

Re-Visioning Sustainable  
Urban Housing  
in 2020

the year of perfect vision

by

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## **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 requested by my examiners.

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

## **Abstract**

Civilization's vantage point has shifted with advances in technology from an eye-level view of the horizon to a bird's eye view from a plane, to a planet-wide view from space. This relatively new global view is now the cultural perspective and embraces the holistic view of the biosphere as a large, interconnected, complex habitat that is subject to ever increasing anthropogenic pressures. The newly realized global perspective and realizations of global scale man-made impacts has added the concept of sustainability to the architectural realm. Architectural design issues of sustainability are inherently multi-scale, interconnected, and complex; and can not be resolved with western reductionist science alone. The holistic perspective is a core component of the evolving analysis methodology for pursuing insights on the interactions and connectivity of sustainable design. This thesis will speculate on the future of sustainable urban housing as a nonlinear outcome resulting from the rebalance of culture, technology and economy interacting with choice in our society. Through time, the interactions of these changing major forces is converging on a new equilibrium point that, to some extent, can be moved by choice. The architecture of urban housing has a potential role to play in moving that rebalance point in the future towards sustainability. This thesis will attempt to put on stage a context for urban housing in Canadian society that is transitioning towards sustainability in 2020, the year of perfect vision.

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## **Dedication**

To two remarkable people who passed away before this thesis was finished: Ilona, my loving mother, Thomas Seebohm, a mentor and friend.

## Table of Contents

List of Figures .....	viii
Chapter 1 Introduction .....	1
1.1 Introduction.....	1
1.2 Significance of Topic .....	1
1.3 Research Methodology .....	3
1.3.1 Transitioning to Sustainability .....	4
1.3.2 Thesis Intent and Key Assumption .....	5
1.3.3 Thesis Boundaries .....	7
Chapter 2 Background .....	8
2.1 Macro Historical Perspective .....	8
2.2 Sustainability.....	8
2.3 Housing and Architects.....	12
2.4 Detached Single-Family Dwelling .....	14
2.5 Density Carriers .....	15
2.6 Forecasting Housing Typologies .....	15
Chapter 3 Analysis.....	18
3.1 Socio-Cultural Influences .....	18
3.1.1 House Form.....	18
3.1.2 Biophilia.....	19
3.2 Socio-Technological Influences.....	20
3.2.1 Efficiency .....	21
3.2.2 Prefabrication and Open Building Systems .....	22
3.3 Socio-Economic Influences .....	25
3.3.1 Energy Rebalance .....	26
3.4 Density and Sustainability .....	26
3.5 Single-Family Dwelling Model for Disentangled & Open-Building Systems .....	28
3.6 Macro-History of Housing and Disentangled & Open Building Systems .....	31
3.7 Open Building Systems and Sustainability .....	35
Chapter 4 The Design Speculation.....	36
4.1 Multi-Scalar Ordering Principles .....	37

4.2 Infrastructure .....	40
4.3 Solar.....	45
4.4 Urban Tissue.....	49
4.5 Support .....	57
4.6 Facade.....	61
4.7 Infill.....	62
4.8 Design Exploration.....	63
Chapter 5 Conclusion .....	85
5.1 Urban Housing at a Re-balance Point.....	85
References.....	88

## Appendices

Appendix A-Basic Site Data.....	94
Appendix B-Cost Comparison.....	107

## List of Figures

1. pie chart of US energy consumption
2. sample of a Special Green issue
3. a speculative architectural concept by Peter Cook of Archigram
4. a discrete dwelling unit speculated by Archigram
5. chart linking oil to economy
6. LeCorbusier's plan for a large infrastructure with individual dwelling units
7. an unbuilt proposal by the architectural firm S.I.T.E.
8. an unbuilt proposal by Frie Otto
9. relationship between control and key design considerations
10. North-South street with south face of structures shadowed
11. same street with East-West orientation
12. schematic cross-section depicting form shaped by solar access
13. chart of significance of infiltration to heat loss
14. schematic cross-section detailing various components of a 5 story unoccupied atria
15. relationship between length and width and Kr value
16. current commercially available reflector system
17. screen shot of results of simulating atria form using Ecotect ver. 5.5
18. optimum population density of an eco-city
19. generic representation of different dwelling unit density
20. examples of form of various housing densities
21. housing types and parking
22. reprint of the City Official Plan Map
23. a schematic portrayal of a pedestrian-friendly streetscape
24. photograph of Church Street located in Burlington VT.
25. typical high density condo housing
26. advantages of solar access in two story form
27. chart of embodied energy values for various building materials
28. urban context schematic



29. the urban context
30. solar access and form
31. project form and solar access
32. project components
33. disentangled urban infrastructure
34. disentangled high traffic commercial
35. view along Queen Street
36. support layers
37. support structural layer
38. roofscape
39. service core and circulation
40. biota
41. view along commercial façade
42. view of neighbourhood institutional façade
43. view of landscaped podium
44. infill
45. a possible unit
46. view of infill dwellings



# Chapter 1

## Introduction

### 1.1 Introduction

From a macro perspective, ‘civilization’ can be viewed as a recent 10,000 year construct of a ‘habitat builder’ species called *Homo sapiens*. All species, and especially the habitat builders, create an impact on the environment. No species lives in isolation from the environment, but is merely a part of the biosphere with its interconnected relationships of cause and effect. The price of ‘civilization’ in ecological terms is, (and always has been), to modify the environment in which we live. The current degree and rate of anthropogenic change to the environment have now reached a global scale of awareness with greenhouse (GHG) emissions directly linked to hazardous climate change scenarios. The greenhouse gas CO<sub>2</sub> in the atmosphere has had a dramatic increase that is now linked to fossil fuel emissions created by our current global annual energy needs of approximately 400 Quads of energy<sup>1</sup>. The US Energy Information Administration projects that over the next 25 years, world energy consumption will increase 62%, or an additional 276 Quads. The convergence of these three issues – global scale awareness, global escalating energy needs, and resulting depletion of fossil fuel feed stocks, and global warming as an anthropogenic change linked to increases in GHG, specifically CO<sub>2</sub>, in the atmosphere – are the over-arching issues that will define the near future, including architecture.

### 1.2 Significance of Topic

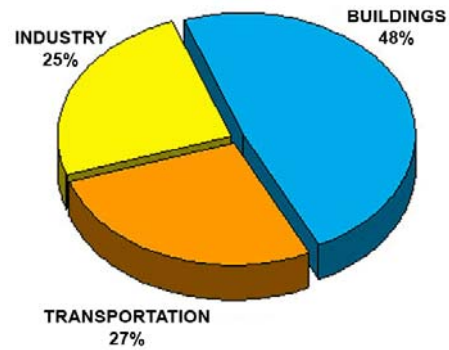
Anthropogenic change is now on a global scale, with 48% of manmade material and energy flows (see Fig. 1), and their associated GHG emissions, attributable to building activity<sup>2</sup>. This makes the

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<sup>1</sup> A quad is a unit of energy equal to quadrillion BTU or 10<sup>15</sup> BTU or 1.055 × 10<sup>18</sup> joules (1.055 exajoules or EJ) in SI units. The unit is used by the U.S. Department of Energy in discussing world and national energy budgets.

<sup>2</sup> F. Schmidt-Bleek estimates that 80 tons of non-renewable resources are devoted every year to maintain the material wealth of Americans and Europeans (Schmidt-Bleek, 1993). As these resources are put into an economy, what comes out of it are emissions, effluents and wastes. Currently, CO<sub>2</sub> emissions are highlighted in our society by its link to global climate change. The scale of anthropogenic materials flows could be causing environmental stresses on a global scale that simply have not been measured yet.

construction and operation of buildings the single largest contributor to global warming<sup>3</sup>. Conversely, a dramatic reduction in GHG emissions can be achieved by changing the way buildings are constructed and operated and a sustainable built-environment would have a large impact in improving the prospects for our society as a whole.



**Figure 1 - pie chart of US energy consumption (Architecture2030, 2008)**

The current urban fabric is often described as unsustainable ‘sprawl’; characterized by the single family dwelling and the car. It is predicted that the Greater Toronto Area (GTA) will have to absorb an additional 1.2 million residents by 2021 (greatertoronto.org, 2008). For this growth to occur in a sustainable fashion, change on a multi-scalar level will be needed. A failure to provide viable, market driven choices that move towards sustainable development will, by default, maintain the current path of accelerated anthropogenic global change. In the near future, this will result in a rapid rebalance of the planet’s ecosystems, sinks, and reserves of the biosphere. If the future rebalance point creates conditions outside the parameters that have sustained ‘civilization’ for the last 10,000 years, then the environmental underpinnings that have supported ‘civilization’ will be threatened.

New approaches will need to emerge to transition towards sustainability in the midst of a major rebalance in the socio-economic (the end of cheap oil), socio-cultural (a global perspective), and socio-technological (efficiencies in material and energy flows) influences that will shape our future and our architecture.

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<sup>3</sup> To create a US Building Sector percentage for the year 2000, the Residential buildings (operations) sector (20.4 QBtu), Commercial buildings (operations) sector (17.2 QBtu), Industrial sector - buildings operations (2.0 QBtu) and the Industrial sector - annual building construction and materials embodied energy estimate (8.57 QBtu) were combined. Total annual 2000 Building Sector consumption was 48.17 QBtu and the total annual 2000 US Energy consumption was 99.38 QBtu.(Architecture2030, 2008)

### 1.3 Research Methodology

The anthropogenic impact of urban housing on the biosphere can be traced back 6,000 years<sup>4</sup>. It is proposed to study this impact through time and speculate on the near future by examining the relationship between housing and architecture. The inter-related dynamic forces of culture, technology, and ecology that shape the context for housing will be the backdrop framing the analysis. The influences that shape choices of habitation patterns that have evolved as the resultant equilibrium of culture, technology, and economy are examined to understand what has led us to this currently unsustainable situation. From this knowledge base, the dynamics of possible choices in the housing marketplace can be proposed that will address our housing future while the major rebalance of the marketplace, the end of cheap oil, ultimately will reverberate throughout our society. If one accepts that the suburban single-family detached house typology has dominated the socio-cultural house form since 1945 based on the sheer numbers of units built<sup>5</sup>, a study of its typological characteristics can provide a guide to the underpinnings of the choices that influence the urban housing marketplace. Further, the typological characteristics can be examined as ordering principles in a denser typology, hopefully transposing that 'success' to the new typology (Straube, John 2008) .

This thesis will speculate on context and ordering principles for architecture that can shape urban housing in the GTA by 2020. The context will be the speculated rebalanced equilibrium point that will occur in 2020 between the inter-related forces of culture, technology, and economy as it shapes our views of our place in the biosphere. This thesis will speculate on ordering principles in housing design that will enable our society to implement strategies to move towards sustainability. The speculations will frame the issues that urban housing can take to move the act of urban habitation building towards sustainable development. The specific scenarios, illustrative examples, and architectural interventions illustrative of those concepts that can provide a possible direction that could be realized by 2020. These are examined and illustrated in a speculative demonstration project

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<sup>4</sup> Although it is recognized that all forms of housing have an impact, this thesis examines housing for the median of society in an urban context since the sheer weight of numbers of the median causes the most collective impact. Housing for the elite as monumental architecture and housing for the impoverished as mass government supported housing with no choice by occupants are not considered.

<sup>5</sup> Based on the 2006 Census, Statistics Canada found that 62% of Canadians live in a detached single family dwelling (Statistics Canada, 2006).

sited in the Greater Toronto Area (GTA) at 1001 Queen St. West – the site of the former Provincial Lunatic Asylum.

### **1.3.1 Transitioning to Sustainability**

Change in modernity was often viewed as a progressive and desirable choice – in any event; change now seems inevitable and global in scale. Ed Mazria has stated in his 2030 Challenge lectures that approximately 75% of the built environment in the US will be either new or renovated by 2035 (Architecture2030, 2008). This rebuilding of the built environment is the opportunity created by change. Buildings can be designed and built using sustainability strategies. It then becomes a question of which of those strategies will be supported by choice in our society.

Dr. Tang Lee addressed a group of architects at the 2007 Canadian Design and Research Network (CDRN) Sustainability Workshop held at the University of Waterloo and made the following opening comment:

“We (architects) do not design for the past, we do not design for the present, we design for the future”.

If we are to transition towards a sustainable-built environment, then architectural design must reflect that intent. To paraphrase Einstein, it is not possible to construct a sustainable built environment using the same design ideologies that created our current built environment, with its associated undesirable global scale anthropogenic changes.

The transition to sustainability is also a transition in our cultural vantage point. Since the Industrial Age, the socio-cultural vantage point has been closely linked to advances in human technology. Civilization’s vantage point has shifted from an eye-level view of the horizon from trains, to a bird’s eye view from planes, to a planet-wide view from space. On December 22, 1968, an iconic photograph was taken from the Apollo 8 Space Mission that showed, for the first time, the planet Earth rising over the moon. This photo is considered by many to have caused the cultural shift that resulted in the birth of the environmental populist movement<sup>6</sup>. This new planet-wide perspective

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<sup>6</sup> In the movie “An Inconvenient Truth”, Al Gore clearly identifies this picture as the milestone to the start of the environmental movement.



**Figure 2 - sample of a Special Green Issue (Vanity Fair, 2006)**

brought on by Space Age technology has established the cultural reference frame that is mainstreaming a new global perspective of the biosphere. This large, holistic point of view is radically redefining the underpinnings of progress. Bountiful and unlimited resources are now understood to be finite resources to be stewarded.

Environmental cause and effect cannot be neatly contained by political borders. The planet Earth is now the fragile planet Earth. This socio-cultural perspective is reflected in pop culture and the mass media with such films as 'The Day After Tomorrow' and, of course, 'An Inconvenient Truth' as well as 'special green editions' of magazines such as Vanity Fair (see Fig. 2). The environment has emerged as the cultural refocus of our time.

Sustainability has moved from a cultural concept at the fringe to a primary force in the mainstream. In his book titled, *The Philosophy of Sustainable Design*, Jason F. McLennan declares his manifesto for architects

based on philosophical first principles of sustainability. It is significant that a philosophy is proposed by him as the underpinning of sustainability. Again, paraphrasing Einstein, we need to change the way we think and the way we act in daily life if we want a different outcome from.

### 1.3.2 Thesis Intent and Key Assumption

A speculative design based on architectural scenarios representing options for sustainable habitation in the near future (2020, the year of perfect vision) has the characteristics of the classic 'wicked' design problem<sup>7</sup>. A society's housing choices are dynamic and complex and are continuously

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<sup>7</sup> Wicked problems have incomplete, contradictory, and changing requirements; and solutions to them are often difficult to recognize as such because of complex interdependencies. The concept of "wicked problems" was originally proposed by Horst Rittel, (a pioneering theorist of design and planning, and late professor at the University of California, Berkeley), and M. Webber in a seminal treatise for social planning, Rittel expounded

evolving in response to the multi-scale influences of the cultural, technological and economic influences - the Triple Bottom Line<sup>8</sup> - of civilization. The sustainability concept in architecture is ill-defined, although several definitions are offered, and speculations of the future never seem to fully anticipate the emergence of a dominant ‘surprise’ factor. It is the intent of this thesis to gain possible insights into this ‘wicked problem’. This thesis posits that habitation patterns within the context of the Triple Bottom Line can be viewed as shifting rebalanced points of equilibrium. It is proposed to study the complex interdependencies and causations between culture, technology, and economy. This approach is based on the premise that everything is connected, (however slightly), to everything else; and that the resultant complexity is constantly evolving as a rebalanced equilibrium of influences. Since there are multiple and changing choices in our society for housing, the outcome is a changing equilibrium moment – the result of constantly changing interactions of demographic shifts, supply and demand issues, and consumer perceptions. As long as housing in the future remains molded by private choice that is integrally shaped by the Triple Bottom Line, and the housing public will continue to voluntarily pay the costs associated with a housing lifestyle and will be free to make the trade-offs they prefer for housing, housing will equilibrate around a moving rebalance point. The dynamics of free choice operating within competing and interactive influences of the triple Bottom Line will ultimately define housing. By studying the competing influences, a possible architecture for urban housing is proposed that lies within the probable rebalance point in 2020, and moves housing toward sustainability.

The architecture of the speculative demonstration project of this thesis reflects architectural design intentions to move toward sustainability for housing in an urban setting. It is not an example of ‘the house of the future, but rather the future of ‘dwelling’ as a component of everyday existence in a society moving toward sustainability. The speculation is framed in a context derived from scenarios

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on the nature of ill-defined design and planning problems which he termed "wicked" (that is, messy, circular, aggressive) to contrast against the relatively "tame" problems of mathematics, chess, or puzzle solving (Rittel, Horst and Melvin Webber, 1995).

<sup>8</sup> John Elkington, co-founder of the business consultancy SustainAbility first coined the phrase “the Triple Bottom Line” as the new metric to assess criteria for measuring organizational (and societal) success - economic, environmental, and social (Elkington, 1998)



of how the near future might unfold based on informed constraints and sustainable possibilities to demonstrate the desired and the feasible.

The derived architectural context will speculate on influences which promoted the choices that have shaped housing. The success of the proposed architectural context will be evaluated on its ability to enable a new re-balance of materials and energy that would move our current society towards sustainable housing within the realm of new choices that would be brought by change.

### **1.3.3 Thesis Boundaries**

The analysis of context is based on the premise that everything is dynamically inter-connected. Yet, no one can be aware of everything at once and dynamic change is unpredictable. Thus, no attempt is made to construct an all-inclusive model of housing dynamics. The analysis is used where it is instructive and, on that basis, a judgment is made on what can be ignored and what is significant. This thesis will focus on sustainable housing in an urban context since the trend towards an urbanized population is projected for the near future. As the context emerges from the dynamic rebalanced equilibrium of 2020, the resulting synergistic effects are used to uncover a closer approximation of a feasible and desirable future.

This thesis, although open-ended in one sense, benefits from boundaries to create a focus. The following are suggested:

- The year 2020 – which defines the technologically feasible
- The study area – which defines the specifics of the culture and of the biosphere
- The multi-scalar cultural, technological, and economic influences – which define the context

The architectural speculation is not a design exercise on housing design ‘never seen before’ in a ‘would be’ future. Instead, it looks at the signs in the past and present that, with good reason, look promising for a sustainable future.

## Chapter 2

### Background

#### 2.1 Macro Historical Perspective

In terms of human civilization as a component of the biosphere, two epochs can be identified: the carbohydrate age, (roughly 6,000 BC to 1850 AD in North America), and the hydrocarbon age, (1850 to present). The carbohydrate age is characterized by energy used for useful work derived from plant and animal matter locked into the specific limits of growth of their own ecosystems. Impacts on the environment were limited by man's physical strength, the strength of his domesticated animals, and on some wind and water power. The limits to growth were capped by society's ability to manage nature's carbohydrate-based technology. The manageable energy man could derive from nature, the productivity of his daily work, was limited. Around 1850, in what is commonly called the Industrial Revolution in North America, human technology raised civilization's ceiling to growth by employing hydrocarbon-based energy to perform useful work. Since the invention of the 'machine', daily productivity to relocate and transform material and energy flows has dramatically increased. This transition in civilization from a carbohydrate energy age to a hydrocarbon energy age marked the beginning of a period where humanity had been able to avoid, at least temporarily, most of the traditional checks and balances that nature used to balance the interconnected relationships of the biosphere. Machines have increased the human capacity for initiating material and energy flows so dramatically that global scale consequences are the new reality.

#### 2.2 Sustainability

At its core, the notion of sustainability is centered on the fact that humanity is still an integral part of the biosphere despite its success in temporarily exceeding the traditional checks and balances of nature. We can not live apart from the biosphere but only as part of it. The biosphere is a planet-bound closed system and at some point a rebalance will occur. There are no exceptions made for us. Ancient history is filled with examples of civilizations that grew and exceeded the checks and balances of nature. In his book *Collapse*, the geographer Jared Diamond graphically details the

history of the rebalance of Easter Island after its forests were denuded by its inhabitants<sup>9</sup>. While it is materially impossible for us to destroy the planet Earth, we now have the capacity to engage in material and energy relocations that are so disruptive to the biosphere that a new rebalance point could emerge that is drastically different from the status-quo of the last 10,000 years which has nurtured civilization<sup>10</sup>.

Since sustainability has now become culturally mainstream it is often used as an umbrella term to describe the many facets of mitigating the human impact on the environment so that meeting the needs of today does not compromise the ability of those in the future to meet their needs. Sustainability in architecture, as a concept, is an eco-centric philosophy that relates fabrication and operation to the interaction of energy flows and material flows in the biosphere to our built environment; all the while couched in a larger question, “What constitutes sustainability”? Specifically, what constitutes sustainability in housing?

The most widely accepted definition of sustainability was developed in 1987 by the World Commission on Environment and Development (the Brundtland Commission) as follows:

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland Report, 1987)

This definition is very broad and unwieldy, but it does convey the core characteristic of sustainability as a process or state that can be maintained indefinitely. The terminology has proved helpful on a

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<sup>9</sup> Jared Diamond recites how troubling the story of Easter Island was to his students. He was always asked the same question: “What was the islander who cut down the last tree thinking?” How could a society make such a disastrous decision? (Diamond, 2005)

<sup>10</sup> F. Schmidt-Bleek states that in the Pre-Industrial Age, nature - the result of millions of years of evolution - had a balanced state of affairs between material flows and environmental reservoirs. Industrial and economic forces have dramatically disturbed these material flows and the environmental reservoirs are rapidly changing their composition. At some future date, a new equilibrium may establish itself. But these new conditions will not be advantageous to humans because they will be divergences from the conditions under which humans first evolved (Schmidt-Bleek, 1993)

pragmatic level in allowing us to evaluate issues as ‘more sustainable’ or ‘less sustainable’. In the design and construction industry, the question of ‘more or less’ has been codified into various sustainable building rating systems in order to apply a standardized metric to the question. These rating systems, (such as LEED™, BREEAM™, CASBEE™, GBTool™, GREEN GLOBES™), address current consensus-derived sustainable design characteristics in a formulaic layout to establish industry benchmarks<sup>11</sup>. There is no question that if a design met the specific criteria of any of the rating systems, it would be ‘more sustainable’ than the equivalent ‘typical’ building of today. Yet, it must be acknowledged that a formulaic methodology simply imposed on a project will invariably create unintended consequences (Bray and McCurry, 2009). Jeremy Bray and Natasha McCurry wrote an article in the Journal of Green Building titled “Unintended Consequences: How the use of LEED™ can inadvertently fail to benefit the environment”. The article looked at specific LEED™ certified projects and demonstrated that achieving a higher LEED™ ‘score’ can create a ‘less sustainable’ scenario. Another generic category of sustainable rating systems evaluates the ecological rucksack attached to building materials<sup>12</sup>. The Athena Institute has developed software, the Athena Impact Estimator for Buildings that models building materials’ full environmental Life Cycle Cost

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<sup>11</sup> K. M. Fowler and E. M. Rauch of the Pacific Northwest National Laboratory operated by the US Department of Energy by Battelle for US General Services Administration completed a comprehensive review of sustainability rating systems for buildings in July 2006. (Fowler and Rauch, 2006)

<sup>12</sup> F. Schmidt-Bleek proposed a new metric be established as an indicator for sustainability that takes into account the full environmental cost of a given product over its useful service life. The unit of measure would account for the resource extraction, manufacturing, transport, packaging, operating, re-use, re-cycling, and re-manufacturing and final disposal. The unit of measure is MIPS - Material (including energy) Intensity Per Unit of Service (utility or function). The ‘ecological rucksack’ is defined as the total quantity (in Kg) of natural material (M) that is disturbed in its natural setting and thus considered the total input (I) in order to generate a product - counted from the cradle to the point when the product is ready for use - minus the weight (in Kg) of the product itself. The disturbed material is analyzed for its impact on five categories of ‘ecological rucksacks’ which correspond to the five environmental spheres that have been traditionally distinguished in environmental sciences and policies: water, air, soil and renewable biomass, non-renewable (abiotic) material. On average, industrial products carry non-renewable rucksacks that are 30 times their own weight. By this measure, a gold wedding band carries 3.5 tons of rucksack mainly caused by the material movement of overburden in the mining operation. (Schmidt-Bleek, 1993)

from cradle to grave in categories such as embodied energy, global warming potential, solid waste emissions, and pollutants (Athena Institute, 2008). At the 3<sup>rd</sup> Annual Green Building Festival held in Toronto ([www.greenbuildingfest.com](http://www.greenbuildingfest.com)), an online sustainable selection tool was discussed as a goal that would provide basic sustainability information akin to and modeled after the ‘nutrition facts’ label on food products. While it is an important metric, this rating also would not answer the question of whether a specific design option moves us towards sustainability or not. A simple example would be this: spray-in-place rigid foam insulation is not in itself an environmentally benign building product but it is such a good insulator, air barrier, and vapor barrier that it can dramatically reduce the energy requirements of a building – energy requirements that can be translated to large material flows required to create the energy. Thus, rigid foam insulation would rate poorly in Athena™ or GreenSpecX™ as a building material, but when used to create a high performance building envelope, it is an eco-efficient material<sup>13</sup>. Another category of sustainability metrics is the absolute benchmark approach illustrated by the ‘Net-Zero House’, the ‘Carbon Neutral House’, and the ‘Zero Squared House’ (zero net energy and carbon neutral). The glaring problem of using an absolute benchmark is that there is no consideration of how one achieved that benchmark – again, the lack of context.

If sustainability rating systems were indeed a complete answer to moving towards sustainability, then, a Net-Zero, Carbon Neutral house in the outer suburbs of the GTA, built to LEED™ Platinum using environmental products rated highly by Athena, would be the obvious answer to sustainable urban housing. Yes, the building would be Green and sustainable – so long as the occupants never had to go anywhere or do anything. The rating systems simply do not address context very well. A car trip not taken is more sustainable than a car trip taken with a hybrid car.

There is merit to the use of the metrics offered by LEED™ and ATHENA™ and others to assist in answering specific, isolated, questions on sustainability, but the metrics lack usefulness in evaluating

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<sup>13</sup> The term ‘eco-efficient’ was used by Frank Bosshart during the meeting in Rio of the 1992 UNCED (United Nations Conference on Environment and Development). The accepted meaning of the term connects economy and ecology: “Eco-efficiency is reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in-line with the earth’s carrying capacity” (World Business Council for Sustainable Development, 1992).

the first principle basics for a given project: is it ‘moving towards sustainability’ or moving away from it?

The rating systems, in a generalized sense, support a kind of appliqué of green technologies to building designs derived from established trendy norms rather than building designs embedded into the flows of the biosphere. They address only parts of the question of sustainability which can lead to concentrating on misconstrued objectives and associated means, thereby obscuring the underlying issue.

Within the context of this thesis, there is usefulness in discussing another kind of metric: factors that enable the means for moving towards sustainability. Since the cultural underpinnings for sustainability are now well-entrenched in the mainstream of our society, the idea of rating, of getting a good score, has lost its avant-garde status to cause real change. There is nothing in LEED™, BREEAM™ or Green Globes™ that questions the fundamental ordering or organization of a building, nor provides any guidance for it. Since factors that enable sustainability differ from project to project, a universal metric for ‘enabling’ may not be possible. Sustainability as a philosophy transcends the metrics of sustainability for enabling. The goal is to move towards sustainability, to enable and facilitate the factors derived from first principles that support that goal as means to a sustainable end.

### **2.3 Housing and Architects**

The geographer, Jared Diamond, posits the change in societal organization from hunter/gather to permanent settlement as the beginnings of “civilization” (Diamond, 1992). Permanent settlements allowed for the creation of ‘specialists’ in society as well as the creation of a society’s ‘surpluses’. The architecture of a society is the artifact of a society’s surplus in the form of monumental structures. As architecture students, we study these artifacts to gain insight into The Triple Bottom Line of that society.

From 6,000 BC to 1500 AD, architecture was created from ‘surplus’ in a pluralistic way by society’s specialists. Architectural artifacts were without authorship and were viewed as cultural products of their time. We often know, historically, who built them, but; since the hands of many artisans were involved, often over several generations, no real association is made between a specific builder as author. Since the technological anchor point of the Triple Bottom Line during this era had only technology (tools) powered by man and beast, a pluralist approach was required. The cultural, economic, technological intersection of forces changed from 1500 to 1850 in architecture with the introduction of a new specialist in society - the architect. Brunelleschi is often credited for being the ‘tipping point’ (Gladwell, 2002) for the creation of this new specialist where design was separated from making<sup>14</sup>. Building monuments from society’s surplus changed from a pluralist effort to an individual’s vision. This was the beginning of architectural authorship. In architecture, we now refer to individual ‘styles’ based on the visions of the authors, such as; Palladian, Wrightian, Miesian, etc. In contrast, housing ‘styles’ are named from their cultural product roots or region, such as; Tudor, Southwestern, Floridian, etc.

Housing, since it is a basic need, is not part of this ‘surplus’; hence did not generally get labeled as architecture - it was vernacular mostly constructed without architects. Housing, as a basic need, was historically created from locally available resources assembled by the occupants of the dwelling, based on a culturally derived common pool of knowledge that had slowly evolved over time. As technology advanced, ‘styles’ emerged that responded to available cheap local resources and the use of specific culturally derived forms to mitigate natural forces. The anthropogenic impact was within limits for ecosystems to restore themselves quickly if left alone. Since this phase of vernacular housing was well-interconnected within the regional ecosystem, it is often studied for potential models of sustainable housing for detached single-family dwellings.

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<sup>14</sup> The Renaissance momentum of change in moving building from a pluralist base to a singular vision of an artist was enabled by small incremental advances in the technology of understanding and being able to draw perspective. Once the technology of understanding perspective reached sufficiency for the accurate portrayal of a building, a single vision (by the architect) for that building could be directed to others, it became possible to build to a predetermined single vision.

In housing, the rebalance caused by the Industrial Revolution with its population shift from rural to urban, marked the start of the erosion of the decision making authority of the dwelling occupant as to the nature of the dwelling, since the dwelling occupant was often not the dwelling owner. As the dramatic social upheavals continued, starting around the 1920's, a rebalance and social reorganization, in response to housing problems, started to engage architects in workforce housing. Architecture was promoted as a social engineering tool, reflecting the socio-cultural issues of the era. Architecture was no longer just buildings, but now included 'the built environment'. Architecture started to engage itself beyond 'housing' for rich patrons, (still a form of society's surplus), to housing for the workforce masses. After WWII, Europe faced a housing shortage that was responded to by government-sponsored mass urban housing with architectural authorship. Since Europe was faced with limited resources in land, capital and material, mass housing became an architectural exercise in stacked dwellings designed with the 'best compromise' of a plan, repeated, for the masses. Direct occupant input was completely excluded as evidenced by the fact that occupants immediately made changes to their dwelling once they took possession. In North America, the rebalance took a different shape due to the availability of cheap land, economic prosperity, automobiles, and still plentiful resources. Housing for the masses, since choice was allowed and the masses had the means, took shape as the detached single-family dwelling with its direct connection to the ground plane (to nature), direct control through ownership of the decision making process, direct control of one's privacy. This is the universally preferred choice of housing - the "American Dream". This concept of a house in a garden, the simulacra of the manor house, has almost universal appeal to the general populace in western civilization.

## **2.4 Detached Single-Family Dwelling**

Cheap oil providing cheap energy is the underpinning of our current society. It has reshaped the urban landscape into what is now commonly called urban sprawl – detached house subdivisions leapfrogging further and further from the city, interconnected and made possible and reliant upon the car. The iconic flagship of this landscape is the detached single family dwelling: cheaply built, affordable, offering privacy and space. Yet, the beautiful illusion of the 'dream home' country retreat conceals many problems. The reality of subdivision homes on small lots has been debunked as individual isolation in a boring environment that offers neither desirable spatial qualities nor urbanity. Acoustic privacy is marginal and can be much better achieved through technical means. In reality the



modest spaces between detached houses become inhospitable and labor intensive nuisances. In detached modern houses there are usually less than 2 sides on the ground floor, (the front is mostly dedicated to the garage), that have an exposure to the exterior and the second floor has 2 sides. If you stagger a row house, you can get 2.5 sides exposed. If you use careful condo designs, you can get 2+ sides (Straube, 2008).

## 2.5 Density Carriers

The current offerings of ‘density-carriers’ as housing in the city core in the form of high-rise buildings, presents its own problems. Few building typologies disconnect people from nature and each other as effectively. Dense urban housing designed by architects that looked laudable in architectural journals turned, in most part, into socially engineered ghettos.<sup>15</sup> A high-rise apartment building with its extruded form and repetitive plan simply does not have the cultural underpinnings of ‘home’. The ‘occupancy’ is often transient, defined by a lease. It is an extended stay hotel with no services where ownership through personalization is not allowed. Where the ‘occupancy’ is defined by ownership under the Condominium Act, a stronger sense of control through ownership is created but the typology limits control typically only to the unit’s interior. This form of ownership is geared towards a narrow demographic and once the ‘occupant’ becomes part of a different demographic, the typology does not allow for change and becomes functionally obsolete for the occupant as it fails to provide specific amenities desired by that changed demographic.

## 2.6 Forecasting Housing Typologies

In his book, *Boom, Bust & Echo*, David A. Foot declares that “Demography, the study of human populations, is the most powerful tool we have to understand the past and to foretell the

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<sup>15</sup> In 1956, 2870 apartments rose skyward in St. Louis, Missouri. The Pruitt-Igoe project was hailed as an incredibly forward-thinking model of public housing, and was Minoru Yamasaki's first big design before he moved on to create the World Trade Center in New York City. Few could have guessed that the complex would become a dystopia that would result in its demolition 16 years later.

future.....Demographics explains about two-thirds of everything” (Foote and Stoffman, 1998)

The use of analysis of census data by workforce housing developers is and has been standard practice since the commoditization of workforce housing after WWII. The validity of demographic data for ‘predicting’ is founded on the assumption that in a homogeneous culture, the individual tends to participate in a given behavior in a specific age group. We tend to all finish high school at about the same age, attend post-secondary educational institutions at about the same age, get married at about the same age, buy our first house at about the same age, etc. Because age is so powerful a predictor of behavior, if you know how many people of each age bracket are around, one can make a fairly reliable forecast.

Participation rates in age-related events has been fairly stable in North America – young men returning from WWII started families that defined the single largest cohort of the 20th century – the Baby Boomers. The cohort all needed the same things including basic affordable workforce housing leading to the explosive growth of car based suburbs. The decision to opt for the suburbs could be viewed not as a rejection of the city as a place to live but as a response to insufficient, affordable, housing options available in the city. Not only were the houses of Levittown all the same, the people who moved there were all the same – a one class community of young couples after the war<sup>16</sup>. Thus, in the past, it made sense to speculatively build workforce housing by developing plans that were a speculation on the best compromise floor plan that reflected an identified ‘market’ (ie: age group participation), and replicate that plan. That is the state-of-the-art today for dense urban housing, repeated floor plans, (in all fairness, a project will try to broaden its base by offering several floor plans in a ‘mix’ that are then repeated on every floor). The obvious shortcoming of this approach is that as the age cohort changes over time, the replacement age cohort population is not the

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<sup>16</sup> The brainchild of developer William J. Levitt, Levittown, Pennsylvania, was the largest planned community constructed by a single builder in the United States. By the time it was completed in 1958, the development occupied over 5500 acres in lower Bucks County and included churches, schools, swimming pools, shopping centers, and 17,311 single-family homes (State Museum of Pennsylvania, 2003)

same (the result of the infamous Baby Boom bulge in demographics). In addition, the homogeneous cultural context is diverging with inflows of new culturally diverse populations. Lastly, the rate of change of technology is impacting lifestyles at a much faster pace, resulting in diverging responses to an age related participation event. As our society experiences a major societal rebalance with the coming of 'End of Cheap Oil', the age dependent participation in housing will be constant (buy your first 'house' at around thirty) but the 'house' will be molded by diversity in cultures, multi-age, and multi-class communities, and new socio-economic realities.

## Chapter 3

### Analysis

#### 3.1 Socio-Cultural Influences

Culture, in very broad terms, can be viewed as the collective memory of a society's ideas, institutions, and conventionalized activities. The connective tissue between building form and socio-cultural forces is man's propensity to symbolize everything (Dubois, 1965). There is a symbolic element to housing that transcends the practical role of environmental mediator that modifies the environment to meet our preferences. The large tracts of essentially single-use housing built after WWII have become the icon of urban sprawl symbolizing the preferred housing choice. The success of that housing choice is linked to the cultural perception of the single-family detached house form as the ideal form to ensure one's privacy and directly control one's living environment. The origins of the strengths of this iconic form stems from the large size of the culturally homogeneous demographic of the population called the 'middleclass' after WWII. From 1951 to 2001, more than half of Toronto's residents were born outside of Canada; and a million people identified themselves as belonging to visible minorities (Toronto.ca, 2008). This large expansion of the cultural matrix could possibly dilute the prominence of any singular iconic form of housing, making housing form less a product of an identified cultural past. This fact will hopefully open the housing form to the new icons of our era, the icons that will develop as the culture of sustainability matures.

##### 3.1.1 House Form

In his book, *House Form and Culture*, Amos Rapoport states that originality and innovation in vernacular buildings are frowned upon and often condemned (Rapoport, 1969). Thus, the iconography of 'home' resists change. There is no question that the informal controls of culture defining the detached house as the typology of home is well established, but the cultural underpinnings are no longer homogeneous and fixed. The culture of sustainability is now mainstream; but it is new, and new is original and innovative. The iconography of sustainability is establishing itself but does not transplant to housing form in a readily identifiable way. To enlarge the cultural matrix from only detached dwellings as house and include stacked dwellings as home as

well, it will require that the underpinnings of the detached home, privacy and control, be transplanted as well as notional architectural forms for housing.

### **3.1.2 Biophilia**

Another key component of the idealized home as represented by the detached house is the direct connection of the ground plane with the house. It is the ‘garden’ component of the ‘house in the garden’ providing a direct connection between occupant and nature.

This connection is described in this quotation from Peter H. Kahn Jr.’s article titled “Developmental Psychology and the Biophilia Hypothesis: Children’s Affinity for Nature” (Kahn, 1997).

“.....The biophilia hypothesis asserts the existence of a fundamental, genetically based, human need and propensity to affiliate with life and lifelike processes. Consider, for example, that recent studies have shown that even minimal connection with nature – such as looking at it through a window – increases productivity in the workplace, promotes healing of patients in hospitals, and reduces the frequency of sickness in prisons. Other studies have begun to show that when given the option, humans choose landscapes such as prominences near water from which parkland can be viewed that fit patterns laid deep down in human history....”

Property values in well-treed lower-density neighborhoods are higher than identical neighborhoods lacking this feature. Realtors assign from 10 % to 23% of the value of a residence to the trees on the property (Brown University Center for Environmental Studies, 2003). In a stacked dwelling configuration, the “ground plane” is limited to a simulacra form. The echo of the occupant-nature connection is limited in higher-density dwellings but can be accommodated. The desirability of contact with verdure is pervasive in western culture and any proposed higher-density housing form should be responsive to this cultural desire. This suggests a cultural preference for mid-rise higher-

density dwellings over high-rise higher-density dwellings where individual dwelling units can connect with the tops of mature trees. The treatment and inclusion of urban biota is a key component in sustainable development as a socio-economic underpinning. If the detached single-family dwelling is to be displaced as the dominant building type of the urban fabric of the study region, then an aesthetic of sustainable stacked dwellings will need to include biota as a significant part of the offering.

### **3.2 Socio-Technological Influences**

In the carbohydrate age biosphere – the result of millions of years of evolution - the material flows between the various ecosystem sinks and reservoirs was fairly balanced, with inputs closely coupled to outputs. Quantities of basic biological materials remained fairly constant. The hydrocarbon age has changed and disturbed those material flows. Anthropogenic disturbances in the biosphere, destabilizing the equilibrium, are technologically leveraged interferences of the in-situ environmental resources. These man-induced material flows are of such scale that they could present a larger long term global environmental crisis than ‘global warming’. We rarely use materials as found in the biosphere, as our carbohydrate age ancestors did. The materials have been materially and chemically altered in the process of becoming consumer products that are eventually thrown away. In some cases, such as CFC’s, we are introducing materials into the environment that do not naturally occur in nature. The chemicalization of these large scale material flows interferes with the natural, ordinary breakdown and recycling processes. The material flows emitted by our technosphere are only able to be absorbed and converted back into material in natural ecosystems over exceedingly long periods of time. We are starting to affect the naturally occurring ratios of different materials on a global scale. CO<sub>2</sub> in our atmosphere is just one example.

Our newly found ‘global perspective’, enabled by space-age technology, allow us to grasp the idea that the planet’s resources are finite. In the early 1970’s, a report called “The Limits to Growth” (Meadows et al, 1972), was prepared for the Club of Rome detailing the magnitude of the ‘world problematique’<sup>17</sup>. There is now a general awareness that there is an ecological rucksack attached to

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<sup>17</sup> Donella H. Meadows, Dennis L. Meadows, Jørgen Randers, and William W. Behrens III wrote the book, *The Limits to Growth*, in 1972, that looked at modeling the consequences of a rapidly growing world population and finite resource supplies and the resulting consequences of interactions between the Earth and human systems (Meadows, 1972).

products and housing. A key concept of moving towards sustainability in housing is based on increasing efficiencies while reducing the ecological rucksack – of doing more with resources while using less nature.

### 3.2.1 Efficiency

Architectural design efforts at efficiency for dense urban housing in the past were based on efficiencies gained through repetition. The architectural design matched the ‘most probable’ user reflected in a simplified floor plan that was always a compromise. The floor plan becomes an exercise in finding a good enough solution to justify continuous repetition for the sake of efficiency achieved through and economies of scale.

The housing construction industry has yet to realize the efficiency gains possible with technology. The Stanford University’s Center for Integrated Facility Engineering (CIFE, 2008), compared the productivity of U.S. construction relative to all non-farm industries over the last 34 years. The results showed that construction productivity declined slightly while all other industries had almost doubled their productivity. Many modern architects have been intrigued by this inefficiency and have asked the question: “Why can’t we build houses like cars?”<sup>18</sup>. Early in the 20<sup>th</sup> century, modernist architecture was conceptually linked to the reductive nature of new assembly methods as a means to efficiency. Le Corbusier predicted that in 20 years, a rational transformation in the methods of construction would come to pass<sup>19</sup>. Walter Gropius and Konrad Wachsmann developed ‘The Package House’ after WWII with support from the US government, but it also only lived on as a concept<sup>20</sup>. Increases in manufacturing efficiencies were tied to standardization, which in turn did not support

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<sup>18</sup> In his book, *The Evolving House*, Alfred Farwell Bemis directly compared the production of a house to the production of a car (Bemis, 1936)

<sup>19</sup> Charles-Édouard Jeanneret-Gris, who chose to be known as Le Corbusier, was a Swiss-born architect, designer, urbanist, writer, and also painter, who is famous for being one of the pioneers of what is now called Modern Architecture or the International Style. He was a pioneer in studies of modern high design and was dedicated to providing better living conditions for the residents of crowded cities (Gans, 2006).

<sup>20</sup> Walter Adolph Georg Gropius was a German architect and founder of Bauhaus, who is widely regarded as one of the pioneering masters of modern architecture.

individuality. This lack of the ability to customize is contrary to the socio-cultural need in housing to be under the control of the unit dweller. Gropius need for ‘aesthetic unity’ and authorship over the dwelling ran contrary to personal choice.

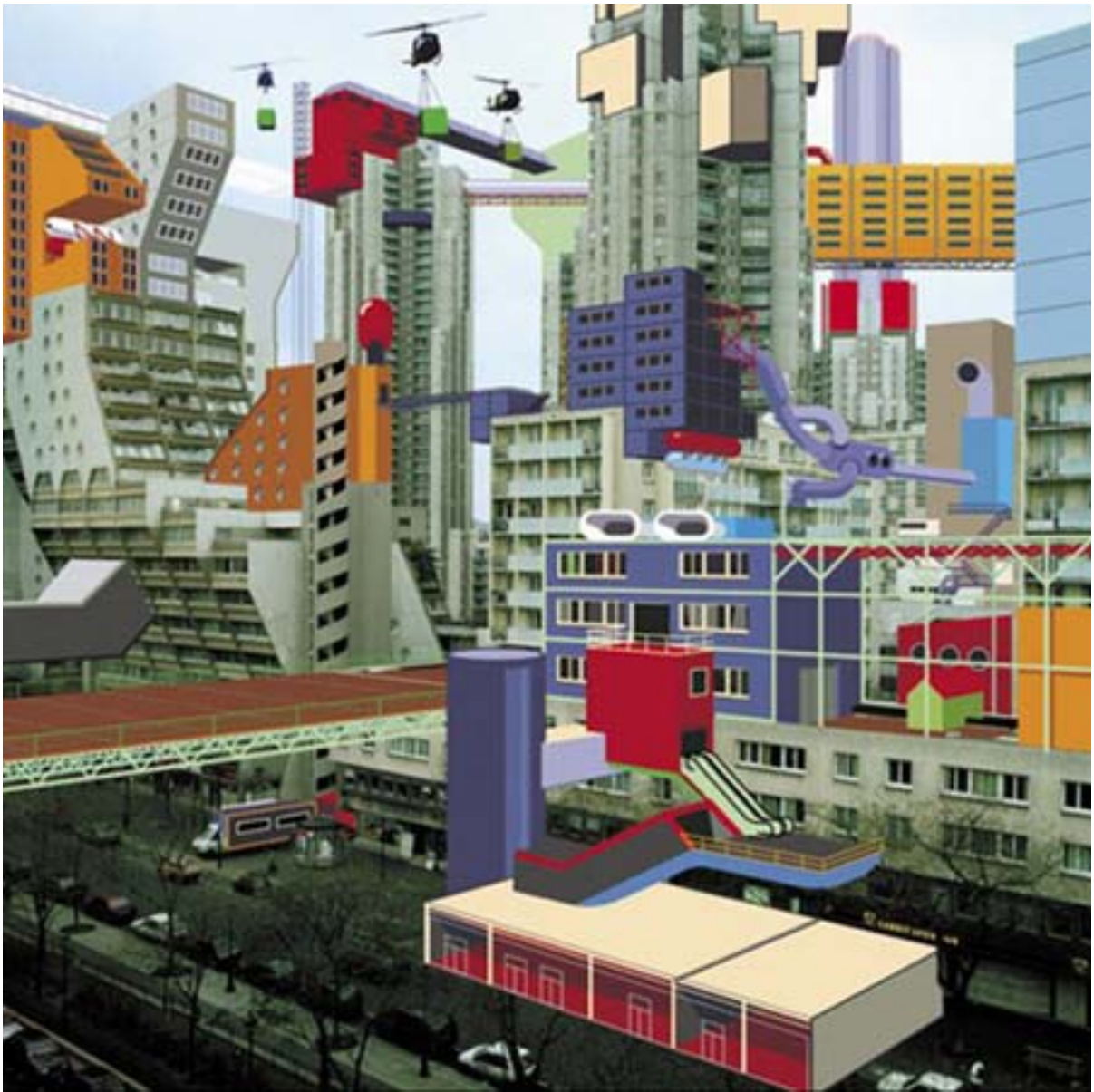
### **3.2.2 Prefabrication and Open Building Systems**

The architectural profession has always struggled with prefabrication. There is a general social prejudice associating prefabrication with the ‘mobile home’. Even though prefabrication made mobile homes cost effective using Fordist methods, it is not considered architecture because the shelters in question were not ‘real houses’. The size and quality were not the issue – it was where they came from and how they got where they were. The lack of architectural authorship relegated mobile homes as an area to study, to learn lessons from, so that the concept can be applied elsewhere, in the real housing industry. One of the dominant lessons inspired directly by mobile homes and prefabrication was plugging living pods into multi-story mega-structures. “Factory produced” became a distinct architectural style. The best known project was ‘Plug-in-City’ by Archigram (see Fig. 3 and 4). Words like ‘Pods’ and ‘Capsule’ appeared in the architectural lexicon rather than ‘house’ or ‘home’. Prefabrication has made some inroads in terms of architectural acceptance. The British High Tech style of Norman Foster uses factory production as an important theme<sup>21</sup>. Architectural authorship has been extended to factory-made building components designed by architects in close consultation with manufacturers in such landmark projects as the Hong Kong and Shanghai Bank buildings. This marked a radical extension of architectural authorship into the factory. Versions of most of the components were already available in semi-standardized form by the manufacturers, but by being redesigned under architectural authorship, they became architecture. This new found legitimacy of prefabrication is causing a recent resurgence in interest.

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<sup>21</sup> The process of architects working in close consultation with manufacturers is called ‘Design Development’ in Foster’s office. ‘Design Development’ as a process is really only feasible on a big project with a big budget where the components can be designed from scratch as a completely new product line requiring large investments in mock-ups, prototypes, testing, and custom manufacturing.





**Figure 3 - speculative urban infrastructure by Peter Cook of Archigram. There is an implied disentanglement between the infrastructure and infill (Archigram 1, 2008).**

The Fordist model of efficiency gains through mass production and standardization is only now being challenged. In 1952, the first numerically controlled machine tool was made for the US Air Force in a research lab at MIT. It was the start of an infiltration of digital technology into manufacturing that would culminate in whole factories controlled by computers. The most important advancement from a designer's point of view is CAM (Computer Aided Manufacturing).



**Figure 4 - a discrete dwelling unit speculated by Archigram (Archigram 2, 2008)**

It has the potential to dispense with standardization as a basis for efficiency once and for all. A computer controlled fabrication can make different components in the same time as identical components. Mass production is now being replaced with lean production responding to specific demand. The socio-technical application of digital control to blocks, chunks, and modules is reducing waste while increasing variety and choice. With advances in digital control, the necessity for standardization is questioned. The logical outcome of efficient, digital production is variety of form and individual choice through mass customization. Digital prefabrication has the potential to re-introduce personal choice into housing while at the same time dramatically increasing resource efficiency by cutting onsite construction waste.

Prefabrication has the potential to facilitate the design and construction of large housing projects without necessarily imposing uniformity and rigidity. It can be the basis for how big scale housing projects do justice to the small scale, where variety and adaptability over time are desirable. If neither the dwelling user nor the technical means are dictating uniformity and rigidity of the built form, then it is designers, and architects, who are imposing dwelling plans that they feel need to be the same for

reason of efficiency. Designers and architects and their need for authorship, by virtue of the fact that designing urban housing is profession-protected, could be retarding the introduction of new sustainable urban housing typologies that are prefabrication-based.

In the non-profession protected housing industry of the detached single-family house, a high (and increasing) percentage of manufactured components are used. The increasing use of components, methods or processes in which there is regularity and repetition is establishing a level of standardization that could easily evolve into an open-building system. The currently established standards include kitchen and bath cabinetry based on 3 inch modules, standardized door sizes, thicknesses and hardware locations, standard 4ft. by 8ft. panel goods, and 3½ inch and 5½ inch widths for framing. Once a prevailing open-building standard is established, the move to pre-assembly of components and sub-assemblies should accelerate, realizing increases in efficiency.

The potential for prefabrication to alter the means of delivery for housing in a more sustainable direction is becoming more self-evident as the fabrication technology advances, but, in the end, it is still only a means. The potential for reduction in construction waste is obvious but the substantial gains in moving towards sustainability lie in the fact that manufacturing processes inherently use partibility and separability of systems as core concepts. That concept, when used in building design, would enable sustainability gains through adaptive re-use and re-cycling since disassembly of building components would be more practical.

### **3.3 Socio-Economic Influences**

First and foremost, the argument for change is an economic argument. And, modern economics is driven by energy. Without energy, there is no work, and without work, no economy. In our current society, the first cause for change is always energy. And, the most significant energy source that our society has tied our economy to is cheap oil. The link between GDP and oil consumption is displayed in Fig. 5.

Peter Tertzakian convincingly connects oil consumption with GDP economic activity, relating the oil dependency of a nation to economic growth (Tertzakian, 2006). An argument is presented in his book that we have reached or will shortly reach global 'peak oil' based on the work pioneered by geologist M. King Hubbert who accurately predicted the peaking of oil production in the US (US

Department of Commerce, 1982). As we enter an era on the downhill slope of Hubbert’s curve of oil production, we find ourselves on the tipping point in oil, what Tertzakian calls a ‘breakpoint’ in a system. The resulting re-balance will change many things on many scales, including the architecture of housing.

### 3.3.1 Energy Rebalance

As the economic impact of energy costs dissolves the underpinnings of the low-density lifestyle, the housing mix can be expected to rebalance to meet the new economic realities. An immediate response will be that the demand for high performance buildings will increase as energy costs tied to operating expenses become more significant. High-performance buildings, with their inherent ‘energy savings’, will move

housing towards sustainability to some extent; but holistic life-cycle cost analysis will require a rebalance in all segments of the Triple Bottom

Line. It can also be expected that another immediate impact of high energy costs will be the increasing economic viability of technologies that need higher cost support levels. Finally, it will be economic forces that will provide the pressures to change lifestyles to those that support sustainability.

### 3.4 Density and Sustainability

Civilization and cities have been intertwined since humanity’s transition from hunter-gatherer to settlement-maker. Historically, housing has always been a part of the diversity of the inner city. The urban agglomerations of the past included housing as intrinsic urban fabric. This was mainly due to technological limitations in transportation connecting the live-work relationship. As city environments deteriorated with industrialization, the live-work relationship changed and suburbs were created for housing based on the transportation technology available. First, the railroad suburbs, then the streetcar suburbs. The mono-cultural car-centric housing suburb of the past sixty years is the

	Oil Dependency Factor 1995–2004	2004	
		GDP <sup>1</sup> \$US Billions	Oil Consumption MMB/d
India	94	661	2.6
China	90	1,649	6.7
Thailand	78	163	0.9
Malaysia	72	118	0.5
Taiwan	63	305	0.9
Canada	60	996	2.2
Singapore	48	107	0.7
United States	45	11,733	20.5
Korea	28	681	2.3
Australia	25	618	0.9
France	16	2,018	2.0
Japan	< 0	4,668	5.3
Germany	< 0	2,707	2.6
Russia	< 0	583	2.6
Italy	< 0	1,681	1.9
United Kingdom	< 0	2,126	1.8
World <sup>2</sup>	29	55,655	82.5

1 GDP at current prices in US billions  
2 GDP based on purchasing-power-parity (PPP) valuation of country GDP

Figure 5 – chart linking oil to economy (Tertzakian, 2006)

latest and relatively new construct and there is a broad set of concerns that coalesce around such low density, single-use ‘sprawl’ suburbs. Using the metric called the ‘ecological footprint’ for comparative purposes, a study of suburban sprawl in Canada prepared by Walker and Rees indicates 53% of the ecological footprint size is related to housing, 44% is related to travel requirements, and 3% to municipal infrastructure (Walker, 1997). Thus, there are two distinct yet connected types of factors based on density that influence moving towards sustainability. The first kind of factor involves the physical form of housing and infrastructure and the second involves lifestyle.

It is relatively straightforward to see the linear connection between increasing housing density and increasing resource efficiency associated with housing form. The PEW Center on Global Climate Change published a report titled ‘Solutions: Towards a Climate Friendly Built Environment’, where it states that “well planned compact growth consumes 45% less land and costs 25% less for roads, 20% less for utilities, and 5% less for schools, than does sprawling growth” (PEW, 2005).

The less obvious benefits of increasing housing density are sustainability gains through changes in daily life couched in the concept of locational efficiency. This is the historical aspect of urban housing where housing is intrinsic to the garrulous spontaneity of diverse communities. It is the re-establishment of a new live-work relationship. In the PEW study noted above, data are presented linking residential density and travel-related CO<sub>2</sub> emissions. The higher densities, mixed-use occupancies, and a job-housing balance are shown to be associated with shorter car trips and lower car ownership and use. There are also inherent efficiencies to be gained in the expensive infrastructure needed to support urban housing. Mixed use at higher densities ensures the economic viability of public transportation, public water and sewer services, security measures, and communal amenities of many forms. While the suburbs are saddled with the inefficiency of every home needing its own lawn mower, higher urban densities and networked communication promote and enables shared resources.

There are, however, practical limits to the gains achievable through increasing density through increased height. Beyond a certain density and height, spatial qualities suffer, structural systems become constraining, water systems need pumps and tanks, and vertical access becomes zoned high-

speed elevators. There does seem to be an optimum range in density for affordable workforce housing in an urban setting. Cultural preferences for a connection to nature, coupled with technological ease of maximizing structural and mechanical systems for buildings six stories or less, optimizes the height at six stories. In urban settings, trees represent nature and 40 to 60 foot tall mature trees connect with urban dwellers in structures that do not rise too far above the tree canopy. Most municipal water systems rely on water towers at a fixed elevation for water pressure, negating the need for complex pumps in buildings up to six stories. The Ontario Building Code differentiates buildings more than six stories as 'high buildings' that require more complex systems and higher performance requirements.

In order to move towards sustainable urban housing, a density range has to be achieved that creates a job-dwelling balance that creates community without complete dependence on the individual car. Authors such as Jane Jacobs suggest mixed-use urban environments with dense concentrations creates true communities resulting from the interacting chaos of urban life<sup>22</sup>. Her favorite examples include the North End of Boston, Georgetown in Washington, Rittenhouse Square in Philadelphia, the "Back of the Yards" in Chicago, and Telegraph Hill in San Francisco. This suggests a density ranging from 40 to 100 units per acre for viable urban 'villages'. The suggested density range results in a housing typology that can only be derived from some form of stacked dwellings – all the while, everyone fully acknowledging that the 'Dream Home' is never a vision of an apartment in a multi-story building.

And that is the prototypical urban housing problem.

### **3.5 Single-Family Dwelling Model for Disentangled & Open-Building Systems**

As previously stated, the physical amenities of a detached house can readily be achieved in a denser form through technology, (ie: sound control, cross ventilation, visual privacy, etc.). If one accepts the single-family detached house as a 'success' in providing the dominant current socio-cultural house

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<sup>22</sup> *The Death and Life of Great American Cities*, by Jane Jacobs, is arguably the most influential book written on urban planning in the 20th century. First published in 1961, the book is a scathing critique of modernist planning policies claimed by Jacobs to be destroying many existing inner-city communities.

form, a study of its characteristics can be used as ordering principles in a denser form; hopefully transposing that 'success' to the new form. Even the fact that a detached house is inherently ground-related with direct access to garden and backyard can be addressed in a denser form with patios, terraces and courtyards.

The distinguishing socio-cultural factor that sets the detached house apart from other housing types is the image of unencumbered ownership and control. This direct control allows the home owners to personalize their environment and control their privacy. This was the historical basis of vernacular housing – direct control of the individual dwelling by the occupant, within a larger societal framework of communal support<sup>23</sup>.

This thesis posits that stacked dwellings, (a form of sustainable urban dwelling), will only be viable as a choice if the characteristics and benefits of the detached single-family dwelling are incorporated. Only when individuals can exert their own decisions and exercise direct control over their dwelling can that dwelling form be a viable choice. The speculation recognizes that dwellings are the result of the dynamics of two spheres of control: Individual + Communal. It is proposed to unbundle the multiple elements of housing, which in current, modern, urban housing have been provided together, and, provide a multilayered form that has discrete communal infrastructural support and flexible individual dwellings. By separating the two spheres of control, it will be shown in the 'demonstration project' that it is possible to create a detached house environment in a sustainable intensified urban setting. By separating the urban fabric and dwellings into distinct, untangled layers, strategies to move towards sustainability are enabled at multiple scales. By fostering an active dweller as a recognizable participant in the housing process<sup>24</sup>, we create the underpinnings of sustainable urban

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<sup>23</sup> In his book, *House Form and Culture*, Amos Rapoport posits that in primitive societies, there is diffuse knowledge of everything by all and in terms of building, this implies that everyone is capable of building his own dwelling. In most cases, for social or technical reasons, buildings which the group needs are done cooperatively by a larger group (Rapoport, 1969)

<sup>24</sup> In his landmark book, *Supports: An Alternative to Mass Housing*, N.J. Habraken outlines the conceptual framework of separating support from dwelling as a response to modernist mass housing. He posits that current mass housing failures are attributable to the elimination of the individual as a means to ensure uniformity. He was a proponent of a more direct relationship between man and dwelling (Habraken, 1972).

housing through enabling socio-culturally directed changes in daily urban life. By enabling walkability through density and locational efficiency, daily choices are enabled that can foster a more sustainable lifestyle.

This is a radical change from the current working model for stacked dwellings where a designer exercises authorship over the entire project<sup>25</sup>. The actual occupant is totally excluded. Then, as soon as the unit dweller establishes control, invariably and universally, he/she begins making changes. Stewart Brand describes this phenomena in his book, *How Buildings Learn*, (Brand, 1994), stating that no matter what the intentions of the designer, buildings behave like living organisms, changing as a response to various stimuli. The entangled layers of buildings make any change difficult with change often resulting in the generation of a waste stream of unusable construction debris. The potential serviceability of the originally constructed assemblies, with their ecological rucksack of energy and material flows, is lost while additional material and energy flows are needed to make the inevitable changes.

By separating the built environment support into functionally defined, discrete layers, further grouped as under communal control, the 'Support', and occupant controlled, the 'Infill', the renewal of dwellings can be flexibly undertaken in response to changes in lifestyle, individuality, and technology. Further, as a work of Architecture, the disentangled 'Support' systems can function as fixed social assets for long periods of time providing a permanence in the urban fabric. Since the support structure will receive the benefit of architectural authorship, it has the potential to be the landmarks in architecture that become durable markers in the urban fabric.

By adopting a highly flexible infill system of layers, different forms of adaptive reuse over varying timelines become practical. The partibility and separability of systems can dramatically improve sustainability by allowing the maximum service life of each component to be independently realized. Current construction practices interweave components and the net effect is that the component with

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<sup>25</sup> Colin Davis, in his book, *The Prefabricated Home*, argues that architecture seems to need the concept of authorship as a means to distinguish architecture from mere building. If the designer of a building can not be identified, then that building's status as architecture is somewhat called into question (Davis, 2005).

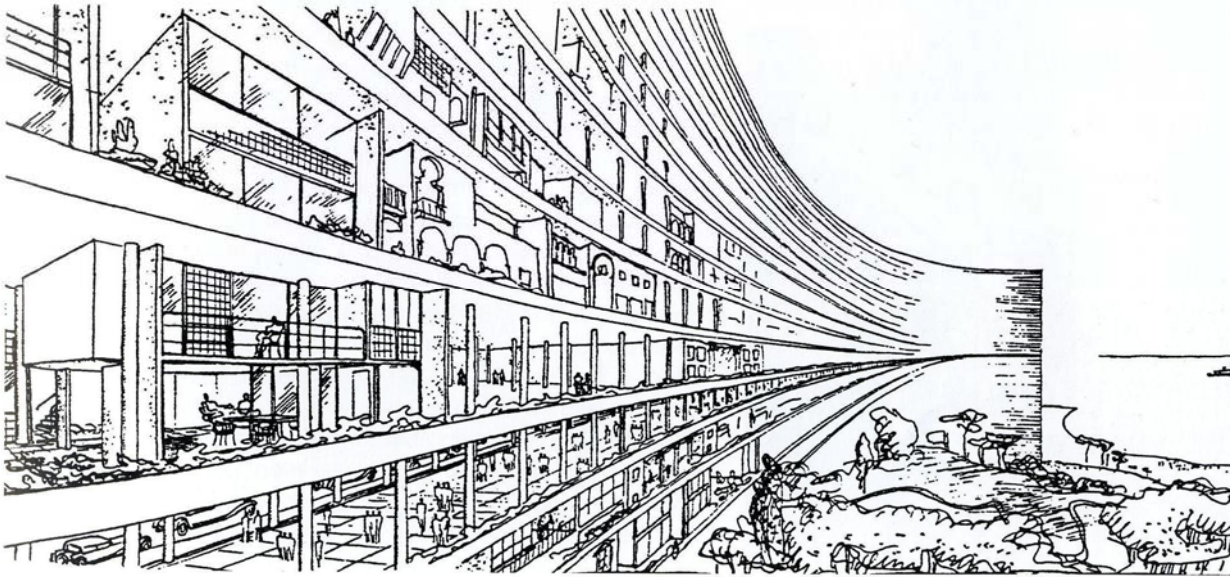


the shortest useful service life determines the useful life of the assembly. Adaptive reuse, repair, reconditioning, upgrading, and recycling are enabled as sustainable building strategies.

The separation of the authorship of a disentangled, open-building system has the potential to facilitate the design and construction of large housing projects without necessarily imposing uniformity and rigidity. It can be the basis for how big scale housing projects do justice to the small scale where variety and adaptability over time are desirable. The architectural solutions for urban housing must be more than inspirational images of never-to-be-built projects of prefabricated plug-in living pods inserted into multi-story mega-structures such as 'Plug-in-City' by Archigram, (Fig.37). The solutions must offer the first principle amenities of privacy, direct control, and personalization in a socio-culturally desirable context for a socio-economically viable cost using sustainable socio-technologically efficient systems.

### **3.6 Macro-History of Housing and Disentangled & Open Building Systems**

The balance between communal and individual prerogatives in our society for housing places the detached house as the built form providing the most individual control over one's dwelling; but, even the detached house is itself part of a communally controlled infrastructure that imposes restrictions on the individual. The communal urban infrastructure includes property lines, zoning regulations, building construction regulations, streets and roads, and utilities. Homeowner Associations and the Condominium Act can further erode the individual control that one can exercise over one's dwelling. In general, the denser the housing building form, the less control allotted to the individual with 'multi-storey' housing limiting the individual to control over interior finishes only. There were some (unrealized) early 'radical architectural proposals' that sought to redefine the communal to individual relationship giving individual control to dwelling occupants in a dense, multi-story built housing form. Most notable was Le Corbusier's plans for Algiers, (Plan A, 1931-1932), that proposed a meandering, elongated, concrete support structure, a 'terrain artificiels', with its interior subdivided for individual housing units that were to be sold to people who would complete the units themselves



**Figure 6 – LeCorbusier’s plan for a large infrastructure with individual dwelling units (Schittich, 2004a) .**

(see Fig. 6)<sup>26</sup>. Within the given constraints of the support structure, each dwelling unit would be unique without an imposed architectural authorship.

The concept of separating structure and infill along lines of communal or individual control can also be seen in sketches from the firm S.I.T.E. (1981) in its housing proposal called “Highrise of Homes” (see Fig. 7 ) as well as Frie Otto’s (1960) “Highrise on the Beach” (see Fig. 8).

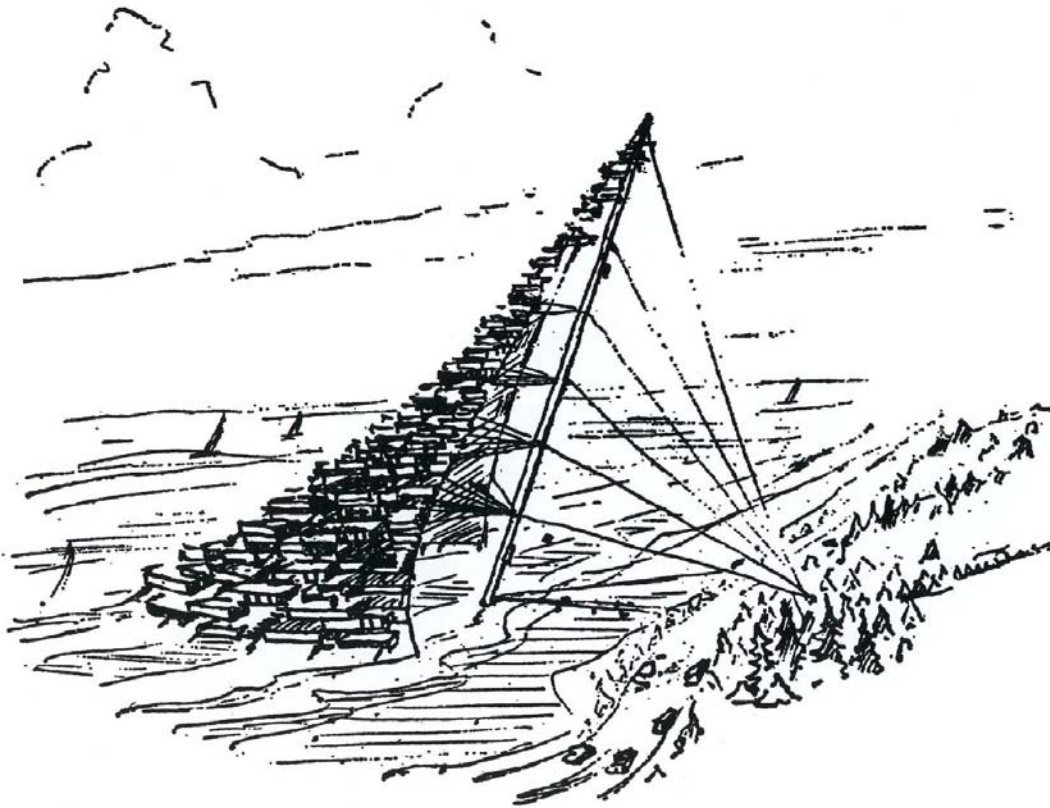
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<sup>26</sup> Le Corbusier, an architect with considerable authorship clout, in 1935, published a ‘revolutionary idea’ for living in one’s own home in the city. In his book, *La Ville Radieuse*, he states: “Here are ‘artificial sites’, vertical garden cities. Everything has been gathered here: space, sun, view; means of immediate communication, both vertically and horizontal; (.....). The architectural aspect is stunning! The most absolute diversity, within unity. Every architect will build his villa as he likes; what does it matter to the whole if a Moorish-style villa flanks another in Louis XVth or in Italian Renaissance? (.....) The artificial lots are created first: highway + floorings of the structure. And these sites are put up for sale as villas with garden and limitless view. “



**Figure 7 – an unbuilt proposal by the architectural firm S.I.T.E where individual stacked dwellings are supported in a structural armature (MoMa, 2008).**

The architectural concept that was to provide the theoretical underpinnings of disentangled building systems was presented by N. J. Habraken in his landmark book, *Supports: An Alternative to Mass Housing*. It was a rebuttal to mass housing designed with architectural authorship as large urban government sponsored housing interventions. Habraken saw his architectural theory as a restoration of the vernacular housing relationship between occupant and dwelling based on restoring control and decisions back to the occupant at a given moment as the architectural author steps aside. The byproduct of ease of change and adaptive re-use as currently relevant to sustainability issues were not



**Figure 8 – an unbuilt proposal by Frie Otto that implies a massive support infrastructure populated with individual units (Schittich, 2004b).**

core to the theory as the focus was on the socio-cultural concerns of urban housing. The ease of change and adaptive re-use possibilities were, however, soon realized by the commercial office building sector as a logical means to accommodate constantly churning tenants. The concept of a permanent ‘base building’ that would have a short-lived and changed ‘tenant fit-out’ is now the standard model for office buildings.

Disentangled building principles are known by various names in different cultures. In Europe, thanks to the early work of SAR headed by Habraken in the Netherlands, it is called Support and Infill. Currently, in Japan, where land development pressures are intense, it is called SI (Skeleton and Infill).

Disentangled building system concepts are employed in North America in specific building typologies to a limited extent. Office building construction clearly separates the Base Building from Tenant Improvements as a means to address constant tenant change. The Base Building incorporates features such as accessible floor systems and accessible ceilings specifically designed for change. Tenant Improvement construction has evolved an open-building architecture based on re-use and change. Open-building systems have evolved that construct office interiors with specialty demountable partition systems and standardized 2x4 ceilings with light fixtures and grilles that fit that grid. The limited need for personalization has helped establish these practical standards. Housing, however, with its strong culturally supported need for individual control and expression has not participated in open systems to the same degree. While some housing components have established industry wide-open systems, a site-built house that is inherently unique is still the preferred choice. The ‘elite’ in NYC do buy empty urban condo space which is then customized with infill to personal taste. In the past, our society based socio-cultural preferences on our ‘elite’. The middle class emulate the ‘elite’ class. This would indicate a socio-cultural preference, or, at least acceptance, for urban housing that is part of a desirable urban context where the dwelling unit is unique and customized for the occupant. Affordable urban housing can be preferred, or, at least accepted, if it emulates this model – a desirable urban context where the dwelling unit is unique and customized for the occupant. Further, as the original model of the ‘mansion in the country’ is degraded in the suburbs with small lots that keep getting smaller and mean building dimensions that degrade spatial quality, the alternatives provided with urban homes as proposed become viable choices.

### **3.7 Open Building Systems and Sustainability**

The fundamental principle of sustainability – consider the consequences of today’s actions on tomorrow – when applied to the design and construction of buildings, support core concepts of a disentangled and open building systems. The disentangled building concept separates buildings into layers and levels based on component life spans, functions, future alterations and repairs, and future re-use. The layered architecture can accommodate future change and thereby remain viable. The open building sub-systems can be removed, changed, or updated without requiring the destruction of adjacent systems. The partibility and separability of open architecture make adaptive re-use of our building investments in energy and resources in the future a real option.

## Chapter 4

### The Design Speculation

It is important to recognize that the speculative ‘demonstration project’ is not presented in this thesis as the only possible solution to the speculative design question of sustainable urban housing; nor is it meant to be a definitive list of all the design considerations possible. Beyond the location of the demonstration project in the biosphere, which does give the design a firm anchor point, the possible design options are inherently varied. The demonstration project is used to illustrate the potential of applying an overarching holistic sustainable design philosophy to a design method. The project is one possible built form out of many that can move urban housing towards sustainability. It is a demonstration of some key precepts selected for speculation that would enable a context for the built environment where sustainability strategies are inherent in the design methodology and are not just ‘green appliqué’ on the same old architecture.

The key precept on urban housing is that an urban lifestyle is more sustainable than a suburban lifestyle. For those sustainability gains to occur, the urban context must be seen as a better choice than the low density suburban experience. The strategies to achieve this are:

1. Achieve a **density** for housing of approximately sixty units per acre. The density will provide a diverse urban lifestyle of immediacy and proximity. The suggested density can support district based efficiencies such as good public transportation and promote a community life supported by active public spaces.
2. Establish a **mixed-use** six-story urban fabric. The mixed use will provide locational efficiencies to support local commerce, neighborhood based institutions, and establish a better work/live balance. The six story height will provide a scale that can connect the urban forestry to urban dwellers to provide a connection to nature.

Another key precept considered is that decision making for housing in the built environment is to be re-aligned between the collective and the individual. The areas of control are:

1. The **occupant has direct control over their dwelling unit** where the units offer the amenities of the single-family dwelling. The areas of façade and infill are independent decisions of each occupant and are the product of individual expression.
2. The occupant makes the decisions about his dwelling unit within a **collective framework that has control over the supporting armature and infrastructure** that houses the unit. Thus, the urban tissue and support layers are collectively controlled and are the product of specialists supported in our society.

The last key precept is that the urban built form can be constructed by employing strategies that reduce energy and resource consumption. The key strategies are:

1. **Disentangling** the levels and layers of urban housing. For this specific design effort, four main levels - urban tissue, support, façade, and infill - with further multiple layered subsets of the four levels, is suggested.
2. Enabling **open building systems** where possible to maximize efficiencies and facilitate adaptive re-use.

Within this interconnected framework, a proposed architecture can take shape that mediates the environment (air, water, sunlight, heating, and cooling); responds to cultural underpinnings (form, space, biota, control), and moves towards sustainability with urban densities and urban lifestyle changes (see Fig. 9).

#### **4.1 Multi-Scale Ordering Principles**

Effective design strategies for sustainable design have an underpinning logic. To be effective, the macro to micro order of the scales has significance for sustainable design. To maximize the benefits of various strategies (and avoid potential negative results), the ordering principle for time is from timeless to temporary and for size is from large to small. The ordering principle of scale for time distinguishes layers based on their expected (or desired) life span and by their anticipated need for modification. An example would be a site as geologically timeless, a structure that lasts 100 to 300 years, a façade that lasts 40 to 100 years and interior finishes that last 10 to 25 years. It should also be self-evident that, in

**Figure 9 - relationship between control and key design considerations:**





terms of scale applied to size, one must consider the climate zone before one considers the micro-climate. It is also worth noting that specific opportunities for sustainability occur at specific scales, (ie: district based heating requires the scale of a district).

One could use a formulaic approach such as LEED™ or Green Globes™ and achieve a level of ‘success’ as measured by that metric. There are, however, limits to that success. As previously discussed, achieving a set of generalized, prescribed targets may not result in moving towards sustainability for a specific project. The current limitations of the popular metrics to measure sustainability do not render those metrics without use and benefit; they are simply the ‘pioneer’ products of a paradigm shift in its infancy.

A holistic metric that organizes and evaluates strategies based on the logical ordering of first principles to move towards sustainability are not available to designers. I would suggest that such a metric would be based on measuring the amount of resources and energy per unit of time, over the full life-cycle of the building; and, full accounting for the ‘ecological rucksack’ attached to the resources and energy used, that is removed from the biosphere as no longer useful and locked away in the landfill. In terms of solid waste, a truly sustainable building would score a ‘0’ going to the landfill. The landfill, as a human construct, severs the inflow and outflow balance of material flows. For a stable sustainable condition to exist, there would be no landfills, just temporary holding areas for materials that would eventually be inflows in another process.

This kind of holistic metric implies a generalized order for design as follows:

**Reduction**, designs that reduce loads, inherently use less ‘nature’ and generate less waste that ends in a landfill. Macro level strategies include locational efficiency, appropriate density and local/district community infrastructure. Micro level strategies include load reduction through high performance building envelopes, controlled ventilation, and daylighting.

**Passive** energy systems, systems that are embedded into naturally occurring, stable, ecosystem cycles and forces, are the preferred design strategies. These strategies rely on bioclimatic forces to function in conjunction with limited resource and energy use. For this reason, sustainable design is site specific; as the location of a site determines the bioclimatic forces that

need to be mitigated and are available to be used. An example would be the available passive solar heat gain based on the sun's radiation and glazing. Another is natural (passive) ventilation based on prevailing winds and building form for cooling. Still another is thermal mass where the properties of a material are used to passively store and release heat radiation. Passive systems are based on an understanding of the climate and place by the designer. They would use the least amount of resources and energy, thus would probably contribute the least amount to the 'landfill' and receive the lowest 'points' in our holistic metric (where low points indicate moving towards sustainability).

**Active** systems, systems that manipulate bioclimatic forces with technology, are the next order of strategies. These strategies consume more resources and energy to use than passive systems but are still embedded in the bioclimatic forces of the site. Active systems are often the only options in urban settings where urban site constraints eliminate viable passive systems. The technology that is used in active systems needs to be evaluated and selected based on efficiency over the entire life cycle of that technology to mitigate energy and resource use.

This metric would also have components that would apply to any scale:

**Durability**, the maximizing of resources to provide the most service life possible, is the next order of strategies. These strategies include design for disassembly, recycling, down cycling, adaptive re-use, and maintainability.

**Reclamation**, the increase of 'nature' in the built environment, is another order of strategies. As socio-cultural forces redefine the post-modern view of nature, architecture can be realized that provides new multiple connections between the biosphere and the built form. These strategies include urban forestry, green roofs, naturalized landscaping and bio-remediation plantings.

## 4.2 Infrastructure

Material and energy inflows supporting urban housing are 'infrastructure' while outflows are 'waste stream'. In a stable system, there is a closed loop between the inflows and outflows. An imbalance in the flows eventually builds up pressures that rebalance the system, often suddenly, with surprising and unpredictable results. Efforts at sustainability are, in essence, efforts to close the loop between the input and output flows to maintain stability within a range that allow for human society.

There are specific economies of scale for various infrastructure and as the rebalance progresses in our society, the correct scale for our existing infrastructure is being re-evaluated. In the past, basic municipal infrastructure was of very large scale and centralized. This was thought to be the most efficient method for delivery of services. The massive centralized scale for electric service, wastewater treatment and potable water has presented problems during natural catastrophes such as floods, ice storms, or heat waves. Basic large scale centralized infrastructure at current scales lack passive survivability, while individual small scale dwelling-based systems can be inefficient. As an example, all water to the city is potable water that is filtered and treated whether it is for fighting fires, watering the lawn or human consumption.

Historically, urban housing generated two major categories of ‘waste’ outflows: human waste disposed of by flushing and garbage disposed of by collection for transport to a landfill. Recent ‘recycling’ initiatives are trying to change the two big waste pipe outflows to at least two big pipes plus some small pipes for paper and glass. In order to actually be able to manage the mechanics of the outflow in a sustainable way, we must abandon all ‘big pipes’ and create discrete numerous small pipes that can become the inflows for processes that will close the material and energy flow loop. For sustainable urban housing, the flushing big pipe should be replaced by the urine collection pipe (valuable inflow for fertilizer process), the black water pipe (inflow for ‘living machine’ process), and grey water pipe (inflow for irrigation reclamation water process). The large garbage pipe should be replaced with as many small pipes as possible such as organic waste (inflow for composting), and glass/paper/plastics/textiles (inflow as raw material in processes).

The following speculations on large scale infrastructure are possibilities of the near future that hopefully will be pursued to move the urban tissue of Toronto towards sustainability:

1. Water service will be provided in different categories for use such as raw water (ie: rainfall for irrigation), filtered water (ie: for cleaning), potable water (ie: for human consumption) and grey water (ie: recycled filtered water for human waste transport). The efficiency gains by not making all water used into potable water will be sought simply due to economics—treating all water unnecessarily is energy intensive. Reducing treatment to only what is needed is simply more efficient and broadens the potential sources of obtaining water.

2. Deep Lake Water Cooling (DLWC) from Lake Ontario will be expanded to residential use as a heat sink to provide chilled water for dehumidification and cooling. Since the resource sink is so large and it is recharged every winter, the potential for any heat build-up issues to the lake due to expanding the system is avoided.
3. Complete separation and harvesting of storm water runoff. Stormwater will culturally shift from ‘something to get rid of’ to a valued natural resource to be managed.

The urban density of 60 units per acre building is a scale that would be able to support the following district scale infrastructures to move towards sustainability in 2020 :

1. District-based heating and cooling is feasible at urban densities. Since the density would support sufficient diversification factors for continuous predictable use, combined heating and power (CHP) systems would be practical.
2. Again, supported by the density, primary wastewater treatment using ‘living machine’ technology can be implemented on a neighborhood basis with anaerobic treatment occurring at the building and final aerobic treatment occurring off-site using bioengineering technologies such as artificial wetlands. Separate dedicated piping for the collection of urine for manufacturing fertilizer to replace synthetic fertilizers manufactured from natural gas would require a major cultural re-alignment but the ease of implementation and large economic gains make that scenario feasible speculation.

It is speculated that by 2020 the changes in building scale infrastructure (what is called building mechanical systems today) will be radically changed. Building forms will be designed by architects to achieve reductions in energy flows as part of the culturally directed focus on sustainability gains through high-performance buildings. Passive solar based building infrastructure strategies are often limited in urban settings due to constraints such as property lines. Opportunities for shallow floor plates on an east-west axis with south-facing solar access to implement basic passive strategies to provide daylighting, direct solar gain, and natural cross-ventilation are limited by density. Active solar building systems can be employed for a broader range of built forms while achieving goals such as density or overcoming constraints such as property lines. The current and projected high cost of hydrocarbon-based high-grade energy fuels coupled with the lowered energy demands for heating/cooling for high performance buildings vastly enlarges the range of passive and active solar strategies that can offer an

economic payback. Because of building envelope advances, the BTU per sq.ft. of heating/cooling energy needed to maintain a building's interior within a 'comfort zone' can be within the range of low-grade solar based energy sources. The incorporation of solar strategies will start to inform building spatial programming and form as tank space, light tubes, shading devices, reflectors, PV panels, solar panels, radiant cooling panels, and wind turbines become the new vernacular. This economic underpinning will change architectural form for housing since solar access will now have easily identifiable economic value.

It is speculated that passive and active systems will impact building infrastructure design and form in the following ways:

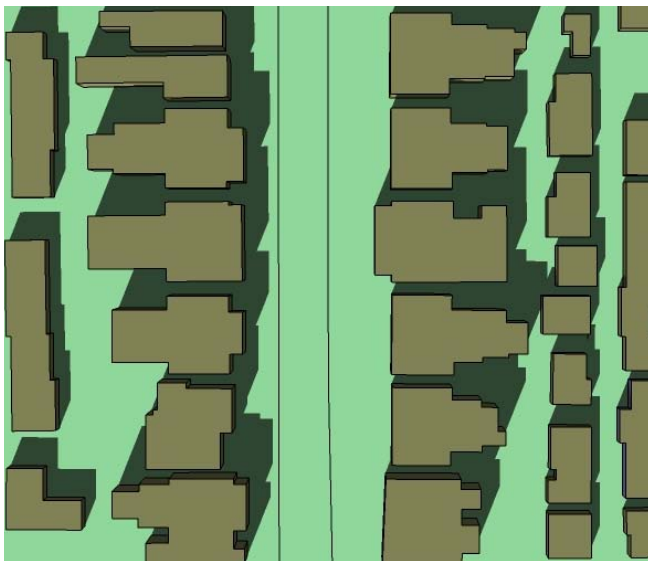
1. Roofs, which now are bleak landscapes used to house rooftop mechanical units and are a major contributor to the 'heat island' effect, will start to become valuable real estate. Roofs are often the face of the building that has the best solar and wind access. In addition to roofs housing biota (green roofs), they will be used to harvest and pre-treat stormwater as well as physically house solar collection panels, photovoltaic panels, and wind turbines.
2. The solid waste stream of a dwelling unit is currently disposed of as a homogeneous material we call 'garbage' regardless of its actual content. Some municipalities do offer voluntary recycling programs for limited sorting but all 'waste' leaves the site. Future solid waste infrastructure will probably be much more demanding of sorting at the dwelling unit level (clear glass, green glass, newspaper, cardboard, mixed and glossy paper, type 2 plastics, other plastics, cloth, wood, aluminum, steel etc.) while readily compostable solid waste would not leave the site but would be treated and used on the premises for urban agriculture with access hauled off-site as a valuable resource.
3. The handling of solid waste using a single 'garbage chute' terminating in a dumpster will give way to multiple chutes terminating in a 'recycling center'. This change in daily life will require new spatial arrangements at the dwelling unit level to pre-sort as well as significant spatial allowances for multiple chutes and a recycling center.
4. Since potable water for human consumption is such a small amount compared to all other water uses, it would be more efficient (use less energy and resources) to make potable water at the source of use, for housing, in the dwelling unit. The traditional two pipe (hot water and cold water)

distribution system will give way to a multi-layered piped distribution systems increasing the spatial allocation for mechanical systems. To service these increasingly complex systems, the desirability of de-tangled finishes and access will inform architectural designs at many scales.

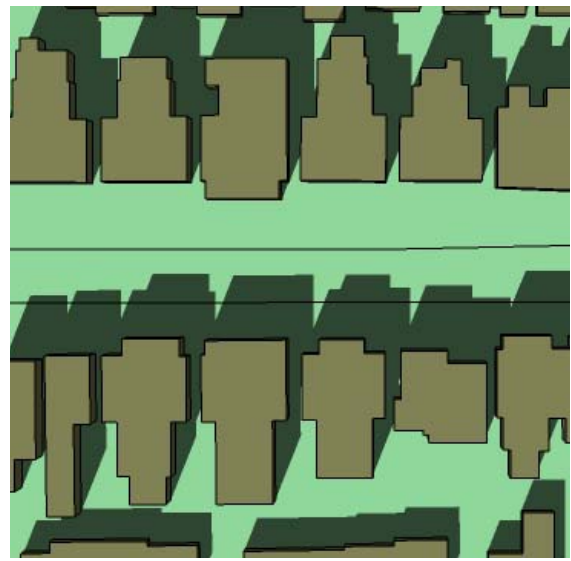
5. The inefficiencies in using air to transport heating/cooling energy from a central location in a large multi-story building will result in a new industry focus on hydronic systems. The building heating/cooling plant will integrate the building active solar systems with multi-fuel sources minimizing the need for high-grade energy sources. High-grade energy production for heating and cooling will still be needed when the active solar based systems can not produce enough and that high grade energy will be based on traditional fossil fuel sources and the regional electric grid. Since the project has a six story density, a centralized multi-tank system can be used where the actual fuel form (fuel oil, coal, natural gas, wood, night rate electric) could be selected based on changing availability and cost.
6. Building envelope science will have improved to the point where infiltration is effectively eliminated. Controlled ventilation will be provided adding fresh air ductwork to the mix of standard mechanical systems found in residential units. The systems will change focus from the basic 'discharge to outside' focus to filtration and energy recapture.
7. Dwelling units today are currently connected to the regional electric grid as the single source of electrical power and when the grid fails, there simply is no electric power to the unit. This quickly renders the unit uninhabitable as heating/cooling/lighting/ventilation mechanical systems do not operate. The technology of the near future will allow for some on-site electrical generation through PV arrays and wind turbines to operate key mechanical and emergency systems for survivable buildings that better respond to large scale disasters. Since lighting and air are already passively provided, and heating and cooling are active solar-based systems, it becomes feasible to maintain a livable environment with a small electrical energy budget. The standard 220/110V electrical distribution system will also be changed into a layered system. The new standard dwelling unit's 'load center' will have multiple buses segregating electrical power into life/safety circuits (fire detection, emergency lighting) which would always be powered; priority circuits (refrigeration, ventilation) selected to maintain the survivability of a dwelling unit, and general purpose circuits. The standard 'one size fits all' receptacle will give way to specialized receptacles and wiring increasing the complexity of 'adding on'. This will further the desirability of de-tangled accessible finishes that can readily accommodate change.

### 4.3 Solar

The existing Toronto street pattern, with its long north-south axis, is not the ideal urban pattern for housing that is designed around passive solar systems. A north-south street orientation results in the south face of a structure being in the side yard and side yards in our zoning culture are much smaller dimensions than front yards or rear yards (see Fig. 10 and 11). Since the north-south street pattern is entrenched in the urban permanence of property lines, it will not change in the near future. Passive solar is further compromised by the fact that six-story structures at 60 units per acre are partially self-shading. Since the density of units is a key ordering principle in moving towards sustainability, limitations on



**Figure 10 - North-South street with south face of structures shadowed by adjacent buildings due to small side yards.**



**Figure 11 - same street with East-West orientation resulting in south faces of structures having solar access.**

direct passive solar strategies inevitably occur in the design. For example, if direct solar gain had a higher impact in moving housing towards sustainability than density, then a reduction in density and building height would be preferred. An example of a built form that is optimized for passive solar is the east-west oriented, shallow floor plate, three story BedZED development in South London, UK (see Fig. 12). It is an acclaimed success environmentally but the low density of 23 units per acre was insufficient to support a live-work rebalance and the project is simply a successful, environmentally sensitive, bedroom community.

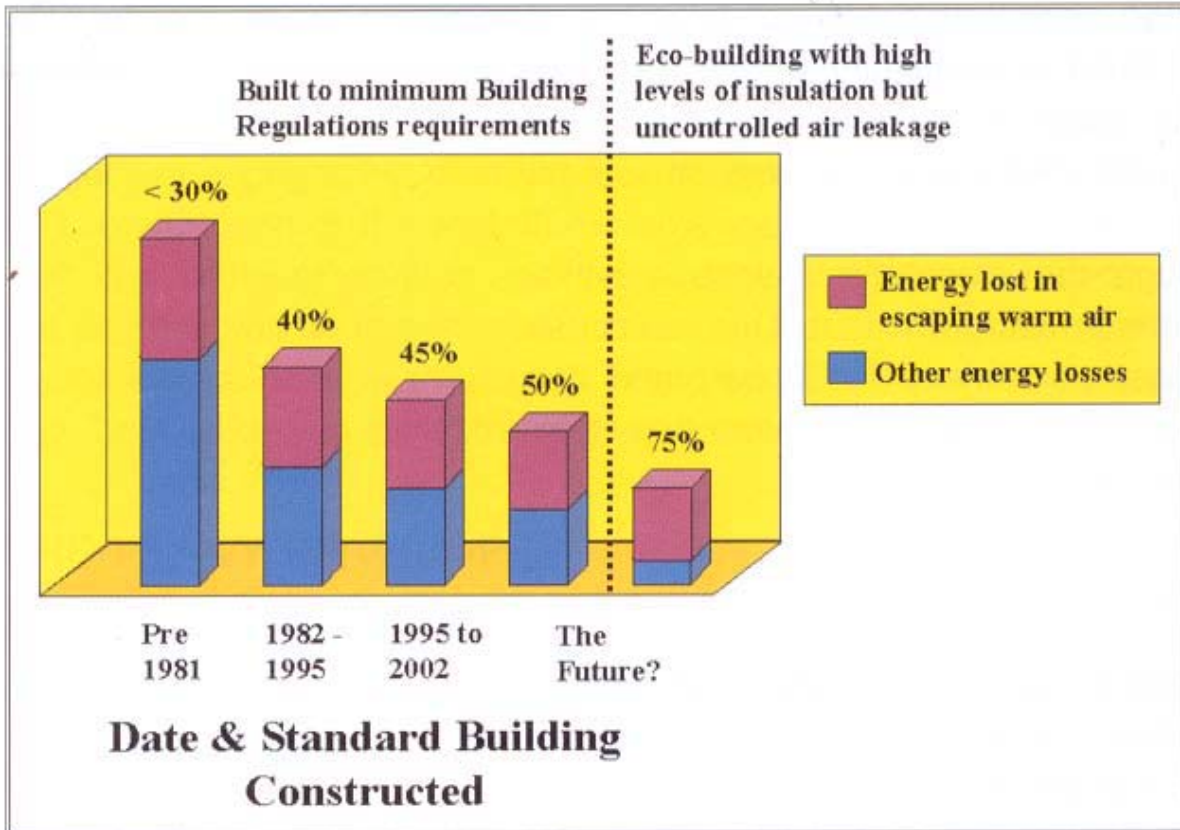
Shallow floor plates with a east-west orientation are ideal but often not possible. When they are a two story unit on a shallow floor plate is the most straightforward strategy to address how to provide light



**Figure 12 - schematic cross-section depicting form shaped by solar access at three stories as used in the design of BedZed in UK. (BedZed, 2008)**

and air to dense stacked dwelling units. There is, however, an old vernacular solution that can be used in a building that has any orientation, and that is the atria form based on bringing light in from above. Currently, large atria spaces are used as occupied, programmed spaces that do bring daylighting into large buildings but are actually more energy intensive than standard buildings (although the daylighting effect is quite pleasant). This is due to the need to maintain a ‘comfortable environment’ for the occupants of the atria. It is proposed for the demonstration project to keep the ‘atria’ an un-occupied space and use the form as a passive solar feature. Rather than fight air stratification as need be done in occupied atria, allow and use it. The unoccupied atria form is the logical progression of the ‘light well’ often employed in early twentieth century urban housing to provide day lighting and ventilation. The older ‘light wells’ were simple vertical spaces open at the top and accessed on the sides with windows by the individual dwelling units. It was mainly a source of outside air and daylighting benefits were small and incidental. This project proposes unoccupied atria with a clerestory form to control unwanted solar gain. The unoccupied atria as illustrated is a passive mechanical system building form that can be the source of daylighting and tempered air for the individual dwelling units. The atria as a daylighting source can provide a third side of the dwelling unit with daylight in a stacked, side by side, dense unit configuration. The atria volume can act as a tempered outside air source for the dwelling ventilation system. As building science has evolved, the building envelope has reduced energy loss through conductance and radiation to the point where infiltration, as a percentage, has increased in significance as a source of heat loss (see Fig. 13).





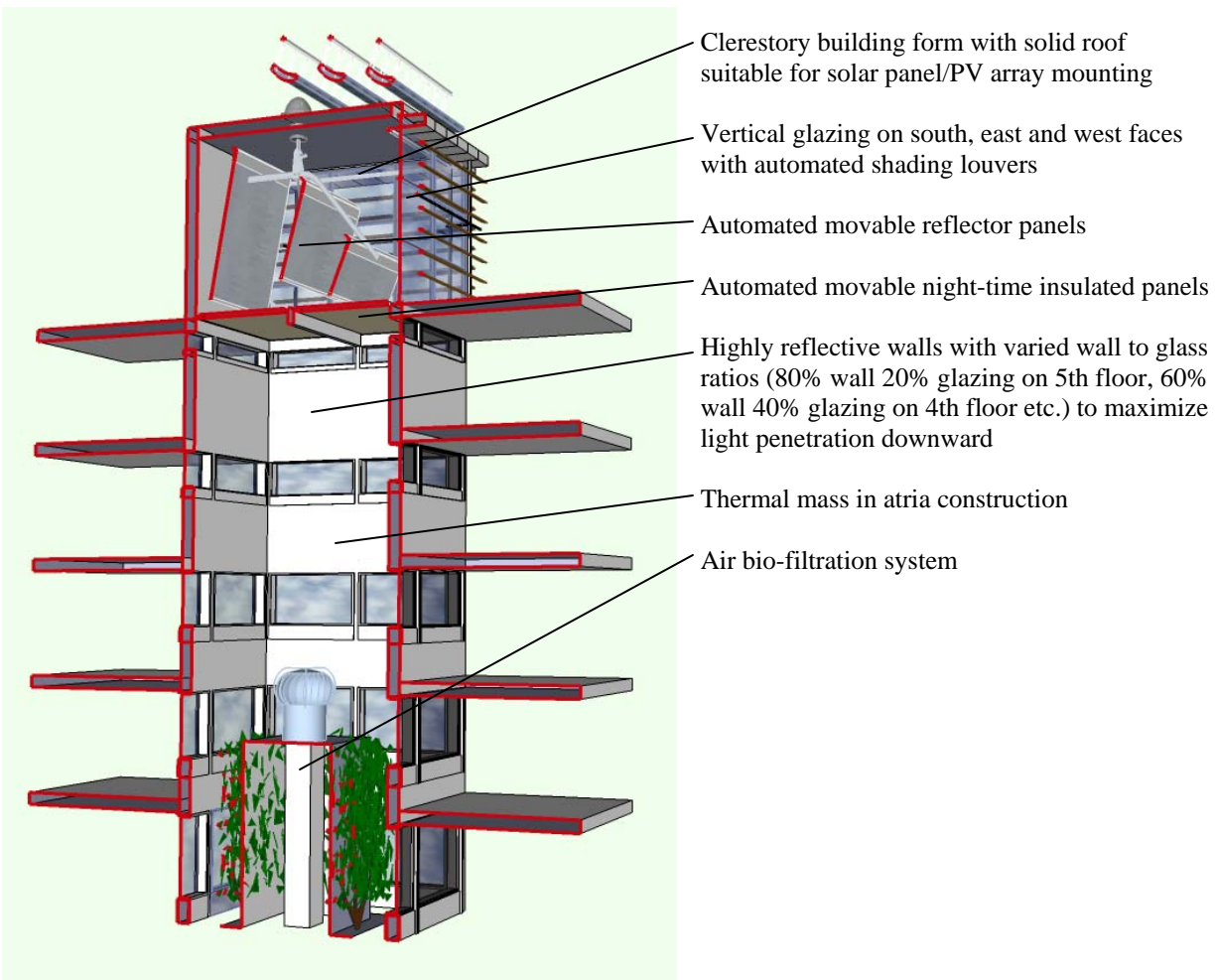
**Figure 13 - chart of significance of infiltration to heat loss as a percentage of total heat loss (Roaf, 2003)**

The unoccupied atria would have the following characteristics to act as a source for tempered fresh air for the dwelling units:

1. The tall volume encourages air stratification. In summer, tempered air for the units is drawn from the bottom and, in winter, from the top.
2. Thermal mass is incorporated into the atria. Where land cost allows, the size of the atria could house masonry or stone for thermal mass. Water for thermal mass could also be used if safeguards against freezing are provided. Where the atria footprint are constricted by land costs, costlier phase change salts could be used.
3. The atria would house air bio-filters to pre-treat the 'outside air'.
4. The atria will provide direct solar gain and act as a solar chimney to promote natural ventilation.

- The vertical atria resolves vertical access for infrastructure such as piping, exhaust stacks, and fresh air for stacked units without needing to run any services for a dwelling unit through another dwelling unit.

The amount of daylight reaching the atria floor is a function of building form where the atria acts as a light funnel. The relationship of length (L), width (W), and height (H), determine the rate of decay in light levels (see Fig. 15). The practical working height for atria for daylighting is approximately five stories in a residential setting. An accepted rule of thumb taken from the book *Design Smart, Energy Efficient Architectural Design Strategies* (Kasian Kennedy Design Partnership, 1995) to determine the percentage of daylight reaching the center of the floor (Kr value) as  $[L \times W]$  divided by  $[(L + W) \times H]$ . For the atria as proposed (20ft x 20ft) this resolves to a Kr value of 0.2 indicating approximately 12% of

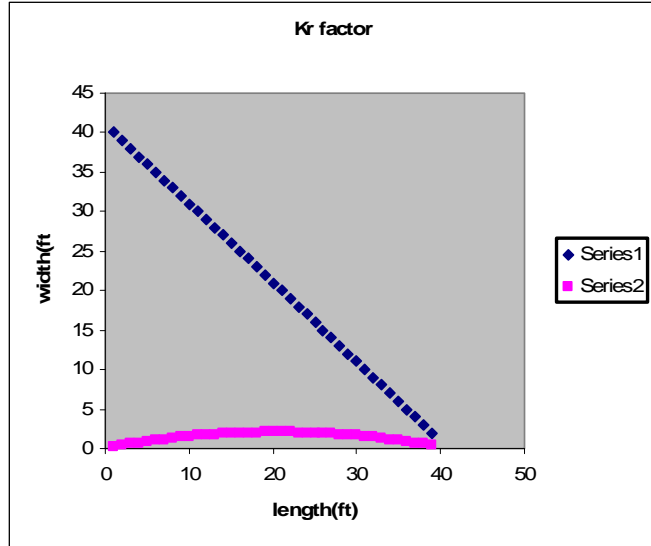


**Figure 14 - schematic cross-section detailing various components of a 5-story unoccupied atria**

the daylight value would reach the floor. It is speculated that automated solar tracking reflectors of the style currently available for providing enhanced daylighting in industrial settings would be further refined in the future and improve the daylighting value (see Fig.16). To further understand and evaluate the viability of the atria form to deliver daylighting, a software simulation using Ecotect ver. 5.50 was run (see Fig. 17). The software gave daylighting results that were higher than indicated in the Design Smart manual.

#### 4.4 Urban Tissue

A sustainable design speculation is inherently embedded in context. Architects must be aware of this context and create the moments for sustainable choices to be possible and preferable within the context. In terms of designing a speculative built form for urban housing for 2020, a physical, site specific, context is required. The site determines the macro-scale bioclimatic forces and the geological strata. The site dictates the highest order of magnitude for scale and time. For this thesis, the site specifics of the former Provincial Lunatic Asylum located at 1001 Queen Street West, Toronto, are attached as Appendix A to provide a brief outline of the biotic and abiotic factors, and history of the site.

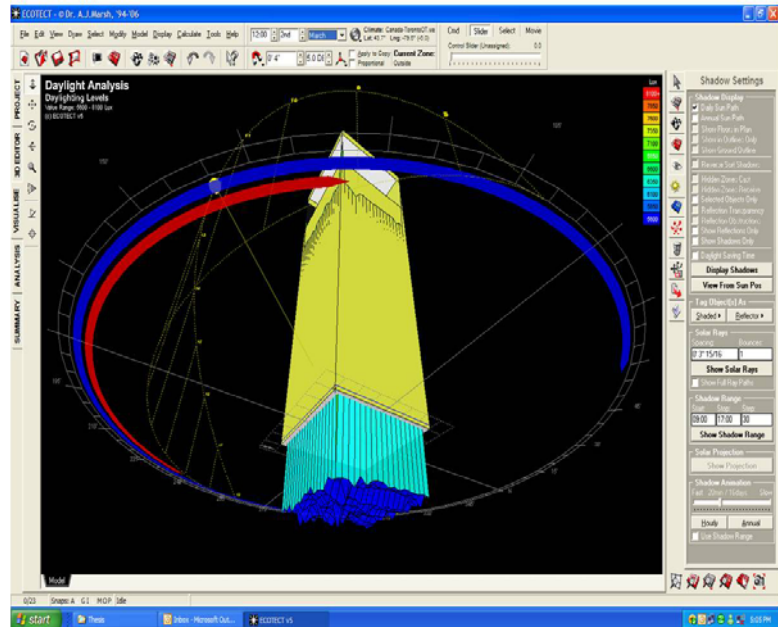


**Figure 15 - chart showing the relationship between length and width and Kr value. The highest Kr value occurs when L=W implying a square atria form works best for daylighting. Kr value is indicated on graph by magenta curve.**



**Figure 16 - current commercially available reflector system to improve daylighting performance available from Solar Tracking Skylights Inc. (Solar Tracking Inc., 2008)**

The recognizable patterns of a specific urban neighborhood, in the ordering of buildings, public spaces, streetscapes, and functions, reinforces an organizing set of urban morphology that makes up a distinct and coherent neighborhood. The urban tissue is the result of collective decisions over time that address the urban patterns of the public realm. Recent collective decisions by the province, such as restrictive land use regulations like the Green Belt and other urban intensification policies, are some of the collective decisions made to pursue a sustainable development



**Figure 17 - screen shot of result of simulating atria form using Ectotect ver. 5.5**

policy. Regulators have connected the environmental costs associated with sprawl with the fiscal dilemma of expanded suburban infrastructure. The new policies aim to decrease agricultural encroachment, reduce the cost of infrastructure, and revitalize existing urban areas through intensification. The possible reductions in resource and energy consumption, however, extend beyond savings for infrastructure. A six-story urban density will support a more sustainable lifestyle. A core component of that lifestyle change is minimizing car use. In an article in *New Scientist*, Fred Pearce argues that the expected change to zero-emission electric cars or hydrogen powered fuel-cell cars are not sustainable options (Pearce, 2006). Any form of car still requires massive networks of streets, roads, freeways, and parking structures. Pearce provides a graph (see Fig. 18) relating urban density to energy use for private transportation that supports this argument.

By 2021, the GTA will need to accommodate an additional 1.2 million people which translates to 480,000 dwelling units (assuming 2.5 persons average per dwelling unit (Statistics Canada, 2008)). For the purposes of this speculation, assume 62% or 297,600 dwellings would be detached single-family dwellings, (Statistics Canada), contributing to urban sprawl. At an average of 5 units per acre, the land required for growth would be 59,250 acres. As a modest speculative goal, assume half of the 297,600 units would be constructed as low-rise (no more than six stories) stacked dwellings, at an average

density of 60 units per acre, then the land area needed for 148,800 units can be reasonably assumed to be 2,480 acres. This represents less than 10% of land area as compared to the 29,760 acres needed for the same number of detached single family dwellings.

It is evident that stacked dwellings can achieve intensification, (and its hoped-for sustainability gains), but architecture must answer the question: “What can it look like and in what context?” Figures 19, 20, and 21 graphically depict the current associated housing typologies for various densities.

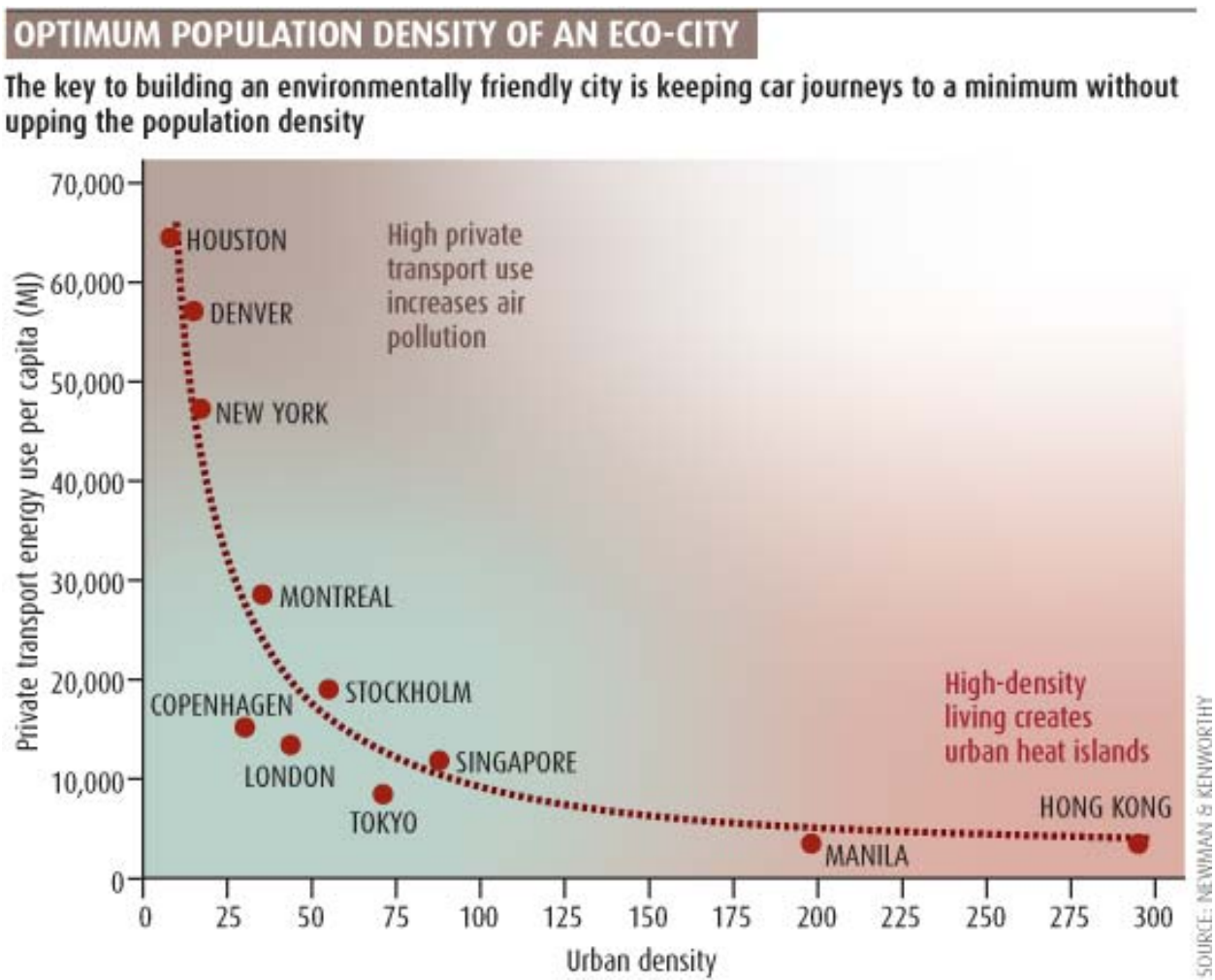


Figure 18 - relationship between density and private transportation energy use (Pearce, 2006)

The context of where this 2,480 acres of intensification can occur is fairly well understood by urban planners. Historically, growth in housing, related to public transportation, connecting work to housing, it can be speculated that public transportation routes will be the framework that will determine the location of new, higher density housing. This suggests that the new housing will follow the linear patterns of transportation routes as opposed to the large block pattern of current single-family suburban subdivisions. Since a five to seven minute walk translates to a quarter mile, the housing would be ideally no more than 1320 feet (about 3 to 6 blocks) from the public transportation line. If one assumes that 50% of the public transportation route frontage can be used for mixed-use housing, then every 33.6 feet of frontage should average 60 dwelling units (one acre). Thus, the 2,480 acres translates to 15.78 miles of street frontage along public transportation routes. As part of Toronto's Official Plan, the TTC has compiled a plan to expand and serve specific avenues and districts. Fig. 22 is a reprint of that 'official' map and clearly shows that a large excess above 15.78 miles of public transportation routes is available. Thus, a choice does exist: 29,760 acres of new greenfield development or 2,480 acres of urban redevelopment along public transit lines.

To further develop the answer to the question, "What can it look like?", one must consider the economics of what can be built in a six-story form for the same relative cost as a single-family house in the suburbs. A quick internet search of new home listings in Vaughn, (a suburb), accessed October 20, 2008, yields a prevailing price of \$521,900 for a 2-story 2,145 sq. ft. detached house. A very crude analysis (see Appendix B) indicates that the \$521,900 price in a six-story form can provide for 1800 sq. ft. of 'owned' slab space, (for private outdoor space and building footprint space), and 360 sq. ft. of 'shared' slab space, (for walkways, stairs, elevators, atria), 1,685 sq. ft. of finished living space, (in a 2 story form), and 400 sq. ft. of parking and storage. Thus, choices such as the demonstration project can be built to directly compete, economically, with the detached suburban home.

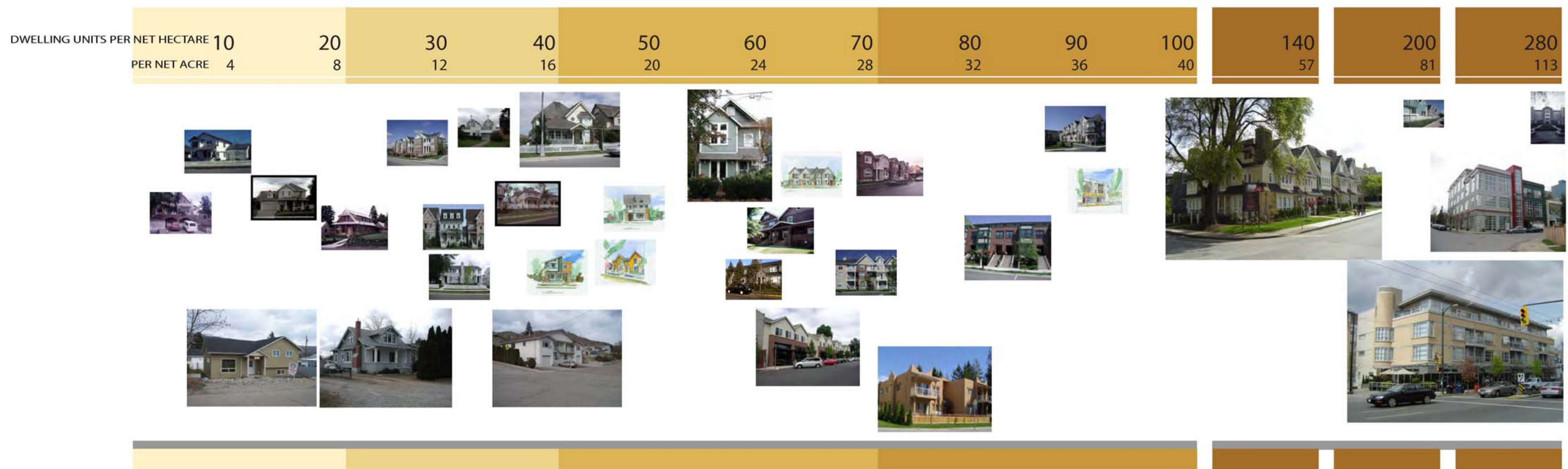
One can reasonably speculate that the urban tissue matrix supporting the demonstration project site will have the following macro scale characteristics by 2020: Queen Street West will continue to grow as a linear commercial artery connected to the downtown core with one and two story shops on both sides of the street. Public transportation will become better established on Queen St., with dedicated 'rapid

Figure 19—Generic representation of different dwelling unit density (Neighbourhood Labs, 2008)



10 units per hectare = 24.7 units per acre

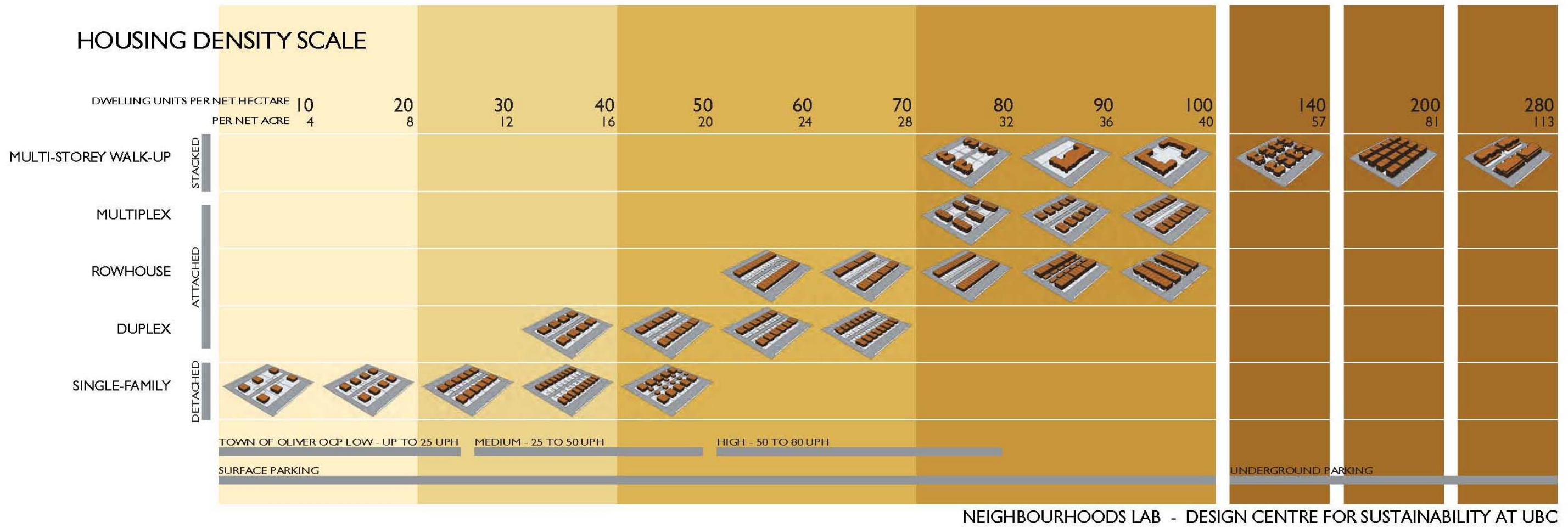
**Figure 20—examples of form of various housing densities (Neighbourhood Labs, 2008)**



NEIGHBOURHOODS LAB - DESIGN CENTRE FOR SUSTAINABILITY AT UBC



**Figure 21—housing types and parking (Nieghbourhood Labs, 2008)**



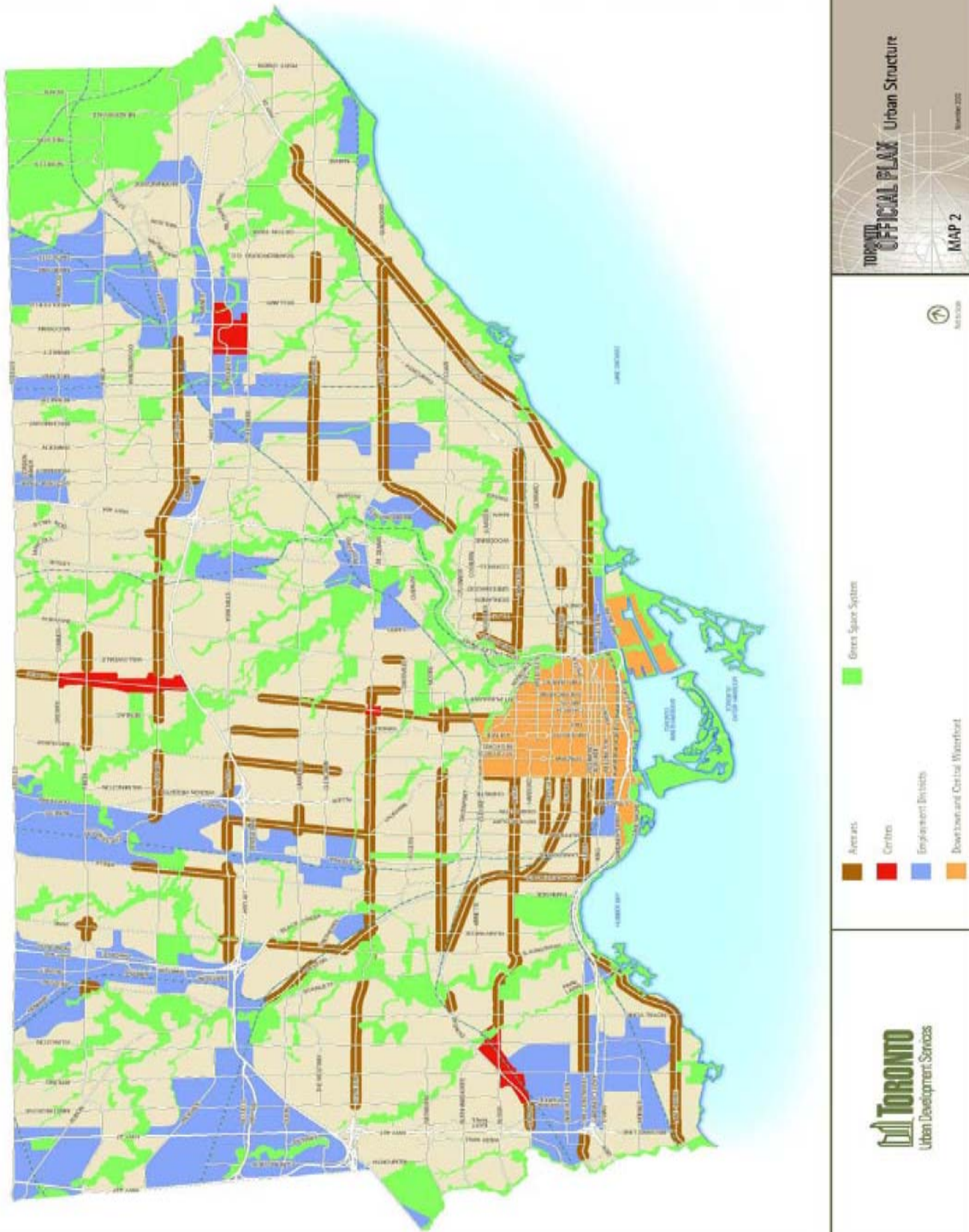
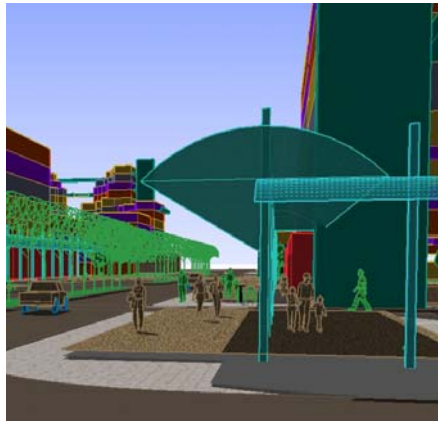


Figure 22 - reprint of the City Official Plan Map, depicting desired location of growth co-related to higher order transit corridors (TTC, 2008)

transit' lanes. The street pattern of the residential neighborhood will be extended into the site for integration with the surrounding urban tissue, but the street would be more pedestrian-friendly. The Queen Street 'streetscape' could be more of a pedestrian-oriented public space with added infrastructure such as free standing canopies to provide some shelter for pedestrian traffic. A speculative view of this scenario is presented in Fig. 23, while Fig. 24 is a photo of this concept as constructed on Church Street in Burlington, Vermont.



**Figure 23 - a schematic portrayal of a pedestrian-friendly streetscape offering shelter for walking**



**Figure 24 - photograph of Church Street located in downtown Burlington, VT. The canopy structures are free standing allowing changes in building facades to occur without disrupting shelter infrastructure (Church St. Burlington VT, 2008)**

## 4.5 Support

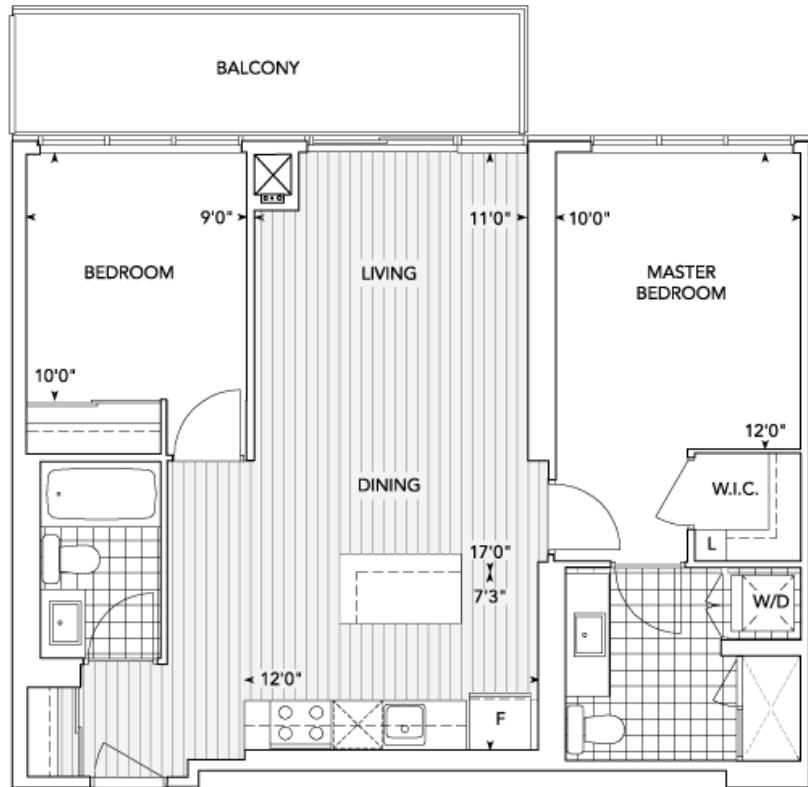
N. J. Habraken coined the phrase 'Support' to describe the grouping of various enabling armatures of a building that are collectively used. A support is more than a structural grid. The support is the durable social asset, the permanence's in the urban tissue that will be serviceable to differing users over time. It is the shared parts of a building that forms a framework to enable change over its lifespan.

The configuration of the support form should be the focus of architect as the design of the support will be that single vision of the specialist that creates what we call architecture. The architectural form of the support should be the locally specific architectural design responsive to bioclimatic forces of the unique site. The support form has to provide technical solutions to problems associated with large scale multi-story buildings that have limited access to daylighting and solar gain. The current practice for multi-story housing is to simply ignore these primary bio-climatic issues (see Fig. 25 for a plan of a standard high-rise building). The dominant current practice is to design high-rise buildings with single-story

single side of unit has access to exterior.



Figure 25 - typical high density condo housing with repetitive floor plans. (Tridel Development, 2008)

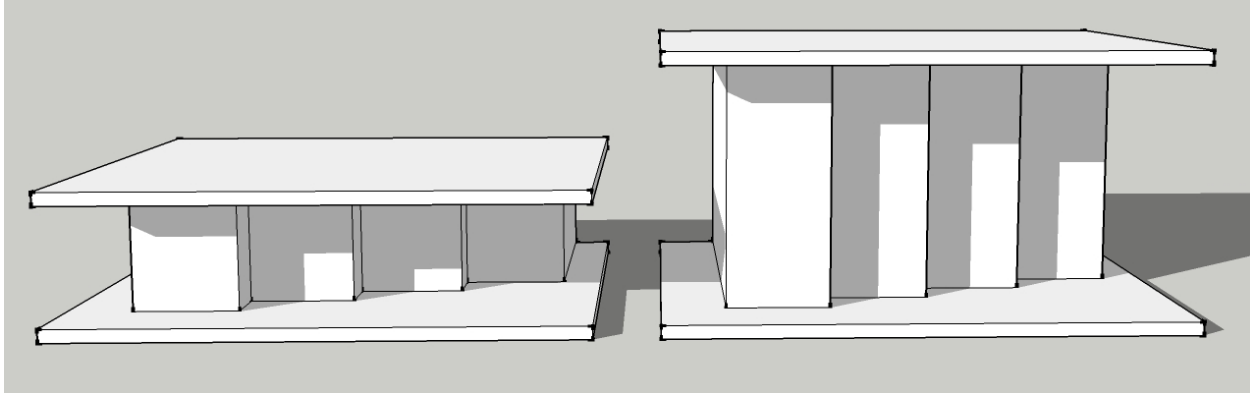


interior double loaded corridor

units in deep floor plates with a double loaded corridor running lengthwise in the middle of the building. This common typology does the following:

1. Limits access to daylight and fresh air to a single face of the unit.
2. Limits the depth of the exterior space to a 'balcony', most commonly five feet deep, since a patio or terrace dimension such as ten to fifteen feet depth would totally self-shade the only daylighting source for the unit.

An obvious improvement from current practice would be a form that employs a strategy of single loaded corridors and shallow floor plates with south facing orientation and two story unit heights (see Fig. 26). This would be the reasonable and feasible approach in a 'greenfield' situation where property line constraints have not yet been imposed.



**Figure 26 - the advantages for solar access in a two story form over a one story form in stacked dwellings is that the balcony/patio/terrace can be much deeper and still not self-shade the dwelling façade.**

In terms of real estate and property ownership of a detached house, the serviced plot of land provides the support for a dwelling. In a multi-story open concept building, the support is vertical real estate to be developed and subdivided in the same way as a traditional subdivision. It includes public ways (stairs, elevators, and walkways), public spaces (elevator lobbies and street level foyers), and semi-public spaces (laundry rooms and community rooms). Parcellation or subdivision will result in dwelling ‘lots’ and individual services will be run to each of these from the public ways. The creation of this artificial ground plane that will be subdivided must be done in ways that satisfy the socio-cultural needs as provided by the traditional ground plane subdivision. The support must avoid technical or social entanglements. There can be no passing of public infrastructure through private ‘lots’ or the creation of control over the ‘lot’ any more restrictive than traditional controls of zoning, setbacks, and use. There can be no fear that a water leak in a unit above will ever be able find itself into a lower dwelling unit or that a fire in an adjacent unit is any more threatening than a similar fire in the ‘house next door’ in a subdivision.

A major function, (but not the only function), of the collectively owned support is as a multi-story structure that creates the artificial ground planes, acts as structural armature for the individual façade and infill for each dwelling ( and associated spaces), and gives the architectural massing ‘form’ to the building. Since the demonstration project is multi-story, preferably six stories for reasons stated before, the current choice of structural material is steel or concrete, (or a hybrid of both). For this demonstration project, cast-in-place reinforced concrete is suggested for the following reasons:

1. Although a steel frame would lend itself towards disassembly and can be completely recycled, the applied fireproofing makes disassembly and recycling impractical.
2. A steel frame is subject to corrosion by water, and, most buildings are subject to water intrusion during some part of their service life.
3. Cast-in-place concrete, reinforced with stainless steel rebar, does not corrode, is inherently fire proof, and, most importantly, is culturally accepted as a ‘permanent material’ capable of a service life of hundreds of years.
4. Although the manufacture of cement for concrete has a large ecological footprint due to high energy demands, cement is typically only 11% of concrete and the embodied energy of concrete is less than steel (see Fig. 27). Further, the ‘aggregate’ in concrete can be industrial byproducts that can be permanently sequestered in concrete.

The support form has to facilitate adaptive reuse over long time frames. A simple column and beam with one-way plate is the most adaptive form. This form should be used for the first two stories adjacent to the natural ground plane to allow for the interchangeable use from housing to institutional/commercial on the first and second floors to accommodate future urban growth. Based on current mid-rise typological models, housing will occupy the buildings from the third floor up and shear walls located as fire walls between units can be introduced as elements that will not need to be changed. There is a premium to be paid for this type of structurally based flexibility, but the true life-cycle costs demonstrate a savings by providing the long term adaptive re-use options for the structure. Adaptive re-use is a core strategy that moves the demonstration project towards sustainability by providing an estimated service life of least 100 years to the structure.

MATERIAL	EMBODIED ENERGY	
	MJ/kg	MJ/m <sup>3</sup>
Aggregate	0.10	150
Straw bale	0.24	31
Soil-cement	0.42	819
Stone (local)	0.79	2030
Concrete block	0.94	2350
Concrete (30 Mpa)	1.3	3180
Concrete precast	2.0	2780
Lumber	2.5	1380
Brick	2.5	5170
Cellulose insulation	3.3	112
Gypsum wallboard	6.1	5890
Particle board	8.0	4400
Aluminum (recycled)	8.1	21870
Steel (recycled)	8.9	37210
Shingles (asphalt)	9.0	4930
Plywood	10.4	5720
Mineral wool insulation	14.6	139
Glass	15.9	37550
Fiberglass insulation	30.3	970
Steel	32.0	251200
Zinc	51.0	371280
Brass	62.0	519560
PVC	70.0	93620
Copper	70.6	631164
Paint	93.3	117500
Linoleum	116	150930
Polystyrene Insulation	117	3770
Carpet (synthetic)	148	84900
Aluminum	227	515700

**NOTE:** Embodied energy values based on several international sources - local values may vary.

**Figure 27 - embodied energy values for various building materials (Architecture2030, 2008)**

Another key consideration of the form of the support is the introduction of ‘nature’, both horizontally and vertically. Vernacular housing has always had a strong connection to ‘nature’. The success of the detached house in suburbia attests to the connection between housing and a naturalized private outdoor space (the ubiquitous suburban backyard with trees). The popular building typologies for mid-rise urban dwellings often provide a shared naturalized courtyard outdoor space but fail to bring ‘nature’ above the original ground plane. The popular typologies provide limited private outdoor space, often with mean dimensions severely limiting functional use, that are truly ‘hard’ landscapes. The structural grid of the demonstration project enables outdoor spaces under the dweller’s control that have sufficient scale for the creation of a naturalized settings, including options to have trees and gardens, for an urban version of the ‘backyard’. The shared semi-public spaces on landscaped podiums create opportunities for naturalized larger scale spaces. Finally, small scale interconnected spaces for urban biota that is inaccessible by people is proposed to promote habitat for plants and animals that have adapted to urban settings. This layering of biota would contribute to the reclamation of urban environments as part of the living biosphere.

#### **4.6 Façade**

Facades are the mediator between the inside and the outside. They are complex social fabrics that, from the dawn of time, have been decorated by the dweller. A façade is not defined just by the building envelope that mediates the environment, but by layers of socio-culturally defined transitions from public to private, from outside to inside. The detached house provides this transition with fences, gates, gardens, walkways, and entrance alcoves. Most mid-rise housing forms acknowledge this social need in the form of decorated elevator lobbies – a brief nod of acknowledgment to this social need. Although this specific social issue is recognized, it is fundamentally not addressed by architects who concentrate on the envelope and the appearance. The elevator lobby is ‘semi-public’ space and is under collective control. The detached house ‘model’, (a traditional vernacular architecture), places the dwelling unit occupant in control of his façade and dwelling entrance. Thus, for the demonstration project, dwelling unit facades and entrance transition spaces are under the occupant’s control, each uniquely designed (decorated) to control contact with the ‘outside’ as the norms of society are accepted (or rejected) by the occupant.

The building façade of housing in any form is integrally tied to the building envelope. A high performance building envelope is essential for the first sustainability ordering principle of ‘Reduction’ to be used. The gains in energy efficiency possible by controlled ventilation with tempered air simply do not exist if the building envelope provides fresh air through infiltration alone.

The construction of a façade as a disentangled building system enables certain sustainability strategies that are simply not viable in standard construction. In standard construction, the façade is closely coupled with the structure and is difficult to change. In the demonstration project, the façade and the building envelope are completely independent of the support structure. The construction of the facade is not subject to axial forces as is often the case with standard construction and only needs to resist the much smaller lateral forces of wind. This less demanding structural scenario permits the use of recycled and ‘down-cycled’ materials that no longer have the structural properties of the original virgin material. There is no technological reason that a renewable material such as wood could not be used. The risk of fire and structural limitations currently prohibit wood in facades in standard midrise construction but the de-coupling of the fireproof structure from the façade controls the fire risk in the same way it is done in wood detached houses – distance separation. Since each façade would be ‘unique’, the opportunities to obtain sustainable materials locally in small quantities is enhanced. The façade construction by the individual dwelling owner enables individual efforts to move towards sustainability using basic strategies such as recycled material, design for disassembly, and open building systems.

#### **4.7 Infill**

The demonstration project is used to illustrate how infill can be de-coupled in buildings but does not attempt to illustrate the wide range of design options possible. Infill is not proposed to be under the design authorship of the building designer, the architect, but rather under the control of the occupant (or his delegate). An infill is more than a dwelling unit. It is an intricate interweaving of space and function directly responding to the unit dweller’s vision of ‘home’. Each dwelling unit is independent and each dwelling unit occupant can participate in the emerging ‘green’ culture by his actions. The means to provide infill can range from conventional site built to off-site prefabricated units. It is conceivable to build infill using conventional ‘site-built’ methods using the limited organizational systems of site construction but building systems based on site construction methods are, however, inefficient and generate large waste streams. By designing infill systems as open building systems, the inherent possible gains of prefabrication can be realized.



The decoupling of infill enables a large range of possible strategies to move us toward sustainability. Some of them are as follows:

1. User directed prefabrication providing mass customization will increase resource efficiencies and reduce the construction waste stream.
2. Materials for infill can be selected that match the limited life span needs of the infill function enabling the use of recycled and 'down cycled' materials.
3. Accessibility and design for disassembly for mechanical systems would allow for repairs and upgrading rather than the current practice of wholesale replacement.
4. Adaptive re-use for components is realized when the components are part of an open building system and adaptability of spaces is practical since the reconfiguration of spaces that do not have to be dictated by structural functions.

#### **4.8 Design Exploration**

In our society basic housing is not the cultural product of monument building associated with architecture that reflects a society's surplus. The architecture of housing is a populist cultural product derived from the vernacular of the day. This thesis posits an architecture for housing derived from combining monument building with the vernacular of the day. The architecture attempts to interconnect the populist vision of individuals through the design of individual dwelling unit façade and infill with the monument building singular vision of a specialist, the architect, designing a support to act as an enabling armature. The parametrics of the supporting armature would be a function of the urban context within which the support would be located. It is further proposed that the interconnected elements of urban context, support, façade and infill are derived in a responsible fashion that transitions housing towards sustainability.

The initial anchor point for this design exploration is the proposed site where the stated objective of enabling sustainable urban housing can be explored. The selected site provides the broadest and largest scale that will inform the design. The understanding of the large scale abiotic and biotic elements provides the large scale reference frame within which culture, technology and economy interact. The urban context can be viewed as the built environment resulting from that interaction over time. The vignette on Fig. 28 is a mapping of the largest scale key elements of the urban context such as street

patterns, rapid transit corridors, traffic patterns and public spaces which shape the design. The vignettes on Fig. 29 establish the demonstration project as a component that is part of a neighborhood scale context that relates to the overall density, height, and use as speculated on in this thesis for sustainable urban housing.

It is the largest urban scale to the neighborhood scale elements that determine the potential solar access for the demonstration project, and, solar access is a key form maker in sustainable design. The vignettes of Fig. 30 demonstrate the connection between solar access and form while the vignettes of Fig. 31 are a study of solar access on the project once the form has been determined.

It has been demonstrated in this thesis that sustainable urban housing does not exist by itself but, rather, that it exists as part of a context. The dwelling units are an interconnected part of an urban mix and linkages occur at every scale. It proposes a rebalance of the live-work relationship in the urban environment. The vignettes on Fig. 32 demonstrate a form that could be realized by incorporating housing in the multi-scale elements of that urban mix. At the largest scale of that mix, Queen St. West, as a rapid transit corridor and high commercial traffic area, relates to the demonstration project by proposing new urban scale infrastructure to enhance the pedestrian element of the street in the form of a detached canopy structure. It would compliment the existing two or three story streetscape that would remain as a detached element capable of rapid transition to various ‘storefront’ commercial uses. This ‘high churn’ element is disentangled from the project to facilitate change yet is connected to it. The vignettes on Fig. 33 and 34 illustrate the disentanglement of the canopy structure to the commercial buildings. Another part of the mix is modeled after an existing disentangled ‘office building’ typology where the support and façade is fixed and the infill is subject to constant change. This element is proposed at street grade fronting on the side streets. A sample of this type of fixed façade is illustrated on the vignette on Fig. 35. The vignette on figure 39 and 41 illustrates the fixed façade relationship to the overall elevation of the project. It is proposed that neighborhood institutional spaces be provided as part of the urban mix of the project. It also would be modeled on the fixed façade office building model yet would be different in that it has exposure only to the neighborhood public space, not to the street. Further, this would be a ‘long span’ structure with open spaces that, again would accommodate change. The vignettes on Fig. 42 and 43 illustrate a possible two story south facing façade for the institutional element. From Fig. 21, a project in the 60 units per acre range addresses parking by putting it underground. This project proposes the space above the parking structure as common public space. The

uses of this space would be connected uses associated with 'open green space' and could vary from 'park' as illustrated by Fig. 40 to urban agricultural plots. Support spaces such as service cores and atria would provide the various infrastructural services needed for the varied 'mixed use' components. The roofs of the project, having unobstructed solar access, will become part of the service infrastructure capturing solar energy and rainwater (as illustrated in Fig. 38).

All of the mixed use spaces, dwelling units, verdure, and service infrastructure are proposed to be supported by an enabling support armature constructed with a 100+ year service life. The support structure would be re-enforced concrete simple column and flat plate design as illustrated by the vignette on Fig. 37. It would act as an armature to various support functions as illustrated on Fig. 36.

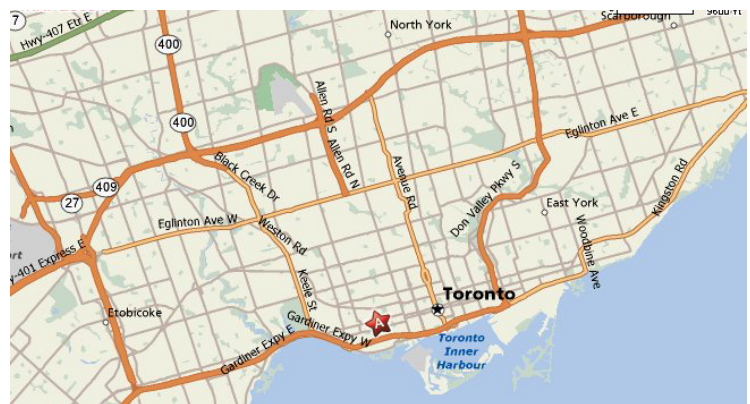
The dwelling unit component of this 'housing' project would consist of individually defined space within the support armature which would act as 'artificial ground'. The vignettes on Fig. 44 and 45 illustrate a possible two story dwelling unit within the supporting armature. The potential for creating diverse vernacular building facades through individuality is illustrated in the vignette on Fig. 46.

No vignettes are prepared to illustrate infill since the possibilities for individual expression at this scale are, literally, limited only by the individual.



**Figure 28 - urban context schematic:**

1. Queen Street West rapid transit corridor
2. High traffic based two to three story commercial buildings
3. Trinity Park providing large scale open space to district
4. Proposed neighborhood small scale open space
5. Established north-south street grid extended into project area
6. Existing low density urban housing

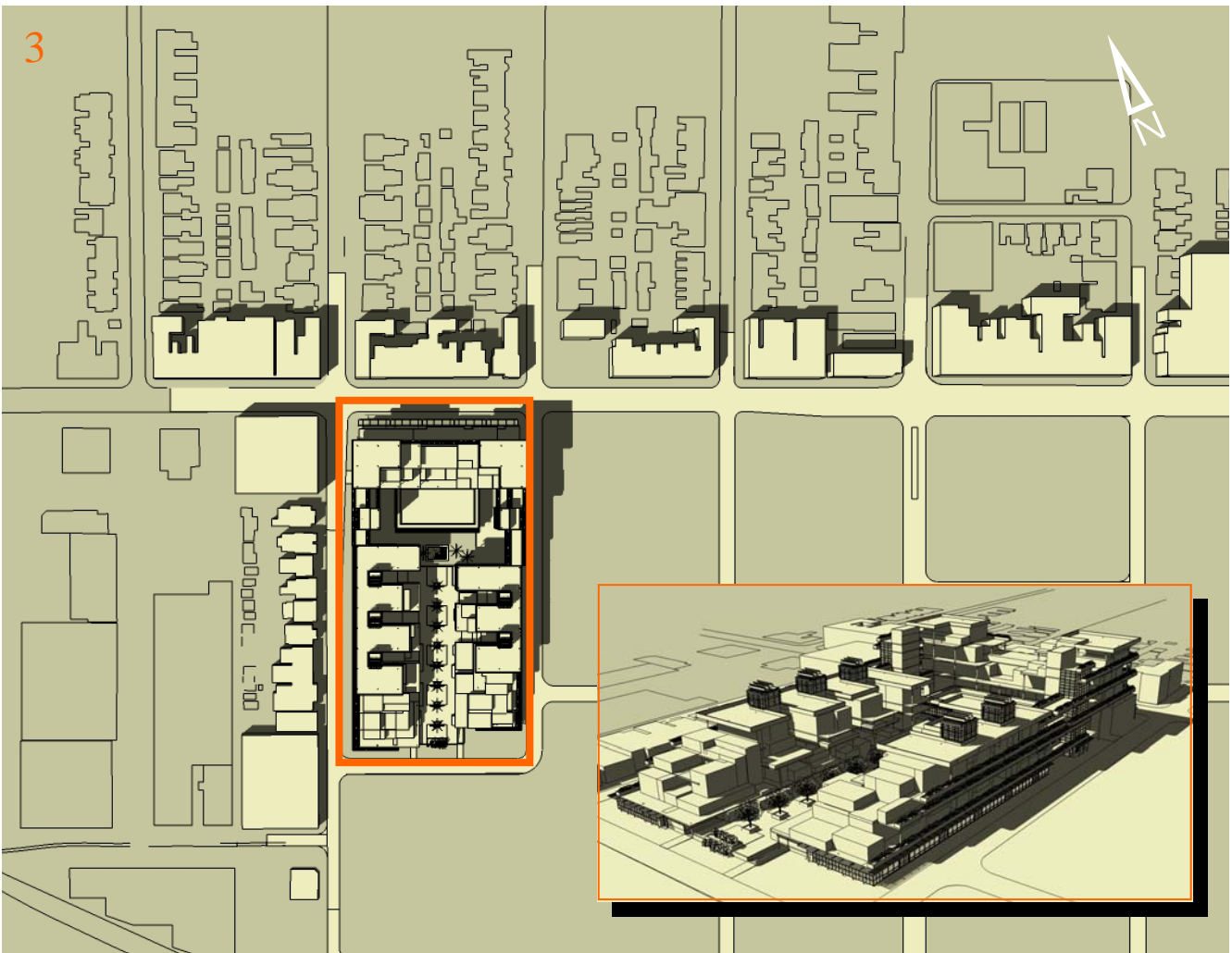


**Location key map**

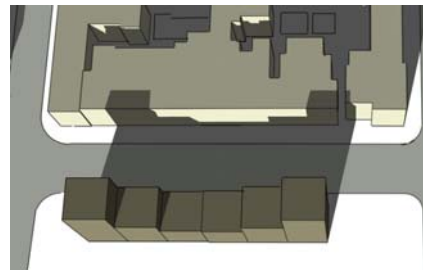
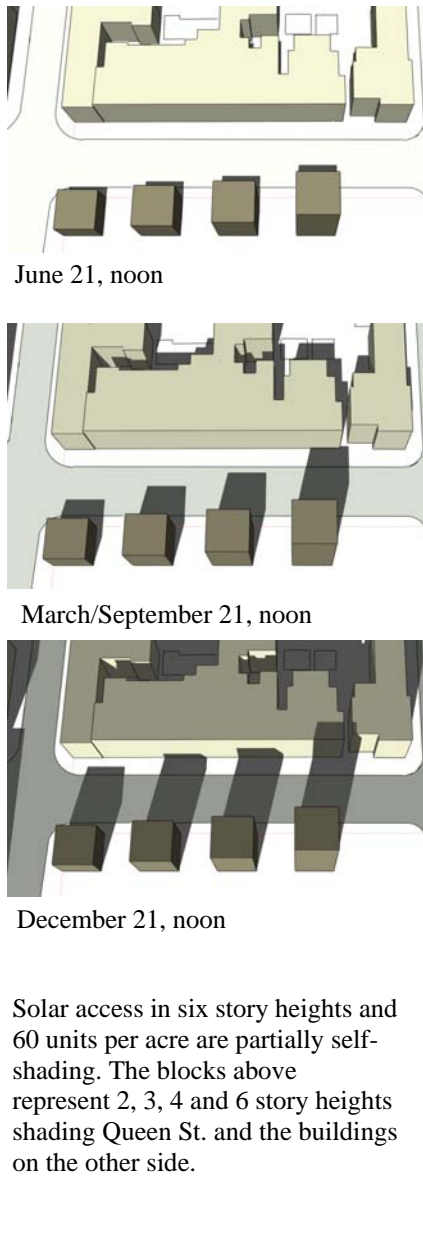


**Figure 29 - the urban context:**

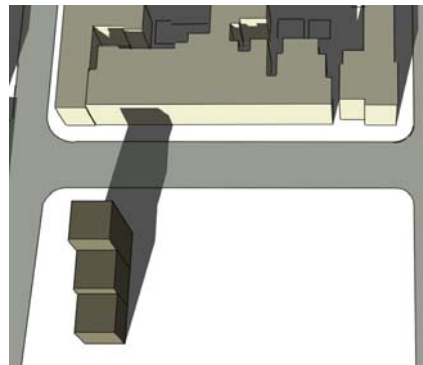
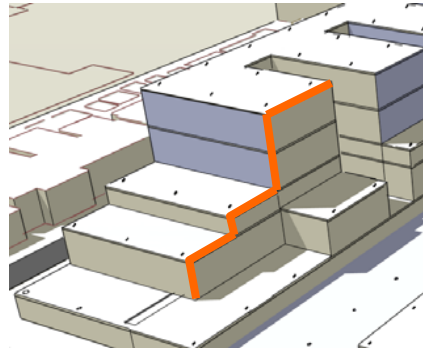
1. North / South prevalent street pattern
2. Redevelopment integrating existing urban patterns of established streets connected to rapid transit corridors.
3. Demonstration project as part of neighborhood district base on a mixed use, six story, density intensification model.



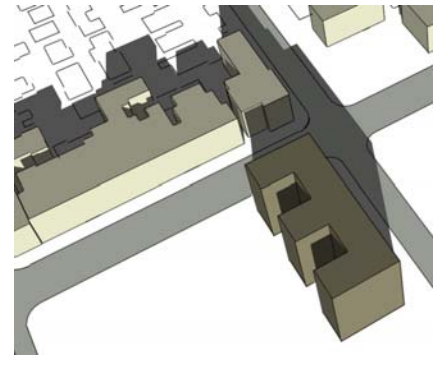
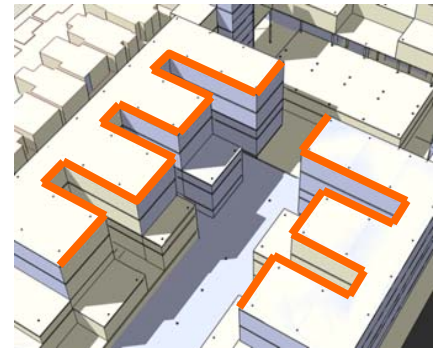
**Figure 30—Solar access and Form**



In order to provide some solar access to Queen St. and the buildings on the other side, the residential mass is set back and a 'slot' is provided.



By stepping the profile on the southern exposure, more of the 'artificial ground planes' have direct solar access.



By indenting the profiles of the east/west faces of the residential mass, solar access is increased.

Figure 31 - Project Form and Solar Access

6:00 am

8:00 am

10:00 am

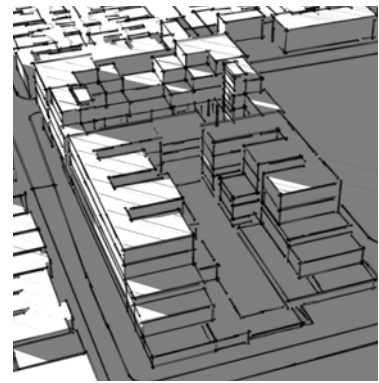
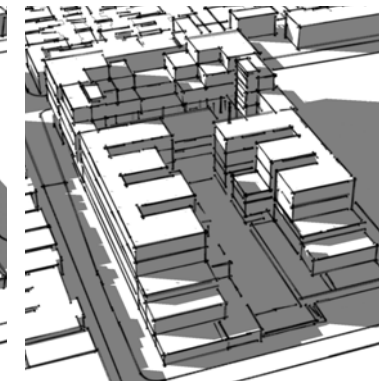
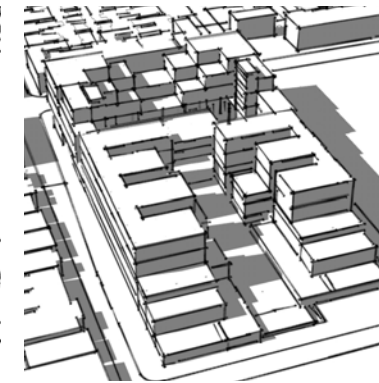
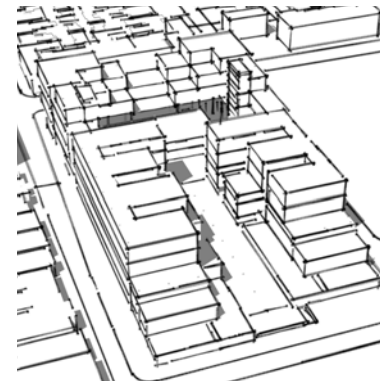
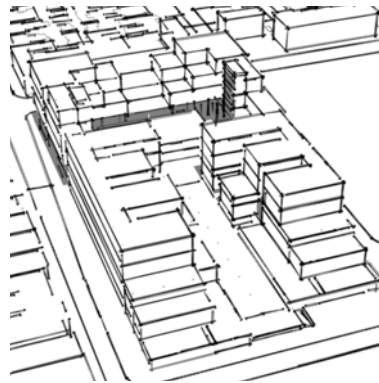
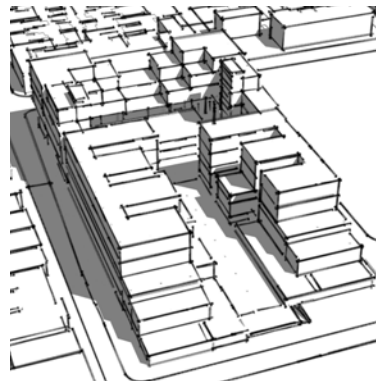
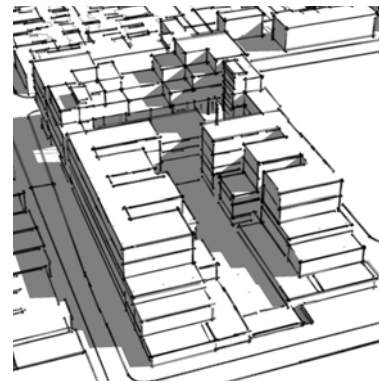
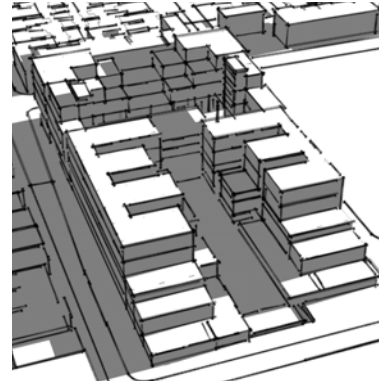
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2:00 pm

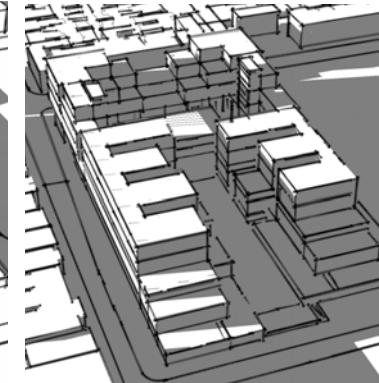
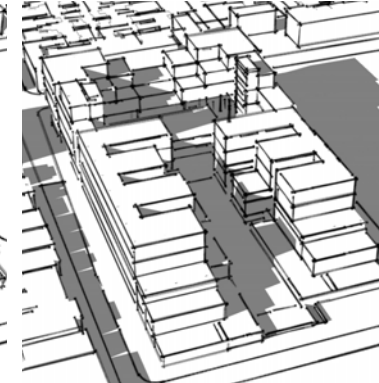
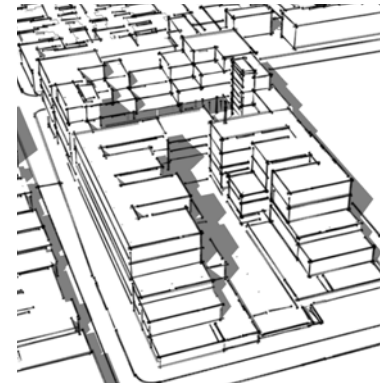
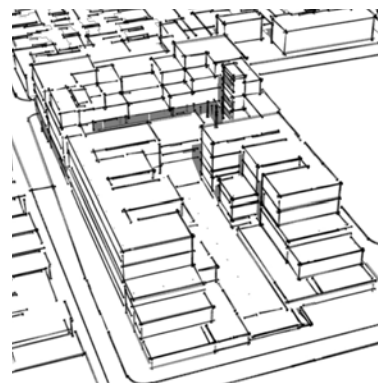
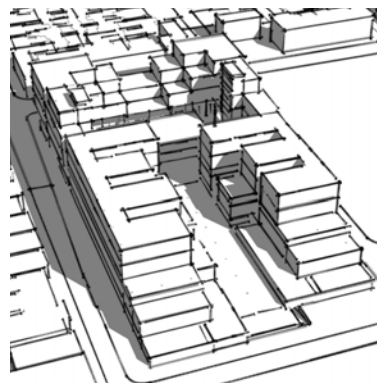
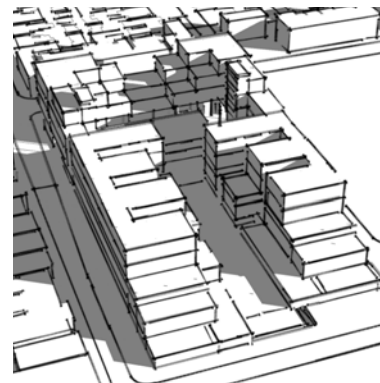
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6:00 pm

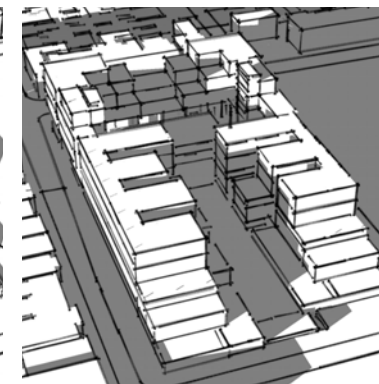
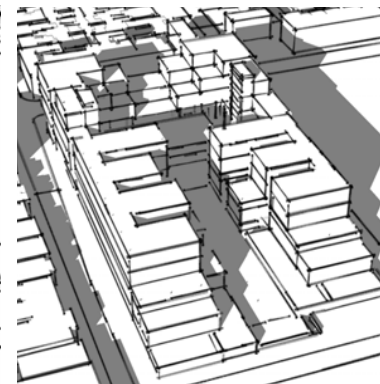
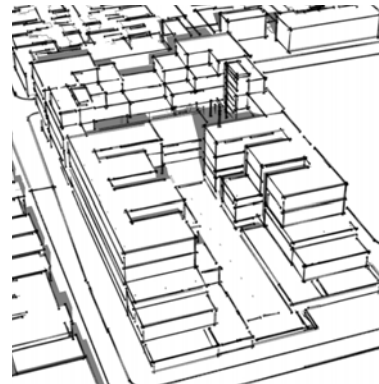
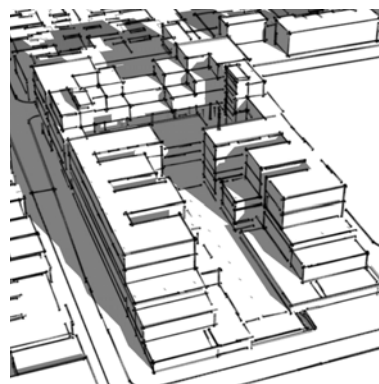
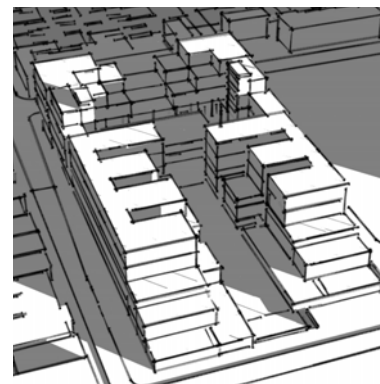
8:00 pm



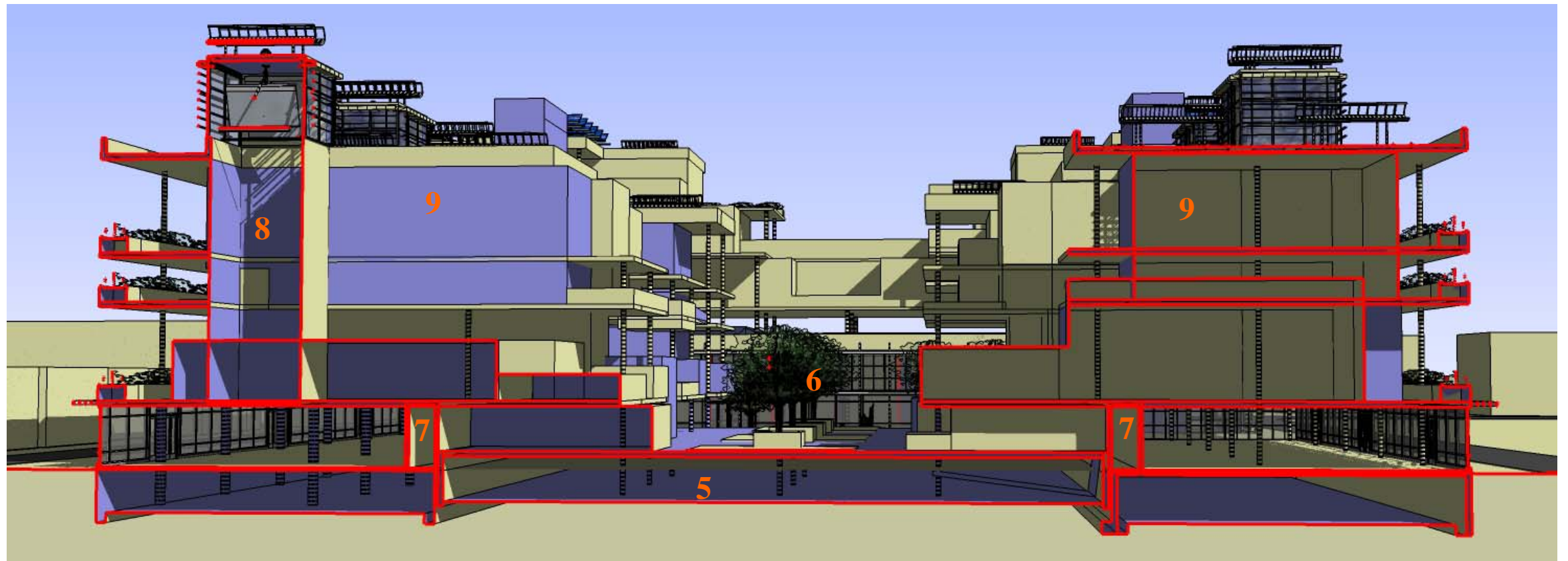
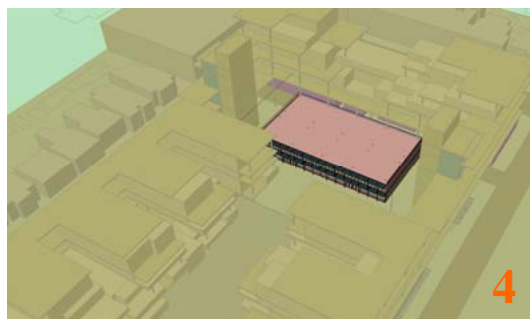
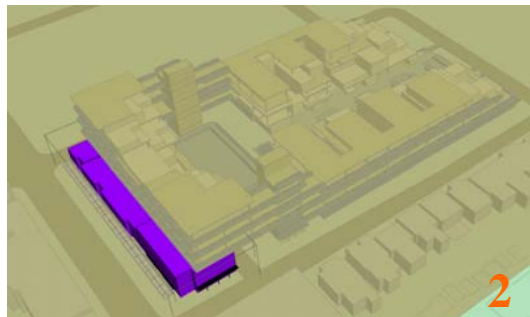
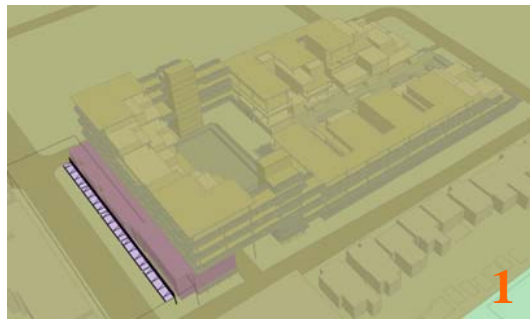
July 21st



March/September 21st



December 21st



**Figure 32 - project components**

- |  |  |
|--|--|
| <ol style="list-style-type: none"> <li>1. freestanding sidewalk canopy system</li> <li>2. Disentangled high traffic commercial</li> <li>3. Destination commercial and service office spaces modeled on 'base building' and 'tenant improvement' system</li> <li>4. Neighbourhood institutional spaces modeled on 'open plan' system</li> </ol> | <ol style="list-style-type: none"> <li>5. Underground parking and long term storage</li> <li>6. Landscaped podium as common neighborhood open space</li> <li>7. Service and circulation cores</li> <li>8. Un-occupied atria mechanical systems</li> <li>9. Occupant controlled dwelling units</li> </ol> |
|--|--|





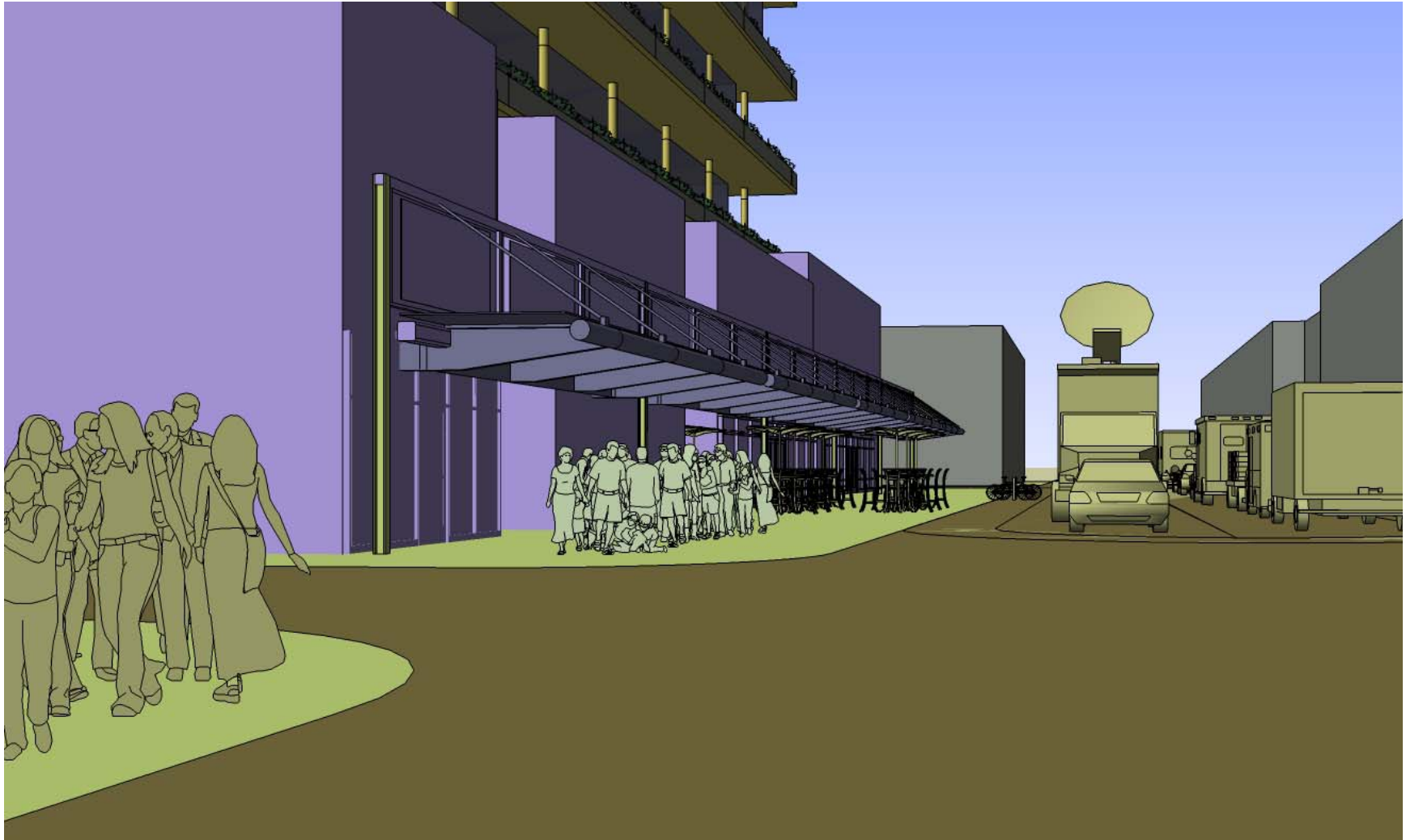
**Figure 33—disentangled urban infrastructure**

Urban amenities such as this free standing sidewalk canopy system are part of the urban infrastructure that could be developed to support urban housing.



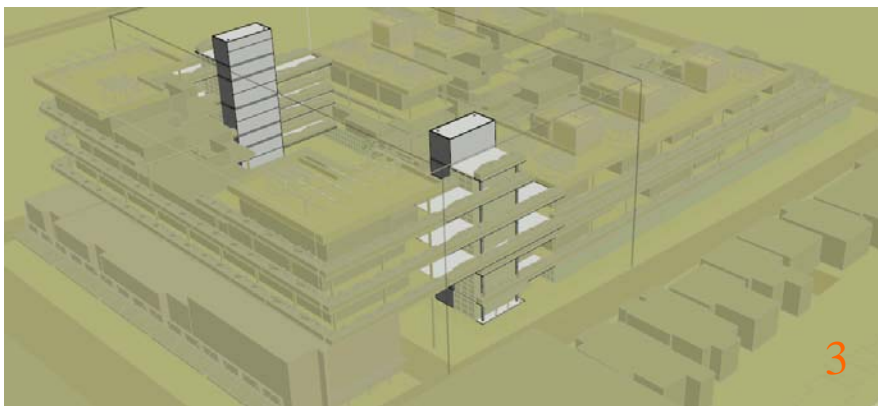
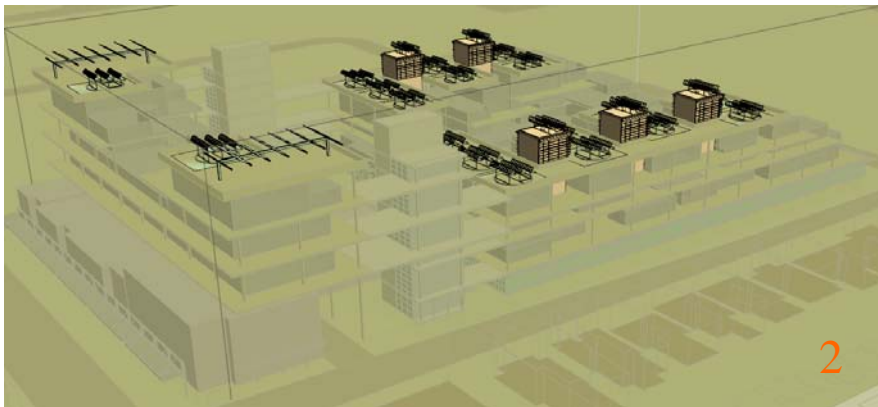


**Figure 34 - Disentangled commercial element**

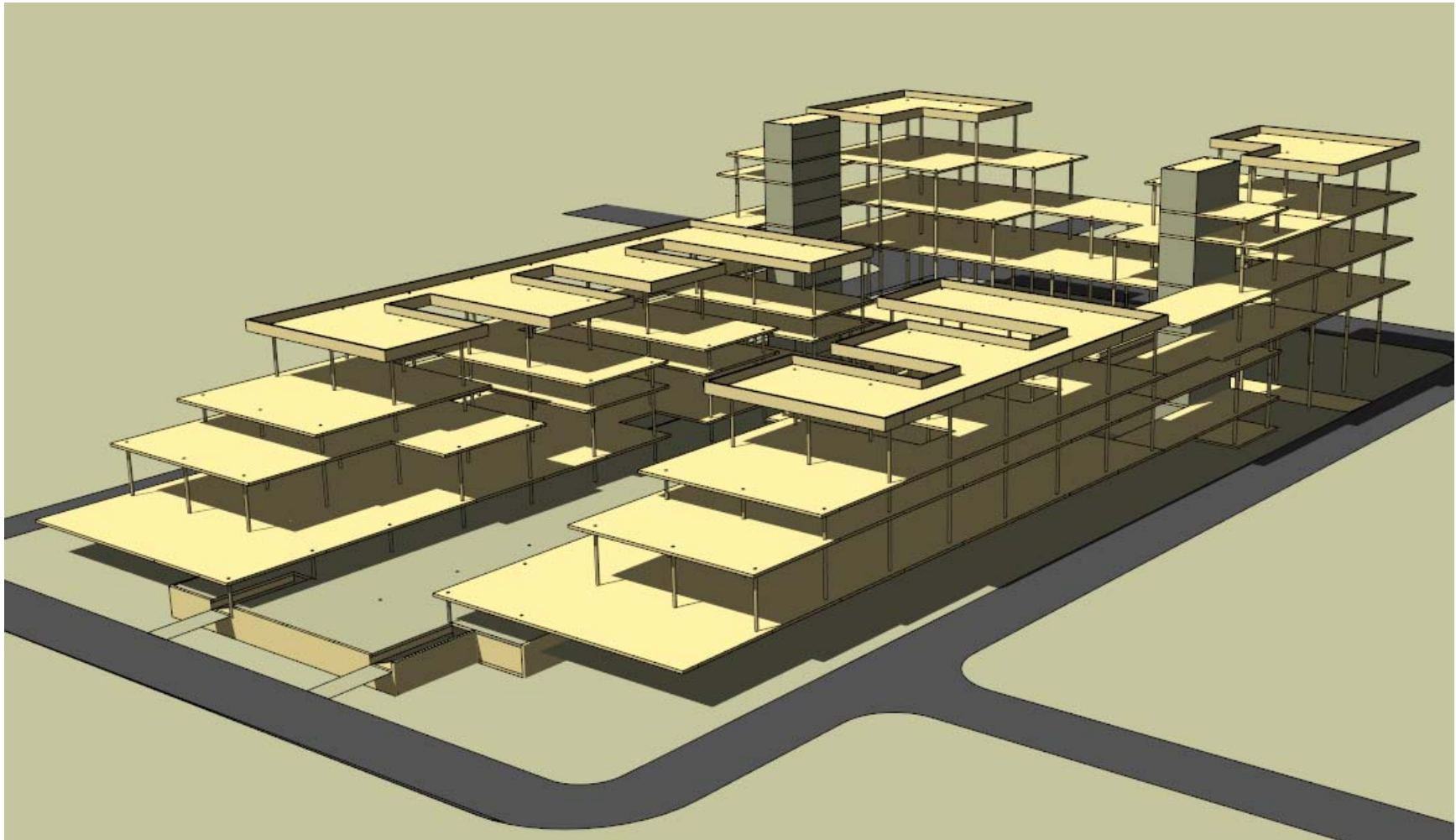


**Figure - 34 view along Queen St.**

**Figure - 36**  
**Support Layers**

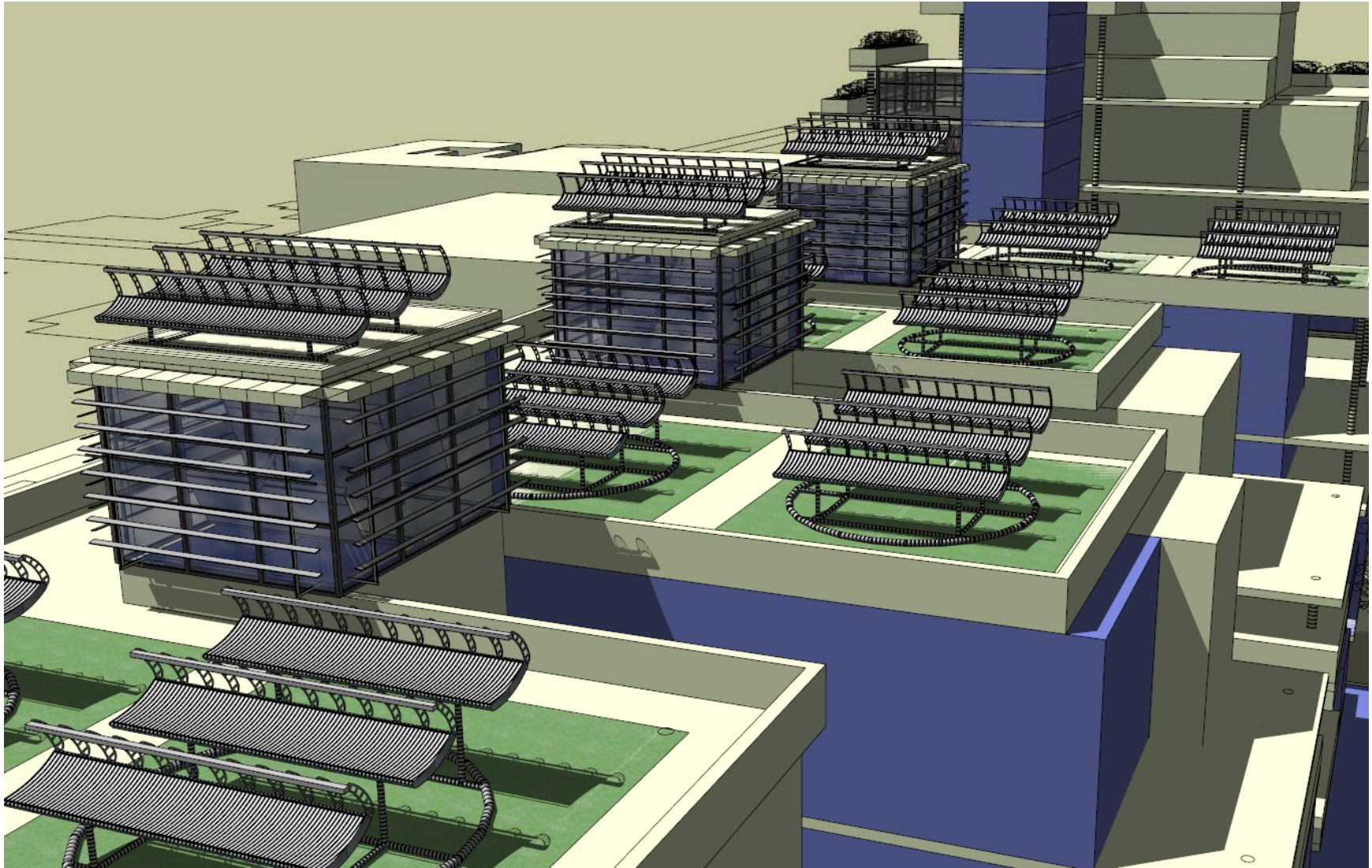


1. highly flexible, durable, long term, structural framework that will act as the constructed ground plane.
2. The support armature for infrastructure for energy production, daylighting, air filtration and tempering.
3. Service core integrated into waste management infrastructure
4. Support armature for biota



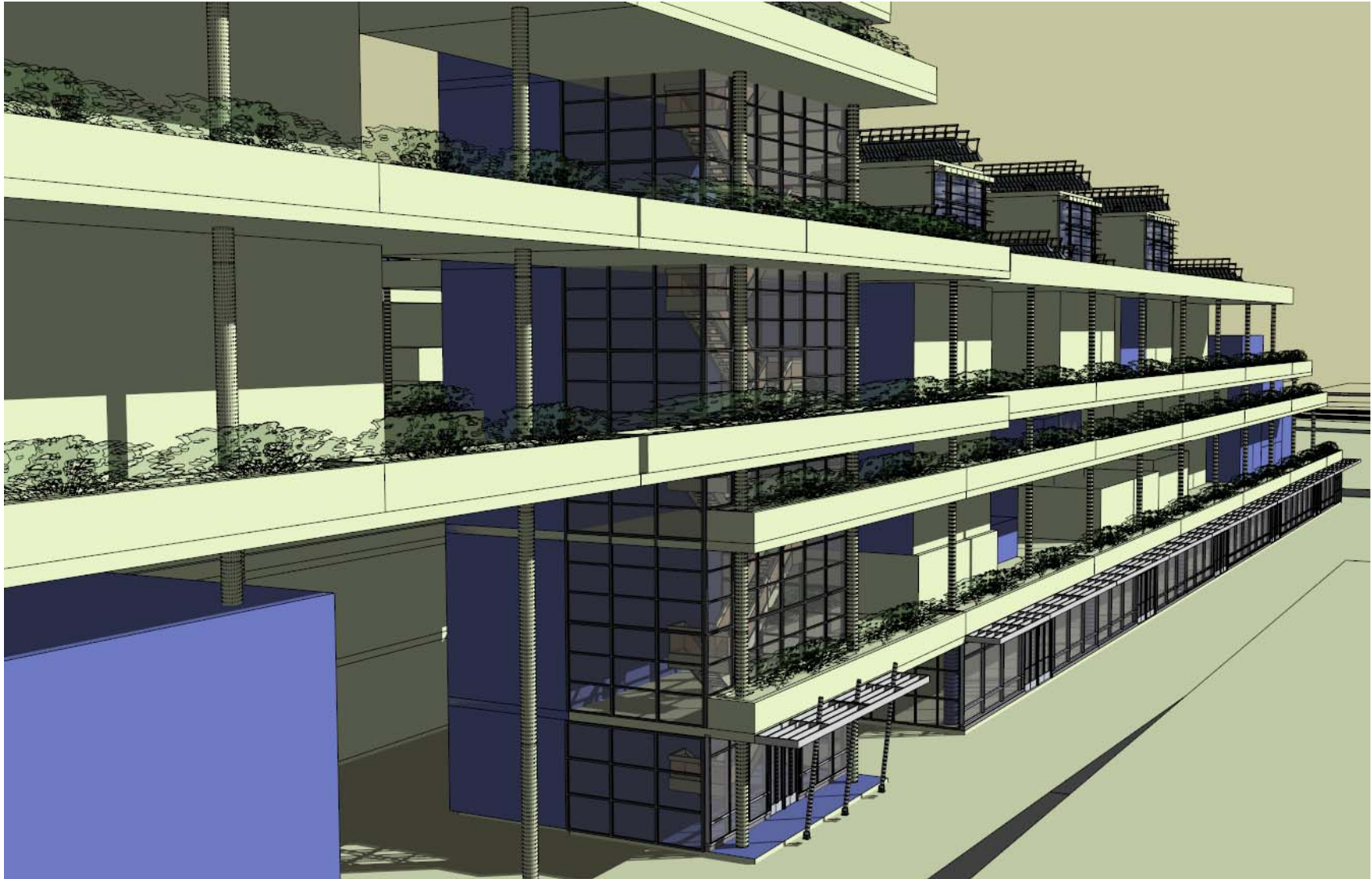
**Figure 37 - structural layer of support**

The structural skeleton creates the artificial ground planes for dwelling units in a stacked configuration.



**Figure 38 - roofscape**

Since the roof area always has solar access, it becomes part of the building infrastructure to capture solar energy and rainwater.



**Figure 39 - service core and circulation**

The service core is separated from the units and is the vertical spine for horizontal circulation.



## Figure 40 - biota

The range of biota could include large scale trees on landscaped podiums by locating them directly above columns.





**Figure 41 - view along commercial façade**



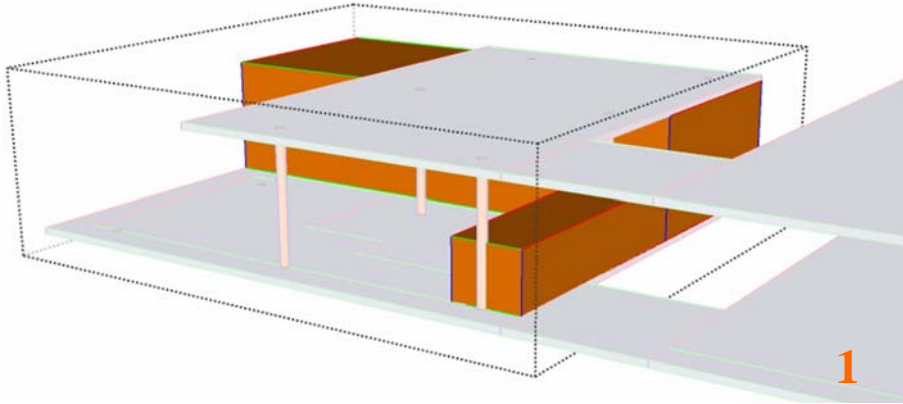
**Figure 42 - view of neighbourhood institutional façade**



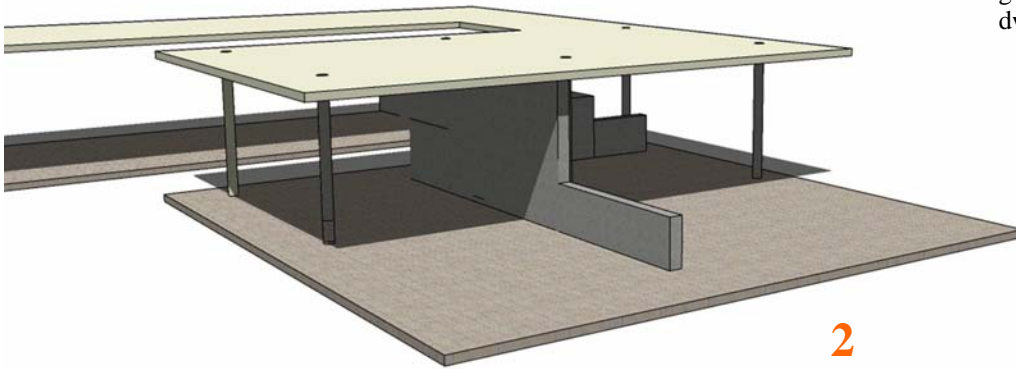
**Figure - 43 view of landscaped podium in front of institutional building**

## Figure - 44 Infill

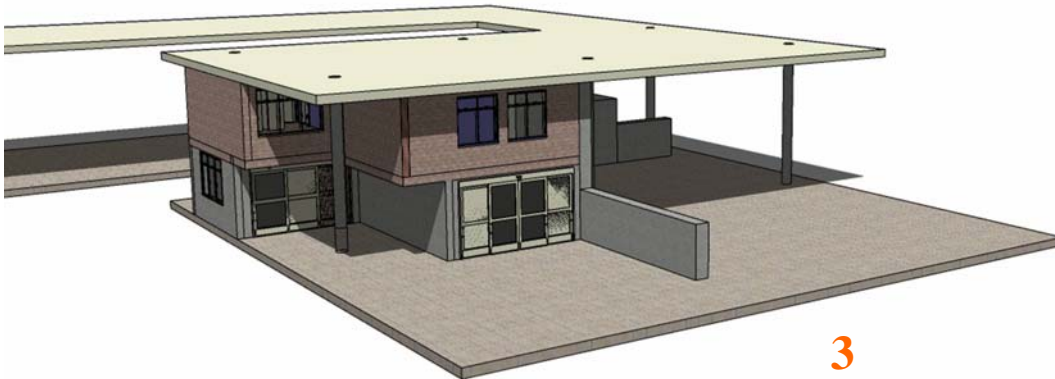
1. defined space in support armature under occupant's control
2. Requirements for fire and safety met with firewalls and distance separations same as typical subdivisions
3. dwelling unit layout and design determined by occupant
4. Artificial ground plane allows occupant to have outdoor green space in stacked dwelling



1



2



3



4

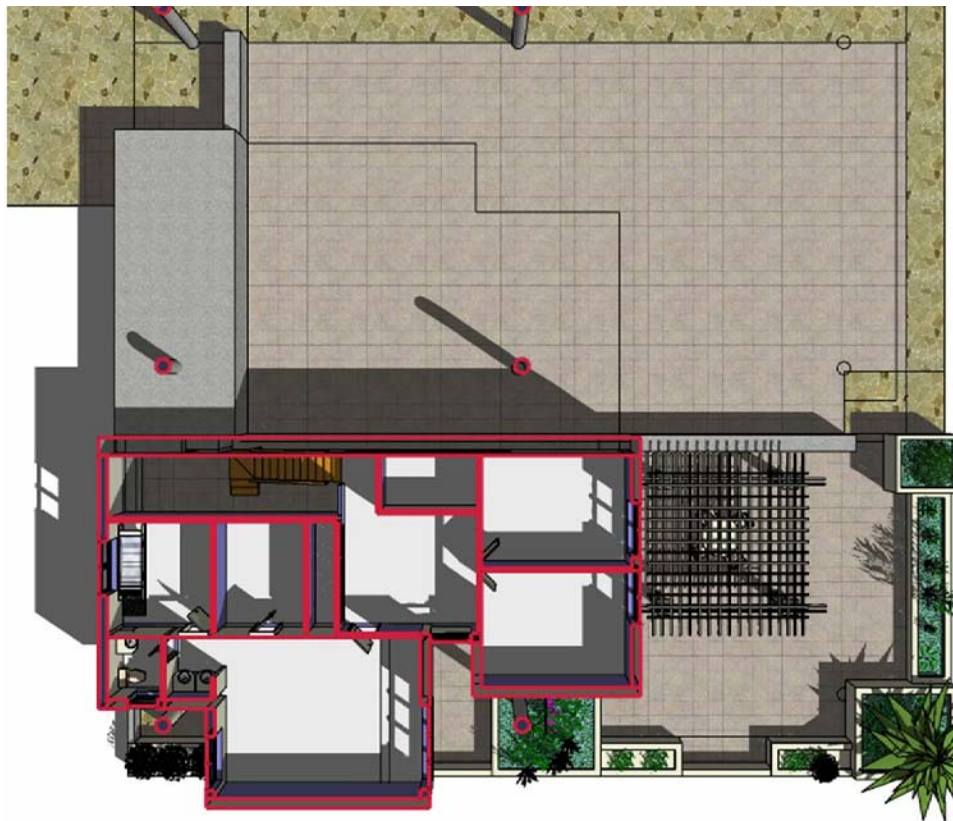


## Figure 45 A possible unit

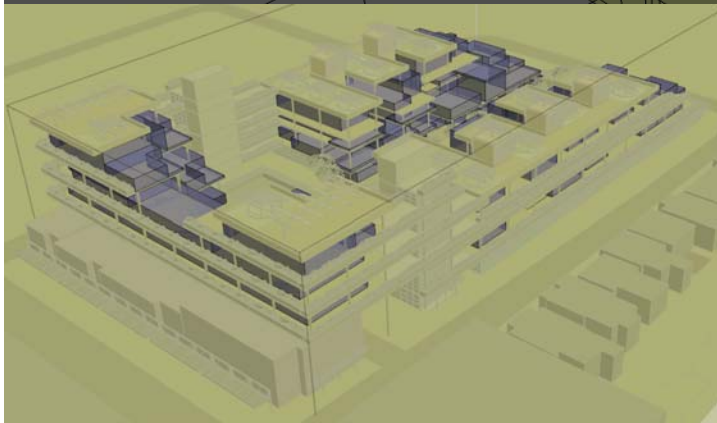
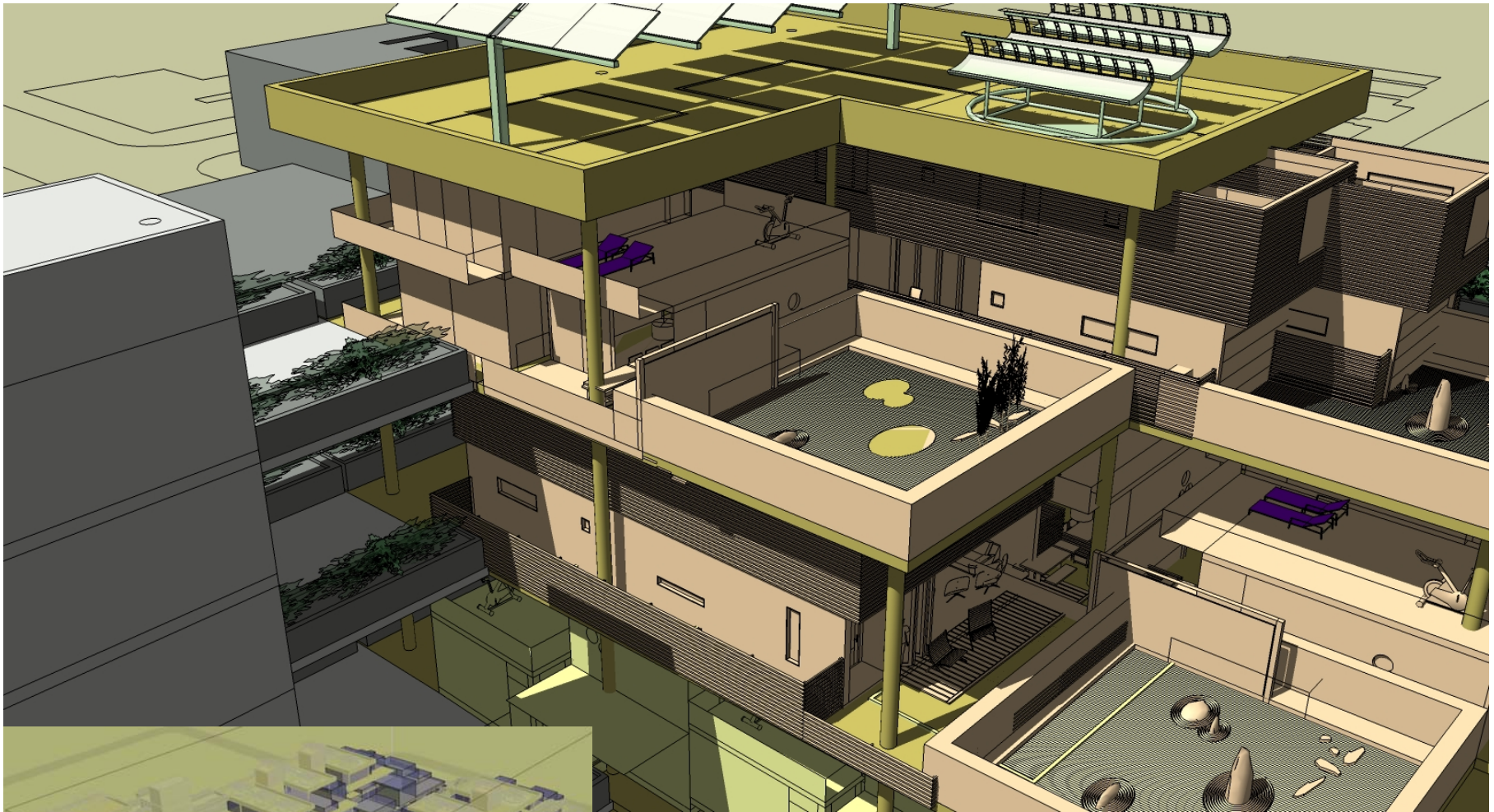
Type and style of dwelling unit is under the occupants control subject to same level of restrictions as a standard subdivision.

The floor plans on this page indicate a typical two story, three bedroom from the suburbs transplanted to the project with outdoor living space in a stacked dwelling typology.

Schematic plan  
First floor



Schematic plan  
Second floor



**Figure - 46 view of infill dwellings**

Individual dwelling facades as visions of the occupant providing diversity through individual control

## Chapter 5

### Conclusion

#### 5.1 Urban Housing at a Re-balance Point

The architecture of urban housing needs re-evaluation and a new vision for 2020.

There is a new environmental discourse being shaped by a new global perspective that is underpinning a rebalance in the Triple Bottom Line of western civilization. Architecture, as a cultural product, reflects the resultant vector of cultural, technological and economic forces as it moves forward in our civilization. The architecture of the past rebalance point will not be the same architecture as the coming rebalance point. As architects we have declared our intention to shape the complete built environment. For architects to carry through with that intent, architecture of the future must be part of the new environmental discourse. The scale of the global anthropogenic change caused by the built environment has been assessed and architects who shape our built environment must re-evaluate where we build, what we build and how we build. The underpinnings of the present architectural concepts that are used to determine the where, what and how are embedded in concepts of unlimited growth. The emerging architectural concepts grounded in the new environmental discourse will be embedded in concepts of sustainability. The contribution of this thesis to the architecture of urban housing is such a concept. It is an emerging concept coalescing around the environmental discourse with the forming of new underpinnings being created and supported by that discourse. The concept starts with an assumption: from our new global awareness that we need to transition towards sustainability, the architecture of urban housing for 2020 should promote possibilities through choice that enable preferred strategies for sustainability to occur.

Disentangled, open-building system concepts enable various sustainability strategies to be implemented at various scales for a variety of building types. In terms of urban housing, a quality urban context must be coupled with disentangled open-building system design maximizes those strategies. By achieving higher densities while providing the benefits linked to the single-family dwelling, a rebalanced socio-cultural view would support urban housing as a choice. It would

underpin real changes in the daily life of the urban population that will move the Triple Bottom Line rebalance point towards sustainability. While it is important to realize some short-term gains in moving towards sustainability by constructing buildings with sustainability guidelines, in the long term, it is changes in daily life that are needed. An urban environment that enables sustainability as a lifestyle can create a large positive impact on our society. By providing a density for urban housing in an architectural form that delivers the desirable qualities of housing defined by our culture, one has created a scenario of locational efficiencies that enable a more sustainable lifestyle. It is not just higher housing density per se that will deliver sustainable advantages; it is this change in the networked efficiencies of an urban lifestyle that will make the largest change in the ecological footprint of our urbanized society.

The residential building type that has been the focus of this thesis has demonstrated a way to extend the service life of buildings to prevent wasted resources. Energy flows must be better managed to lower operating costs to occupants and ecological costs to society. The average service life of the modern suburban detached single-family dwelling is relatively short with a major remodeling often undertaken before 20 years of service life. Mid and highrise urban dwellings have a more substantial structure and longer service life but major renovations are often undertaken before 45 years of service life. In most cases, buildings with a rigid, single purpose design become functionally obsolete well before the end of their potential service life. They must be capable of adaptive re-use and change over time with some building systems changing at different rates than others systems in the building. By employing disentangled open-building system construction technologies, a new re-balance point in housing can be achieved where 100 years (plus) service life of some core components of buildings is the reality.

Mainly because of the ecological rucksack attached to the car and locational efficiencies achieved with density, an urban lifestyle is more sustainable than a suburban lifestyle. As waste and inefficiencies simply become too expensive (economically, environmentally, and socially), the small, incremental increase in construction cost to de-couple systems to simplify renovation work will be viewed as an incidental cost for the construction of durable buildings with a long service life capable of constant adaptive re-use.



There are, however, numerous roadblocks to the implementation of projects as proposed:

When one acquires a detached house on a piece of land, the land will always be there. If a constructed 'supporting armature' is to replace this land, that same sense of permanence must be achieved. Although the original structure can easily be design for an expected 100 year life span, it still lacks the permanence of a piece of dirt. The collectively held ownership of the support armature will need to be institutionalized in our society with new forms of 'trusts in perpetuity' and new financing methods to support those 'in perpetuity' trusts.

Building construction codes will need to be modified to require the same level of fire protection and life safety in a detached house on a piece of land as a detached house on 'constructed land'. This would imply the use of wood frame in the 'infill' of a six story building, something that is not allowed now.

The whole question of zoning and setbacks will need re-evaluation. The 'Front Yard' of a detached house does not make sense when there is no 'vehicular street' to relate to. Zoning and setbacks will still be needed in the 'constructed land' of the supporting armature but the lack of street and driveway radically changes the parameters.

There is no reason that all of these roadblocks, and any others, can not be overcome. When condominiums first appeared, they were initially mistrusted by the public. Governments eventually came up with needed regulations in zoning, building codes, financing and shared ownership funding to support this departure from the 'fee simple' ownership of the detached house. A transition involves change and change in housing is often resisted. The transition will more likely occur if the benefits of change outweigh the inertia of the status quo. In this case, the status quo is simply becoming untenable. A change in urban housing will occur and architects do have a role in presenting viable housing choices that are part of the larger transition towards sustainability. An architecture can be developed with core concepts that support the preferred scenarios that would move urban housing towards sustainability at the re-balance point of 2020.

## References

- Archigram 1, 2008 reprint from MuralMania\_archiblog, accessed December 8, 2008  
<<http://muma.freeblog.hu/tags/news/>>
- Archigram 2, 2008 reprint from Design Museum London, accessed December 8, 2008  
<[http://www.designmuseum.org/\\_\\_entry/4511?style=design\\_image\\_popup](http://www.designmuseum.org/__entry/4511?style=design_image_popup)>
- Architecture2030, 2008 source for pie chart in Fig.1: US Energy Information Administration  
<[http://www.architecture2030.org/current\\_situation/building\\_sector.html](http://www.architecture2030.org/current_situation/building_sector.html)>, accessed October 3, 2008
- Architecture2030 projections based on data obtained from 2030 Challenge website,  
<[http://www.architecture2030.org/current\\_situation/hist\\_opportunity.html](http://www.architecture2030.org/current_situation/hist_opportunity.html)> accessed October 4, 2008
- Architecture 2030, The Building Sector: a Hidden Culprit  
<<http://www.architecture2030.org/home.html>> accessed October 3, 2008
- Athena Institute, 2008 website for access to EcoCalculator software  
<<http://www.athenasmi.org/index.html>> accessed November 10 2008
- BedZed, 2008 reprint of solar access diagram from Green Bim Network Blog, accessed October 20, 2008  
<<http://greenbimnetwork.blogspot.com/2008/06/forum-first-pass-chicken-or-egg.html>>
- Bemis, Alfred Farwell and John Ely Bourchard. 1936 *The Evolving House* :Cambridge, Mass. ;Technology Press, Massachusetts Institute of Technology.
- Bosma, Koos, Dorine van Hoogstraten, and Martijn Vos. 2000 *Housing for the Millions : John Habraken and the SAR (1960-2000)*. Rotterdam : New York, NY: NAI Publishers ; DAP/Distributed Art Publishers [distributor].
- Brand, Stewart. 1994 *How Buildings Learn : What Happens After they'Re Built*. New York, NY: Viking.
- Bray, Jeremy and Natasha McCurry, 2006 “Unidentified Consequences: How the Use of LEED can Inadvertently Fail to Benefit the Environment”, *Journal of Green Building* : volume 1 number 4 FALL 2006
- Brown, David J. (David Joseph) and Steven Badanes. 2004 *HOME House Project : The Future of Affordable Housing*. 1st MIT Press ed ed. Winston Salem : Cambridge, MA: Southeastern Center for Contemporary Art ; MIT Press.

- Brown University Center for Environmental Studies, 2003 “Enhancing Rhode Island’s Urban and Suburban Forests”, economic benefits, accessed December 8, 2008  
<<http://envstudies.brown.edu/oldsite/Web/special%20reports/Classes/ES201/2003/Forestry/index.htm>>
- Bruntland Report, 1987 full text of the Brundtland Report, hosted by the Center for a World in Balance, can be downloaded as a scanned copy of the UN General Assembly document A/42/427 <http://www.worldinbalance.net/PDF/1987-Bruntland.PDF>, accessed October 4, 2008
- Church St. Burlington VT, 2008 reprint of photo, accessed June 21, 2007,  
<<http://churchstmarketplace.com/gallery/marketplace-life.html>>
- CIFE, 2008 Center for Integrated Facility Engineering, University of Stanford,  
<<http://cife.stanford.edu/Publications/index.html>> accessed October 3 2008
- Crosbie, Michael J. 2003 *Multi-Family Housing : The Art of Sharing*. Mulgrave, Vic. : Woodbridge: Images ; ACC Distribution.
- Davies, Colin. 2005 *Prefabricated Home*. London: Reaktion Books.
- Diamond, Jared M., 2005 *Collapse : How Societies Choose to Fail Or Succeed*. New York: Viking.
- Diamond, Jared M., 1992 *The Third Chimpanzee: The Evolution and Future of the Human Animal* New York, HarperCollins.
- Dubois, Rene 1965 *Man Adapting*, New Haven: Yale University Press, pg 7
- EIA, 2008 “World Total Energy Consumption by Region”, reference Case, 1990-2030 (Quadrillion BTU), accessed October 27, 2008, <[http://www.eia.doe.gov/oiaf/ieo/pdf/ieoreftab\\_1.pdf](http://www.eia.doe.gov/oiaf/ieo/pdf/ieoreftab_1.pdf)>
- Elkington, John. 1998 *Cannibals with Forks: The Triple Bottom Line of 21st Century Business* Gabriola Island, BC ; Stony Creek, CT : New Society Publishers.
- Foot, David K. and Daniel Stoffman 1998. *Boom, Bust & Echo 2000 : Profiting from the Demographic Shift in the New Millennium*. [Rev. ed.], fully expanded, updated, and illustrated millennium ed ed. Toronto: Macfarlane Walter & Ross.
- Fowler KM, and EM Rauch, 2006 *Sustainable Building Rating Systems Summary*. PNNL-15858, Pacific Northwest National Laboratory, Richland, WA. 2006 < <http://www.pnl.gov/>> accessed October 6, 2008
- Gans, Elizabeth 2006 *The Le Corbusier Guide*. Princeton Architectural Press, New York NY.
- Gladwell, Malcolm. 2002 *Tipping Point : How Little Things can make a Big Difference*. 1st Back Bay pbk. ed ed. Boston: Little, Brown.
- GreaterToronto.org 2008 projection from website  
<[http://www.greatertoronto.org/investing\\_demo\\_03.htm#1](http://www.greatertoronto.org/investing_demo_03.htm#1)>, accessed October 3, 2008

- Habraken, N. J. 1976 *Variations : The Systematic Design of Supports*. Cambridge, Mass.: Laboratory of Architecture and Planning at MIT.
- Habraken, N. J. 1972. *Supports : An Alternative to Mass Housing*. London: Architectural Press.
- Habraken, N. J. and Jonathan Teicher. 2005 *Palladio's Children*. London ; New York: Taylor & Francis.
- Habraken, N. J. 1998 *Structure of the Ordinary : Form and Control in the Built Environment*. Cambridge, Mass. ; London: MIT Press.
- Harvey, David. 1990 *The Condition of Post Modernity, an Enquiry into the Origins of Cultural Change*. Malden, MA, USA: Blackwell Publishers Ltd.
- Jacobs, Jane. 1961 *The Death and Life of Great American Cities*. New York NY, Random House
- Rittel, Horst, and Melvin Webber; 1973 *Dilemmas in a General Theory of Planning*, Policy Sciences, Vol. 4, pp. 155-169, Elsevier Scientific Publishing Company, Inc., Amsterdam.
- Kahn, Peter 1997 *Developmental Psychology and the Biophilia Hypothesis: Children's Affinity for Nature*. *Developmental Review*, 17, 1-61, 1997 article no. DR960430  
<[http://faculty.washington.edu/pkahn/articles/Developmental Psychology Biophilia Hypothesis.pdf](http://faculty.washington.edu/pkahn/articles/Developmental_Psychology_Biophilia_Hypothesis.pdf) > accessed November 12 2008
- Kasian Kennedy Design Partnership, the. 1995 *Design Smart : Energy-Efficient Architectural Design Strategies*. Burnaby, B.C.: Power Smart, B.C. Hydro.
- Kellert, Stephen R. and Edward O. Wilson. 1993 *Biophilia Hypothesis*. Washington, D.C.: Island Press.
- Kendall, Stephen and Jonathan Teicher. 2000 *Residential Open Building*. London ; New York: E&FN Spon.
- Levitt, Steven D. and Stephen J. Dubner. 2005 *Freakonomics : A Rogue Economist Explores the Hidden Side of Everything*. 1st ed ed. New York: William Morrow.
- Manzini, Ezio and Francois Jegou. 2003 *A Catalogue of Promising Solutions*. Milano, Italy: Edizioni Ambiente srl.
- Manzini, Ezio and Francois Jegou. 2003 . *Sustainable Everyday Scenerios of Urban Life*. Milano, Italy: Edizioni Ambiente srl.
- Mazria, Edward. 1979 *Passive Solar Energy Book : A Complete Guide to Passive Solar Home, Greenhouse and Building Design*. Emmaus, Pa.: Rodale Press.
- McDonough, William and Michael Braungart. 2002 *Cradle to Cradle : Remaking the Way we make Things*. 1st ed ed. New York: North Point Press.
- McLennan, Jason F. and Bob Berkebile. 2004 *Philosophy of Sustainable Design : The Future of Architecture*. Kansas City, Mo.: Ecotone.

- Meadows, Donella H., and Dennis L. Meadows, Jorgen Randers, and William W. Behrens III. 1972 *The Limits to Growth*. New York: Universe Books.
- Mendler, Sandra and William Odell. 2000 *HOK Guidebook to Sustainable Design*. New York: J. Wiley.
- MoMa, 2008 reprinted from MoMA website, accessed October 20, 2008  
<[http://www.moma.org/collection/printable\\_view.php?object\\_id=709](http://www.moma.org/collection/printable_view.php?object_id=709)>
- Nieghbourhoods Lab, 2008 Design Centre for Sustainability at UBC  
<[http://www.sxd.sala.ubc.ca/9\\_resources/density/DensityScale\\_NBL.pdf](http://www.sxd.sala.ubc.ca/9_resources/density/DensityScale_NBL.pdf)>  
Accessed October 3 2008
- Pearce, Fred. 2006. Eco-Cities special: Ecopolis now. *New Scientist*, 16 June, magazine issue 2556  
<<http://www.newscientist.com/article/mg19025561.600>> accessed December 13 2008
- PEW Center on Global Climate Change, 2005, Marilyn A. Brown, Frank Southworth, Therese K. Stovall, *Solutions: Towards a Climate Friendly Built Environment*. Oak Ridge National Laboratory  
<<http://www.pewclimate.org/technology-solutions/pubs> > accessed December 10 2008
- Rapoport, Amos. 1969 *House Form and Culture*. Foundations of Cultural Geography Series. Englewood Cliffs, N.J.: Prentice-Hall.
- Roaf, Susan, Manuel Fuentes, and Stephanie Thomas. 2003 *Ecohouse 2 : A Design Guide*. 2nd ed ed. Oxford: Architectural Press.
- Safdie, Moshe and Wendy Kohn. 1997 *City After the Automobile : An Architect's Vision*. Toronto: Stoddart.
- Schittich, Christian. 2004a *High-Density Housing : Concepts, Planning, Construction*. In Detail. MuLncen : Basel ; Boston, Mass.: Edition Detail ; BirkhaLuser. reprint of Fig. 2.9
- Schittich, Christian. 2004b *High-Density Housing : Concepts, Planning, Construction*. In Detail. MuLncen : Basel ; Boston, Mass.: Edition Detail ; BirkhaLuser. reprint of Fig. 2.15
- Schoenauer, Norbert. 2000 *6,000 Years of Housing*. Rev. and expanded ed ed. New York ; London: W.W. Norton.
- Schmidt-Bleek, Frederick. 1993 *The Fossil Makers* : Translation by Reuben Deumling, Berkeley, USA of the book *Wieviel Umwelt Braucht Der Mensch – MIPS Das Mass Für Ökologisches Wirtschaften*, 1993, <<http://www.factor10-institute.org/publications.html> > accessed December 7, 2008
- Schmidt-Bleek, Frederick. “The Factor Ten/MIPS-Concept: bridging ecological, economic, and social dimensions with sustainability indicators” <<http://www.factor10-institute.org/publications.html> > accessed December 7, 2008

- Solar Tracking Inc., 2008 reprint of picture from company website, accessed Feb. 3, 2008, <<http://www.solar-track.com/gallery.html>>
- State Museum of Pennsylvania, 2003 <<http://server1.fandm.edu/levittown/>> accessed November 10 2008
- Statistics Canada, 2006 Data <<http://www12.statcan.ca/english/census06/data/>> accessed October 20, 2008
- Straube, John 2008 personal communication - paraphrased from posted comment by Dr. John Straube on Thesis blog, accessed October 4, 2008, <<http://jim70027520.blogspot.com/>>
- Tertzakian, Peter. 2006 *Thousand Barrels a Second : The Coming Oil Break Point and the Challenges Facing an Energy Dependent World*. New York: McGraw-Hill.
- Toronto.ca 2008 A Brief History of Toronto, accessed October 20, 2008, <<http://www.toronto.ca/culture/history/history-1951-onward.htm>>
- Tridel Development, 2008 rendering and floor plan of for sale condo, accessed October 23, 2008, <<http://www.tridel.com/jamescoopermansion/>>
- TTC, 2008 transit route planning map, accessed October 20, 2008, <[http://www.toronto.ca/ttc/pdf/building\\_a\\_transit\\_city.pdf](http://www.toronto.ca/ttc/pdf/building_a_transit_city.pdf)>
- US Department of Commerce, 1982 *Techniques of Prediction as Applied to Production of Oil and Gas*, NBS Special Publication 631, May 1982
- Vanity Fair, Special Green Issue, May 2006, Conde Nast Publications, 4 Times Square New York, NY
- Wachsmann, Konrad. 1995 *Building the Wooden House: Technique and Design* :Basel; Boston Birkhauser.
- Walker, L. and W. Rees. 1997 “Urban density and ecological footprints: an analysis of Canadian Households”. *Eco-City Dimensions: Healthy Communities, Healthy Planet*. Mark Roseland (ed.): New Societies Publishers, Gabriola Island, BC, Canada.
- Weizsäcker, Ernst U. von (Ernst Ulrich), Amory B. Lovins, and L. Hunter Lovins. 1997 *Factor Four : Doubling Wealth, Halving Resource use : The New Report to the Club of Rome*. London: Earthscan Publications LTD.

Williamson, T. J. (Terry J. ), Antony Radford, and Helen Bennetts. 2003 *Understanding Sustainable Architecture*. London ; New York: Spon Press.

Wilson, Edward O. 1984 *Biophilia*. Cambridge, Mass.: Harvard University Press.

Wines, James and Philip Jodidio. 2000 *Green Architecture*. KoLln ; New York: Taschen.

World Business Council for Sustainable Development, 1992

<http://www.wbcsd.org/templates/TemplateWBCSD5/layout.asp?MenuID=1> accessed November 10 2008

Yeang, Ken. 2000 *Service Cores*. Detail in Building. Chichester [England]: Wiley-Academy.

## Appendix A - basic site data

This appendix is a compilation of excerpts from a final report prepared for the graduate course in the winter term of 2007 designated as Arch 623—Ecosystem Design for Urban Landscapes. The course was directed by Professor Val Rynimiri of the University of Waterloo School of Architecture at Cambridge. The original report has been augmented with printouts from analysis software called The Weather Tool and The Solar Tool by Ecotect ver5.50 written by Dr. A. J. Marsh.

Since the construction of habitation is directly linked to the need to mediate the environment, climatic determinism has been regarded as the foundation of vernacular architecture, where vernacular architecture is viewed as the prototypical sustainable habitation form. However, habitation patterns are manifestations of many complex, interactive factors where climate may determine what can not be built (an igloo can only be built with snow) more than what will be built. Sustainable habitation can be viewed as biosphere determinism if one broadens the definition of biosphere to include the abiotic, biotic and anthropogenic elements.

Sustainable building design strives to be embedded in the biosphere without disrupting the balance of interconnected self-sustaining systems that have evolved in nature over time. The building of habitation is a localized anthropogenic event in the biosphere and that makes sustainable building design a localized, site specific, activity. For this specific project, the context of that biosphere at the specific urban site can be understood by examining the following parameters:

*Abiotic*

*climate*

*solar access*  
*wind*  
*precipitation*

*geomorphology*

*landforms*  
*waterflows*

*Biotic*

*urban biota*

*micro-climates*  
*urban forestry*

*Anthropogenic*

*historical context*

*habitation history*  
*historical markers*

*urban context*

*streetscape*



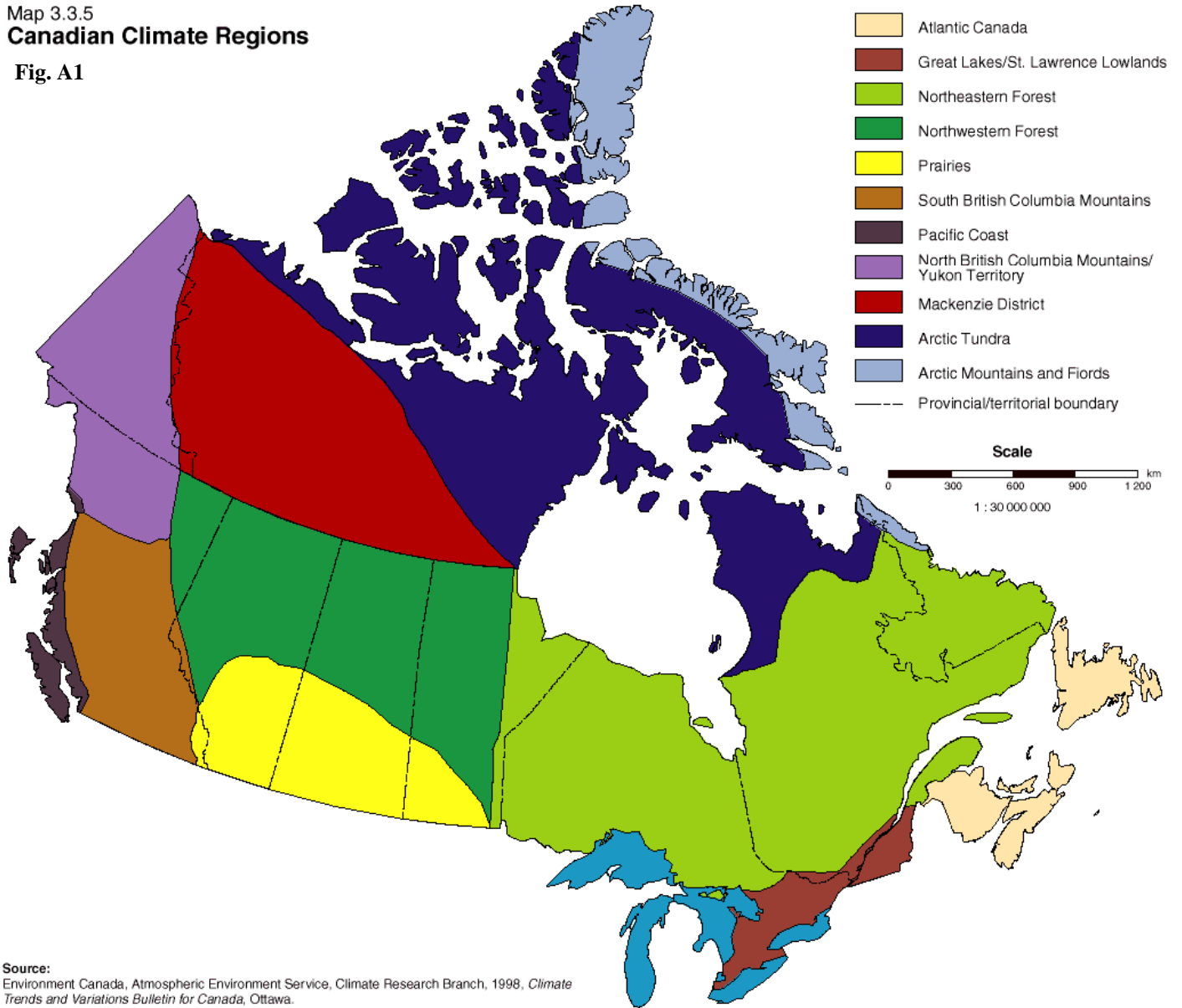
# Climate:

The project site is located in the climate region designated the Great Lakes/St. Lawrence Lowlands climate region of Canada (see Fig. A1). It is a cold dominant climate where temperatures are generally below the comfort band for human occupancy (see Fig. A2).

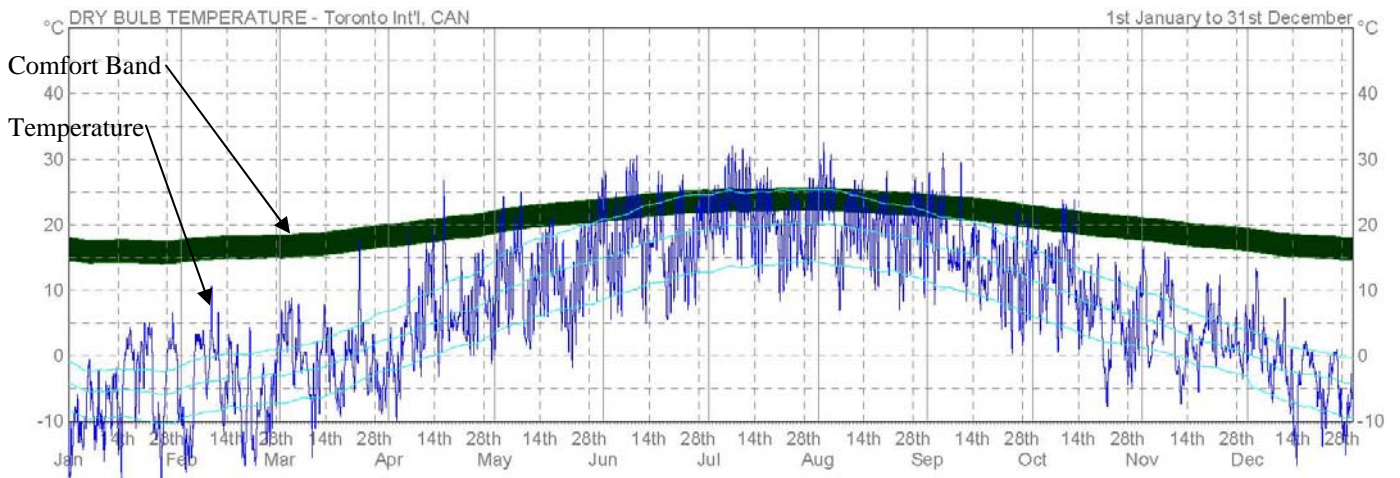
Map 3.3.5

## Canadian Climate Regions

Fig. A1



Source: Environment Canada, Atmospheric Environment Service, Climate Research Branch, 1998, *Climate Trends and Variations Bulletin for Canada*, Ottawa.



# Precipitation:

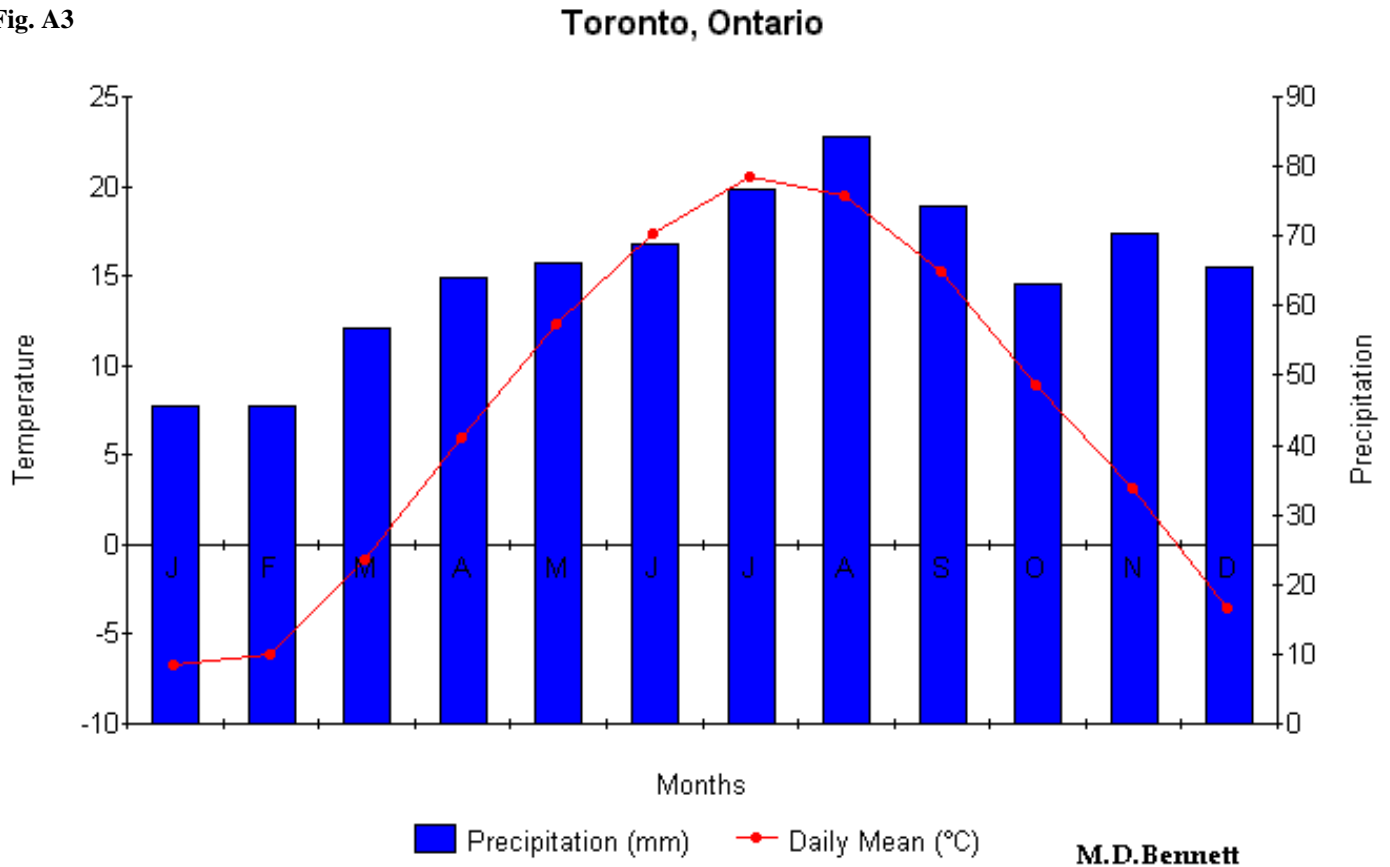
Precipitation has two prominent roles in sustainable housing:

A—a resource of fresh water which can be harvested

B—an agent of deterioration that shortens the useful service life of valuable resources put into service.

Temperature, in conjunction with moisture, also is a prominent factor in building deterioration since the climate zone of the study area has temperatures falling below the freezing point of water. Sustainable housing for this climate requires strategies to address water droplet intrusion, water vapor pressures, freeze-thaw cycling and large temperature swings. Fig. A3 illustrates the quantity of precipitation as charted against temperature.

Fig. A3



# Wind:

Wind can have four dominant roles in housing:

- A—a renewable force that can be converted to electrical energy with the use of wind turbines
- B—a source of natural cooling and ventilation to maintain occupant comfort
- C—a driving force for water and vapor intrusion into built assemblies and spaces
- D—a laterally applied force that must be resisted by the building structure

Prevailing wind direction can inform housing shape and fenestration to implement strategies for natural cooling and ventilation while wind speed can inform structural strategies. Fig. A4 graphically depicts the wind characteristics for the site.

Wind as a renewable resource for generating electrical power has limited application in an urban setting due to the current state of the technology. Of greater importance is recognizing wind as a sustainable ventilation strategy that will enlarge the comfort zone for human occupation thereby reducing the use of energy to maintain a comfort zone. This would directly relate to reductions in energy usage to maintain a comfortable interior environment. Prevailing winds are also a significant parameter for establishing micro-climates and reducing heat losses associated with 'wind washing' effects.

## Prevailing Winds

### Wind Frequency (Hrs)

Location: Toronto Int'l, CAN (43.7°, -79.6°)

Date: 1st January - 31st December

Time: 00:00 - 24:00

© Weather Tool

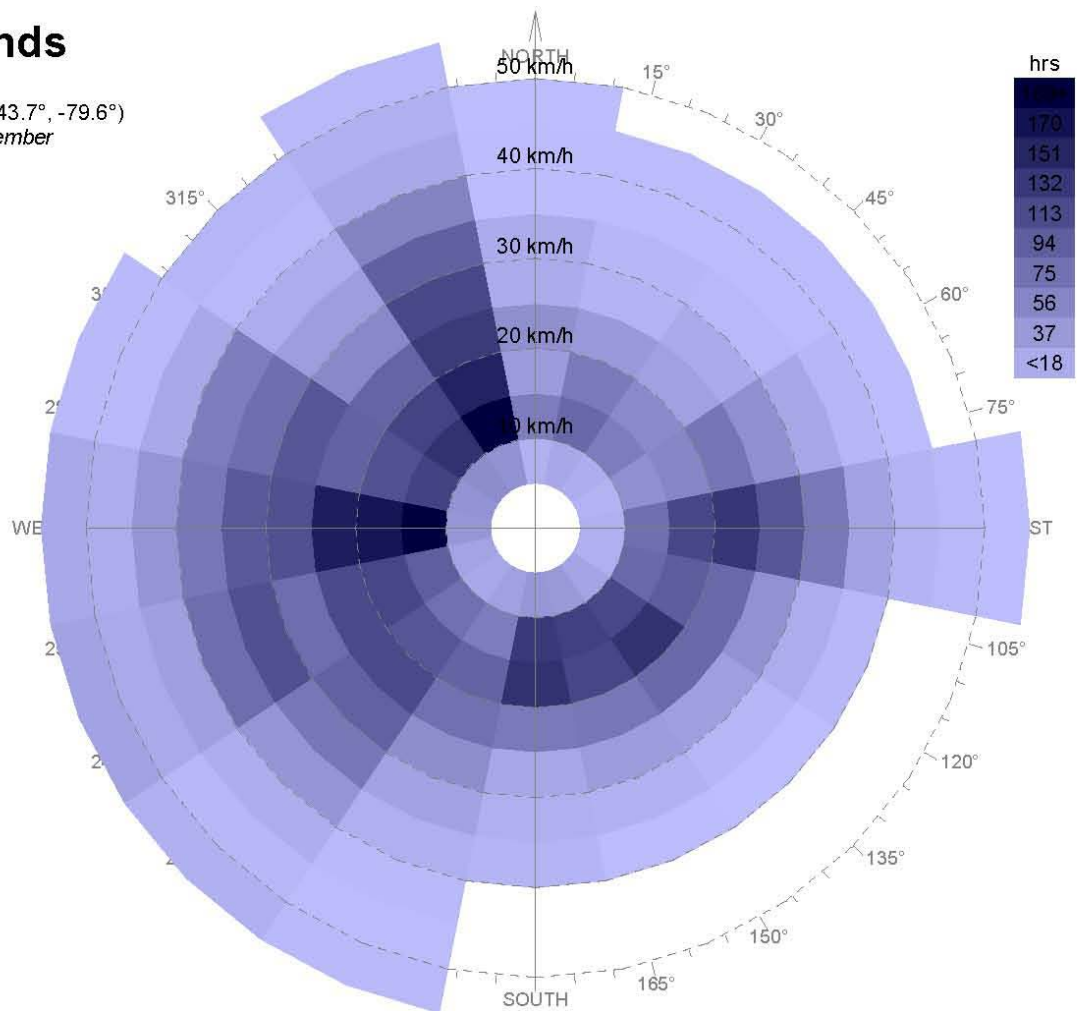


Fig. A4

# Solar Access:

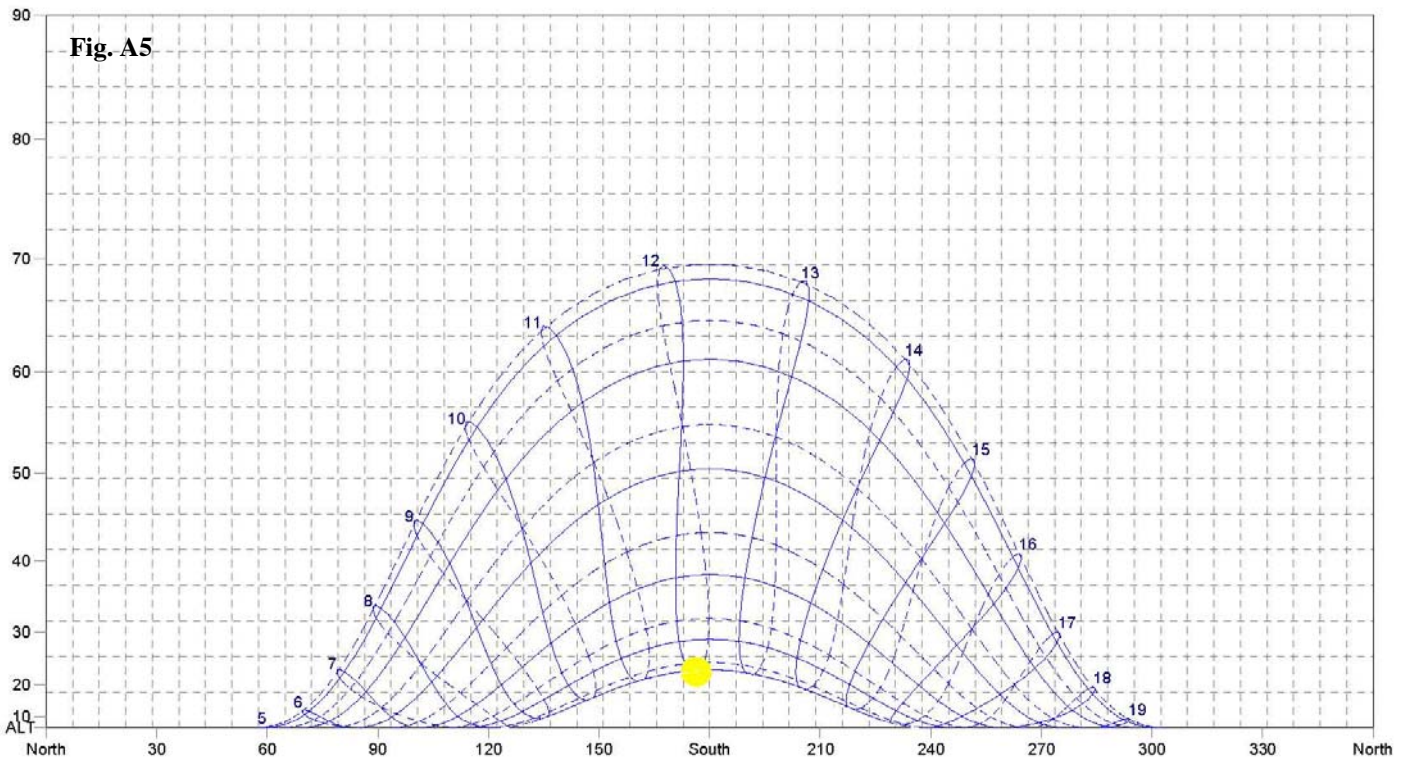
Solar radiation as renewable energy is the basic strategy that informs sustainable housing. A thorough understanding of direction and quantity (Fig. A5, A6, and A7) is a first order determinant for shape and orientation.

## Waldram Diagram

Location: 43.6°, -79.3°  
Sun Position: 176.4°, 22.8°

BRE VSC: 14.4%  
Overcast Sky: 11.4%  
Uniform Sky: 16.4%

Date/Time: 12:00, 21st Dec  
Percentage Shading: [Behind]  
HSA: 176.4°, VSA: 157.1°



## Waldram Diagram

Location: 43.6°, -79.3°  
Sun Position: 168.0°, 69.5°

BRE VSC: 14.4%  
Overcast Sky: 11.4%  
Uniform Sky: 16.4%

Date/Time: 12:00, 21st Jun  
Percentage Shading: [Behind]  
HSA: 168.0°, VSA: 110.1°

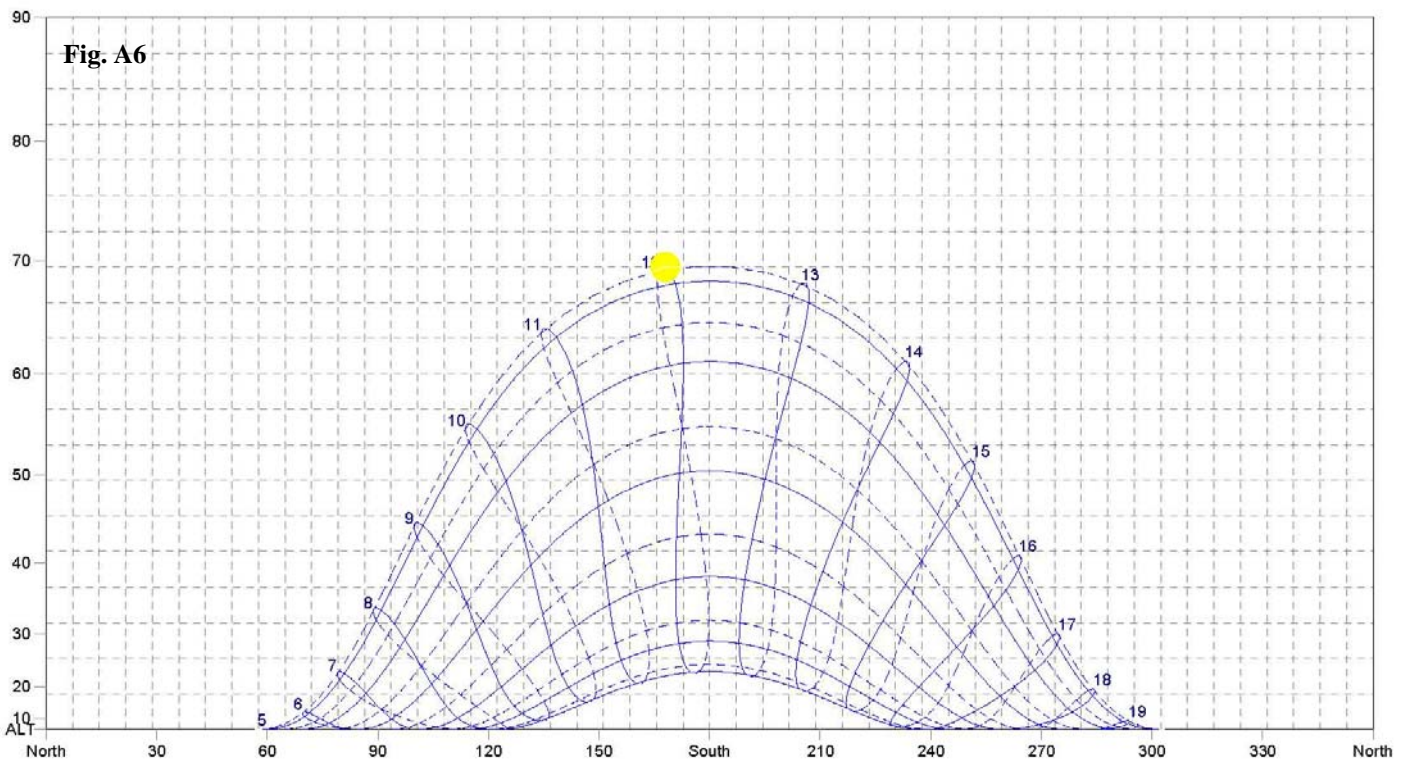
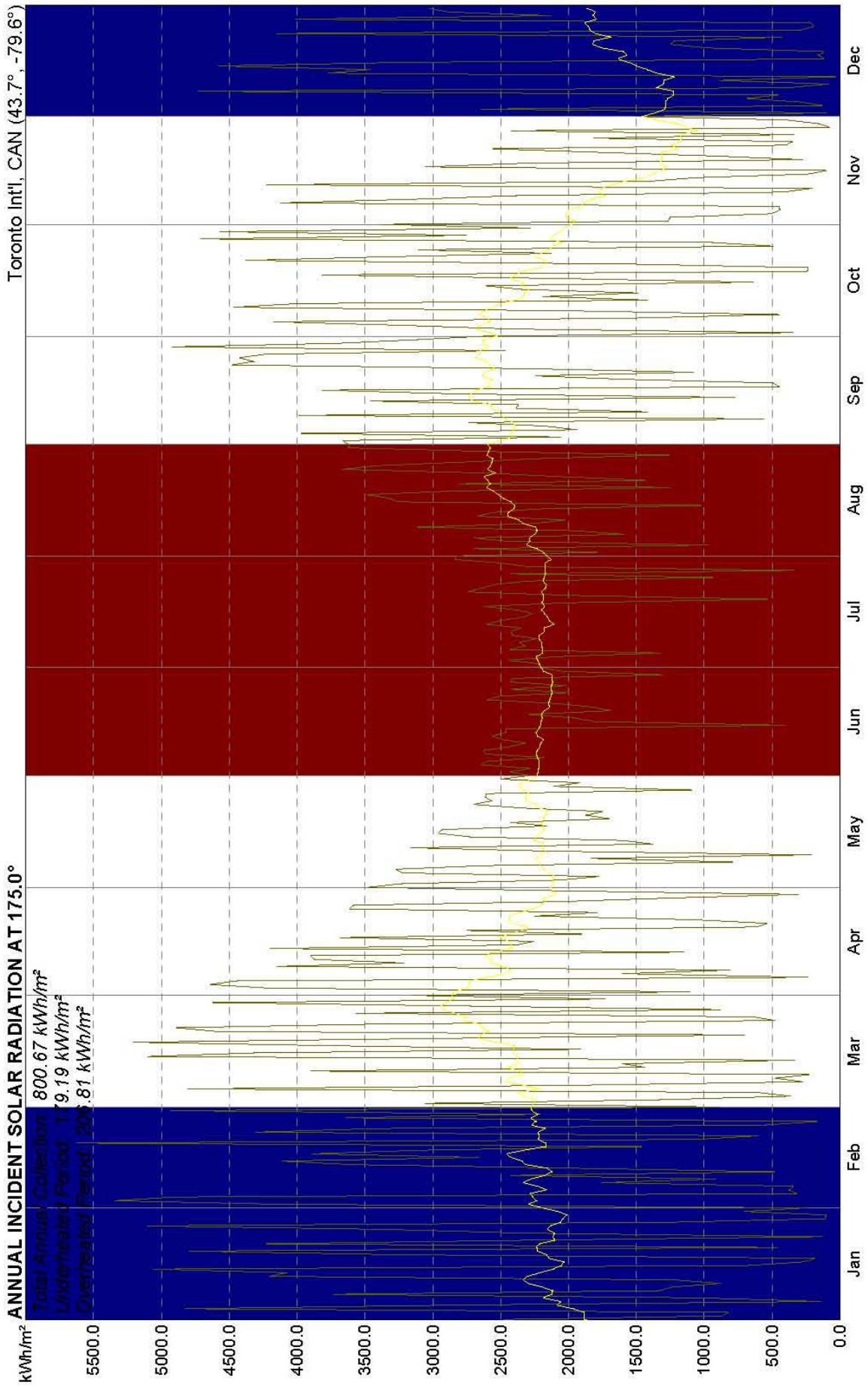
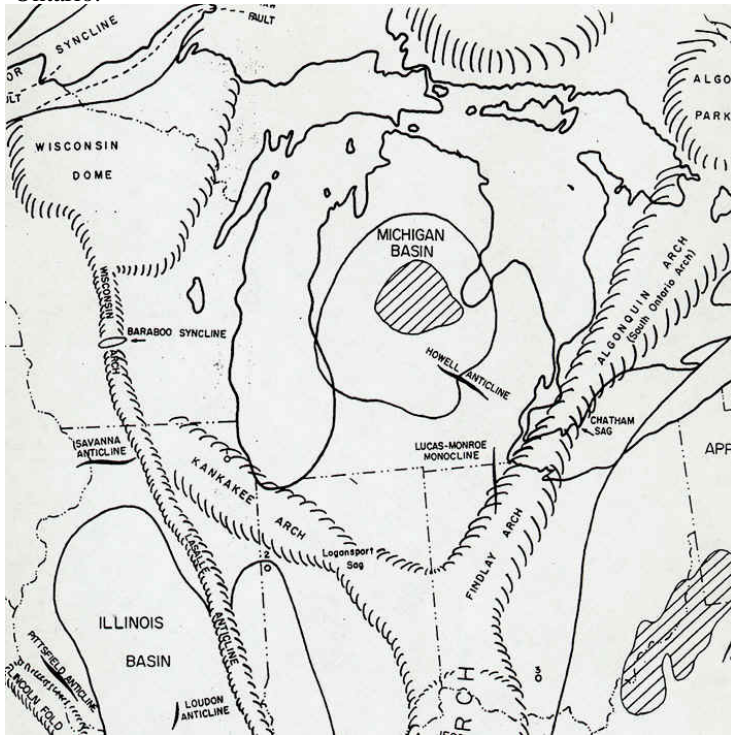


Fig. A7



# Geomorphology and Landform:

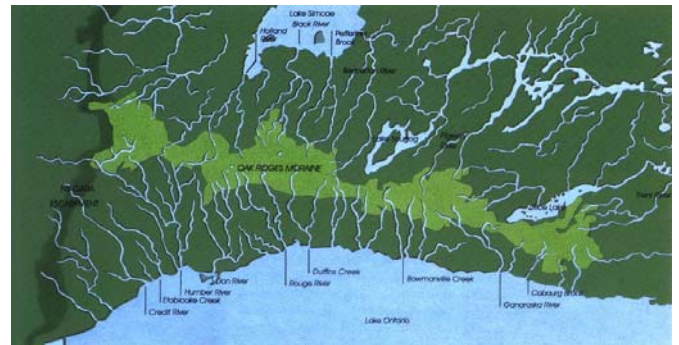
The physical landform of the study area took shape during the last ice age resulting in two large prominent land features: the Niagara Escarpment and the Oak Ridge Moraine. The Niagara Escarpment is part of large land formation known as a cuesta (see Fig. A8) that extends around Lake Michigan, Erie, Ontario and Huron. The Oak Ridge Moraine is a glacial deposit ridge formed by the deposits of two lobes of receding glaciers during the last ice age (see Fig. A9 and A10)). This large moraine formation contains aquifers and recharge areas that form the headwaters of the rivers and streams that flow south through the study site to Lake Ontario.



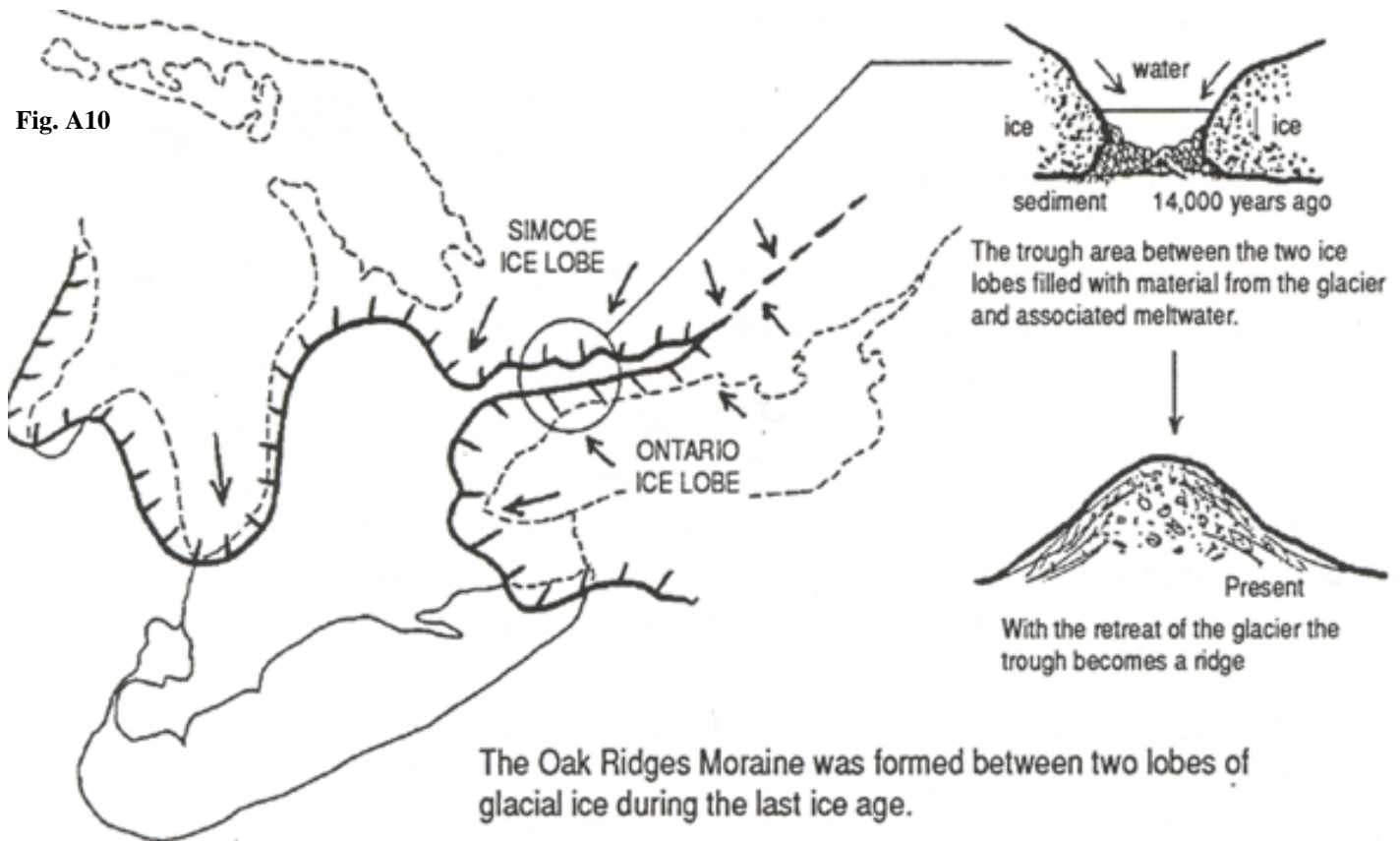
**Fig. A8**

Although the large scale natural geomorphology is evident, the site has been modified by anthropogenic effects. The changes are due to purposeful human activities consisting of grade modifications and drainage course containment as part of the process of urban habitation.

**Fig. A9**



**Fig. A10**



## Waterflows:

The study region has a series of rivers and creeks that have shaped the development of the region historically. As the urban fabric grew over time, numerous smaller creeks have been absorbed by the urban fabric and are no longer open or visible watercourses. The larger rivers are still maintained as green corridors and open waterways simply due to their scale but even some of them like the Don River have now been lined as part of the urbanization of the region. The site was once part of the Garrison Creek watershed with Asylum Stream running along its southern border. (see Fig. A11, A12 and A13).

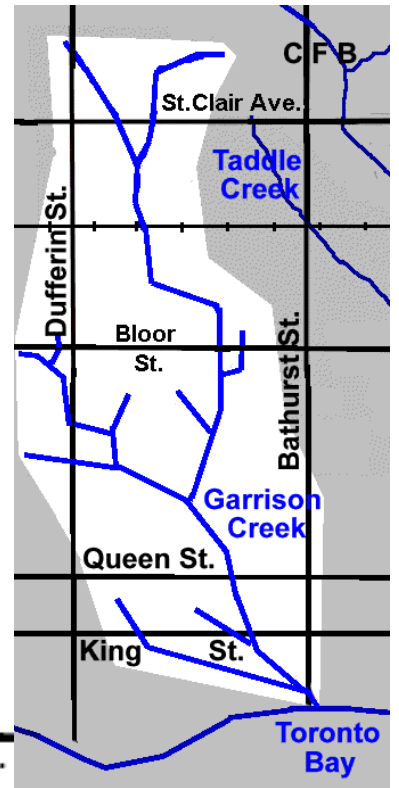
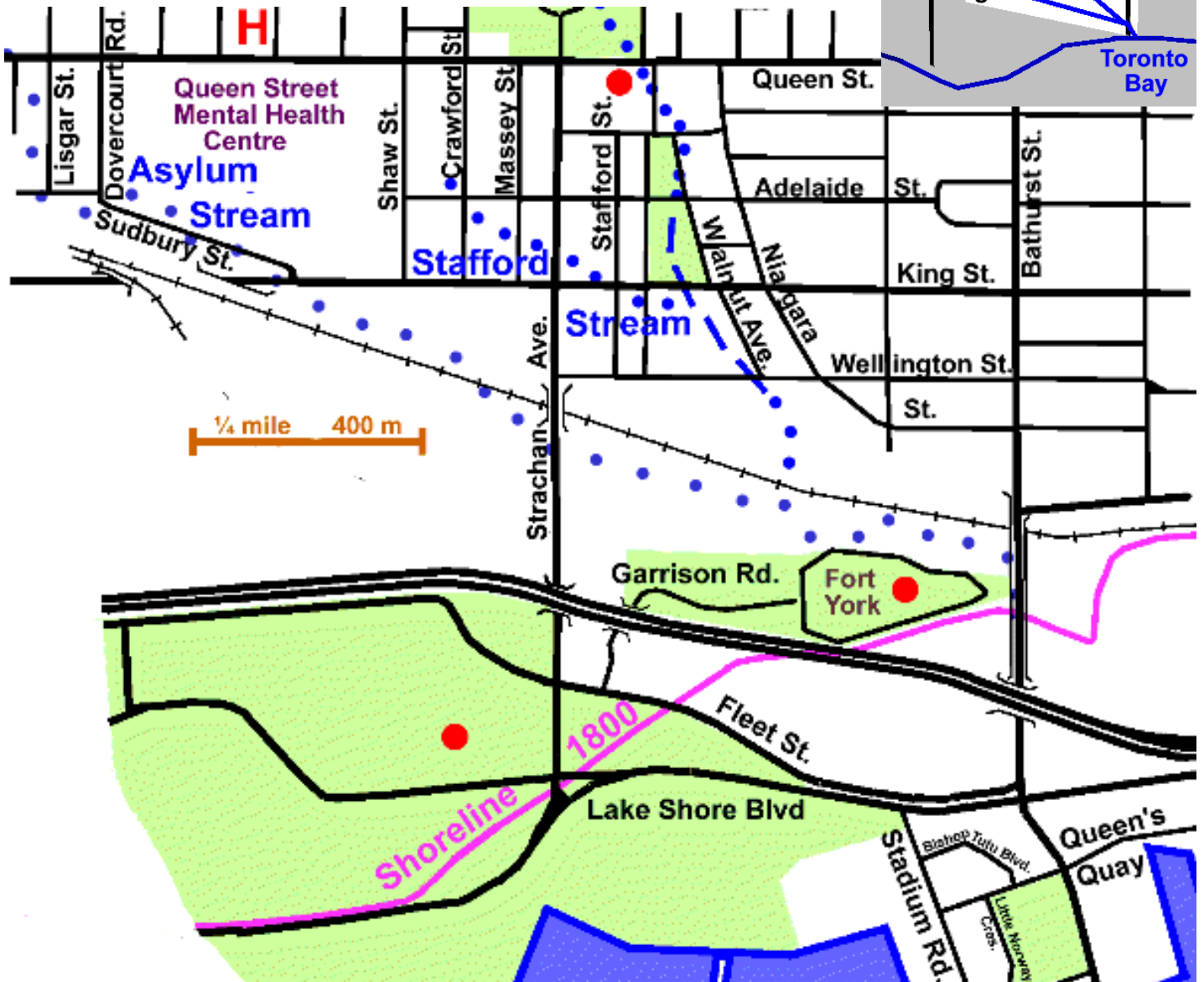
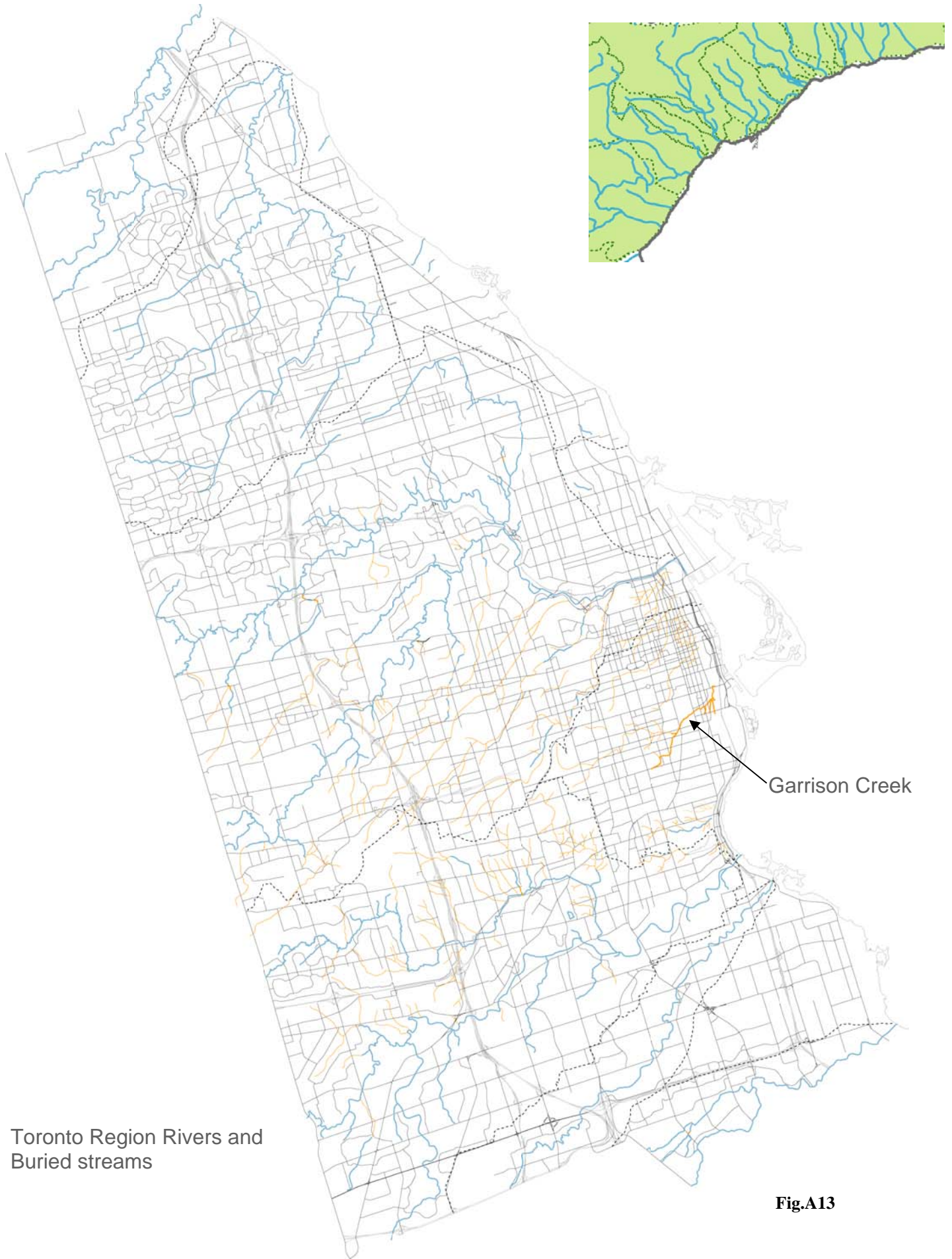


Fig. A11

Fig. A12





Toronto Region Rivers and Buried streams

Fig.A13



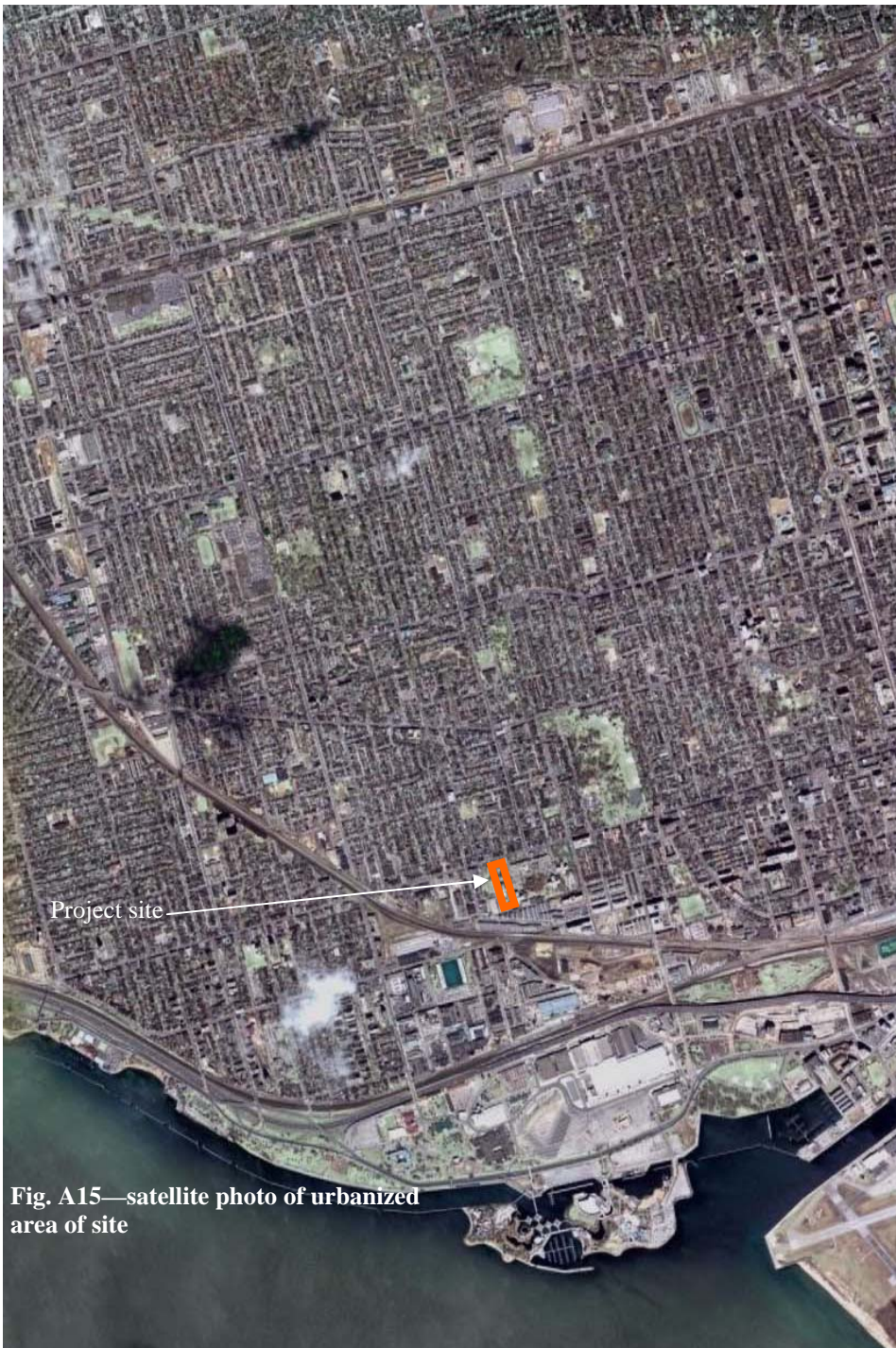


Fig. A15—satellite photo of urbanized area of site

## Micro-climate:

The current urban environment creates the ‘Heat Island’ effect. It is the result of the uncontrolled storage of thermal energy in concrete, steel and asphalt raising temperatures above the surrounding rural areas where biota absorb and use (thereby dissipate) solar radiation (see Fig. A14)

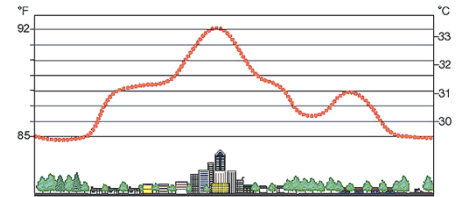


Fig. A14—relationship of temperature to land use

## Urban Forestry:

The dominant land cover of the study region is urban development which has displaced open croplands which had displaced mixed hardwood forests.

A 2003 study by the Dept. of Urban Forestry assessed Toronto’s tree canopy coverage at approximately 17.5%. To maintain a healthy urban forest, coverage of 30-40% is recommended by the Toronto Dept. of Urban Forestry (<http://www.toronto.ca/trees/pdfs/UFORE.pdf> accessed Nov.27, 2008).

UFORE is an acronym for "Urban Forest Effects" and refers to a computer model that calculates the structure, environmental effects and values of urban forests. The software analysis confirms the large contribution of urban forestry to carbon sequestration and removal of air pollutants (see Fig. A16 and A17)

Estimated Pollution Removal in Toronto

Fig. A17

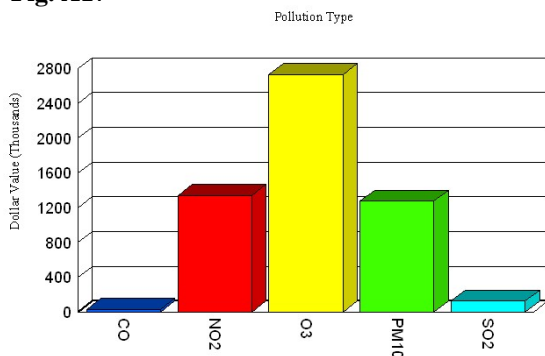


Fig. A16

Total C Storage (metric tons) and Net C Sequestration (metric tons/year) by Land Use

Landuse	CarbonStorage	NetSequestration
Commercial	102	2
Industrial	7,670	757
Institutional	52,939	236
Open Area	352,724	8,040
Residential Hi	69,250	2,313
Residential Low	148,413	7,331
Residential Med	243,875	9,076
Special Purpose	25,334	587
<b>Total</b>	<b>900,307.00</b>	<b>28,342.00</b>

## Habitation History:

The region now known as the GTA started its urban development in 1793 as a military town by Lord Simcoe. He named it York and it was established as a more defensible provincial capital than Niagara on the Lake. As a provincial capital, it attracted province wide institutions such as banks and schools. In the 1840's land was set aside on Queen West for a provincial asylum and in 1850, at the project site, the Provincial Lunatic Asylum was opened (see Fig. A18 and A19).

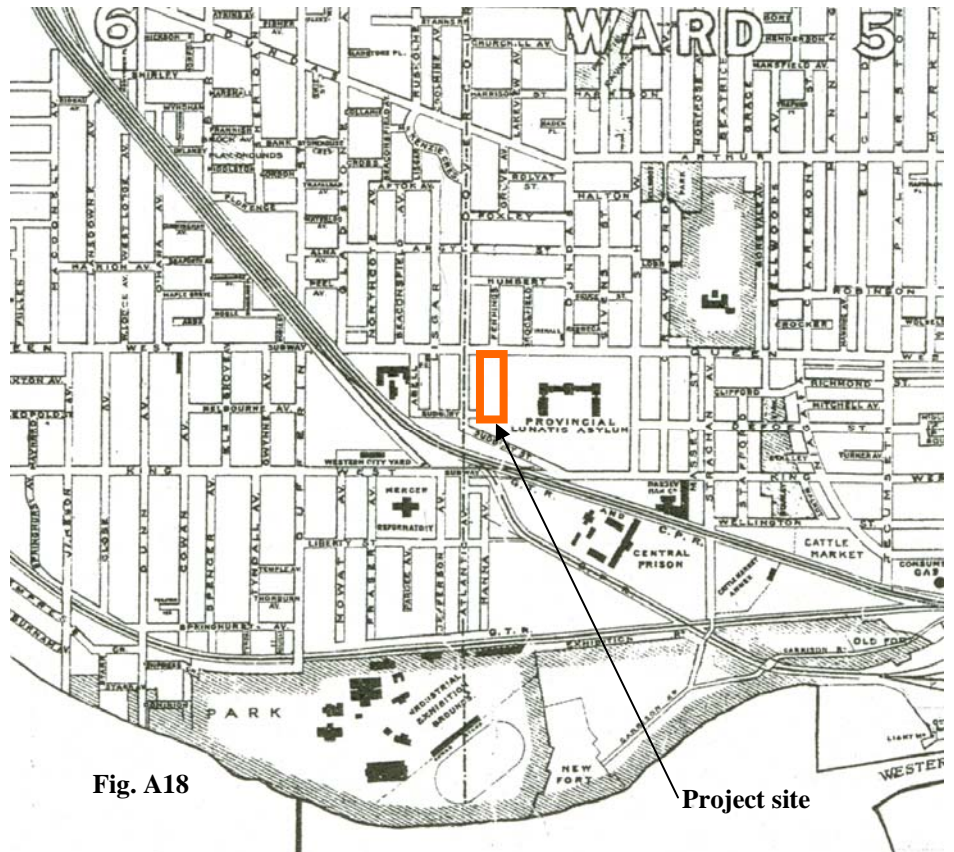


Fig. A19

Fig. A18

Project site



Fig. A20

## Historical Markers:

As urban fabrics evolve, linkages to the past become longlived anchorpoints that have been labeled 'permanence's' in urban design and often are cultural bridges to the past. Sections of the original asylum walls still stand to connect the present with the past (see Fig. A20).

## Streetscape:

The character of urban streetscapes is shaped by transportation patterns and modes, building facades, street and sidewalk widths, urban forestry and activities. It is defined by property lines defining boundaries between private and public on the ground plane. These property lines have a persistence, a permanence, through time that other elements of the urban fabric weave through. As the urban fabric intensifies in density, the streetscape becomes more dynamic and integrated into an urban lifestyle of proximity and immediacy. It is the attraction of a diverse urban streetscape that can anchor urban housing as a choice over the insular suburban lifestyle.

The dominant urban streetscape of the project site is Queen Street West. It is a high traffic based retail commercial street with one or two story retail storefront facades with low end residential above (see Fig. A21 to A25).



**Fig. A21**

**Fig. A21—The streetscape is diverse and lively but, in general, in disrepair. Urban forestry is limited and pedestrian amenities are absent.**

**Fig. A22—Utilities and car traffic dominate.**



**Fig. A22**



**Fig. A23—view of Queen St. West looking east from Ossington St.**



**Fig. A24—View of Ossington St looking north from Queen St.**



**Fig. A25—View along King St. at southern edge of site. Note pedestrians forced to share sidewalk with cars.**

## Appendix B – cost comparison

Assumed selling price \$ 521,900.00

### Analysis of 2145 sqft detached SFD

Construction Cost (note 1)	sqft	\$/sqft	total \$
indoor conditioned space	1785	\$ 139.40	\$ 248,829.00
garage	360	\$ 111.52	\$ 40,147.20
development cost (18% of selling price)			\$ 93,942.00
profit (10% of selling cost)			\$ 52,190.00
residual land value (note 2)			\$ 86,791.80

### Analysis of 1785 sqft SI dwelling unit

slab area of exclusive use to unit (note 3)	1800	\$ 58.33	\$ 104,994.00
slab area shared for common use	360	\$ 58.33	\$ 20,998.80
slab area for parking (1 space)	300	\$ 58.33	\$ 17,499.00
slab area for storage	100	\$ 58.33	\$ 5,833.00
dwelling infil (note 4)	1685	\$ 118.49	\$ 199,655.65
development cost (18% of selling price)			\$ 93,942.00
profit (10% of selling cost)			\$ 52,190.00
residual land value (note 5)			\$ 26,787.55

#### Notes:

1. data for construction cost from Reed Residential Cost Calculator (<http://www.homedesigndirectory.com.au/calculators/ConstructionCostEstimatorPage2.shtml>)
2. the maximum cost the developer could pay for land to net 10% profit
3. The cost data for slab from Hanscomb Yardsticks for Costing 2008 pg 160 for multilevel parking garage, average square foot price. 1800 sqft size of slab was based on 900 sqft of building area (2 stories to net 1685 sqft unit) and 900 sqft area for an urban backyard.
4. The dwelling infil size was reduced by 100 sqft from the comparable SFD unit since the 100 sqft of storage is proposed to be detached from the unit in the underground parking level. The construction cost of the dwelling unit infil was reduced by 15% to account for the lack of a foundation and that the structure only needed to support itself axially.
5. The residual land value for the urban setting, assuming an average of 60 units versus 5 units per acre would be  $12 \times \$26,777.55 = \$321,330.60$  for the same footprint area as the SFD land area.