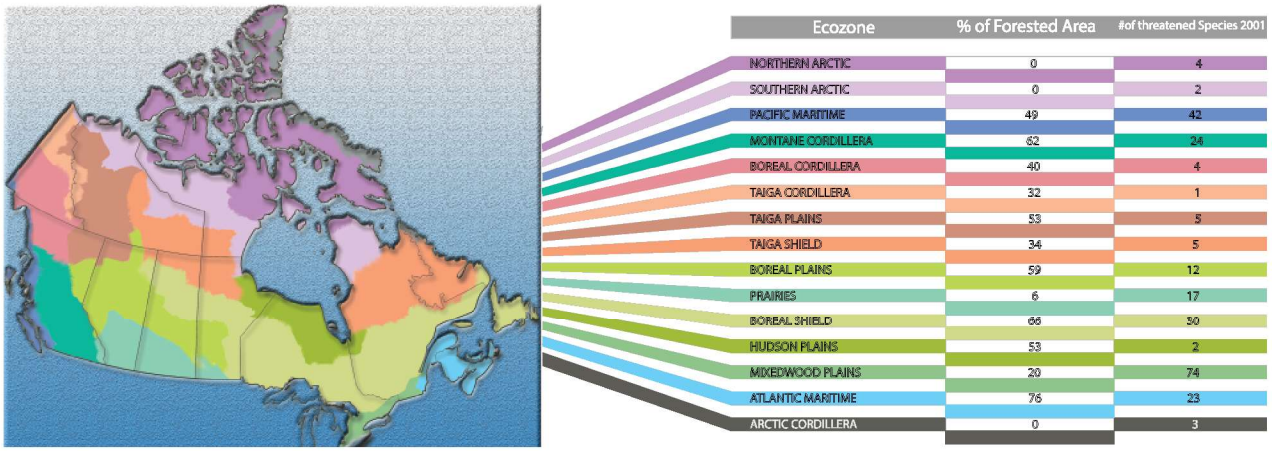
Appendix A - Additional Mapping

Appendix B - Arcology Requirement Calculations

Appendix C - Arcology Benefit Calculations

Appendix A - Additional Mapping

A.1 Ecozones



Ecozone	% of Forested Area	#of threatened Species 2001
NORTHERN ARCTIC	0	4
SOUTHERN ARCTIC	0	2
PACIFIC MARITIME	49	42
MONTANE CORDILLERA	62	24
BOREAL CORDILLERA	40	4
TAIGA CORDILLERA	32	1
TAIGA PLAINS	53	5
TAIGA SHIELD	34	5
BOREAL PLAINS	59	12
PRAIRIES	6	17
BOREAL SHIELD	66	30
HUDSON PLAINS	53	2
MIXEDWOOD PLAINS	20	74
ATLANTIC MARITIME	76	23
ARCTIC CORDILLERA	0	3

Figure A.1: Canada‘s Ecozones

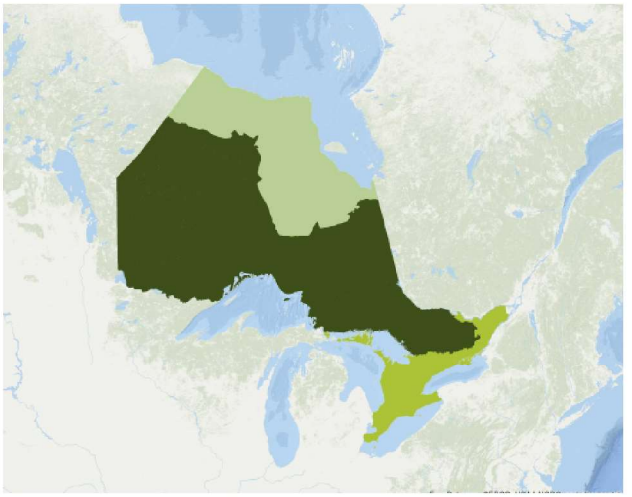


Figure A.2: Ontario has three Ecozones - Niagara Falls is located in the mixedwood plains

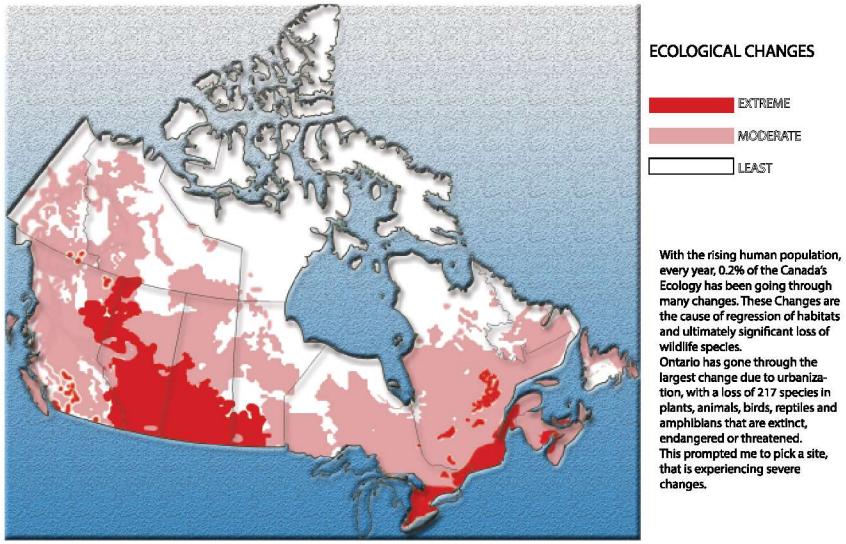


Figure A.3: Significant ecological changes in Canadian ecosystems - including Niagara Falls Region

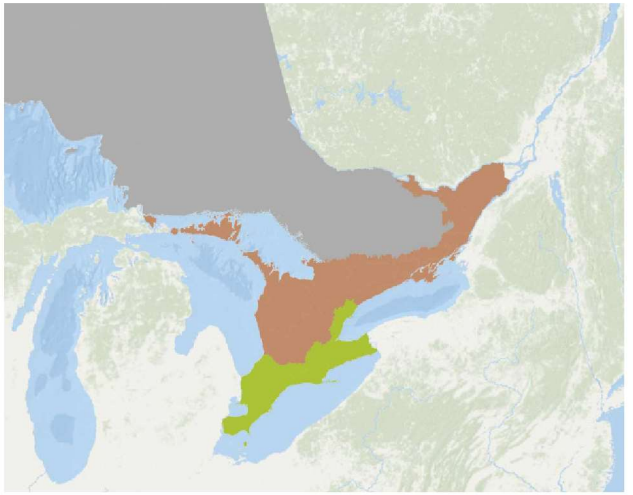


Figure A.4: Ontario has two Ecoregions- Niagara Falls is located in Lake Erie Lowlands

A.2 The GTA and Niagara Escarpment



Figure A.5: Niagara Escarpment Horse Shoe



Figure A.6: Niagara Escarpment & GTA with Ecological Processes (water sheds)

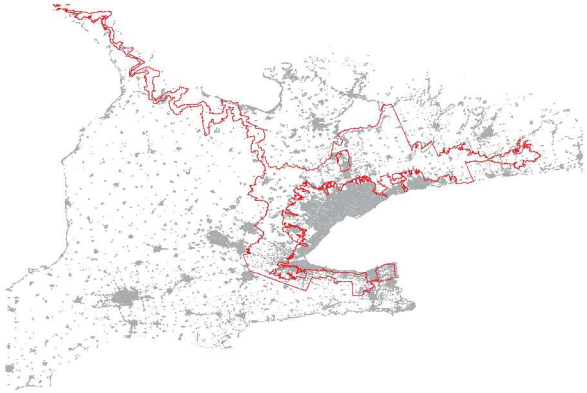


Figure A.7: Niagara Escarpment & GTA with Urban Processes (cities)

A.3 Seismic, Soil and Bedrock

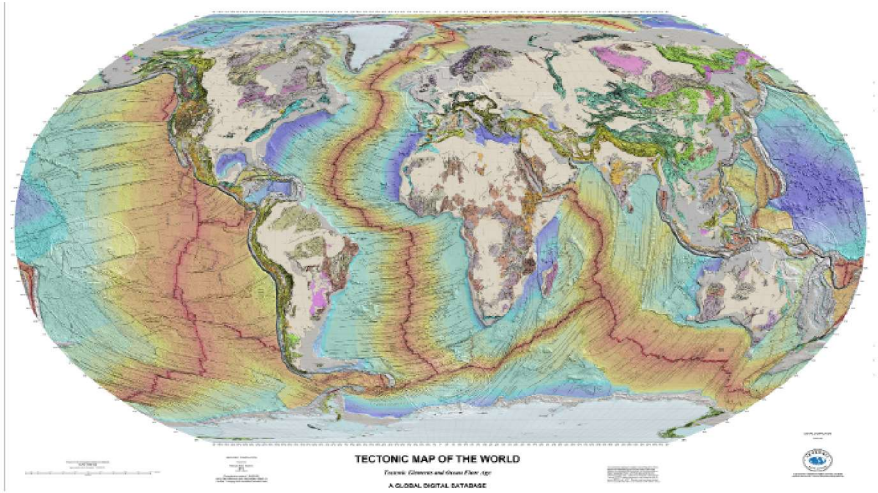


Figure A.8: Ecological Megastructures are massive structures and require to review global seismic plates

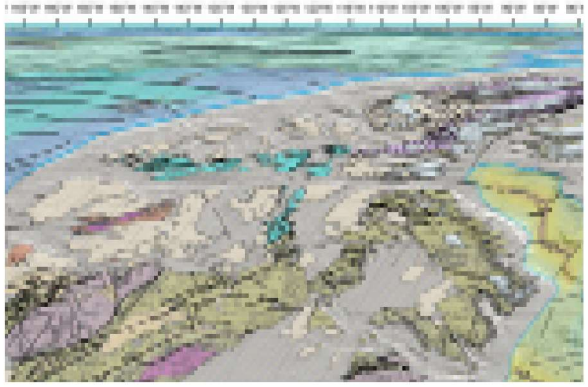


Figure A.9: No seismic plates within Niagara Falls and limited activities within the surrounding areas

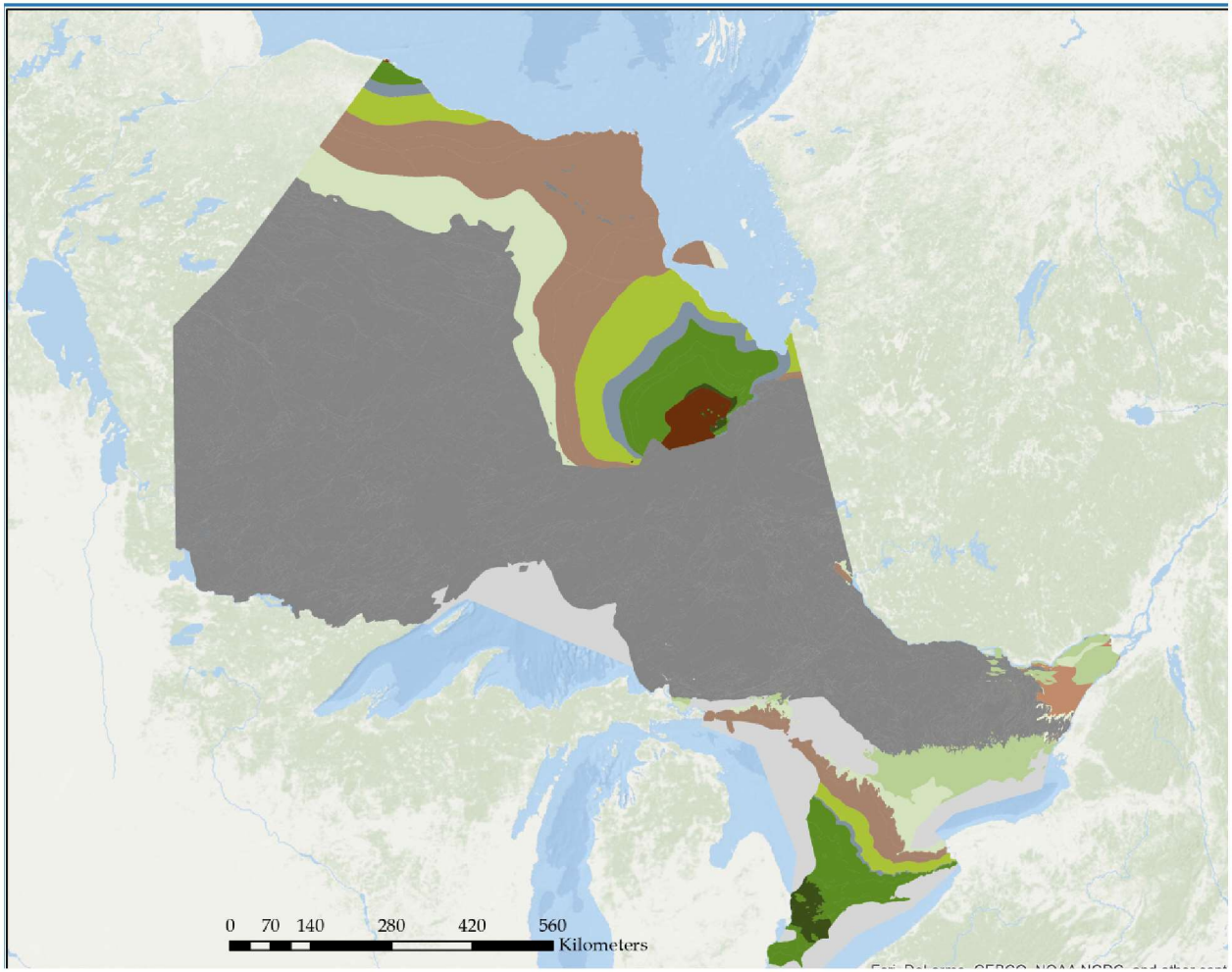


Figure A.10: Ontario Soil Drainage - Niagara Falls seems to mainly be clay and loam.

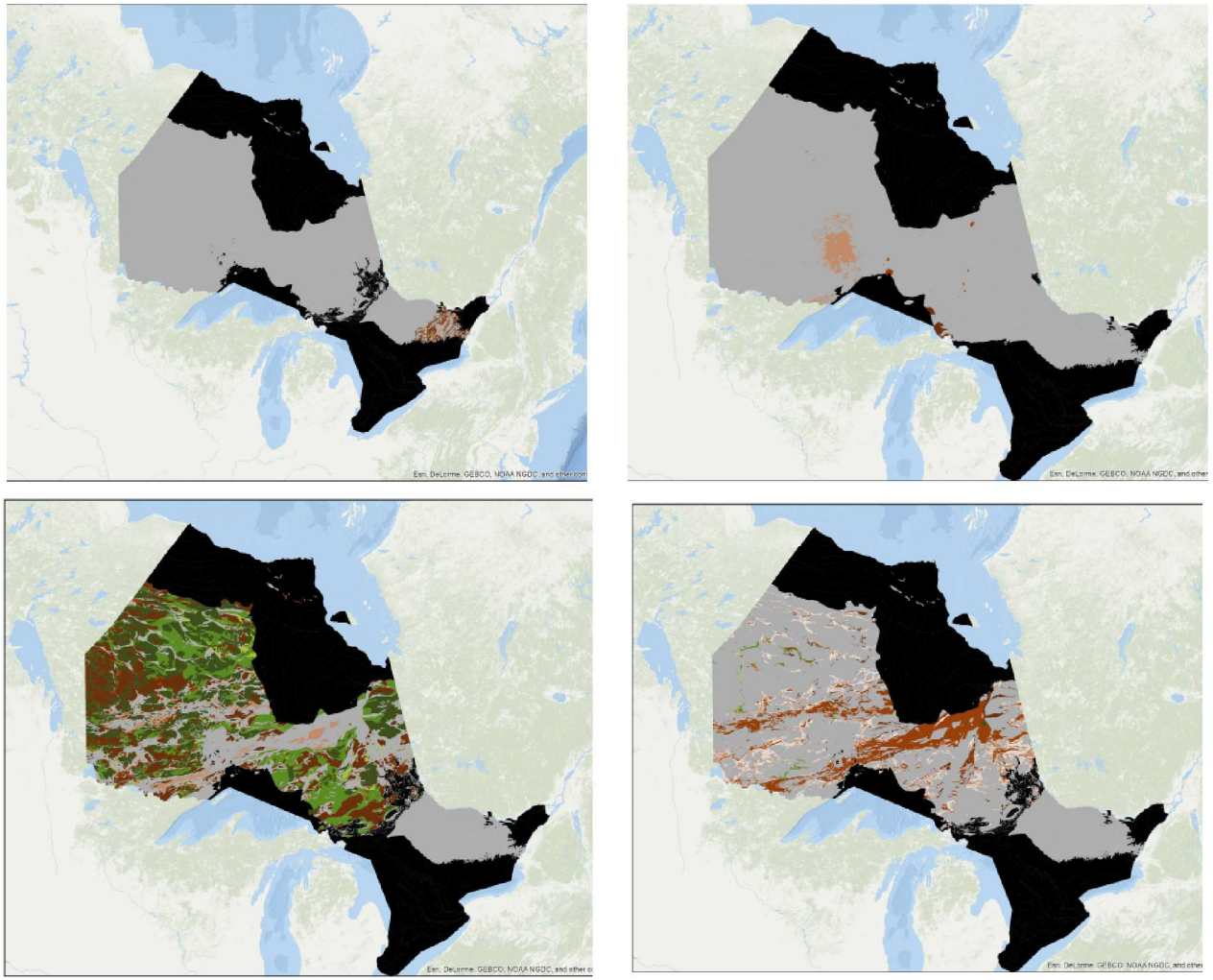


Figure A.11: Geological bedrock - marbeling through out a variety of ecozones. Niagara Escarpment is known to be bed rock but due to it‘s close proximity to Niagara Falls, the soil is mainly covered with man-modified structures

A.4 Quality of Water & Flood Occurrences

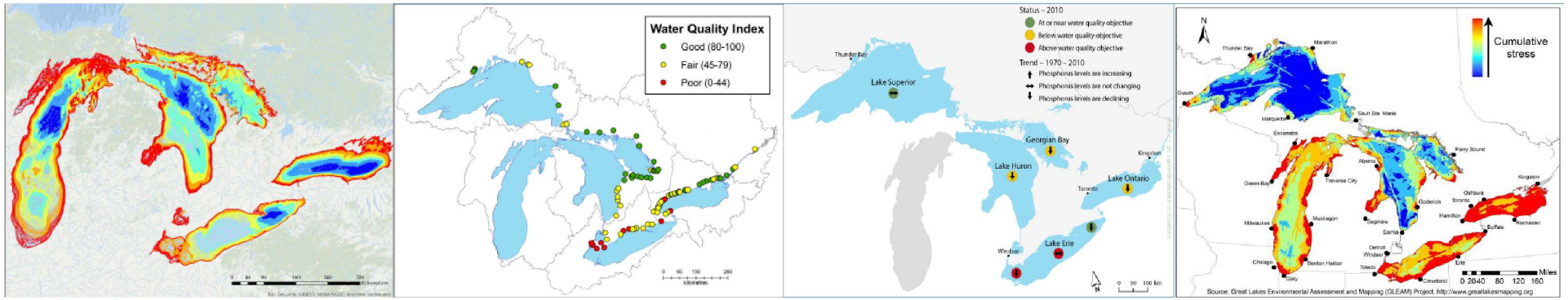


Figure A.12: Lake Networks indicates poor to medium quality of water in the Niagara Falls.

Figure A.13: Cumulative stress caused by excess phosphorous levels in the Lake of Ontario. Indicating one of the reasons why the quality of water is low. This is an indication that water is draining into the lakes without proper processing from existing ecosystems.

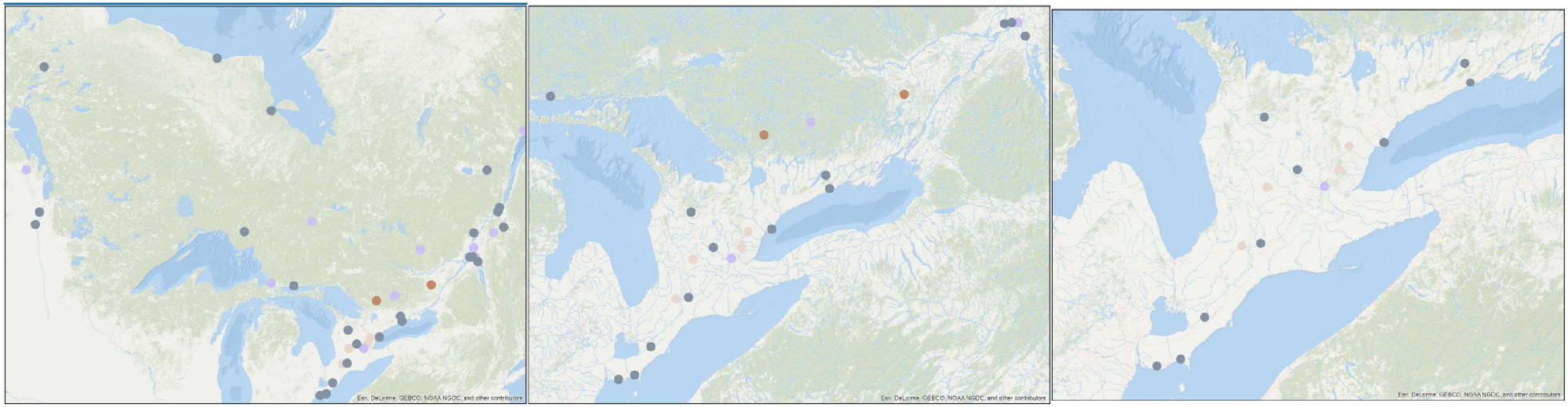


Figure A.4: Flood occurances within the last 100 years within nested loops - Niagara Falls has no flood occurances.

A.5 Natural Drainage Systems



Figure A.15: Watershed and drainage systems within a Nested loops
The first drawing indicating main water streams, the second indicating all steams of water. the third is a blow up of Niagara Region.

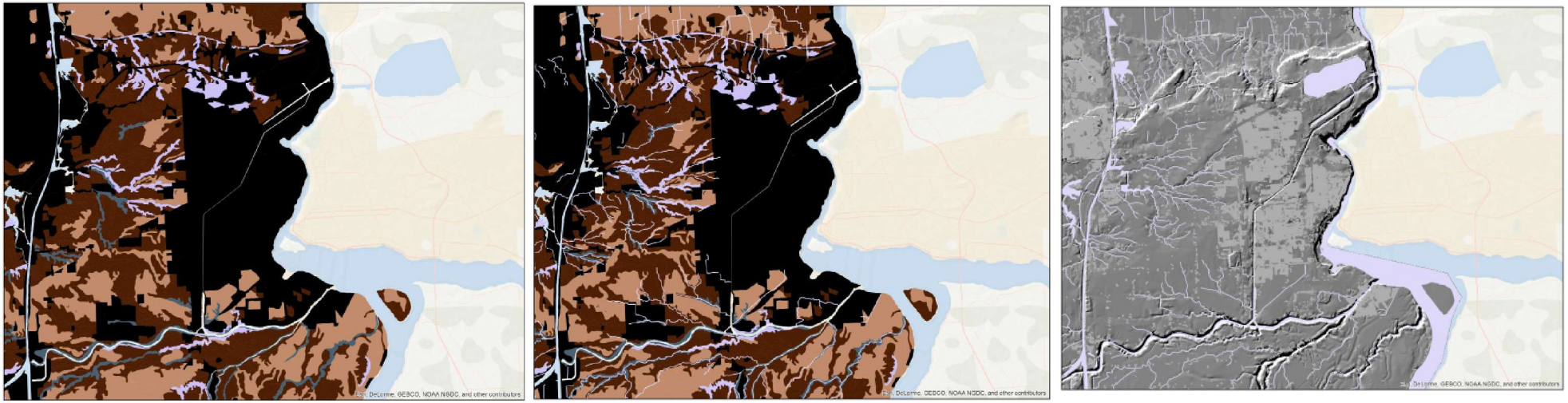


Figure A.16: Watershed and drainage systems within a Nested loops - within Niagara Falls
The first drawing indicating main water streams, the second indicating all steams of water. the third is a blow up of Niagara Falls to indicate that region has large bodies of water and many streams.

A.6 Niagara Falls Info

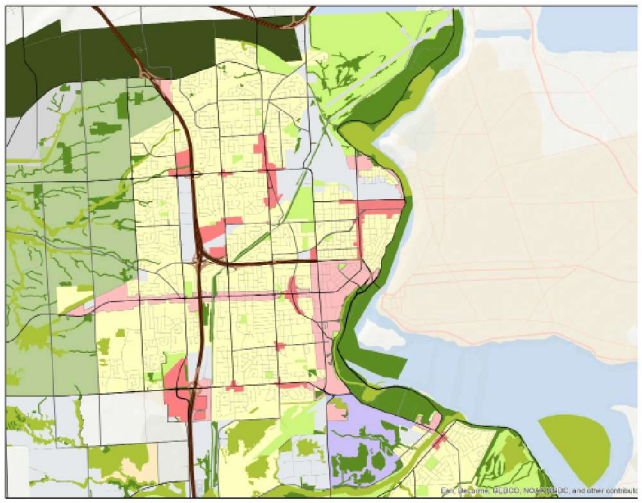


Figure A.18: Official City Plan

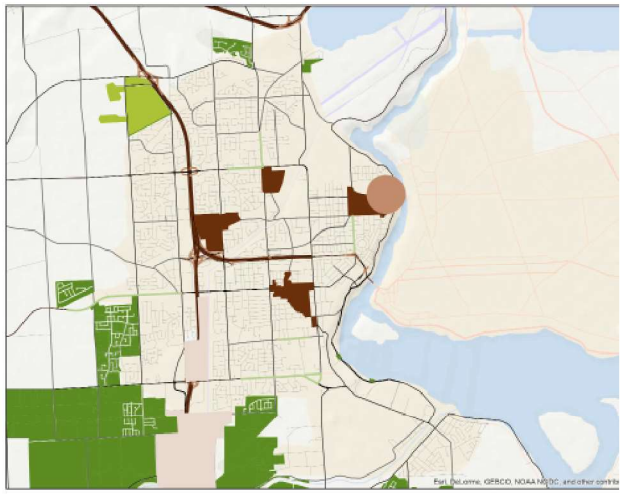


Figure A.19: Special Policy Plan



Figure A.20: Plans for City Improvement



Figure A.21: Plans for Brownfield Improvements



Figure A.22: Plans for Community Imrpvement

A.7 Social Attractors

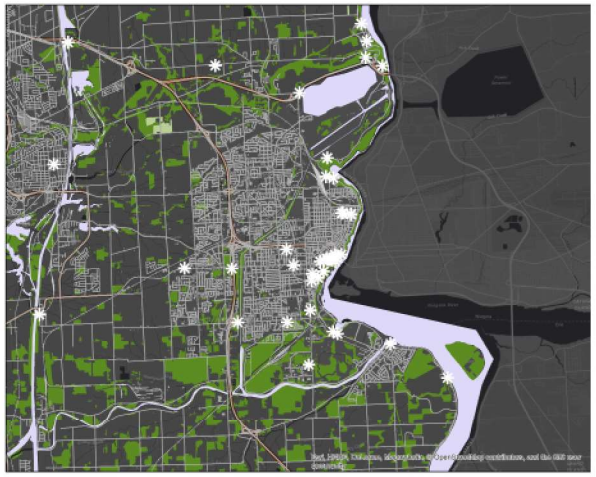


Figure A.23: Tourist Attractions



Figure A.24: Tourist Accomodations



Figure A.25: Heritage



Figure A.26: Community Services



Figure A.27: Hostels



Figure A.28: Schools



Figure A.29: Library



Figure A.30: Supermarkets



Figure A.31: Banks

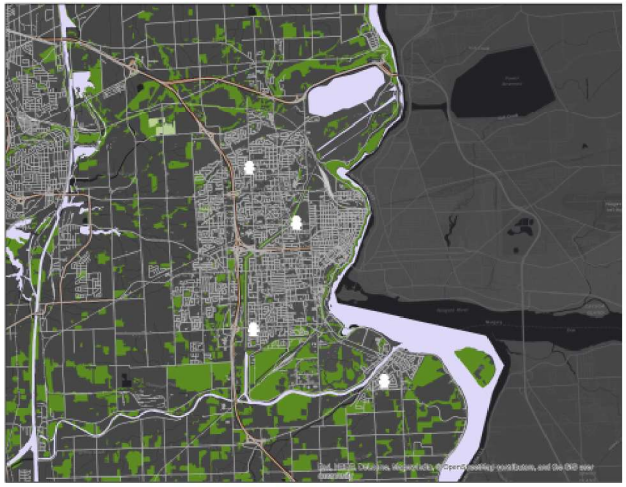


Figure A.32: Firestations



Figure A.33: Post offices



Figure A.34: Places of Worship



Figure A.35: Cemeteries



Figure A.36: Marina



Figure A.37: Sports arena



Figure A.38: Museums



Figure A.39: Outdoor Art



Figure A.40: Golf Courses

A.8 Land Manager Licence



Figure A.41: Amusement Parks



Figure A.42: Tourist Establishments



Figure A.43: Niagara 2% or conveyance of land for Parks



Figure A.44: Exhibits



Figure A.45: Condominiums



Figure A.46: Lodge Houses



Figure A.47: Camping establishments



Figure A.48: Cart Refreshments



Figure A.49: Truck Refreshments

Appendix B - Arcology Requirement Calculations

Human Processes

1. Niagara Falls Population & the Arcology

	Male	Female	Total		Percentage	
Population				Male	Female	Total
Overall Population of Arcology			11000			
0 - 4 y	254	240	493	2.31	2.18	4.48
5 - 9 y	281	265	546	2.55	2.41	4.96
10 - 14 y	290	277	568	2.64	2.52	5.16
15 - 19 y	321	307	627	2.92	2.79	5.70
20 - 29 y	636	602	1,238	5.78	5.47	11.25
30 - 49 y	1,253	1,357	2,610	11.39	12.34	23.73
50 - 69 y	1,486	1,627	3,114	13.51	14.79	28.31
70 - 74 y	235	261	496	2.14	2.37	4.51
75 + y	512	798	1,309	4.65	7.25	11.90
Total	**5,268**	**5,733**	**11,000**	**47.90**	**52.12**	**100.00**

All processes have to be quantified, it is not enough to know them. Through the processes, albiet abstract, we have the capacity to zone and set goals for the system, which is the first step to designing an Arcology.

2. Niagara Falls Demographic & the Arcology

	Male	Female	Total		Percentage	
Age Brackets Demographic						
0 - 4 y	2,095	1,975	4,070	2.31	2.18	4.48
5 - 9 y	2,315	2,185	4,500	2.55	2.41	4.96
10 - 14 y	2,400	2,285	4,685	2.64	2.52	5.16
15 - 19 y	2,650	2,530	5,175	2.92	2.79	5.70
20 - 29 y	5,250	4,970	10,215	5.78	5.47	11.25
30 - 49 y	10,340	11,205	21,545	11.39	12.34	23.73
50 - 69 y	12,270	13,430	25,705	13.51	14.79	28.31
70 - 74 y	1,945	2,155	4,095	2.14	2.37	4.51
75 + y	4,220	6,585	10,800	4.65	7.25	11.90
Total	**43,485**	**47,320**	**90,790**	**47.90**	**52.12**	**100.00**
Niagara Falls Poulation	42,530	45,540	88,070	48.29	51.71	100.00

3. Typology of Buildings in Niagara Falls

Types of Private Dwellings		Percentage
Total	35,775	100.00
Single-Detached	23,820	66.58
Apartment (5 + stories)	1,420	3.97
Semi-Detached	2,010	5.62
Row Housing	2,420	6.76
Apartment in Duplex	1,300	3.63
Apartment (less than 5 stories)	4,690	13.11
Single Attached Other	65	0.18
Moveable Dwellings	45	0.13

4. Calibrating Spaces required for the Arcology for the Individual

Percentage of People in Dwellings	Percentage		m2
Total Private Dwellings	35,775	100.00	
1 Person (studio)	10,110	28.26	70
2 Person (1 bdrm)	12,445	34.79	95
3 Person (2 bdrm)	5,790	16.18	140
4 Person (2 bdrm)	4,770	13.33	140
5+ Person (3 bdrm)	2,655	7.42	190

(the individual spaces are exagerated to compensate for amenity spaces as well as residential spaces)

5. Calculating Space Designing & Capacity of People the Arcology can hold

The Area for plots designed in my Arcology for each of the four residential floors. This surface area only includes the plots and not the pathways, for an accurate estimation.

	1st	# flats	#ppl	2nd	# flats	#ppl	3rd	# flats	#ppl	4th	# flats	#ppl
Surface Area	134,715			125,312			95,039			31,740		
	38,070	544	544	35,413	506	506	26,858	384	384	8,970	128	128
	46,863	493	987	43,592	459	918	33,061	348	348	11,041	116	232
	21,803	156	467	20,281	145	435	15,381	110	110	5,137	37	110
	17,962	128	513	16,708	119	477	12,672	91	91	4,232	30	121
	9,998	53	263	9,300	49	245	7,053	37	37	2,356	12	62
	134,696	1,374	2,774	125,294	1,278	2,580	95,025	969	969	31,736	324	654

	#flats	# ppl		people : flat	flat : people
	3,945	6,977		1.77	0.57
1 floor	3,945	6,977	required	population	flats required
2 floor	7,889	13,954		11,000	6,219
3 floor	11,834	20,931	approx.	# ppl / 4	#flats / 4
4 floor	15,778	27,908		10,466	5,917
5 floor	19,723	34,885			
6 floors	23,668	41,862			

	Total Flats Required							
	1st	2nd	3rd	4th	5th	6th	Sum	
	6219	3148.89	1594.38	807.279	408.749	206.961	104.791	6271.05
Res Types								
1st	1,374	695	351	178	90	45	23	1,383
2nd	1,278	646	327	165	84	42	21	1,286
3rd	969	490	248	125	63	32	16	975
4th	324	164	83	42	21	11	5	326

6. Calculating Water Requirements for Each Individual. Canada uses water at an unsustainable rate, where the average house hold water use is 251 L and 109 L for agriculture.

Water Use in Canada	
percentrage (%)	usage
68	Electric Power Generation, Transmission & Distribution
10	Manufacturing
9	Households
5	Agriculture
3	Mining & Oil & Gas Extraction
5	Other

	Volume (L) per day
Water Use Per Person (L)	251
Agriculture Per Person (L)	109

Agriculture Irrigation Water Use		
	percentage (%)	Volume(L) for each use per day
field crops	61	66.49
forage crops	34	37.06
fruits	3	3.27
vegetables	2	2.18

Residential Water Use	percentage (%)	Volume(L) for each use per day
bathing	35	87.85
toilet	30	75.3
cleaning	25	62.75
drinking	10	25.1

Calculating Filtered Water Usage	
Per Person	average (L)
Filtered Water (sink, bathing, cleaning)	150.6
Grey Water (for toilet flushing)	75.3
Drinking Water	25.1
Total Water Usage without Toilet Water	175.7

To conserve water reasonably, the grey water will be used for toilet flushing. Therefore the Filtered Water Usage Required per person, is reduced to 175.7 L Per Person Per Day for a population of 11'000, this adjustment will save a lot of water.

7. Calculating Food and Activity Level Required for Each Individual

Population and Calories			
Males - Age (years old)	Sedentary level	Active level	
2-5 y	1000	1600	*
6- 9 y	1200	2000	*
10 - 14 y	1600	2800	*
14 - 19 y	2200	3000	*
19 - 29 y	2400	3000	*
30 - 49 y	2400	3000	*
50 - 69 y	2200	2600	*
70 - 74 y	2000	2600	*
75+ y	2000	2400	*
Females - Age (years old)	Sedementary	Active level	
2-5 y	1000	1600	*
6- 9 y	1200	1800	*
10 - 14 y	1400	2400	*
14 - 19 y	1800	2400	*
19 - 29 y	2000	2400	*
30 - 49 y	1800	2200	*
50 - 69 y	1600	2000	*
70 - 74 y	1600	2000	*
75+ y	1600	2000	

Sedentary Lifestyle: includes only the physical activity of independent living.
Moderately Active Lifestyle: includes physical activity equivalent to walking about 1.5 to 3 miles per day at 3 to 4 miles per hour, in addition to the activities of independent living.
Active Lifestyle : includes physical activity equivalent to walking more than 3 miles per day at 3 to 4 miles per hour, in addition to the activities of independent living.
NB: Estimates for females do not include women who are pregnant or breastfeeding.
Source: Institute of Medicine. Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. Washington (DC): The National Academies Press; 2002

Ecological Processes

1. Rainfall Harvest in Niagara Falls

Water Harvest Monthly	Rain		Percipitation		Water Collection (1 m2 x 1 m2)
	average (mm)	extreme daily (mm)	average (mm)	extreme daily (mm)	average (L)
January	27.2	38.1	69.5	38.1	69.5
February	28.5	82.8	67.4	82.8	67.4
March	55.6	43.9	75.5	43.9	75.5
April	68.2	51.1	75.5	51.1	75.5
May	75.6	47.8	76.5	47.8	76.5
June	87.5	75.2	87.5	75.2	87.5
July	74.4	81	75.4	81	75.4
August	81.6	95.3	81.6	95.3	81.6
September	95.2	81.5	95.2	81.5	95.2
October	83.7	72.4	84.3	72.4	84.3
November	79.4	64.8	91	64.8	91
December	50.6	71.9	90.7	71.9	90.7

2. Rainfall Harvest in Niagara Falls

Water Harvest Monthly	Water Collection Per Sector (2583.8m2)	Water Per Sector Per Person (420 per Ppl / month)	Water Per Sector Per Person Per Day (251/day)
	average (L)		
January	179,574.10	427.56	1.70
February	174,148.12	414.64	1.65
March	195,076.90	464.47	1.85
April	195,076.90	464.47	1.85
May	197,660.70	470.62	1.87
June	226,082.50	538.29	2.14
July	194,818.52	463.85	1.85
August	210,838.08	502.00	2.00
September	245,977.76	585.66	2.33
October	217,814.34	518.61	2.07
November	235,125.80	559.82	2.23
December	234,350.66	557.98	2.22

Water Harvest Monthly	Water Collection Per Site (442'331.7m2)	Water Collection Per Site (442'331.7m2) Per Resident	Water Per Resident Per Day
	average (L)	average (L)	days
January	30,672,553.15	2,788.41	11.11
February	29,745,756.58	2,704.16	10.77
March	33,320,543.35	3,029.14	12.07
April	33,320,543.35	3,029.14	12.07
May	33,761,875.05	3,069.26	12.23
June	38,616,523.75	3,510.59	13.99
July	33,276,410.18	3,025.13	12.05
August	36,012,666.72	3,273.88	13.04
September	42,014,777.84	3,819.53	15.22
October	37,204,262.31	3,382.21	13.47
November	40,161,184.70	3,651.02	14.55
December	40,028,785.19	3,638.98	14.50

3. Tree and Plant Watering Requirements

Watering Trees	height			
Height Tree	Average tree 3-4 m tall			
Tree diameter@ knee level (inch)		6.5 ***		
Watering every 2 weeks (L)		123	Calc:	6.5 in x 5 minutes
Monthly Water (L)		246		equals 32.5 minutes
Yearly Water (L)		2952		32 .5 minutes x 2 (per month)
Area of 4.5 high tree (m2)		20.25		10 gallons every 5 minutes
Water per day		8.79		thus 65 gallons or 246 L per month

*** I measured the diameter of the tree in front of my house that was approximately 3-4 meters tall

			Percentage	
Tree Transpiration Percentage	90% of Water			
Moisture released in the air				
for 3-4 m tall tree per month (L)		221.4	90 %	(transpiration really depends on the biome and temperature conditions
Water Absorbed by Tree per month (L)		24.6	10 %	and many variables, it is not a simple arithmatic equation
Transpiration by Tree Daily (L)		7.28		but a general rule is it is between 75%-90%)
Water Absorbed by Tree Daily (L)		0.81		75% in the amazon rainforest is a high percentage due to
				its intricate open system)
Transpiration by Plant Daily (L)		0.67		assuming a tree 6.5 compared to a plant 0.6m tall
Water Absorbed by Plant Daily (L)		0.07		so ratio 6.5 : 0.6

Compare to People Usage Per Day		
in my Arcology	175.70	
Drinking Water	25.10	14.29 %
Daily Water Absorbtion per Tree	0.81	0.46 %
Daily Water Absorbtion per Plant	0.07	0.04 %

Article that has a much more complex algorithem to calculate plant transpiration and water absorption in Canada but its far too complex for this thesis.

4. Farming Requirement

Agriculture Yield Land	acres	m2	m x m
per person			
Conventional Farming			
Grain, Meat, Dairy, Veggies & Fruits	0.5	2023	45 x 45
Veggies & Fruits Only	0.08	324	18 x 18
Closed Enviornment			
Biosphere 2 Today			pod size
1 food pod per person		18	3 x 6
Vertical Farming			
If 75% more efficient than regular farming		81	9 x 9

Aquaponic VS Farming Stacks	stacks	m	m	m2	total	stack (depth variations) height (min) (m) with 30 cm bed	height (max) (m) with 60 cm bed	Aquaponic Water Way (m3)	Water Actually Consumed by Vertical Farming (m3)	Water Absorbed by Plants (m3)
if using conventional farming sized lots	2	12.80	12.80	163.84	327.68	2.60	3.20	98.30	32.77	19.66
stacked vertically per person.	3	10.40	10.40	108.16	324.48	3.90	4.80	97.34	32.45	19.47
	4	9.00	9.00	81.00	324.00	5.20	6.40	97.20	32.40	19.44
the space designated for growing	5	8.05	8.05	64.80	324.01	6.50	8.00	97.20	32.40	19.44
seems extremely unreasonable	6	7.35	7.35	54.02	324.14	7.80	9.60	97.24	32.41	19.45
and for 11'000 people we will require	7	6.81	6.81	46.38	324.63	9.10	11.20	97.39	32.46	19.48
8 floors, approximately 15 meters each	8	6.37	6.37	40.58	324.62	10.40	12.80	97.38	32.46	19.48
to accomidate the Arcology's Residents.	9	6.00	6.00	36.00	324.00	11.70	14.40	97.20	32.40	19.44
	10	5.70	5.70	32.49	324.90	13.00	16.00	97.47	32.49	19.49
Therefore, we need to densify our Farming.	11	5.45	5.45	29.70	326.73	14.30	17.60	98.02	32.67	19.60
	12	5.20	5.20	27.04	324.48	15.60	19.20			

Aquaponic VS Farming Stacks	stacks	m	m	m2	total	stack (depth variations) height (min) (m)	height (max) (m)	Aquaponic Water Way (m3)	Water Actually Consumed by Vertical Farming (m3)	Water Absorbed by Plants (m3)
For one season (divided by four)										
Veggies & Fruits Only	0.02	81.00	9 x 9							
Vertical Farming Stacks	2	6.36	6.36	40.50	81	2.60	3.20	24.30	8.1	4.86
	4	4.50	4.50	20.25	81	5.20	6.40	24.30	8.1	4.86
	6	3.67	3.67	13.50	81	7.80	9.60	24.30	8.1	4.86
	8	3.18	3.18	10.13	81	10.40	12.80	24.30	8.1	4.86
	10	2.85	2.85	8.10	81	13.00	16.00	24.30	8.1	4.86
	12	2.60	2.60	6.75	81	15.60	19.20	24.30	8.1	4.86
	14	2.41	2.41	5.79	81	18.20	22.40	24.30	8.1	4.86
	16	2.25	2.25	5.06	81	20.80	25.60	24.30	8.1	4.86

5. Aquaponic Requirements for Conventional Farming

Aquaponic System per person	calculations			
for Conventional Farming				
Area of Plants (m2) per person	324		m2	
Volume of Vertical Farming (m3) per person	min of 0.3 m depth		97.2	m3
Volume of Aquaponic Water Way (m3) per person	1 : 1 ratio		97.2	m3
Fish in Weight (kg) :				
Ratio - 1 pound : 1 sqft farming				
0.5 kg for every growing plot 0.0929 (m2)	1,581.91		kg	
Fish Density without a lot of filters (kg)				
0.5 kg per 20 Liters (0.02 m3)	**Never Exceed**		2,430.00	kg
0.5 kg per 26 Liters (0.026 m3)	**Never Exceed**		1,869.23	kg
Fish Feed or biological equivalent (kg)		0.5 kg per 26 Liters	0.5 kg per 20 Liters	
0.06 kg of Weight of Fish	94.91	112.15	145.80	kg
0.1 kg of Weight of Fish	158.19	186.92	243.00	kg
Range of Fish Food x3 times a day		0.5 kg per 26 Liters	0.5 kg per 20 Liters	
0.06 kg of Weight of Fish	284.74	336.46	437.40	kg
0.1 kg of Weight of Fish	474.57	560.77	729.00	kg
Range of number of Fish		0.5 kg per 26 Liters	0.5 kg per 20 Liters	
If the fish was 2 kgs	790.95	934.62	1,215.00	fish
If the fish was 0.9 kgs	1,757.67	2,076.92	2,700.00	fish

(requires minimal filtration and oxygen tanks to help supplement the system to manage fluxes)

Notes:
Dr Rakocy and Dr Lennard are pioneers in aquaponic systems
Biofilters required : 50 sqft / 1 pound of fish but there will be plants in the aquaponic pond so that could be reduced.

Soil Options for the Aquaponic Water Way

LECA (light weight expanded clay aggregate AKA Hydroton
Lava Rock
Gravel
(avoid concrete, lime and marbel because they alter the water's pH level)

Figure : Aquaponic System Required for 324 m2 of Farming per Person

6. Aquaponic Requirements for Unconventional Farming

Aquaponic System per person	calculations			
for Conventional Farming				
Area of Plants (m2) per person	81		m2	
Volume of Vertical Farming (m3) per person	min of 0.3 m depth		24.3	m3
Volume of Aquaponic Water Way (m3) per person	1 : 1 ratio		24.3	m3
Fish in Weight (kg) :				
Ratio - 1 pound : 1 sqft farming				
0.5 kg for every growing plot 0.0929 (m2)	395.48		kg	
Fish Density without a lot of filters (kg)				
0.5 kg per 20 Liters (0.02 m3)	**Never Exceed**		607.50	kg
0.5 kg per 26 Liters (0.026 m3)	**Never Exceed**		467.31	kg
Fish Feed or biological equivalent (kg)		0.5 kg per 26 Liters	0.5 kg per 20 Liters	
0.06 kg of Weight of Fish	23.73	28.04	36.45	kg
0.1 kg of Weight of Fish	39.55	46.73	60.75	kg
Range of Fish Food x3 times a day		0.5 kg per 26 Liters	0.5 kg per 20 Liters	
0.06 kg of Weight of Fish	71.19	84.12	109.35	kg
0.1 kg of Weight of Fish	118.64	140.19	182.25	kg
Range of number of Fish		0.5 kg per 26 Liters	0.5 kg per 20 Liters	
If the fish was 2 kgs	197.74	233.65	303.75	fish
If the fish was 0.9 kgs	439.42	519.23	675.00	fish

(requires minimal filtration and oxygen tanks to help supplement the system to manage fluxes)

Notes:
Dr Rakocy and Dr Lennard are pioneers in aquaponic systems
Biofilters required : 50 sqft / 1 pound of fish but there will be plants in the aquaponic pond so that could be reduced.

Soil Options for the Aquaponic Water Way

LECA (light weight expanded clay aggregate AKA Hydroton
Lava Rock
Gravel
(avoid concrete, lime and marbel because they alter the water's pH level)

Water - Fish Density
The fish density varies... but the general rule of thumb is as follows...
20 kg to 1000 L is the Maximum fish/water density before active management is required to
maintain the aquatic pond. The ratios calculated shows a range of possibile fish densities
this does not put into consideration the aqua ecosystem (ie snails, frogs, plants that also add oxygen into the system
therefore, increasing the health benefit of the Aquaponic Water Way. An expert is needed to calculate the specific ratio.
With an average of approximately 200+ fish for every Resident, the benefit is all residents can enjoy a fresh fish dinner,
when there is an excess of fish, or sell their share of fish in the Farmer's Market...

7. Solar Panels - Energy Information

Total Energy		
per person (kW)	10	
Home use Percentage	22	
Services use Percentage	78	
Solar Panels		
production @ full sun (kW)	48	5 hours sun per day
with 15% effeciency (kW)	10	
array (m)	18 x 18	
with 22% effeciency (kW)	46	5 hours sun per day
array (m)	16.75 x 16.75	
Experimental Solar Panels		
with 75% effeciency (m)	3.6 x 3.6	
with 90% effeciency (m)	3 x 3	
Experimental Glass Panels		
Effeciency Percentage	1	
Future Effeciency Percentage	12	
SolarWindow Coating Technology	50	

Note: All the stats were generated Statistics from Statistics Canada.

Appendix C - Arcology Benefit Calculations

Calculations: Deliverables of Arcologies

1. Calculating The Soil & Water Required for Each Floor

Previously each of the processes were calculated and zoned. However, each of the trees have water and soil requirements. When they are calculated on each floor, the ecological capacity of each floor can be compared to the human systems in the entire Arcology.

Commercial											
Indoors		Surface Area	Tree/Plant Size (m)	Surface Area Per Tree (m2)	# Trees	Surface Area Per Plant	# Plants	Soil Height (m)	Soil Volume (m3)	Water Height (m)	Water Volume (m3)
	Vines	10,943.63	1.20			1.44	7,599.74	0.40	4,377.45	0.10	1,094.36
	T1	1,844.70	1.20			1.44	1,281.04	0.40	737.88	0.10	184.47
	T2	32,448.50	2.00			4.00	8,112.13	0.67	21,632.33	0.17	5,408.08
	T3	0.00	4.00	16.00	0.00	1.20	0.00	1.33	0.00	0.33	0.00
	T4	6,651.80	6.50	42.25	157.44			4.00	26,607.20	1.00	6,651.80
Outdoors											
	Edge Periphery	5,709.80	6.50	42.25	135.14	1.44	1,982.57	4.00	22,839.20	1.00	5,709.80
	Periphery	18,435.60	6.50	42.25	436.35	1.44	6,401.25	4.00	73,742.40	1.00	18,435.60
Totals	Hydroponic Clay								26,747.67		
	Soil								123,188.80		
	Water										37,484.12

Farming											
Indoors		Surface Area	Tree/Plant Size (m)	Surface Area Per Tree (m2)	# Trees	Surface Area Per Plant	# Plants	Soil Height (m)	Soil Volume (m3)	Water Height (m)	Water Volume (m3)
	Vines	7,804.62	1.20			1.44	5,419.88	0.40	3,121.85	0.10	780.46
	T1	1,275.50	1.20			1.44	885.76	0.40	510.20	0.10	127.55
	T2	16,339.80	2.00			4.00	4,084.95	0.67	10,893.20	0.17	2,723.30
	T3	0.00	4.00	16.00	0.00	1.44	0.00	1.33	0.00	0.33	0.00
	T4	0.00	6.50	42.25	0.00			4.00	0.00	1.00	0.00
	Food Plants										
	per person	81.00	1.20			1.44	56.25	0.30	24.30	0.10	8.10
	Total Space	56,853.10									
	16 Stacks	909,649.60	1.20			1.44	631,701.11	0.30	272,894.88	0.10	90,964.96
Outdoors											
	Edge Periphery	5,709.80	6.50	42.25	135.14	1.44	1,982.57	4.00	22,839.20	1.00	5,709.80
	Periphery	17,527.95	6.50	42.25	414.86	1.44	6,086.09	4.00	70,111.80	1.00	17,527.95
Totals	Hydroponic Clay								287,444.43		
	Soil								92,951.00		
	Water										117,842.12

1st Floor Res

		Surface Area	Tree/Plant Size (m)	Surface Area Per Tree (m2)	# Trees	Surface Area Per Plant	# Plants	Soil Height (m)	Soil Volume (m3)	Water Height (m)	Water Volume (m3)
Indoors											
	Vines	15,102.60	1.20			1.44	10,487.92	0.40	6,041.04	0.10	1,510.26
	T1	4,028.10	1.20			1.44	2,797.29	0.40	1,611.24	0.10	402.81
	T2	19,056.60	2.00			4.00	4,764.15	0.67	12,704.40	0.17	3,176.10
	T3	18,828.30	4.00	16.00	1,176.77	1.20	15,690.25	1.33	25,104.40	0.33	6,276.10
	T4	18,365.20	6.50	42.25	434.68			4.00	73,460.80	1.00	18,365.20
Outdoors											
	Edgeway	5,709.80	6.50	42.25	135.14	1.44	1,982.57	4.00	22,839.20	1.00	5,709.80
	Periphery	17,527.95	6.50	42.25	414.86	1.44	6,086.09	4.00	70,111.80	1.00	17,527.95
Totals	Hydroponic Clay								20,356.68		
	Soil								211,872.88		
	Water										52,968.22

2nd Floor Res

		Surface Area	Tree/Plant Size (m)	Surface Area Per Tree (m2)	# Trees	Surface Area Per Plant	# Plants	Soil Height (m)	Soil Volume (m3)	Water Height (m)	Water Volume (m3)
Indoors											
	Vines	14,048.39	1.20			1.44	9,755.83	0.40	5,619.36	0.10	1,404.84
	T1	3,402.80	1.20			1.44	2,363.06	0.40	1,361.12	0.10	340.28
	T2	17,419.00	2.00			4.00	4,354.75	0.67	11,612.67	0.17	2,903.17
	T3	18,765.50	4.00	16.00	1,172.84	1.20	15,637.92	1.33	25,020.67	0.33	6,255.17
	T4	16,179.90	6.50	42.25	382.96			4.00	64,719.60	1.00	16,179.90
Outdoors											
	Edgeway	5,709.80	6.50	42.25	135.14	1.44	1,982.57	4.00	22,839.20	1.00	5,709.80
	Periphery	18,969.05	6.50	42.25	448.97	1.44	6,586.48	4.00	75,876.20	1.00	18,969.05
Totals	Hydroponic Clay								18,593.14		
	Soil								188,455.67		
	Water										51,762.20

3rd Floor Res

		Surface Area	Tree/Plant Size (m)	Surface Area Per Tree (m2)	# Trees	Surface Area Per Plant	# Plants	Soil Height (m)	Soil Volume (m3)	Water Height (m)	Water Volume (m3)
Indoors											
	Vines	10,678.48	1.20			1.44	7,415.61	0.40	4,271.39	0.10	1,067.85
	T1	2,197.50	1.20			1.44	1,526.04	0.40	879.00	0.10	219.75
	T2	10,162.20	2.00			4.00	2,540.55	0.67	6,774.80	0.17	1,693.70
	T3	14,682.30	4.00	16.00	917.64	1.20	12,235.25	1.33	19,576.40	0.33	4,894.10
	T4	11,639.60	6.50	42.25	275.49			4.00	46,558.40	1.00	11,639.60
Outdoors											
	Edgeway	5,709.80	6.50	42.25	135.14	1.44	1,982.57	4.00	22,839.20	1.00	5,709.80
	Periphery	17,864.55	6.50	42.25	422.83	1.44	6,202.97	4.00	71,458.20	1.00	17,864.55
Totals	Hydroponic Clay								11,925.19		
	Soil								160,432.20		
	Water										43,089.35

4th Floor Res											
Indoors		Surface Area	Tree/Plant Size (m)	Surface Area Per Tree (m2)	# Trees	Surface Area Per Plant	# Plants	Soil Height (m)	Soil Volume (m3)	Water Height (m)	Water Volume (m3)
	Vines	3,555.60	1.20			1.44	2,469.17	0.40	1,422.24	0.10	355.56
	T1	621.70	1.20			1.44	431.74	0.40	248.68	0.10	62.17
	T2	2,526.80	2.00			4.00	631.70	0.67	1,684.53	0.17	421.13
	T3	8,152.70	4.00	16.00	509.54	1.20	6,793.92	1.33	10,870.27	0.33	2,717.57
	T4	3,253.70	6.50	42.25	77.01			4.00	13,014.80	1.00	3,253.70
Outdoors											
	Edgeway	5,709.80	6.50	42.25	135.14	1.44	1,982.57	4.00	22,839.20	1.00	5,709.80
	Periphery	8,898.45	6.50	42.25	210.61	1.44	3,089.74	4.00	35,593.80	1.00	8,898.45
Totals	Hydroponic Clay								3,355.45		
	Soil								82,318.07		
	Water										21,418.38

Roof Garden											
Indoors		Surface Area	Tree/Plant Size (m)	Surface Area Per Tree (m2)	# Trees	Surface Area Per Plant	# Plants	Soil Height (m)	Soil Volume (m3)	Water Height (m)	Water Volume (m3)
	Roof Top Plots	89,810.13	6.50	42.25	2,125.68	1.44	31,184.07	4.00	359,240.53	1.00	89,810.13
Totals											
	Soil								359,240.53		
	Water										89,810.13

2. Collective Total Volume of Water

When an estimate of the amount of water required is calculated, the water volume for the Arcology is capped. The Aquafiers hold approximately 2 days of water for 11‘000 residents, and the Arcology holds 1 day of Water for it‘s residents in the Aquaponic Water Way.

Total Volume of	h20 - 1 floor	h20 - 2 floor	Population	2 floors	Population x 2 day	water cycle	Population x 3 day	water cycle
Commercial	37,484.12	74,968.23	213.34	426.68	106.67	213.34	71.11	142.23
Farming	117,842.12	235,684.24	670.70	1,341.40	335.35	670.70	223.57	447.13
1st Floor Res	52,968.22	105,936.44	301.47	602.94	150.73	301.47	100.49	200.98
2nd Floor Res	51,762.20	103,524.40	294.61	589.21	147.30	294.61	98.20	196.40
3rd Floor Res	43,089.35	86,178.70	245.24	490.49	122.62	245.24	81.75	163.50
4th Floor Res	21,418.38	42,836.76	121.90	243.81	60.95	121.90	40.63	81.27
Roof Garden	89,810.13	89,810.13						

		Commercial		Farming		1st Floor Res.		2nd Floor Res.		3rd Floor Res.		4th Floor Res		Roof G
Water Way	Total h20	Supply	Return	Supply	Return	Supply	Return	Supply	Return	Supply	Return	Supply	Return	
WaterWay-Area m2	522,526.60	46,587	46,587	46,587	46,587	46,587	46,587	46,587	46,587	46,587	46,587	28,328	28,328	
WaterWay-Vol m3	2,246,864.38	200,324.10	200,324.10	200,324.10	200,324.10	200,324.10	200,324.10	200,324.10	200,324.10	200,324.10	200,324.10	121,811.69	121,811.69	
		first layer	second layer	first layer	second layer	first layer	second layer	first layer	second layer	first layer	second layer	first layer	second layer	1L
Plants (m3)	1,063,503.30	37,484.12	74,968.23	117,842.12	235,684.24	52,968.22	105,936.44	51,762.20	103,524.40	43,089.35	86,178.70	21,418.38	42,836.76	
Volume(m3)	3,310,367.68													
c Water Way														

Waste - Retention period	1 Day	2 Days
Water Per Person	175.70	351.40

Site Area	44331.7
Population of Arcology	11000
Aquafier Total Water Reserve	5798.1
for 2 Day Retention Cycle	
for Arcology Residents	
Height of Aquafier for Arcology	0.130789029
Aquafier Total Water Reserve	7,730.80
for 2 Day Retention Cycle	
for Arcology Residents	
Height of Aquafier for Arcology	0.174385372

Water	
(for Residences Only)	
Per Person (L)	175.70
Population Desired	11,000.00
Reserve for Aquafiers (L)	3,865,400.00
Running Water in Arcology (L)	1,932,700.00
Total: L or m3	5,798,100.00

Water		
(for Residences Only)		
Per Person (L)	175.70	
Population Desired	11,000.00	
Reserve for Aquafiers (L)	3,865,400.00	5,798,100.00
(for a 2 Day Reserve)		(for a 3 Day Reserve)
Filtered Water in Arcology (L)	1,932,700.00	
(for a 1 Day Reserve)		
Total: in Liters	5,798,100.00	7,730,800.00
Total: in cubic meter	5,798.10	7,730.80

3. Collective Total Number of Trees & Plants

When an estimate of the amount of water required is calculated, the water volume for the Arcology is capped. The Aquafiers hold approximately 2 days of water for 11‘000 residents, and the Arcology holds 1 day of Water for it‘s residents in the Aquaponic Water Way.

Number of Trees	1 Floor	2 Floors
Commercial	728.93	1,457.86
Farming		
(plants)	550.01	1,100.01
(food)	n/a	n/a
1st Res	2,161.45	4,322.91
2nd Res	2,139.91	4,279.83
3rd Res	1,751.11	3,502.22
4th Res	932.31	1,864.62
Roof Garden (1 floor only)	2,125.68	2,125.68
Total	10,389.41	20,778.82

Number of Plants				
Commercial			25,376.73	50,753.46
Farming				
	(plants)		18,459.25	36,918.50
	(food)	not included	not included	
1st Res			41,808.27	83,616.54
2nd Res			40,680.59	81,361.19
3rd Res			31,902.99	63,805.98
4th Res			15,398.83	30,797.66
Roof Garden (1 floor only)			31,184.07	31,184.07
Total			204,810.74	409,621.48

4. Collective Total Volume of Soil

Calculating the Amount of Soil required for the structure to hold the amount of plants.

Total Volume of	Soil	2 floors	
Commercial		123,188.80	246,377.60
Farming		92,951.00	185,902.00
1st Floor Res		211,872.88	423,745.76
2nd Floor Res		188,455.67	376,911.33
3rd Floor Res		160,432.20	320,864.40
4th Floor Res		**82,318.07**	**164,636.13**
Roof Garden			
Total			1,718,437.23

Total Volume of	Hydro. Clay	2 floors	
Commercial		26,747.67	53,495.33
Farming		287,444.43	574,888.86
1st Floor Res		20,356.68	40,713.36
2nd Floor Res		18,593.14	37,186.29
3rd Floor Res		11,925.19	23,850.38
4th Floor Res		3,355.45	6,710.91
Total			736,845.12

5. Significant Improvement in Water Cycling

The Water Cycling in the System can cycle for a minimum of 3-days. This improves the Arcology to traditional water usage by 76.67%. even after watering all the plants and trees in the entire structure (not including the waste management plants).

Compare to People Usage Per Day (L)					
	in my Arcology	175.70			
human	Drinking Water	25.10	14.29 %	25.10	
tree	Daily Water Absorbtion	0.81	0.46 %	1.53	for 1.89 trees per person
plant	Daily Water Absorbtion	0.07	0.04 %	2.61	for 37.24 plants per person
farmed food	Daily Water Absorbtion	0.07	0.04 %	3.94	for 56.25 farmed plants per person

	Daily Loss	Total Loss (L)	33.17 L		
		Total Loss (%)	18.88 %		
	Reusing Water		81.12 %		
	So you need to replenish ur water in a 4-5 day cycle				
including res, commercial	Replenish	5 day Cycle	35.14 L	seems unlikely	
ammenities, farming etc		4 day Cycle	43.925 L	possible under strict water consumption	
		3 day Cycle	58.57 L	very likely	
	Compare to Today's Use				
		Today	251		
		5 day Cycle	86 %	better use of Water	seems unlikely
		4 Day Cycle	82.5 %	better use of Water	maybe under strict water consumption
		3 day Cycle	76.67 %	better use of Water	possible

6. Arcology Expansion Typologies Calculations

Expanding the Naturalizing Areas in Niagara			
Types of Plots to be Naturalized	Current	Percentage	Naturalizing
Total	35,775	100.00	6271.00
Single-Detached	23,820	66.58	4175.41
Apartment (5 + stories)	1,420	3.97	248.91
Semi-Detached	2,010	5.62	352.33
Row Housing	2,420	6.76	424.20
Apartment in Duplex	1,300	3.63	227.88
Apartment (less than 5 stories)	4,690	13.11	822.11
Single Attached Other	65	0.18	11.39
Moveable Dwellings	45	0.13	7.89
Percentage of Naturalizing Plots (%)			17.53

7. Calculated Fauna and Soil for the Individual

Ecological Benefits Per Person	
Soil	156.2215661
per person	
Hydroponic Clay	66.98592024
per person	
Number of Trees	1.89
Per Person	
Number of Plants	37.24
Per Person	
Number of Farming Pl.	56.25
per person	
Number of Fish	198 - 675
per person	

8. Conclusion - Calculations Percentages

Calculating the total Volume for each program.

	Area (m2)	Area (m2)	Height (m)	Volume (L or m3)	Cubic Root (m)	Percentages	Percentages			
Soil						26,142,667.63	89,509,081.82	3,173,763.41	16,287.40	90.49
Soil	varies	varies	varies	2,436,918.29	134.57	9.73	2.83	3.68	12,506.00	69.48
Hydroponic Clay	varies	varies	varies	736,845.12	90.32	2.94	0.85		3,781.41	21.01
Water								8,697,893.75	24,640.74	129.69
In Use Requirements	varies	varies	varies	1,932,700.00	124.56	7.72	2.24	10.09	9,918.40	52.20
Water for Flora	varies	varies	varies	666,160.46	87.34	2.66	0.77		3,418.66	17.99
Aquatic Water Way	varies	varies	varies	2,202,633.29	130.11	8.80	2.56		11,303.67	59.49
Aquafiers	varies	varies	varies	3,896,400.00	157.36	15.56	4.52		19,995.89	105.24
Farming								2,183,159.04	11,203.73	58.97
	909,649.60	1,819,299.20	1.20	2,183,159.04	129.73	8.72	2.53	2.53	11,203.73	58.97
Plants and Trees								4,104,659.68	21,064.66	108.02
Vines	62,133.32	124,266.64	1.20	149,119.97	53.03	0.60	0.17	4.76	765.27	3.92
T1	13,370.30	26,740.60	1.20	32,088.72	31.78	0.13	0.04		164.68	0.84
T2	97,952.90	195,905.80	2.00	391,811.60	73.17	1.56	0.45		2,010.73	10.31
T3	60,428.80	120,857.60	4.00	483,430.40	78.48	1.93	0.56		2,480.91	12.72
T4	56,090.20	112,180.40	6.50	729,172.60	90.01	2.91	0.85		3,742.03	19.19
Edgeway	34,258.80	68,517.60	6.50	445,364.40	76.37	1.78	0.52		2,285.56	11.72
Periphary	99,223.55	198,447.10	6.50	1,289,906.15	108.86	5.15	1.50		6,619.66	33.95
Rooftop Garden	89,810.13	89,810.13	6.50	583,765.85	83.58	2.33	0.68		2,995.82	15.36
Commercial								1,105,829.34	5,674.99	28.37
Commercial Zone		335,099.80	3.3	1,105,829.34	103.41	4.42	1.28	0.60	5,674.99	28.37
Residential Zone								1,025,168.19	5,261.05	26.31
Single-Detached		206,873.09	3.3	682,681.19	88.05	2.73	0.79	1.19	3,503.44	17.52
Apartment (5 + stories)		12,332.48	3.3	40,697.20	34.40	0.16	0.05		208.85	1.04
Semi-Detached		17,456.55	3.3	57,606.60	38.62	0.23	0.07		295.63	1.48
Row Housing		21,017.33	3.3	69,357.20	41.09	0.28	0.08		355.93	1.78
Apartment in Duplex		11,290.30	3.3	37,258.00	33.40	0.15	0.04		191.20	0.96
Apartment (less than 5 stories)		40,731.94	3.3	134,415.40	51.23	0.54	0.16		689.80	3.45
Single Attached Other		564.52	3.3	1,862.90	12.30	0.01	0.00		9.56	0.05
Moveable Dwellings		390.82	3.3	1,289.70	10.89	0.01	0.00		6.62	0.03
Organizational Structure							0.00	5,852,194.22	30,032.81	150.16
Circulation		205033.637	3.3	676,611.00	87.79	2.70	0.79	6.79	3,472.29	16.94
Structure		5,175,583.22		5,175,583.22	172.98	20.67	6.00		26,560.52	129.56
Open Space				56,585,335.26	383.91		65.65	56,585,335.26	290,389.69	1,350.65
								65.65		
Waste Water Management								2,150,000.00	11,033.56	52.54
Septic Tanks	125,000.00	250,000.00	4.3	1,075,000.00	102.44		1.25	2.49	5,516.78	26.27
Commercial Waste System		41,666.67	4.3	179,166.67	56.37		0.21		919.46	4.38
Residential Waste System		83,333.33	4.3	358,333.33	71.03		0.42		1,838.93	8.76
Lagoons & Sand Filtration		62,500.00	4.3	268,750.00	64.53		0.31		1,379.20	6.57
Constructed Wetlands		62,500.00	4.3	268,750.00	64.53		0.31		1,379.20	6.57
Parking								4,631,078.93	23,766.19	113.17
Parking - 3 floors	317,331.70	951,995.10	4.3	4,093,578.93	159.97		4.75	5.37	21,007.79	100.04
Circulation		125,000.00	4.3	537,500.00	81.31		0.62		2,758.39	13.14
Total				89,509,081.82	447.32					
Total Without Aquafiers				85,612,681.82	440.74					

9. Conclusion Calculations

The total sum of volume per person.

Total Volume	Volume (m3)	Per Person (m3)
Soil	2436918.29	221.54
per person		
Hydroponic Clay	736845.12	66.99
per person		
Waste Water (res)	1,836,458.32	166.95
Per Person		
Waste Water (total)	2150000	195.45
per person		
Water (total)	8697893.75	790.72
per person		
Parking	4,631,078.93	421.01
Per Person		
Logistics (Structure)	5,852,194.22	532.02
Per Person		
Trees	3,048,209.00	277.11
Per Person		
Plants	1056450.69	96.04
Per Person		
Farming Zone (mech + plants)	2183159.04	198.47
per person		
Residential Zone	2185197.68	198.65
per person		
Commercial Zone	1105829.25	100.53
per person		
per person (with visitors)		50.26