GETTING SERIOUS ABOUT SUSTAINABILITY: EXPLORING THE POTENTIAL FOR ONE-PLANET LIVING IN VANCOUVER

by

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MA, University of British Columbia, 1994

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

in

The Faculty of Graduate Studies

(Planning)

THE UNIVERSITY OF BRITISH COLUMBIA

(Vancouver)

May 2013

Abstract

One-planet living represents the per capita share of global ecosystem services that each person on Earth could use were humanity to live equitably within ecological carrying capacity. My research uses ecological footprint analysis to explore the potential for the City of Vancouver to achieve one-planet living. Specifically, I examine what reductions in per capita ecological footprint would be necessary, what policies or changes to management practices are available to the City to facilitate those reductions, and what one-planet living might "look like" if those policies and changes to urban management practices were implemented. I use 2006 data to conduct an integrated urban metabolism and ecological footprint assessment for the City in order to establish a baseline from which to estimate the necessary reductions in material and energy consumption. I develop lifestyle archetypes of societies living at a one-planet ecological footprint (both real and hypothetical) to inform estimates on how changes in diet, buildings, consumables and waste, transportation and water could achieve one-planet living in Vancouver. I also draw on examples from the international sustainable cities literature and interviews with City of Vancouver and Metro Vancouver staff and elected representatives to develop policy proposals for reducing Vancouver's ecological footprint. Getting to one-planet living in Vancouver requires at least a 58% reduction in the per capita ecological footprint with the greatest contributions coming from reducing food waste, red meat consumption, and virtually eliminating personal motor vehicle use (shifting instead to an 86% walk, cycle and transit mode share which the City already achieves in its Downtown). The City has and can continue to influence individual and corporate choices through zoning and permitting. However, citizens would have to accept lifestyle changes pertaining to food and personal

consumption to achieve the one-planet living goal. Involvement by senior governments in reducing the ecological footprint is also required. It remains to be seen whether Vancouverites, or any population accustomed to modern consumer lifestyles, will voluntarily accept and implement the changes necessary to achieve equitable sustainability as articulated by one-planet living.

Preface

This research received approval from the Behavioural Research Ethics Board, certificate number: H10-00996. It was supervised by Doctor William Rees with the technical assistance of several of his former and present students in particular: Doctor Meidad Kissinger, Doctor Cornelia Sussmann, Ruth Legg and Walleed Giratalla. The method for developing the ecological footprint used in this research was developed collaboratively with Dr. Meidad Kissinger as described in chapter 3. Specifically, I designed the overall structure of the ecological footprint including the components, sectors and sub-sectors that orient to the way that local governments in Metro Vancouver address demand side management analysis of energy and materials consumption. Doctor Kissinger contributed the data for the food component based on his research of Canada's food footprint (see section 3.2.3.1 in chapter 3). Doctor Kissinger and I developed an aggregated list of food categories that could be used to group the foods assessed by his research, and I then organized the data according to the structure that I developed for the ecological footprint, e.g., materials, embodied energy, operating energy (i.e., food miles) and built area. Professor Maged Senbel provided unpublished schematic drawings that were used by Walleed Giratalla with assistance from Doctor Meidad Kissinger to estimate both the materials and the embodied energy of residential and institutional archetypal buildings (see section 3.2.3.2 in chapter 3). Additional data about the embodied energy of institutional buildings was provided by Robert Sianchuck. I collected all the operating energy data for buildings in Vancouver and estimated the materials and embodied energy within the building stock, based on Giratalla's, Kissinger's, and Sianchuck's estimates for each archetypal building. I also estimated the built area occupied by buildings in the City. Doctor Kissinger developed the lifecycle factors that were used to estimate the embodied energy and materials within consumable goods (see section 3.2.3.3 in chapter 3). Cornelia Sussmann undertook a literature review to collect lifecycle assessment data for the various materials. This provided the data for both the greenhouse gas emissions associated with the manufacturing process of the materials as well as the input data for the lifecycle factors. I collected the data for the City's waste, including its composition, and estimated the proportions of waste distributed to the various waste management facilities within the region. I also estimated the energy used to provide waste management services for both solid and liquid waste, including associated greenhouse gas emissions, as well as landfill gas and biogas recovery and use. I also estimated the total land area occupied by waste management services. Walleed Giratalla estimated the embodied energy within the water and sewer pipes, and I estimated the embodied energy within the Cleveland Dam. Doctor Kissinger estimated the embodied energy in an average mid-size sedan vehicle and Walleed Giratalla estimated the embodied energy in roads (see section 3.2.3.4 in chapter 3). Ruth Legg estimated the fuel consumption and associated greenhouse gas emissions for air travel by the Metro Vancouver population. I oversaw this research including its design. I then extrapolated Vancouver's share of greenhouse gas emissions from air travel. I collected fuel consumption and associated greenhouse gas emissions data for all other forms of transportation. I also estimated all the potential reductions required to get to one-planet living.

The text in this dissertation is original. However, several publications have resulted either as a direct outcome of this research or as a means to further explore issues related to the research methods and/or its findings. These include two co-authored book chapters with my supervisor. The first is: Moore, J., Rees, W.E. 2013. Getting to one planet living, chapter 4 in Linda Starke ed., *State of the World 2013: Is Sustainability Still Possible?* Washington DC: Island Press in which I wrote most of the text with editorial assistance by the co-author. The second is: Rees, W.E., Moore, J. 2013. Ecological footprints, fair earth-shares and urbanization, chapter 1 in B. Vale and R. Vale, eds., *Living within a Fair Share Ecological Footprint*. London: Routledge in which I wrote the text pertaining to the Vancouver case study based on preliminary findings from this dissertation research. There are two publications for which I reviewed and provided editorial feedback: i) Kissinger, M., Sussmann C., Moore, J. Rees, W.E. 2013. Accounting for greenhouse gas emissions of materials at the urban scale - Relating existing process life cycle assessment studies to urban material and waste composition in *Low Carbon Economy* 4(1): 36-44 and ii) Kissinger, M., Sussmann, S., Moore, J., Rees, W.E. 2013. Accounting for the ecological footprint of materials in consumer goods. *Sustainability* 5(5): 1960-1973. Finally, I am solely responsible for the writing of: Moore, J. 2012. Measuring climate action in Vancouver: Comparing a city's greenhouse gas emissions inventory protocol to the inventory of consumption, in Benjamin Richardson, ed. *Local climate change law: environmental regulation in cities and other localities*. Cheltenham UK: Edward Elgar Publishing Limited.

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Acknowledgements

First and foremost, I would like to thank Professor (now Emeritus) William E. Rees for serving as my supervisor and for constantly keeping the faith. I would also like to thank Professor Thomas A. Hutton and Professor Ronald Kellett who served on my supervisory committee with good cheer and, along with Professor Rees, always supplied thoughtful feedback to my written submissions in a timely manner. Your contributions to my learning have been immense and I remain deeply indebted. Thank you. I would also like to thank Professor Stephen Sheppard for serving as my Prospectus examiner and Professors Ray Cole and Robert F. Woollard for providing thoughtful feedback and enthusiasm for the research. I would like to thank Professor Leonie Sandercock, director of SCARP's PhD program, for sage advice and unwavering support, and I would like to extend my appreciation to Professors Penny Gurstein and Stephanie Chang, as well as Sherli Mah, Rhoda Thow, Patti Toporowski, and Karen Zeller. Rob Sianchuck and Professor Maged Senbel generously shared unpublished research about institutional building embodied energy and Professor Senbel also provided schematic drawings that were used to estimate the embodied energy of residential buildings. I am deeply appreciative of the research assistance provided by Meidad Kissinger, Cornelia Sussmann, Walleed Giratalla, and Ruth Legg who helped with the Vancouver ecological footprint assessment. I am grateful to the research interviewees and the many staff at the City of Vancouver, Metro Vancouver, TransLink and BC Government who graciously gave of their time to answer questions, search for data, and supply reports not available online. Specifically at the City of Vancouver I would like to acknowledge: Bob McLennen, Brian Beck, Carolyn Drugge, Dave Boyko, Doug Thomas, Lindsay Moffatt and SJ Santos. At Metro Vancouver, I would like to acknowledge: Ali Ergudenler, Chantal Babensee, Derek Jennejohn, Ed von Euw, Ken Stephens, Laurie Fretz, Marcel Petre, Mike Stringer, Richard Visser, Robert Hicks, Roger Quan, and Ruben Anderson. At TransLink I would like to acknowledge Lyle Walker. At BC Government, I would like to acknowledge Hillary Kennedy, Jonn Braman, and Ted Sheldon. Several individuals from private sector organizations also provided insights and data, specifically I would like to thank: Graham Finch and Warren Knowles at RDH Building Engineering Ltd., Rob Sianchuck at Coldstream Consulting, Mike van Ham at Sylvis Environmental, Helen Goodland at Brantwood, Aviva Savelson and Innes Hood at Stantec (formerly Sheltair), and Sebastian Moffatt at Consensus Institute (and past president of Sheltair). I would also be remiss if I did not acknowledge the support of friends and family who have seen me through some of life's most challenging moments, on all fronts. I would especially like to acknowledge my husband, Jonn Braman, friends Mike Van Ham, Dan Klingspon, Mark Roseland, and especially library comrade Sue Ann Mitchell, and sister in spirit Rhona Berens. In addition I would like to thank John English and Rod Goy who have both, in their capacity as Dean of the BCIT School of Construction and the Environment, provided unwavering support and encouragement to see this project through to completion. I am indebted to them both. Finally, this research would not have been possible without the support of the BCIT Professional Development Program and the financial support of the Social Sciences and Humanities Research Council (SSHRC) PhD Fellowship (752-2009-2166), the Pacific Institute for Climate Solutions Fellowship (10901), the British Columbia Pacific Century Graduate Scholarship (6413), the University of British Columbia Graduate Fellowship (6302). Major funding came from SSHRC (410-2007-0473) to Doctor Rees on "Getting Serious About Urban Sustainability."

Dedication

In memory of my mother, Rita Moore.

Always ahead of her time and an exemplar of one-planet living.

1 Getting Serious About Sustainability

1.1 Introduction

There comes a time in every relationship when a decision is reached to “get serious” or to keep things casual. This marks the difference between being committed or merely involved with something or someone. Commitment can be scary. It often entails life changes that respond to the needs and demands of the other. For example the accountability and assumption of responsibility required of a parent to his/her child, or of a government to its people, or of Nations to each other in binding agreements and protocols.

Arguably, we have passed through the early stages of our affair with the concept of Sustainability. *Silent Spring* (1962) and *The Limits to Growth* (1972) raised our interest. The United Nations Conference on the Human Environment in Stockholm (1972), the International Union for the Conservation of Nature’s *World Conservation Strategy* (1980), the World Commission on Environment and Development’s report *Our Common Future* (1987), the Rio Earth Summit (1992), *Agenda 21*, Local Agenda 21, UN Conventions on Biodiversity and Climate Change, the World Summit on Sustainable Development (2002), the Millennium Development Goals (2010), and Rio+20 (2012) give evidence to our infatuation. But as the saying goes: “actions speak louder than words,” meaning the truth, or integrity, behind the value of our commitment is revealed by what we do. It is our actions that matter – not our declarations. This is not to dismiss the formulation of consensus that is emerging globally about the value of sustainability and the need for the human community to address pressing ecological and social issues. These are important steps. I remain hopeful that the momentum that has taken decades to achieve will carry us through a sustainability transition in order to secure humanity’s future.

However, my intent is to examine what a sustainability transition entails for cities and more specifically high-consuming cities of the developed world such as Vancouver, Canada. This chapter introduces the research that explores what it would take to "get serious about sustainability" as well as the theoretical framework, presented as part of the literature review, which is used to guide the analysis and inform the findings.

1.2 Problem Statement

There can be little dispute that the direct or proximate driver of global ecological change and the (un)sustainability conundrum is excessive energy and resource consumption and waste production by the human enterprise. The global urban transition increasingly positions cities as a nexus of consumption activity, pollution, and an important locus of influence in determining sustainability outcomes (Rees 2012, 1999a, 1995; Rees and Wackernagel 1996; Wackernagel et al. 2006; McGranahan and Satterthwaite 2003; Barrett et al. 2002; Satterthwaite 1997; Folke et al. 1997). As much as two thirds of global energy and materials consumption and related pollution can be attributed to consumption in cities of wealthy countries (MEA 2005; Rees and Wackernagel 1996). Excessive consumption in these high-income cities contributes to an unsustainable trajectory of development (Rees 2009; WWF 2008; Wilson and Anielski 2005; Carley and Spapens 1998).

In order for the global population to live within the ecological carrying capacity of Earth, the World Wide Fund for Nature[1] (2008, 14) has shown that there are under two global hectares[2] of biologically productive land and water on Earth to sustain each person, assuming those shares

[1] The original World Wildlife Fund changed its name in 1986 to World Wide Fund for Nature which is used outside North America (http://wwf.panda.org/wwf_quick_facts.cfm#initials viewed November 25, 2010).
[2] A global hectare is assumed to be a hectare with global average biocapacity, i.e. the average net primary productive potential of global ecosystems.

were equally distributed. However, despite growing awareness about the properties of cities that contribute to ecological sustainability through physical design, utilization of new technologies, and engagement of citizens in behaviour change and environmental initiatives (Newman and Jennings 2008; Register 2006; Beatley 2004, 2000; Devuyst et al. 2001; Newman and Kenworthy 1999; Weizsacker 1997), there has been very little analysis of the cumulative effects of such strategies to achieve a level of consumption commensurate with such a "fair Earthshare."[3] This target is estimated at approximately 1.8 global hectares per capita (BioRegional 2009; Ravetz 2007; James and Desai 2003).[4]

Vancouver is often cited in the literature as an example of a sustainable city (Wheeler and Beatley 2009, 429; Register 2006, 131; Wheeler 2004, 120). However, Rees (2009, 2010) argues that Vancouver is unsustainable based on its ecological footprint. Despite achievements in creating a compact, mixed use, liveable urban environment, Vancouver's ecological footprint is on par with most high-income cities at approximately seven global hectares per capita (Boyd 2009; Sheltair 2008; Wilson and Anielski 2005). If everyone lived with the ecological footprint of an average Vancouverite, it is estimated that an additional three to four earth-like planets would be needed to yield sufficient resources and waste assimilation services without incurring problems of ecosystem destruction (Boyd 2009; Rees 2009). Critical analysis about what actually constitutes an ecologically sustainable city is needed.

[3] The term "fair Earthshare" was coined by Wackernagel and Rees (1996) to describe the per capita availability of global biocapacity supply.

[4] Since the initiation of this study, the global population has reached 7 billion and the fair Earthshare has reduced to 1.7 gha/ca (Rees personal communication, March 11, 2013).

The original intention of ecological footprint analysis (EFA) was to serve as a policy and planning tool (Rees 1992; Wackernagel 1994; Wackernagel and Rees 1996). EFA is widely acclaimed for its ability to communicate the need to live within ecological limits (Mcmanus and Haughton 2006; Aall and Norland 2005; Barrett et al. 2004; Rees 2000b). Numerous ecological footprint assessments have been undertaken for cities (Wilson and Anielski 2005; Aall and Norland 2005; Barrett et al. 2005, 2004, 2002; Wackernagel 1998), including several for Vancouver (Sheltair 2008; Wilson and Anielski 2005; Wackernagel and Rees 1996). Nevertheless, criticism persists regarding the utility of EFA as a tool for policy analysis at the municipal scale based on: a) disbelief that modified national data sets accurately reflect the local policy context (Xu and San Martin 2010; A. Fournier, personal communication November 27, 2009; Wilson and Grant 2009; Aall and Norland 2005; Chambers, Simmons and Wackernagel 2004; Levett 1998), and b) difficulty accessing locally relevant data and related resource requirements in terms of money and staff and/or consultant time to compile a bottom-up component footprint (Currey et al. 2011; Weidman et al. 2006; A. Fournier, personal communication, November 27, 2009; Wilson and Grant 2009; Aall and Norland 2005). Exploration of how EFA can be adapted to support the needs of municipal governments who seek to achieve the fair Earthshare target therefore remains an important area for research and a primary motivator for this research.

1.3 Research Purpose and Questions

The purpose of this study is to identify, using EFA, some of the most important changes to policy and planning that the City of Vancouver could implement to enable its residents to lead lifestyles which, on average, are equivalent to biocapacity demand of two global hectares per capita, approximating the fair Earthshare. This target is commensurate with a goal of one-planet living (www.oneplanetcommunities.org). The concept of "One Planet Living," coined by BioRegional, an enterprising not-for-profit consultancy, and delivered through an international campaign in cooperation with the World Wide Fund for Nature (WWF), represents an attempt to position sustainable living, and indeed urban sustainability, as a quantifiable objective (Durney and Desai 2004; WWF 2004). The value of targeting a global fair Earthshare is acknowledged in the literature (Vale and Vale 2013; James and Desai 2003; Haughton 1999, 1997; Rees 1997a, 1996). More recently this value has been depicted in the language of one-planet living (Mayhew and Campbell 2008; Eaton et al. 2007; Sutcliffe et al. 2007; James and Desai 2003). However, research on specific urban policy measures to achieve such goals in connection with ecological footprint analysis is still in a fledgling state (Cardiff 2012; BioRegional 2011; Ravetz 2007; James and Desai 2003). It is to this gap in knowledge that my dissertation research contributes.

1.3.1 Research Questions

My inquiry pursues the following questions:

1. What are some changes to planning policy and practice that the City of Vancouver could make to facilitate one-planet living options for its residents?

2. What reduction of ecological footprint could be achieved through implementation of these changes to planning policy and practice?

3. What could an ecologically sustainable Vancouver "look like," meaning what changes to urban lifestyles and/or urban morphology might result from the identified changes to policy and planning practice?

1.4 Scope of the Research

Following the philosophy articulated by proponents of the ecological footprint that the consumer bears ultimate responsibility for production activities (BioRegional 2011; Barrett et al. 2005; Wackernagel and Rees 1996), the research focuses on changes to municipal planning policy and management practice within the City of Vancouver that affect both the city's operations and urban residents' consumption patterns. Although consumption and production are inherently linked, in order to limit the scope of the research production will be explored only to the degree that changes in city policy and reductions in the ecological footprint affect production processes, e.g., introduction of urban agricultural production that reduces the need to transport food over long distances.

While urban morphology and management practices are identified as important factors in reducing a city's demand for energy and materials (Rees 2010; Wackernagel et al. 2006; Satterthwaite 1997; Haughton and Hunter1994), a focus on these alone may be insufficient to achieve levels of consumption that would be commensurate with what would be required to stay within ecological carrying capacity (Newman 2010; Rees 2008; Register 2006; Onyx 2005; Lenzen et al. 2004; Hoyer and Holden 2003; James and Desai 2003; Carley and Spapens 1980). The choices that urban residents make about their lifestyles are critical (Lenzen et al. 2004). Examples include choices about diet, housing, appliances, personal electronics and other consumables, transportation and travel abroad for vacation or work, just to name a few. Although the ecological footprint is not a comprehensive indicator of urban sustainability, let alone ecological sustainability (Rees 2000b), it nevertheless is an important indicator for determining whether a city's resident population exists within its equitable share of global ecological carrying capacity. EFA has the capacity to capture information about personal consumption choices by a city's residents as well as consumption resulting from urban morphology and its related demand on ecosystem services. Therefore it is an important indicator to study in connection with policy effectiveness aimed at achieving ecological sustainability generally, and one-planet living in particular.

To identify which changes in policy or practice could bear the most significant reduction in ecological footprint, I refine existing ecological footprint assessments of Vancouver using material flow analysis and lifecycle assessment methods, following the work of Barrett et al. (2002). Based on my own experience as a demand side management planner focussed on reducing consumption of energy and materials in Metro Vancouver,[5] I adapt the ecological footprint to organize data about resource consumption using taxonomy familiar to planners in the Greater Vancouver area, including planners at the City of Vancouver. This structure is intended to enable planners to use EFA more effectively as a policy tool. The resulting analysis is used to identify the components of consumption that comprise the largest contribution to Vancouver's ecological footprint. I then target consumption patterns in order to explore how to reduce the ecological footprint associated with these components. Examples of components include: food, buildings, transportation, consumables and wastes, and water.

Ecological footprint assessments previously undertaken for Vancouver (Sheltair 2008) as well as the Global Footprint Network's (2010) Ecological Footprint Calculator

[5] Metro Vancouver (previously known by its legal name: Greater Vancouver Regional District) comprises four legal entities. These are the: Greater Vancouver Regional District, Greater Vancouver Water District, Greater Vancouver Sewerage and Drainage District, and the Greater Vancouver Housing Corporation. The Greater Vancouver Transportation Authority, known as TransLink, is a separate, sister organization.

(http://www.footprintnetwork.org/en/index.php/GFN/page/calculators/) reveal that the federal and provincial services component of the Ecological Footprint comprising: military, healthcare, and other services of national and provincial interest account for approximately two global hectares of biocapacity per capita (i.e., this component alone approximates demand equivalent to a fair Earthshare). It is not clear whether and how municipal policy intervention could significantly influence this portion of the footprint. Because the focus of the research is on changes to Vancouver's planning policy and practice, I do not assess service sectors predominantly affiliated with senior government jurisdiction. Future research regarding how nationally provided services affect the potential of cities to enable their citizens to achieve sustainable lifestyles defined as one-planet living is needed but falls outside the scope of this research.

The fair Earthshare and one-planet living are essentially dynamic indicators. Increasing population and per capita consumption coupled with deteriorating biocapacity results in a shrinking value for the fair Earthshare year-over-year, making one-planet living ever more difficult to achieve. For illustrative purposes, I focus on a value of 1.8 gha/ca in order to fix the analysis within the data space provided for the 2006 study year.

Population itself is an important driver of consumption and demand for natures' services. However, the research does not address excessive population and population growth *per se*. Vancouver, Metro Vancouver, the Province of British Columbia, and the Government of Canada should, of course, develop population and/or immigration policies as part of their overall sustainability strategies.

The fair Earthshare, EFA, and one-planet living do not address social factors related to self-interest, greed, corruption, political agenda, and other issues that intervene through community activism, corporate strategies, and politics. These factors are important, but I do not address them in depth. I also acknowledge that global market forces and international politics could have a bearing on the potential for implementation of policy interventions identified in the research. However, these factors are also outside the scope of my analysis. My focus is on what is ecologically necessary for sustainability, unfettered by what is perceived as politically and economically feasible.

Finally, for the ecological footprint analysis, I use national data to supplement gaps in local data collected by the regional and municipal government levels. This is an accepted practice in the component[6] ecological footprint method (Barrett et al., 2002). However, this approach is not compliant with the standards articulated by the Global Footprint Network for EFA of cities (Kitzes 2009). Only a top-down, i.e. compound,[7] EFA method is accepted by the Global Footprint Network (Kitzes 2009). If local data are used to supplement nationally derived data then results must be presented using both approaches, i.e. an exclusively top-down component method in comparison with a modified top-down method that uses some locally derived data (Kitzes 2009). Future research to explore whether and how the method I am using for completing a bottom-up, i.e. component, ecological footprint analysis could align with the

[6] The component method relies on locally available data to estimate the ecological footprint. See chapter 3 for a detailed description of how it is applied to this study.

[7] The original method for estimating an ecological footprint relies on national data that assesses consumption as a value of total domestic production plus imports, minus exports (Wackernagel and Rees 1996). This approach is referred to as the "compound" method (Chambers, Simmons and Wackernagel 2004, 67; Barrett et al. 2002, 24). See section 1.7.3 for additional information.

standards promoted by the Global Footprint Network is warranted but outside the scope of this research.

1.5 Structure of the Dissertation

The dissertation uses complexity theory, the laws of thermodynamics, and ecological footprint analysis as a theoretical framework in which to undertake an exploratory case study of what one-planet living might entail in the City of Vancouver. Chapter 1 introduces the research and frames its contribution to knowledge in terms of assessing whether proposed policies for urban sustainability can actually achieve consumption levels within ecological carrying capacity, i.e., commensurate with a fair Earthshare target. It identifies the following areas of exploration: i) what policies the City could implement to reduce its ecological footprint and/or what policies the City could implement to enable citizens to make lifestyle choices that reduce their footprint, ii) what level of reduction in the ecological footprint could be achieved by implementation of such polices, and iii) what one-planet living might look like in Vancouver if those policies were implemented. Chapter 2 introduces the City of Vancouver as the case study. Chapter 3 describes my research methods, including development of lifestyle archetypes and an ecological footprint analysis for Vancouver that is designed to serve municipal policy and planning needs for identifying interventions that the City of Vancouver could take to enable its residents to make one-planet living lifestyle choices. Chapter 4 comprises an analysis of Vancouver's sustainability gap based on the City's ecological footprint in 2006 compared to the actual fair Earthshare. Chapter 5 explores various scenarios for one-planet living in Vancouver using ecological footprint analysis coupled with identification of policy interventions and changes to urban management practices informed by interviews with City of Vancouver staff and other key informants. Chapter 6 discusses the research findings, draws conclusions, and proposes ideas for future research.

1.6 Significance of the Study and Contribution to Knowledge

The research makes the following contributions:

1. Refines ecological footprint analysis as a policy tool to meet municipal policy and planning needs, specifically focussed on Vancouver.
2. Develops lifestyle archetypes to inform one-planet living research based on empirical data about how people in different cities around the world are consuming coupled with scenarios for one-planet living in Vancouver developed through the application of a refined ecological footprint analysis.
3. Uses the refined ecological footprint assessment of the City of Vancouver to identify policy interventions or changes to City management practices that the City could implement to enable its residents to choose one-planet lifestyles.
4. Conceptualizes Vancouver as a One-Planet City and creates a vision of what Vancouver might be like if everyone were to live within their ecological fair Earthshare.

1. 7 Sustainability and Cities (Literature Review)

1.7.1 Urban Sustainability

As the world urbanizes, the role of cities in determining sustainability outcomes grows in importance (Seitzinger et al. 2012; Rees 2012, 2010, 1999a, 1999b; Rees and Wackernagel 1996; Wackernagel et al. 2006; McGranahan and Satterthwaite 2003; Girardet 1999). Cities are the dominant form of human habitat, and most of the world’s resources are either directly or indirectly consumed in cities (Rees 2012, 2009, 1999b; McGranahan and Satterthwaite 2003).

Friedmann (2002) explores three definitions of urbanization. The first corresponds with demographic movement of people to urban settlements, denoted by higher population density than the surrounding area. A second definition of urban is economically derived as land-based, primary forms of production related to agricultural and resource extraction give way to other forms of economic activity. The third definition of urbanization is socio-cultural and refers to participation in urban ways of life. Examples include high levels of literacy and participation in “communication-intensive networks” (Friedmann 2002, 5).

Friedmann (2002, 3) uses the term “city-region” to denote the dependent relationship that a city has on its immediately surrounding hinter-land, “typically extending outward from a core for a distance of … fifty to one hundred kilometers.” Rees (2009), however, argues that this distance extends much further as an outcome of global trade. A city’s hinterland is, in fact, scattered all around the world. Therefore, cities should be reconceived and considered within their global context (Rees 2012, 2010, 2009; Rees and Wackernagel 1996). Indeed, economic and socio-cultural urbanization has transgressed urban boundaries in the same way that Rees (2009) argues the flow of energy and materials has exceeded the boundaries of what Friedmann (2002) conceptualizes as the city region. Cities effectively become nodes of consumption in a global urban web of material and energy flow, capital flow, migration flow, and information flow (Rees 2012; Seitzinger et al. 2011). This distinction between the city per se and the urban ecosystem upon which a city depends is helpful in understanding the extension of urban organizational structure beyond the physical representation of a specific geographic location and shall be addressed in more detail below.

“Sustainable” in its simplest sense means capable of being maintained indefinitely (Rees 2006a; Dale 2001; Beatley 1995a). Applied to human civilization, it takes a decidedly anthropocentric perspective that combines aspirations for human flourishing tempered by the recognition of factors that impede it (Dale 2001; UNCED 1992; WCED 1987; Meadows et al. 1972). There are many working definitions of sustainable development from the popularized Brundtland Commission’s: development that “meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED 1987, 8) to more specific prescriptions such as that offered by Rees: “Sustainable development is positive socioeconomic change that does not undermine the ecological and social systems upon which communities and society are dependent” (Rees 1989, 3 cited in Dale 2001, 6). Common to these definitions is a recognition that sustainable development “involves a progressive transformation of economy and society” for the purposes of satisfying “human needs and aspirations” (WCED 1987, 43). It also requires a societal transformation that addresses humanity’s relationship to the natural environment rather than mere environmental conservation efforts that fail to question societal structure and its impacts (Lovelock 2006; Dale 2005; Fowler 2004; Wheeler 2004; Becker and Jahn 1999; Rees 1995; Beatley 1994).

Strong sustainability argues for the need to preserve adequate natural capital[8] per capita as a non-substitutable form of capital that is essential to provision of life support services, as well as the provision of utility to support man-made capital (Neumayer 2003; Rees and Wackernagel 1996). Strong sustainability clearly aligns with the paradigm that recognizes ecological limits (Meadows et. al 1972) and the Steady State Economy articulated by Herman Daly (1977) and

[8] Natural capital refers to a stock of ecosystem assets that yield ecological goods and services (Neumayer 2003).

later evolved further as ecological economics (Victor 2008; Neumayer 2003; Rees 1995). Furthermore, Wackernagel and Rees (1996) observe that because humanity, particularly in wealthy countries, is already unsustainable such that world consumption is in excess of global ecological carrying capacity, sustainability also requires reducing consumption and reversing ecological deterioration.

The specific question of how humanity can continue to develop in the face of ecological limits distinguishes the concept of sustainable development, implying continuing improvement, from sustained growth. The prevailing growth paradigm is predicated on neoclassical economic thinking that values market-based approaches to sustainability. Sustained economic growth is seen as a means to create the wealth necessary to eradicate poverty while simultaneously addressing environmental challenges (UNDESA 2006; UNWSSD 2002; UNCED 1992; WCED 1987; IUCN 1980).

Various analysts challenge the growth paradigm as being at odds with the achievement of sustainable development (Victor 2008; Montague 2006; Hayes 2006; Nijkamp et al. 2004; Rees 2002, 2000a, 1995; Dale 2001). First, the benefits of growth go mainly to the wealthy[9] and it is consumption by the wealthy that poses the real challenge (Victor 2008; Rees 2002). Second, consumption has historically increased with income so the net effect is that ecological impacts constantly increase with income, regardless of technological innovation – and, indeed, sometimes precisely because of it (Victor 2008; Lenzen et al. 2004; Nijkamp et al. 2004; Satterthwaite 1997). Third, “sustained [material] economic growth” is a biophysical

[9] The “wealthy” refers to the 20% of global population that is responsible for approximately 80% of private consumption and waste production (Shah 2012).

impossibility given Earth's finite ecological capacity (Montague 2006; Rees 2002, 2000a, 1995). Fourth, economic growth on its own has not and cannot address the issue of equitable distribution of wealth, let alone the challenge of equitable opportunities to secure one's own chances for economic prosperity (Montague 2006; Giddings et al. 2005; Daly 1977). Indeed, as Herman Daly (1977, 8) observes: "If we are serious about helping the poor, we shall have to face up to the moral issue of re-distribution and stop sweeping it under the rug of aggregate growth."

In summary, focusing exclusively on economic growth side-steps the issue of distributive justice (Rees 2008, 2002, 2000a; Montague 2006) and ignores mounting evidence that decades of economic growth have not alleviated global poverty (UNDESA 2011, 2006; UNDP 2010; Victor 2008). Instead it threatens to increase the vulnerability of the poor to ecological risks from climate change, unsafe drinking water, desertification, and deforestation, to name a few effects (Rees 2012, 2002; UN DESA 2011, 2006; UNDP 2010, 2007; Victor 2008; Hayes 2006; Dale 2001; Karr 2000; Westra 2000). Moreover, the historical evidence reveals that growth-oriented economics has entrenched global economic disparities while simultaneously degrading global ecosystem integrity (UNDP 2010, 20007; WWF 2008; UN DESA 2006, MEA 2005). The ideological dominance of the growth paradigm and its inherent value system are barriers to new ways of thinking (Rees 2010; Victor 2008; Dale 2001; von Weizsäcker et al. 1997; Daly 1977).

Given these considerations, I believe urban sustainability represents an integrated approach to both the built environment and social behaviour as two important and related aspects that enable cities to contribute to an ecologically sustainable world (McGranahan and Satterthwaite 2003; Kay et al. 1999).

1.7.2 Complexity Theory and the Laws of Thermodynamics,

Complexity theory and the laws of thermodynamics provide a useful theoretical framework for exploring the research questions. Thermodynamics is part of "the science of complex systems" (Prigogine and Stengers 1984, 122). It explores how systems respond to exogenously imposed change (Prigogine and Stengers 1984). It is founded upon two laws: first, that energy cannot be created or destroyed, and second, that energy is degraded by physical and chemical processes which are irreversible (i.e., nature's tendency towards maximum disorder or entropy) (Schneider and Kay, 1994). A complex, thermodynamic system tends to gravitate toward a dynamic equilibrium state - exogenous forces imposed upon it are neutralized by the system's ability to dissipate those forces at an equivalent rate (Prigogine and Stengers 1984). A complex system can be defined as interacting, identifiably separate entities that when taken together form an organization, a systemic whole or holon, wherein the parts express different behaviours than they would in isolation. Furthermore, the system as a whole performs tasks that cannot be accomplished individually by the entities comprising it (Partridge 2000; Kay and Regier 2000; Wilber 1995; von Bertalanffy 1950).

The ecosphere, and indeed the universe, can be characterized as a nested hierarchy of sub-systems or holons that exist in dynamic relationship from the sub-cellular organelle to the macro social organizations of species into ecosystems (Rees 2012; Kay and Regier 2000; Partridge 2000; Wilber 1995; Miller 1978). Open systems, which include all living systems, are characterized by a continuous exchange of energy and materials (Rees 2012; Kay and Regier

2000; Prigogine and Stengers 1984; von Bertalanffy 1950). These systems include both naturally or biologically occurring entities, such as animal organisms and ecosystems, as well as socio-cultural entities such as human civilization, cities, nations, and also social constructs such as the economy (Rees 2012, 1995; Victor 2008; Prigogine and Stengers 1984; von Bertalanffy, 1950).

Open systems exchange energy and materials with their surroundings through dissipative processes (Prigogine and Stengers 1984; Rees 2012; Kay 2000). Structure (i.e., order or negentropy) within systems emerges and is maintained at the expense of imported available energy and materials, e.g., sunlight, fossil fuels, plants (Kay et al. 1999; Schneider and Kay 1994). This process follows the laws of thermodynamics and the law of mass balance whereby energy and material gradients are dissipated as they are exchanged between systems, yet the total amount of energy and/or mass remains the same. In other words, local systems build order by creating disorder in their host systems. This self-organizing phenomenon occurs continuously: as new structure emerges, a new organizational context develops within which new dissipative processes and structures can emerge (Kay and Regier 2000). Thus, self-organizing holarchic open (SOHO) systems build local internal structure (i.e., create order or negentropy) by importing high-grade available energy and materials from their host systems and export degraded energy and material wastes thereby creating disorder or entropy in their host systems (Rees 2012; Kay and Regier 2000).

On Earth, a nested hierarchy of integrated systems can be conceptualized beginning with the ecosphere that is the largest system, meaning it has the greatest span of energy, materials, and information. From the ecosystem, the sub-system of society evolved in dependent relationship, drawing on the energy, materials, and information of the ecosystem. Society is a system within which the economy, as a societal sub-system, was created and upon which it depends. Urban systems, including cities, develop from and are governed by socio-economic system processes and are ultimately dependent on ecosystems (Rees 2012; Victor 2008; Girardet 2004; Prigogine and Stengers 1984). The first gives birth to the next and so on. The literature frequently defines sustainability as comprising three (and sometimes more) dimensions, i.e., ecological, social, and economic that are of equal importance, e.g. three legs of a stool, three imperatives, three overlapping spheres or goals (Onyx 2005; Wheeler 2004; Dale 2001; Carley and Spapens 1998). However, this approach masks the hierarchical context in which these dimensions exist and thereby avoids confronting the reality of the economy's and society's absolute dependence on global ecosystems (Rees 2012, 1995; Lovelock 2006). Using complexity theory and the laws of thermodynamics as a theoretical framework for analysis helps make these relationships explicit. Cities emerge and maintain their internal structure through dissipative socio-economic processes that create negentropy in their host ecosystem(s) (Prigogine and Stengers 1984; Rees 2012, 2010; 2009). There is a direct link between urban development and dissipation of ecosystems.

Furthermore, SOHO systems follow the "maximum power principle" described by Lotka in 1922 as the propensity to utilize all available energy and materials. This is a universally observed survival tactic in all species including humans (Rees 2008). Because energy and materials are limited, competition among systems and their component parts emerges as a characteristic of systems evolution (von Bertalanffy 1950). However, cooperative or symbiotic behaviour also emerges to increase the competitive position of cooperating entities (Miller 1978). Indeed, it is the characteristics of components and their interactions within systems that give rise to a system's characteristics and behaviour (Meadows et al. 1972). Therefore, qualitative changes in the structure of feedback relationships within and among systems can stimulate new evolutionary trajectories (Meadows et al. 1972). Thus, it may be possible to introduce qualitative changes to the operation of urban processes in order to change their development trajectory, e.g. from one of high consumption and wastefulness to one of lower consumption.

Finally, allometric growth is a function of an entity's ability to capture a proportion of what is totally available within the system (von Bertalanffy 1950). Positive allometry means that the capacity of an individual entity is greater than its proportional relationship to the whole system, i.e. the individual entity captures relatively more than others and grows more quickly. Differing capacity to capture resources determines an entity's ability to thrive and competitively displace, to the point of extinction, those with lesser capacity (von Bertalanffy 1950). The record of successful self-organization is encoded in both genes and cultural memes (i.e., taught beliefs and behaviours) of the surviving entities (Rees 2008; Key and Schneider 1994). Genes and memes that confer evolutionarily success persist and give rise to a hierarchy of values and decision rules (Miller 1978). As these emerge, their force of influence gains dominance and creates an increasingly endogenous system orientation, meaning internal regulation grows and the capacity for flexibility and adaptation diminishes (Holling and Gunderson 2002). This process can be seen in the dominance and entrenchment of the growth paradigm, promoted by high-consuming western European and North American cultures that comprise only a small percentage of global population but consume most of the world's resources (as described above).

The endogenous relevance of values held by dominant cultures is an important area of investigation. In simple systems, components act predominantly in response to environmental triggers, i.e. exogenous factors. However, in highly evolved systems, including human systems, some system components are capable of exercising choice. Agency is the "capacity, condition or state of acting or exerting power" (Merriam-Webster Dictionary online 2012) or the means by which action is taken to achieve a result (WordNet 2009). In more highly evolved, complex systems, feedback mechanisms enable the system and its components, some of which are capable of exercising choice, to respond according to a combination of exogenous and endogenous factors. Systems and their components exist in dynamic relationships of agency and communion (Wilber 1995).[10] Agency in complex systems can be understood as: action expressed by a component in response to external or internal triggers that predominantly serves its own interest as a distinct entity (Wilber 1995). Similarly, communion is expressed by components acting as part of a larger system (Wilber 1995). Positive agency works within the constraints of communion and contributes to the health of the system and it's supra and subordinated systems (Wilber 1995). Pathological agency conflicts with the constraints of communal relationship of the system, creating stress that can break the structural relationships between the component and the system of which it is part (Wilber 1995). The outcome of pathological agency causes harm to the system and sub-systems dependent upon it (Miller 1978), while releasing super-systems and their component parts from further influence (Wilber 1995). Therefore, an important challenge for urban sustainability is how to elicit positive agency within dominant (i.e., western) society and socio-economic processes that give rise to cities

[10] Gidden's (1984) observes this relationship in Structuration Theory that explores the ways that individuals are governed by social institutions while simultaneously contributing to their recreation.

that operate within global ecological carrying capacity. To this end, an inquiry into qualitative changes that can alter the structure of urban system relationships and their related feedback mechanisms becomes a fertile field of investigation. This includes the policies and urban management practices that a city government invokes and implements. Despite the dominant cultural memes, citizens can choose to act differently to affect urban development trajectories and related consumption patterns. Urban policy that enables such choices becomes an important focus.

The concepts of city and urban ecosystem in this research assume an integration of socio-economic and bio-physical processes whereby human agency gives rise to urban systems and the agglomeration of many individuals acting as a social entity can be interpreted as an animated city. Cities are dissipative structures (Rees 2012, 1997b) that emerge through the self-organizing processes of people acting within socio-economic systems that draw on available resources from surrounding ecosystems. Because cities emerge through dissipative processes, limits to the availability of energy and materials constrain their potential growth and development (Rees 2012). This is a critical reality pertaining to the sub-system's dependence on its super-system. Urban systems can influence the rate at which cities consume energy and materials from their supra-system, but they must consume, i.e., dissipate, energy and materials to survive, i.e., maintain structural integrity (Kay and Regier 2000). Excessive demand, i.e., growth, will degrade the structural integrity of the host system (Rees 2012, 1997b). In effect, the need to conserve the super-system imposes constraints or limits on sub-systems. There is a range or domain of stability (a "window of vitality") within which the sub-system can flourish, and a sub-system's survival depends on its operating within that optimum, not at maximum dissipative capacity (Kay and Regier 2000; Kay et al. 1999; Tainter 1995; Schneider and Kay 1994). The most successful sub-systems are those that are superior competitors for energy and matter within the constraints of the host system. If a sub-system does "not conform with the circumstances of the super-system it is part of, it will be selected against… Living systems that are evolutionarily successful have learned what these constraints are and how to live within them" (Kay and Schneider 1994, 36).

Complex systems, including urban systems, follow an adaptive cycle of organization, growth and solidification, climax and collapse (Holling and Gunderson, 2002). As certain components within a system and their attendant relationships gain dominance, their trajectories of evolution foreclose the potential of other possible futures and greater predictability emerges within the system (Holling and Gunderson 2002). The frequent and dense structural relationships that form during the organizational phase create an inertia that constrains flexibility and capacity to respond to novelty (Holling and Gunderson 2002). This momentum, once it has established a growth phase, confounds intervention. Connections among dominant components within the system tighten, with an emphasis on maximizing the efficiency of existing relational exchange processes; meanwhile, new entrants find it difficult to gain access (Holling and Gunderson, 2002).[11]

Ironically, the strategies that bring early wins and contribute to the trajectory of the system's evolution also eventually contribute to its demise (Harris 2007; Holling and Gunderson 2002).

[11] This process parallels the logic behind Kuhn's (1962) *The Structure of Scientific Revolutions* that describes the entrenchment of the dominant paradigm which holds sway over competing concepts and suppresses innovation in response to anticipated changes. Only at the point of collapse, when the dominant paradigm can no longer successfully meet the needs of those who abide by it, does the need for change become self-evident. Yet, through this process, the ability for proactive agency has been squandered.

Although some of the components in highly evolved systems have the capacity to exercise choice, the constraints of the relational structures in which they are situated limit the range of choices that can be effectively implemented. Risk from endogenous or exogenous forces increases as a system's structure solidifies and reaches its climax stage because variability within the system has diminished (Holling and Gunderson 2002).

Conflict can occur between two competing systems at the same or different levels. Examples include: competition for the same scarce input or when "a system makes demands which threaten the existence of its supra-system" (Miller, 1978, 39). When adjustment processes, in the form of negative feedback, fail to re-stabilize a system, "the structure and process of the system alter markedly – perhaps to the extent that the system does not survive" (Miller, 1978, 37). However, rather than a gradual transition, change can be episodic with periods of slow evolution punctuated by rapid change when a threshold to system stability is crossed (Holling and Gunderson 2002; Kay and Regier 2000).

A stability threshold is the point in a system at which energy and material inputs exceed the system's dissipative capacity (Kay et al. 1999). Conversely, a stability threshold can also be a point at which scarcity of energy and material inputs fail to supply what would be necessary to sustain the system in its existing structure. The system loses internal coherence as the relational bonds among its components break-down. An abrupt "flip into an irreversible (typically degraded) state controlled by unfamiliar processes" emerges (Holling et al. 2002, 9). As described above in the tension between agency and communion, the system itself disintegrates as the components that comprised it are freed from their relational structure to each other.

Applying these theoretical observations from complex systems theory to the challenges of achieving sustainable urban development, Kay et al. (1999) observe that complex systems thinking, and in particular the behaviour of self-organizing open holarchic (SOHO) systems, accurately reflects ecological and human systems. There is wide agreement in the urban sustainability literature that an ecosystems-based approach is an appropriate theoretical framework for understanding how cities and their relationships to economy, society and ecology function (Newman and Jennings 2008; Register 2006; Fowler 2004; Hough 2004; Wheeler 2004; Girardet 1999; Todd and Tukel 1981). However, Kay et al. (1999) argue that this approach is insufficient and propose that a theoretical framework grounded in complex systems theory is required. It subsumes the ecosystem approach because ecosystems are themselves complex systems, and more importantly it adds depth of understanding about the unstable, unpredictable and uncontrollable ways that such systems operate (Kay et al. 1999; Kay and Schneider 1994).

Jane Jacobs is credited as the first to propose that the city is an example of “organized complexity” (Batty 2007, 4) requiring exploration of “how individuals behave and the processes that they use to develop their environment” including the built environment of cities and the structural relationships of energy and material flows that support them (Batty 2007, 3). Rees (2009, 1999a, 1999b), Batty (2007), Folke (2006), Hallsmith (2003), Odum and Odum (2001), Holmberg et al. (1999) pay particular attention to the interpretation of urban sustainability through complex systems theory. There is an emerging literature in the fields of planning, physics, economics, engineering (including industrial ecology and biomimicry) that explores urban sustainability through complex systems theory and promises to bring valuable insights about how to navigate towards policies that support the development of sustainable cities (Innes and Booher 2010; Baynes 2009; Chen and Jiang 2009; Weik and Walter 2009; Frame 2008; Garmestani et al. 2008; Batty 2008; Isalgue et al. 2007; Ruth and Coelho 2007; Bai 2003; Funtowicz et al. 1999; Rees 1995).[12]

Interpreting urban sustainability through complex systems theory yields insights about: the way that urban structure develops and functions (Batty 2007; Hallsmith 2003; Crabbe 2000), the multi-scalar context of relationships within which a city is situated (Chen and Jiang 2009; Garmestani et al. 2008; Batty 2008), how and why cities transform and the power of global forces to affect urban outcomes (Odum and Odum 2001), the viability and vulnerability of cities in terms of their needs and dependencies (Rees 2009, 1999a; Odum and Odum 2001), and the life cycle of cities that follow an inevitable pattern of creation, growth, decay, and ,sometimes, renewal (Gunderson and Holling 2002; Odum and Odum 2001; Kay and Regier 2000).

For example, understanding how self-organizing holarchic open (SOHO) systems: a) develop structure in response to available energy, b) dissipate and degrade the available energy, and c) in so doing create entropy in the supra-systems of which they are part (Kay and Regier 2000;

[12] It should be noted that in the evolution of planning theory, "systems theory" has historically been understood as positivist analysis of structural relationships from which deterministic outcomes could be predicted, thereby biasing favour towards a technocratic role for planners (Taylor 2003; Allemendinger 2002). The nuance of complexity theory which perceives systems as fundamentally uncertain with indeterminate outcomes, and therefore aligned with a post-positivist perspective biasing towards a communicative role for planners in the formulation of political decisions (Innes and Booher 2010; Rees 1995), has been slow to emerge.

Kay and Schneider 1994; Schneider and Kay 1994) yields insights about the way that cities , as dissipative structures, developed and grew through the industrial, post-industrial and post-modern periods (Rees 2012; Odum and Odum 2001). Fossil fuels represented an energy bonanza. People in industrializing cities harnessed this energy and thus were able to develop massive infrastructure and political power structures that in turn required and enabled the city to grow and develop further through trade, a form of co-option of resources from afar that yields additional energy and material inputs (Rees 2006b).

This cycle demonstrates a positive feedback; it is the maximum power principle at work (Odum and Odum 2001). Cities seen through a complex systems theory lens are interpreted as performing according to the laws of thermodynamics, as open dissipative structures (Rees 2012). The structural transformation affecting todays growing, post-industrial cities is a process of only apparent de-industrialization that results in energy and materials dissipation over a wider territory. In effect, the industry that emigrated through de-industrialization didn’t functionally leave the city system, it merely geographically relocated. This urban structural transformation creates local dislocation (Hutton 2008) but also the emergence of the city as a super-urban structural system with extensions to remote locations that enable it to attract more resource-inputs to its centre. In summary: cities grow and create structural networks with other locations as they transform into a complex, globally networked, hierarchical urban system structure (Odum and Odum 2001; Girardet 1999). Thus we can describe the emergence of the “consumer city” (Erdkamp 2001) as a post-modern outcome whereby cities, functioning as dissipative structures, extend their reach across the vast areas needed to support their ever-growing structural demands for energy and material resources.

Odum and Odum (2001, 77) observe that all systems function through “pulses” of growth and decline. Kay and Schneider (1994) connect these cycles to catastrophe theory. Holling and Gunderson (2002) use the notion of a repeating, adaptive cycle to explain the concept in terms of an evolutionary process of emergence, climax, decline and regeneration. These insights challenge both the notion of unlimited growth and the notion of growth that eventually levels-off to a “steady-state” (Odum and Odum 2001). Tainter (1995) observes that the greater the complexity of a system the more energy and materials are required to support it. This leads to his conclusion that because of limits to resource availability eventual collapse of complex societies is to be expected (Tainter 1995). Tainter’s observations are corroborated by Meadows et al. (1972) and Diamond (2005) who note that the prevalence of collapse remains constant throughout history despite ever-increasing levels of technological sophistication that humanity achieves. Schneider and Kay (1994) observe that stressed ecosystems will retreat, devolving to previous, i.e. more primitive, stages of structural development. In decline, therefore, systems contract and reduce their footprint.

An important strategy in planning for urban sustainability is to know where in the cycle of growth and decline society is located in order to inform how to appropriately adapt to anticipated changes (Odum and Odum 2001; Tainter 1995). Adaptive capability is important: history reveals that cities that have lasted the longest were not necessarily the biggest nor did they offer inhabitants the highest standard of living. Rather, they were able to moderate their demands on the land (Sorenson et al. 2004) and function within a window of vitality.

Because of energy and resource constraints, Tainter (1995), Odum and Odum (2001), Kunstler (2005) and Lovelock (2006) anticipate a need to prepare for decline of the current global, urban, socio-economic system. Cities are predicted to retract following a pattern of "decentralized concentration" (Odum and Odum 2001, 209). This means there will be pockets of dense urbanization distributed across rural and/or wild areas. The rise in cost of fossil fuels will reduce material transportation over large distances and the resulting scarcity will trigger depopulation in cities as people return to rural areas to secure subsistence (Kunstler 2005; Odum and Odum 2001). Societal values are also predicted to shift from competition to cooperation (Odum and Odum 2001).

A number of strategies are proposed to facilitate the transition from climax to decline including: reintegration of the city to its immediately surrounding region (e.g. bioregionalism), integration of municipal and regional governance, rebirth of inner city living, dense and ground oriented development replacing high-rises, avoidance of infill development and increase in green spaces in an attempt to support local bio-capacity (e.g. urban agriculture), increased recycling and materials repurposing as well as sharing of resources following strategies informed by industrial ecology (Kunstler 2005; Odum and Odum 2001). Not surprisingly, many of these strategies parallel those proposed for sustainable cities, communities, and livelihoods (Roseland 2012; Register 2006; Wackernagel and Rees 1996; Aberley 1994; Jack-Todd and Todd 1994; Mollison 1988; Todd and Tukel 1981).

From this analysis it is evident that a dual approach to urban sustainability is warranted that pays attention to: i) the thermodynamic operation of a city in terms of its energy and materials consumption and waste production, and ii) the social organization in terms of access to knowledge and information, governance regimes, individual and organizational activities. In effect, a sustainable city requires a sustainable society living within it. This means that while a focus on: land use; buildings; transportation; utility services for water, energy, and waste; agriculture; and green space provide important focal points, they represent only part of what constitutes a sustainable city. The other part addresses institutional and socio-cultural issues pertaining to: ethics and values, social capital, governance structure, participation and cooperation, equity and access, organizational capacity, and shared vision.

One can argue, therefore, that what constitutes urban sustainability includes:

- A prioritization of ecological integrity and commitment to stay within ecological limits, defined by both local and global carrying capacity.

- A local governance regime that supports individual and organizational activities aimed at achieving the above objectives.

- A high level of effort by citizens to behave in ways conducive to achieving the above objectives.

- Adaptive capabilities within society to respond to feedback and adjust goals accordingly.

1.7.3 Ecological Footprint Analysis

The fact that cities are dissipative structures implies that those who reside in cities will need to become active agents in sustaining that which sustains them. Ecological footprint assessment can inform an integrated approach to urban policy development that addresses both urban form and social behaviour. Such an integrated approach is essential to achieving sustainability, and more specifically it is essential to the ability of cities to contribute to a sustainable world (McGranahan and Satterthwaite 2003; Kay et al. 1999). To this end, there is growing support for the use of ecological footprint analysis and its related concept of the fair Earthshare (Eaton et al. 2007; Sutcliffe et al. 2007; Mcmanus and Haughton 2006; Holden 2004; Nijkamp et al. 2004; Portney 2003; Rees 2000b; Holmberg et al. 1999).

Ecological footprint analysis is a quantitative method developed by Professor William Rees and his students, most notably Dr. Mathis Wackernagel, which "acknowledges that humanity is facing difficult challenges, makes them apparent, and directs action toward sustainable living" (Wackernagel and Rees 1996, 3). EFA recognizes that "every category of energy and material consumption and waste discharge requires the productive or absorptive capacity of a finite area of land or water" ecosystems (Wackernagel and Rees 1996, 51). A significant innovation behind the concept is that it inverses the traditional approach to calculating carrying capacity. Rather than asking how many people a given area can support, ecological footprint analysis asks how much area is needed to support a specific population (Rees 1992). Specifically it estimates the area of biologically productive land and water required to continuously support the material and energy consumption and waste assimilation demands of a given population at prevailing levels of technology, money income, and socio-cultural values (Wackernagel and Rees 1996).

EFA orients the city within its global context by accounting for its ecological load, meaning the productive land required to support its biological and industrial metabolism "wherever on Earth that land is located" (Wackernagel and Rees 1996, 11). It therefor addresses not only the life processes of urban residents but also the technological, physical and mechanical demands of modern lifestyles (Wackernagel and Rees 1996). This enables the ecological footprint to be applied to anything that consumes energy and materials – including cities, their buildings and infrastructure, and/or the urban populations that reside within them (Wackernagel et al. 2006).

Eco-footprint estimates can be made at any scale from individuals to entire populations. Sub-populations can be analyzed, providing potentially important information about how urban built form, income, and lifestyle choices interact to affect consumption patterns and ecological load in different parts of a city (Lenzen et al. 2004; Holden, 2004). Similarly differing consumption patterns and ecological loads can be compared across cities or countries or used to inform equity issues when the footprint is assessed against the "fair Earthshare," the amount of bio-productive capacity available on a global per capita basis (Wackernagel and Rees 1996, 54). This last point is important in light of uneven global development patterns. "In the Third World, … cities are faced with unacceptably low levels of quality of life to the extent that even human health is at stake" (Finco and Nijkamp 2001, 290). Most people in these cities have an ecological footprint of less than two global hectares per capita while people in the developed world, particularly Europe and North America, have a per capita ecological footprint that is more than twice this amount (WWF 2008).

Ecological footprint analysis and the fair Earthshare concept have the potential to inform urban policy pertaining to i) global social equity in terms of increasing access to resources by those who are otherwise marginalized, and ii) global ecosystem integrity in terms of reducing demand for nature's services by those who consume a disproportionate share to levels that could be considered ecologically sustainable. The emphasis on municipal government and its influence on the city's role in the global context may seem far-fetched because municipal jurisdiction is confined to issues of local concern. However, as demonstrated above, urban form can influence both consumption patterns and urban management practices, particularly those related to demand side management that affect people's lifestyle choices. Indeed, the ecological footprint was conceived as a tool to inform the sustainable development of cities, or more precisely as a "tool to help us plan for sustainability … (that) addresses such global concerns as ecological deterioration and material inequity" (Wackernagel and Rees 1996, 28).

The original ecological footprint method relied on national data to assess consumption defined as domestic production plus imports, minus exports (Wackernagel and Rees 1996). This approach is referred to as the "compound" method (Chambers, Simmons and Wackernagel 2004, 67; Barrett et al. 2002, 24). If relevant local data are available, a more detailed city-level analysis of urban metabolism can be undertaken combining material flows analysis, lifecycle assessment, and input-output analysis (Kennedy et al. 2011; Barrett et al. 2002). This approach is referred to as the "component method" because it better reveals the contribution of different components that contribute to a city's ecological footprint (Chambers, Simmons and Wackernagel 2004, 68; Barrett et al. 2002, 24). Examples of components include: energy, shelter, food, transportation, goods and services (Wackernagel and Rees, 1996). Component EFA has been adapted over time to address: household, infrastructure, commercial and public service sectors (Barrett et al 2002), as well as water, materials and wastes (Chambers, Simmons and Wackernagel 2004). In all cases and for all methods, the ecological footprint expresses human demands on nature's services in terms of the corresponding area of ecologically productive cropland, pasture land, fish area, forest land, energy land, and built area (Chambers, Simmons and Wackernagel 2004; Barrett et al. 2002; Wackernagel 1998; Wackernagel and Rees 1996). These estimates are then converted to global hectares (gha). The term "global hectare" refers to the average biological productivity of the world's land and water area (Ewing et al. 2009, 8). Because ecological footprint estimates and available biocapacity are both measured in global hectares, the ecological footprint allows a comparison between the supply and demand for nature's services (Ewing et al. 2009). This enables assessment relative to biocapacity thresholds for a variety of ecosystem types, thereby expanding the scope of analysis beyond that which can be measured by a carbon footprint, for example, with its singular focus on carbon sink capacity.

The use of locally derived data in the component method for ecological footprint analysis is preferred for urban policy purposes (A. Fournier, personal communication, November 27, 2009; Seyfang 2009; Aall and Norland 2005; Barrett et al. 2002). According to Barrett et al. (2002) this component method was first documented by Simons and Chambers (1998). The component method supports claims by Rees and Wackernagel (1996, 231) that "unlike ordinary measures of total resource use, ecological footprint analysis provides secondary indices that can be used as policy targets." However, in practice a hybrid approach that relies on local consumption data to the extent that it is available is combined with national statistical data to derive the footprint (Aall and Norland, 2005). The challenge to secure relevant data for sub-national EFA, particularly at the municipal scale continues (Xu and San Martin 2010; Wilson and Grant 2009).

EFA is criticized in the literature for its limited scope (Weidman and Barrett 2010; Fiala 2008; Mcmanus and Haughton 2006; Aall and Norland 2005; Nijkamp et al. 2004; van Kooten and

Bulte 2000; Van den Bergh and Verbruggen 1999). Other criticisms rest primarily on issues pertaining to: aggregation of data and boundary definition of the study area (Weidman and Barrett 2010; Fiala 2008; McManus and Haughton 2006; van Kooten and Bulte 2000; Van den Bergh and Verbruggen 1999); a singular focus on land as a unit of measure and the exclusivity of land uses (Fiala 2008; Mcmanus and Haughton 2006; Yencken and Wilkinson 2000); singular focus on greenhouse gas emissions (Fiala 2008) or more precisely carbon dioxide emissions (Nijkamp et al. 2004; Ayers 2000; Van den Bergh and Verbruggen 1999) to express waste; lack of transparency and available data (Wilson and Grant 2009; Aall and Norland 2005); inconsistency of method (Curry et al. 2011); and lack of capacity by local government to undertake EFA analysis (Curry et al. 2011; Wilson and Grant 2009; Aall and Norland 2005). This last criticism is linked to use of input-output analysis (Wilson and Grant 2009).[13] However, many of these arguments have been refuted (Kissinger 2008; Rees 2006a; 2000b; Barrette et al. 2005), and the positive attributes of the ecological footprint have secured local government interest in EFA and its potential use as a policy tool (Weidmann et al. 2006; Collins and Flynn 2006; Aall and Norland 2005). Nevertheless, it is important to bear in mind that the ecological footprint is an index of demand for biophysical goods and services and not a comprehensive indicator of human-induced environmental impacts including pollution, geological excavation, disruptions in hydrological flows, etc. In other words the ecological footprint does not assess all of humanity’s demands on nature and as such provides only a single, albeit important, lens through which to assess ecological unsustainability.

[13] An additional criticism laid at input-output analysis deals with the issue of proportionality because dollars are assumed to be a reliable proxy for physical flows (Levett 1998).

1.7.4 One-Planet Living

The concept of one-planet living adopts the fair Earthshare target, of 1.8 global hectares per capita, and relies on the ecological footprint as its primary metric (James and Desai 2003).[14] Sustainable urban development approaches including: bioregionalism, circular metabolism, compact cities and eco-villages inform a vision for one-planet living that comprises a series of small, interconnected, high-density, mixed-use, pedestrian oriented communities that are well served by transit, produce their own heat and power locally without relying on fossil fuels, keep waste to a minimum, and are surrounded by space for: recreation, wildlife habitat, and growing food (James and Desai 2003; Desai and Riddlestone 2002). Each community is oriented around a transportation interchange and envisioned as "a distinct element within the unified whole" of the city (James and Desai 2003, 17).

The vision is similar to what is proposed in the sustainable urban development literature generally (Downton 2009; Newman and Jennings 2008; Register 2006; Jenks and Dempsey 2005; Viljoen 2005; Roseland 1997; Girardet 1996) and what is informed by complex systems theory specifically (Rees 2012; Batty 2005; Odum and Odum 2001). With regard to the sustainable urban development literature, these visions, in-turn, originate from the works of: Ebenezer Howard's *Garden Cities of To-morrow* (c. 1898); Patrick Geddes (c. 1915) *Cities in Evolution*, and Lewis Mumford's body of work (c. 1930-60) that advocate for the re—integration of country-urban linkages, a whole systems perspective, fostering of human ecology and an orientation to the bioregion (Register 2006; Wheeler 2004; Haughton and Hunter 1994; Aberley 1994). Indeed, Mumford's articulation of an ideal city (as reported by Wheeler 2004)

[14] Estimates vary. For example Rees (1995) cites a value of 1.5 gha/ca whereas Desai and Riddlestone (2002) cite a value of 1.9 gha/ca. More recently, projected targets for the year 2020 of 1.2 gha/ca and 1 tCO_2/ca have also been articulated (BioRegional 2011).

maps almost precisely to that articulated in a vision for one-planet living as "an organic community, designed on a human scale, oriented towards human needs, fueled by a life-enhancing economy, surrounded by undeveloped lands, and with streets filled with people instead of automobiles" (Wheeler, 2004, 21). The thread of these early visions can be traced through a lineage of subsequent writers including: Howard Odum (*American Regionalism*, c. 1938), Kevin Lynch (*Good City Form*, c. 1981), Christopher Alexandre et al. (*A Pattern Language*, c. 1977), Ian McHarg (*Design with Nature*, c. 1969) among others (Haughton and Hunter 1994; Aberley 1994). Aberley (1994) also cites Aldo Leopold and Ludwig von Bertalanffy as thinkers that influenced Geddes and Mumford. Therefore, although one-planet living may not add anything new conceptually to a vision for urban sustainability, it does make explicit a link between vision and performance assessment using EFA and the notion of a fair Earthshare.

BioRegional has developed the following ten guiding principles:[15]

i) Zero Carbon – build energy efficient buildings with 100% renewable energy.

ii) Zero Waste – reduce, reuse, recycle/compost, and send zero waste to landfill.

iii) Sustainable Transportation – reduce emissions and the need to travel.

iv) Sustainable Materials – source locally, renewable, low-embodied energy products.

v) Sustainable Food – choose seasonal, organic, locally produced with low-impact.

vi) Sustainable Water – use and re-use efficiently with attention to floods and pollution.

vii) Land Use and Wildlife – protect and restore biodiversity and natural habitats.

viii) Culture and Heritage – strengthen local identity and participation in the arts.

ix) Equity and Local Economy – support fair trade and employment in the bioregion.

[15] Adapted from www.oneplanetliving.org

x) Health and Happiness - facilitate happy and meaningful lives, health and wellbeing.

Again, these principles generally echo those identified in the sustainable urban development literature (Wheeler and Beatley 2009; Newman and Jennings 2008; Register 2006; Jenks and Dempsey 2005; Newman and Kenworthy 1999). Initiatives under the one-planet living banner include: BedZed (Beddington Zero Energy Development), a brownfield redevelopment site near London, and the restructuring of Brighton, an existing community also near London (www.oneplanetliving.org). Several other initiatives are promoted by BioRegional as one-planet living communities including: Sutton and Manchester in the UK; Masdar in the United Arab Emirates, Jinshan in China, and Sonoma Mountain Village in the USA (www.bioregional.com). A similarly inspired approach called SuN Living is also being tested in Emerald Hills, Alberta (Mayhew and Campbell 2008). Whether any of these communities can achieve the one-planet living goal remains to be seen.

One-planet living provides a framework for sustainable urban development that serves both as a call to action and as a means for monitoring progress using EFA. The benefit is two-fold. First, the fair Earthshare target sets a limit to personal demand for ecological goods and services. By adopting the fair Earthshare target, the concept of one-planet living communicates the parameters or "window of vitality" for personal consumption and establishes a benchmark against which progress can be measured. This creates a context in which feedback can occur. People and cities can assess their ecological footprint relative to the fair Earthshare target, and by continually assessing their footprint they can determine their progress and adjust behaviour accordingly. They are informed and can choose to act in communion with positive agency.

Second, by using a metric that is scalable, the target for one-planet living links agents (i.e. people) to the emergent structures (e.g. cities) and behaviours (e.g. trade) of the urban system of which they are part. In this way one-planet living informs the emergence of a one-planet city.

2 Introducing Vancouver as the Case for Analysis

This research comprises an exploratory case study (Yin 2005) that uses ecological footprint analysis (Wackernagel and Rees 1996) to inform policy directed at enabling one-planet living. I focus on municipal government because it has authority for land-use planning decisions and several factors lend support to a focus on the City of Vancouver specifically. By contrast, the regional metropolitan government of which Vancouver is part oversees delivery of utility services and management of unincorporated[16] lands but does not have direct land use planning authority. As noted in chapter 1, Vancouver is held up in the urban planning and urban sustainability literature as an example of a sustainable city (Wheeler and Beatley 2009, 429; Register 2006, 131; Wheeler 2004, 120) despite exceeding per capita ecological carrying capacity (Rees 2009, 2010; Boyd 2009; Sheltair 2008; Wilson and Anielski 2005). This contradiction demands further investigation, especially since the ecological footprint was invented at the University of British Columbia's Vancouver campus. The City of Vancouver has strong discretionary planning powers thanks to the *Vancouver Charter* (see details below). More recently, Vancouver has put the sustainability spotlight on itself stating an intent to become the world's "Greenest City" which includes in initiative aimed at achieving one-planet living (COV 2011a). These factors position the City favourably in terms of a unique ability to implement policies aimed at one-planet living.

[16] Unincorporated lands are rural areas that are not part of a municipality. In southwester BC, these lands tend to be forested areas such as watersheds and small islands; agricultural land generally falls within municipal jurisdiction.

2.1 Introduction to the Case Study

The City of Vancouver, defined by its municipal boundaries and legal powers granted by the Province of British Columbia through the *Vancouver Charter*, comprises an area of 11,467 hectares (Metro Vancouver 2006a). The population at the time of the 2006 census was 578,041 (Statistics Canada 2006a). Although Vancouver's population has grown since then, the research uses 2006 as the base year for analysis because this was the most recent census data available at the time of the study, and therefore, most of the data required to undertake the research was available for this year.

In 2006, Vancouver had an average density of 50 people per hectare, making it the most densely populated municipality among the 21 municipalities that comprised Metro Vancouver (Statistics Canada 2011). Vancouver is also Canada's most densely populated city (Statistics Canada 2011). Multi-family apartment dwelling constituted 59% of total housing, followed by ground-oriented, attached dwellings (22%) and single detached dwellings (20%) (Metro Vancouver 2007a). Surprisingly, however, over one-third of Vancouver's land area was dedicated to single family detached and duplex housing (37%) and almost another third was used for roads, including communication, utility and lane right-of ways (27%). The remaining land area comprised: multi-family residential and mixed use housing (9%), commercial and institutional (8%), industrial and port lands (4%), agricultural land (1%), and recreational, open space and natural areas (14%) (Metro Vancouver 2006a).

Vancouver's history follows the evolutionary trajectory of cities through their development phases of industrial, post-industrial, and post-modern, from cities as sites of production to cities as sites of consumption (Ley 1996). Founded in 1886, Vancouver served as an industrial port for the processing and shipping of BC's natural resources and as a terminus of the Canadian Pacific Rail line that united Canada (Berelowitz 2005; Punter 2003). Although Vancouver never reached a fully developed industrial capacity (Hutton 2008, 2004; Ley 1996), during the 1950s, the City was the headquarters for several resource-based companies (Punter 2003). However, by the 1980s Vancouver had transitioned to a post-industrial city (Punter 2003). Today, though the port still serves an important function, Vancouver's economy is also driven by tourism and film (Punter 2003). Vancouver's evolution has resulted in an urban economy that largely relies on small and medium sized enterprises specializing in consumer goods and services (Hutton 2008; Ley 1996). Seventy percent of the businesses in Vancouver employ fewer than ten people (VEC 2011). These businesses are diverse comprising one third office workers, one third retail and hospitality, and the remaining distributed predominantly between manufacturing and health care, followed by construction, creative services, and transportation (VEC 2011).

2.1.1 Vancouver the Sustainable City

Through the 1990s and 2000s Vancouver gained an international reputation as one of the world's most livable and sustainable cities (Wheeler and Beatley 2009; Register 2006; Beatley 2004; Berelowitz 2005; Punter 2003). The genesis for this distinction tracks to the granting of the *Vancouver Charter* by the Province of British Columbia in 1953. The *Vancouver Charter* is a unique piece of legislation that singularly allows the City of Vancouver to exercise far greater authority over its domain than is enjoyed by other municipalities in BC. Through the *Vancouver Charter*, the City has introduced discretionary zoning, development controls over height and views, development cost levies and amenity cost-charges, heritage conservation and transfer of development rights. These tools enable the City to respond innovatively to changing circumstances and needs (Punter 2003).

Shortly after the adoption of the *Vancouver Charter* in 1956, City council introduced new zoning to allow high density development in the West End of Vancouver's downtown peninsula and also in the Kitsilano neighbourhood. The population in the West End doubled between 1950 and 1980, stimulated by demand for housing in close proximity to the central business district (Punter 2003). Despite the increase in population density, however, the size of living units also increased. High-rise residential development offering larger suites and balconies replaced the smaller unit, three story low-rise buildings that had stood before (Punter 2003). Furthermore, the manifestation of high-density directly adjacent to one of the largest urban parks, Stanley Park, with close proximity to nature including the ocean and nearby mountains served to attract residents (Boddy 1994 in Punter 2003) and bolster the City's livability (Register 2006). Thus, the City's distinguishing feature: its ability to combine high-density with high amenity living (Punter 2003) was born along with its endemic challenge to maintain social inclusion through protection of affordable housing choices.

Paralleling Vancouver's rise to fame as a livable city is the story of Vancouver's emerging social and environmental activism. The Non-Partisan Association (NPA) ruled City council for 30 years (starting in the 1940s), and through the 1950s and 1960s City planning was driven by Council working directly with development interests and planning staff without input from other citizens (Punter 2003; Harcourt et al. 2007). Indeed, even the high density development of the West End was initiated by the business community who wanted to bring shoppers closer to the central business district (Punter 2003). However, in 1968, Vancouver residents from the Strathcona neighbourhood successfully confronted the City's plans to demolish homes and build a freeway through downtown (Harcourt et al. 2007). Then, in 1972, "The Electoral Action Movement (TEAM)" wrested control of City council from the NPA (Hutton 2004; Punter 2003; Harcourt et al. 2007). TEAM ushered in a new and more democratic approach to land use planning, advocated by Alderman Walter Hardwick. Hardwick, a Geography Professor at the University of British Columbia (UBC,) promoted a vision for the City as a "livable city through good planning practice" (Punter 2003, 26). TEAM hired a new Director of Planning, Ray Spaxman, who oversaw the reorganization of the planning process through reforms to permit processing and refined uses of discretionary zoning, the introduction of new design goals and guidelines, and activation of Official Development Plans (ODPs) to guide development (Punter 2003).

The first ODP to be developed, in 1974, was for False Creek South. The "brainchild" of Hardwick and his students who developed a concept for the project in 1965 (Punter 2003, 34), False Creek South is arguably Vancouver's first living laboratory of sustainability. The redeveloped industrial lands follow design principles informed by the work of McHarg (*Design with Nature*, 1969), Lynch (*Image of the City*, 1960), and Jacobs (*The Death and Life of Great American Cities*, 1961) among others and feature (Punter 2003, 37-9):

- Social mix of incomes and variety of tenures, including retention of some land ownership by the City;
- Compact, clustered, ground-oriented housing designed to promote social interaction;

- Range of dwelling types from townhomes to multi-unit and multi-storied buildings;
- Terraced and landscaped roofs and balconies, complemented by landscaped private and semi-private “outdoor rooms;”
- Protection of solar axis and maximum daylight penetration in suites;
- Articulation of views to both the community, e.g. eyes on the street, and farther reaching vistas;
- Preservation of adaptability through a hierarchy of open space that gives primacy to large public open spaces linked by pedestrian pathways to semi-private and private yards.

With 47% of the land dedicated to park and 40% dedicated to housing, False Creek South demonstrates strategic use of density to maximize open space (Punter 2003). At build-out, in 1981, densities ranged from 35-65 units per hectare (Punter 2003).

The second ODP to be put forward in 1975 was for the downtown central area. It called for “lively, safe, attractive” streets and public amenities balanced with well-designed private residences (Punter 2003, 73). The formula for a compact, mixed-use, urban centre was born. The economic downturn in 1982 lent further support to the plan through a reduced demand for commercial space that triggered planners to reappraise their forecasts for business’ requirements in the downtown central business district (Punter 2003). In 1986, the Expo86 world’s fair was held in Vancouver resulting in senior government infrastructure investments and an international marketing opportunity for the City (Murray and Hutton 2012; Punter 2003). Punter (2003) perceives Expo 86 as the catalyst that began a long trend of marketing Vancouver real estate directly over seas that persisted through the 1990s and 2000s with development of mega projects in Coal Harbour and False Creek North, among others. Indeed, by the late 1980s, an obsession with views coupled with an influx of Asian immigration and foreign direct investment in real estate that drove demand for condominium development at premium prices created a strong stimulus for residential development in the downtown (Murray and Hutton 2012; Berelowitz 2005; Punter 2003). These factors: an ODP that enabled residential development in the central business district coupled with strong demand for urban real estate from Asian markets further entrenched one of Vancouver's most interesting paradoxes. On the one hand, Vancouver achieved the highly compact and mixed-use urban form that characterizes the City's downtown peninsula and proliferation of high-rise development around False Creek. On the other hand, during this same period Vancouver lost half of its affordable housing in the downtown as lower income properties were replaced by premium, high-density and high amenity residences that were marketed directly to more affluent, overseas buyers (Punter 2003). Trading livability for affordability remained one of Vancouver's most challenging predicaments. A second challenge was managing the tension between a desire to engage citizens in planning their city and a desire by Council and planning staff to appease developer's seeking high returns on their investments. By 1986, the NPA had regained control of Council and efforts were underway to curtail the extensive public engagement processes and relative autonomy in discretionary powers enjoyed by the planning department under TEAM (Punter 2003). Following these changes, in 1989, Ray Spaxman resigned as Director of Planning (Punter 2003).

By 1990, Larry Beasley was the Associate Director of Planning for the Central Area and Ann McAfee was the Associate Director for General Planning; they eventually became the codirectors of Vancouver's Planning Department in 1994. Also in 1990, City Council unanimously adopted the *Clouds of Change Report* (COV 1990) marking the City's first official commitment to climate action. The Report was prepared by a specially designated citizen's Task Group on Atmospheric Change that was co-chaired by Professor William Rees, from UBC's School of Community and Regional Planning, and Professor Robert Woollard, Dean of Family Practice, in the Faculty of Medicine at UBC. The report called for 35 recommendations that covered energy-efficient land use and energy conservation measures including: prioritization for transit, cycling and walking; energy efficient buildings; and the re-instatement of the City's Special Office of the Environment (SOE) (COV 1990). Dominic Losito, the City's Environmental Health Manager assumed SOE leadership with participation from various municipal departments including engineering and building permits. The SOE was charged with monitoring and reporting on implementation progress of the *Clouds of Change Report's* recommendations (Moore 1994). The Report called for a 20% reduction of greenhouse gas emissions below 1988 levels to be achieved by 2005. Furthermore, all major development projects undergoing rezoning required an official comment to Council by the SOE about anticipated impacts towards achieving the report's objectives (COV 1990).

In 1991, City council adopted the Central Area Plan (Murray and Hutton 2012; Hutton 2004). It created a more compact business district, allowing deeper penetration of residential and mixed land uses within the downtown peninsula. Close proximity of jobs and housing allowed for a "New Economy" in the inner city to take shape (Hutton 2004, 1955). These planning efforts played a decisive role in shaping the trajectory of Vancouver's subsequent development (Murray and Hutton 2012; Hutton 2004). Also in 1991, Vancouver council launched the CityPlan process to engage a wide spectrum of people from across the City to think about the future of their neighbourhoods and articulate a vision for the City. The final outcome, presented in 1995, was a vision for a "city of neighbourhood centres" (Punter 2003, 162). It featured improved community safety and services, reduced need to travel by car, variety and affordability of housing, diversity of parks and public places, and greater participation by citizens in decision-making (Punter 2003; COV 2011b). The outcomes of CityPlan appear to embrace sustainable development (Punter 2003); however, I argue that this reading masks many residents' desire to retain a suburban lifestyle. Through the CityPlan process, residents also articulated their preference to retain the single family character of neighbourhoods from Dunbar in the west to Cedar Cottage in the east (Punter 2003). "Concentrating development in neighbourhood centres would have less impact on existing low-density neighbourhoods" (Punter 2003, 165). And, although secondary suites were supported, infill housing was not. The bias towards a "low density, green village character with limited development" prevailed (Punter 2003, 170).

Nevertheless, in contrast to the polite NIMBYism[17] evident through CityPlan, a palpable activism was brewing in the City, aimed at advancing social equity and ecological integrity. In 1994, environmental and social activists held the "Greening Our Cities" conference in Vancouver that culminated with a pledge by participants to work towards the sustainable development of the City and its region (Carr 2004, 221). This marked the birth of Vancouver's Eco-city Network that was launched the same year to enable non-government organizations and grass roots interests to advance a sustainability agenda (Carr 2004; Moore 1997). The Network served as a forum for activists to collaborate towards the achievement of

[17] NIMBY is an acronym for Not in My Back Yard.

sustainability within their communities, including spurring on the implementation of the recommendations in the *Clouds of Change Report*. Participants in the Network came from a wide background of community organizers, non-government organizations, academics, municipal elected officials and staff. Many participants had also participated in developing *the Clouds of Change Report* or were participating in assessing its ongoing implementation.[18]

One of the initiatives called for in the *Clouds of Change Report* was the re-development of the industrial zoned Southeast False Creek lands as a model sustainable community (Sussmann 2012; Punter 2003; Moore 1994; COV 1990). In 1994, City Council asked the SOE to explore with the City's Real Estate Division the potential for sustainable development of Southeast False Creek (Punter 2003). This initiative was also subsequently targeted for action by the Eco-city Network who in collaboration with a range of community organizations and neighbourhood associations formed the Southeast False Creek Working Group to advocate for a community-oriented development that pushed the limits of green performance (Sussmann 2012; Carr 2004; Moore 1997). In 1996, the City Manager's Office, again in collaboration with the Real Estate Division, commissioned a study of the Southeast False Creek lands following the model used to develop North False Creek and Coal Harbour, aimed at generating maximum revenues (Sussmann 2012; Punter 2003). It was the activism of the Southeast False Creek Working Group that "convinced council that sustainability was something worth pursuing" (Punter 2003, 230). This observation draws attention to the role of social and environmental activism in the City as an important driver in Vancouver's sustainability leadership (Sussmann 2012; Carr 2004). Yet,

[18] I am included in this group and I served as a founding member and coordinator of the Eco-city Network.

residents are not unified. The outcomes of CityPlan reveal a fragmented citizenry, some favouring traditional suburban development and some who want a more sustainable approach.

In 1997, the City struck the Southeast False Creek Advisory Group, including subject matter experts,[19] land owners, residents from neighbouring South False Creek, and representatives from the Southeast False Creek Working Group to develop a policy to guide the model sustainable community development (Sussmann 2012). The Southeast False Creek Policy Statement was delivered to council and unanimously adopted in 1999 (Punter 2003). However, many of the environmental performance targets that the Advisory Group recommended were stripped from the actual document and supplied in an appendix to the report instead (Sussmann 2012; Punter 2003). This action was taken to appease concerns that the targets being put forward were unachievable, or uneconomic (Sussmann 2012). To this, the Advisory Group responded with a request that their role be transitioned, subsequent to the adoption of the Policy Statement, to become a “Stewardship Group” that would serve in both a watch-dog capacity to ensure that the intention of the policy be upheld through the ODP phase, as well as to help orient new residents to sustainability upon occupancy. This move is lauded in the literature for its innovative foresight (Punter 2003).

In 2004, the City launched the Sustainability Office, replacing the SOE (Lee 2010). The Sustainability Office reports to the City Manager’s Office and includes the climate action portfolio along with green buildings and a range of other initiatives. Staff serves as a resource to the various departments in City Hall. In 2006, under an NPA council led by Mayor Sam

[19] I was a member of the Southeast False Creek Advisory Group, serving in the capacity of energy specialist. John Irwin was the representative from the South East False Creek Working Group.

Sullivan, Brent Toderian was hired as the new Director of Planning, following the retirement of Beasley and McAfee. Toderian's selection was supported by Beasley who mentored Toderian as a young planner working in Calgary. Immediately, Toderian set to work developing an "EcoDensity" charter. EcoDensity was passionately supported by Mayor Sullivan, who participated in the Eco-City Network as a City of Vancouver councillor (Carr 2004) prior to his tenure as Mayor. He coined the term EcoDensity, and the *EcoDensity Charter* was unanimously approved by council in 2008. The *EcoDensity Charter* (COV 2011b) commits the City to prioritize environmental sustainability in its planning decisions while retaining values of livability and affordability. It builds on the vision put forward through *CityPlan* and climate action leadership initiated through *The Clouds of Change Report*, and focuses on adapting the City and ways of life of its residents with the aim of achieving a "more sustainable, affordable and livable" future (COV 2011b). The *EcoDensity Charter* (COV 2011b, 4) proposes that the City move toward becoming an "Eco-city" and references similar objectives to those articulated in the sustainability literature for: "… green energy and waste systems, affordable housing for all, … urban agriculture and local food access…" It also proposes infill and laneway housing (COV 2011b, 4); something that residents said they did not support through the *CityPlan* process. Finally, while the *EcoDensity Charter* mentions the ecological footprint it does not specifically call for its use as a metric to assess progress towards achieving ecological sustainability (COV 2011b).

In 2009, however, a council dominated by the newly minted Vision Vancouver party, led by Mayor Robertson, adopted a new initiative aimed at making Vancouver the Greenest City. *Vancouver 2020: A Bright Green Future* (Boyd 2009) is the title of the ten point action plan proposal developed by a Mayoral appointed Greenest City Action Team. The initiative aims to enable Vancouverites to achieve a "one planet ecological footprint" (Boyd 2009, 14) by focusing on developing a green economy, green communities, and protecting human health. The *Greenest City 2020 Action Plan* articulates how the City will implement these points and was officially adopted by council in July 2011 (COV 2011a).

2.1.2 Vancouver the Consumer City

A strong planning regime based on political consensus about the importance of the City's livability, environmental quality, and participatory planning are frequently cited as merits worthy of Vancouver's sustainable city label (Punter 2003). The City has achieved the lowest per capita greenhouse gas emissions in North America and is a leader in building construction (Boyd 2009). However, contrasting the story of Vancouver as a sustainable city is its evolution as a consumer city. Vancouver's sustainability is contested in the literature on the grounds of its consumerist orientation to lifestyle (Berelowitz 2005; Punter 2003; Ley 1996) that results in the use of natural resources above ecological carrying capacity (Rees 2009; Berelowitz 2005; Wackernagel and Rees, 1996). Berelowitz (2005, 25) goes so far as to observe that: "Vancouverites tend to over-idealize their place in the world as a natural paradise and to underestimate their impact on it." He remarks further that: "Vancouver's apparently happy co-existence with its natural environment is far more ambiguous than it would have the world (or itself) believe" (Berelowitz 2005, 37). Vancouver is also home to extreme economic polarization including some of the wealthiest and the poorest postal codes in Canada (Murray and Hutton 2012).

Indeed, the City of Vancouver has the characteristics of what is described in the literature as a "consumer city." In contemporary analysis, consumer cities emerge from the post-modernism era with its effects of gentrification, spatial fragmentation and social-polarization (Ruppert 2006; Ley 1996). The successive emergence of the consumer city as a post- modern phenomenon can be traced to the role of "consumption as a major engine of urban social change" that includes issues of urban redevelopment and lifestyles (Ruppert, 2006, 89). Consumer cities reflect the increasing wealth of citizens who can vote with their feet and move to preferred locations, regardless of work or other socio-economic obligations. Attributes of consumer cities generally include: a mild and sunny climate and proximity to the coast; high levels of human capital including education and income; and reverse commuting, where citizens who live in the central business district commute to suburbs (Glaeser et al. 2001) or other countries.

"Selected efforts to attract mega-events by its community leaders" (Murray and Hutton 2012, 314) contributed to Vancouver's emerging cultural tourism economy. When coupled with the City's bio-physical attributes this economic trajectory strengthens Vancouver's characterization as a consumer city and reflects its mature development as a post-modern, transnational city (Hutton, 2008). The migration of economic activity from Vancouver proper to the suburbs and the introduction of regional town centres, followed by additional layering-in of neighbourhood centres (Murray and Hutton 2012; Hutton, 2008) marks the transition of Vancouver, and the metropolitan region in which it is situated, to a postmodern expression of development. Vancouver's transition to a consumer city is further revealed by a continued fracturing of land-use driven by land economics that favour commercial development in low-density suburban areas (i.e., commercial parks) and residential development in high-density urban centres that can command a premium. Even the desire on the part of the City's officials (i.e., council and staff) to turn Vancouver into the world's greenest city represents an expression of "green consumerism." It is belied by the hopes that economic activity can be generated through: a) tourism, based on people visiting the City to learn about how it achieved sustainability, and b) export of technology and consulting services to help people in other cities achieve sustainability following Vancouver's model (Boyd 2009). This characterization of cultural economy, with an emphasis on tourism, can also be seen as a reflection of the emergence of the consumer city (Hutton, 2008).

2.1.3 A Tale of Two Cities?

City officials' desire for Vancouver to become sustainable may be one of the City's most "sustainable" attributes. Fainstein et al. (1983, 1) observe that cities are constantly being reproduced through a "complex interaction of private and public decisions" where socio-economic conditions represent fast cycles of change and physical conditions represent slow cycles. Thus, while the aspirations of Vancouverites are significant to the future direction of the City's evolution, its legacy of physical infrastructure, i.e. the built environment, represents a challenge to the City's ability to effect change in the near term. Nevertheless, Frey (1999) positions the task of urban planning to enhance the city's advantages and reduce or eliminate its disadvantages. This includes a focus on social engagement of the citizenry in sustainability coupled with near-term initiatives to leverage aspects of the built environment that enable citizens to choose more sustainable lifestyles, while simultaneously removing barriers and directing long-term plans towards a sustainable urban form.

Certainly the City of Vancouver can point to evidence of sustainability as a value in its municipal planning and management efforts. Examples include its leadership to address climate change, commencing with the adoption of the 1990 *Clouds of Change Report*; densification of the downtown through adoption of the *Central Area Plan* in 1991; efforts to develop Southeast False Creek as a model sustainable community (1997-2010); formation of a "Sustainability Office" (c. 2004); adoption of the *EcoDensity Charter* subsequently rebranded as an "EcoCity" charter (2006-2008);[20] articulation of its aspiration to become the world's greenest city (2009-2011); and hosting of the 2010 Winter Olympics predicated on delivering a "sustainable games." In this regard, the urban regime that sets the context for local governance appears supportive of sustainability, reflecting Wheeler's (2009) prediction of an emerging ecological worldview as the next era to super-cede post-modernism. The ecological worldview is influenced by "(e)cological science; chaos theory; systems theory. … (It e)mphasizes interrelationships, networks, systems" and "(a)cknowledges pluralism but also a shared core value set based on common problems" (Wheeler, 2004, 30).

However, juxtaposed with the desire to become the world's greenest city is the fact that Vancouver comprises a diverse community with diverging interests. For example, a growing majority (52%) of the City's residents are immigrants, most of whom (25%) hail from Chinese origin (Punter 2003). The cultural beliefs and values of this group will undoubtedly play a strong role in the unfolding path that the City takes. Indeed, whereas Punter (2003) observes that Asian immigration in the 1980s drove the condominium market, assisting Vancouver to achieve

[20] A December 2010 Planning By-Law Administration Bulletin entitled *EcoCity Polices for Rezoning of Large Sites* issued by the City of Vancouver Director of Planning notes that henceforth the *EcoDensity Charter* would be referred to as the *EcoCity Revised Charter*.

a super-compact central area, today Ley (2010) notes that Asian immigrants show a decided preference for the single-family detached homes typical of the more sprawling neighbourhoods within the City, e.g., Dunbar, Shaughnessy and Kerrisdale.

Structural formation of the city is stimulated by global economic processes, and it is also influenced by local urban policies and management strategies (Hutton; 2009). The latter are, in turn, determined by socio-political values and cultural norms (Hutton, 2008). Therefore, global and local drivers of change exist in iterative tension, each acting on the other in a dialectical production and reproduction of urban form and culture (Hutton 2004). How Vancouver: its elected officials, public servants, residents and business owners navigate this tension may be the most important factor in determining the City's sustainability outcomes.

2.2 Vancouver's Regional Context

The City of Vancouver is situated at the western edge of Metro Vancouver's Burrard Peninsula, located in the southwestern corner of the Province of British Columbia, on the west coast of Canada. The peninsula is bordered by the Fraser River to the south, the Strait of Georgia to the west, and Burrard Inlet to the North. To the east the land stretches up the Fraser Valley. Only Vancouver Island and the Pacific Ocean lie west of Vancouver. Surrounding Vancouver to the North, East and South is the metropolitan region, Metro Vancouver, that includes some of Canada's most fertile agricultural land; the delta of one of Canada's largest rivers: the Fraser River; forested mountains; and coastal shores with salmon, crab and smelt fisheries (Hutton 2011). A moderate climate supports commercial agriculture (Carr 2004), and deep sea ports both in Burrard Inlet and the mouth of the Fraser River allow for extensive shipping and industrial activities along the foreshore.

In 2006, the study year for this research, the region was home to 2,116, 581 people (Statistics Canada 2006b) spanning an area of 283,183 hectares (Metro Vancouver 2006a).[21] Adjacent to Metro Vancouver is the Fraser Valley Regional District, which is predominantly rural comprising mostly agricultural farmland that is part of the Fraser River flood zone. In 2006, it was home to an additional 257,031 people and spanned an area of 133,617 hectares (Statistics Canada 2006c). Together, the lands within Metro Vancouver and the Fraser Valley Regional District comprise the Lower Fraser Valley, representing that portion of the local bioregion that falls within Canada. This river delta and its watershed comprise part of the larger Fraser Basin drainage area. It is bordered to the northeast by the Coast Mountains and to the southeast by the Cascade Mountains. These mountain ranges converge at the far eastern point of the Fraser Valley giving the region its triangular shape. The mountains also form the bases for the regional air-shed. The valley fans out as one heads westward and is intersected to the south by the United States Border (Carr, 2004, 227).

Approximately sixty percent of Metro Vancouver's land area is protected in the "Green Zone" comprising: agricultural land (19%), watersheds (17%), natural and recreational areas (24%). An additional 9% is open or undeveloped land. Almost fifteen percent of the region's land area comprises residential development of which: 3% is rural and 10% is urban or suburban single-detached and duplex housing, 1% is in townhouse development, and the remaining 1% is in multi-family and mixed use residential high-rise and low-rise development. Nine percent of the

[21] Population and land area include City of Vancouver. Statistics Canada (2006b) reports a slightly larger area (287,736 ha) which may include unincorporated lands adjacent to the region.

region’s land is devoted to industrial, commercial and institutional uses. Eight percent is used for roads and utility right-of ways (Metro Vancouver 2010).

Metro Vancouver comprises four legal entities that, in 2006, delivered regional utility and development services to twenty-one member municipalities, including the City of Vancouver. Although the phrase Metro Vancouver is currently used, the legal names of all four entities use “Greater Vancouver” as follows. The Greater Vancouver Housing Corporation provides affordable housing to over ten thousand people (Metro Vancouver 2011a). The Greater Vancouver Regional District oversees the coordination of growth management in cooperation with its member municipalities, air quality protection, and management of multiple regional parks. The Greater Vancouver Water District oversees the watershed lands that surround three coastal mountain watersheds from which the metropolitan region, including the City of Vancouver, derives its drinking water supply. The Greater Vancouver Water District also operates three drinking water treatment facilities within the watershed and a man-made reservoir, Little Mountain, located within the City of Vancouver. The Greater Vancouver Sewerage and Drainage District operates five wastewater treatment facilities, of which one: the Iona wastewater treatment plant treats all of the City of Vancouver’s wastewater. The Greater Vancouver Sewerage and Drainage District also oversees solid waste management including operation of five waste transfer stations that collect and sort recycled materials and organize municipal solid waste to be transferred either to the Waste-to-Energy Facility, where waste is incinerated, or to landfill. There are two municipal solid waste landfills. One is operated by the Greater Vancouver Sewerage and Drainage District and is called the Cache Creek Landfill, located outside the region some 500 kilometres away. The other, the Vancouver Landfill, is owned by the City of Vancouver but is located in the Corporation of Delta, another member municipality comprising Metro Vancouver. The Waste-to-Energy Facility is a municipal solid waste incinerator located in Burnaby, a municipality within Metro Vancouver. It is also operated by the Greater Vancouver Sewerage and Drainage District. It supplies some electricity back to the BC Hydro electrical grid as well as steam to nearby industries. Several privately owned demolition and land clearing landfills also operate throughout the region. In 2006, Metro Vancouver achieved a 52% waste diversion rate through its various recycling and product stewardship programs (Metro Vancouver 2006b). For the City of Vancouver, in terms of the solid waste it disposed in 2006: approximately 75% was disposed to the Vancouver Landfill, 7% was disposed to the Cache Creek Landfill, and 14% was disposed to the waste-to-energy facility (COV 2007a; Petre personal communication, July 27, 2010).

Regional transportation services are delivered through TransLink, legally known as the Greater Vancouver Transportation Authority. It functions as a sister agency to the Greater Vancouver Regional District and is obligated to coordinate its transportation planning services with the region's growth management plans. TransLink oversees the operation of five subsidiary companies providing: i) bus and sea-bus service, ii) regional elevated light-rapid rail system known as SkyTrain, iii) commuter rail, iv) local car ferry, v) AirCare vehicle emissions testing facilities (GVTA 2002). A separate federal agency operates the Vancouver International Airport, located in the City of Richmond, located on the south border of the City of Vancouver.

Paralleling the City of Vancouver's articulation of a livable city in the early 1970s, the Greater Vancouver Regional District produced its first vision, calling for *The Livable Region,* adopted in

1975 (Hutton 2011; Murray and Hutton 2012; Carr 2004; Punter 2003). It articulates a future comprising five regional centres, including downtown Vancouver, and an accompanying open space plan. In 1986, the notion that each municipality should be self-contained was added to the plan. In 1996, the Region adopted the *Livable Region Strategic Plan* premised on four strategies: to protect the green zone, to build a compact metropolitan region, to build complete communities, and to increase transportation choice by prioritizing pedestrian, cycling, transit, goods movement and lastly the motor vehicle (GVRD 1999). *The Livable Region Strategic Plan* is predicated on a concept of the metropolitan region situated within its larger bioregion comprising not only the Fraser Valley as described above, but the entire "Georgia Basin and Puget Sound regions" (GVRD 1999, 5). This is an area that extends from Whistler to the North all the way to Olympia, Washington in the South. The *Livable Region Strategic Plan* relies on consensus agreement by all of its member municipalities and is deemed to be the regional growth management strategy by the Province of British Columbia (GVRD, 1999). The *Livable Region Strategic Plan* calls for updating every five years.

In 2002, Metro Vancouver introduced the "Sustainable Region Initiative" that establishes a framework for the development of all new regional plans aligned with sustainability aspirations to protect natural capital assets and live within ecological carrying capacity, promote social justice through inclusive and collaborative governance, and support economic prosperity through efficient use of infrastructure and pricing mechanisms that account for ecological and social costs and equitable distribution of benefits (Metro Vancouver 2011b).[22] The first regional

[22] In my role as Division Manager, Strategic Initiatives at Metro Vancouver I oversaw the development of this framework and the corresponding template for regional plans which was first applied in 2005 to the regions Drinking Water, Air Quality, and Regional Parks plans.

plans to be revised under this framework were adopted in 2005; however, it was not until 2011 that a revised growth management strategy (replacing the 1996 *Livable Region Strategic Plan*) was adopted.[23] The new plan is called *Metro Vancouver 2040: Shaping Our Future* (Metro Vancouver 2011c). The focus is on land use policy to guide regional development towards the achievement of five goals: i) create a compact urban area, ii) support a sustainable economy, iii) protect the environment and respond to climate change impacts, iv) develop complete communities, v) support sustainable transportation choices.

[23] This delay was primarily due to the challenges associated with reaching consensus among the member municipalities regarding the contents of the revised plan.

3 Methods

This chapter describes the methods used to: a) develop Vancouver’s ecological footprint using the bottom-up component method, b) identify and explore policy interventions and changes to urban management practices that have the potential for reducing Vancouver’s ecological footprint to a level commensurate with a fair Earthshare, c) estimate the level of reduction in ecological footprint that could be achieved if the identified policy interventions and changes to urban management practices were implemented, and d) develop a vision of Vancouver as a one-planet city. My approach comprises seven steps:

i) develop lifestyle archetypes,

ii) estimate Vancouver’s ecological footprint,

iii) calculate Vancouver’s sustainability gap,

iv) identify policy interventions and changes to urban management practices,

v) develop baseline estimates for closing Vancouver’s sustainability gap,

vi) analyze options,

vii) develop policy proposals for what Vancouver might look like as a one-planet city.

3.1 Develop Lifestyle Archetypes

The word “lifestyle” means an approach to living, including moral attitudes (Stein 1984). A lifestyle can also be affected by the political, geo-physical, and socio-economic conditions in which a person finds themselves. The word “archetype” means an original pattern, model, or prototype (Stein 1984). In this research, the two words combined describe patterns of living that can be used as prototypes.

I use the concept of "lifestyle archetype" to explore various patterns of living articulated to a fair Earthshare of less than two global hectares per capita. This is commensurate with one-planet living. By correlating consumption and waste data for various cities to their ecological footprint data, I am able to establish a range of consumption benchmarks for: food, shelter, consumables and waste, transportation, and water. I then use these consumption benchmarks to develop a lifestyle archetype for one-planet, two-planet and three-plus-planet living (see table 3.1). Although I acknowledge that socio-cultural factors may have a tremendous impact on personal consumption, the method does not attempt to determine how socio-cultural factors affect consumption. This limitation helps manage the overall scope of the research.

Table 3.1 Lifestyle Archetypes According to Per Capita Ecological Footprint Values

One-Planet Living	Two-Planet Living	Three-Plus-Planet Living
< 2.0 gha/ca	2 to 4 gha/ca	> 4.0 gha/ca

I begin with an analysis of literature for various cities around the world that document household and per capita consumption (WRI 2010; Menzel and Mann 1994; Menzel and D'Aluisio 2005; Holden 2004; Hoyer and Holden 2003; Lenzen, Dey and Foran 2004) and urban metabolism studies (Scotti et al. 2009; Sahely, Dudding and Kennedy 2003; Warren-Rhodes and Koenig 2001; Folke et al. 1997). I compare this to per capita ecological footprint assessments for the same cities (where possible) or the countries in which they are located (WWF 2010a; Scotti et al. 2009; Wilson and Anielski 2005; Hoyer and Holden 2003; Warren-Rhodes and Koenig 2001; Wackernagel 1998). I use the findings to build "international profiles" of what one-planet, two-planet and three-plus-planet living looks like. Each profile includes a qualitative description of personal and household consumption patterns coupled with quantitative data pertaining to both consumption and ecological footprint.

I then use the Global Footprint Network (2010) calculator to develop "super green" lifestyle profiles. The term super green is used by GFN to depict the most sustainable choice in every set of questions presented in the calculator. The calculator uses nationally derived, i.e., compound method, ecological footprint data and a series of questions that allow the user to choose from a range of pre-determined answers to build hypothetical personal consumption profiles for various cities and countries around the world. I run through the questions, always choosing the super green option, for a sample of cities and countries that match those in the international profiles which were developed based on empirical research. I compare the characteristics of the super green scenarios to the findings in the international profiles in order to further probe the lifestyle characteristics associated with one-planet living.

Next, I analyze literature that documents consumption and ecological footprints of "intentional communities" (Giratalla 2010; Hodge and Haltrech 2009; Tinsley and George 2006; Haraldsson, Ranhagen and Sverdrup 2001). An intentional community comprises a group of people, representing several households, who choose to live in a sustainable way. This includes choosing to live in a built environment that is designed to reduce their ecological footprint, e.g. an eco-village. In order to narrow the scope of the research, I focus on intentional communities located in countries that on-average have a per-capita ecological footprint equivalent to three-plus-planet living, i.e., similar to the ecological footprint of the case study city of Vancouver, Canada. I compare the information on consumption patterns and ecological footprint to build profiles of what attempts to achieve one-planet living looks like in intentional communities.

Table 3.2 lists the cities and countries studied according to their respective lifestyle archetype groupings. The table also indicates the different types of data used. Since there are still relatively few urban metabolism studies that are combined with city-level ecological footprint studies, the sampling is determined by what I could find in the literature. Rees (2004) argues that in countries with urbanization levels of 80% or higher it is appropriate to use a national footprint to represent city-level ecological footprints. I have followed this guideline to expand the scope of the sample.

For each archetype grouping, I analyze the household and per capita consumption data documented in field research and/or statistical data sources that describe the number of family members, personal possessions including: motor vehicles; housing type and square footage; consumables including: furniture, appliances, personal electronics, hobby equipment; amount of energy consumed and/or carbon dioxide emissions emitted; and per capita consumption of various foods. I also document statistical data for each selected country, including: average income and human development indicators (e.g. daily caloric intake, literacy, and longevity). Based on these data, I am able to interpret a lifestyle archetype for each grouping including: diet, density (i.e., dwelling space per capita), home energy use, personal consumption (e.g. appliances, personal electronics) and wastes, motor vehicle ownership, transit ridership, air travel, and drinking water use.

My goal is to first understand what one-planet living looks like based predominantly on empirical evidence in order to establish baselines and benchmarks for consumption. I then use this information to explore what one-planet living could look like in Vancouver using scenarios that are also informed by data gathered for Vancouver's ecological footprint analysis, as will be described in subsequent sections.

Table 3.2a Cities and Countries Studied by Lifestyle Archetype Grouping

Three-Plus-Planets	**National Urbanization Over 80%**[24]	**EF**[25]	**International Profiles of household consumption and/or urban metabolism**	**GFN Calculator: Super Green**	**Intentional Communities**
USA	√	**7.99**		√	
Pearland, TX			√		
San Antonio, TX			√		
Raleigh, NC			√		
Canada	√	**7.00**			
Calgary				√	
Toronto			√		
Quayside in North Vancouver					√
Australia	√	**6.83**		√	
Sydney			√		
Brisbane			√		
Kuwait	√	**6.33**			
Kuwait City			√		
Sweden	√	**5.88**			
Toarp in Malmo					√
Norway	77%	**5.55**			
Greater Oslo			√		
Mongolia	57%	**5.53**			
Ulanbataar			√		

[24] WRI 2010

[25] WWF 2010a

Three-Plus-Planets	National Urbanization Over 80%	EF	International Profiles of household consumption and/or urban metabolism	GFN Calculator: Super Green	Intentional Communities
Spain	77%	**5.42**			
Segovia			√		
Germany	75%	**5.09**			
Cologne			√		
Italy	68%	**4.98**		√	
Pienza			√		
UK	√	**4.90**			
BedZed in Greater London, England					√
Godalming, England			√		
Findhorn, Scotland					√
New Zealand	√	**4.89**			
Auckland			√		
Israel	√	**4.82**			
Tel Aviv			√		
Japan	66%	**4.71**		√	
Tokyo			√		
Kodaira			√		
Russia	73%	**4.40**			
Suzdal			√		

Table 3.2b Cities and Countries Studied by Lifestyle Archetype Grouping

Two-Planets	**National Urbanization Over 80%**	**EF**	**International Profiles of household consumption and/or urban metabolism**	**GFN Calculator: Super Green**	**Intentional Communities**
Chile	√	**3.23**			
Santiago de Chile			√		
Mexico	76%	**2.99**			
Guadalajara			√		
Cuernavaca			√		
Brazil	√	**2.90**		√	
Sao Paulo			√		
Bosnia/ Herzegovina	46%	**2.76**			
Sarajevo			√		
Argentina	√	**2.6**		√	
Salta			√		
Thailand	32%	**2.36**			
Ban Muang Wa			√		
South Africa	59%	**2.3**		√	
Soweto			√		
China	40%	**2.21**		√	
Beijing			√		
Shiping			√		
Hong Kong			√		

Table 3.2c Cities and Countries Studied by Lifestyle Archetype Grouping

One-Planet	National Urbanization Over 80%	EF	International Profiles of household consumption and/or urban metabolism	GFN Calculator: Super Green	Intentional Communities
Mali	31%	**1.93**			
Kouakourou			√		
Ecuador	63%	**1.88**		√	
Tingo			√		
Cuba	76%	**1.84**			
Havana			√		
Guatemala	47%	**1.78**			
Todos Santos			√		
San Antonio De Palopo			√		
Uzbekistan	37%	**1.74**			
Tashkent			√		
Viet Nam	26%	**1.4**			
Viet Doan			√		
Iraq	67%	**1.35**			
Baghdad			√		
Philippines	63%	**1.3**			
Manila			√		
Ethiopia	16%	**1.11**			
Moulo			√		
India	29%	**0.91**		√	
Ujjain			√		
Ahraura Village			√		
Haiti	39%	**0.67**			
Maisssade			√		

3.2 Calculate the Ecological Footprint of Vancouver

The scope of the ecological footprint assessment is limited to: a) data obtained by tracking the energy and materials consumption and waste production of Vancouver residents and b) estimating the amount of biologically productive ecosystems, measured in global hectares, required to provide these resources and assimilate the wastes.[26] The intent is to understand the biocapacity demand associated with the lifestyles of the Vancouver population, not the total flow-through of energy and materials that constitute Vancouver's role as one of Canada's most important trade gateways. This distinction is noted in the literature as the difference between a territorial assessment and a residential assessment (Chambers et al. 2002; Eurostat 2001). In a territorial assessment all energy and materials flowing through a geographic entity, such as a municipality, are counted. However, this excludes up-stream energy and materials that may have been used to produce manufactured goods that are imported into the territory. By the same token, the territorial approach includes energy and materials that flow through the territory and are used in industrial processes to manufacture goods that are destined for export markets. In a residential assessment only the energy and materials associated with the consumption of a territories' resident population is counted. This includes energy and materials flows that are directly or indirectly destined for residential consumption as well as the up-stream energy and materials used in supply-chains to manufacture imported goods that are consumed by the resident population.

I use the residential approach in my research. This means that I exclude energy and materials consumption associated with large industrial processes (e.g., chemical manufacturing, rail and shipping activities tied to the port). However, I have chosen to include the commercial sector in the analysis which I assume to be in service to the resident community because the majority of businesses in Vancouver are small to medium enterprises with less than ten employees (Hutton 2011; Muarry and Hutton 2008; VEC 2011). Likewise, the institutional sector is counted because

[26] The ecological footprint only assesses the assimilation of carbon dioxide wastes.

the majority of Vancouver's institutional enterprises, including hospitals and schools, serve the needs of Vancouver residents. However, centralized government services that benefit Vancouverites but are operated in the Provincial and national capital (e.g., military and treasury) are excluded from this study due to limited data and the associated challenge of their estimation. The research, therefore, includes energy and materials flowing into the territory for direct or indirect consumption by residents and includes the energy and materials required to produce the various products consumed by Vancouver residents, regardless of where in the world they were produced. The energy and materials associated with managing the wastes produced by the resident population is also considered.

The year 2006 is chosen as the base year for the study because it represents the most recent Canadian census and the most recent year for which complete data were available at the time this study was undertaken. The approach I use integrates a residential urban metabolism study, using material flows analysis and lifecycle assessment,[27] coupled with a component ecological footprint assessment to produce three data outputs:

i) material flows analysis quantifying energy and materials consumed,

ii) greenhouse gas emissions inventory of consumption,

iii) ecological footprint.

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[27]A residential urban metabolism study focuses only on the energy, materials and associated wastes related to residents' lifestyles. This excludes the industrial production processes that may take place in the city, but serve the needs of non-residents. A material flow analysis tracks energy and materials entering the city and corresponding wastes and emissions leaving the city. Lifecycle assessment estimates the amount of energy and materials associated with all the phases of a product's lifecycle from primary resource extraction, through manufacturing, distribution, and final disposal.

This approach enables me to understand the impact of consumption from various perspectives. First, the residential urban metabolism provides insight into which consumption activities constitute the greatest demand for energy and materials, providing both a sector analysis (e.g., residential, commercial, institutional) and component analysis (e.g., food, buildings, transportation). This includes the magnitude of embodied energy from upstream production and downstream disposal associated with the lifecycle of various products consumed.

Second, the greenhouse gas emissions inventory of consumption provides insight into the greenhouse gas emissions associated with consumption activities regardless of where in the world products were made. Again, this analysis can be broken down by sector and/or component. The greenhouse gas emissions associated with consumption can be compared to greenhouse gas emissions inventories that are defined by municipal boundaries, i.e., a territorial emissions inventory that tracks emissions sourced within the municipality. These are prepared by local governments using protocols such as the Partners for Climate Protection program administered by the Federation of Canadian Municipalities in cooperation with the International Council for Local Environmental Initiatives (ICLEI), now known as ICLEI – Local Governments for Sustainability.[28]

Third, the ecological footprint assessment provides insight into the demand on nature's services that is needed to both supply the materials and energy consumed by the residents of the City and absorb its wastes in the form of carbon dioxide emissions. Only carbon dioxide emissions are counted in the ecological footprint (Wackernagel and Rees 1996). The rationale is that only

[28] Internationally this program is administered by ICLEI-Local Governments for Sustainability as the Cities for Climate Protection Program.

carbon dioxide emissions can be absorbed by the oceans and sequestered through photo synthesis by terrestrial ecosystems. The ecological footprint assessment can be used to compare total ecological demand by Vancouver residents with both the available biocapacity (i.e., ecological carrying capacity) of the region in which the City is located and the global per capita ecological carrying capacity of Earth.

Figure 3.1 illustrates the data inputs and outputs derived in sequence starting with:

(A) Primary data inputs for the material flows analysis that informs the metabolism study. These data are collected in units of tonnes, litres, Giga Joules, kilowatt hours, cubic metres, and litres.

(B) Actual hectares (ha) occupied by the urban environment are counted regardless of where they are physically located (e.g. the area of a remote landfill that serves the city is counted). Land required to produce the renewable resources, such as wood and wheat, consumed by city's residents is also counted. The productive ecosystem area required to produce the renewable resources is calculated using national and international yield data provided by the Government of Canada and the United Nations Food and Agriculture Organization respectively. Land within the urban environment that is preserved for natural habitat protection, e.g., a protected watershed, is not counted but disturbed land within protected areas, e.g., service roads within the watershed are counted.

(C) Greenhouse gas emissions associated with the embodied and operating energy of the primary inputs are calculated. For example: the energy associated with logging and manufacturing of dimension lumber is considered as part of the embodied energy of the wood. The energy consumed to operate a house made from that wood is considered as operating energy. The embodied energy data are derived from lifecycle assessment literature and the operating energy data come from government statistics and municipal greenhouse gas emission inventories. The unit of measure is tonnes of carbon dioxide equivalent (tCO_2e) denoting that several greenhouse gases are measured and valued according to their carbon dioxide equivalent.

(D) Carbon dioxide emissions that comprise part of the greenhouse gas emissions inventoried in step (C) described above are then estimated. The unit of measure is tonnes of carbon dioxide (tCO_2)

(E) Ecological footprint calculations use data from (B) and (D). Actual hectares and carbon dioxide emissions are converted into global hectares (gha) (Wackernagel and Rees 1996). Details about the calculations to convert actual hectares and carbon dioxide emissions into global hectares are provided below.

Figure 3.1: Structure and Sequence of Data Inputs and Outputs for the Integrated Urban Metabolism and Ecological Footprint Assessment

Component Name	A. Material Flows Analysis	B. Actual Area (ha) or Yield (t/ha)	C. Greenhouse Gases (tCO2e)	D. Carbon Dioxide (tCO2)	E. EFA (gha)
1. Materials					
Residential **Commercial** **Institutional**	n tonnes n litres	n ha			n gha
2. Embodied Energy					
Residential **Commercial** **Institutional**	n tonnes n GJ		n tCO2 e	n tCO2	n gha
3. Operating Energy					
Residential **Commercial** **Institutional**	n GJ n kWh		n tCO2e	n tCO2	n gha
4. Built Area					
Residential **Commercial** **Institutional**		n ha			n gha
TOTAL			GHG	CO2	gha

3.2.1 Orientation to Local Government

The study is structured to facilitate local government interpretation and use of the ecological footprint analysis and related findings. I have drawn on my own experience as a planner in the region to develop the structure for the ecological footprint assessment using a framework informed by local government demand side management efforts.[29] I reviewed the structure and preliminary data findings with staff in the City of Vancouver Sustainability Office (August 2010)

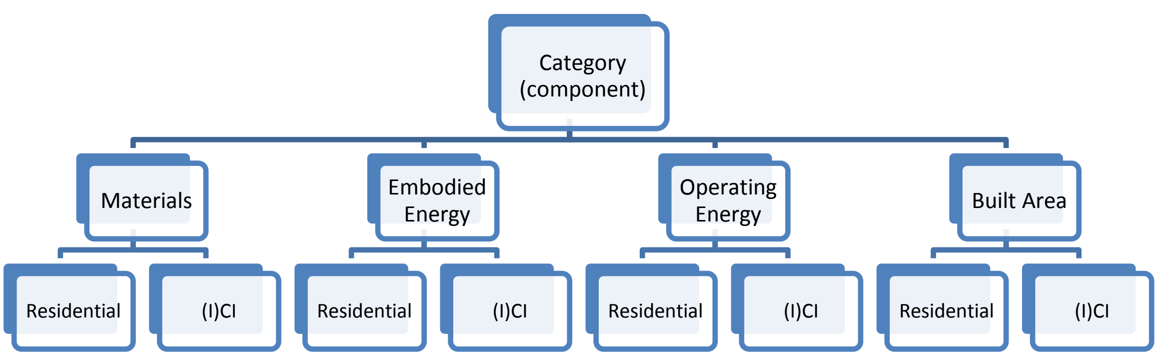
[29] Regional demand side management planning shapes the demand for energy and resources through education, regulation and incentives. Program delivery focuses on the residential and industrial, commercial, institutional (ICI) sectors. Program services include: solid and liquid waste management, transportation, and water. More recently programs addressing food and buildings have also been introduced. Energy demand management initiatives are carried out in tandem with local energy utility service providers.

and subsequently with staff from the City's planning, engineering and social policy departments (March 2011) to test whether they could easily understand the structure of the analysis and whether they felt they could use the findings to inform their work. Specifically, I organized the ecological footprint assessment using the following consumption categories: Food, Buildings (including residential, commercial and institutional), Consumables and Wastes (including solid and liquid wastes), Transportation, and Water. The materials and energy passing through the City are allocated according to each category of consumption. Within each category, sub-components are established to provide a more refined analysis. The sub-components are structured in order to capture both the weight and type of materials, embodied energy associated with producing and transporting the materials, direct operating energy associated with using the products made by the materials, and built area associated with the accommodation of those products within or outside the City.

The sub-components are disaggregated further to allocate the material flows to either the residential or: industrial, commercial and institutional (ICI) sectors. This follows the same division used by the City of Vancouver and all local governments in Metro Vancouver. However, as described above, industrial consumption is excluded because the purpose of the study is to capture data associated with urban residents' consumption. Therefore, industrial process energy is excluded unless it passed through an electrical or gas meter in the residential, commercial or institutional sectors. This exception applies to the operation of light industry, e.g. buildings and vehicle operations associated with warehousing, which are commercially metered. Therefore, with regard to addressing the ICI sector, the research reflects predominantly commercial and institutional consumption with the understanding that light industrial activities are rolled into the former, hence the brackets around the first "I" of "(I)CI" in figure 3.2. The embodied energy and materials generated through up-stream supply-chain manufacturing (i.e., the industrial metabolism of consumer goods) that are consumed in Vancouver (whether produced locally or abroad) is captured in the lifecycle analysis of materials described below. Finally, where possible, the data are disaggregated further by type: e.g., type of food, type of building, type of consumable material, type of vehicle and/or mode of transportation, etc.

Figure 3.2 demonstrates the basic structure of data organization for each category. Organizing the data in this way enables further manipulation to extract, for example, the embodied and operating energy associated with each component (or sub-components) in order to calculate the "energy footprint" for the City. It also allows more refined analysis of which sub-

Figure 3.2: Component Structure of the Integrated Urban Metabolism and Ecological Footprint Assessment



components constitute the largest consumption, e.g., residential or commercial or institutional sectors. Recall that given Vancouver's predominant service economy comprising small-to-medium enterprises, the commercial and institutional sectors are assumed to reflect, for the most part, the demand for goods and services by local residents, i.e. residential consumption in the City.

3.2.2 Data Management

The information derived from an integrated urban metabolism and ecological footprint assessment should be useful to urban policy-makers who seek to reduce consumption of energy and materials and their associated wastes. I believe therefore that it is important to observe the following guidelines when making decisions about data sources:

i) Accuracy: There are frequent discrepancies among data sources (Chambers, Simmons and Wackernagel 2004, 69). For example, in lifecycle analysis, the same product produced by multiple countries could have varying embodied energy profiles depending on what method and energy source was used to manufacture and transport it. Studies also vary in terms of the scope of what factors are included and excluded. Therefore, whenever possible, I used multiple data inputs. Where there was convergence among the data, I used the most commonly cited value or an average of at least three data inputs that closely approximate each other. Outliers were excluded unless there was strong documentation to support the validity of the research, thereby warranting its inclusion.

ii) Subsidiarity: Locally produced data were preferred, especially when local authorities trusted its validity and used it to inform policies and management practices. I believe that locally derived data reflect the nuance of the local community being profiled and can resonate more readily with local authorities who also use these same data points for their work.

iii) Conservatism: In cases where two data sources equally met the accuracy and subsidiarity criteria, the final decision rested on which data point conveyed a more conservative estimate. The purpose of this approach is to err on the side of caution and avoid overstating consumption amounts.

3.2.3 Data and Calculations to Estimate the EF Components

3.2.3.1 Food

Estimating food consumption at a city scale is problematic, given that data about food production and consumption is mostly gathered at the national scale. Therefore, I assume in this research that Vancouver food consumption is similar to average Canadian food consumption patterns and includes food lost due to spoilage and plate waste (Statistics Canada 2007a). The food types are as follows: i) fruits and vegetables (including processed fruits and vegetables); ii) fish, meat and eggs (including beef, veal, pork, and poultry); iii) stimulants (including tea, coffee, sugar and cocoa); iv) grains (including flour, other grain products, and rice); v) oils, nuts and legumes; vi) dairy products; vii) beverages (including soft drinks and products from breweries, wineries, and distilleries). These groupings were developed collaboratively with Dr. Meidad Kissinger, a graduate from the School of Community and Regional Planning at the University of British Columbia. The metabolism and ecological footprint for the food component were calculated by Dr. Kissinger as described below.

Data on the quantity of food available for consumption in Canada were taken from Statistics Canada (2007a). Dr. Kissinger also relied in part on research undertaken for his PhD to compile

Canada's food footprint, including disaggregated statistical information provided by Agriculture Canada and Department of Fisheries and Oceans (Kissinger 2008).[30] Data on the money value for domestically produced food were taken from Statistics Canada (2009) and data on trade adjustments (imports and exports) were taken from Industry Canada (2010). Dr. Kissinger ran these data through environmental input-output assessment tools (Statistics Canada 2008a; Green Design Initiative 2010) to estimate the carbon dioxide emissions associated with the lifecycle production of the food consumed. This includes carbon dioxide emissions associated with the material inputs to food production including: fertilizers, pesticides, and fuel used in on-farm activities, as well as food processing including sterilization and refrigeration.[31] The greenhouse gas emissions emitted through the transportation of imported food (i.e., as part of the "food miles") that covers the distance between the exporting country and Canada was also estimated. Domestic food miles, meaning the transportation of food produced and distributed within Canada, are not counted due to lack of data. To calculate the food miles for imported food, Dr. Kissinger's research used the distance from a major port in the exporting countries or a central geographic point in each U.S.A. state exporting food to Canada. Within Canada, as the recipient of these exports, Dr. Kissinger identified the major cities within each Province and used this as the proxy destination to which imported food arrives. He decided to calculate the total food miles for the country because data on transportation of food within Canada is not available; therefore, it is impossible to track how food imports are distributed to Vancouver once they have landed on domestic soil. Dr. Kissinger used the Canadian Computing in Human

[30] Dr. Meidad Kissinger, personal communication, March 30, 2012.
[31] The emissions associated with the disposal of food (e.g. plate waste) are counted in the Consumables and Waste component. For additional information about calculating Canada's food ecological footprint see Kissinger (2013).

and Social Science (CHASS) Trade Analyzer Database (CHASS 2010) to determine the amount of food by quantity and type arriving to each of the major cities within each Province in Canada. He estimated both land (rail and truck) and sea import distances using a combination of tools including Google Maps Travel Distance Calculator and the PortWorld.com and then used emission coefficients for truck, rail and sea transportation found in the literature to estimate the carbon dioxide emissions associated with Canadian food imports (i.e., food miles). Air travel was not assessed because only a very small amount of food is important this way (Kissinger 2012).

So far I have described how to calculate the metabolism of food for Canada including the total materials, in tonnage, related carbon dioxide emissions from embodied energy for production and processing, and related carbon dioxide emissions from transportation energy, i.e., food miles. To determine that portion of Canada's food metabolism that can be attributed to the Vancouver population, I divided the output data by the total population of Canada in 2006 using the 2006 Census data (Statistics Canada 2006d). This gives the per capita value that can subsequently be multiplied by the total population of Vancouver. The latter is also determined using Statistics Canada 2006 Census Data (Statistics Canada 2006a).[32]

To calculate the ecological footprint of food, Dr. Kissinger followed the procedure recommended by the Global Footprint Network (Ewing et al. 2008b; Ewing et al. 2009). He used

[32] At this point, the per capita consumption values for each food type could also be further modified by weighting the consumption of various food types to reflect Vancouver household consumer preferences. This is done by using the Statistics Canada (2001) Food Expenditure Survey that documents a sample of Vancouver household food consumption over a two week period. This was the most recently available survey at the time of the research. However, because the household consumer survey data pre-dates the census data by several years, I decided to omit this step to avoid introducing additional uncertainty to the data set.

all of the above data inputs to calculate the total land and fish area required to actually produce the food as well as the associated land area required to sequester the carbon dioxide emissions from the fossil-based energy used to produce and transport the food. Then he translated these actual land estimates into global hectares.

The following formula is used to calculate the ecological footprint of consumption of product "i" in global hectares (Ewing et al. 2009):

$$EF_i \text{ (gha)} = C_i \text{ (t)}/Y_iN\text{(t/ha)}*YF*EQF \qquad (1)$$

Where:

i) EF_i represents the ecological footprint for the product in question measured in global hectares,

ii) C represents the weight of product measured in tonnes,

iii) YN represents the national yield for that product measured in tonnes per hectare,

iv) YF represents the yield factor (a ratio of the national yield divided by the global yield for that same product) measured in tonnes per hectare, and

v) EQF represents the equivalence factor (a ratio of the average global productivity of a specific ecosystem type (e.g., cropland) divided by the global average productivity of all ecosystem types) measured in global hectares.

Since the formula calls for the multiplication of 1/YN by YF, and since YF comprises a ratio of YN/YG (where YG represents the global average yield), the result is a cancelling-out of the YN value. Therefore, the formula can be contracted for practical purposes (Ewing et al. 2009) and represented as:

$$EF_i\,(gha) = C_i(t)/YG_i*EQF \qquad (2)$$

In this formula, YG represents the global average yield for the product in question. Global average yield data for a wide range of agricultural products is available on-line from (FAO 2010a).

To convert actual hectares to global hectares, the unit of measurement of the ecological footprint, I multiplied Dr. Kissinger's output data for the total actual hectares of cropland, pasture land, and fish area used to produce each food product by the global equivalence factor for cropland, pasture land, and fish area respectively. The equivalence factors for all land types are made available by the Global Footprint Network (www.footprintnetwork.org). Global equivalence factors for cropland, pasture land, and fish area in 2006 are reported in the Ecological Footprint Atlas (Ewing et al. 2009).

The following formulas demonstrate how the equivalence factors are used to calculate the global hectares, i.e. ecological productive capacity, of cropland with an EQF in 2006 of 2.39 (4), pasture land with an EQF in 2006 of 0.51 (5), and fishing area with an EQF in 2006 of 0.41 (6):

$$EF_{\text{Crop Land (gha)}} = C(t)/Y_N*YF*\ 2.39\ \text{gha/ha} \qquad (3)$$

$$EF_{\text{Pasture Land (gha)}} = C(t)/Y_N*YF*\ 0.51\ \text{gha/ha} \qquad (4)$$

$$EF_{\text{Fish Area (gha)}} = C(t)/Y_N*YF*\ 0.41\ \text{gha/ha} \qquad (5)$$

Second, by documenting the energy inputs associated with growing (e.g. fertilizing), harvesting, processing and distributing food products as part of the lifecycle assessment, Dr. Kissinger was able to determine the total amount of fossil fuels used and the amount of energy land required to sequester the carbon dioxide emissions associated with this energy use. The following formula, recommended by the Global Footprint Network (Ewing et al. 2008b), was used to calculate the energy land, measured in global hectares, that was required to sequester the carbon dioxide emissions associated with the production, processing and transportation of the food consumed:

$$EF_{\text{Energy Land}} = P_{tCO2}\,(1 - S_{ocean})/Yc{*}EQF \qquad (6)$$

Where P represents the total amount of carbon dioxide emissions associated with the production of the food, (1-S_{ocean}) represents the amount of anthropogenic carbon dioxide emissions sequestered by the world's oceans, and Yc represents the amount of carbon dioxide sequestered by the world's forests. In this formula, EQF represents the 2006 equivalence factor for energy land which is the same as that of forest land (Ewing et al. 2009). Dr. Kissinger substituted the following values for global ocean carbon dioxide sequestration: S_{ocean} = (1-.26) and for global terrestrial carbon dioxide sequestration: Yc = 3.7 tCO_2/ha based on the work of Kitzes and Wermer (2006). Thus the formula becomes:

$$EF_{\text{Energy Land}} = (P_{tCO2}\,(1 - 0.26)/3.7){*}1.24 \qquad (7)$$

Where P represents the carbon dioxide emissions associated with the fossil based energy inputs to growing, harvesting, processing and distributing the food product in question, S_{Ocean} has a value of (1-26) and assumes that 26% of anthropogenic carbon dioxide emissions are sequestered in world oceans (Kitzes and Wermer 2006; IPCC 2001), Yc has a value of 3.7 tCO_2/ha and assumes that the global average terrestrial sequestration rate for carbon dioxide is

3.7 tonnes carbon dioxide per hectare (Kitzes and Wermer 2006), and the equivalence factor for energy land in 2006 is 1.24 (Ewing et al. 2009).

After aggregating the EF values for cropland, pasture land, fish area, and energy land (i.e., the total land (and sea) area required for agricultural production, processing and transportation of specific food commodities consumed in Canada), Dr. Kissinger was able to calculate Canada's ecological footprint of food. To determine that portion of Canada's food footprint that can be attributed to the Vancouver population, I subsequently divided the output data by the total population of Canada in 2006 using the 2006 Census data (Statistics Canada 2006d). This provided the per capita value that could then be multiplied by the total population of Vancouver. The latter was also determined using Statistics Canada 2006 Census Data (Statistics Canada 2006a).

3.2.3.2 Buildings

To estimate the urban metabolism associated with buildings, I first established four sub-components to help organize the data: i) building materials, e.g., wood, steel, concrete, glass; ii) embodied energy in building materials; iii) operating energy, e.g., electricity and natural gas for water heating, lighting and space conditioning; and iv) built area occupied by the buildings. Within each sub-component, there was further disaggregation to apportion consumption of energy and materials to residential or commercial/institutional uses. As described above, electrical and heating loads for light industry activities, e.g., warehousing, were counted with commercial buildings.

Instead of calculating the materials and related embodied energy associated with new construction in 2006, I attempted to estimate the materials and embodied energy of the entire building stock amortized over the lifespan of the buildings in the City. This enabled an estimate of the average, annual quantity of materials and energy embodied in the building stock unaffected by industry cycles, e.g., economic booms and busts that affect the construction industry from year to year.

To determine the amount of building materials and related embodied energy in Vancouver's building stock I utilized research (Sianchuck 2009 unpublished; Senbel 2009 unpublished) that uses the Athena Institute's Impact Estimator for Buildings 4.0 – selected for Vancouver (ASMI 2008). This software is capable of estimating the required materials and related embodied energy necessary to build a variety of building archetypes representative of Vancouver's building stock, e.g., single family detached, duplex, wood-frame multi-unit under five stories, and concrete high-rise over five stories. These archetypes generally matched those used by Statistics Canada (2006a). For each of these archetypes, I selected case buildings in consultation with City of Vancouver staff (D. Ramslie, personal communication, February 16, 2011) based on the average square footage and building materials representative of each archetype. Data from building drawings for the case buildings were input to the Athena Impact Estimator to estimate the materials and embodied energy associated with their construction. Commercial and institutional building archetypes were developed in consultation with City of Vancouver staff (D. Ramslie, personal communication, February 16, 2011) and included: high-rise office tower, low-rise (under five story), and community centre. The high-rise office tower was assumed to be similar to the high-rise residential building archetype in terms of materials used for construction and related embodied energy. The low-rise building was assumed to be similar to buildings located on the University of British Columbia Point Grey Campus which had already been modeled, and for which the output data were permitted to be used in this study.[33] The Round-House Community Centre was selected as the case building for the community centre archetype. All selections were again confirmed with City staff (D. Ramslie, personal communication February 23, 2011) as being reasonable, broad approximations of Vancouver's commercial and institutional building stock, given the intent of the research.

The stock of each building archetype in Vancouver was calculated using statistical data (Statistics Canada 2006a; Natural Resources Canada 2007). Census data provides the total number of residential dwellings in Vancouver and a percentage break-down by dwelling type. The total number of dwellings by type is calculated by multiplying the percentage representation of each building type by the total number of dwellings in the stock (Statistics Canada 2006a). The total number of dwellings for each building type is then multiplied by the materials and embodied energy calculated for the case building that matches that type, i.e. the archetype. This yields an estimate of the total materials and embodied energy in the residential building stock. Natural Resources Canada (2007) data provides the total number of commercial and institutional buildings in British Columbia. I assumed that half of these buildings were located in Metro Vancouver, where half of BC's population resides (Statistics Canada 2006b). I further assumed that 30% of Metro Vancouver's commercial and institutional building stock is located in the City of Vancouver, where approximately one-third of the region's population resides (Statistics Canada 2006a, 2006b). The total amount of materials and embodied energy comprising Vancouver's building stock was then amortized by an average building life of 40

[33] Research assistant Walleed Giratalla obtained permission from Robert Sianchuk, Civil Engineering, University of British Columbia.

years for wood frame constructed buildings, e.g., spanning single family to low rise, and by 75 years for concrete buildings, e.g., high-rises, in order to determine an annual estimate of the materials and embodied energy represented in the total building stock.[34] The operating energy was estimated by the Province of British Columbia's Ministry of Environment as part of a larger study to assess greenhouse gas emission sources in the Province (BC MOE 2010). Built area was estimated by Metro Vancouver (2006).

The building ecological footprint comprises three land categories – forestry land, energy land, and built land. The standard formula to calculate the ecological footprint of forestry land required to sustainably yield the wood used in construction of Vancouver's building stock follows the general formula introduced in equation (1):

$$EF_{\text{Forest Land (gha)}} = C(t)/Y_N(t/ha)*YF*1.24 \qquad (8)$$

Where EF represents the ecological footprint for forest land, C is the amount of timber, YN is the national yield for timber, YF is the yield factor that is a ratio of the national yield divided by the global average yield for timber, and 1.24 is the equivalence factor for forest land calculated by the Global Footprint Network for the 2006 study year (Ewing et al. 2009).

However, I assumed in this research that timber used for wood frame construction is entirely domestically sourced. Therefore, I omit the global yield factor (which accounts for the yields of imported wood). My formula therefore becomes:

$$EF_{\text{Forest Land (gha)}} = C(t)/Y_N(t/ha)*1.24 \qquad (9)$$

[34] These values fall within the Canadian Standards Association Guideline on Durability in Buildings as referenced by Metro Vancouver's Build Smart program (GVRD 2001).

First, I calculated the sustainable yield for Canadian forestry land by taking the total wood harvested in round logs (184,008,000 m^3) divided by the "allowable cut"[35] area designated for harvest in 2006 (831,424 ha) (National Forest Inventory 2006). Then I amortized the harvest over the average life of Canadian forests (70 years) (Wackernagel and Rees 1996, 83) to calculate a national, sustainable yield.

$$Y_N = (184{,}008{,}000 \text{ m3}/831{,}424 \text{ ha}) \times (1/70) = 3.16 \text{ m3/ha/yr} \qquad (10)$$

Next, I converted the units of measure from cubic meters to tonnes using standard metric conversion factors as follows: i) to convert m3 to ounces multiply by 33814.02, ii) to convert ounces to kilograms multiply by 0.02835, iii) to convert kilograms to tonnes multiply by 0.001.

$$Y_N = 3.16 \text{ m3/ha/yr} \times 33814.02 \times 0.02835 \times 0.001 = 3.03 \text{ t/ha/yr} \qquad (11)$$

Then, I multiplied the national yield by the total lumber in the building stock, amortized for a 40 year lifespan in wood frame buildings as described above, in order to calculate the amount of land that would be required annually to supply timber for the building stock.

The energy land calculation to estimate the carbon sink capacity required to absorb emissions associated with the embodied energy of building materials, including for concrete and steel, was described above (see equation 7).

Built land is the amount of land occupied by a city's residential, commercial and institutional buildings (Metro Vancouver 2006a). I calculated the ecological footprint of built land using the following formula (Ewing et al. 2010):

[35] The "allowable cut" is calculated by the Canadian Forest Service based on the amount of wood that can be harvested sustainably year after year without compromising the forest's yield capacity.

$$EF_{\text{Built Land}} (gha) = A*YF*2.39 \qquad (12)$$

Where A is the area of land occupied by the city, YF is the global yield factor (assumed in this case to be a constant value of 1 because there is no crop production), and 2.39 is the equivalence factor for crop land calculated by the Global Footprint Network (Ewing et al. 2009). The assumption is that cities develop close to where people grow food and, therefore, occupy the same land type as cropland (Ewing et al. 2009).

Finally, to calculate the ecological footprint of buildings I added the EF values for forest land, energy land and built land (as described above).

3.2.3.3 Consumables and Wastes

To estimate the urban metabolism associated with consumables and wastes, I first established four sub-components to help organize the data: i) materials contained in the final product as well as those used up-stream in the manufacturing process (i.e., embodied materials), ii) embodied energy associated with the manufacturing process, iii) operating energy associated with the management of consumable products once they enter the waste stream (including both solid and liquid waste), iv) built area associated with the land occupied by waste management facilities (for both solid and liquid waste).

I used a forensic approach, based on regional solid waste composition survey data, to estimate the amount and type of materials consumed (Chambers, Simmons and Wackernagel 2004, 96). I used City and regional solid waste and recycling reports (COV 2007b; COV 2007b; TRI 2008; Metro Vancouver 2006b) to determine the total amount of solid waste generated within the 2006 study year by: a) each sector (e.g. residential, commercial and institutional) and b) method of disposal (e.g., City owned landfill, regional landfill, regional incinerator).[36] I estimated the total tonnage of Vancouver's solid waste distributed to each facility for disposal according to data provided by Metro Vancouver (Petre, personal communication July 27, 2010) and the City of Vancouver (COV 2007b). I also used regional and City greenhouse gas emissions inventory data (Metro Vancouver 2008a; COV 2007c) and consultant reports (CH2M Hill 2009) to calculate the greenhouse gas emissions associated with the disposal of solid waste at these facilities. I calculated the per tonne greenhouse gas emissions associated with waste disposal in order to estimate the City's contribution to greenhouse gas emissions from solid waste. The tonnage of waste diverted from disposal, i.e. through recycling, is estimated for the urban metabolism study but not added to the materials sub-component of the ecological footprint. I assume these materials will be utilized as inputs to new manufacturing processes; therefore, they are not fully consumed.[37] Regional reports on liquid waste management are also used to assess the total flows of wastewater and bio-solids (measured in dry tonnes) extracted from wastewater treatment facilities (Metro Vancouver 2008a). These are counted in the urban metabolism but not included in the ecological footprint to avoid double-counting.[38]

Lifecycle assessment data were used to estimate the materials and embodied energy associated with the production of consumable items (e.g., paper, cardboard, plastics, diapers) that were disposed to landfills and the incinerator as solid waste. Lifecycle assessment data were also used to estimate only the embodied energy of recycled products. The choice to

[36] The incinerator co-generates heat and power and is known as the Waste-to-Energy Facility.
[37] An alternative approach would be to track the recycled content of materials consumed. However, because this study uses a forensic approach that relies on waste audits, the amount of materials recycled post consumption is used instead.
[38] Since biosolids are predominantly the waste from digested food, they are not counted because these materials have already been counted in the food component of the ecological footprint.

include the embodied energy of recycled products is based on the assumption that the energy required to manufacture these products is consumed over the course of their use. Although their material content can be re-purposed through recycling, additional energy inputs will be required to re-manufacture the products into something new. Reference values were developed for: a) the amount of material inputs as well as b) the amount of carbon dioxide emissions associated with the production of one tonne of product for a range of household consumer items, based on the literature (Norgate and Haque 2010; Jawjit, Kroeze and Rattanapan 2010; Steinberger et al. 2009; Leroy 2009; Humbert et al. 2009; Aumonier, Collins and Garrett 2008; Shen and Patel 2008; Dias, Arroja and Capela 2007; Norgate, Jahanshahi, and Rankin 2007; Tucker et al. 2006; Mata and Costa 2001).

Lifecycle assessment data were also used to calculate the embodied energy of liquid waste infrastructure, i.e. sewer pipes. Lifecycle data of the sewer system was estimated using embodied energy data for concrete pipe (Ambrose et al. 2002; Baetz 1999) and applied to the total length (1,900 km) and diameter (300 mm) of Vancouver's concrete sewer pipes (COV 2009).

Operating energy data were collected for the buildings and heavy duty equipment at the waste management facilities, e.g. landfills, incinerator, and waste transfer stations (Beck and Santos, personal communication, August 4, 2010; COV 2007c). Operating energy data were also collected for the buildings and equipment at the Iona wastewater treatment facility where all of the City's wastewater is treated (Metro Vancouver 2008a).[39] Beneficial use of landfill gas (in the case of solid waste management) and biogas (in the case of liquid waste management) that offsets demand for natural gas purchased from the provincial gas utility is counted but not added to the mass flow balance because, like recycling, it represents a re-purposing and use of a waste product.[40]

I estimated the built area of all solid and liquid waste treatment facilities that serve the City of Vancouver (Metro Vancouver 2008a; COV 2007b; COV 2010; Stephens 2010). For the Cache Creek Landfill and Burnaby Waste-to-Energy Facility, I apportioned the land according to the percentage of waste managed at these facilities that is sourced from the City, i.e. 7% and 14% respectively (Petre, personal communication July 27, 2010)

The consumables and waste ecological footprint component comprises four land categories: energy land, cropland, forest land, and built land. To estimate the energy land, I first added the total carbon dioxide emissions generated from: a) solid waste disposed to landfill or incinerator, b) embodied energy associated with the manufacture of consumable products, and c) operation of the solid and liquid waste facilities. Specifically, to calculate the emissions associated with the embodied energy of consumable products, I used reference values (Sussmann unpublished data)[41] for the amount of carbon dioxide produced per tonne of product manufactured for various materials in consumable items. I multiplied these by the tonnage of the various

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[39] The Iona Wastewater Treatment Plant (WWTP) also treats a small amount of wastewater from the City of Richmond and YVR. However, this accounts for less than 10% of total WWTP volume, and therefore, was not excluded from the study due to the almost insignificant impact this has on the total ecological footprint.

[40] Recall that carbon dioxide emissions from waste were already counted as part of the materials sub-component.

[41] For a detailed description of the method and some of the reference values it generated see Kissinger et al. (2013a).

materials comprising the consumable items found in the waste stream (including waste disposed and recycled). I repeated this step for every identifiable material, e.g., paper, metal, glass, etc. and then summed the total amount of carbon dioxide emissions. I then estimated the amount of forested area required to sequester all of the carbon dioxide emissions (see equation 7 above).

To estimate the crop land and forest land required to produce the materials (e.g., cotton, latex, wood) that were used to manufacture the consumable items (e.g., textiles, rubber, paper), I relied on reference values (Kissinger and Sussmann unpublished data)[42] for the amount of upstream materials, measured in tonnes, that are required to produce one tonne of product for various consumable items. The amount of land required to produce the materials for each product was calculated using global average yield data (FAO 2010a) that was then converted into global hectares to derive the ecological footprint for each land type (see equations 3 and 9). The output data are an estimate of biocapacity demand (i.e., ecological footprint) associated with the production of one tonne of product, calculated for various consumable products. I multiplied these values, called "life cycle assessment factors," by the total tonnage of the various consumer products found in the waste stream to estimate their respective ecological footprint.

To estimate the built land, I summed the built area occupied by all the solid and liquid waste management facilities and/or the appropriate proportion therefore that could be attributed to Vancouver's use. I then calculated the ecological footprint for this total sum (see equation 12).

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[42] For a detailed description of the method and some of the reference values it generated see Kissinger et al. (2013b).

Finally, to calculate the ecological footprint of consumables, I added the total EF values for energy land, cropland, forest land, and built land (as described above).

3.2.3.4 Transportation

To estimate the urban metabolism associated with transportation, I first established four sub-components to help organize the data: i) transportation materials encompassing: total number of vehicles by vehicle type and total kilometres of road (measured in lane-kilometres); ii) embodied energy of vehicles and roads, iii) operating energy, measured in terms of fossil fuels consumed, and iv) built area of roads.

The Provincial Government (BC MOE 2010) estimates the total number of vehicles registered in Vancouver by type (e.g., light duty, heavy duty, motorcycle, etc.) and also by use: private vehicles, commercial vehicles and public transportation vehicles. The tonnage of materials comprising the private vehicle fleet (which accounts for 99% of the total vehicle stock) was estimated using BC MOE (2010) data for number of vehicles and Zamel and Li (2006) for average weight (1,324 kg) of a passenger vehicle. Data from Zamel and Li (2006) was also used to estimate the weight of specific materials within an average passenger vehicle (e.g., steel, aluminum, copper, zinc, lead, glass, rubber, plastics, other) and total kilometers driven by an average vehicle over its lifespan (estimated at 300,000 km). The total lane kilometres of roads was estimated from the literature (Puil 1999), and the total built area of roads in Vancouver was estimated by Metro Vancouver (2006a). Materials used for road construction were estimated using data from Athena Institute (2006).[43]

[43] The tonnage of materials comprising the total vehicle fleet and the materials used for road construction are not needed to estimate the ecological footprint. For non-biological materials, e.g. steel, glass, cement, stone, only the

I relied on lifecycle data taken from the literature (EPA 2006) to assess the embodied energy of the total vehicle stock by vehicle type. These data were calculated in units of carbon dioxide emissions (Kissinger unpublished). The embodied energy associated with construction and maintenance of the total road area assumes a lifecycle of 50 years for roads, using data from the literature (Athena Institute 2006). These data were also presented in units of carbon dioxide emissions (Giratalla unpublished).

Operating energy and equivalent carbon dioxide emissions for the private and commercial vehicle fleet as well as the public transit bus fleet is estimated by the Province of British Columbia (BC MOE 2010). Operating energy for other public transit vehicles including: electric trolley buses, Westcoast Express commuter rail, SeaBus, and SkyTrain were estimated by a study undertaken by RWDI Consultants for TransLink (RWDI 2008).[44] These data were obtained by request to TransLink. Operating energy for air travel was estimated by calculating total fuel consumption for all outbound travel from the Vancouver International Airport to all major international and domestic destinations (Legg unpublished). This value was then doubled to estimate the fuel consumed for the return trip as well. Total consumption of fuel for round trip travel was scaled by 29% to represent the amount of travel that the Vancouver International Airport Authority estimates is representative of Metro Vancouver residents (YVR 2010a). This

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area affected by mining activities and the energy associated with material extraction, processing and manufacturing is counted in the ecological footprint. Furthermore, because materials such as steel and road aggregate have a very high recycled content, I omitted the calculation of up-stream land affected by mining activity. Therefore, only the embodied energy used to produce steel, the primary material in vehicles, and aggregates such as crushed gravel which is the primary material in roads are counted in this ecological footprint study.

[44] Translink is the Metro Vancouver public transportation service agency operated by the Greater Vancouver Transportation Authority.

value was then divided by the population of the Metro Vancouver population to yield a per capita value that could be used to represent the Vancouver per capita EF of air travel.

This paragraph describes in detail how the fuel consumed for air travel was calculated. Because fuel consumption data are not available from the airport or from the jet airlines, it was estimated as a function of total passenger kilometres travelled by vehicle engine type (Legg unpublished). Data on the number of outbound passengers, sorted by destination, from the Vancouver International Airport (YVR 2010a, b; Statistics Canada 2006e) was used in combination with the International Travel Survey, Air Exit Surveys for Canadian Resident Trips Abroad (Statistics Canada 2008b) to group major travel destinations by continent for international travel and by sub-region within the United States. The most frequently visited major international airport within each continent (e.g., London, Mexico City, Dubai, Johannesburg) was selected to represent average distance for all travel to that region. A majority of outbound trips were to U.S. destinations. Statistics Canada (2008b) establishes eleven US sub-regions, and the most frequented airport in each sub-region was selected to serve as the representative distance for all travel to that sub-region. Domestic travel originating from the Vancouver International Airport was obtained by request to the Vancouver International Airport Authority (YVR 2010a). The distances between the Vancouver International Airport and the selected destination airports were obtained using the World Airport Codes (2010) web tool. Data were obtained about the type of aircraft flown (YVR 2010a), capacity and average number of occupied seats (Air Broker Center International 2009; Environment Canada 2010), mileage (Air Broker Center International 2009; RITA 2010) and number of hours flown per one-way trip (Kayak Flight Finder 2010). Finally, the total estimated fuel consumed for outbound trips was doubled in order to account for the return flight and scaled by 29% which is the estimated number of passengers originating from Metro Vancouver (YVR 2010). Jet fuel emission coefficients (Environment Canada 2010; Leblanc 2010) were used to estimate the amount of carbon dioxide emissions associated with the total amount of fuel consumed (Legg unpublished). To calculate the amount of carbon dioxide emissions associated with the fuel consumed in air travel by the City of Vancouver residents, I assumed that their travel patterns were the same as the regional population and simply divided total carbon dioxide emissions by the regional population (Statistics Canada 2006b) to calculate a per capita fuel consumption value. Then I multiplied this number by the total population in Vancouver (Statistics Canada 2006a).

The ecological footprint of transportation comprises two land types – energy land and built area. To estimate the energy land, I first added the total carbon dioxide emissions associated with a) the embodied energy of the vehicle fleet, b) the operating energy of private, commercial and public transit vehicles, and c) the operating energy (i.e., jet fuel) of air travel. I then estimate the amount of forested area required to sequester all of the carbon dioxide emissions (see equation 7 above). To estimate the built area, I used the Metro Vancouver (2006a) statistic for Vancouver's road area (3,372 ha) and calculated the ecological footprint for this total sum (see equation 12).[45] Finally, to calculate the ecological footprint of transportation, I add the total EF values for energy land and built land.

[45] I did not estimate the portion of the Vancouver International Airport surface area that could be attributed to Vancouverites use.

3.2.3.5 Water

To estimate the urban metabolism associated with water, I first established four sub-components to help organize the data: i) total volume of drinking water flows ii) embodied energy of the water distribution system (i.e., dams and pipes), iii) operating energy, meaning energy consumed by drinking water treatment facilities, and iv) area of watershed, including the reservoirs, and built area dedicated to access roads and water treatment facilities.

The total annual volume flows of treated drinking water were counted using data provided by Metro Vancouver (2008b). The materials comprising the largest dam, Cleveland Dam, and the water distribution infrastructure, i.e. pipes, were estimated and amortized over their lifetime. I assumed a lifecycle of 100 years for the dam (R. Anderson, personal communication, February 23, 2011) and 50 years for the pipes (Metro Vancouver 2011d; COV 2009). The embodied energy associated with these materials was estimated (Giratalla unpublished) using lifecycle data obtained through the literature (Flower and Sanjayan 2007; Ambrose et al. 2002). The total amortized embodied energy for the drinking water infrastructure system (i.e., the dam and pipes) was then apportioned on a per capita basis and multiplied by the population of Vancouver using 2006 census data (Statistics Canada 2006a) in order to estimate that proportion that should be attributed to the City of Vancouver population. The operating energy for the three facilities that treat all of Metro Vancouver's drinking water was estimated by Metro Vancouver as part of its corporate greenhouse gas emissions inventory (Metro Vancouver 2008a). The total amount of water treated was estimated by Metro Vancouver (2008b). For purposes of this study, the operating energy per litre of water treated was estimated based on the total energy consumed to treat drinking water (Metro Vancouver

2008a) divided by the total average daily water consumption for the region (Metro Vancouver 2008b) multiplied by 365 days. I then divided by the total population of the region using 2006 census data (Statistics Canada 2006b) to calculate the amount of per capita energy used to treat the drinking water, which is assumed to be the same for Vancouver residents. Metro Vancouver (2006a) estimates the total area of watershed lands (46,689 ha) that encompass all three reservoirs supplying drinking water to the region. Metro Vancouver (2007b) also estimates the total length of roads (125 km) that traverse the watershed for use by Metro Vancouver staff for maintenance and operation of the reservoirs.

The ecological footprint of Vancouver's water system comprises two land types – energy land and built land. To estimate the energy land, I first added the total carbon dioxide emissions associated with a) the embodied energy of the drinking water distribution infrastructure and b) the operating energy of the drinking water treatment facilities. I then estimated the amount of forested area required to sequester all of the carbon dioxide emissions (see equation 7 above). To estimate the built area, I converted the Metro Vancouver estimate for total kilometres of roads within the watershed to hectares. Then I divided the area by the population of the region to calculate a per capita value for regional watershed roads and multiplied by the total population of Vancouver, using 2006 census data (Statistics Canada 2006a), to estimate the total portion of watershed roads associated with the Vancouver population. The area of land dedicated to the watersheds was not counted because Metro Vancouver has designated these lands as ecological reserves meaning their ecological functions are protected (e.g., there is no public access and timber harvesting is prohibited). Next I calculated the ecological footprint for built land, which comprised the Vancouver portion of the watershed roads (see equation 12).

Finally, to calculate the ecological footprint of Vancouver's water system, I added the total EF values for energy land and built land.

3.3 Calculate Vancouver's Sustainability Gap

The term "sustainability gap" refers to the difference between available ecological biocapacity and an existing population's level of consumption, as measured by the ecological footprint (Wackernagel and Rees 1996, 159-160). In effect, this is the difference between overshoot and one-planet living.

To calculate Vancouver's sustainability gap, I first compared the City's per capita EF to the global fair Earthshare of 1.8 global hectares per capita (WWF, 2008). Specifically, I compared Vancouver's EF based on demand for ecosystem services from cropland, pasture land, fish area, forest land, energy land, and built area to the global per capita biocapacity supply for each of these land types. This enabled me to estimate which land types in Vancouver's EF are in overshoot and by how much.

Next, I assessed the demand on ecological services represented by activities. I compared Vancouver's EF based on demand for ecosystem services for food, buildings, consumables and wastes, transportation, and water to the lifestyle archetypes starting with the international profile (where demand is expressed in terms of consumption benchmarks), the Global Footprint Network super green hypothetical profile, and the intentional communities profile. Specifically, with regard to the latter, I compare Vancouver's EF to the EF of various intentional communities in Western society, as documented in the literature, that are able to come close to the one-planet consumption target (Tinsley and George 2006; Haraldsson, Ranhagen and Sverdrup 2001). This process is described in further detail in chapter 4.

3.4 Identify Policy Interventions

I reviewed the urban sustainability literature covered in step 1 above to identify examples of policy interventions in cities around the world. I also reviewed City of Vancouver and Metro Vancouver policies and initiatives aimed at sustainability. I limited the research by focusing on those activities that contribute the most to Vancouver's sustainability gap. Then I conducted a first round of interviews with City of Vancouver staff and Metro Vancouver staff to further inform my efforts to identify policy interventions or changes to the City's management practices that could enable citizens to reduce their ecological footprint, with the ultimate aim of reducing Vancouver's EF to a level commensurate with the fair Earthshare. The interviews were intended to both capture initiatives that I may have missed in my literature and archive research, as well as identify any new and emerging initiatives. I also asked interviewees to identify additional people whom they believed I should interview, including key informants from outside local government.

3.5 Develop Baseline Estimates for Closing Vancouver's Sustainability Gap

First I estimated the potential reduction in demand within each component and/or sub-component of Vancouver's ecological footprint needed to achieve the one-planet target of 1.8 gha/ca. I estimated the potential reduction in tonnage of materials, kilowatt hours and Giga Joules of energy consumed and then translated the revised consumption data into global hectares. I proceeded to develop multiple baselines for one-planet living in order to identify which reductions in which components and/or sub-components could yield a cumulative EF of 1.8 gha/ca.

Next, I selected a case study neighbourhood, informed by the research interviews, and used it to explore what the reductions in ecological footprint might look like if implemented at a neighbourhood scale. Using the insights gained from this exercise, I then developed a preliminary scope of policy interventions and/or changes to management practices sufficient to achieve EF reductions capable of reaching the 1.8 gha/ca target. These were informed by the baseline and visualization exercise as well as exploration of interventions (outlined in Section 3.4) that the City could implement to reduce consumption of energy and materials or production of carbon dioxide emissions.

3.6 Analyze Options

Based on the outcomes of step 3.5, I reviewed the sustainability literature along with Vancouver's existing policies and the outcomes from the interviews (step 3.4) and assessed which potential policies or changes to management practices identified thus far could be introduced within the Vancouver context to achieve the one-planet living target. I assumed the base year of 2006 is held constant. In effect, I am focusing on what one-planet living could have looked like in 2006 by assuming constant population and consumption levels. Therefore, the ecological footprint for each component in 2006 serves as the starting point for analysis. Potential reductions are assumed to be implemented in the same year. I also assume that reductions are cumulative, meaning that energy and materials consumption reductions are achieved incrementally with the introduction of each change to policy or management practice. In addition to changes that yield quantitative reductions in the EF, I also reflect on the potential of qualitative changes in urban system relational structures that could emerge as a result of implementing the identified policies and/or changes to urban management practices. Recall from chapter 1 that complexity theory, as a theoretical lens for the research, draws attention to the qualitative characteristics of system components and their relational structures. Changes that affect the way feedback mechanisms function give rise to the system's properties (Meadows et al. 1972). Therefore, a transition to sustainability, manifested as one-planet living, likely requires qualitative change in the urban system's existing structural relationships and feedback mechanisms.

Next, I conducted a second round of interviews with the same people interviewed previously. In the second interview, I presented the baselines and preliminary analysis that identified policy interventions and/or changes to management practices that could be implemented to reduce the EF in each component, e.g., food, buildings, consumables and wastes, transportation, and water. I asked interviewees to identify technical, financial or jurisdictional issues that could impede implementation of the policy interventions and/or changes to management practices identified. I also asked them to reflect on any other institutional barriers or market challenges, including issues pertaining to existing built form of the City, that could impede implementation of selected policy interventions. Interviewees were also asked to identify technical or regulatory constraints at senior government levels as well as opportunities for collaboration with senior governments, for example through advocacy for needed changes to policy and/or management practices to overcome barriers.

3.7 Develop Policy Proposals

I developed policy proposals to enable one-planet living based on reflection of the outcomes from the second round of interviews. I considered the potential for energy and materials consumption reductions in light of the proposed policies' technical and institutional feasibility. While the primary purpose of the research is to identify what policy interventions and changes to management practices could enable Vancouverites to adopt lifestyles conducive with one-planet living, the feasibility of implementation is a secondary consideration that could bring additional insights to the research findings.

4 One-Planet Living and Vancouver's Sustainability Gap

This chapter introduces the lifestyle archetypes and Vancouver's ecological footprint followed by an exploration of Vancouver's sustainability gap. First I describe the lifestyle archetypes with specific focus on one-planet living including: international profiles (compiled using statistical consumption benchmarks), super green profiles using the Global Footprint Network's ecological footprint calculator, and profiles of intentional communities. Next I present the findings of Vancouver's integrated residential urban metabolism and ecological footprint. This includes a greenhouse gas emissions inventory of consumption. Finally, I explore Vancouver's sustainability gap which is the difference between the City's per capita demand on nature's services and what could be sustained within global ecological carrying capacity, i.e. at the one-planet level of consumption. I probe each component of Vancouver's ecological footprint and compare it with consumption data compiled for the one-planet archetype in order to illuminate: a) the size of the sustainability gap relative to each component, b) lifestyle patterns of people who are already consuming at the one-planet level, c) hypothesized lifestyle patterns at the one-planet level, and d) attempts by people who are trying to reduce their consumption and/or achieve a goal of one-planet living. Finally, I review the cumulative reductions in ecological footprint that could be achieved if Vancouverites adopted the lifestyle patterns presented in the one-planet archetype, and I identify which components present the greatest potential for reducing Vancouver's per capita ecological footprint.

4.1 Lifestyle Archetypes

Empirical data for lifestyle patterns of people living at the one-planet, two-planet, three-planet and three-plus-planet levels of consumption are summarized in Table 4.1. Data documenting household consumption in various countries were obtained from field studies (FAO 2010b, 2008, 2003a, 2003b, 2001a, 2001b, 1999a, 1999b; UN Habitat 2010; Menzel and D'Aluisio 2005; Menzel 1994) and statistical data bases (UNDP 2011; World Bank 2011; WRI 2010; Worldmapper 2010; International Civil Aviation Organization 2005). The countries were then grouped according to their national ecological footprint assessments based on study year 2007 (WWF 2010b).[46] The average values for EF and consumption within each grouping (i.e., one-planet, two-planet, etc.) were then calculated.

Each archetype, therefore, represents average consumption and household characteristics from a sample of countries according to their average ecological footprint. Countries were selected based on availability of data, particularly respecting ease of access to field-study research at the household level within cities. Eleven countries were included in the one-planet category, eight in the two-planet category, and fifteen in the three-plus-planet category, for a total of thirty-four countries (see Appendix A).

In the three-plus-planet category, there was a marked difference between the four highest-consuming countries and the rest. The four highest consuming countries were: USA, Canada, Australia and Kuwait. For illustrative purposes, I have separated these highest consuming countries and retained the label of "three-plus-planets" because the average per capita ecological footprint exceeds 6 gha/ca. The remaining countries fall into a new category called "three-planets" because the average ecological footprint ranges between 4 and 6 gha/ca.

[46] This report is produced every two years, hence 2007 is the closest and most recent study year to 2006 for which data are available.

Table 4.1: Summary of Consumption Data by Lifestyle Archetype

Component	Three-Plus-Planets (>6 gha/ca)	Three-Planets (6 - 4 gha/ca)	Two-Planets (4 - 2 gha/ca)	One-Planet (< 2 gha/ca)	World Average
Ecological Footprint (gha/ca)	7.04	5.11	2.76	1.45	2.21
Carbon Footprint (tCO_2/ca)	19	9	4	1.5	4.1
Food (t/ca) Daily caloric supply	0.693 3,525	0.857 3,240	0.693 2,893	0.548 2,424	n/a 2,809
Buildings (kWh/ca) and Built Area (m^2/ca)	14,381 51	8,850 29	2,545 13	692 8	2,596 10
Consumables (Paper t/ca) **and Wastes** (solid waste t/ca)	0.2 0.55	0.2 n/a	0.1 0.41	0.01 0.25	0.1 n/a
Transportation (VkmT/ca) (AkmT/ca) Transit Ridership	 9,482 3,622 10%	 5,550 2,264 20%	 1,265 484 24%	 582 125 19%	 2,600 564
Water (m^3/ca) % domestic	1,159 23%	498 24%	702 13%	822 9%	632 10%
Other/Government (HDI)	0.869	0.849	0.703	0.544	n/a

Table 4.1 reveals that the three-plus-planet countries have the highest levels of consumption across virtually all component categories. They also have the highest human development index rating. In general, the progression from high to low consumption correlates with the archetype groupings, where the lowest levels of consumption and human development index are associated with the one-planet archetype.

There are some exceptions within and between the archetypes that reveal important opportunities for further investigation. For example, many of the countries in the three-planet archetype, e.g., Germany and Japan, achieve commensurate levels of education and longevity with countries in the three-plus archetype.[47] Also, some countries in the one-planet archetype, e.g. Ecuador and Cuba, achieve a high human development index (UNDP 2011; WRI 2010).

4.1.1 One-Planet Living

The countries selected for study in the one-planet category have an ecological footprint at or below 2 gha/ca. I include a range of countries including those with ecological footprint values close to the 1.8 gha/ca target all the way down to some of the lowest per capita values at under 1 gha/ca.

4.1.1.1 International Profile

Table 4.2 comprises a summary of statistical data and a description of average lifestyles within the one-planet countries studied.[48] The study draws on information provided by: FAO (2010b, 2008, 2003a, 2003b, 2001a, 2001b, 1999a, 1999b), World Bank (2011), UN Habitat (2010), WRI (2010), Worldmapper (2010), International Civil Aviation Organization (2005), Menzel and D'Aluisio (2005), Menzel and Mann (1994).

Table 4.2 International Profile of One-Planet Living (under 2.0 gha/ca)

Component	**Consumption (units/ca/yr)**	**Comments**
Ecological Footprint	1.45 gha	Ecological footprint values range from 1.93 to 0.67 gha/ca.
Carbon Dioxide Emissions	1.5 tCO_2	Includes total country emissions amortized over the entire population. Emissions range from 5 to 0.1 t_{CO2}/ca. Approximately 0.2 t_{CO2}/ca can be attributed to emissions from home heating and electrification.

[47] Wilkinson and Pickett (2009) observe that equality within a society contributes more to social health outcomes than average wealth. In comparative analyses of social health, equality, and wealth in western countries, Germany and Japan rank higher on the first two than the USA, which rankest highest in the latter.

[48] I have chosen to represent the average rather than the median because the data that I draw on for this research also relies on statistical averages. My assumption is that consistent representation of data using average values captures the full range of consumption across a given study group, whereas the use of median data may under-represent total consumption. Also consistent use of averages supports an easy to understand method that can be repeated, challenged and improved upon in future research.

Component	Consumption (units/ca/yr)	Comments
Food	548 kg Includes: - meat 21 kg	The diet is predominantly vegetarian with 60-40% of daily energy supplied from cereal crops and 7-4% from meat. Average daily consumption is 2,424 calories. Approximately 66% of total income is spent on food, supplemented by subsistence agriculture. With the exceptions of Ecuador and Cuba, malnutrition and food insecurity remain a challenge.
Buildings and Built Area	10 m^2 692 kWh 0.2 toe[49] 0.2 tCO_2	Less than half the population (45%) is urban, with approximately 5 people per household. Approximately 70% of the urban population has access to sanitation services and infrastructure.
Consumables and Wastes	0.3 radio 0.2 telephone 0.2 TV 0.02 computer 247 kg waste	There is no disposable income. Most consumable items are shared both within and among households. Many items are re-purposed and reused.
Transportation	0.02 vehicles 582 VkmT 125 AkmT	There is low to no ownership of motorized passenger vehicles. Approximately 19% of the population uses public transit for commuting purposes. Personal motorized vehicle travel averages 582 km/ca and air travel 125 km/ca.
Water	74 m^3	Only 9% of total water consumption (822 m^3/ca/yr) is utilized for domestic purposes.
Other/ Government	0.544 HDI	With the exceptions of Cuba and Ecuador, the Human Development Index ranges from low (0.430) to medium (0.595).

4.1.1.2 Super Green Profile

I compiled the super green profile using the Global Footprint Network (2010) ecological footprint calculator. Further to the preliminary description provided in section 3.1 above, the calculator offers the user a set of choices pertaining to questions about food (e.g., frequency of meat consumption, whether food purchases are organic and locally produced), shelter (e.g., type, size, occupants and percentage of renewable energy used in the home), consumption (e.g., purchases of books and clothing, degree to which wastes are recycled), and

[49] Measures the amount of primary energy from all sources consumed by the residential sector (excluding transportation) in unit of tonnes of oil equivalent (toe).

transportation (e.g., kilometers travelled by automobile, number of trips by airplane). The least impact choice for every set of questions is termed super green (Global Footprint Network 2010). I use the label super green to reflect the consistent selection of the least impact choice at every decision point in the use of the calculator in order to compile hypothetical profiles of one-planet living. The Global Footprint Network calibrated the calculator based on studies they have completed for various clients around the world. In some cases, the clients are a city, e.g., an ecological footprint compiled for the City of Calgary is used to represent Canada. There are inconsistencies in the answer choices offered across the 15 case studies used to populate the calculator. However, in every case, I chose the least-impact option available, i.e., the super green choice, in order to compile the super-green profile. I created super green profiles for 11 countries, out of a total possible 15 countries that are profiled in the calculator. The countries that I chose are the ones already selected for this research (see Appendix A) and include: USA, Canada, Australia, Italy, Japan, Brazil, Argentina, South Africa, China, Ecuador, and India. I used characteristics of the one-planet living descriptions summarized in Table 4.2 to inform choices in the super green profile comprising: a primarily vegetarian diet, the highest possible number of people per household in the smallest type of shelter possible, minimal purchases of consumable products such as clothing and appliances, and zero car ownership. Where additional choices were available, I selected what I perceive to be the lowest impact lifestyle including: locally grown, in-season, organic and none-processed food; green construction methods; renewable energy; high transit ridership and no car or air travel. Table 4.3 summarizes the outcomes of those profiles that managed to achieve the one-planet living target. The following countries were eliminated because their profiles remained above the one-planet target: USA, Canada, Australia, Italy, and Japan. All five of these countries represent societies at or over three-planet living, and it is possible that the energy intensity of service provision in these economies, including provision of senior government services, exceeds the equivalent of 2 gha/ca.

Table 4.3 Super Green Profile of One-Planet Living using the Footprint Calculator

Component	**Consumption (units/ca/yr)**	**Comments**
Ecological Footprint	1.13	Ecological footprint values ranged from 1.7 to 0.5 gha/ca.
Carbon Dioxide Emissions	n/a	At least 75% of energy comes from renewable sources.
Food	No meat No fish No eggs No dairy	The diet is exclusively vegetarian, with virtually no processed food consumed. Most food is grown locally, meaning either within the country or within a 1,000 km radius.
Buildings and Built Area	5 m^2 240 kWh 0 toe	There are approximately 7 people per household. Dwellings are small studios and/or apartments that use efficient lighting fixtures and renewable energy sources.
Consumables and Wastes	0 radio 0 telephone 0 TV 0 computer	Purchases of clothing and household furnishings are minimal and everything is recycled. Books, magazines, appliances and personal electronics are never purchased.
Transportation	0 vehicles 0 VkmT 0 AkmT	All transportation is by walking, cycling or rideshare.
Water	n/a	There are no questions pertaining to water consumption in the calculator.
Other/Government	n/a	There are no questions pertaining to other services, including government services.

4.1.1.3 Intentional Community Profile

Because my purpose is to explore what life-style changes would be needed for high-income societies to achieve one-planet living, I have selected a sample of intentional communities from western cultures (e.g., North America and Europe) for which an ecological footprint assessment is available (Giratalla 2010; BioRegional 2009; Tinsley and George 2006; Haraldsson et al. 2001). None of the intentional communities identified in this research achieves one-planet living (see Appendix B). However, some register low per capita ecological footprints in certain components. By selecting the lowest ecological footprint value achieved by any of these communities for each component, I can create a hypothetical composite 'community' that meets the one-planet living criterion for the intentional community profile (see Table 4.4). This one-planet composite is drawn from Findhorn, Scotland for food, buildings and transportation (Tinsley and George 2006) and Toarp, Sweden for consumables and services (Haraldsson et al. 2001). The study year for both is 2004-2005. It should also be noted that my composite is not a perfect representation because of methodological differences among the original EF studies of the selected intentional communities.

Table 4.4 Intentional Community Composite Profile of One-planet Living

Component	**Consumption (units/ca/yr)**	**EF (gha/ca)**	**Comments**
Food	n/a	0.42	The diet is predominantly vegetarian, comprising mostly locally grown, organic produce. Cheese, meat and eggs are supplied by local, organic farms. Most meals are cooked in communal kitchens.
Buildings and Built Area	18.69 m2	0.29	Buildings are predominantly single-family, wood frame construction with some row-housing and co-housing units (i.e. shared kitchen and common space). Electricity is entirely from the on-site wind farm. Hot water and heating is achieved through passive solar design and wood burning stoves, which are dominant, with some gas boilers in small district energy systems for multi-unit buildings. All energy consumption is metered.
Consumables and Wastes	n/a	0.19	Purchase of consumer goods is similar to most conventional urban households in Sweden.

Component	Consumption (units/ca/yr)	EF (gha/ca)	Comments
Transportation	539 VkmT 8,439 AkmT	0.37	Local travel is predominantly by train (25% or 3,055 km/ca/yr), followed by car (4% or 539 km/ca/yr), local bus (1% or 127 km/ca/yr). Motorcycle and walking/cycling account for less than 1% each (with motorcycles accounting for 26 km/ca/yr and walking/cycling accounting for 20 km/ca/yr). Air kilometer travel (AkmT) for business and vacation purposes comprises 70% of total kilometers travelled BUT this is not included in the EF estimate. Transportation infrastructure (e.g. road maintenance) accounts for 10% of the footprint.
Water	n/a	n/a	All water consumption is metered.
Other/Government	n/a	0.09	
Total		1.36	

4.2 Vancouver's Ecological Footprint

As per the methods description provided in section 3.2.3 above, my component ecological footprint approach relies on data collected directly from local government sources through a residential urban metabolism study based on material flows analysis.[50] I also use lifecycle assessment studies, taken from the literature, to estimate the embodied energy in material stocks including: buildings, roads, infrastructure, and consumable goods. All data represent consumption over a one year period. This approach produces three data outputs:

i) material flows (quantifying energy and materials consumed),

ii) greenhouse gas emissions inventory of consumption,

iii) ecological footprint.

[50] Recall that food estimates rely on national data due to lack of local data.

Table 4.5 provides a summary of the data outputs (data sources are identified in section 3.2.3). The following sections provide detailed analysis of these data.

Table 4.5 Summary of Data Outputs

	Material (tonnes, litres, cubic metres)	**Embodied Energy (kWh, GJ, tCO_2)**	**Operating Energy (kWh, GJ, tCO_2)**	**Built Area (ha)**	**Total GHGs (tCO_2e)**	**Ecological Footprint (gha)**
Food	720,125 t	887,554 tCO_2	63,381 tCO_2	n/a	950,935	1,230,982
Buildings	36,536,669 t	2,924,193 GJ	4,950,470,807 kWh 21,869,767 GJ	6,232	1,449,753	386,752
Consumables and Wastes	572,402[51] t 1,180,987 l fuel 213,690,000 m^3 waste H_2O	637,770 tCO_2	16,111,280 kWh 399,337 GJ	454	931,393	335,330
Transportation	115,890 t 714,510,415 l fuel	192,200 GJ	1,845,195 tCO_2	3,372	1,977,702	468,735
Water	125,195,000 m^3 drinking H_20 28,122 t	39,609 GJ	10,571,029 kWh	3,414	2,086	8,677

[51] This includes food waste as well as yard and garden wastes.

4.2.1 Material Flows Analysis

Table 4.6 summarizes the material and energy inputs and waste outputs for each component of the EF associated with Vancouver residents' lifestyles. The table is based on energy and material flows and lifecycle assessment data. It was not always possible to capture direct energy inputs for all products. For the food component, I rely on Dr. Kissinger's estimates. Rather than track actual energy inputs for food production, processing, and distribution, Dr. Kissinger follows an economic input-output approach that uses the dollar value of net food consumption in Canada (i.e. production plus imports minus exports) combined with lifecycle analysis data to estimate the volume of carbon dioxide emissions from fossil energy used for food production, processing and distribution. He also estimated the carbon dioxide emissions that would be associated with the transportation of food imports.[52]

The accuracy of ecological footprint estimates improves with the duration of the data collection period. At least one full, typical year of material flows data should be used to produce an EF snapshot. However, it was not always possible to obtain material inputs for all products on an annualized basis. For example, data about building materials coming into the region are not readily available. I therefore amortized the quantity of materials in the existing building stock over the buildings' lifecycle assuming 40 years for wood-frame structures and 75 years for concrete high-rises (Metro Vancouver 2001) in order to estimate the annual in-flow of building materials in the study year.[53] This approach has an added advantage for ecological footprint analysis in that the data are unaffected by ups and downs in construction activity which could create larger values for some years.

[52] Transportation data for domestically produced food was not available.
[53] Vancouver is and has been a growing city over the last 100 years. According to Statistics Canada (2006a) 40% of the residential stock was built since 1986.

Finally, materials that were produced, consumed, and decomposed within the City (such as yard and garden waste) are noted but not included in the material flows analysis. However, the energy inputs required to transport and manage these materials is included. This approach is consistent with the way that recycled materials from the waste stream are addressed, i.e., recycled materials are noted but not counted as a material flow; however, the associated energy inputs are included.

Table 4.6 Summary of Vancouver Urban Metabolism of Consumption

	Material Inputs (tonnes of materials, including annually amortized stocks of materials, and cubic metres of water)	**Energy Inputs** (litres of fuel, GJ of natural gas, kWh electricity)	**GHG Emissions Outputs** (tCO_2e)	**Solid and Liquid Waste Outputs** (tonnes of materials, cubic metres of water)
Food	720,125 t	n/a[54]	950,935	86,654 t[55]
Buildings	36,536,669 t[56]	24,793,960 GJ[57] 4,950,470,807 kWh	1,449,753	75,004 t[58]
Consumables and Wastes	482,140[59] t	339,337 GJ 16,111,280 kWh 1,180,987 l fuel	931,393	280,007 t[60]
Transportation	115,890 t[61]	714,510,415 l fuel	1,977,702	n/a
Water	125,195,000 m^3 28,122 t[62]	39,609 GJ 10,571,029 kWh	2,086	213,690,000 m^3 [63]

[54] Energy inputs are not reported by Kissinger (unpublished) who uses economic input-output data to estimate only the carbon dioxide emissions that result from the energy inputs.

[55] Includes 81,654 tonnes of wasted food and 5,000 dry tonnes of biosolids from wastewater treatment. Excludes backyard composting of food waste due to lack of available data.

[56] Represents the per year equivalent of materials in the building stock, i.e., total materials in the building stock amortized over its lifecycle (assuming 40 years for wood frame and 75 years for concrete high-rise).

[57] Includes 2,924,193 GJ/yr of embodied energy in the building stock.

[58] Demolition and land-clearing waste.

[59] Excludes 81,654 tonnes of food waste (see footnote 48 above). Excludes 8,608 tonnes of yard and garden waste that was sourced within the City and the compost used beneficially on soils within the City, representing a circular path rather than a flow-through. Approximately 51% of materials consumed were recycled.

[60] Approximately 38,920 tonnes of this waste was incinerated to produce steam and electricity that was used locally by industry and residents through BC Hydro's electrical grid.

[61] Represents the per year equivalent of concrete in roads (91,388 tonnes) amortized over a 50 year lifecycle and the per year year equivalent weight of private motor vehicles (24,502 tonnes) amortized over a 15 year life cycle.

Kissinger's method produces a total food consumption estimate that is 12% higher than what Statistics Canada (2007a) reports (630,990 tonnes). This is due to methodological differences. Recall from section 3.2.3.1, that several data sources are used. Variations in data quality between Statistics Canada and other agencies (e.g., Agriculture Canada, Department of Fisheries and Oceans) can produce differences in reported material volumes. Also, Dr. Kissinger uses extremely disaggregated data in his estimates and there could be some effect of rounding errors.[64] Both Dr. Kissinger's and Statistics Canada's (2007a) estimates are for gross consumption, i.e., wastage is not subtracted from reported quantities.[65]

Net consumption represents the amount of food that is assumed to actually be ingested, meaning wastage is subtracted. Comparing Statistics Canada (2007a) data estimates for gross consumption (631,990 tonnes) and net consumption (441,924 tonnes), one sees that approximately 30% is wastage. Wastage can occur throughout the food supply chain and includes spoilage prior to or during retail, carcass by-product not suitable for human consumption, food scraps and plate-waste. When comparing the material inputs and outputs for food in Table 4.6, however, one sees that food waste accounts for approximately 11% of total food consumed. This lower value could reflect the fact that only the portion of food waste that ends up in the municipal solid waste stream is being counted.

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[62] This is the material weight of water infrastructure, e.g. pipes and dams, amortized over their operating life to present a one-year snap shot.

[63] The high volume of wastewater treated is primarily due to inflow and infiltration in sewer pipes from ground water and surface runoff.

[64] Dr. Meidad Kissinger, personal communication, March 30, 2012.

[65] Statistics Canada (2007a) uses the phrase "not adjusted for losses." Losses could occur through the supply chain in manufacturing, storage and transportion or from spoilage and plate-waste.

4.2.2 Greenhouse Gas Emissions Inventory of Consumption

A consumption approach to GHG emission inventorying attributes emissions to the end user (Dawkins, Roelich and Owen 2010; Turner et al. 2006). Ecological footprint methods are consistent with this approach and can be used to guide their development (Bastianoni 2004; Turner et al. 2006; Dodman 2009). By allocating “emissions to the consumers of products and services,” the approach focusses on *why* emissions are generated and *who* is driving that demand (Dawkins, Roelich and Owen 2010, p. 1).

Led in part by EFA (Rees 1992; Rees and Wackernagel 1994; Wackernagel and Rees 1996), the consumption approach is growing in importance as a communication and policy tool. It can complement territorial approaches to emission inventories that are used by most local governments in Canada and around the world (FCM 2012; ICLEI Local Governments for Sustainability 2009; FCM and ICLEI Local Governments for Sustainability 2008). A territorial approach focuses on the geographic location where emissions occur, but a consumption approach provides important insights about how trade affects emission profiles among countries (Dawkins, Roelich and Owen 2010). This is particularly relevant to international negotiations where issues of equity and accountability are critical (Weidmann 2009). For example, most high-income countries have transitioned to a service economy, which theoretically should be concomitant with lower GHG emissions. Many developing countries now host the industries that still serve the needs of high-income states. A territorial approach to emissions inventories penalizes the developing economies. A consumption approach, on the other hand, could foster greater collaboration and technology transfer to help developing economies manage emissions while simultaneously holding high-income consumers accountable (Weidman 2009; Barrett et al. 2002). The consumption approach also expands the scope of local government's ability to identify linkages between policy and planning interventions and emissions associated with lifestyle choices (Moore 2012).

Table 4.7 and figure 4.1 present Vancouver's greenhouse gas emissions inventory of consumption. Greenhouse gas emissions total 5,311,869 tCO2e or 9.2 tCO2e per capita. Transportation accounts for the majority of emissions (37%) followed by buildings (27%), food (18%), consumables and wastes (18%), and water (0.04%).

Table 4.7 Vancouver's Greenhouse Gas Emissions Inventory of Consumption

Component	GHGs (tCO2e)	Per Capita GHGs (tCO2e/ca)
Food	***950,935***	***1.66***
Fruits and Vegetables	174,633	0.30
Meat, Fish, Eggs	321,425	0.56
Grains	88,467	0.10
Stimulants	55,019	0.15
Oils, Nuts, Legumes	73,409	0.13
Dairy	178,337	0.31
Beverages	59,645	0.10
Buildings	***1,449,753***	***2.51***
Residential	805,688	1.39
Commercial/Institutional	644,065	1.11
Consumables and Wastes	***764,086***	***1.61***
Paper	222,117	0.38
Plastic	155,864	0.27
Metal	94,692	0.10
Glass	32,133	0.16
Organics	55,076	0.06
Household Hygiene	34,396	0.06
Hazardous Material Containers	68,748	0.12
Other	79,377	0.14
Electronic waste	35,309	0.06
Residential solid waste disposed	86,512	0.15
Commercial solid waste disposed	46,022	0.08
Solid waste management	1,883	0.003

Component	GHGs (tCO2e)	Per Capita GHGs (tCO2e/ca)
Liquid waste management	19,263	0.03
Transportation	***1,977,702***	***3.42***
Roads	6,727	0.01
Street Lights	1,226	0.002
Private Vehicles	1,465,002	2.53
Commercial Vehicles	153,126	0.26
Public Transit	26,339	0.05
Air Travel	325,282	0.56
Water	***2,086***	***0.004***
Water Infrastructure	1,713	0.003
Water Treatment	373	0.001
TOTAL	**5,311,868**	**9.2**

Figure 4.1 Vancouver's Greenhouse Gas Emissions Inventory of Consumption

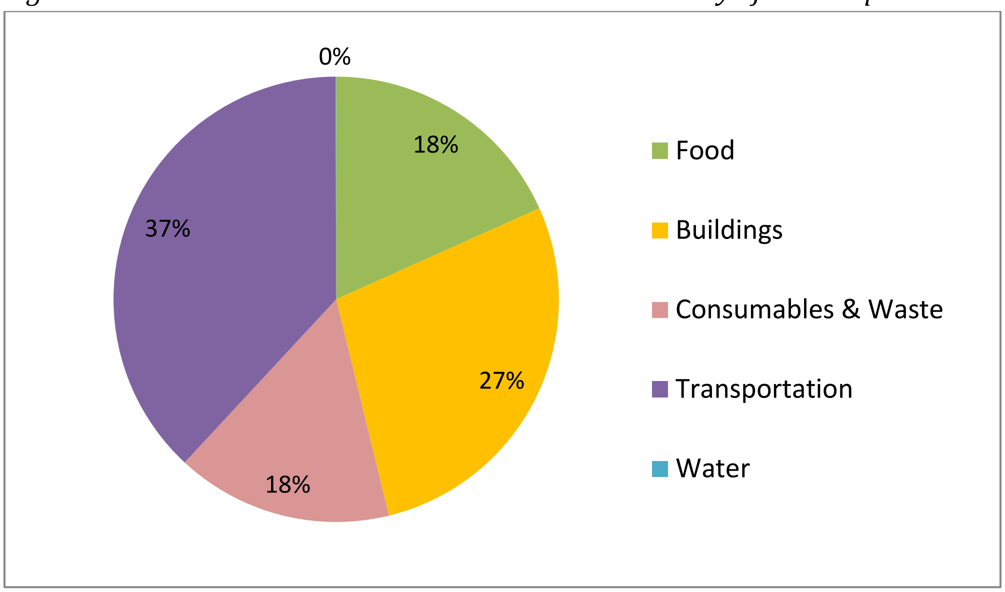
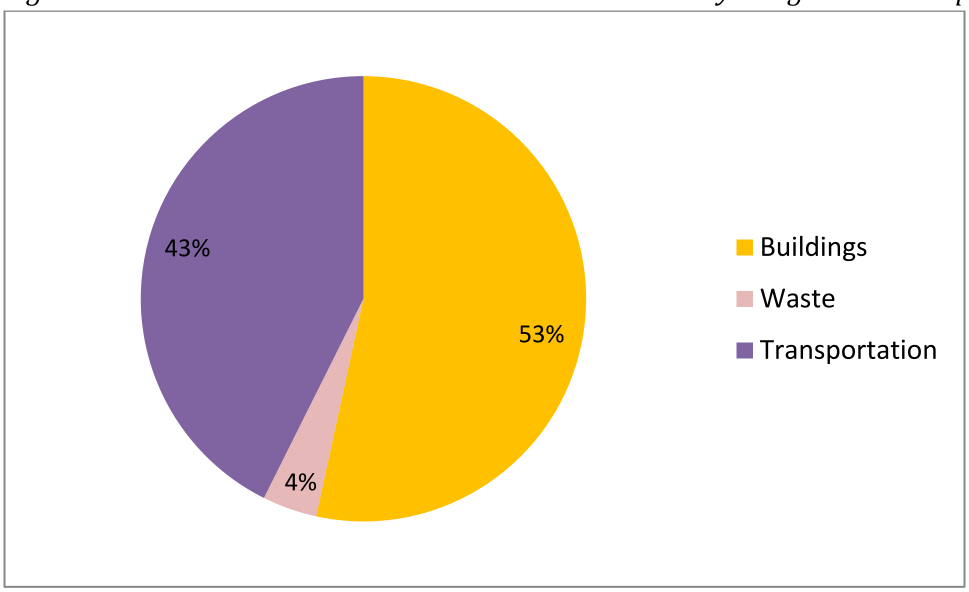


Figure 4.2 shows the City of Vancouver's inventory for 2006 based on the territorial approach to community-based greenhouse gas emissions. The City's reported emissions are 4.9 tCO_2e/ca (COV 2007c) or 2,832,401 tCO_2e assuming 2006 census population of 578,041. One sees that the scope of emissions inventoried is limited to transportation, buildings and waste. This limitation in scope was prescribed by the National Climate Change Process (NCCS 1998, 1999; Environment Canada 2006) following the protocol proposed by the Federation of Canadian

Municipalities in delivery of the Partners for Climate Protection (PCP) Program in Canada (Moore 2012; FCM 2008). The PCP program is the leading climate change action initiative for local governments in Canada. The rationale for reporting on transportation, buildings and waste is that local governments have greatest influence over these types of emissions (NCCS 1998, 1999). For example, local governments have control over land use which affects transportation patterns. The national greenhouse gas emissions inventory produced by Environment Canada (2008) also uses a territorial approach and reports emissions of 22 tCO2e per capita for study year 2005. This includes the emissions associated with resource extraction (e.g. forestry, oil and gas, minerals) much of which is delivered to export markets.

Figure 4.2 Vancouver's Greenhouse Gas Emissions Inventory using territorial approach



4.2.3 Ecological Footprint

Vancouver's total ecological footprint is 4.21 gha/ca or 2,431,912 gha. This represents an area that is approximately 211 times larger than the City's actual size (11,500 ha). Vancouver's ecological footprint is summarized in Table 4.8 as a Consumption Land Use Matrix (CLUM) that breaks down the ecological footprint by the biologically productive land and water ecosystems required on a continuous basis to: a) produce the material and energy inputs consumed by residents in the city and b) assimilate the wastes (measured as carbon dioxide emissions). One sees that energy land accounts for the largest land component (2.21 gha/ca), followed by cropland (1.51 gha/ca). The CLUM also summarizes the demand for nature's services according to the consumption categories used in the study. Here, one sees that food accounts for the greatest demand (2.13 gha/ca) followed by transportation (0.81 gha/ca).

Table 4.8 Consumption Land Use Matrix

EF by Land Type:	**Cropland**	**Pasture Land**	**Fish**	**Forest**	**Energy**	**Built Area**	**Total gha/ca**
Food	1.47	0.13	0.12		0.41		2.13
Buildings				0.03	0.61	0.03	0.67
Consumables	0.04			0.15	0.39		0.58
Transportation					0.80	0.02	0.81
Water					0.001	0.014	0.02
Total gha/ca	1.51	0.13	0.12	0.18	2.21	0.06	4.21
Total gha	874,219	75,145	69,365	103,913	1,272,658	36,612	2,431,912
As percentage	36	3	3	4	52	2	100

In addition to presenting the ecological footprint by land type (figure 4.3) and consumption activities (figure 4.4), I also present how demand on nature's services breaks down within each component. In other words, the integrated urban metabolism and ecological footprint approach provides detailed information about the EF of various sub-component categories as well as the EF of the materials and energy used throughout their lifecycle (i.e., from cradle to grave). This approach enables detailed analysis of the resources required to support Vancouverites' lifestyles. By exploring the footprint through various representations, I can better understand how changes in urban planning policy or production technologies could affect residents' consumption activity and their ecological footprint.

Figure 4.3 presents Vancouver's ecological footprint by land type. One sees that energy land (2.21 gha/ca) accounts for 52% of the total ecological footprint. Cropland (1.51 gha/ca) accounts for 36% of the footprint. Together, energy land and cropland account for 88% of Vancouver's ecological footprint. Previous studies (Sheltair 2008; Wilson and Anielski 2005) using the compound method also identify these two components as comprising the majority (68% and 74% respectively) of Vancouver's EF. However, energy land was estimated to range between 3.65 gha/ca (Sheltair 2008) and 4.21 gha/ca (Wilson and Anielski 2005), nearly double the amount presented in this research. This discrepancy is most likely due to a difference in methods, whereby the compound approach is able to capture a more comprehensive scope of carbon dioxide emissions including senior government services. Note, however, that because forest Land also accounts for a larger share of the EF in the compound method, the percentage proportions for energy's contribution to the EF are similar despite differences in actual quantitative findings.

In my research, forest land accounts for only 4% of the footprint (0.18 gha/ca). This is significantly low compared to previous studies. For example, Sheltair (2008) and Wilson and Anielski (2005) estimate that Vancouver's EF for forest land ranges between 1.15 gha/ca and 1.18 gha/ca respectively. Again, I hypothesize that this discrepancy is due to a difference in methods since both Sheltair (2008) and Wilson and Anielski (2005) use the compound method. Furthermore, Statistics Canada does not track energy and material flows at the municipal level

(Grant and Wilson 2009; Wilson and Anielski 2005) so analysts using the compound method must rely on consumer expenditure (i.e., dollars spent on product purchases) as a proxy to infer energy and material flows at sub-national levels. The compound approach does not appear to account for materials savings from recycling. My use of the component method combined with a residential urban metabolism which does track energy and material flows at the municipal scale allows for finer grained analysis that can distinguish between paper that is consumed and paper that is diverted from the waste stream for recycling. I believe that the low EF for forest land in my analysis is due to the exclusion of that portion of forest land associated with recylced paper. To test this assumption, I compare the Wilson and Anielski (2005) findings for Vancouver (i.e. Metro Vancovuer) to my ecological footprint data (adjusted to reflect the Metro Vancouver population). When I include the forest land associated with recycled paper in my EF the numbers are closer to what Wilson and Anielski (2005) estimate, i.e. a forest land EF of approximately 0.82 gha/ca or 15% of Vancouver's total EF. Because the majority of paper (78%) is recycled, the difference in data output between the two methods is significant.

Fish area accounts for only 3% of the ecological footprint (0.12 gha/ca). This is lower than what it would be if municipal expenditures were used to reflect local consumer preferences. In 2001, Vancouverites spent approximately 8% more than the national average on seafood (Wilson and Anielski 2005). Adjusting for local expenditure preferences yields a higher fish area EF (0.21 gha/ca) for Vancouverites (Wilson and Anielski 2005).[66] Pasture land also accounts for only 3% of the footprint (0.13 gha/ca). However, in 2001 Vancouverites spent less on meat than the national average (Wilson and Anielski 2005). Therefore, it is reasonable to assume that the

[66] Note, however, that Sheltair (2008) reports only 0.15 gha/ca for fish area.

pasture land estimate would be lower if adjusted for local preferences. However, Wilson and Anielski (2005) report that the expenditure adjusted EF for pasture land, based on Statistics Canada's (2001) Food Expenditure Survey for Vancouver is 0.23 gha/ca, placing it higher than the Canadian average (0.21 gha/ca). This seems to contradict the statement about lower than average expenditures on meat consumption in Vancouver.[67] I cannot explain this discrepancy, nor do Wilson and Anielski (2005). I hypothesize that differences in method account in part for the lower pasture land estimates in my research. I note there are differences in starting assumptions about pasture land (measured in hectares) between Wilson and Anielski (2005) who assume 15,200,000 ha (7,752,000 gha) and Kissinger (unpublished) who assumes 8,029,084 ha (4,094,833 gha). This could explain the substantially lower pasture land estimate in my research.

The total built area of the City accounts for only 2% of Vancouver's ecological footprint. This is typical of most high-income societies (Rees 1999), but again is lower than the estimates provided by previous studies using the compound method which estimate a built area of 5% in both Sheltair (2008) and Wilson and Anielski (2005). I hypothesize the discrepancy is due to differences in primary data sources. For example, Sheltair (2008) relied on City of Vancouver 2001 land use data and used different equivalence factors generated by the Global Footprint Network in 2003 whereas I use Metro Vancouver 2006 land use data and 2006 equivalence factors.[68]

[67] Sheltair (2008) reports an even higher pasture land EF at 0.40 gha/ca.

[68] Note that Wilson and Anielski (2005) do not specify what equivalence factors were used in their calculations. The Global Footprint Network (www.globalfootprint.org) generates year-specific equivalence factors that vary in accordance with changes in biocapacity estimates.

Figure 4.3 Vancouver's Ecological Footprint by Land Type

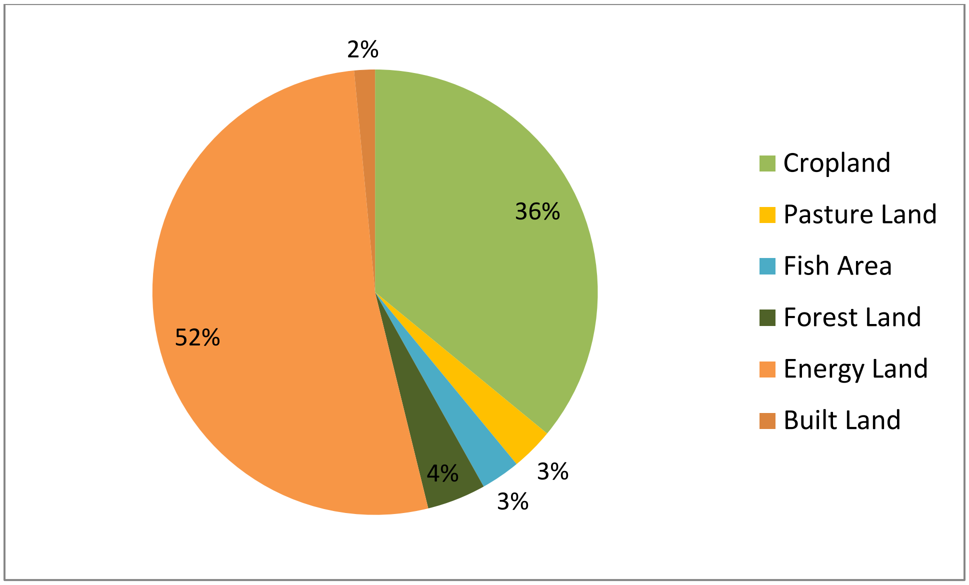


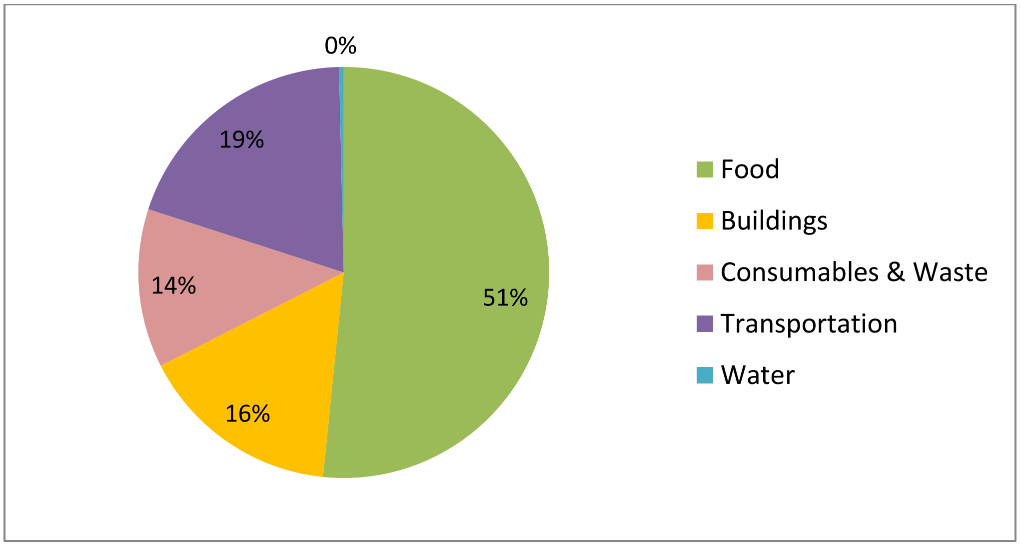
Figure 4.4 present's Vancouver's ecological footprint by consumption activity. Consistent with the CLUM (table 4.8), one sees that food accounts for the largest component (51%), followed by transportation (19%), buildings (16%), and then consumables and waste (14%). Water, specifically the energy used in drinking water treatment, is negligible (less than 1%).

It is important to recall that the food component of this study is derived through the compound method, and represents consumption patterns of all Canadians. Because the compound method is more comprehensive than the component approach, the food component may be larger than had a component method been used.[69] It is also customary in the compound method to adapt the national data set to reflect local preferences. This is usually done through application of weighted values to express food preferences according to household expenditure survey data of the local population. However, the most recent household consumer expenditure survey to include food consumption preferences by Vancouverites was completed in 2001 (Statistics Canada 2001; 2003). The national consumption data for the food footprint

[69] Lack of available local food consumption data prevented use of the component method for this study.

uses 2006 statistics. Because my goal is to capture a one-year snapshot of Vancouverite's demand on nature's services resulting from consumption, I have chosen to abstain from modifying the data set with the 2001 consumer preferences to avoid biasing the data based on historical patterns.

Figure 4.4 Vancouver's Ecological Footprint by Consumption Activity



4.2.3.1 Ecological Footprint of Food

Table 4.9 reveals that fruits and vegetables comprise the largest sub-component of the food footprint by weight and account for the largest share of emissions from food miles.[70] However, fish, meat and eggs comprise the largest sub-component in the food footprint overall due primarily to cropland used to produce animal feed, e.g. corn and hay, and to a lesser extent the pasture land used to graze animals and the carbon dioxide emissions from embodied energy used in the production process. Indeed, this sub-component accounts for almost half of the food footprint (figure 4.5).

[70] Note that this term refers to the distance food is transported from farm to plate; however, for purposes of this research distances are measured in kilometres.

Table 4.9 Integrated Urban Metabolism and Ecological Footprint for Food

FOOD	**Materials tonnes**	**Embodied Energy (Production) tCO_2**	**Operating Energy (Food Miles) tCO_2**	**Ecological Footprint gha**
Fruits and Vegetables	166,227	140,705	33,928	120,180
Meat, Fish, Eggs	88,067	317,546	3,878	590,615
Stimulants	42,764	48.937	6,081	28,488
Grains	94,199	74,943	13,524	122,211
Oils, Nuts, Legumes	94,981	68,333	5,077	183,692
Dairy	129,885	177,443	893	171,004
Beverages	104,002	59,645	n/a	14,792
TOTAL	720,125	887,554	63,381	1,230,982

Figure 4.6 reveals that cropland used to produce food materials (e.g., fruits, grains, nuts) comprises the largest demand on nature's services within the food component. Moreover, approximately half of the cropland and all of the pasture land is attributed to producing animal feed (e.g., for meat production). Note that built area (e.g. land occupied by farm buildings such as barns and storage sheds) was not measured and therefore has a value of zero.

Figure 4.5 Vancouver Food Footprint by Food Type

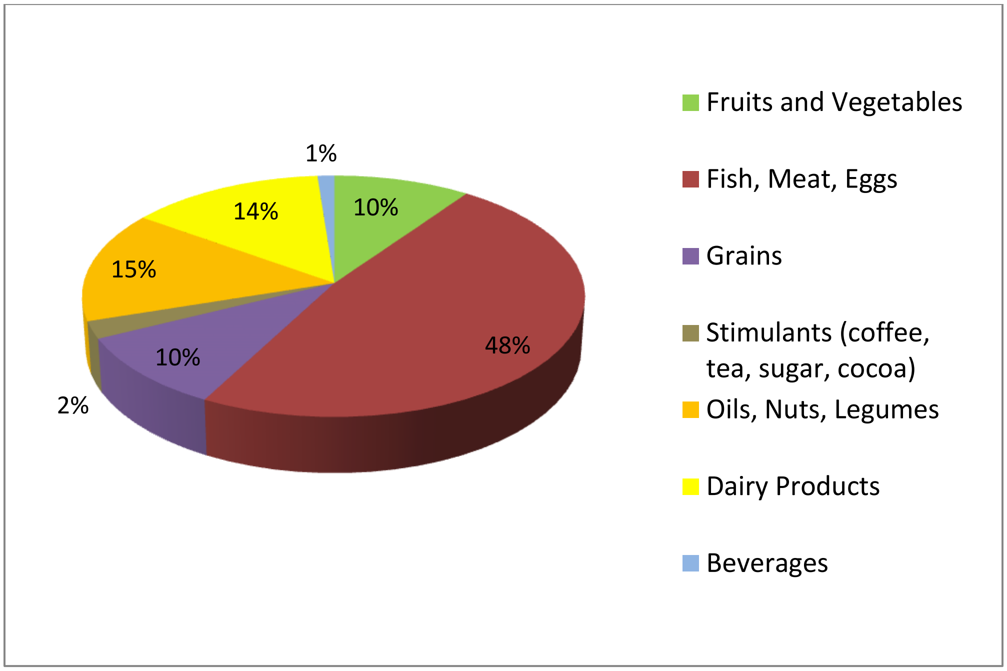
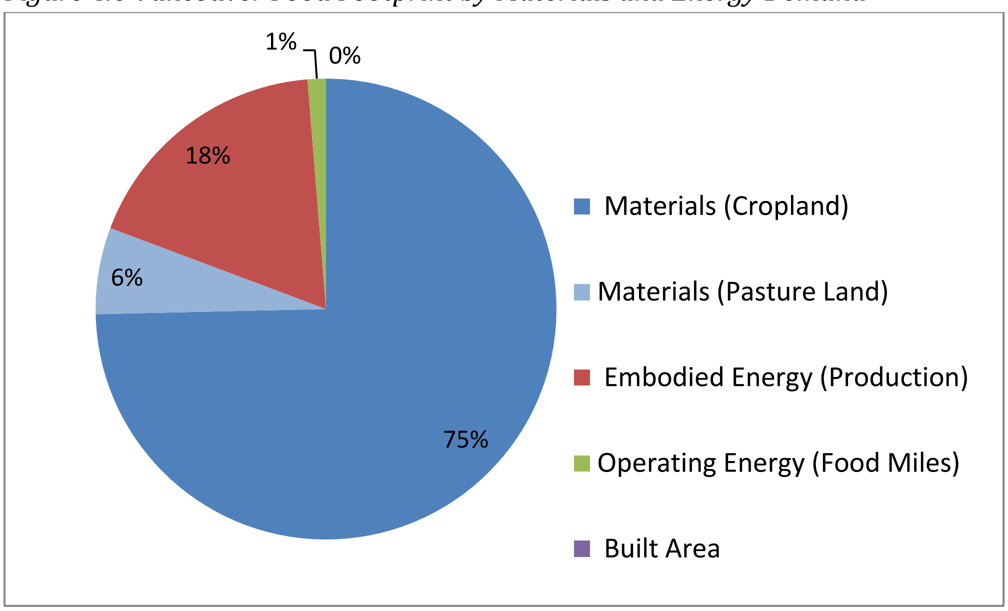


Figure 4.6 Vancouver Food Footprint by Materials and Energy Demand



4.2.3.2 Ecological Footprint of Buildings

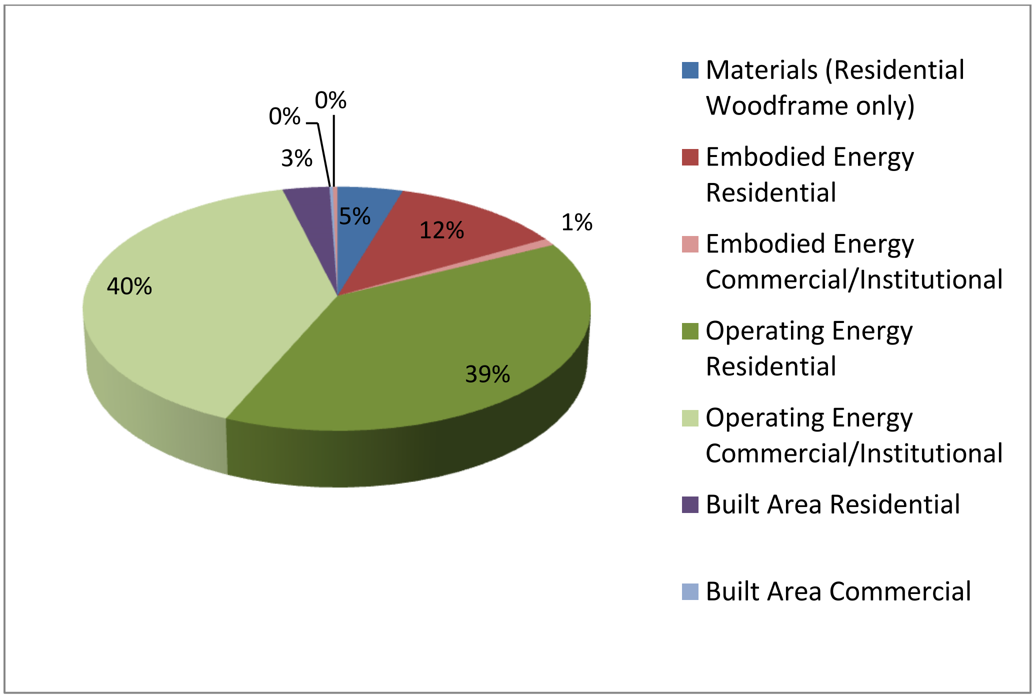
Table 4.10 reveals that electricity for the operation of commercial and institutional buildings comprises the largest energy flow. However, natural gas for residential space and water heating represents the largest contribution to greenhouse gas emissions. Building materials defined as “other” comprising products such as: gypsum, PVC, foams, fiberglass, etc. account for the largest material flow (36,114,156 tonnes per year) assuming a 40 year lifespan for wood frame buildings and a 75 year lifespan for concrete buildings (Metro Vancouver 2001).

Table 4.10 Integrated Urban Metabolism and Ecological Footprint for Buildings

Buildings	**Sub-components**	**Material Flows Analysis**			**Ecological Footprint**
		(Energy/Materials)	**(Emissions)**		
		Tonnes (t) Litres (l) Giga joules (GJ) Kilowatt hours (kWh) Hectares (ha)	GHGs (tCO_2e)	Carbon Dioxide (tCO_2)	Global Hectares (gha)
Materials	Wood Steel Concrete Other	44,094 t 5,750 t 372,669 t 36,114,156 t			18,046
Embodied Energy	Residential	2,741,000 GJ	189,700	189,720	47,046
	Commercial/ Institutional	183,193 GJ	14,970	14,970	3,713
Operating Energy	Residential	1,813,268,028 kWh	44,728	44,728	150,036
		11,052,725 GJ	571,260	560,256	
	Commercial/ Institutional	3,137,202,779 kWh	77,385	77,385	153,323
		10,817,042 GJ	551,710	540,852	
Built Area	Residential	5,317 ha			12,708
	Commercial/ Institutional	915 ha			2,187
TOTAL		36,536,669 t 4,950,470,807 kWh 24,793,960 GJ 6,232 ha	1,449,753	1,274,808	387,057

Operating energy (both electricity and natural gas) for the institutional and commercial building sectors comprises the dominant share (40%) of the building EF (see figure 4.7). This is followed closely by operating energy for residential buildings (39%). Embodied energy within the residential building stock constitutes the third most significant share of the footprint, driven primarily by single family homes. Building materials, namely wood used in residential construction, accounts for the fourth largest share of the buildings footprint, followed by the built area occupied by residential buildings. Recall that most of the city's land area (37%) is dedicated to single family and duplex construction (Metro Vancouver 2006a).

Figure 4.7 Vancouver Buildings Footprint



4.2.3.3 Ecological Footprint of Consumables and Wastes

Residential wastewater (128,214,000 m^3 or 128,214,000 tonnes) accounts for the largest material flow in the consumables and waste component (see table 4.11). Electricity used to treat wastewater accounts for the largest energy flow within this component. Nevertheless, wastewater management contributes relatively few greenhouse gas emissions because the biogas that is generated through the treatment process is utilized on-site (i.e., combusted to produce energy). Therefore, wastewater treatment does not account for a major share of the consumables and waste ecological footprint (see figure 4.8). By contrast, recycled paper (214,975 tonnes) accounts for the second largest material flow and it has the largest contribution of greenhouse gas emissions, due to the energy needed to process the amount of paper being recycled.[71] Consequently, paper constitutes the largest sub-component of the consumables and waste ecological footprint (see figure 4.9). Note that food accounts for the largest category of waste disposed to landfills and the incinerator (81,654 tonnes). However, recall that food waste is included in the EF estimate for the food component and is therefore omitted here to avoid double counting.

Lifecycle data taken from the literature (see chapter 3, section 3.2.3.3) was used to determine the material inputs and carbon dioxide emissions associated with various materials in consumer products. The land area required to grow the materials (e.g. wood, cotton) was then estimated using yield data and converted into an ecological footprint value using the equivalence factors provided by the Global Footprint Network for the 2006 study year. Similarly, the land area required to sequester the carbon dioxide emissions associated with the manufacturing process was also estimated (see chapter 3 for equations and equivalence factors). Adding the land area required to produce the materials for a particular product with the land area required to sequester the emissions from the energy used to manufacture that product generates a lifecycle assessment factor that represents the total global hectares required per tonne of materials used in a given product. A summary of the lifecycle assessment factors used in this research for both growing materials and sequestering emissions is provided in Appendix C.

[71] Approximately 3.5 times more paper was recycled (214,975) than consumed as virgin product (62,000 tonnes).

Table 4.11 Integrated Urban Metabolism and Ecological Footprint for Consumables and Wastes

Consumables and Wastes	Sub-components	Material Flows Analysis (Energy/Materials)	Material Flows Analysis (Emissions)		Ecological Footprint
		Tonnes (t) Cubic metres (m^3) Litres (l) Giga joules (GJ) Kilowatt hours (kWh) Hectares (ha)	GHGs (tCO_2e)	Carbon Dioxide (tCO_2)	Global Hectares (gha)
Materials	Solid waste[72] - Residential - Commercial/ Institutional	182,830 t 97,177 t	86,512 46,022	57,420 30,570	14,294 7,610
	Wastewater - Residential - Commercial/ Institutional	128,214,000 m^3 85,476,000 m^3			
Embodied Energy	Sub-component break-down by weight of all goods consumed and recycled:				
	Paper: Disposed Recycled	61,904 t 214,975 t	43,903 178,214	43,903 178,214	89,685 45,145
	Plastic: Disposed Recycled	41,521 t 11,699 t	143,346 12,518	143,346 12,518	35,982 3,159
	Metal: Disposed Recycled	9,451 t 23,106 t	26,460 41,683	22,491 35,431	14,833 10,398
	Glass: Disposed Recycled	6,820 t 42,615 t	12,563 27,700	12,563 27,700	3,143 6,818
	Organic:Disposed Recycled	17,549 t[73] 0 t[74]	55,076 -	54,181 -	28,761 -
	Other[75]	51, 364 t	217,830	190,485	67,341

[72] Solid waste only counts waste disposed to landfills and incinerators. Data sources include: Metro Vancouver 2006b; TRI 2008; COV 2007b, 2007c.

[73] This sub-component includes wood, rubber and textiles (e.g. cotton fabrics). Although food waste (81,654 tonnes) is excluded from the sub-component breakdown to avoid double counting with the Food footprint, the greenhouse gas emissions from disposal of food waste as well as operating energy associated with managing these wastes is counted in order to capture the post-consumption emissions that are not counted in the Food footprint. Also 8,608 tonnes of yard and garden waste is composted. It is not counted in the urban metabolism or the ecological footprint because the materials were produced and used within the city, e.g., soils produced from the compost are beneficially used in municipal landscaping and/or sold through garden supply stores (COV 2012a; J. Braman, personal communication, Septemeber 28, 2012).

[74] Backyard compost data are not available.

Consumables and Wastes	Sub-components	Material Flows Analysis (Energy/Materials)	Material Flows Analysis (Emissions)		Ecological Footprint
		Tonnes (t) Cubic metres (m^3) Litres (l) Giga joules (GJ) Kilowatt hours (kWh) Hectares (ha)	GHGs (tCO_2e)	Carbon Dioxide (tCO_2)	Global Hectares (gha)
Operating Energy	Solid Waste management - Electricity - Fuel - Natural Gas	4,559,760 kWh 1,180,987 l 337 GJ	1,883	1,600	475
	Liquid Waste management - Electricity - Natural Gas - Biogas	11,551,520 kWh 1,066 GJ 397,934 GJ[76]	19,263	19,197	4,761
Built Area	Solid Waste Operations	235 ha			561
	Liquid Waste Operations	190 ha			454
TOTAL		454,341 t 213,690,000 m^3 waste H_2O 1,180,987 l fuel 16,111,280 kWh 399,337 GJ 425 ha	768,031	654,198	291,257

Figure 4.8 indicates that embodied materials and embodied energy (i.e. the upstream resources used to manufacture products) account for most of the consumables and waste footprint. This

[75] This category includes household hygiene products (10,748 t), hazardous material containers (5,374 t), electronic waste (10,447 t) and products that could not be categorized (24,805 t). In order to ascribe some sort of numerical representation as it pertains to the EF of these items, I assume that the majority of the weight in electronic waste is plastic and that the majority of unclassified waste is household hygiene. Recycling data for these wastes was not included in the municipal data sheets provided form the City, resulting in potential underestimates.

[76] Approximately two-thirds of the biogas (or digester gas) produced at the Iona wastewater treatment plant is used to offset demand for commercial natural gas. The remaining third of unused biogas is flared.

is followed by the energy required to recycle products for subsequent consumption. Indeed, 92% of the demand on nature's services related to the consumption of consumer goods seems to occur in the supply and re-supply (i.e., recycling) chain, before products are consumed. The materials that are managed as municipal solid waste account for only 7% and all the energy (trucks, bull-dozers, facilities operations) and land (landfills) related to solid and liquid waste management account for less than 2% of the consumables and waste ecological footprint.

Figure 4.8 Vancouver Consumables and Waste Footprint

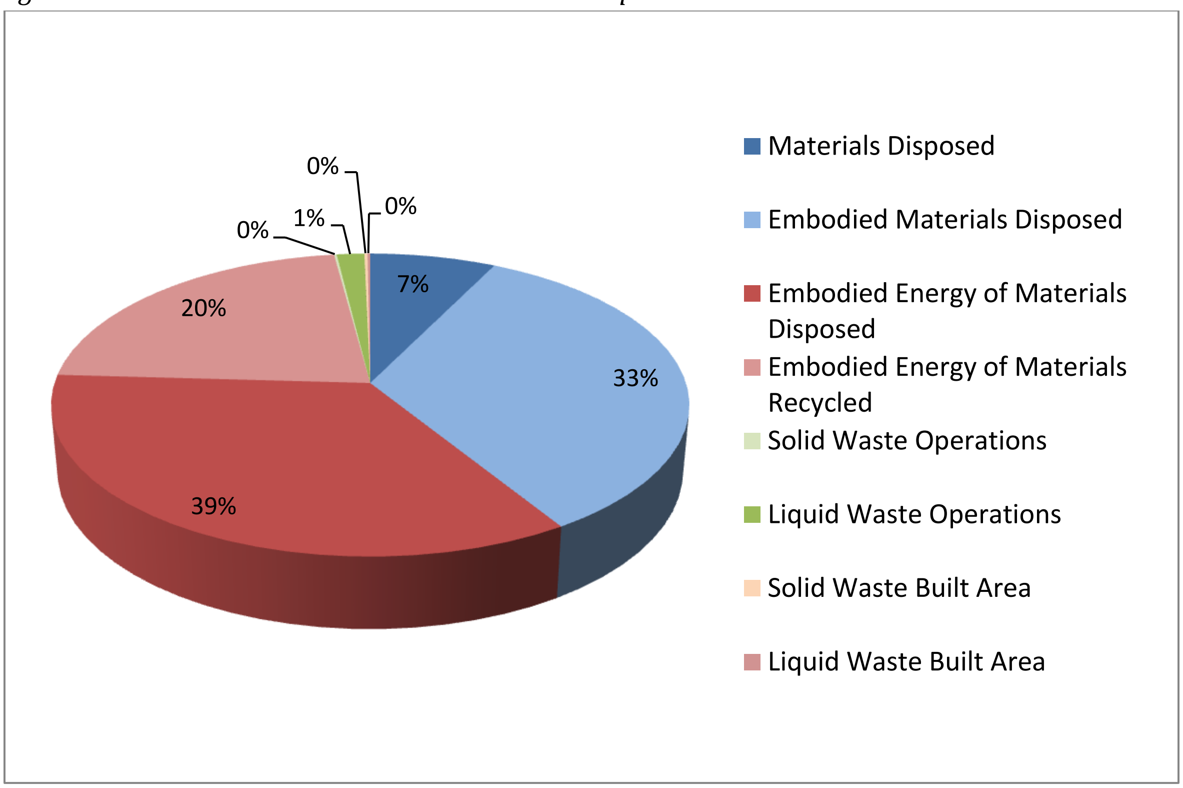
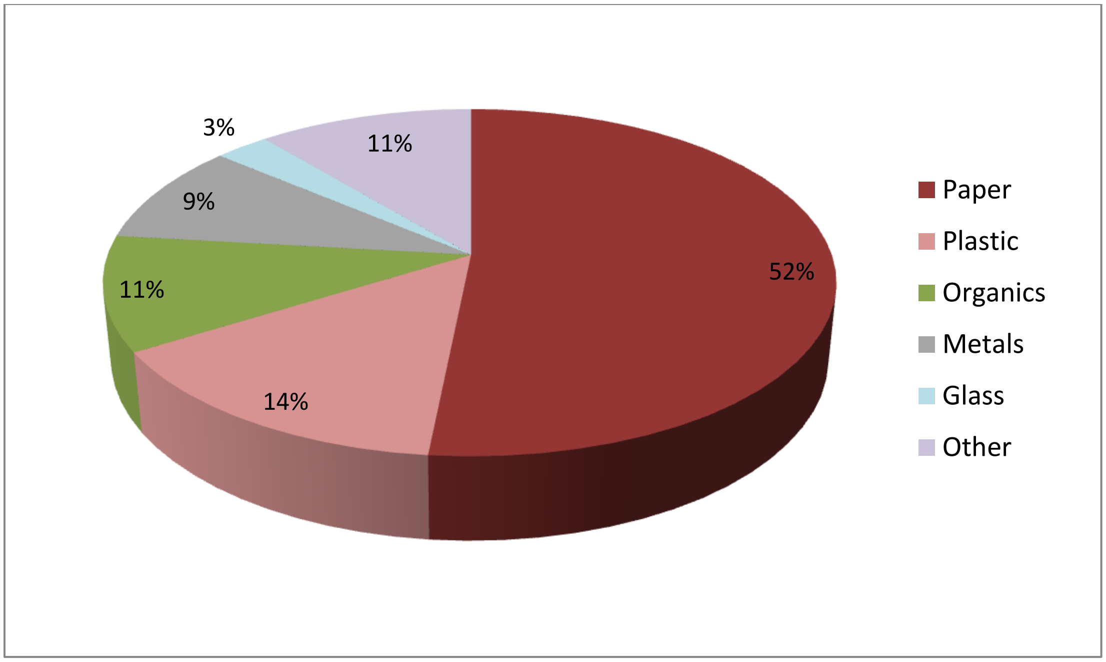


Figure 4.9 Vancouver Consumables Footprint by Material Type



4.2.3.4 Ecological Footprint of Transportation

Fuel to operate privately owned vehicles accounts for the largest material flow in the transportation component of the urban metabolism (see table 4.12). It also contributes the most greenhouse gases. Consequently, operating energy for private vehicles also accounts for the largest share (55%) of the transportation footprint (see figure 4.10). Fuel used in air travel by Vancouver residents accounts for the second largest material flow, followed by fuel to operate commercial vehicles. In terms of the ecological footprint of transportation, air travel contributes the second largest share (17%) of the ecological footprint, tied with embodied energy of privately owned vehicles.[77]

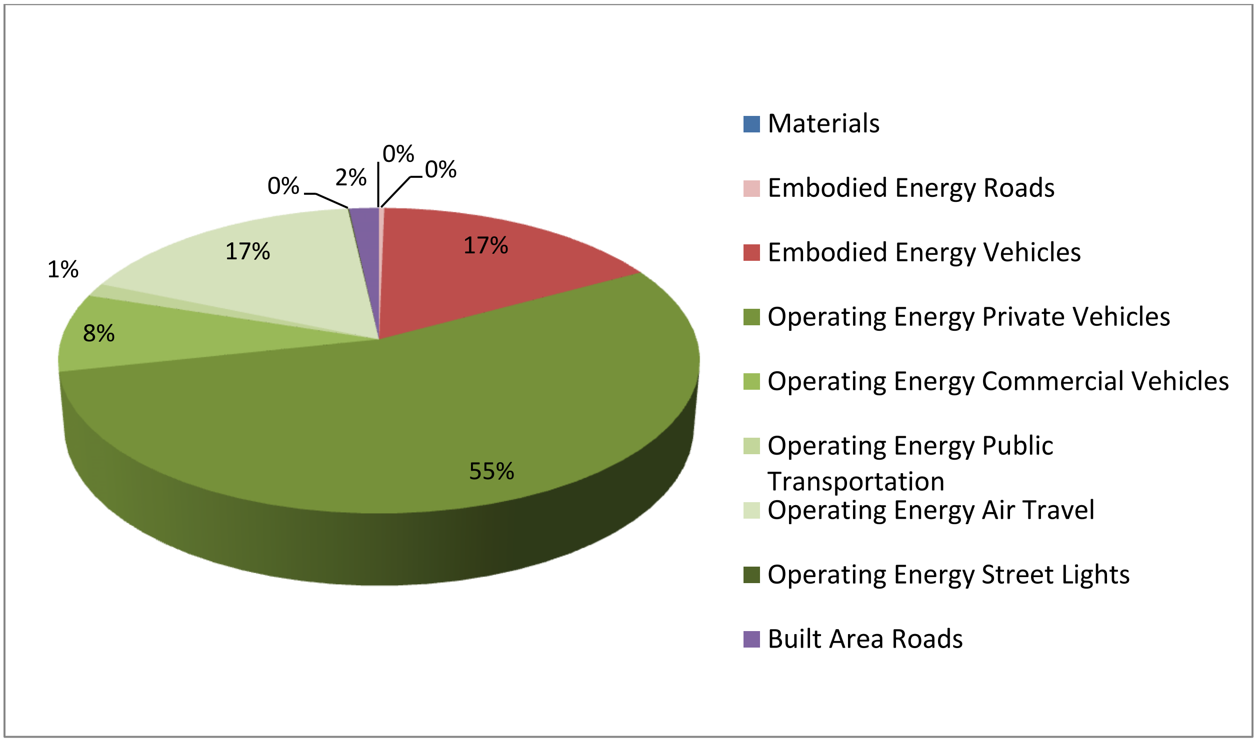
[77] The embodied energy of commercial and public transit vehicles and airplanes was not estimated.

Table 4.12 Integrated Urban Metabolism and Ecological Footprint for Transportation

Transportation	Sub-components	Material Flows Analysis (Energy/Materials)	Material Flows Analysis (Emissions)		Ecological Footprint
		Tonnes (t) Litres (l) Giga joules (GJ) Kilowatt hours (kWh) Hectares (ha)	GHGs in (tCO_2e)	Carbon Dioxide (tCO_2)	Global Hectares (gha)
Materials	Private Vehicles Steel Aluminum Plastics Rubber Glass Other	277,590 vehicles 16,396 t 1,499 t 1,851 t 999 t 648 t 3,109 t			
	Commercial Vehicles	2,591 vehicles			
	Institutional Vehicles	622 vehicles			
	Roads	1,240 lane km			
Embodied Energy	Vehicles	24,502 t[78]	440,732	314,430	77,979
	Roads	192,200 GJ	6,727	5,718	1,429
Operating Energy	Private Vehicles	431,666,210 l	1,028,853	1,021,306	255,327
	Commercial Vehicles	57,385,233 l	153,126	155,280	38,820
	Institutional Vehicles	10,140,603 l[79]	26,339	26,662	6,665
	Air Travel	215,318,369 l	325,282	316,081	79,020
Built Area	Streets, Lanes and Sidewalks	3,372 ha			8,059
TOTAL		367,550 t 714,510,415 l 3,372 ha	1,981,059	1,845,195	469,357

[78] This is the sum of the materials' breakdown for vehicles and should not be added to the grand total to avoid double counting.
[79] This represents the bus fleet only and includes SkyTrain and Seabus. Exclusions are based on the assumption that most inter-regional travel is by non-Vancouver residents commuting to the City.

Figure 4.10 Vancouver Transportation Footprint



4.2.3.5 Ecological Footprint of Water

Electricity to operate drinking water treatment facilities accounts for the largest energy flow in the water component of the urban metabolism, and potable water accounts for the largest material flow (see table 4.13). The watersheds are protected areas, meaning they are closed to the public and maintained in their natural state. However, there is an extensive road network that is used by the water utility for watershed maintenance. This road area constitutes the largest share of the water ecological footprint (see figure 4.11). The embodied energy in drinking water infrastructure (e.g., dams amortized over 100 years and pipes amortized over 50 years) constitutes the largest contribution of greenhouse gas emissions and also accounts for the second largest share of the water footprint.[80]

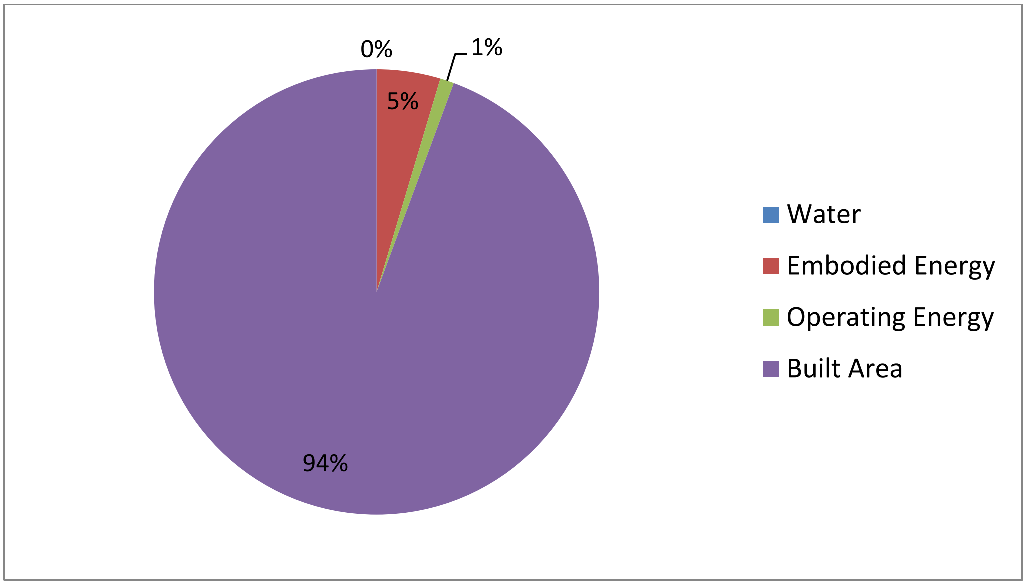
[80] The embodied energy of chemicals such as chlorine used to treat drinking water was note estimated.

Table 4.13 Integrated Urban Metabolism and Ecological Footprint for Water

Water	**Sub-components**	**Material Flows Analysis**			**Ecological Footprint**
		(Energy/Materials)	**(Emissions)**		
		Tonnes (t) Cubic metres (m^3) Giga joules (GJ) Kilowatt hours (kWh) Hectares (ha)	GHGs in (tCO_2e)	Carbon Dioxide (tCO_2)	Global Hectares (gha)
Materials	Residential Water Supply	75,117,000 m^3			
	Commercial/ Institutional Water Supply	50,078,000 m^3			
	Concrete (dams)	28,122 t			
	Ductile iron (pipes)	1,450 km			
Embodied Energy	Dams	800 GJ	96	96	24
	Pipes	38,809 GJ	1,613	1,613	403
Operating Energy	Water Supply treatment	10,571,029 kWh	328	328	82
	Water Supply distribution	n/a	45	45	11
Built Area[81]	Protected Watershed	12,751 ha			
	Protected Reservoir	15,976 ha			
	Road Area	3,414 ha			8,159
TOTAL		125,195,000 m^3 28,122 t 39,609 GJ 10,571,029 kWh 28,727 ha	2,082	2,082	8,679

[81] Land that is protected as natural habitat is not included in the ecological footprint because it represents preservation of existing biocapacity.

Figure 4.11 Vancouver Water Footprint



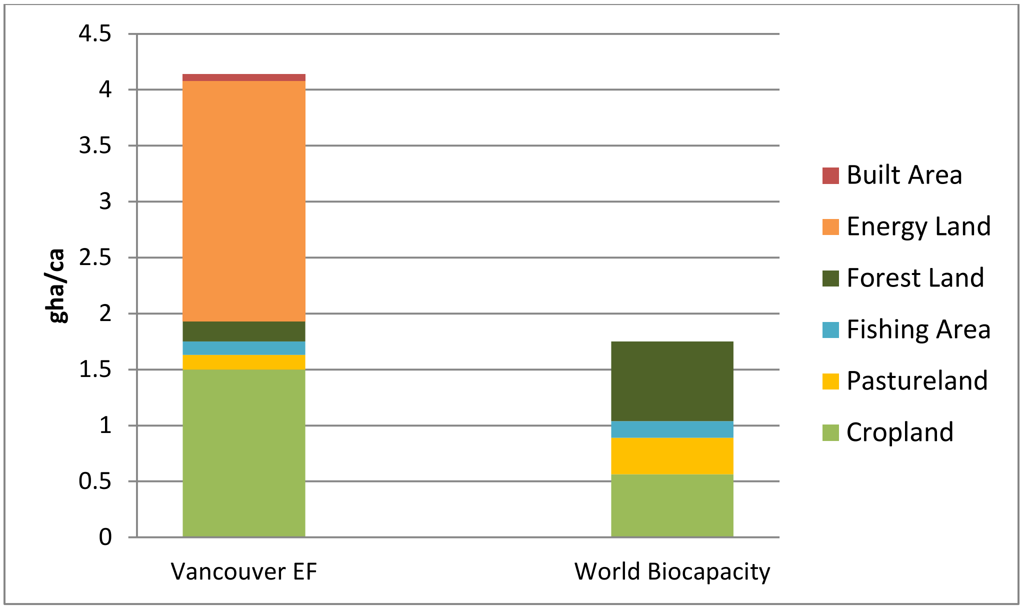
4.3 Vancouver's Sustainability Gap

Vancouver's per capita ecological footprint of 4.2 gha/ca is well above the 1.8 gha/ca targeted as the fair Earthshare. In order to explore the potential for one-planet living, I first establish the gap between the City's current demand on nature's services and available per capita biocapacity supply for each land type.[82] Note that the total per capita biocapacity available in the world is 2.1 gha/ca (WWF 2008, p. 33). However, the fair Earthshare assumes that 12% of available biocapacity is set aside for natural preservation. This brings the remaining available biocapacity for human use down to 1.75 gha/ca or 1.8 gha/ca with rounding-up (WWF 2008).

Biocapacity supply is measured using four ecologically productive area types: cropland, pasture land, fish area and forest land. However, the ecological footprint is measured using these plus two additional types: energy land and built area (see figure 4.12). In order to be able to

[82] Wackernagel and Rees (1996, 159-160) describe the sustainability gap as the difference between available ecological biocapacity and an existing population's level of consumption, as measured by the ecological footprint.

Figure 4.12: Vancouver's Per Capita EF Compared to Per Capita Global Biocapacity Supply



estimate the sustainability gap for these two additional land types, I must consider how they relate to existing biocapacity supply. Since energy land represents the exclusive demand on forests for carbon sequestration, I associate it with available biocapacity of the forest land type. Similarly, since built area is generally considered to be crop land that was converted to urban development (Ewing et al. 2010, 11), I associate it with available biocapacity of the cropland type. Therefore, I can calculate the sustainability gap by subtracting Vancouver's per capita EF for forest land and energy land from the available per capita biocapacity supply of forest land. Similarly, I can subtract Vancouver's per capita EF for cropland and built area from the available per capita biocapacity supply of cropland (see "collapsed overshoot" in table 4.14).

Table 4.14 presents the sustainability gap by land type between Vancouver's per capita EF and global per capita biocapacity supply. One sees that total overshoot[83] is 2.46 gha/ca. Vancouverites' demand exceeds supply in cropland by 1.01 gha/ca and forest land by 1.68

[83]Overshoot means that demand (ecological footprint) exceeds biocapacity supply.

gha/ca. However, Vancouverites use less pasture land and fish area than available global per capita supply. Furthermore, if one looks at the Vancouver EF for forest land, as distinct from energy land, one sees that Vancouverites demand less forest land (0.18 gha/ca) than available supply (0.71 gha/ca). In other words, it is the EF for energy land alone that exceeds the total available biocapacity supply for forest land.

Table 4.14: Vancouver's Sustainability Gap by Land Type

	Cropland	Pasture Land	Fish Area	Forest Land	Energy Land	Built Area	Total
Vancouver EF	1.51	0.13	0.12	0.18	2.21	0.06	4.21
World Biocapacity	0.56	0.33	0.15	0.71	0.00	0.00	1.75
Overshoot	-0.95	0.20	0.03	0.53	-2.21	-0.06	-2.46
Collapsed Overshoot	-1.01	0.20	0.03	-1.68	-	-	-2.46

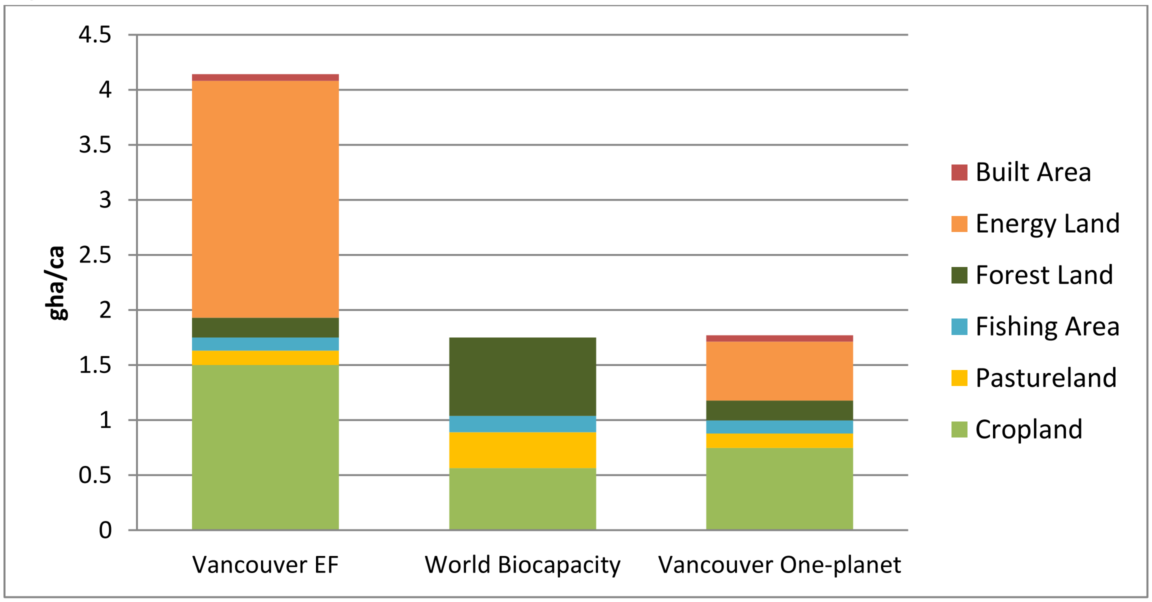
Next, I consider what Vancouver's total EF could be like at a one-planet level of consumption if the excess available biocapacity supply of pasture land and fish area were allocated to offset total demand in cropland, and if the excess in forest land were allocated to offset demand in energy land (see table 4.15 and figure 4.13).[84] This approach refines the sustainability gap estimate for each land type. For example, net demand on ecosystem areas to produce food is 0.78 gha/ca. Similarly, net demand on ecosystem areas to sequester carbon dioxide emissions is 1.68 gha/ca. One can now see how demand on various ecosystems might be distributed across the various land types if Vancouver were consuming at a one-planet level (see figure 4.14).

[84] I assume that the total built area of the City remains constant. Therefore, the built area demand in Vancouver's EF under the one-planet scenario is still counted as part of the cropland overshoot.

Table 4.15: Vancouver's Net Sustainability Gap by Land Type

	Cropland	Pasture Land	Fish Area	Forest Land	Energy Land	Built Area	Total
Vancouver EF	1.51	0.13	0.12	0.18	2.21	0.06	4.2
World Biocapacity	0.56 +0.20 +0.03 -0.06	0.33 - 0.20	0.15 -0.03	0.71 -0.53	0.00 +0.53	0.00 +0.06	1.75
Vancouver EF at One-planet	0.73	0.13	0.12	0.18	0.53	0.06	1.75
Gap:	**-0.78**	**0**	**0**	**0**	**-1.68**	**0.00**	**-2.46**

Figure 4.13: Vancouver's EF, Global Biocapacity Supply, and Vancouver EF at One-Planet



Now I can compare Vancouver's EF, as well as the hypothesized Vancouver EF at one-planet, to the actual EF of societies living at one-planet levels of consumption. First, I compare Vancouver's per capita EF to the EF of the international profile for the one-planet archetype (see figure 4.15). Appendix D shows the individual EF of the eleven countries that comprise the international profile for the one-planet archetype.

Figure 4.14: Vancouver EF at One-Planet

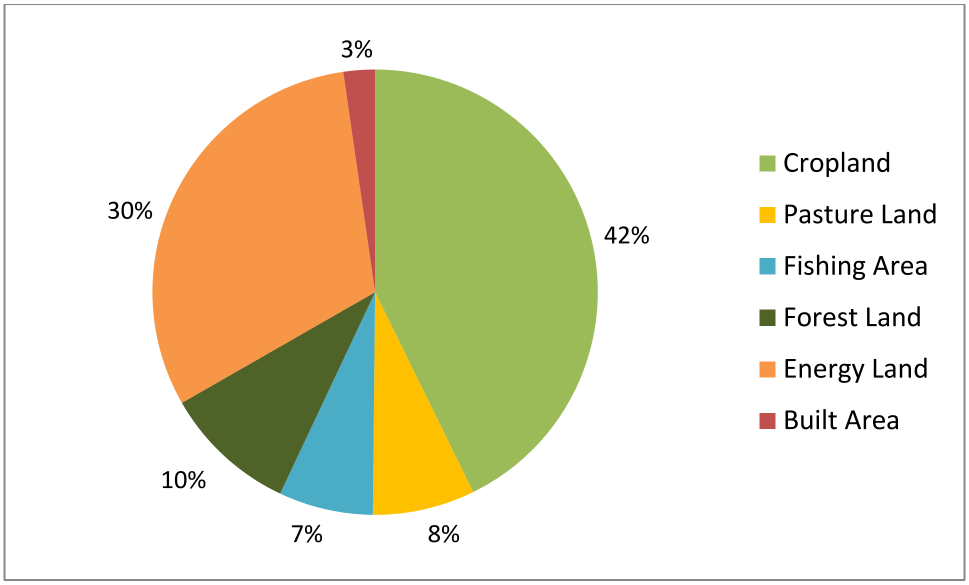
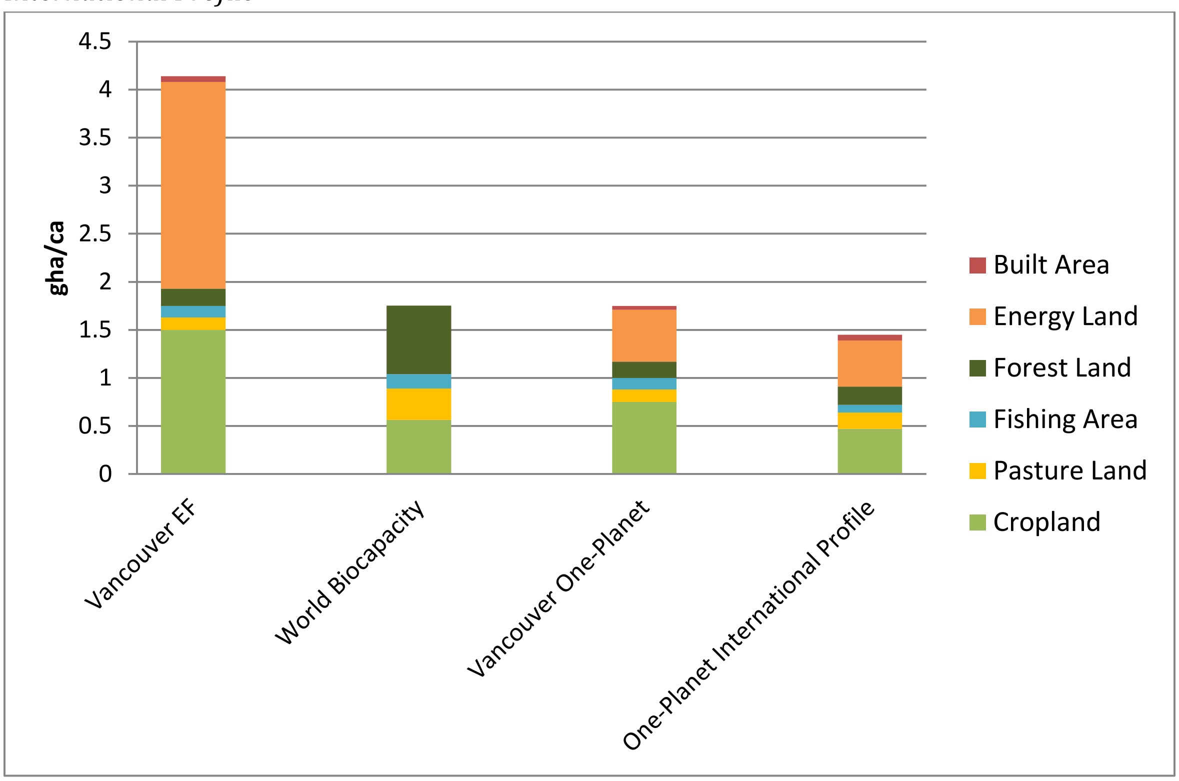


Figure 4.15: Vancouver's EF, Global Biocapacity Supply, Vancouver at One-Planet, and the One-Planet International Profile

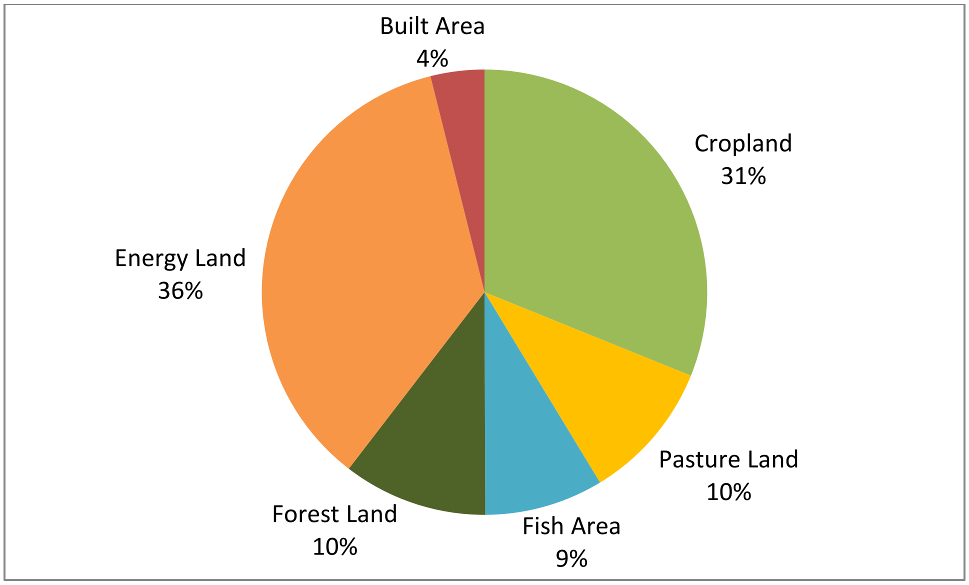


For Vancouver to achieve one-planet living requires a 58% reduction in the per capita footprint, equivalent to 2.46 gha/ca. If one compares Vancouver's ecological footprint to the one-planet international profile, with an average ecological footprint of 1.45 gha/ca, the reduction becomes greater still (approximately 66% or 2.76 gha/ca).

A detailed representation of the international profile for the one-planet living archetype is presented in figure 4.16 (compiled with data from WWF 2010b). One sees that demand for nature's services is distributed approximately in thirds, with one third of ecosystem services dedicated to sequestering carbon dioxide emissions in the form of energy land, one third dedicated to crop production, and another third distributed relatively equally across forest land, pasture land and fish area. A small proportion (4%) is dedicated to the built area.

When compared to Vancouver's ecological footprint (see figure 4.3), one sees that the one-planet living archetype demonstrates significantly less relative demand for energy land (36% vs. 52%) and slightly less relative demand for cropland (31% vs. 36%). However, the relative demand for all other land types is greater. One sees closer approximation in the distribution of the land-types between the one-planet living archetype and the hypothesized Vancouver EF at the one-planet level of consumption (figure 4.14). There is slightly less demand for energy land in the Vancouver scenario (30% vs. 36%) and significantly more land dedicated to crops (42% vs. 31%). This implies that there is flexibility in the way that demand for nature's services is expressed by a society at the one-planet level. The observation is consistent with the variations expressed by the EF of the individual case studies that comprise the international profile for the one-planet archetype (see Appendix D).

Figure 4.16: EF of International Profile for One-Planet Archetype



4.3.1 Exploring the Sustainability Gap for Food

To understand how the sustainability gap reflects differences in consumption patterns, I compare the benchmarks presented above for the one-planet living archetype (see tables 4.2, 4.3 and 4.4) to Vancouver's existing consumption. Because I am primarily interested in exploring the impacts of lifestyle choices, I assume that the methods of production and the sources of energy used in the Vancouver case remain constant. In other words, I specifically explore what changes to the ecological footprint could be made if Vancouverites chose to mimic the lifestyle of the one-planet archetype in the existing Vancouver context. For example, I substitute the type and total throughput of food consumed in the equations used to estimate the food EF (see chapter 3), but hold constant the assumptions about the yields and greenhouse gas intensity of food production (i.e., embodied energy) as well as transportation (i.e., operating energy/ food miles). This approach is followed for all subsequent component explorations as well.

First, I analyze the international benchmarks data for one-planet living (see table 4.2). Total annual food consumption is approximately 0.5 tonnes per capita. This is less than the amount of food consumed by Vancouverites (0.8 t/ca) (Statistics Canada 2007a).[85] I use Nutrition Country Profiles (FAO 2010b, 2008, 2003a, 2003b, 2001a, 2001b, 1999a, 1999b)[86] to assess what type of food is being consumed and in what quantities for eight of the eleven case study countries that represent the international profile of the one-planet archetype (for details see Appendix E). Note that the average per capita food consumption of the eight countries profiled in detail is only 0.41 t/ca/yr, which is less than the average (0.5 t/ca/yr) for the eleven international cases studies in the one-planet category (table 4.2). Henceforth, the analysis relies on the lower value represented by the FAO case studies so that I can capture detailed data about consumption of different food types.

Figure 4.17 compares average per capita food consumption patterns for the one-planet international profile (based on the FAO case studies) with the Vancouver case study (based on net food consumption). In addition to differences in the total amount of food consumed, there are also differences in their relative proportions. For example, Vancouverites consume more stimulants (21% vs. 6% in the one-planet archetype) and prepared beverages (25% vs. 4%). Although Vancouverites consume more meat and dairy products overall, the relative proportion of meat in the diet (7%) is less than in the one-planet profile (9%) and equal for dairy (at 11% in both cases). The one-planet diets are higher in grain consumption (32% of the diet) than the

[85] Refers to net food consumption, meaning plate waste and other in-system losses are excluded. To facilitate comparison to the FAO country profiles which count only net consumption of food, I use Statistics Canada (2006a, 2006d, 2007a) data to estimate net food consumption for Vancouver residents at 441,921 tonnes (or 0.76 t/ca).
[86] Nutrition profiles are not available for Uzbekistan, Iraq and India.

Vancouver diet (11%). Vegetable consumption is also higher in the one-planet profile (33% vs. 25%).

Figure 4.17: Vancouver Food Consumption Compared to the One-Planet International Profile

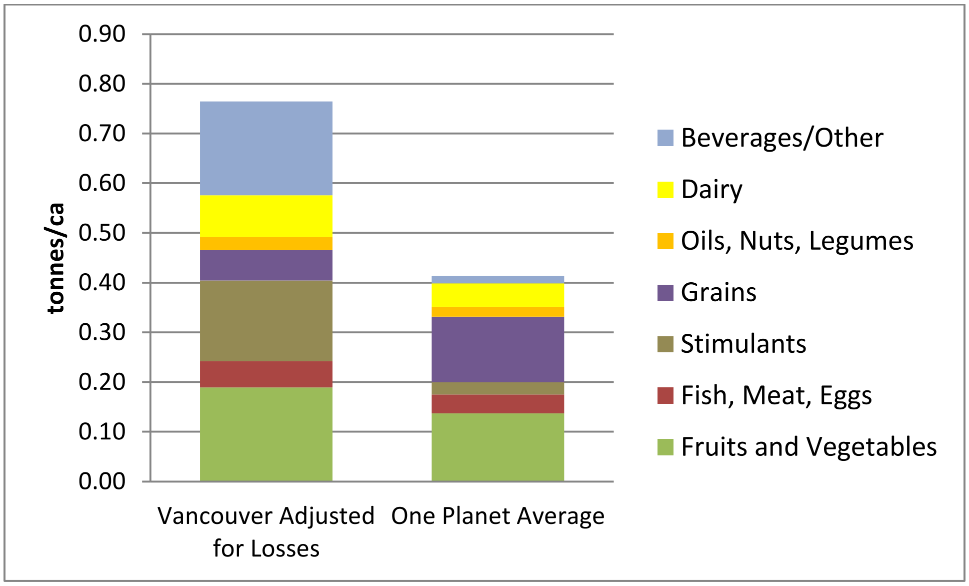


Table 4.16 presents the gha/t for the various categories of food used in the Vancouver EF. I calculated these numbers by dividing the total gha by total tonnes of food consumed for each food type (see table 4.9 for data inputs). I then used the resulting values to estimate the ecological footprint for food if Vancouverites followed a diet similar to the one-planet archetype. I multiplied the average amount of food consumed by food type in one year by the gha/t as calculated in table 4.16 for that same food type. Through this approach, I assumed that the same production and delivery methods are applied to the one-planet scenario as was estimated for Vancouver's original food footprint (see table 4.8).

Table 4.16: Global Hectares per Tonne of Food Based on Vancouver's Consumption Patterns

Food Category	gha/t
Fruits and Vegetables	0.72
Fish, Meat, Eggs	6.71
Stimulants	0.67
Grains	1.30
Oils, Nuts, Legumes	1.93
Dairy	1.32
Beverages	0.14

The estimate also reflects the difference between Vancouver's ecological footprint which is based on gross consumption (i.e., not adjusted for in-system losses/wastes at 2.13 gha/ca) and a footprint based on net consumption (i.e., only the food that was eaten at 0.87 gha/ca). Because the FAO case studies use net consumption, I had to first estimate the ecological footprint of food at one-planet based on net food consumption values (see Appendix E). The estimated food footprint for the one-planet international case studies is 0.64 gha/ca. This is 0.23 gha/ca less than Vancouver's net food footprint of 0.87 gha/ca. I subtract this difference from Vancouver's gross food footprint of 2.13 gha/ca to provide a first estimate of the food EF (1.90 gha/ca) that would be achieved if Vancouverites adopted a one-planet diet.

Table 4.17 compares the food EFs for Vancouver (based on gross and net consumption), the societies already living at one-planet (international profile), the super green and super green plus scenarios, and the intentional community composite profile. Note that the one-planet international case studies represent generally mal-nourished societies (FAO 2008, 2003b, 2001b, 1999a, 1999b). Since the percentage of meat and dairy is similar in both diets, it appears that the majority of EF reduction that could be achieved if Vancouverites ate a diet similar to those in the one-planet international profile is achieved through reducing the quantities of food consumed.

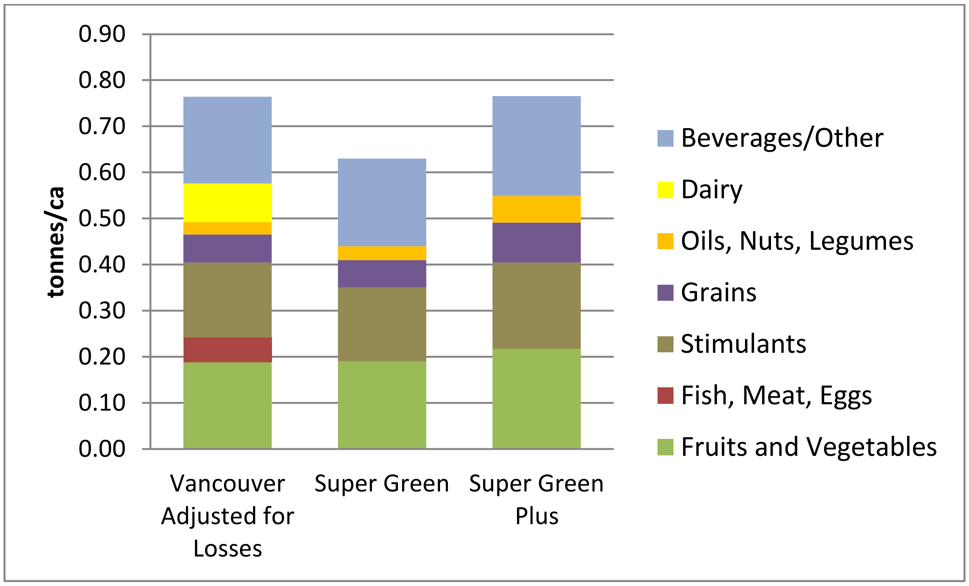
Table 4.17 Vancouver EF of Food Compared with One-Planet Lifestyle Archetype Profiles.

	Vancouver (not adjusted for losses)	Vancouver (adjusted for losses)	International Profile	Super Green	Super Green Plus	Intentional Community Composite Profile
	gha/ca/yr	gha/ca/yr	gha/ca/yr	gha/ca/yr	gha/ca/yr	gha/ca/yr
Fruits and Vegetables	0.21	0.14	0.10	0.14	0.16	n/a
Fish, Meat, Eggs	1.02	0.35	0.25	0.00	0.00	n/a
Stimulants	0.05	0.11	0.02	0.11	0.12	n/a
Grains	0.21	0.08	0.17	0.08	0.11	n/a
Oils, Nuts, Legumes	0.32	0.05	0.04	0.06	0.11	n/a
Dairy	0.30	0.11	0.06	0.00	0.00	n/a
Beverages/ Other	0.03	0.03	0.00	0.03	0.03	n/a
TOTAL	2.13	0.87	0.64	0.41	0.54	0.42

The super green scenarios (table 4.3) derived through the Global Footprint Network calculator indicate that total elimination of meat, fish, eggs and dairy from the diet is conducive to one-planet living. Since the Vancouver diet already comprises more food in total than the one-planet archetype, one could argue that compensation for loss of animal protein in the diet may not be necessary. However, since we know that the diet of the one-planet international case studies is correlated with malnutrition, one might reasonably assume that the elimination of animal protein foods must be compensated for by an increase in consumption of other foods. Figure 4.18 represents a comparison of the Vancouver diet (based on net consumption) and the proposed super green diet that eliminates all animal proteins. I also include an additional comparison, called super green plus, that assumes that the total weight of food consumed by

Vancouverites remains constant despite the elimination of animal proteins. This means that the elimination of animal proteins is compensated for by an equally distributed increase in the amount of all remaining food types such that the net weight of food consumed is the same.[87]

Figure 4.18: Comparison of Vancouver Food Consumption to the Super Green Profile



Following the same estimation methods as described above for the international case studies, if Vancouverites followed the super green scenario and eliminated all animal proteins from their diet and did not compensate for this loss by consuming other food stuffs, the per capita EF for food could be reduced by 0.46 gha/ca to 1.67 gha/ca. If Vancouverites followed the super green plus scenario, where the total amount of food consumed is held constant despite the elimination of animal proteins, the per capita EF for food could be reduced by 0.33 gha/ca resulting in a food footprint of 1.80 gha/ca. In both of these scenarios, the reduction potential to the EF for food is greater than what was estimated for the Vancouver diet following the one-

[87] This approach represnents a first approximation only because simply increasing the wight of other foods across the diet may not adequately compensate for the nutritional losses from reduced meat consumption.

planet international case studies. This implies that the type of food consumed affects the EF as much as or more than how much food is consumed.

The Intentional Community Composite Profile (table 4.4) represents a mostly vegetarian diet that includes local and organic food production as well as communal food preparation methods. The average per capita food footprint in the Intentional Community Composite Profile is 0.42 gha/ca. If Vancouverites mimicked these food consumption patterns, they could achieve a reduction of 0.45 gha/ca in their food footprint. This would result in a food footprint for Vancouver of 1.68 gha/ca (down from 2.13 gha/ca).

Table 4.18 summarizes the potential reduction in the food EF that could be achieved if Vancouverites adopted a diet similar to the one-planet international case studies, super green or super green plus profile, or the intentional community composite profile. In all cases, the potential reduction falls short of what would be necessary to close the sustainability gap of 0.78 gha/ca for cropland (or 2.46 gha/ca overall). The analysis reveals that if Vancouverites changed only the type of food they consumed, i.e. super green plus scenario, the EF for food could be reduced more than if they reduced the total quantity of food consumed following the consumption patterns of the one-planet international case studies. Further reductions might be possible with changes to the way that food is produced and prepared (as implied by the intentional community profile). However, this is only speculation at this point. Further analysis into how production of food could render additional reductions in the food footprint will be explored in subsequent sections of the dissertation.

Table 4.18 Comparison of the Potential Reductions in the Food Footprint

	Vancouver	International Profile	Super Green	Super Green Plus	Intentional Community
Reduction potential	-	-0.23	-0.46	-0.33	-0.44
Food Footprint	2.13	1.90	1.67	1.80	1.68

4.3.2 Exploring the Sustainability Gap for Buildings

Table 4.2 reveals that there is an average of five people per household with an average living space of 8 m2 (86 ft2) per capita for people at the one-planet level of consumption. This is equivalent to 40 m2 (430 ft2) per household. Average per capita energy use is equivalent to 692 kWh per year and approximately 0.2 tCO_2 emissions per capita are associated with home energy use. In contrast, the average Vancouverite lives in 43 m2 (467 ft2) or 99 m2 (1,065 ft2) per household, assuming an average of 2.2 people per household (D. Ramslie, personal communication, February 16, 2011; Statistics Canada 2007b). Average annual, per capita electricity use is 3,137 kWh, and there is approximately 1 tCO_2 emissions per capita associated with home energy use (BC MOE 2010, Statistics Canada 2007b). Therefore, the average Vancouverite lives in a space five times larger, consumes 4.5 times more electricity, and produces five times more carbon dioxide emissions per capita related to home energy use than the one-planet archetype based on the international profile.

If Vancouverites consumed electricity at the same per capita level as those already living at one-planet, the per capita EF for Vancouver's buildings footprint could be reduced by 0.02 gha/ca. This would result in an overall building footprint of 0.65 gha/ca (down 3% from 0.67 gha/ca). In other words, a 78% reduction in electricity consumption would only yield a three percent reduction in Vancouver's building footprint. This is probably due to the low greenhouse gas emission coefficient for electricity in Vancouver (24.666 tCO2/GWh) as a result of significant hydro power capacity (BC MOE 2010).

If, on the other hand, Vancouverites reduced greenhouse gas emissions from residential buildings to a level commensurate with those already consuming at the one-planet level, the per capita EF for Vancouver's buildings footprint could be reduced by 0.21 gha/ca. This would result in an overall building footprint of 0.46 gha/ca (down 31% from 0.67 gha/ca). This means that an 80% reduction in greenhouse gas emissions from fossil-based energy sources (e.g. natural gas used for space and water heating) could yield a 69% reduction in the buildings footprint. See Appendix F for calculations.

The super green scenario (table 4.3) indicates that average per capita living space is 5 m^2 and electricity consumption is 240 kWh/ca. The super green scenario is silent on greenhouse gas emissions; however, most energy (over 75%) is derived from renewable sources. If Vancouverites consumed electricity at the same levels as the super green scenario, the per capita EF for Vancouver's buildings footprint could be reduced by 0.02 gha/ca. The super green scenario depicts per capita electricity consumption at one-third that of the international profile for one-planet living (i.e., 240 kWh/ca/yr versus 692 kWh/ca/yr). However, because of the low greenhouse gas emission coefficient for electricity in Vancouver, the additional reductions in carbon dioxide and corresponding reduction in the ecological footprint are insignificant. If I assume that 75% of Vancouverites' fossil based energy is converted to renewables with low to no greenhouse gas emissions, the resulting reduction in EF from the buildings component would be 0.18 gha/ca.[88] This would result in an overall building footprint of 0.49 gha/ca (down 27% from 0.67 gha/ca). Thus the super green scenario produces results commensurate with the international profile for one-planet living.

The average per capita dwelling space in the intentional community composite profile (table 4.4) is 19 m2/ca (201 ft2/ca) comprising 100% renewable energy sources for electricity and a dominant reliance on renewable energy for space heating. The average per capita buildings footprint is 0.29 gha/ca. If Vancouverites used energy in residential buildings the same way, derived from similar renewable energy sources, they could achieve a reduction of 0.38 gha/ca in the buildings footprint. This would result in an overall buildings footprint for Vancouver of 0.29 gha/ca (down 57% from 0.67 gha/ca).

Table 4.19 reveals the potential reduction in the ecological footprint for residential buildings that could be achieved if Vancouverites utilized residential energy the same way as the international, super green, or intentional community composite profiles comprising the one-planet archetype.

Table 4.19 Comparison of the Potential Reductions in the Buildings Footprint

	Vancouver	International Profile	Super Green	Intentional Community
Potential Reduction		- 0.21	- 0.18	- 0.38
Buildings Footprint	0.67	0.46	0.49	0.29

The potential reductions fall short of what would be necessary to close the sustainability gap of 1.68 gha/ca for energy land (or 2.46 gha/ca overall). The analysis reveals that the greenhouse

[88] Note, however, that if the renewable energy source includes virgin wood, the land associated with the production of that wood would be counted as a contribution to the EF.

gas intensity of energy is more important than the overall amount of energy consumed. This means the type of energy (and its greenhouse gas emissions coefficient) is a crucial consideration. Because most electricity consumed in Vancouver is generated from hydropower, it has a very low greenhouse gas emissions coefficient. To close the sustainability gap, therefore, requires a focus on managing fossil based energy used for space conditioning and domestic hot water heating. Consideration of how to reduce greenhouse gas emissions from commercial and institutional buildings could also be considered.

4.3.3 Exploring the Sustainability Gap for Consumables and Wastes

I estimate consumption data for household goods by analyzing municipal waste and recycling data (see chapter 3). However, it is difficult to ascertain household waste and recycling levels for societies comprising the international profile of the one-planet living archetype. Systems for measuring and weighing waste are rare in developing countries and differences in the way that wastes are classified impede data comparisons (UN Habitat 2010). In many countries municipally provided waste management services do not cover the entire urban population, and a significant portion of recycling is handled through the informal sector (UN Habitat 2010). It is also difficult to determine how municipal solid waste data in the one-planet living case studies translates into energy and material flows. For example, the international benchmark data for one-planet living (table 4.2) reveals that most household electronic appliances (e.g., radio, telephone, television and personal computers) are shared among several members within a household, or even among households. This makes it challenging to ascertain individual usage of such items. In countries such as Zambia,[89] most people purchase second hand clothes that are imported from North America and Europe (Mansvelt 2005). Therefore, only the energy required to reuse the clothing (i.e. energy used to transport the clothes from North America and Europe) should be counted.[90] To compensate for the challenges in estimating the actual energy and materials flows associated with a high degree of sharing as well as recycling and trade of goods in the informal economy, I assume that reported municipal waste data in the one-planet case studies represents all the materials consumed. This approach most likely produces an underestimate thereby reducing the risk of over-estimating the impacts from materials that contain a high percentage of recycled and re-used content.

I use data from urban waste audits (UN Habitat 2010) to estimate what type of materials are being consumed in household goods and in what quantities for three countries that comprise part of the international profile for the one-planet archetype (i.e., Mali, Philippines and India).[91] I average these data to develop a consumption profile for household goods (see table 4.20).

Total annual consumption of goods, based on waste data for the international case studies is 0.24 tonnes per capita (UN Habitat 2010). This is significantly less than the per capita amount of goods consumed and disposed as municipal waste by Vancouverites (0.48 t/ca) and far less still if all materials, including recycling, is counted (0.99 t/ca) (COV 2008a; Statistics Canada 2007b). One sees that organics comprise the largest sub-component of the one-planet waste stream.

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[89] Zambia is not a one-planet living case study country, but its population does live at the one-planet level of consumption (WWF 2010b).

[90] In theory a portion of the embodied energy of the clothing should also be attributed to the second-hand owner according to the amount of use they derive from the clothing – and this should be subtracted from that originally ascribed to the first owner.

[91] Data is for cities in Mali, Philippines, and India. Ciities in the other countries that comprise the international profile were not available.

This is probably due to the inclusion of food waste which makes it difficult to ascertain precisely how much of the organic waste is comprised of non-food waste (e.g. wood, rubber, and cotton from discarded household furniture and clothing). Recall that the Vancouver case study does not count food waste in the consumables and waste footprint component (it is assumed under the food footprint). If food waste was counted within consumables and waste, Vancouverites' per capita amount of waste would increase to 1.13 t/ca.

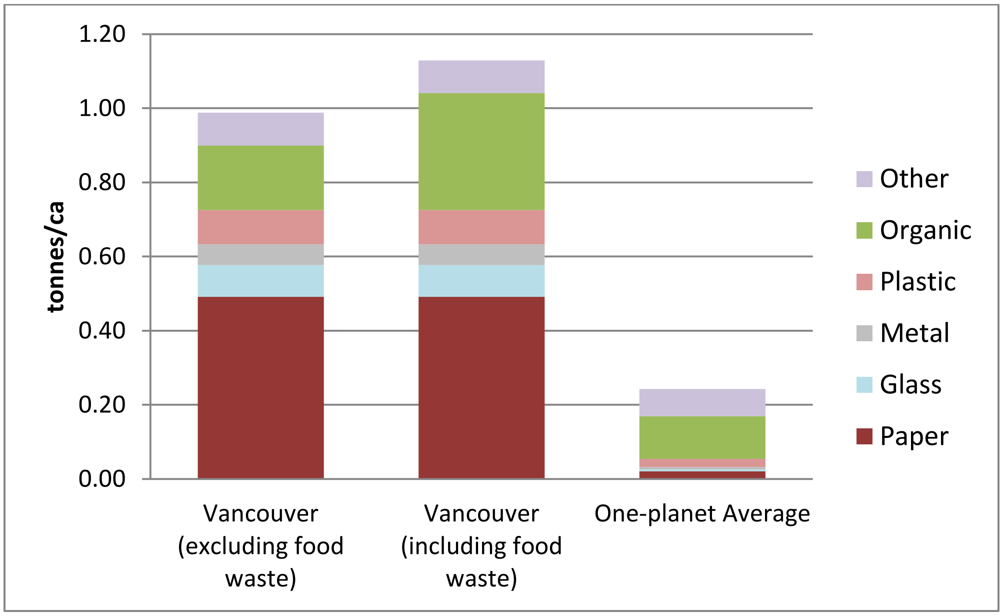
Table 4.20 Comparison of Vancouver and One-planet International Profile of waste

	Vancouver Municipal Solid Waste (excluding food waste)		**Vancouver Municipal Solid Waste (including food waste)**		**One-Planet Municipal Solid Waste (including food waste)**	
	t/ca/yr	%	t/ca/yr	%	t/ca/yr	%
Paper	0.49	50	0.49	44	0.02	8
Glass	0.09	9	0.09	8	0.01	2
Metal	0.06	6	0.06	5	0.01	3
Plastic	0.09	9	0.09	8	0.02	7
Organic	0.17	18	0.31	28	0.12	49
Household Hazardous	0.03	3	0.03	2	0.00	0
Other	0.06	6	0.06	5	0.07	29
Total	0.99	100	1.13	100	0.24	98

For purposes of comparison, I show both the Vancouver data without food waste (i.e., the data used to compile Vancouver's EF) as well as with food waste. In both cases, paper remains the dominant material in the waste-stream (mostly from recycling). Comparing Vancouver to the one-planet international case studies, one sees that in addition to variations in the total amount of goods consumed there are also differences in the proportions of materials consumed. Specifically, Vancouverites consume more paper (50% vs. 8% in the one-planet archetype) and glass (9% vs. 2%). Other materials include plastic (9% vs. 7%) and metal (6% vs.

3%). In contrast, the majority of waste in the one-planet case studies comprises organics (49% vs. 18% in Vancouver). As noted, this is probably due to the inclusion of food waste in the one-planet data set. However, the one-planet case studies data still shows a greater proportion of organics in the waste stream even when food waste is also included in the Vancouver data (49% vs. 28% in Vancouver). In the one-planet case studies, the category called "Other" which captures undefined waste materials accounts for 29% (vs. 6% in Vancouver).[92]

Figure 4.20: Comparison of Vancouver Household Goods Consumption Patterns to the One-planet archetype using international case study data



If Vancouverites consumed the same amount of materials in the same proportions as the one-planet international case studies, and if those materials were manufactured and disposed or recycled in the same manner as what was estimated for Vancouver's original consumables and waste footprint (see table 4.11), then the Vancouver EF for consumables and wastes could be reduced by 0.25 gha/ca. This would result in an overall consumables and waste footprint of

[92] The category called "Other" includes undefined materials, hazardous household wastes (e.g., household hygiene products) that are soiled by bodily fluids such as feminine pads and diapers, hazardous materials containers (e.g., paint cans), electronic products (e.g., computers and light bulbs).

0.33 gha/ca (down 43% from 0.58 gha/ca). Note that the high percentage of organics in the waste stream of the one-planet case studies reduces the overall EF reduction potential. Because I assume that the organic materials are manufactured and disposed in the same manner as what was estimated for Vancouver's original consumables and waste footprint, my estimates attribute a high value to the embodied energy of organic material waste.

The super green profile (table 4.3) assumes extremely low levels of consumption and 100% recycling. For example, books, magazines, appliances, and personal electronics are never purchased. Clothing and household furnishings are minimal. However, in the Global Footprint Network (2010) calculator, the super green profile does not indicate energy and material units of consumption which are needed to compile benchmark data. To overcome this data constraint, I subtract the previously estimated super green per capita food footprint of 0.41 gha/ca (see table 4.17 above) from the total super green per capita ecological footprint of 1.13 gha/ca (see table 4.3) and then distribute the difference (0.72 gha/ca) across the remaining four components. This produces an estimate of 0.18 gha/ca per component. If Vancouverites consumed in a similar way to the super green profile, then based on the assumptions outlined above, the Vancouver EF for consumables and waste footprint could be reduced by 0.40 gha/ca. This would result in an overall consumables and waste footprint of 0.18 gha/ca (down 69% from 0.58 gha/ca).[93] (The same estimates apply for the super green plus profile with a food footprint of 0.54 gha/ca and total ecological footprint of 1.26 gha/ca.)

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[93] If I further assume that the water component is insignificant (as it is in the Vancouver case) and distribute the difference equally across the remaining three components, I could assume that the consumables and waste component is approximately 0.24 gha/ca for the Super Green Scenario.

The intentional community composite profile (table 4.4) indicates that consumption of goods and production of wastes is similar to conventional urban households in Sweden at 0.19 gha/ca.[94] If Vancouverites consumed with an EF similar to the value reported for the intentional community composite profile, the Vancouver EF for consumables and waste could be reduced by 0.39 gha/ca. This would result in an overall consumables and waste footprint of 0.19 gha/ca (down 67% from 0.58 gha/ca).

Table 4.21 summarizes the findings from this analysis and reveals the potential reduction in the ecological footprint for consumables and wastes that could be achieved if Vancouverites consumed household goods at the same rate as the one-planet international profile case studies, super green and super green plus profiles, or the intentional community composite profile. Note that these numbers are based on significant assumptions. The potential reductions fall short of what would be necessary to close the sustainability gap of 0.78 gha/ca for cropland and 1.68 gha/ca for energy land (or 2.46 gha/ca overall).

Table 4.21: Comparison of Potential Reductions in the Consumables and Waste Footprint

	Vancouver	International Profile	Super Green	Super Green Plus	Intentional Community
Potential Reduction		- 0.25	- 0.40	- 0.40	- 0.39
Consumables and Waste Footprint	0.58	0.33	0.18	0.18	0.19

[94] Other intentional communities report per capita footprints for consumables and wastes of: 0.23 gha/ca for Quayside Village in North Vancouver, Canada (Giratalla 20010), 0.3 gha/ca for Findhorn in Scotland (Tinsley and George 2006), and 0.79 gha/ca for BedZed in London, England (BioRegional 2009). Note that the latter value for BedZed exceeds Vancouver's per capita EF for consumables and wastes.

4.3.4 Exploring the Sustainability Gap for Transportation

Table 4.2 indicates that there is 0.02 per capita car ownership and a total of 582 vehicle kilometers travelled (VkmT) per capita in the one-planet living archetype. Air travel is minimal at an average of 125 AkmT/ca. In Vancouver, there are 0.5 vehicles per capita and a total of 6,363 VkmT/ca (BC MOE 2010). Air travel is approximately 4,857 AkmT per person (Legg unpublished). Table 4.2 also indicates that there is approximately 19% transit ridership for commuting purposes. These statistics imply that most transportation in the one-planet archetype is by foot or bicycle (e.g., up to 81%). In Vancouver, the mode split is: 17% walking, 3% cycling, 18% transit, 12% passenger in a private vehicle, 50% driver of a private passenger vehicle (Memon et al. 2006).

If Vancouverites followed similar patterns of motor vehicle ownership and average per capita vehicle kilometers travelled as those already living at one-planet, the reduction in Vancouver's per capita transportation footprint would be 0.5 gha/ca. This would result in an overall transportation footprint of 0.31 gha/ca (down 62% from 0.81 gha/ca). If I also assume that Vancouverites switch to using air travel as infrequently as those already living at one-planet, the reduction in Vancouver's per capita transportation footprint is an additional 0.13 gha/ca. This means the total reduction in Vancouver's transportation footprint would be 0.63 gha/ca. This would result in an overall transportation footprint of only 0.18 gha/ca (down 78% from 0.81 gha/ca).

The super green profile (table 4.3) indicates that there is virtually zero motor vehicle ownership per capita. Almost all transportation is by walking, cycling and transit/rideshare. This means there is practically no motorized forms of private vehicle transportation and no air travel. If

Vancouverites achieved the same modal split as the super green profile, the reduction in Vancouver's per capita transportation footprint would be 0.67 gha/ca. This would result in an overall transportation footprint of only 0.14 gha/ca (down 83% from 0.81).

The intentional community composite profile (table 4.4) is silent on the level of per capita vehicle ownership and indicates that per capita car travel is 539 km annually. The ecological footprint presented in table 4.4 associated with the transportation component (0.37 gha/ca) appears to only account for this mode of transportation. If Vancouverites drove an average of 539 km/ca annually the ecological footprint for transportation could be reduced by 0.40 gha/ca. This would result in an overall transportation footprint of only 0.41 gha/ca (down 49% from 0.81). However, for the intentional community profile there is also a significant amount of air travel at 8,439 AkmT/ca which was not included in the ecological footprint estimate. This is almost twice the average per capita travel estimated for Vancouverites.[95] If Vancouverites drove and flew the same amount as in the Intentional Community Composite Profile, then Vancouver's transportation footprint would actually increase by 0.17 gha/ca. This would result in an overall transportation footprint of 0.98 (up 21% from 0.81).

Table 4.22 summarizes the findings of this analysis and reveals the potential change in the transportation footprint that could be achieved if Vancouverites travelled in the same way as the one-planet case studies, super green scenario, or intentional community composite profile. In all cases, the potential reduction falls short of what would be necessary to close the sustainability gap of 1.68 gha/ca for energy land (or 2.46 gha/ca overall). Indeed, when air

[95] I suspect the high air mileage for the intentional community profile is partly associated with the hotel operations of Findhorn, which accommodates people who visit for short durations (weeks to months) inorder to experience an intentional life as a form of lifestyle tourism.

travel is factored into the Intentional Community Composite Profile the result exceeds Vancouver's per capita transportation footprint. This observation calls attention to the importance of including all aspects of lifestyle-related consumption activities when measuring ecological footprints, particularly with regard to attempts to model sustainable lifestyles in intentional communities.

Table 4.22: Comparison of the Potential Reduction in the Transportation Footprint

	Vancouver	International Case Studies	Super Green	Intentional Community (without air travel)	Intentional Community (with air travel)
Potential Reduction		- 0.63	- 0.67	- 0.40	+ 0.17
Transportation Footprint	0.81	0.18	0.14	0.41	0.98

4.4. Summary

Table 4.23 summarizes Vancouver's sustainability gap for the four components: food, buildings, consumables and waste, and transportation. Recall that because the ecological footprint for the water component was so small (0.02 gha/ca), I have excluded it from further analysis. This reduces the total EF represented in Table 4.23 accordingly to 4.19 gha/ca (down 0.02 gha/ca from 4.21 gha/ca).

Table 4.23 reveals that if Vancouverites adopted lifestyle patterns similar to those in the one-planet archetype, they could reduce their footprint but not enough to achieve the one-planet living target. Recall that the analysis assumes that the modes of production and sources of energy in the Vancouver case study are held constant in order to isolate for the impact of resident lifestyle choices. Therefore, it appears that the energy and materials intensity of the modes of production used to deliver goods and services to Vancouverites comprises a significant share of the ecological footprint. Lifestyle choices that reflect the one-planet archetype are insufficient to reduce the per capita ecological footprint to a level commensurate with one-planet living. Changes to economy-wide energy and materials intensity would also be needed. In most cases these types of changes fall outside the scope of local government jurisdiction, implying that engagement by senior government (i.e., the Province of British Columbia and the Government of Canada) is needed.

Table 4.23 Lifestyle Archetype Potential to Reduce Vancouver's Sustainability Gap

	Vancouver	International Case Studies	Super Green	Super Green Plus	Intentional Community (without air travel)	Intentional Community (with air travel)
Food Potential Reduction	-	-0.23	**-0.46**	-0.33	-0.44	
Food Footprint	2.13	1.90	1.67	1.80	1.68	
Buildings Potential Reduction		- 0.21	- 0.18		**- 0.38**	
Buildings Footprint	0.67	0.46	0.49		0.29	
Consumables and Waste Potential Reduction		- 0.25	**- 0.38**		- 0.37	
Consumables and Waste Footprint	0.58	0.33	0.20		0.21	
Transportation Potential Reduction		- 0.63	**- 0.67**		- 0.40	+ 0.17
Transportation Footprint	0.81	0.18	0.14		0.41	0.98
Total	4.19	2.87	2.50	2.61	2.59	3.14

The hypothetical super green profile depicted by the Global Footprint Network's (2010) ecological footprint calculator generates the greatest cumulative potential reduction in total per capita EF (down 1.69 gha/ca to 2.50 gha/ca). This is primarily due to EF reductions in food and transportation reflecting: a) a reduction in the total amount of food consumed combined with a vegan diet comprising primarily organic, in-season, locally produced food, and b) relying exclusively on walking, cycling and public transit with no air travel.

The intentional community profile generated the second greatest cumulative potential reduction. Specifically, it shows the greatest single reduction in the buildings component, implying that fuel type (predominantly renewable energy) affects the EF more than density. However, the intentional community shows the lowest potential reduction in the transportation component, and even exceeds the Vancouver per capita average when air travel is included. While the data for the intentional community profile is too limited to draw precise conclusions, it appears that use of single occupant vehicles and air travel are key determinants in the EF. Even among communities who choose to reduce their ecological footprint through multiple strategies, this element of lifestyle choice is critical to achieving one-planet living. In this light, while density may not be a determining factor in the buildings component of the footprint, it may play an important indirect role in affecting the transportation component. Of course the context in which density occurs is also important. An isolated dense community that stimulates a desire for people to drive or fly to other places may not prove as effective a choice as a dense community situated in a location where access to abundant services and amenities contribute to a high-quality of life that reduces a desire to travel elsewhere. Finally, the intentional community shows strong potential reductions in the food component. This is due to the predominantly vegan diet. Communally prepared meals are also a common characteristic in the intentional communities. This could be an important energy-saving strategy. According to my methodology, the energy savings would appear in the buildings component (i.e., reduced operating energy). This may be another factor that explains the very low buildings EF in the intentional community profile.

The super green profile and intentional community profile show similar reduction potential in the consumables and waste component. Recall, however, that the super green profile assumes virtually zero consumption of any household goods, and the intentional community profile data represents the community with the lowest ecological footprint achieved in the consumption component. Therefore, it seems that my method, using available data taken from the literature, under-estimates consumption in intentional communities.

The international case studies profile is, among all three profiles in the one-planet archetype, the one that is supported with the most robust data available through the literature. Curiously, however, it did not generate the greatest potential reduction in any of the components. Nevertheless there is general convergence across the one-planet archetype revealing that lifestyle choices could potentially contribute between 1.32 and 1.69 gha/ca reductions in Vancouverites' ecological footprint. This is approximately equivalent to a 32% to 41% EF reduction, with the most significant impacts generated through changes in transportation, followed by food, and to a lesser extent buildings and consumables.

5 Exploring the Potential for One-Planet Living in Vancouver

This chapter explores changes to planning policy and management practices that the City of Vancouver could implement to facilitate one-planet living options for its residents. The research builds on the findings from chapter 4 that identifies transportation and food as the two components with the greatest potential for reducing Vancouver's per capita ecological footprint. As outlined in chapter 3, I conducted a first round of interviews (see Appendices G – names of interviewees and H – interview 1 script) with City of Vancouver and Metro Vancouver staff to share my preliminary findings based on an analysis of Vancouver's sustainability gap (see chapter 4). The purpose of this round of interviews was to investigate: a) what policies the City has in place to manage demand for energy and materials across the various components that comprise the EF, b) what changes to policy and/or management practices are being developed, and c) what additional changes interviewees would like to see introduced. I supplemented the findings from the interviews with archival research based on reports, plans and policies from the City's records as well as Metro Vancouver and TransLink reports. I also surveyed the international sustainable cities literature in order to search beyond local boundaries for innovative changes to planning policy and/or urban management practices that could further enable a reduction in the City's ecological footprint. Next, I analyzed the City's ecological footprint data and developed a one-planet living baseline informed by the findings from the first round of interviews and literature on sustainable cities. I used the baseline to explore what reduction in EF could potentially be achieved through implementation of changes to Vancouver's planning policies and urban management practices. I considered how these policies might be implemented at a neighbourhood scale and what that might look like in terms of lifestyle patterns for Vancouverites. I selected a neighbourhood in Vancouver as a focal point to help ground this aspect of the research. My selection of a neighbourhood was informed by the first round of interviews that included a question asking participants to identify neighbourhoods in the city that, in their opinion, best reflect urban sustainability (see Appendix H – Interview 1 script).

I explored a variety of options in order to estimate what would be required to reduce Vancouver's ecological footprint to a level commensurate with one-planet living (see section 5.3 below). Once a baseline for one-planet living in Vancouver was established, I investigated policy interventions and changes to urban management practices that could provide the means through which the City could act to achieve the necessary ecological footprint reductions. Next, I conducted a second round of interviews in order to identify which policy interventions and changes to management practice that I had identified could be implemented within the City's jurisdiction and what challenges might be encountered (see Appendix I – Interview 2 script). I also asked interviewees to identify which of the changes to planning policy and management practices they believe would be the most important to achieve the one-planet living goal and why.

5.1 Vancouver's Policy Framework Pertaining to One-Planet Living

The *Greenest City 2020 Action Plan* (COV 2011a) is the City's most recent policy initiative, spanning ten action areas that together comprise a sustainability plan for Vancouver. Of most relevance to this research are the chapters within the plan that address a one-planet ecological footprint (chapter 7), transportation (chapter 4), and food (chapter 10). Additional chapters of interest address greenhouse gas emissions management (chapter 2), buildings (chapter 3), waste (chapter 5), and green spaces (chapter 6). My own research helped to inform chapter 7: Achieve a One-planet Ecological Footprint (COV 2011c). I estimated the potential ecological footprint reductions that could be achieved through implementation of actions recommended by a Citizens' Task Group (Boyd 2009) for inclusion in the Greenest City Action Plan using a similar method as that applied in chapter 4 of this dissertation.[96]

As a preliminary step towards developing the Greenest City Action Plan, Boyd (2009) proposed ten initiatives and anticipated that a 33% reduction in Vancouverites EF could be achieved by 2020 through their implementation. No explanation is provided about how this estimate in potential EF reduction was developed (Boyd 2009). Only five of the proposed initiatives could be assessed with regard to their potential reduction in the components that comprise Vancouver's ecological footprint, these included:

i) a 20% reduction in operating energy across the entire building stock
ii) a majority of trips, over 50%, by walking, cycling and transit
iii) a 40% reduction in the amount of waste that is landfilled or incinerated
iv) a 33% reduction in the greenhouse gas emissions associated with food production and distribution
v) a 33% reduction in the amount of drinking water consumed

I estimated that these initiatives could achieve a 9% reduction in Vancouver's ecological footprint. Subsequently, City staff expanded the scope of some of the proposed initiatives (specifically addressing food, buildings, consumables and waste) and used my ecological

[96] I also explored potential changes to production and energy intensity, e.g., in the food analysis I explored how reductions in the greenhouse gas intensity of food could reduce the ecological footprint.

footprint data to re-estimate the potential reduction that could be achieved at 11.5% (COV 2011c, 111).[97] Staff also then estimated the potential EF reductions that could be achieved if citizens assumed a leadership role by participating in additional efforts to reduce their EF (e.g., reduce air travel). Staff estimated that an additional 8.2% reduction could be achieved (COV 2011c). Therefore, the total estimate for potential reduction in Vancouverites EF by 2020 is 19.7% below 2006 levels (COV 2011a, 2011c). However, this still falls short of the goal of a 33% reduction in the total EF by 2020. The *Greenest City 2020 Action Plan* also does not address the long-term goal to achieve one-planet living by 2050 which would, based on chapter 4, require an additional 25% reduction in the EF (i.e., a total reduction of 58% below 2006 levels by 2050).

Because I am interested in one-planet living, I focus on policies and changes to management practices that have the potential to reduce Vancouver's ecological footprint through:

i) reducing materials use (e.g., the total number of motor vehicles, food inputs and wastes),

ii) reducing embodied energy (e.g., fossil fuel intensity of infrastructure and food production),

iii) reducing operating energy (e.g., fossil fuels used in buildings for space-heating, in vehicle transportation and for goods movement),

iv) reducing built area (e.g., total area dedicated to roads, parking and paved surfaces).

[97] Details of all changes in scope of actions are presented on page 111 of the *Greenest City 2020 Action Plan* (COV 2011c). Changes include a 10% reduction in consumption of high EF food, a 15% reduction in consumption of goods, a 50% reduction in municipal solid waste, and implementation of district energy systems to further improve the efficient use of energy in buildings. The changes are anticipated to yield a 3.4%, 2% and 0.5% reduction in the EF respectively.

5.1.1 Policy Framework for Transportation

The City's 1997 transportation plan set the direction for limiting the existing road network and parking supply to existing levels and increasing capacity for walking, cycling and transit (COV 1997). The plan aligned with the 1995 *City Plan* and the regional growth management strategy (i.e., the *Livable Region Strategic Plan* (GVRD 1999)) and regional transportation plan known as *Transport 2021* (GVRD 1993). These plans established the framework for a transportation hierarchy that prioritizes pedestrian, cycling, transit, goods movement and lastly the private motor vehicle (COV 1997). The targets set by the 1997 *Vancouver Transportation Plan* called for a mode shift across the City to achieve 18% walking and cycling, 15% transit, and 67% private automobile by 2021 (COV 1997). The Plan also identified more aggressive targets for travel to the University of British Columbia, along Broadway and to the Downtown. The most aggressive targets were set for travel to and within the Downtown, calling for 14% walking and cycling, 40% transit ridership, and 42% motor vehicle by 2021. The Plan noted these were ambitious targets that point towards a desired future (COV 1997). Nevertheless, the Downtown targets were achieved by 2004 (COV 2006) and the overall targets by 2008 (COV 2011a).

The *Greenest City 2020 Action Plan* calls for more than 50% of all trips to be by walking, cycling and transit (COV 2011a).[98] This mode split has already been achieved in the Downtown where those who live and work downtown achieve an 86% walk, cycle and transit mode share (Klimchuk 2011). The City overall achieves a 42% walk, cycle and transit mode share (COV 2012b).

[98] The *Greenest City 2020 Action Plan* also calls for a 20% reduction in per capita vehicle kilometres travelled (VkmT) below 2007; however, the 2007 VkmT baseline has not been established (COV 2011c). In 2006, the median commute in Vancouver was 5 km/ca (Metro Vancouver 2008c). While this is not a measure of total VkmT, it helps point towards a minimum estimate threshold. For example, assuming people use their vehicles for more than commuting, then total VkmT will be at or above 5 km/ca.

A new plan, *Transportation 2040*, is now being developed. This new plan will share a similar name to the recently adopted *Transport 2040* regional transportation plan developed by TransLink (2008). Draft directions proposed for the City's *Transportation 2040 Plan* retain the transportation hierarchy that prioritizes walking, cycling and transit, as well as a focus on densification, i.e., co-locating jobs and housing, in areas that are already well-served by transit. The plan incorporates the *Greenest City 2020 Action Plan* goals and proposes that by 2040 two-thirds of all trips will be by walking, cycling and transit. The plan also advances restrictions on motor-vehicle use through proposals to support regional road pricing, provincial pay-as-you-drive insurance, employer transportation demand management programs, and reductions in available parking. It also calls for a shift to low-carbon fuel vehicles and support for local modes of production and distribution that reduce the need for long-haul transportation of goods. This includes emphasis on the preservation of existing industrial lands as well as support for urban agriculture (COV 2012c).

5.1.2 Changes to Transportation Policy and Management

Recall that the second largest component within Vancouver's ecological footprint is Transportation, and within Transportation the largest sub-component is operating energy for private vehicles (see table 4.12 and figure 4.10 in chapter 4). This sub-component accounts for just over half (55%) of the transportation footprint (255,327 gha out of a total of 468,735 gha) and just over one-tenth (10.5%) of the entire ecological footprint (255,327 gha out of a total 2,430,476 gha).

Research interviewees identified changes to policy and management practices that generally align with the proposals in the draft *Transportion 2040 Plan* including: land use linked to prioritization of walking, cycling and transit; use of transportation demand management pricing incentives and regulatory changes to reduce automobile dependence, and support for low carbon (e.g., electric) vehicles. Additional recommendations include working with the Province to change the Motor Vehicle Act to allow a 40 km/hr speed limit,[99] recreating a streetcar network, and integrating the existing cycling and greenway networks with stormwater management. For example, the primary purpose of San Antonio's River Walk is to assist with stormwater management; however, it also serves as an urban amenity and pedestrian greenway through the heart of the city (Newman and Kenworthy 1999). Interviewees also identified Helsinki and Copenhagen as examples of cities that have achieved high walking, cycling and transit mode share (63% and 74% respectively) (Taylor 2005; Nelson 2007). In particular, Copenhagen has a very high bicycle mode share of 36% (Nelson 2007) and one of the lowest rates of vehicle car ownership in Europe (0.21 vehicles/ca)(Taylor 2005). Nevertheless, Vancouver exceeds Copenhagen in terms of walking mode share at 12% vs. 7% respectively (Urban Systems 2012).

Downtown Vancouver's mode share (86%) for walking, cycling and transit already approximates levels achieved in Hong Kong (89%) and Tokyo (88%)[100] some of the world's densest and highest walk, cycle, transit mode share cities (Land Transport Authority 2011).[101] These cities produce annual transportation greenhouse gas emissions that range from 0.38 tonnes per capita for Hong Kong to 0.82 tonnes per capita for Tokyo (UITP 2010).[102] Vancouver's greenhouse gas

[99] This was called for in the original 1997 Transportation Plan (COV 1997b), but apparently never implemented.
[100] Refers to the traditional urban area known as 23 Ward, not the whole metropolitan area.
[101] Most of the mode share in Hong Kong and Tokyo is accounted for by public transit, including light, rapid rail.
[102] The higher emissions cited for Tokyo refer to the entire metropolitan area which achieves a lower modal share for walking, cycling and transit than Ward 23.

emissions from transportation across the entire City are 3.2 tCO_2e per capita based on a 42% walking, cycling, and transit mode share (see table 4.5 in chapter 4). If Vancouver could achieve the walk, cycle, transit mode share of Downtown (86%) across the entire City, I estimate that transportation emissions could be reduced to approximately 1.6 tCO_2e per capita. Nevertheless, Vancouver's existing mode share (42%) across the entire city is better than most North American and Australian Cities (with the exception of New York at 77%) (Land Transport Authority 2011). However, it falls short of most European Cities, e.g., London (60%), Paris (62%), Berlin (68%) (Land Transport Authority 2011). South American and Asian cities generally achieve even higher mode shares (e.g., Singapore (71%), Curitiba (72%), Seoul (76%), Beijing and Shanghai (80%), Delhi (81%), Bogota (85%), Mumbai (85%) (Land Transport Authority 2011). African cities achieve the highest mode shares (e.g., Harare (87%), Nairobi (93%), Dar es Salaam (94%) (Mbara 2002). In the case of African cities, these mode shares are predominantly related to poverty (Pendakur 2005). South American and Asian cities generally also have less affluent populations, but several of the highest mode shares are achieved in affluent cities, e.g., Hong Kong and Tokyo (as noted above). Asian cities also have a more fuel efficient vehicle fleet and the lowest greenhouse gas emissions per capita from transportation (UITP 2010; TransLink 2010; Newman and Kenworthy 1999).

In more affluent societies, mode share is the predominant determinate of per capita greenhouse gas emissions from transportation (Newman and Kenworthy 1999). Land use, meaning the co-location of jobs, housing and services – including transit services, as well as urban design that gives priority to a safe and pleasant pedestrian and cycling environment are the critical factors that determine mode share (TransLink 2010; Newman and Kenworthy 1999).

Fortunately, land use decisions are in the domain of local government jurisdiction and, therefore, local governments have an important role to play (TransLink 2010).

> The best transportation plan is a land use plan with contiguous high-density, mixed uses, and a fine-grained road network designed for walking and cycling. This is equally if not more important than focusing on improved transit service (T. Raad, personal communication, April 29, 2013).

The long-term mode share target proposed for Vancouver is for two-thirds of all trips to be by walking, cycling, and transit; however, the draft *Transportation 2040 Plan* is silent on the issue of air travel, aside from affirming support for transportation connections to the Vancouver International Airport (COV 2012c).[103] Yet, as revealed in chapter 4, to achieve the one-planet living goal would require that all personal travel be by walking, cycling and transit – with virtually no air travel. Alternatively, if the entire motor vehicle fleet, including commercial vehicles, produced low or zero carbon dioxide emissions that could offset the impacts of a reduced mode share for walking, cycling and transit as well as a modest amount of air travel.

Cities with very high walking, cycling and transit mode share (i.e., 75% or more) typically have high density, mixed use urban centres at or above 100-200 people per hectare and are supported by a transportation strategy that prioritizes pedestrians, cyclists and transit users (Newman and Kenworthy 1999). For example, cities such as Bogota, Curitiba, and Copenhagen placed emphasis on a more equitable transportation system, one that promotes accessibility by

[103] The per capita EF of air travel is 0.14 gha/ca or 79,020 gha which represents an area approximately 7 times larger than the City's actual size (11,500 ha). Air travel, like diet, pertains to personal choice and is outside the City's jurisdiction. Nevertheless, it could be addressed through a collaborative education and awareness campaign, e.g., working with the business community to scale-down non-essential travel.

everyone not just those who can afford a car (Curtis 2003; Goodman et al. 2005; Nelson 2007). These cities implemented an integrated land use and transportation demand management strategy including a) increases in density of both jobs and housing close to transit services, b) expansion of pedestrian, bicycle and transportation infrastructure and services, c) restrictions on motor vehicle use. Restrictions included a cap or even a reduction in roadway and parking available to cars, road tolls and parking fee increases, and limited access to the downtown based on licence plate numbers and designated car-free days. Combining an education program with the regulatory and financial changes that favour walking, cycling, and transit was also deemed necessary to address significant public resistance during the introduction of the changes. However, once implemented, these changes gained public acceptance that eventually grew into strong public support (Curtis 2003; Goodman et al. 2005; Nelson 2007).

The strategies described above generally align with what is being proposed in Vancouver's draft *Transportation 2040 Plan* and builds on what has already been implemented through the 1997 plan. Interviewees noted that public acceptance affects the rate of change (J. Dobrovolny, personal communication, September 28, 2012; P. Judd, personal communication, March 5, 2013), and small but motivated pockets of resistance are a barrier to implementing more aggressive transportation demand management strategies, particularly with regard to increasing density and increasing restrictions on motor vehicle access and parking (A. Reimer, personal communication, September 19, 2012; P. Judd, personal communication, March 5, 2013). Examples include Dunbar community resistance to Eco-density proposals, and developer resistance to parking maximums in Southeast False Creek (Sussmann 2012).

A strategic focus on densifying key neighbourhoods such as the Cambie Corridor and Broadway Corridor where there is existing rapid transit services could help develop new centres. Concentrating jobs in urban centres supports public transit as the predominant mode of commuting to work and enables systematic phasing-out of automobile oriented infrastructure (Kenworthy 2006). However, higher-density, mixed use development is needed across the entire city because an exclusive focus on corridors and neighbourhood centres leaves low-density residential neighbourhoods largely untouched (T. Raad, personal communication, April 29, 2013). European and Asian cities retain approximately 20% of jobs within urban centres (Kenworthy 2006).[104] Even higher percentages would probably be required to achieve one-planet living. Dedicated transit right-of-ways that enable the free-flow of transit vehicles whether on rail or roads are also key (Kenworthy 2006; Goodman et al. 2005; Curtis 2003).

5.1.3 Policy Framework for Food

In 2003 the City initiated a Food Action Plan which included formation of the Vancouver Food Policy Council. The Council is comprised of citizens with a mandate to “help set policies that guide how food is produced, processed, distributed and purchased” (COV 2012d). In 2005, the City allowed backyard bee-keeping and hens were allowed in 2010 (COV 2011c). The City adopted a Food Charter in 2007 that establishes Vancouver’s commitment to set food policy based on five principles: i) community economic development, ii) ecological health, iii) social justice, iv) collaboration and participation, v) celebration. The goals are: to support local production, sales, and purchases of food, and to promote sustainable food choices (COV 2012e). In 2010, the City initiated curb-side food waste collection (COV 2011c). This initiative

[104] European cities average 50 people per ha (Kenworthy 2006). This is equivalent to Vancouver.

aims to divert food waste from landfills and incinerators and instead turns it into compost (COV 2012g).

The *Greenest City 2020 Action Plan* builds on the Food Charter with goals to increase the City's food assets, including urban farms and community gardens, build community capacity to produce local food and ensure that the majority of the City's residents live within a five minute walk of a food retailer or distribution outlet (COV 2011c). Examining barriers to local food production and economic development opportunities is also identified as an important measure (COV 2011c).

A Food Strategy is being developed that will serve as Vancouver's official plan comprising goals and actions to advance a sustainable food system in Vancouver (COV 2012f). Specific initiatives could include: integrating food policies into city-wide plans, improving access to nutritious and local food, creating more opportunities to grow food within the City, and reducing the distance between food consumption and production (COV 2012f). Tools for implementation include zoning and bylaw changes, land use regulations and policies, grant programs, public outreach and partnerships with other levels of government and the community (COV 2012f).

5.1.4 Changes to Food Policy and Management

The largest component within Vancouver's Ecological Footprint is Food, and within Food the largest sub-component is Fish, Meat and Eggs (see table 4.9 and figure 4.5 in chapter 4). This sub-component accounts for nearly half (48%) of the food footprint (590,615 gha out of a total 1,230,982 gha) and nearly a quarter (24%) of the total ecological footprint (590,615 gha of a total 2,430,476 gha).

Research interviewees identified enabling urban agriculture, protecting the Agricultural Land Reserve (ALR),[105] promoting locally produced and organic food, supporting low EF dietary choices, and reducing food waste as important strategies. Specifically they identified opportunities for enabling urban agriculture through re-allocating laneways and roads and using roofs and building facades. Some interviewees also supported buying and converting land to agriculture. Development of an ecological health plan that integrates naturalization of specific areas, e.g. day-lighting of streams, with urban agriculture was also identified. In order to build the City's capacity to advance a local, sustainable food system, an interviewee also noted that dedicated staff resources are needed, perhaps in the form of a full-time food systems coordinator (O'Neil, personal communication, September 25, 2012).

Urban form, particularly density and land use, is critical to how a city relates to its bioregion especially respecting how much space is allocated to built-up land compared to natural habitat and agriculturally productive areas from which the city can source its food, water, energy and materials (Kenworthy 2006). A challenge associated with the concentrated development of Vancouver's downtown is that it leaves very little room for agriculture. A pattern of dispersed density, where development is concentrated in nodes interspersed with agriculturally productive green space could be an alternative (Kenworthy 2006; Viljoen 2005; Odum and Odum 2001). Nevertheless, many very dense cities are able to produce substantial amounts of food, complemented by nearby peri-urban agricultural capacity. Examples at the metropolitan scale include: Hong Kong (45% of vegetables and 68% of poultry), Shanghai (60% of vegetables

[105] The ALR is protected under provincial legislation as land that is zoned for agricultural production. Only 1% of Vancouver's land area is zoned agriculture while 19% of the land in the surrounding Metro Vancouver area is zoned agriculture (Metro Vancouver 2006). There has been a 9% reduction in ALR land in Metro Vancouver since its inception in 1974 (Serecon and Zbeetnoff 2009).

and 90% of milk and eggs), Hanoi (80% of vegetables; 50% of pork, poultry, and fresh water fish; and 40% of eggs), Dar es Salaam (90% of vegetables, 60% of milk), Dakar (70% of vegetables, 65% of poultry), Accra (90% of vegetables) (FAO 2007).[106] Indeed, urban agriculture accounts for 90% of vegetables and 50% of meat and poultry consumed in China's 18 largest cities (Smit et al. 2001). Asian cities also typically follow a pattern of development known as Desakota that intersperses high density development with agriculture land uses (Newman and Jennings 2008). This approach reflects ecocity principles of development that juxtapose agricultural production with urban development (Register 2006). Permaculture[107] has also been used successfully to achieve high yields in urban agriculture (e.g., in Havana, Cuba and Bogor, Indonesia) (Newman and Jennings 2008).

Cities with high agricultural output retain a culture of acceptance towards agricultural practices in urban environments (Smit et al. 2001) and supportive policies and programs for urban agriculture at both the national and local government levels (van Veenhuizen 2006). Sustainable food systems within cities require local government participation in planning for the productive use of both public and private land (Viljoen et al. 2005). Many cities support urban agriculture as a means towards economic development and food security, especially for poorer populations (van Veenhuizen 2006; Mougeot 2006; Smit et al. 2001). In addition to food security, urban agriculture brings multiple co-benefits including reduced greenhouse gas emissions associated with the production, processing and distribution of food (Viljoen 2005b).

[106] Urban boundaries can affect these estimates, particularly if they encircle significant tracts of rural and/or peri-urban land.
[107] Permaculture is the practice of permanent culture which emphasizes working with natural processes to achieve sustainable agriculture and livlihoods. Examples include building soils through mulching of garden wastes and leaf litter, beneficially co-locating plants to reduce pest infestations, and landscaping for water conservation as well as wind and fire resistance (Mollison 1988).

Additional benefits include increased resilience of the overall food system, social inclusion and urban amenity benefits, and improved population health generally (van Veenhuizen 2006; Smit et al. 2001). Urban agriculture can also improve urban waste management (e.g., through utilization of waste water and compost) as well as reduce a city's ecological footprint (van Veenhuizen 2006; Smit et al. 2001). Urban agriculture is best suited to the provision of perishable products such as vegetables, milk, poultry and eggs (van Veenhuizen). Finally, urban agriculture complements rather than competes with rural agriculture because perishable products can be brought to market quickly and cost effectively leaving an uncontested demand for crops such as grains that can be produced more cost-effectively by rural agriculture (Lovell 2010; van Veenhuizen 2006).

Cities with high urban agricultural capacity pursue strategies such as permissive zoning that allows food growing and raising of small animals such as chickens and rabbits in private yards, on balconies and rooftops, and on vacant land (van Veenhuizen 2006; Smit et al. 2001). For example, in Cagayan de Oro, Philippines, 40% of households maintain gardens that produce leafy vegetables and fruits (Texier and de Bon 2006). Additional strategies include provision of community owned land and buildings for urban agriculture (e.g., school fields, parks, utility right-of-ways, and public service buildings), a permitting system to allow farm-gate sales of produce, and programs to enable small-scale food distribution centres, including farmers markets (van Veenhuizen 2006; Smit et al. 2001). An interviewee also noted that the City could work with restaurants and grocery stores to promote low ecological footprint food choices (L. Cole, personal communication, September 25, 2012).

Approximately 20% of vegetables and 40% of fish are derived from local sources in Metro Vancouver (Secon and Zbeetnoff 2009).[108] This is lower than the cities cited above and indicates an opportunity for significant increases in urban vegetable production in particular. Metro Vancouver's predominantly urban and peri-urban landscape produces about 20% of total regional food demand (Serecon and Zbeetnoff 2009). However, when combined with the Fraser Valley Regional District, a predominantly rural agricultural area adjacent to Metro Vancouver, production capacity can meet most of Vancouver's food demands including: 100% of milk, 90% of eggs, 97% of poultry, 33% of pork, 10% of beef, and 9% of lamb (Serecon and Zbeetnoff 2009).[109] Capacity is higher still within the Province of British Columbia where farms produce 48% of all provincially consumed food, including fruit. There is 100% self-sufficiency for poultry, eggs and milk and British Columbia has capacity to be self-sufficient in the production of fish and vegetables as well. However, specialization in crops and limited growing seasons result in a significant amount of export and re-supply through imports to meet local demands when and as needed (Serecon and Zbeetnoff 2009). Therefore, self-reliance in fruit and meat ranges between 10% and 50% depending on food type. Nevertheless, Serecon and Zbeetnoff (2009) observe that it is unlikely that Vancouver, Metro Vancouver or British Columbia could achieve complete food sufficiency, especially given the very low capacity for production of cereal crops.

Almost 19% of Metro Vancouver's land is zoned for agriculture, comprising 53,619 ha (Metro Vancouver 2006a). Of this, only 41,035 ha are farmed (Metro Vancouver 2012). There is a wide

[108] Data for the City of Vancouver, distinct from the region, is not available. Metro Vancouver's seaside location enables access to fisheries that may be perceived as "local" but are governed by provincial/federal jurisdications.
[109] Although there is no grain production in the Lower Mainland, including the Fraser Valley, BC produces 36% of grains needed to meet total Provincial demand. However, most (34%) is used for animal feed. Approximately 76% of BC agricultural land is dedicated to livestock production (Secon and Zbeetnoff2009).

range of other uses including right-of-ways, transportation, utilities, commercial and residential, parks and certain recreational activities such as golf (T. Duynstee, personal communication, August 29, 2012). By comparison, Greater London has 10% of its land in agricultural production (Howe et al. 2005), Dar es Salaam has 33% (Newman and Kenworthy 1999, 254), Shanghai has 50%(Griardet 2005), and Greater Bangkok has 60% (Smit et al. 2001).[110]

In 2006, less than 1% (72 ha) of the City of Vancouver's land was zoned for agriculture (Metro Vancouver 2006a). Most of this land was and is located adjacent to the Fraser River and is used for equestrian sports and estate homes. The City has recently introduced *Urban Agricultural Guidelines* for development (COV 2012h) that address shared garden plots and edible landscapes (Morris and Tapp 2008). Across the entire City, there are plans to create 4-6 small parks through reallocation of roads that could serve as community gardens or orchards (COV 2011a). Over 75 community gardens are already distributed across the City (COV 2012i) with plans to increase this number by 50% by 2020 (COV 2011c). However, neither the *Urban Agricultural Guidelines* nor the strategies targeting expansion of community gardens specifically identify linkages with urban stream rehabilitation. Integrating urban agriculture with ecological restoration in both parks and urban streams expands contiguous ecologically productive areas while simultaneously creating urban amenity (Bohn and Viljoen2005; Newman and Kenworthy, 1999). Zurich provides an example of urban naturalization efforts that integrate stream day-lighting and urban agriculture. Developers are allowed density bonuses in exchange for stream

[110] Urban boundaries can affect these estimates.

day-lighting and naturalization efforts that include provision of garden allotments (Newman and Kenworthy 1999, 252).

Vancouver is already pursuing many of the strategies identified in the literature for building urban agriculture capacity (see above). This includes enabling use of private gardens for food production through zoning permissions, e.g., hens and beehives, and collaborating with organizations such as City Farmer that provides a matching service to enable land-owners and those who want to practice urban agriculture to find each other (COV 2012j). The City also provides community garden plots on civic land, e.g., parks and gardens surrounding the municipal hall, as well as on civic rooftops, e.g., West End Community Centre (COV 2011a). Bee-keepers are permitted to use the roof-tops of civic buildings (e.g., City Hall) and public schools participate in food growing activities on school land. The City's park system, comprising 1,490 ha, also includes some fruit and nut trees as well as edible plants that are stewarded for harvest through community and educational programs (COV 2011a). An inventory of the City's food production capacity (e.g., total area in agricultural production and yield by type and weight) is also identified as an important next step (O'Neil, personal communication, September 25, 2012). However, the City does not allow farm-gate-sales of local produce except by commercial operators (O'Neil, personal communication, September 25, 2012). This restriction is imposed by the Vancouver Coastal Health authority and covers all non-commercial production of food, including preserves. Several initiatives overcome this constraint through the collective pooling of private land in cultivation under the stewardship of a commercial enterprise. Land owners allow their land to be farmed in exchange for a portion of the produce. The majority of the harvest is then sold through local markets (O'Neil, personal communication, September 25, 2012).

Community interest about where and how food is produced can stimulate demand for locally produced and organic food (T. Duynstee, personal communication, August 29, 2012; Serecon and Zbeetnoff 2009). Approximately 15% of Vancouver's locally produced fruits and vegetables and 1% of locally produced meats and livestock products (e.g., eggs, milk) are organic (Serecon and Zbeetnoff 2009). The City provides an extensive amount of information about local and organic agricultural practices as well as producers, retailers, and restaurants on its web site (COV 2012k). Information about choosing local and organically produced food is explicitly aligned with efforts to reduce the City's carbon footprint, e.g., by reducing food miles. However, information is not provided about how specific food choices, e.g., avoiding or reducing consumption of red meat, could help reduce the City's Ecological Footprint. Instead, the City provides very general information about food and initiatives that can help reduce the ecological footprint (e.g., backyard hens, farmers markets, community gardens and composting) (COV 2012l).

Approximately half (48%) of the food consumed in Metro Vancouver is wasted (Serecon and Zbeetnoff 2009). Note that this estimate is significantly higher than the national average estimated at 30% (Statistics Canada 2007a). Food waste can occur throughout the supply chain; however, Cities can influence food waste at the retail level, e.g., grocers and restaurants, and at the household level through education and waste management programs. The City of Vancouver aims to increase waste diversion from landfills by 50% by 2020 (COV 2011a). This includes a focus on food wastes that can be composted. Food scraps including raw vegetables, egg shells, coffee grounds and tea bags are collected with yard wastes. The City is also contemplating expanding the collection to include bread products, fish, meat and bones (COV 2012g).

5.2 Estimating a One-Planet Living Baseline for Vancouver

In chapter 4, I explored Vancouver's sustainability gap and the potential reductions that could be achieved using the one-planet living archetype. In this section, I probe deeper and explore what types of reductions in consumption would be necessary to get to one-planet living in Vancouver. I develop various baselines, starting with a focus on food and transportation, and then I look systematically at the remaining components that comprise Vancouver's ecological footprint with special attention given again to the largest sub-components (see table 5.1 below). In all baseline assessments, I assume that the 2006 population of Vancouver is held constant at 578,041 people to facilitate comparison of estimated potential EF reductions to Vancouver's original EF as calculated in chapter 4. Next, I explore baselines that assume implementation of the *Greenest City 2020 Action Plan* and then I layer-in additional reductions in the EF until one-planet is achieved.

5.2.1 Baseline 1 - Big Things First

Because food is the largest component of Vancouver's total eco-footprint, and fish, meat and eggs comprise the majority of the food footprint, I begin with a baseline in which Vancouverites abstain from consuming fish, meat and eggs.[111] In chapter 4, I discovered that food choice has a potentially stronger influence on the footprint than the amount of food consumed. Although

[111] Note this is different from the Super Green Scenarios explored in chapter 4 because dairy is still included.

Vancouverites consume more food than the international case studies of societies already living at the one-planet level, those societies are often malnourished. Therefore, in this baseline I assume that fish, meat and eggs (88,067 tonnes) are substituted by an equivalent weight of other food categories so that the total tonnage of food consumed remains constant (see Appendix J for a description of the procedural steps followed to calculate this adjustment).

Transportation is the second largest component of Vancouver's eco-footprint, and within Transportation, operating energy for private motor vehicle emissions comprises the largest sub-component. Therefore, in this baseline, I assume that Vancouverites abstain from using private motor vehicles for transportation (i.e., zero CO_2 emissions from private motor vehicle operating energy). To compensate for this shift, I also assume that transit use is doubled (i.e., CO_2 emissions from the transit fleet doubles). Doubling the CO_2 emissions of the transit fleet increases the ecological footprint by 0.01 gha/ca.

If Vancouverites abstained from consuming fish, meat and eggs as well as avoided driving personal motor vehicles (or alternatively drove zero emissions vehicles), the ecological footprint could be reduced to 2.76 gha/ca (down 1.45 gha/ca from 4.21 gha/ca). See table 5.1 for details. Greenhouse gas emissions would also be reduced to 6.7 tCO2e/ca (down 2.5 tCO_2e/ca from 9.2 tCO_2e/ca).

The third largest component of Vancouver's eco-footprint is buildings, and the largest sub-component is operating energy for commercial buildings (see table 4.10 and figure 4.7 in chapter 4). This sub-component accounts for 40% of the buildings footprint (153,323 gha out of a total of 386,752 gha) and 6% of the entire ecological footprint (153,323 out of a total of

2,430,476 gha). Recall from the sustainability gap analysis in chapter 4, that because Vancouver's electricity is predominantly hydropower, most of the building sector's operating energy emissions are due to natural gas consumed for water heating and space conditioning. In this scenario, I assume that Vancouver's commercial buildings operate with zero emissions which would require replacing natural gas with renewable energy. However, the renewable energy supply should avoid increasing demand for hydro-powered electricity and biomass (unless utilized from waste). First, Vancouver has a relatively high proportion of buildings that use electrical base-board heating, which is not an efficient use of energy despite the low greenhouse gas emissions it produces. Transmission losses coupled with increasing plug load, stimulated by technological innovation in computing and telephony, mean that electrical energy is becoming increasingly scarce. In 2007, BC became a net importer of electricity (BC Hydro 2009) with concomitant higher fossil-fuel content (e.g., from coal and natural gas fired plants in Alberta). In short, increasing demand for electrical power is resulting in greater reliance on fossil fuels, at least in the near-term. Second, the combustion of biomass produces carbon dioxide. Because the ecological footprint accounts for the area of forested land required to sequester carbon dioxide emissions regardless of source, it reflects emissions from burning biomass. (This differs from the protocol used by the City, which considers combustion of biomass, e.g., wood, as greenhouse gas neutral because the emissions can be re-absorbed within the 100 year lifecycle associated with the emissions counting methodology.[112]) Using imported virgin wood in a biomass boiler to generate heat and power could potentially increase

[112] The City follows the Federation of Canadian Municipalities Partners for Climate Protection Protocol which is the same as the International Council of Local Environmental Initiatives Cities for Climate Protection Protocol, which is informed by the Intergovernmental Panel on Climate Protection.

the ecological footprint.[113] If Vancouver's commercial building operating energy could be switched to a renewable supply with zero emissions, the Buildings component could be reduced to 0.4 gha/ca (down 0.27 gha/ca from 0.67 gha/ca).

The fourth largest component of Vancouver's ecological footprint is consumables and wastes, with the largest sub-component being paper (see table 4.11 and figure 4.9 in chapter 4). Paper accounts for half (48%) of all consumables by weight and 40% of the consumables and waste footprint (134,830 gha out of a total of 335,330 gha). It comprises 5.5% of the total ecological footprint (134,830 gha out of a total 2,430,476 gha). To establish this baseline, I assume no paper use so there is zero paper recycling as well.

Table 5.1 presents the cumulative reductions that could be achieved in the ecological footprint if Vancouverites abstained from eating fish, meat and eggs; if they abstained from driving private motor vehicles (or all private motor vehicles were zero emissions); if the commercial building stock operated with zero emissions, and if there was zero consumption of paper. Vancouver's original 2006 EF estimate appears in the first column and the estimated reduction that could be achieved in the second (the third column is described below). White rows represent the EF for each component. Grey shaded rows represent the EF reduction potential.

[113] Using wood or other biomass fuels that are harvested from trees or plants grown in the City could offset the impact somewhat as would using recycled or repurposed wood, in which case only the embodied energy associated with recycling is counted.

Table 5.1 Baseline 1 - Big Things First

Baseline 1	**Vancouver EF (gha/ca)**	**a)Big Things (gha/ca)**	**b)Big Things Plus Next (gha/ca)**
<u>Food Potential Reduction:</u>			
No Fish, Meat, Eggs (substitute with other foods)		-1.02	-1.02
No Dairy (substitute with other foods)			-0.08
Food	2.13	1.11	1.03
<u>Transportation Potential Reduction:</u>			
No Private Vehicle Operations/Zero Emissions		-0.43	-0.43
Double Public Transit Operations			+0.01
No Private Vehicle Ownership			-0.13
No Flying			-0.13
Transportation	0.81	0.38	0.13
Buildings Potential Reduction:			
Zero emissions Commercial building sector		-0.27	-0.27
Zero emissions Residential building sector			-0.27
Buildings	0.67	0.40	0.13
Consumables and Waste Potential Reduction			
Eliminate consumption of paper		-0.24	-0.24
Eliminate consumption of plastics			-0.07
Consumables and Waste	0.58	-0.34	0.27
Water N/A			
Water	0.02	0.02	0.02
TOTAL	4.21	2.25	1.58

Greenhouse gas emissions in this baseline (1a) would be reduced to 5.3 tCO2/ca (down 3.9 tCO2e from 9.2 tCO2e), and the ecological footprint would be reduced to 2.25 gha/ca (down 1.96 gha/ca from 4.21 gha/ca). While this represents a significant reduction in Vancouver's EF, it is not sufficient to achieve the one-planet target of 1.80 gha/ca. I therefore explore further reductions in the next largest sub-components under various assumptions (baseline 1b), as described below.

Within Food, the second largest sub-component is oils, nuts, legumes, comprising 15% of the food footprint (183,692 gha out of 1,230,982 gha), followed by dairy comprising 14% (171,004 gha out of 1,230,982 gha). I am reluctant to contemplate a scenario that eliminates oils, nuts and legumes from the diet, given that fish, meat and eggs are already eliminated.[114] However, many people maintain adequate nutrition and eat a vegan diet that avoids all animal proteins including dairy products. Most dairy products are produced within the BC Lower Mainland (i.e., the Metro Vancouver and Fraser Valley Regional Districts). If Vancouverites abstain from consuming dairy products, and assuming the tonnage of dairy products that was consumed is redistributed to the remaining five food categories (i.e., excluding Fish, Meat, Eggs) then the food footprint could be reduced by 0.08 gha/ca.[115] Alternatively, if Vancouverites cut consumption of dairy products in half, without compensating by increasing consumption in other food sub-components, a 0.15 gha/ca reduction in the food footprint could be achieved. This option is explored further below and assumes that half of the dairy products consumed are fluid milk, and that water would be a sufficient substitute providing healthy dietary choices were made to obtain sufficient calcium and nutrients from other food choices.

In the Transportation component, air travel and motor vehicle ownership are tied as the second largest sub-components, each comprising 17% of the transportation footprint. Given the assumption in the Big Things First scenario that there is zero travel by private motor vehicle, it is reasonable to assume that people also no longer need to own vehicles. Eliminating ownership

[114] Canada's Food Guide to Healthy Eating groups meat and legume consumption and considers them to be mutually substitutable (MAL 2006).
[115] This assumes a corresponding increase in EF of the remaining food sub-components commensurate with the redistributed tonnage. The procedural steps for estimating the adjusted EF follows that outlined in Appendix J.

of motor vehicles results in a 0.13 gha/ca reduction in the transportation footprint.[116] Eliminating air travel also results in a 0.13 gha/ca reduction (see table 5.1 for details).

In the buildings component, the second largest sub-component is residential operating energy (39%) This is very close to the commercial share (40%); however, the operating energy profile is somewhat different. Residential buildings use one-third the electricity of the commercial building stock, and close to an equivalent amount of natural gas. Because the carbon coefficient for electricity is very low, the discrepancy in electrical consumption between residential and commercial buildings does not substantially affect the footprint. Therefore, the residential building energy sub-component (150,036 gha) is very close to and slightly under that of the commercial sector (153,323 gha). Eliminating CO_2 emissions from the residential sector, as well as from the commercial sector, could achieve an additional 0.27 gha/ca reduction in the ecological footprint.

In the consumables and waste component, the second largest sub-component is plastics (12% or 39,141 gha out of a total of 335,330 gha). Eliminating consumption of plastics could reduce the ecological footprint by 0.07 gha/ca.

Assuming a totally vegan diet, abstaining from flying as well as owning and operating private motor vehicles, zero emissions in the operation of the entire building stock, and eliminating all consumption of paper and plastics are sufficient to reduce Vancouver's ecological footprint to the one-planet level. Indeed, as table 5.1 reveals, the reductions exceed what is necessary, resulting in a 1.58 gha/ca EF.

[116] Assumes the embodied energy and associated CO2 emissions from the private motor vehicle fleet is zero.

5.2.2 Baseline 2 – Greenest City Action Plan 2020 with Local Food and Zero Emissions

To refine the analysis and narrow-in on changes to policy and management practices that the City of Vancouver can influence, I take a closer look within each component to identify alternative approaches to achieving the one-planet living goal. First, I make assumptions about what reductions can be achieved through implementation of the *Greenest City 2020 Action Plan* (COV 2011a). Note that because the City uses my ecological footprint data in their analysis, it would constitute circular logic for me to reference the City's data as a starting point for the analysis. Furthermore, the City's analysis does not clearly specify what policies can be implemented to achieve the proposed reductions in ecological footprint (COV 2011a, 2011b). Since my goal in this research is to identify some changes to planning policy and management practices that the City can implement to enable one-planet living lifestyle choices by its residents, I begin my analysis with the following assumptions and estimates (see table 5.2, Baseline 2a below):

1. A quarter of all fresh vegetables and eggs are produced organically within the city (i.e., assume a 25% reduction in materials land for vegetables and eggs, and 25% reduction in carbon dioxide emissions associated with production and operating energy for vegetables and eggs). The *Greenest City 2020 Action Plan* specifies increasing local food assets by 50% but does not relate this to specific increases in local agricultural production. Therefore, I assume that these initiatives could support a 25% increase in local production of eggs and vegetables based on: a) what other cities have already

achieved and b) current City policy to allow backyard hen-keeping[117] and to expand community gardens. A 25% local and organic production of vegetables and eggs could result in a 0.02 gha/ca reduction in the food footprint.

2. Improved energy efficiency across the entire building stock by 20%. This assumes reductions in both electrical and natural gas usage (i.e., reduce all CO2 emissions from residential and commercial buildings by 20%) which could reduce the buildings footprint 0.11 gha/ca.
3. Implementation of five district energy systems powered by renewable energy. I assume these systems are zero emissions, i.e., not fuelled by biomass or natural gas.
4. Increased landfill gas capture at Vancouver landfill to achieve a 75% capture efficiency (up from 67% in 2007). I estimate this would result in a Vancouver landfill gas coefficient of 0.18 tCO2 per tonne MSW (down from the original estimate of 0.2 tCO_2). This results in a total reduction of 3,275 tCO_2 or 0.0014 gha/ca. (See Appendix K for calculations.)
5. Reduced waste disposed to landfill or incinerator by 50%. I assume that CO_2 emissions from all waste disposed to landfills and incinerators is reduced by 50% which results in a reduction of 0.064 gha/ca.
6. A majority of trips (over 50%) are by walking, cycling and transit. I assume a 66% reduction in GHGs (including CO_2) from private passenger vehicles, based on the City's 2040 proposed target. This results in a 0.22 gha/ca reduction. I also assume a 50% increase in transit ridership and a 0.01 gha/ca increase respectively.

[117] Note the by-law prohibits the slaughtering of hens in back-yards. My interpretation is that the by-law aims to support egg production, but not consumption of poultry.

7. Reduced water consumption by 33% (i.e., assume CO_2 emissions associated with operating energy used to treat water is reduced by 33%). This results in a 31 gha reduction or 0.00005 gha/ca.
8. Planting of 150,000 trees (i.e., assume reduction in the total ecological footprint equivalent to the amount of CO_2 sequestered). I assume an annual carbon dioxide sequestration rate of 48 lbs or 22 $kgCO_2$/tree/year (NCSU 2013). This results in a total sequestration of 3,300 t_{CO2}/year or 0.001 gha/ca.

Table 5.2 (baseline 2a) reveals that implementation of these actions could yield a potential EF reduction of 15% (in between the City's low estimate of 11.5% and high estimate of 19.7% as described above).

Next, I explore a baseline (table 5.2, 2b) comprising intense local food production and conservation. Cities can produce very high quantities of poultry, pork and eggs within the urban environment, and Vancouver's proximity to the Pacific coast enables a local food fishery. Cities can also be self-sufficient in vegetable production. I assume Vancouver is on par with the highest food producing cities, is self-sufficient in vegetable production, and all production takes place within the built environment. I also assume that production is organic, meaning no additional fertilizers or pesticides are added and that the harvest is by hand (i.e., no embodied energy). Finally I assume that the vegetable harvest is delivered to local markets within the City using public forms of transportation, or efficient utilization of the existing commercial fleet of vehicles (i.e., no operating energy/food miles). Self-sufficiency in vegetable production in this scenario results in a 0.08 gha/ca reduction in the footprint.

Table 5.2 Baseline 2 – Greenest City 2020 Action Plan with Intensive Food Production and Conservation as well as Zero Emissions Transportation and Buildings

Baseline 2	**Vancouver EF (gha/ca)**	**a) Greenest City 2020 - 25% local vegetables and eggs (gha/ca)**	**b) Greenest City 2020 - intense food production and conservation (gha/ca)**	**c) Greenest City 2020 - zero emissions (gha/ca)**
Food Potential Reduction:				
Produce 25% of vegetables in city		-0.01		-0.01
Produce 25% of eggs in city		-0.01		-0.01
Produce 100% of vegetables and eggs in city			-0.08	
Produce 100% of pork and poultry in city			-0.18	
Abstain from eating red meat (with substitutes)			-0.65	
Abstain from consuming dairy (with substitutes)			-0.08	
Allocate all grain production to local consumption			-0.01	
Eliminate consumption resulting in food waste			-0.52	
Food	2.13	2.11	0.61	2.11
Transportation Potential Reduction:				
Make 66% of trips by walking, cycling and transit		-0.29	-0.29	
Make 86% of trips by walking, cycling and transit				-0.38
Make 100% of private vehicle fleet zero emissions				-0.05
Make 100% of commercial fleet zero emissions				-0.08
Transportation	0.81	0.52	0.52	0.30
Buildings Potential Reduction:				
Improve energy efficiency 20%		-0.11	-0.11	
Improve energy efficiency 40%				-0.21
Implement 5 district energy systems		-0.17	-0.17	
Make 100% of commercial buildings zero emissions				-0.17
Make 100% of residential buildings zero emissions				-0.17
Buildings	0.67	0.39	0.39	0.12

Baseline 2	Vancouver EF (gha/ca)	a) Greenest City 2020 - 25% local vegetables and eggs (gha/ca)	b) Greenest City 2020 - intense food production and conservation (gha/ca)	c) Greenest City 2020 - zero emissions (gha/ca)
<u>Consumables and Waste Potential Reduction:</u>		-0.006	-0.006	-0.006
Increase landfill gas capture at VLF to 75%		-0.064	-0.064	-0.064
Reduce waste to landfill by 50%				
Consumables and Waste	0.58	-0.51	0.51	0.51
Water N/A				
Water	0.02	0.02	0.02	0.02
TOTAL	4.21	3.55	2.05	3.06

Within the Fish, Meat and Eggs sub-component, beef and veal (i.e., red meat) accounts for 64% (376,849 gha out of a total 590,615 gha) or 0.65 gha/ca.[118] Of this amount, two-thirds (67%) is attributed to cropland (275,887 gha) used to produce animal feed (e.g., hay and corn). Pasture land (71,526 gha) because of its lower global average yield, accounts for only 12%. In this baseline (2b), I assume that Vancouverites abstain from eating red meat and substitute other foods such as pork, poultry and eggs which are produced locally and organically.

Grains account for 10% of the Food component. If Vancouverites abstain from eating meat, it is reasonable to assume that some of the BC cropland currently involved in production of grains for animal feed could be used to produce food for humans instead. To test what impact this could have on the footprint, I assume that BC's entire grain growing capacity is dedicated to humans, thereby reducing the operating energy (i.e., food miles) of the grain sub-component.

[118] Consumption of lamb is relatively low and data are not provided in Kissinger's Canada Food Footprint.

Recall that BC grows enough grain to provide 38% of the province's human demand. However, almost all of the grain produced is diverted to animal feed, resulting in only 2% of total grain production directed towards feeding people. If all grain were directed towards feeding BC's human population, I could assume that an additional 36% of grain consumed by Vancouverites was produced in BC, with an equivalent reduction in operating energy (food miles) in the grains sub-component. Reducing the food miles associated with grain by 36% results in a 0.01 gha/ca reduction in the food footprint.

Recall that an estimated 48% of food purchased in BC is wasted, e.g., plate waste, food spoiling (Serecon and Zbeetnoff 2009). The *Greenest City 2020 Action Plan* already assumes a 40% reduction in greenhouse gas emissions from the landfill and incinerator. Diverting food waste from the landfill can help towards achieving this goal. However, if more efficient use of food could translate into a reduction in the amount consumed to begin with, additional reductions to the ecological footprint could be achieved. I assume that eliminating food waste translates into an equivalent (i.e., 48%) reduction in the net amount of food consumed, which results in a 0.32 gha/ca reduction.

Through an intense focus on managing the ecological footprint of food, coupled with the *Greenest City 2020 Action Plan* initiatives identified above, Vancouver's ecological footprint could theoretically be reduced to 2.05 gha/ca (down 2.16 gha/ca from 4.21 gha/ca).

Finally, I explore the potential impact of reduced emissions from transportation and buildings (table 5.2.baseline 2c).[119] In this baseline assessment, I again assume that the *Greenest City*

[119] For additional baseline assessments developed in this research refer to Appendix L.

2020 Action Plan is fully implemented with 25% of vegetables, pork and poultry produced organically within the City. My focus now is on how reductions in emissions from motor vehicles and buildings can reduce the footprint. I assume that 86% of trips are by walking, cycling and transit. Recall that this mode split is what is currently being achieved in the Downtown. All of the remaining 14% of private motor vehicle traffic is assumed to be zero emissions along with the entire commercial vehicle fleet. Note that a city-wide shift in mode split in favour of walking, cycling, and transit means fewer emissions from private automobiles, thereby reducing the potential reductions that could also be achieved by making the fleet zero emission. I also assume that any increase in capacity in the public transit fleet is achieved through zero emission vehicles that would not create an increase in the EF for transportation operating energy. The building energy efficiency is doubled (i.e. from 20% to 40%) across the entire building stock. Furthermore, all buildings are zero emissions. This could be achieved through a variety of means, including expanding the number of non-biomass renewable energy district systems.

5.2.3 Baseline 3 – Multi-Faceted Approach Toward One-Planet Living

In this baseline (see table 5.3, 3a) I explore a variety of approaches to achieve one-planet living. I begin with the assumption that The *Greenest City 2020 Action Plan* is fully implemented. Within the food component, I assume the moderate food scenario, wherein 50% of all vegetables, eggs, pork and poultry are produced organically within the City. I also assume a 50% reduction in consumption of stimulants (e.g., coffee, tea, sugar, cocoa) and packaged beverages (e.g., sodas, wines, spirits). I do not substitute for this reduced consumption because these items are not needed from a nutritional perspective. I also assume that all consumption resulting in food waste is reduced by 50%. In the transportation component, I retain a 66% walking, cycling and transit mode split and assume that 50% of all private and commercial vehicles are emissions free. I also assume that private vehicle ownership is reduced by 25% and air travel is reduced by 25%. In the buildings component, I retain the 20% improvement in energy efficiency and installation of five district energy systems[120] and assume that 50% of the residential and commercial buildings operate with zero emissions. I also explore the potential EF reductions from assuming that the lifespan of the residential and commercial building stock is extended by 50%. This assumption increases the residential building stock lifespan from forty to sixty years and the commercial/institutional building stock from 75 to 112.5 years. Presumably, a longer life-span could reduce the amount of materials flow-through because the building structures remain intact for a longer period. However, a cultural practice of retaining existing interiors might also be needed to fully utilize the benefit of such an approach. Table 5.3 reveals that a reduction of 0.05 gha/ca could be achieved by extending the lifespan of residential buildings by 50%. However, there appears to be no discernible reduction in EF from extending the commercial/institutional building lifespan, most likely because the embodied energy in the materials is already almost fully amortized. Finally, I explore how reduced consumption of consumable materials could affect the EF. I begin with the *Greenest City 2020 Action Plan* goals of a 75% landfill gas capture rate and 50% reduction in waste that is landfilled or incinerated. My assumption in estimating the impact of a 50% waste reduction scheme is that greenhouse gas emissions from landfills and the incinerator are accordingly reduced by 50%. However, since most greenhouse gases result from the decomposition or combustion of

[120] I assume that the district energy systems operate on renewable energy sources that produce zero emissions when combusted. I also assume they do not utilize virgin wood as a source of biomass.

organic matter (e.g., food, paper) the assumption of an equivalent reduction in emissions may be an overestimate. In this scenario, I further explore how actually reducing consumption of materials might affect the EF. I assume that total consumption of paper is reduced by 25%, plastics 50%, organics (e.g. wood, rubber) 50%, glass 50%, and metals 50%. Nevertheless, the cumulative reductions in EF from the above stated assumptions are not sufficient to achieve the one-planet living goal.

In baseline 3b, I increase food productivity to 75% of all vegetables, eggs, poultry and pork produced organically and within the City. I also eliminate consumption of stimulants and packaged beverages. I retain the assumption that consumption resulting in food waste is reduced by 50%. However, because total food consumption is reduced (e.g. by eliminating stimulants and packaged beverages) the potential reduction in EF from this action is also slightly reduced (see table 5.3). In the transportation component, I assume that 86% of trips are made by walking, cycling and transit and that all private and commercial vehicles are zero emissions. I assume that private vehicle ownership and air travel are reduced by 50%. In the buildings component, I assume that energy efficiency across the entire building stock is doubled, i.e. 40% improvement in energy efficiency, and that all buildings are zero emissions. Because all buildings are zero emissions, I do not include the implementation of 5 district energy systems to avoid double-counting EF reduction potential. Presumably, in order to achieve zero emissions in the building stock, many renewable energy district systems would be implemented. In the consumables and waste component, I assume that landfill gas capture is at 75% and there is a 50% reduction in the amount of waste that is landfilled and/or incinerated (with an equivalent 50% reduction in emissions). I also assume that consumption of paper is reduced by 50%. This scenario is sufficient to achieve the one-planet living goal.

Table 5.3 Baseline 3 – Multi-faceted Approach to One-Planet Living

Baseline 3	**a) Greenest City – Multi-facet (gha/ca)**	**b) Greenest City – One-Planet (gha/ca)**
Food Potential Reduction:		
Produce 50% of vegetables and eggs in city	-0.04	
Produce 50% of Pork and Poultry in city	-0.09	
Produce 75% of vegetables and eggs in city		-0.06
Produce 75% of Pork and Poultry in city		-0.13
Reduce red meat by 50% (with substitutes)	-0.34	-0.34
Reduce dairy consumption 50% (with substitutes)	-0.04	-0.04
Reduce stimulants 50% (no substitutes)	-0.025	
Reduce beverages 50% (no substitutes)	-0.013	
Eliminate stimulants (no substitutes)		-0.03
Eliminate beverages (no substitutes)		-0.05
Reduce consumption resulting in food waste 50%	-0.38	-0.37
Food	1.20	1.11
Transportation Potential Reduction:		
Make 66% of trips by walking, cycling and transit	-0.29	
Make 86% of trips by walking, cycling and transit		-0.38
Make 50% private vehicle fleet zero emissions	-0.07	
Make 50% commercial vehicle fleet zero emissions	-0.04	
Make 100% private vehicle fleet zero emissions		-0.05
Make 100% of commercial fleet zero emissions		-0.08
Reduce private vehicle ownership 25%	-0.04	
Reduce private vehicle ownership by 50%		-0.07
Reduce flying by 25%	-0.04	
Reduce flying by 50%		-0.07
Transportation	0.33	0.16

Baseline 3	a) Greenest City – Multi-facet (gha/ca)	b) Greenest City – One-Planet (gha/ca)
Buildings Potential Reduction:		
Improve energy efficiency 20%	-0.11	
Improve energy efficiency 40%		-0.21
Implement 5 district energy systems	-0.17	
Make 50% commercial buildings zero emissions	-0.07	
Make 50% residential buildings zero emissions	-0.07	
Make 100% of commercial buildings zero emissions		-0.17
Make 100% of residential buildings zero	-0.05	-0.17
emissions	0.0	
Increase residential building lifespan by 50%		
Increase comm/inst building lifespan by 50%		
Buildings	0.20	0.12
Consumables and Waste Potential Reduction		
Increase landfill gas capture at VLF to 75%	-0.006	-0.006
Reduce waste to landfill by 50%	-0.064	-0.064
Reduce paper consumption 25%	-0.06	
Reduce paper consumption 50%		-0.12
Reduce plastic consumption 50%	-0.05	
Reduce organics consumption 50%	-0.025	
Reduce glass consumption 50%	-0.01	
Reduce metals consumption 50%	-0.02	
Consumables and Waste	0.35	0.39
Water N/A		
Water	0.02	0.02
TOTAL	2.10	1.80

5.3 Conceptualizing One-Planet Living at the Neighbourhood Scale

In order to explore what one-planet living might look like, I conceptualize the application of baseline 3b at a neighbourhood scale. Research interviewees were asked to identify which neighbourhoods in Vancouver they believe best depicted sustainability. They most commonly identified Southeast False Creek (SEFC), a neighbourhood that was intentionally developed as a model sustainable community on what was once an industrial site (COV 2007e). I use this neighbourhood as my focus in order to explore what changes to existing planning policy and urban management practices might facilitate the implementation of baseline 3b and how these changes might manifest. Note, however, that the actions identified in baseline 3b extend beyond merely addressing transportation and food. Although these are the components where the greatest reductions can be achieved, they remain insufficient to get to one-planet living. Reductions in buildings and consumables must also be addressed. Furthermore, the actions identified in baseline 3b also extend beyond the scope of what the City can influence directly through policy and includes actions by citizens who choose to moderate their lifestyles in order to live within the means of nature. This implies that achieving one-planet living is beyond the scope of what the City can implement alone and requires intentional stewardship on the part of citizens. This means that education and awareness programs are important. In this analysis, I assume that the citizens living in Southeast False Creek are motivated to learn and willing to pursue lifestyle changes that support one-planet living.

Southeast False Creek is part of the larger False Creek area adjacent to Vancouver's Downtown. Its first phase of development was completed in 2010 and served as the Olympic Athlete's Village for the Vancouver 2010 Winter Olympic Games. In 2011, SEFC became the second neighbourhood in the world to achieve the LEED (Leadership in Energy and Environmental Design) Platinum level for neighbourhood development (COV 2012m). Construction of the second phase of development is now underway. At build-out the 36 hectare site is anticipated to house between 11,000 and 16,000 people in a mixed-use community (COV 1999) that will provide: walking access to most services, including rapid transit; high performance (i.e. green) buildings; energy efficient utility services; and utilization of rainwater to reduce consumption from regional drinking water supplies by 50% (COV 2012m). One third of the land (10.46 ha) will be dedicated to parks that will include agricultural production (COV 2012m). Up to 50% of rooftop areas will comprise green roofs, also capable of food production (Sussmann 2012). There are also provisions for community gardens and a farmers market. A strategy to prioritize walking, cycling and transit is linked to the objective of reduced car ownership that will be supported through provision of car-share parking coupled with un-bundled parking for residential units (i.e., parking stalls are independent from residential unit ownership) (COV 2012m). A minimum 20% of available parking will also be required to provide electrical-plug-in capacity for electric vehicles (Sussmann 2012). There is also provision for a neighbourhood association to promote public involvement and education about living sustainably (COV 2007e).

While the *SEFC Policy Statement* (COV 1999), *SEFC Green Building Strategy* (COV 2008b) and *SEFC Official Development Plan* (COV 2007e) contain several elements that support implementation of baseline 3b, as described above, additional measures would be needed to achieve one-planet living.

5.3.1 Conceptualizing Food for One-Planet Living in Southeast False Creek

First, with regard to food: attention is given in SEFC to building capacity for urban agriculture in parks, farmer's markets, community gardens, and on rooftops. However, to achieve 75% of local vegetable, egg, poultry and pork production within SEFC would require intensive multi-functional land use approaches capable of super high yields. For example, approximately half a hectare (0.524 ha) is required to produce enough food for one person for one year in British

Columbia (MAL 2006). Of this total, 0.0177 ha is used to produce vegetables (MAL 2006).[121] Therefore, a population of 11,000 to 16,000 in SEFC would require approximately 146 to 212 ha to produce 75% of their total vegetable consumption (as per baseline 3b) assuming equivalent yields. This is four to six times the total site area of SEFC (at 36 ha). A multi-functional approach to intensive urban agriculture in SEFC may not only include zoning and urban design solutions aimed at expanding urban agricultural capacity and increasing yields, it could also include regulating the number of food assets (or agriculturally productive area) required per capita (Lovell 2010; Cassidy and Patterson 2008). In order to achieve one-planet living, the minimum amount of agricultural capacity required to produce 75% of vegetables, eggs, poultry and pork would be specified as part of the overall development plan. This could be set as performance criteria that would limit total site density according to demonstration by the development proponent of a strategy for how the required agricultural capacity could be achieved. Such an approach should allow for flexibility, e.g., to incorporate some fruit production in lieu of vegetables, or consideration with regard to how much food could be grown in adjacent, lower density neighbourhoods, to offset demand in SEFC.

Building on the literature surveyed above (see section 5.1.4), examples of intensive urban agriculture in SEFC include: 1) integrating agricultural production with green infrastructure initiatives (e.g., increasing permeability of surface areas for improved stormwater management); 2) incorporating fruit and nut trees and berry bushes in urban landscaping (e.g. in boulevards and pocket parks – as well as major parks and greenways), 3) using agriculturally

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[121] Reference data for eggs, poultry, and pork is not specified in this report. Prevailing agricultural practices are assumed.

productive plants to provide weather protection adjacent to building facades as well as on rooftops (e.g. living walls and green roofs). Roads could be converted to agricultural production over time and with careful attention to soil rehabilitation (Register 2006). In the interim, raised beds could be used to begin immediate agricultural production, as has proven successful in cities like Havana (Mugeot 2006). Roads account for 25% of urban land in Vancouver (Metro Vancouver 2006a), and conversion of roads to other uses complements transportation demand management efforts including those aimed at reducing vehicle ownership (which is also identified in baseline 3b).

Additional measures, particularly with regard to pork and poultry production, would also need to be explored (Lovell 2010). These could involve changes to zoning that expand allowance for backyard hens to produce eggs to also allow raising a variety of animals for slaughter. Whether this permission would be granted to individuals (e.g., in private homes on balconies/rooftops or in gardens) or to a business operating within a specialized and perhaps more centralized facility capable of supporting several neighbourhoods would be a matter for careful consideration and public debate. Since SEFC comprises a high density community, meat production that encompasses a wider scope of animals better suited to enclosed spaces could also be considered. For example, guinea pigs and rabbits are easily raised in small spaces such as apartments (e.g., on balconies and rooftops) (Mougeot 2006), and some fish species such as Carp and Talapia are well suited to nutrient-rich waters that could comprise part of a localized wastewater management system while simultaneously serving as a small scale fish-farm (Jack-Todd and Todd 1994). Again, this type of enterprise might be better suited to a business with technically trained staff and specialized facilities or a co-operative of local producers organized for commercial production (Mougeot 2006).

Vancouver's climate also limits potential for year-round production of vegetable crops. As noted in section 5.1.4 above, trade supplements vegetable supply through the winter months. However, opportunities could exist to create indoor or semi-sheltered cultivation areas to facilitate year-round production, including of some tropical foods (Mougeot 2006). For example, the Rocky Mountain Institute, built in 1984, maintains an indoor, passive solar greenhouse that supports fruit-bearing banana and mango trees year-round in Snowmass Colorado (RMI 2013). Opportunities may also be identified to expand capacity for food production by using multiple stories within buildings. The Beddington Zero Energy Development (BedZed) in Greater London is designed specifically with the goal of one-planet living and includes in-suite solar greenhouses to complement roof-garden access in most of its residential units.[122] However, experience shows that residents prefer to use these spaces for other purposes (e.g. storage, office/den) (BioRegional 2009). This illustrates that the built environment, while essential to enable one-planet living, is not sufficient for achieving the goal if those occupying the space are not intentionally utilizing it, e.g., to produce food. Although the City can provide education and awareness programs to help citizens understand the importance of urban agriculture, it is not empowered to regulate behaviour inside the home. An alternative approach could be to focus on creating urban agricultural spaces, both indoor and out, for

[122] BedZed comprises a medium-density, row housing built form with units stacked to a maximum of three stories (BioRegional 2009). This represents a much lower density than what is proposed for SEFC, and conversely allows more rooftop and garden plot area per unit for agricultural production.

professional urban farmers. There is a demand by farmers for access to urban agriculture assets (Mougeot 2006), and urban agriculture can be a viable economic activity (Lovell 2010).

Finally, the research demonstrates that the greatest reductions to the ecological footprint in the food component can be achieved through changes in consumption, specifically reducing food waste and red meat consumption. Demand side management aims to shape consumption patterns and includes education and awareness about the impacts of consumption (Newman and Jennings 2008). The SEFC Policy Statement and ODP call for a community association whose role is specifically to advance education and awareness. How this association will be established remains an open question. Such an association, however, would have an important role in advancing efforts to enable residents in SEFC to make choices that support one-planet living. Demand side management initiatives often include pricing incentives and disincentives (e.g., taxes) as well as regulatory controls that complement education and awareness campaigns in attempts to shape consumption (Brandes and Mass 2004). Thought could be given to using these tools to reduce food waste and encourage low EF dietary choices in SEFC.

5.3.2 Conceptualizing Transportation for One-Planet Living in Southeast False Creek

Regarding transportation: projected density in SEFC ranges between 306 and 444 people per hectare, sufficient to support high (over 75%) walking, cycling and transit mode shares (Newman and Kenworthy 1999).[123] Indeed, all residential units will be located within 350 metres of services required to support day-to-day living, including links to rapid transit (Sussmann 2012). These parameters coupled with a transportation demand management strategy that includes provisions for pedestrian, cycling and transit (i.e., streetcar)

[123] Note that lower densities ranging from 111 to 139 people per hectare were originally envisioned in the SEFC Policy Statement (COV 1999).

infrastructure improvements as well as un-bundled parking, car-share parking, and electrical plug-in capability appear to be sufficient to reach an 86% mode split for walking, cycling and transit.

Reducing motor vehicle ownership by 50% can be supported by reducing the amount of available parking by 50% supplemented by increasing the costs of parking. Of the parking that remains available, it could be designed as flex-space, allowing for other uses over time that could either meet the needs of residents or be leased as space for use by other individuals or businesses (Register 2006). To achieve 100% zero emissions vehicles, all parking facilities may need to have plug-in capability supplied by electricity from renewable energy. On-site photo-voltaics, wind, tidal or other forms of renewable energy generation could supply some of the electrical energy demand. Hydrogen fuel cell powered vehicles could also be considered. Whether the total embodied energy related to these technologies would produce net positive results from a lifecycle perspective would need to be carefully considered. Consideration could also be given to alternative vehicle materials (e.g., Amory Lovin's Hyper Car uses very light weight carbon fibres that drastically reduce a vehicle's total weight, resulting in substantial energy efficiency gains) (von Weizsäcker et al. 2009). Changes in vehicles (e.g., Segways[124] and modified electrical bicycles designed for carrying and/or pulling loads) could be integrated more comprehensively with mobility-devices that are part of the built environment (e.g., elevators, people movers and/or conveyor belts) (Register 2006). An important challenge with regard to achieving zero emissions in the commercial vehicle fleet pertains to goods movement and

[124] Segways use silicon solid-state gyroscopes and small electrical motors to move in response to the tilting and balancing motions of the human body. (http://science.howstuffworks.com/engineering/civil/ginger.htm)

operation of heavy equipment, such as bulldozers, that require concentrated forms of energy to do work. Where limits to available technology require fossil fuels, emissions may need to be sequestered through carbon offset regimes financed through a carbon tax or some other mechanism. The same approach could apply to reducing emissions from air travel which currently falls outside the scope of the City's jurisdiction. Regulation of a carbon tax or cap and trade scheme to achieve these purposes would require senior government intervention.

5.3.3 Conceptualizing Buildings for One-Planet Living in Southeast False Creek

With regard to buildings, all new development in Vancouver must be built to LEED[125] (Leadership in Energy and Environmental Design) Gold (COV 2011a). This supersedes the *Southeast False Creek Green Building Strategy* (2008) that set policy for construction, calling for a minimum LEED Silver rating. Nevertheless, provision of a neighbourhood district energy system in SEFC that relies on sewer waste-heat exchange supplemented by natural gas achieves a 55% reduction in emissions from buildings (COV 2011a; Sussmann 2012).[126] One building has also achieved net-zero energy status, meaning it produces as much energy as it uses (COV 2011a). However, I question this designation because the building relies on other buildings and infrastructure to achieve its status. For example, a solar thermal array on a neighbouring building is used to heat water for the net-zero building (Winham et al. 2009). Nevertheless, the net-zero building demonstrates significant energy savings through passive design and use of super-insulating materials, e.g., triple glazed windows (Winham et al. 2009). The net-zero

[125] LEED (Leadership in Energy and Environmental Design) is the North American green building rating system to assess the performance of buildings from an environmental and occupant health perspective. The ratings start at "certified," and move through Bronze, Silver, Gold and Platinum, which is the highest level.

[126] Outside the scope of SEFC, the 2008 Green Homes Program targets new construction of single and two-family homes requiring that they be energy efficient and retrofit ready, meaning capable of retrofitting for the installation of rooftop solar energy systems and electrical charging stations for vehicles (COV 2012n). Staff estimates that this program will reduce energy consumption in new construction by 33% over existing bylaw standards (COV 2012n).

building also relies on the neighbourhood district energy system that utilizes sewer heat exchange and operates with zero greenhouse gas emissions (Sussmann 2012).

To achieve one-planet living according to baseline 3b, all buildings in Southeast False Creek would have to operate with zero greenhouse gas emissions. This could be achieved through a combination of energy efficiency measures (e.g. passive design, use of insulating materials) and renewable energy sources. It could also include provisions for offsetting greenhouse gas emissions that are produced through small amounts of fossil fuel and/or biomass combustion, e.g., planting trees and ensuring their long-term capacity to sequester carbon.

5.3.4 Conceptualizing Consumables and Waste for One-Planet Living in Southeast False Creek

With regard to consumables and wastes: the SEFC Policy Statement (COV 1999) calls for environmentally responsible retail and services located near transit stops and in community centres with strong pedestrian links to residential units. A focus on reducing consumption is addressed through the chapter on "Waste, Recycling and Composting" with aims to reduce the total amount of waste produced, increase recycling and economic development opportunities associated with waste management, and minimize the transportation of waste materials (COV 1999).

To achieve one-planet living according to baseline 3b, paper consumption in SEFC would be reduced by 50%. This could be achieved through a concerted effort on the part of both residents and business operators to avoid using: i) paper-based packaging products, ii) printed materials, and iii) paper transactions (e.g., receipts, bank statements, utility bills).

5.4 Policy Proposals

Based on baseline 3b and the exercise to conceptualize how it could be implemented at the neighbourhood scale, and considering existing policy and practice at the City as well as input from interviewees in the first round of interviews, I have identified the following changes to planning policy and practice that could enable citizens to make choices in support of one-planet living. Because the research attempts to identify changes in planning policy and urban management practices that the City of Vancouver could implement to enable citizens to make choices that support a one-planet lifestyle, the policy recommendations are focused exclusively on the City as actor/enabler.

Food:

1. Zoning for minimum agricultural capacity that is tied to site density.
2. Zoning to allow roof-tops, wall facades, and garden plots for agricultural business operations.
3. Zoning to allow raising and slaughtering of small livestock (e.g. hens, guinea pigs, rabbits, and pigs).
4. Issue business permits to food cooperatives to enable farm-gate sales of produce and/or centralized sales of locally produced food at community grocers and/or farmers markets.
5. Implement an education and awareness campaign to promote low EF dietary choices and food conservation.
6. Reduce food-waste collection by a) limiting capacity (e.g., number and size of bin pick-ups), and b) charging more for second and third bins.

or

7. Require on-site disposal of food waste (e.g., through community or commercially operated compost centre).

Transportation:

1. Introduce parking maximums tied to site density at 0.5 parking spaces per unit (i.e., provision of parking spaces cannot exceed half the total number of units).
2. Unbundle parking from residential units in all multi-family development so that parking spaces can be purchased independent of residential units.
3. Require all parking to be flex-space to permit alternative uses of the space, including for commercial purposes (e.g. valet storage). Special good neighbour bylaws that regulate noise and nuisance may also need to be considered.
4. Require all parking to have plug-in capability to support electric vehicles, and require that the electrical load for parking be offset by on-site renewable energy generation and/or purchase of renewable energy certificates.
5. Permit road spaces to be converted to agricultural or park uses, including for operation by an agricultural business.
6. Implement an education and awareness campaign to promote low EF travel choices for inter-urban and international travel.
7. Petition the Province to expand the carbon tax to apply to inter-provincial and international air travel (i.e., eliminate the carbon tax rebate).

Buildings:

1. Work with the Province of British Columbia, BC Utilities Commission, BC Hydro, and Fortis BC to make building energy consumption public information, e.g., through a building labeling program.
2. Require businesses, as part of their business licence, to report energy use per square metre of operating space.
3. Consider implementing a sliding fee attached to business licences that penalizes high energy users. Such a fee should be assessed according to the type of business and location of business, e.g., type of building in which it is located.[127]
4. Require commercial property managers to install individual unit meters in leased spaces and submit an energy management plan every five years with annual reporting on progress towards achieved energy management objectives for the building.
5. Require strata councils and/or their building management companies to install individual unit meters and to submit an energy management plan every five years with annual reporting on progress towards achieved energy management objectives for the building.
6. Require all residential and commercial buildings to operate at zero emissions through any combination of: improved energy efficiency (including district energy), on-site renewable energy generation, waste-heat exchange, purchase of renewable energy certificates.

[127] Some businesses are more energy intensive by nature of their operation. Some building types are more energy efficient than others. Building orientation (e.g., south exposure) also can affect energy consumption. The fee should be responsive to these considerations in order to apply equal consideration to businesses within the same category and/or building typology.

Consumables and Wastes:

1. Raise awareness about the impact of paper on the EF and promote reduced paper consumption through: a) avoiding unnecessary paper transactions (e.g., bank statements, receipts), b) reusing durable products to avoid one-time use of paper products (e.g., reusable mugs and food containers), c) demonstrate leadership through an institutional paper-less initiative that encourages staff to avoid the use of paper in civic transactions (e.g., permitting and licensing, tax notifications and payments, records management).
2. Advocate to the Province of British Columbia, and to the Federal Government through the Federation of Canadian Municipalities, to regulate printed paper and packaging products with the goal of reducing consumption by 50%.
3. Implement an education and awareness campaign to promote low EF consumer choices in general including: a) conservation through repair and repurposing of durable products such as books, computers, and upholstery; b) reduced demand through sharing of durable products such as tools, garden equipment, and sporting equipment.

5.4.1 Interviewee Feedback on Policy Proposals

In the second round of interviewees, I asked interviewees to comment on baseline 3b and the viability of implementing the changes to policy and management practices identified above. I then used their feedback to modify and/or eliminate policies for which implementation seems infeasible from a technical perspective (e.g., the City does not have legal jurisdiction or financial resources). A revised list of policies is presented in section 5.5 and table 5.6 below.

5.4.1.1 Interviewee Feedback on Food Policy Proposals

All interviewees agreed that increasing urban agricultural capacity was within the City's jurisdiction; however, producing pork and poultry would require a bylaw change. Interviewees believed this change would not be supported by citizens and would therefore be difficult to pass and potentially costly to implement. Careful attention would need to be given to how animals were raised, slaughtered, and processed. Most likely this would occur at a commercial level for retail purposes due to socio-cultural norms, i.e., most people are unfamiliar and uncomfortable with the backyard slaughtering of animals. Interviewees also questioned whether a significant impact in reducing the footprint would be attained through such a policy given that most of the poultry consumed in Vancouver is produced within the Lower Mainland and/or Fraser Valley (J. O'Neil , personal communication, September 25, 2012; anonymous).[128] To answer this question would require that the ecological footprint for the food component be carried out using locally generated data. An initiative by the City to generate better local food production and consumption data could be considered.

When the City initiated its Greenest City public consultation known as "Talk Green to Us," a significant number of respondents recommended veganism as a strategy to achieve a lighter footprint. In fact, "encourage veganism options for all" was the number one ranked suggestion (1,079 votes) followed by recommendations to extend the cycling infrastructure: "cycling for everyone" (1,058 votes) and extending the food waste collection program to include condominiums and apartments (771 votes) (COV 2012o). The City already encourages people to choose locally and organically produced food (COV 2012k; COV 2012l), and several interviewees

[128] Similarly, while the City encourages urban agriculture, it is not tied to land use at a level of production sufficient to achieve food security (K. Hiebert, personal communication, March 6, 2013).

agreed that helping citizens understand the opportunities available to them to reduce their ecological footprint simply by making changes to their diet was important (J. O'Neill, personal communication, September 25, 2012; A. Fournier, personal communication, September 28, 2012; P. Judd, personal communication, March 5, 2013; K. Hiebert, personal communication, March 6, 2013). However, changes in diet and reduction of plate waste happen at the individual level within private households and are, therefore, outside the domain of the City's jurisdiction and ability to influence through policy (A. Reimer, personal communication, September 19, 2012; K. Hiebert, personal communication, March 6, 2013; anonymous). Education and awareness campaigns are considered costly and ineffective in the absence of regulatory or pricing changes that would need to be simultaneously introduced to effect behaviour change. Therefore, participation in education and awareness campaigns about food choices for one-planet living might be better suited to a non-government organization or a collaboration between the City and non-government organizations (A. Reimer, personal communication, September 19, 2012; K. Hiebert, personal communication, March 6, 2013). For example, the Heart and Stroke Foundation promotes a diet low in red meat as being conducive to cardiovascular health (Heart and Stroke Foundation 2012). The One Earth initiative (http://oneearthweb.org/) is based in Vancouver and promotes sustainable production and consumption, including awareness about lifestyle choices that support reducing one's ecological footprint.

Restricting food waste collection could run counter to efforts currently underway to promote greenwaste source separation. A policy promoting on-site disposal of food waste through a community or commercially operated compost centre makes more sense (A. Reimer, personal communication, September 19, 2012; J. O'Neil, personal communication, September 25, 2012; L. Cole, personal communication, September 25, 2012). However, past attempts to introduce this in SEFC were unsuccessful (K. Hiebert, personal communication, March 6, 2013). The regulatory requirements from all levels of government are not well understood and could be better coordinated to help enable small scale composting operations (T. Duynstee, personal communication, February 7, 2013). There is also a risk that the inconvenience or impracticality of these options results in food waste going in the garbage instead of in a source-separated stream. A longer term strategy to introduce volume or weight-based pricing, also known as pay-as-you-throw, could prove more effective (M. Kosmak, personal communication, May 3, 2013). Switching the collection frequency of different waste streams (e.g., weekly for food scraps and bi-weekly for garbage) is also an effective strategy (S. Pander, personal communication, May 2, 2013).

5.4.1.2 Interviewee Feedback on Transportation Policy Proposals

Upon seeing Baseline 3b (see section 5.2.3 above) and noting that Vancouver's downtown mode-share approximates what would be needed for one-planet living, several interviewees agreed that increasing the mode share of walking, cycling and transit to 86% could be achieved across the City by 2050 and beyond.[129] They were also confident that reducing motor vehicle ownership by 50% and shifting to 100% zero emissions vehicles could be achieved by virtue of the above mode shift coupled with market-driven evolutions in technology. The history of Vancouver's efforts to reduce motor vehicle use (e.g., through compact, mixed land use coupled with pedestrian and bicycle infrastructure) demonstrates that people are willing to

[129] Note that this was not a policy proposal identified in section 5.4.

choose alternatives when they are available. Vancouver has repeatedly surpassed its targets ahead of schedule, and several interviewees noted that fewer people under the age of 22 are interested in obtaining their drivers' licence than in previous years (J. Dobrovolny, personal communication, September 28, 2012; S. Pander, personal communication, September 28, 2012). Technology is also capable of supporting electric vehicles and integrated renewable energy sources that can be tailored to the urban environment for on-site power generation. Electric vehicles can also be used to manage energy demand, e.g., off-peak charging and load-shedding (P. Judd, personal communication, March 5, 2013). Interviewees noted the value of building bicycle infrastructure ahead of demand, or using streets for non-automobile purposes (e.g., Sunday market), because it symbolically represents the direction that the City wants to take and psychologically prepares people to think of cycling as a viable transportation choice (A. Reimer, personal communication, September 19, 2012; anonymous). Converting streets to agricultural production is also possible.

The City already uses parking maximums. For example, in SEFC the limit was set according to unit size ranging from a 0.5 parking space for units with less than 50 m^2 (538 ft^2) gross floor area to 2.0 parking spaces for units over 189 m^2 (2,034 ft^2) (K. Hiebert, personal communication, March 6, 2013). The City supports un-bundled parking, but does not have jurisdiction to require developers to provide it. Developers may provide it as a voluntary measure. Purchasers of condos often do not need the parking for themselves, but worry about the resale value of their units without it (J. Dobrovolny, personal communication, September 28, 2012; S. Pander, personal communication, September 28, 2012). The City is currently seeking authority so that it may choose to require unbundled parking in some areas (J.

Dobrovolny, personal communication, September 28, 2012). Several interviewees noted that underground parking in the downtown is underutilized. Creating flex-space parking makes sense so that it can be used for other purposes. However, whether such a change contravenes the *Building Code* or planning by-laws would need to be considered (J. Dobrovolny, personal communication, September 28, 2012; M. Hartman, personal communication, September 28, 2012).

Interviewees agreed that the City was not equipped to address reductions in air travel. (J. Dobrovolny, personal communication, September 28, 2012; K. Hiebert, personal communication, March 6, 2013). The City could request that the Provincial Government change its practices with regard to the carbon tax on jet fuel. Currently all airlines pay the tax at the time of fuel purchase. However, flights outside of BC are exempt and the airlines can claim a rebate for that portion of the flight outside the Province (H. Kennedy, personal communication, September 27, 2012). Interviewees perceived an information campaign that targets vacationers as a challenging prospect because where and how people choose to recreate is generally outside the scope of the City's jurisdiction. Specifically, the City does manage parks and provide recreational services, but out-of-town travel is beyond the City's mandate. Several interviewees noted that collaboration with tourism associations in Vancouver and BC could achieve positive messaging about local tourism opportunities, thereby encouraging people to stay closer to home, e.g., staycations. Encouraging corporations to reduce air travel by employees through use of teleconferencing could also be pursued. For example, several telecommunication companies are expanding the possibilities for virtual conferencing and the City could consider supporting this technology by encouraging neighbourhood teleconference centres (J.

Dobrovolny, personal communication, September 28, 2012; S. Pander, personal communication, September 28, 2012).

5.4.1.3 Interviewee Feedback on Buildings Policy Proposals

City staff believes that achieving substantial energy efficiency improvements across the entire building stock is achievable (M. Hartman, personal communication, September 28, 2012). The City is planning to introduce mandatory disclosure of commercial building energy use by 2020 based on programs already operating in Seattle, San Francisco, and New York. Natural Resources Canada is currently adapting the U.S Environmental Protection Agency's "Portfolio Manager" software for use in Canada. Once the change is made, the City of Vancouver plans to begin using it in a building energy benchmarking program and, eventually, for building labeling (M. Hartman, personal communication, September 28, 2012). The age of Vancouver's commercial and high-rise building stock is not correlated to its energy performance. Indeed, many of the newer multi-family residential, high-rise buildings in Vancouver lose a significant amount of heat through their glass curtain walls. Interior hallways and common areas that require twenty-four hour lighting are also energy intensive (D. Ramslie, personal communication, December 19, 2011).[130] Choice of materials and building design (including orientation) affect building energy performance. "We need building envelopes that really perform, and we need to balance this off against demand for views" (K. Hiebert, personal communication, December 9, 2011). A building energy labeling program can help alert developers and consumers to the real value of a building, which includes its energy performance (H. Goodland, personal communication, September 26, 2012).

[130] Low-medium rise development with retail at grade is generally a more efficient design (D. Ramslie, personal communication, December 19, 2011).

The City could explore the use of business licences as a vehicle to influence energy conservation, e.g., through requirement of an energy management plan and energy performance reporting requirements tied to fee structures that incent energy efficiency. However, Vancouver (like most cities) relies on its commercial tax base and is reluctant to pursue initiatives that impede the viability of existing businesses or deter interest by new businesses to locate in the City (M. Hartman, personal communication, September 28, 2012). Nevertheless, improving energy efficiency in the commercial and institutional sector remains important. Working with businesses to make energy efficiency a part of their performance metrics could help (M. Hartman, personal communication, September 28, 2012). For example, changes could include a campaign to "close the door on climate change" directed at street-grade businesses that entice customers during the winter months by leaving their shop doors wide open during business hours.[131] Several initiatives underway through the Vancouver Economic Commission (VEC) under the auspices of advancing a green economy can play an important role. For example, the VEC aims to work with the business community to improve the environmental performance of their operations, including an awards and recognition program aimed at rewarding more sustainable business practices (J. Tylee, personal communication, November 23, 2011).

The City is exploring, with the BC Government, a policy to require energy efficiency upgrades in commercial buildings and in the common areas of multi-family residential buildings. Such a

[131] I personally have witnessed this practice in multiple businesses in downtown Vancouver through the winter months. When I questioned two managers in stores located at the intersection of Robson and Burrard about these practices on November 16, 2010, they advised that it was a strategy to entice people to come into the store. A total of eight retail stores at this intersection had their doors open on this day. I have also observed this practice at stores on South Granville.

policy would target high energy consumers based on reported energy data. The City is also working on a policy to require energy upgrades in residential and commercial buildings if a building owner applies for a renovation permit (L. Cole, personal communication, September 25, 2012; M. Hartman, personal communication, September 28, 2012). The City processes approximately 1,300 residential and 2,000 commercial/institutional retrofit permits annually (D. Ramslie, personal communication, December 19, 2011; COV 2012p). Yet, in 2006 there were approximately 90,000 single-family/duplexes homes, 250,000 condominium units, and 400,000 businesses in Vancouver (M. Hartman, personal communication, September 28, 2012). Therefore, interviewees agreed that creating incentives to improve the business case for energy retrofits as well as making it easy for building owners to access trusted sources of information and technical expertise to guide them through the process are important strategies. Several programs are available to provide both technical and financial assistance to home owners for energy retrofits (e.g. Live Smart BC, Vancouver Home Energy Loan Program). Staff in the Sustainability Office are also exploring whether the scope of the community amenity contribution for new development could be expanded to include contributions to support building energy retrofits and/or district energy infrastructure. For example, as of 2020 new high-rise multi-unit residential construction in the City is required to achieve zero greenhouse gas emissions. If applied across the entire building stock, new technologies such as air-source heat pumps can achieve 80% efficiency gains in residential development and approximately 40% in commercial development (M. Hartman, personal communication, September 28, 2012).[132] Thermal insulation, triple-glazed windows, design for passive solar/ventilation and a

[132] In Victoria, BC air-source heat pump technology is now present in approximately 65% of new homes; however,

variety of other strategies can further reduce the energy load. However, to achieve the last bit of energy savings in order to achieve zero emissions can be very costly. A program that allows developers to contribute to a fund used to incent existing building retrofits to achieve energy savings and greenhouse gas reductions equivalent to the outstanding amount required by the developer to achieve zero emissions could provide a cost-effective strategy that also stimulates more retrofit interest (M. Hartman, personal communication, September 28, 2012).

Interviewees also agreed that individual metering of units was an effective strategy to conserve energy. In pilot applications of this technology, it has demonstrated the potential to achieve significant savings, e.g., up to 40% of total building energy consumption (M. Hartman, personal communication, September 28, 2012). However, the city cannot require the installation of individual unit meters in existing buildings and a financing mechanism may be needed to offset the costs to stratas associated with implementing energy reporting (K. Hiebert, personal communication, March 6, 2013).

5.4.1.4 Interviewee Feedback on Consumables and Wastes Policy Proposals

The City can raise awareness and encourage people to use less paper, and the City can leverage influence through its waste-management functions, e.g. banning paper from waste disposal to landfills and incinerators and promoting recycling. However, there are no regulatory or financial incentives that the City can directly access to reduce paper consumption because the City does not control paper manufacturing and how it is used. In the absence of a policy lever, the City would require more resources than presently available to sustain an awareness campaign

in Vancouver it comprises less than 5%. This variance may be due to constrained natural gas supply on Vancouver Island and poor experiences with the former propane system (M. Hartman, personal communication, September 28, 2012).

sufficient to achieve citizen engagement on an ongoing basis. Lack of information about the ecological impacts of using electronic communication devices in place of paper and concerns about socially regressive impacts to lower income groups who may not have the financial means to purchase and use these devices would also need to be addressed (M. Kosmak, personal communication, September 4, 20102).

Rather than attempting to immediately eliminate paper, a targeted approach that addresses specific types of paper could be more feasible, as a member of City staff explains:

> "Eliminate is a tough word. Alternatively, cutting consumption of paper in half could trigger more exploration into appropriate strategies for managing different types of paper products. Eliminate simply shuts down motivation to act on initiatives to reduce consumption" (M. Kosmak, personal communication, September 4, 2012).

This statement is echoed by another employ who observes that "breaking it down into bite-size policy measures is more engaging than blanket statements" and can enable "the will to explore and implement" (L. Cole, personal communication, September 25, 2012). Furthermore, a strategy aimed at reducing specific types of waste would be more effective than a broad sweeping approach to waste in general:

> "If you think about the spectrum of materials we consume, a specific focus on a few provides a practical place to start. Solutions will come from targeting very narrow slices of the waste stream" (M. Kosmak, personal communication, September 4, 2012).

The *Vancouver Charter* would have to be changed to enable the City to ban the use and/or sale of specific materials. The Province has declined changing the Charter to expand Vancouver's jurisdiction to regulate materials in this way, preferring extended producer responsibility (EPR) instead. This approach engages manufacturers in developing and implementing plans to manage the full lifecycle of their products, and can include demand-side management to reduce overall consumption. However, industry push-back may limit the Province's willingness to set binding targets for reduced consumption (M. Kosmak, personal communication, September 4, 2012; J. Braman, personal communication, September 28, 2012).[133] Without regulation, manufactures are slow to act.

The City can advocate to the Province and the Federal Government to strengthen existing EPR initiatives, including a consumption reduction target for managing paper. In 2009, the Canadian Committee of Ministers for the Environment (CCME) identified packaging and printed paper as important products to address through EPR (CCME 2009), and the BC Recycling Regulation (BC Reg 449/2004) Schedule 5 addresses packaging and printed paper and requires producers to implement a stewardship plan by May 19, 2014 for how to manage these products through to the final stage of their lifecycle as residential waste (BC MOE 2004). However, neither directive sets targets for reducing consumption.

Finally, the City can implement an education and awareness campaign to promote low EF consumer choices, including conservation through repair, repurposing and sharing. There are several community-based initiatives throughout the City that already support these types of activities and interviewees identified a need for more "zero-waste assets." These are facilities

[133] The Province can also regulate increased recycled content or set design requirements through EPR.

that support materials conservation and may include: fix-it shops and do-it-yourself repair shops, e.g., for bicycles; tool, equipment, and clothing rental businesses; tool libraries and share-it sheds; thrift stores, second-hand and antique stores; dedicated swap meet spaces, and eco-depots where people can drop-off their reusable products for pick-up by others who might want them. Some operate as businesses, social enterprises and voluntary initiatives, while others may require financial support (M. Kosmak, personal communication, September 4, 2012; L. Cole, personal communication, September 25, 2012; A. Fournier, personal communication, September 28, 2012; P. Judd, personal communication, March 5, 2013).

5.5 Analysis

Although food and transportation were identified in chapter 4 as the two components with the highest EF reduction potential, City staff generally believes transportation and buildings offer the greatest potential to affect change (see section 5.4 above). This may reflect the City's long history of engagement in these sectors. Staff's reticence to implement the full scope of actions available to reduce the EF of food stem primarily from concerns about the appropriateness of addressing dietary choice and the expense of education and awareness campaigns without complementary financial incentives and regulatory mechanisms. Vancouverites apparent willingness to support veganism seems to have little bearing on this perspective. This observation draws attention to the role that staff beliefs and interests can play in advancing changes to planning policy and urban management practices.

Baseline 3b identifies 18 actions to reduce the average Vancouverites ecological footprint to levels commensurate with one-planet living. These initiatives assume full implementation of the *Greenest City 2020 Action Plan* as adopted by City Council in 2011. Of the 18 initiatives identified, two require no further effort because they are already identified for implementation in the *Greenest City 2020 Action Plan*. These actions are in the consumables and waste component: i) increase landfill gas capture at the Vancouver landfill to 75% and ii) reduce waste to landfills and incinerators by 50%.

Of the remaining 16 actions in baseline 3b that require additional effort by the City to implement, seven are outside the scope of the City's jurisdiction and would require changes to the *Vancouver Charter* or action by senior government agencies to implement. The seven initiatives in question are: i) reduce red meat consumption by 50% (with substitutes), ii) reduce dairy consumption by 50% (with substitutes), iii) eliminate stimulants (no substitutes), iv) eliminate manufactured beverages (no substitutes), v) reduce consumption resulting in food waste by 50%, vi) reduce flying by 50%, and vii) reduce paper consumption by 50%. Options available to the City to leverage its influence to address these initiatives include advocating senior governments for changes to the *Vancouver Charter* to enable the City to take action, advocating senior governments to take action within the scope of their authority, or appealing to citizens and businesses (through education and awareness campaigns) to voluntarily take action.

Of the nine remaining actions, three still fall outside the scope of City jurisdiction, but the City can play an important influencing role to enable their implementation through its powers over land use and built form. The three actions in question are: i) make 100% of the commercial vehicle fleet zero emissions, ii) make 100% of the private vehicle fleet zero emissions, iii) reduce private vehicle ownership by 50%.

Of the remaining six actions, the City has jurisdiction to influence future outcomes, but is limited in its ability to exert changes in present conditions. Specifically, the City has authority to make 100% of *new* commercial and residential buildings zero emissions. However the City does not have authority to require the retrofit of existing single-family and duplex residential buildings for purposes of improving energy efficiency or mitigating greenhouse gas emissions.[134] Similarly, it is within the City's jurisdiction to support local production of vegetables and eggs toward a 75% target through increasing urban agriculture assets and granting business licences to urban farmers. However, whether citizens and businesses choose to participate in urban agriculture remains at their discretion. Although more politically challenging, the City could also support production of 75% of pork and poultry within the City through bylaw and permitting changes. Again, however, this raises questions about where and how animals would be reared and slaughtered, including public health and nuisance (noise and odour) concerns. The potential scale of these operations is also of concern because large commercial operations could require additional permits by regional and/or senior government authorities (e.g., for meat inspection, air quality management, and animal waste discharge into sewer systems). The City can pursue compact and mixed land uses and invest in public infrastructure that favours walking, cycling and transit, and it can limit the amount of road and parking space to encourage movement toward an 86% mode-share target. Finally, the City can support efforts to improve energy efficiency in buildings by 40% through development of district energy systems and creation of incentive programs that provide technical expertise and

[134] Instead, the City can and is pursuing incentives to accelerate voluntary retrofits by home owners. The City is also exploring whether it has authority to require commercial building energy efficiency improvements.

financial support to building owners. These actions represent an extension of efforts that are already underway by the City to advance sustainability.

Clearly the City's scope of jurisdiction to implement the actions necessary to achieve one-planet living is limited. Nevertheless, the City does play an important enabling role to facilitate creation of the conditions in which citizens can make lifestyle choices in support of one-planet living. The City also plays an important advocacy role to communicate to senior governments the type of jurisdictional changes and/or regulatory and financial support needed to advance urban sustainability towards the goal of one-planet living. Full implementation of the six actions over which the City has jurisdiction could contribute to a 1.12 gha/ca reduction in the EF. Recall that there are also two actions held constant for implementation from the *Greenest City 2020 Action Plan* (addressing landfill gas capture and waste reductions). Adding these to the scope of consideration could shave an additional 0.07 gha/ca off the EF for a total reduction of 1.19 gha/ca (down 28% from 4.21 gha/ca to 3.02 gha/ca). If Vancouver were also able to positively influence the three actions dealing with zero emissions vehicles and reduced car ownership, the EF could be reduced by an additional 0.2 gha/ca for a total reduction of 1.39 gha/ca (down 33% from 4.21 gha/ca to 2.82 gha/ca). If one assumes that the remaining seven actions outside the scope of the City's jurisdiction were voluntary implemented by Vancouverites, they could achieve an additional 1.02 gha/ca reduction in the EF (down 24% from 4.21 gha/ca to 3.19 gha/ca). Assuming the City and citizens (including in their roles as residents and business owner/operators) came together to fully engage in one-planet living, their combined efforts could theoretically achieve a 57% reduction in the Vancouver EF, sufficient to reach the one-planet living target articulated in baseline 3b (see figure 5.1).

Figure 5.1 Comparing Vancouver's 2006 EF to Baseline 3b for One-Planet Living

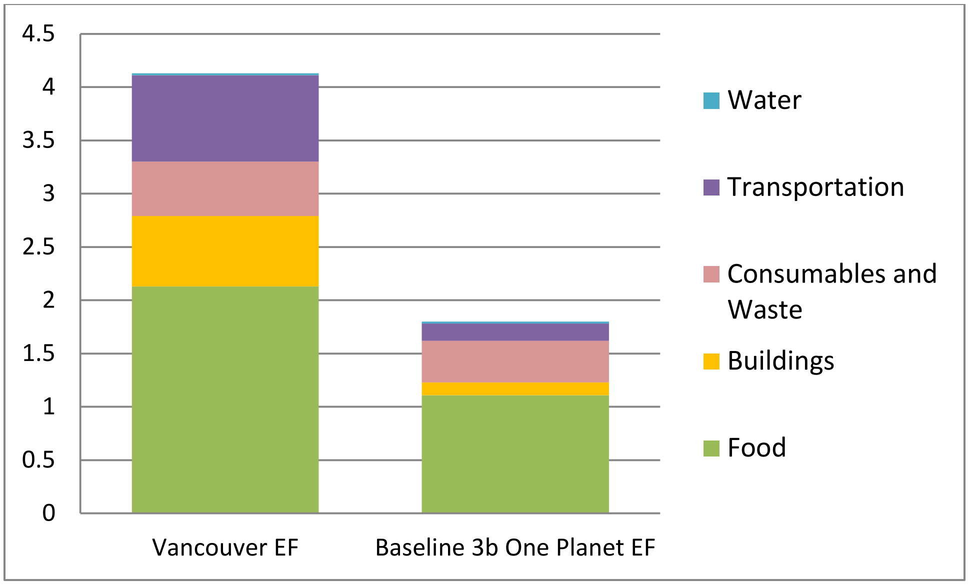

Table 5.6 summarizes the reduction estimates data and reveals that even though the City's scope for action is limited, its role in enabling other actors to participate in reducing Vancouver's ecological footprint is important, accounting for most of the potential reductions. Citizen behaviour also plays a vital part in reducing the EF. (See section 5.6 for an explanation of changes to policy and urban management also identified in Table 5.6.)

Whether Vancouverites implement the personal behaviours identified in table 5.6 remains an open question. Many of these actions may be perceived as impositions on personal quality of life (e.g., reducing air travel by 50%). Nevertheless, history has shown that Vancouverites are willing to change, sometimes faster than anticipated (e.g., achieving transportation mode splits for walking, cycling and transit faster than planned), and sometimes in ways that may be unanticipated (e.g., voting for support of vegan dietary choices as the number one action in the "Talk Green to Us" public consultation).

Table 5.6 Potential EF Reductions within City's Jurisdiction vs. Personal Lifestyle Choice

	Greenest City (municipal leadership)	**Green Economy** (business/ citizen leadership)	**Technical Innovation** (industry leadership)	**Senior Government or Behaviour Change**	
	City Led	City Influenced	City Facilitated	Citizen Led	
Baseline 3b Action	(Regulation)	(Zoning and Permitting)	(Permitting and Incentives)	(Communication)	Policy or Urban Management Change
Food					
1. Produce 75% of vegetables and eggs within City		-0.06			i)Zoning to tie agricultural capacity to site density ii) Permit agricultural business operations on building exteriors and municipal and private lands iii) Permit food producer co-ops to participate in farm-gate sales and/or grocers and famers markets
2. Produce 75% of poultry and pork within City		-0.13			
3. Reduce red meat consumption by 50%				-0.34	iv)Promote low EF dietary choices and food conservation
4. Reduce dairy consumption by 50%				-0.04	
5. Eliminate consumption of stimulants				-0.03	
6. Eliminate consumption of packaged beverages				-0.05	v) Require on-site disposal of food waste
7. Reduce consumption resulting in food waste by 50%				-0.37	

	Greenest City (municipal leadership)	**Green Economy** (business/ citizen leadership)	**Technical Innovation** (industry leadership)	**Senior Government or Behaviour Change**	
	City Led	City Influenced	City Facilitated	Citizen Led	
Baseline 3b Action	(Regulation)	(Zoning and Permitting)	(Permitting and Incentives)	(Communication)	Policy or Urban Management Change
Transportation					
8. Make 86% of trips by walking, cycling and transit		-0.38			vi) Increase mode share for walk, cycle, transit to 86% vii) Permit conversion of road space to urban agriculture or greenspace
9. 100% zero emissions commercial fleet			-0.05		viii) Require all parking to have plug-in capability and require that increased electrical load be offset by onsite renewable energy generation and/or purchase of renewable energy certificates
10. 100% zero emissions private vehicle fleet			-0.08		
11. Reduce car ownership 50%			-0.07		ix) Introduce parking maximums at 0.5 spaces per unit x) Introduce flex space parking to allow alternative uses
12. Reduce air travel 50%				-0.07	xi) Promote low EF travel choices for inter-urban and international travel xii) Petition the Province to eliminate the carbon tax rebate for inter-provincial and international travel

	Greenest City (municipal leadership)	**Green Economy** (business/ citizen leadership)	**Technical Innovation** (industry leadership)	**Senior Government or Behaviour Change**	
	City Led	City Influenced	City Facilitated	Citizen Led	
Baseline 3b Action	(Regulation)	(Zoning and Permitting)	(Permitting and Incentives)	(Communication)	Policy or Urban Management Change
Buildings					
13. Improve efficiency 40%		-0.21			xiii) Work with BC utilities to make building energy performance information public xiv) Require business licence holders to report on energy use per m^2 operating space xv) Introduce a sliding fee associated with business licences that is tied to energy consumption (accounting for building and business types)
14. 100% zero emissions commercial buildings		-0.17			
15. 100% zero emissions residential buildings		-0.17			
Consumables and Waste					
16. Increase landfill gas capture to 75%	-0.006				Part of Greenest City 2020
17. Reduce waste to landfills and incinerators by 50%	-0.064				Part of Greenest City 2020

	Greenest City (municipal leadership)	**Green Economy** (business/ citizen leadership)	**Technical Innovation** (industry leadership)	**Senior Government or Behaviour Change**	
	City Led	City Influenced	City Facilitated	Citizen Led	
Baseline 3b Action	(Regulation)	(Zoning and Permitting)	(Permitting and Incentives)	(Communication)	Policy or Urban Management Change
18. Reduce paper consumption by 50%				-0.12	xvi) Promote reduced paper consumption and demonstrate corporate leadership through City of Vancouver paperless initiative xvii) Advocate to the Province and through the Federation of Canadian Municipalities to the Federal Government to regulate printed paper and packaging products with the goal of reducing consumption by 50% xviii) Promote low EF consumer choices
Potential Reduction	-0.07	-1.12	-0.20	-1.02	

5.6 Translating Proposed Actions into Policy and Urban Management Practice

The changes to policy and urban management practices proposed in section 5.4 represent a preliminary attempt to identify how the City could move forward with implementation of the actions in baseline 3b. They also reveal what options are available to the City to leverage its influence through: a) engaging citizens to change their behaviour, b) advocating for support from senior governments, and c) collaborating with other government and non-government agencies. In this section, the analysis is extended to explore whether the proposed changes to policy and urban management practices are feasible to implement from a technical, regulatory and financial perspective. The emphasis in this exploration is on what the City can do to further enable Vancouverites to make lifestyle choices in support of one-planet living, i.e., to implement the baseline 3b actions.

Table 5.6 maps a modified list of the proposed policy and urban management changes to baseline 3b actions and their respective potential EF reductions. Policy proposals were grouped as: City led; City influenced, City facilitated, and citizen led. These represent a spectrum of influence that the City has with regard to planning policy and urban management to effect one-planet living. For example, City led initiatives are those that the City could implement on its own, e.g. regulatory changes to manage waste. As shown, these initiatives have the potential to deliver a 0.07 gha/ca reduction in the EF. Note that since the City has already identified these actions for implementation in the *Greenest City 2020 Action Plan*, they are excluded from further analysis. City influenced initiatives are those that involve zoning and permitting changes. These changes could help stimulate participation by citizens and businesses in activities that promote one-planet living, such as starting an urban farm or choosing to purchase produce from such farms. The research reveals that these types of policy changes have the potential to deliver a 1.12 gha/ca reduction in the EF. Indeed, the City's greatest potential as an enabler of one-planet living appears to be through the influence it can exert via zoning and permitting. Citizen-led initiatives also hold tremendous potential to achieve EF reductions, but this is where the City perceives itself to have the least capacity to act. A common theme that ran through interviewee feedback is that education and communication on its own does not directly influence behaviour. Other tools such as regulation, financial incentives or disincentives would also be needed. This calls into question whether certain policy and urban management changes can indeed effect EF reductions or more specifically to what degree, and whether this could be sufficient to what is being sought.

Of the 23 proposed policy and urban management changes identified in section 5.4, interviewees believe that 17 could potentially be implemented, meaning they appear to be feasible from a technical, regulatory and financial perspective. A new policy recommendation was also identified, bringing the revised list to 18. The new policy recommendation is to increase the City-wide share of trips by walking, cycling and transit to 86% (see table 5.6).

The six policy and urban management changes identified as presently infeasible are: i) zoning to allow raising and slaughtering of small livestock, ii) restricting food-waste collection, iii) unbundling parking from multi-unit residential buildings, iv) requiring commercial property owners/managers to install individual unit meters, v) requiring strata councils to install individual unit meters; vi) requiring existing buildings to become carbon-neutral. City staff perceived a zoning change to allow backyard raising and slaughtering of small animals to be unwanted by the citizenry and costly to implement with little perceived benefit given the high percentage of local poultry production in Metro Vancouver. Working to enable carefully stewarded small-scale commercial operations could prove more effective. City staff believed that a policy aimed at restricting food waste collection could prove counterproductive in light of new source-separation regulations for green waste in their curb-side waste collection program. Food wastes are now collected in a separate bin. The goal of this action is to keep food wastes out of landfills (and incinerators) where they contribute to emissions of greenhouse gases (M. Kosmak, personal communication, May 3, 2013). This can best be achieved by making it easy for people to separate their food wastes from the rest of their garbage. Imposing a restriction on food waste collection through limiting the capacity of bins, the frequency with which they are collected, and/or imposing an escalating fee for collection could inadvertently discourage people from separating their food wastes (J. O'Neill, personal communication, September 25, 2012; A. Fournier, personal communication, September 28, 2012). However, once Vancouverites become accustomed to separating food wastes from their regular garbage, a longer term strategy to introduce volume or weight-based pricing could be effective (M. Kosmak, personal communication, May 3, 2013) as could switching the collection frequency of different waste streams (e.g., weekly for food scraps and bi-weekly for garbage) (S. Pander, personal communication, May 2, 2013). With regard to unbundling parking, the City has requested that the Province grant expanded jurisdiction to make unbundled parking mandatory in some areas (J. Dobrovolny, personal communication, September 28, 2012). At present this is left to the discretion of the developer. Also, as noted above, the City does not have the authority to require building owners to retrofit their properties. However, installation of meters within individual units could be introduced as a permitting requirement at the time a building owner decides to apply for a permit to undertake a major retrofit of their building.

Of the remaining 18 policy and urban management changes, interviewees identified one that could create unwanted consequences and may, therefore prove counter-productive: permitting road spaces to be *permanently* converted to other uses (however, a temporary change is fine). Transportation right-of-ways are strategically important for the City to maintain flexibility to adapt to future change. The temporary permitting of these right-of-ways for other uses is feasible and enables the City to meet the needs and/or wishes of its citizens. However, the permanent change of transportation right-of-ways reduces the scope of the City's future options to adapt and respond to the needs and/or wishes of its citizens and should, therefore, be considered very carefully (J. Dobrovolny, personal communication, September 28, 2012).

Of the remaining 17 policy and urban management changes, several interviewees raised questions about whether one policy proposal could be implemented in light of the *Building Code* or existing planning by-laws: i.e., require all parking to be flex-space to permit alternative uses of the space, including for commercial purposes. For example, this could be infeasible if *Building Code* requirements preclude the use of designated parking for other uses without significant retrofits (J. Dobrovolny, personal communication, September 28, 2012; S. Pander, personal communication, September 28, 2012).

Of the remaining 16 policy and urban management changes, interviewees identified four that could be costly to implement without confidence that the objective would be achieved in the absence of City authority to impose regulatory and/or financial incentives to support the desired behaviour change. These initiatives call for the implementation of education and awareness campaigns to: i) promote low EF dietary choices and food conservation, ii) promote low EF travel choices for inter-urban and international travel, iii) promote reduced paper consumption, and iv) promote low EF consumer choices in general (M. Kosmak, personal communication, September 4, 2012; A. Reimer, personal communication, September 19, 2012; L. Cole, personal communication, September 25, 2012; J. Dobrovolny, personal communication, September 28, 2012; S. Pander, personal communication, September 28, 2012; P. Judd, personal communication, March 5, 2013).

Most interviewees agreed that the remaining 12 policy and urban management changes could readily be implemented. These include: i) zoning for minimum agricultural capacity that is tied to site density; ii) zoning to allow roof-tops, wall facades, and garden plots for agricultural business operations; iii) business permitting process for food cooperatives to support farm-gate sales of local produce; iv) requiring on-site disposal of food waste; v) increasing the mode share for walking, cycling and transit to 86% of all trips in the City, vi) introducing parking maximums tied to site density at 0.5 parking spaces per unit; vii) requiring all parking to have plug-in capability to support electric vehicles, and requiring that the electrical load for parking be offset by on-site renewable energy generation and/or purchase of renewable energy certificates; viii) asking the Province to expand the carbon tax to apply to inter-provincial and international air travel (i.e., eliminate the carbon tax rebate); ix) working with the Province of British Columbia, BC Utilities Commission, BC Hydro, and Fortis BC to make building energy consumption public information, e.g., through a building labeling program; x) requiring businesses to report their energy use per square metre of operating space when they renew their licence; xi) implementing a sliding fee attached to business licences that penalizes high energy users; xii) advocating to the Province of British Columbia, and to the Federal Government through the Federation of Canadian Municipalities, to regulate printed paper and packaging products with the goal of reducing consumption by 50%.

Most of the policy and urban management changes that could readily be implemented support actions that are already within the scope of the City's jurisdiction. Three actions call for engaging with senior governments to leverage the City's influence, and of these only two target personal behaviour changes: i) reducing air travel and ii) reducing paper consumption (see table 5.6). If the City was successful in implementing the 12 policy and urban management changes deemed readily feasible, and if senior government agencies also agreed to support the City's requests to use their influence in support of reducing air travel and paper consumption, it would still be insufficient to achieve one-planet living without voluntary citizen engagement, particularly with regard to changes in diet and reducing food that is wasted post-purchase. Dietary choices and reduced food waste cumulatively account for 0.83 gha/ca. This represents 20% of the total EF (4.21 gha/ca) and 34% of total EF reduction potential (2.41 gha/ca). This analysis draws attention to the importance of engaging the citizenry through education and awareness campaigns about their role in achieving one-planet outcomes. It also opens questions about whether and how complementary financial and regulatory mechanisms aimed at supporting education and awareness campaigns could be pursued given the perception that education in the absence of these tools is insufficient to illicit behaviour change.

Finally, in addition to the policy and urban management changes that I identified (above), interviewees were asked to identify what they believed were the most important changes to policy and urban management practices to achieve one-planet living. Responses included a) collaborating with other agencies, including non-government organizations, to communicate about the co-benefits of one-planet living and other healthy lifestyle choices,[135] b) symbolic gestures that create visible change in the City to demonstrate more desirable and sustainable lifestyle choices that encourage people to change their expectations about the future,[136] c) telling the truth about statistics that demonstrate people's willingness to support sustainability in order to change norms and expectations about what is achievable in the future,[137] and d) working with institutions and large commercial operations to change their policies in support of one-planet living.[138]

[135] For example, the City is already considering collaborating with Coastal Health on active transportation that has both a health and ecological benefit. Similar collaborations could be pursued to communicate the benefits of changes to diet.

[136] For example, building bicycle infrastructure that stimulates people to change their perceptions about how they can commute to work and travel around the City.

[137] For example there already is an over-abundance of under-ground parking in the Downtown and Vancouver has historically achieved its transportation mode-split goals ahead of schedule. Communicating these facts can challenge false beliefs about the dominance of the car and people's preference to use it in Vancouver (J. Dobrovolny, personal communication, September 28, 2012).

[138] For example, purchasing policies, travel policies and waste management policies within large institutions and corporations can shape market demand and employee behaviours including in areas of dietary choices and better conservation of food to reduce the amount that is waste, reducing air travel, and reducing consumption of paper as well as repurposing and reusing other consumable products.

6 Discussion and Conclusions

In this research, sustainability is defined as one-planet living, which uses the ecological footprint as a metric to orient consumption to global ecological carrying capacity. The research demonstrates the application of ecological footprint analysis as a policy tool to both estimate Vancouver's sustainability gap and identify changes to policy and urban management practices that could help close it. To this end, the research answers the primary questions posed in chapter 1. Specifically, it identifies changes to policy and planning practices that the City of Vancouver could make to facilitate one-planet living by its residents. The research estimates what reduction in ecological footprint could be achieved through implementation of these changes. Finally, the research articulates what sustainability, defined as one-planet living, might look like in terms of changes to lifestyle and urban morphology if these changes were implemented.

Assuming a 2006 baseline for population and consumption, chapter 4 reveals that getting to one-planet living in Vancouver requires at least a 58% reduction in the per capita ecological footprint. Chapter 5 reveals that this entails a 50% reduction in food purchases that ultimately wind up as waste, a 50% reduction in consumption of red meat and dairy products, 75% production of local vegetables and white meats within the City, abandoning personal motor-vehicle use and ownership, zero-emissions fuels in all motor vehicles (including commercial and transit fleets), a 40% improvement in energy efficiency across the entire building sector coupled with zero emissions energy supply, and a 50% reduction in consumption of paper.

The role of senior governments in reducing the ecological footprint is also critical. Even if the City and its residents did everything they could to achieve the one-planet living target of 1.8 gha/ca, City staff estimates that the senior government services component accounts for an additional 18% of the EF (or 0.76 gha/ca) (Vancouver 2011). If this were included in the scope of the analysis, it would mean that total demand for nature's services, despite implementation of the changes cited above could only achieve an ecological footprint of 2.56 gha/ca, well above the fair Earthshare goal of 1.8 gha/ca.

Nevertheless, the research demonstrates that the City can greatly influence EF reductions and enable Vancouverites to make lifestyle choices that support one-planet living. Leaving senior government services aside, the City and its citizens can reduce that portion of the ecological footprint that comprises municipal operations and residential consumption, i.e. the EF components of food, transportation, buildings, consumables and wastes, to within the one-planet parameter. Policy proposals were developed in chapter 5 that focus on what the City of Vancouver could do to support one-planet living through: regulatory requirements, changes to permitting and zoning, education and awareness initiatives, and advocacy campaigns that lobby senior government for change. For the City to be successful in implementing any such initiatives requires that citizens support the changes and then engage in the activities that leverage their impact. Following this assumption, table 5.6 in chapter 5 reveals that the greatest potential reductions in EF can be achieved through changes to permitting and zoning followed by communication efforts. This calls attention to the role of the City in influencing urban development, including stimulating business and citizen engagement in activities that support one-planet living, e.g., through supportive policies towards urban agriculture. It also calls attention to the tremendous power that citizens themselves have to make lifestyle choices that support one-planet living.

Changes to planning policy and practice that hold the greatest EF reduction potential are in the areas of transportation and food (see chapters 4 and 5). Specifically, these include: i) increasing the mode share of walking, cycling and transit to 86% for all in-city travel and ii) promoting low-EF dietary choices (e.g., reducing consumption of red meat) and food conservation (i.e., reducing the amount of food that is wasted post-purchase).

6.1 Findings and Research Contributions

In this section I summarize the answers to each of the research questions originally posed in chapter 1 and draw out what I believe to be some of the major contributions that the findings make to Vancouver's efforts to achieve one-planet living specifically and planning for sustainability generally.

6.1.1 Answers to the Research Questions

Question 1: What are some changes to planning policy and practice that the City of Vancouver could make to facilitate one-planet living options for its residents?

The research identifies 18 changes to planning policy and practice that the City of Vancouver could make to facilitate one-planet living options for its residents. Specifically these include:

1. Zoning for minimum agricultural capacity that is tied to site density (e.g. through development contributions or as part of an onsite development plan).

2. Allow agricultural business operations on building exteriors and municipal and private lands through special zoning and/or permits.

3. Enable through business permitting process the formation of food producer cooperatives to enable farm-gate sales of produce and/or centralized sales of locally produced food at community grocers and/or farmers markets.

4. Initiate an education campaign to promote awareness about low EF dietary choices and food conservation.

5. Require on-site disposal of food waste (e.g., through community or commercially operated compost centres).

6. Increase the City's mode share target for walking, cycling and transit from 66% to 86%.

7. Permit road spaces and other right of ways to be used for parks or agricultural production, including for operation by an agricultural business.

8. Introduce a parking maximum of 0.5 parking spaces per unit. (Note this could be introduced in medium and high-rise residential buildings coupled with a strategy to scale-up the walking, cycling and transit mode share target across the entire City to 86%).

9. Require all parking to have plug-in capability and require that the increased electrical load be offset by onsite renewable energy generation and/or purchase of renewable energy certificates.

10. Require all parking to be flex-space to permit alternative use, including for commercial purposes. This may require the introduction of flex-space requirements for new

development and a permitting process to facilitate the retrofit of existing parking to meet such requirements.

11. Initiate an education campaign to promote awareness about low EF travel choices for inter-urban and international travel.
12. Petition the Province to eliminate the carbon tax rebate.
13. Work with BC utilities to make building energy performance information public.
14. Require business licence holders to report on energy use per m2 of operating space.
15. Introduce a sliding fee associated with business licences that is tied to energy consumption (accounting for building base load and type of business).
16. Initiate an education campaign to promote reduced paper consumption, and demonstrate corporate leadership through development of a City of Vancouver paperless initiative for civic transactions including: permitting and licensing, tax notifications and payments.
17. Advocate to the Province and through the Federation of Canadian Municipalities to the Federal Government to regulate printed paper and packaging products with the goal of reducing consumption by 50%.
18. Initiate an education campaign to raise awareness about low EF consumer choices.

Question 2: What reduction of ecological footprint could be achieved through implementation of these changes to planning policy and practice?

The level of reduction in ecological footprint that could be achieved depends on the degree of engagement by Vancouverites in both taking advantage of business opportunities and making lifestyle choices to adopt behaviours conducive to one-planet living. The findings assume full engagement and reveal that a reduction of approximately 57% (down 2.41 gha/ca from 4.21 gha/ca) could be achieved as a result of full implementation and take-up by the citizenry of the proposed changes to planning policy and practice. For purposes of this research, the reduction is sufficient to achieve a 1.79 gha/ca footprint, commensurate with the one-planet target of 1.80 gha/ca. However, the research excludes senior government services which could account for up to an additional 18% of the City's ecological footprint, equivalent to approximately 0.76 gha/ca. Because the research focus is on changes that the City could make to enable its citizens to pursue one-planet lifestyles, the impact of senior government services was intentionally omitted. Nevertheless, the findings reveal that engagement by senior governments is essential. Even if the City and its citizens did everything they could to reach the one-planet living target, the impact of senior government services is anticipated to push the per capita ecological footprint above the one-planet living levels (e.g., to 2.56 gha/ca).

Question 3: What could an ecologically sustainable Vancouver "look like," meaning what changes to urban lifestyles and/or urban morphology might result from the identified changes to policy and planning practice?

My study reveals that one-planet living would require radical changes to the average Vancouverite's lifestyle affecting: diet, travel (both within the City and outside of it), home energy use, and personal consumption. Changes to urban morphology would also be needed including: increased densification of urban centres in compact, mixed use built environments; increased utilization of surface areas, including walls, balconies and rooftops, for food production; conversion of some roadways, parking lots, parks and other green spaces at grade to urban agriculture; increased utilization of buildings and infrastructure for generation of renewable energy (e.g., installation of photovoltaics on roofs and canopies).

The findings reveal a vision for one-planet living in which Vancouverites are conscious consumers who choose to substitute legumes, fish and white meat (including pork) over red meat at least 50% of the time. They also limit consumption of dairy products by 50% and avoid stimulants e.g. coffee, tea, sugar and cocoa and consumption of packaged beverages. Vancouverites make a concerted effort to grow and purchase locally produced fruits and vegetables and the entire city-scape is affected by an effort to produce 75% of vegetables within the urban and peri-urban environment. Buildings serve double-duty as places of shelter for people and as greenhouses and growing platforms for their food. An edible landscape approach to parks, roadways and greenways is also evident, and many Vancouverites participate in urban agricultural businesses activities that lease municipal and privately owned land as well as building spaces for food-growing purposes. This even includes production of small livestock such as chickens, rabbits, tilapia (a type of fish), and perhaps even goats and pigs, in an attempt to produce 75% of animal protein needs within the City limits. All food waste is also managed locally through composting in backyards and at community centres or designated facilities. Vancouverites walk, cycle and use public transit as the dominant modes of transportation. In fact very few people (less than 50% of the population) even own cars. All motor vehicles, including the public transit system and commercial fleet operate with zero emissions. Increased load demands from electric vehicles are met through on-site generation of renewable energy or the purchase of renewable energy certificates[139] to ensure that fossil-fuels are avoided. The City's downtown, featuring the co-location of housing, jobs and services in immediate proximity is used as a model to inform how an 86% walking, cycling and transit mode split could be achieved across the entire City AND Vancouverites embrace such an approach. Since agricultural capacity is tied to density development, a transformation of the urban landscape simultaneously emerges to address increased capacity for food production in tandem with concentrated development in walkable neighbourhood town centres. Being mindful of their carbon footprint, Vancouverites prefer to use telecommunication technologies such as video conferencing instead of air travel. The City provides these facilities at community centres and libraries, and businesses also offer these services to employees as part of their (no fly) policy. Because most people no longer need or choose to own a motor vehicle, there is a concerted effort to adapt existing built space dedicated to parking to serve other uses. All buildings in the City are energy efficient, achieving at least a 40% increase in efficiency over the 2006 consumption baseline. They also produce zero carbon emissions through their operations. This is achieved through reliance on passive design that optimizes for passive solar gain and shading and use of building materials and mechanical systems that are exceedingly efficient in order to maintain thermal comfort. Vancouverites participate in ensuring that their homes and business operations use as little energy as possible, and what ever energy is used comes from renewable sources. Vancouverites are also extremely conscientious consumers. Practically no food is wasted and unnecessary use of paper is avoided, e.g., no paper receipts, invoices,

[139] In British Columbia one can purchase "renewable energy certificates" that support the generation of non-fossil-based energy. This program is managed through BC Hydro, the provincial energy utility.

cheques, etc. This represents Vancouverite's commitment to reduce the amount of food and paper purchased by 50%. Many durable goods are borrowed, rented or shared instead of purchased. The City operates and/or encourages businesses and community organizations to offer multiple shared use programs (expanding on the library model) for tools, sporting goods, clothing, appliances, and other durable goods. Finding ways to fix, repair and repurpose these items are easy and most business offer refurbished products along-side those that are new.

6.1.2 Contributions to the Study of One-planet Living

This research is the first systematic assessment undertaken for a city in North America to explore through an integrated urban metabolism and ecological footprint analysis the reductions in various aspects of lifestyle that would be needed to get to one-planet living. The research contributes to the quantification of Vancouver's ecological footprint, its sustainability gap, and identification of some changes to planning policy and practice that could help close it. The research develops targets and measures necessary to achieve one-planet living in Vancouver and presents a pathway that the City could pursue to achieve it. The research also helps develop metrics that can provide a mechanism for feedback and improved accountability by cities seeking to become more sustainable and/or claiming to already be so.

The City of Vancouver is aiming to reduce its ecological footprint 33% by 2020 with an ultimate goal of achieving one-planet living by 2050. However, the City lacked the means by which to assess whether and how such targets could be achieved. Preliminary assumptions about what could be achieved, based on the work of Boyd (2009), proved to over-anticipate the benefits of proposed sustainability initiatives in the *Greenest City 2020 Action Plan*. This dissertation makes an important contribution by enabling comparisons between prevailing perceptions of what sustainable urban development entails and what would actually be needed to achieve one-planet living. Using the case of Vancouver, the research also identifies changes to planning policy and urban management practices that could enable citizens to participate in one-planet living lifestyle choices. Whether the City and its citizenry pursue such actions remains an open question.

The findings indicate that while the largest potential reductions in ecological footprint can be achieved in the areas of food and transportation, one-planet living cannot be achieved through the exclusive pursuit of any one particular EF component nor any one specific lifestyle change. This is particularly relevant to the issue of municipal approaches to greenhouse gas emissions management that tends to narrow focus on transportation, buildings and wastes while overlooking impacts associated with food and consumption of durable goods.

Using residential urban metabolism (described in chapter 3) to develop a bottom-up, component ecological footprint in this research provided a robust method for policy assessment that effectively engaged municipal staff in wanting to explore how the City could reduce its ecological footprint. Defining the EF components based on the categories and sectors that the City already uses in policy development enabled staff to see how the use of EFA could support their efforts to advance sustainability, specifically the one-planet living goal defined in the *Greenest City 2020 Action Plan*. Past EF assessments relied on modifications of national data and grouped consumption categories in ways that did not directly map to the policy work being done by the City. This approach left staff skeptical about the degree of fit between the EF and their policy and planning work as well as whether an EF derived from national data could accurately reflect local circumstances. In this project, I relied predominantly on local data to generate the EF and I used a taxonomy for the components and sub-components that directly reflected that used by City of Vancouver staff in their policy and planning work. This meant that I was using the same data that City staff use and trust for their own policy analysis. Also, building the EF through a residential urban metabolism study made it easy to translate actual consumption data to ecological footprint outcomes, allowing staff to see in a stepwise fashion how their local data were being utilized to generate the EF. The method also produces a greenhouse gas emissions inventory of consumption which could be compared to the City's own emissions inventory based on a territorial approach prescribed by the Partners for Climate Protection Protocol (FCM 2008). Again, this approach enabled staff to see how their existing data were being utilized and how the present EF approach could further inform their policy and urban management practices towards reducing carbon dioxide emissions.

This research also contributes to an understanding of one-planet living through the development of lifestyle archetypes, specifically the use of empirical data to reveal what one-planet living actually entails for the majority of the world's population. To date, theorizing about one-planet living has been predicated on reducing the ecological impacts of high-consuming populations which are generally associated with affluent lifestyles. The innovative use of lifestyle archetypes in chapter 4 provided information about what one-planet living looks like in other countries, based on field studies and consumption statistics. Lifestyle archetypes were also developed to illustrate one-planet living in hypothetical cases based on data available from the Global Footprint Network (www.footprintnetwork.org) and a sample of intentional communities, e.g., eco-villages in western society.

Comparing the EFs of societies engaged in one-planet living to Vancouver's EF informed the assessment of Vancouver's sustainability gap. It also illuminated the component areas, namely food and transportation, offering the greatest potential to reduce Vancouver's EF and demonstrated that the energy intensity of production affects the ecological footprint such that the impact of lifestyle choices must be assessed on a case by case basis. In other words, if Vancouverites' consumption patterns mimicked those of the one-planet archetype, Vancouverites' ecological footprint would still exceed the one-planet target because of the energy intensity of the production processes upon which Vancouver's economy depends.

6.1.3 Contributions to the Field of Sustainability Planning

My research presents what I believe to be the first detailed empirical study of the City of Vancouver's energy and materials flows, i.e. its urban metabolism. I use these data to develop the first greenhouse gas emissions inventory of Vancouverite's consumption and the first component method ecological footprint analysis for the City. I estimate what levels of reduction in energy and materials consumption would be required to achieve a per capita EF commensurate with one-planet living, also known as a fair Earthshare. I use these findings to identify changes to planning policy and practice that the City could implement to facilitate one-planet living by its residents. I also use these findings to build a vision of what Vancouver could be like if the proposed changes to planning policy and practice were implemented. While the vision reflects what is commonly found in the sustainable cities literature (Newman 2010; Rees 2010; Register 2006; Kenworthy 2006), my method builds the vision from the bottom-up, meaning as a result of empirical analysis that provides a transparent link between energy and materials consumption, projected reduction targets and anticipated sustainability (i.e., one-planet living) outcomes. I believe this contributes a robust analysis to complement research on sustainable cities and eco-cities in particular (e.g., Joss 2010; Rees 2010; Wheeler and Beatley 2009; Kenworthy 2006; Wheeler 2004).

Ecocities place emphasis on pedestrian-oriented urban environments where access by proximity eliminates the need for motor-vehicle ownership and use, and where the transfer of development rights allows for transformation of the built environment to include extensive areas dedicated to food production coupled with a socio-cultural ethic of care for stewardship of the bioregion in which the City is located and upon which it depends (Register 2006, 1987; Roseland 1997). The research reveals that these attributes are key to achieving ecological sustainability and one-planet living in particular. Furthermore, the design of the ecocity is informed by ecology which seeks to understand processes "of engagement by living creatures with their environment and with eachother" (Downton 2007, 36). Because one-planet living emerges from the concept of bioregionalism, living within the ecological carrying capacity of one’s home place (Wackernagel and Rees 1996; Desai and Riddlestone 2002; Newman and Jennings 2008), it represents a social adaptation in response to the recognition of ecological limits. For example, while there may be variations in consumption among community members, staying within ecological carrying capacity is a generally agreed upon objective for the whole community. Based on the findings in this research, I believe one-planet living has the greatest potential to manifest physically in the form of ecocities (e.g., as articulated by Register 2006, 1987; Kenworthy 2006; Roseland 1997) and culturally through intentional practices of ecological stewardship that in addition to bioregionalism (e.g., see Freidmann 2011; Carr 2004; Aberley 1994; Rees 1992) also include permaculture and ecopolis (e.g., see Downton 2009;

Rees 1995; Mollison 1988).[140] One-planet living embraces environmental ethics which is "concerned with the fundamental basis of humanity's relationship with, and moral obligations to, the earth community" (Martin and Beatley, 1993, 117) as well as issues of social justice pertaining to fair distribution of access to Earth's resources in order to secure basic livelihoods (Victor 2008; Westra 2000; Rees 1995). As such, one-planet living is an expression of sustainability planning. Sustainability planning orients toward a holistic and integrated perspective of humanity, including intra and intergenerational relationships, and humanity's relationship to other species and the natural environment (Roseland 2012; Friedmann 2011; Wheeler 2004; Downton 2007; Rees 1995; Beatley 1994).[141]

Furthermore, my research stands in sharp contrast to the technical reform approach aimed at addressing ecological challenges (e.g., Smart Growth and New Urbanism) that dominates the current discourse and manifests from a historical progression of planning models that assume economic growth and expansion of the human enterprise as an ongoing necessity. This approach is paraded under the banner of sustainability planning yet fails to address the fundamental beliefs, values and assumptions of consumer societies (Jepson 2001; Rees 1995). It fails to recognize absolute limits to consumption in order to stay within ecological carrying capacity, let alone the moral obligations of emancipation and socio-political transformation of values that would be needed to bring about social justice in a world of ecological limits (Jepson

[140] Recall that permaculture is the practice of permanent culture that emerges from a sustainable approach to agriculture and working harmoniously with natural systems (Mollison 1988). Ecopolis is ecologically informed governance that encompasses ideals of community and self-determination (Downton 2007).

[141] Recently, Friedmann (2011) has embraced the recognition of ecological limits as an inherent value in what he terms the "good city" which encompasses similar attributes to those of the sustainable city identified within the sustainability planning literature. Friedmann's preference for the word "good" is to convey a normative value that "sustainability" as a word lacks. Nevertheless, the substantive content of what he proposes the good city to encompass is fundamentally the same as that presented in the sustainability planning literature cited herein.

2001; Rees 1995). Several theorists agree that planning requires new orientations toward a more holistic and integrated perspective of humanity and its relationship to other species and the natural environment (Frank 2006; Rees 2003, 1995; Sandercock, 1999; Beatley, 1995b; Martin and Beatley, 1993). The ecologically-based approach prioritizes an ethic of stewardship and cooperation coupled with design solutions that work with nature (Wheeler 2004; Rees 1995; Aberley 1994; Beatley 1994). Early theorists included Ebenezer Howard, Patrick Geddes and Lewis Mumford who focused on social and physical health as an outcome of the relationship between urban form and issues of over-crowding, poor sanitation, air and water pollution (Wheeler and Beatley 2009). What these thinkers envisaged is strikingly similar to what is proposed for sustainable cities today. For example, Ebenezer Howards' vision in *Garden Cities of To-morrow* (c. 1898) which integrates nature with social cooperation (Haughton and Hunter, 1994) is cited as an early example of the ecocity by Register (2006). Patrick Geddes (c. 1915) *Cities in Evolution* which advocates for the re-integration of country-urban linkages advances a whole systems perspective that fostered concepts of human ecology and orientation to the bioregion (Freidmann 2011; Aberley 1994; Haughton and Hunter 1994). Wheeler (2004, 21) notes that Lewis Mumford's (c. 1930-60) articulation of an ideal city maps to contemporary literature about the "sustainable city" as "an organic community, designed on a human scale, oriented towards human needs, fueled by life-enhancing economy, surrounded by undeveloped lands, and with streets filled with people instead of automobiles."

I believe that it is important for this ecological perspective to acknowledge the tremendous inertia within existing institutional and socio-economic processes, urban policy and infrastructure that cannot be overcome merely by a vision of a preferred future. Indeed as

Peter Hall (cited in Haughton and Hunter 1994, 295-296) observes, successful attempts to innovate new urban form tend to show a “strong grasp of the socio-economic framework” within which urban restructuring processes operate. Therefore, policy analysis aimed at developing a pathway for change within the existing context is needed. I believe my research contributes insights about what such a pathway entails. Wheeler (2004) observes that by the 1990s there was a convergence of movements interested in planning with more attention to: economic, social and environmental aspects. Examples include embracing community, meaning local interests; addressing concerns for eco-violence and social justice; and designing with nature to achieve ecological restoration and less resource-dependent built environments (Wheeler 2004). Recent focus, i.e. since the mid 1990s, has also expanded to include consideration of the global, ecological impacts of cities (Beatley 2000; Newman and Kenworthy 1999; Rees 1997b; Satterthwaite 1997; Folke et al. 1997; Haughton and Hunter 1994) and the vulnerability of cities to these impacts (World Bank 2010b; Newman et al. 2009; Rees 2006, 1997a; Girardet 2004). While this trend seems hopeful, I believe that there is still a fair distance to cover before concepts such as one-planet living and practices prescribed by the ecologically-based approach, which scholars agree is aligned with achievement of sustainability and sustainable cities, are main-stream within urban planning practice. My research helps illuminate the scope of this gap.

Finally, my research contributes to a growing body of evidence that points toward urban agriculture as an important component of sustainable cities (Lovell 2010; Vitiello 2008; Girardet 2005; Deelstra and Girardet 2000). Planners play an important role in designing urban environments for agricultural production through appropriate zoning and regulation of minimum productive areas per capita or as a percentage of total built area (Lovell 2010; Cassidy and Patterson 2008; Mubvami and Mushamba 2000). While at first glance this may seem to be a question most pertinent to the regional scale, in Metro Vancouver, land-use decisions vest with the municipalities. Therefore, questions about whether the urban environment has the capacity for significant food production and how urban, peri-urban, and rural food production systems are integrated for effective, efficient, and sustainable food supply are questions that should engage municipalities as well as regional and provincial authorities. The research also shows that dietary choices, i.e., the type of food consumed, has a greater influence on the EF than the amount of food consumed (chapter 4). This draws attention to the importance of communication about dietary choices as part of an overall one-planet living strategy. These insights create an interesting tension between the traditional scope for municipal service provision and what might be needed by way of new approaches to engage with citizens in choices that pertain to their private interests, such as the types of food they consume, and their cumulative effect in the global commons.

6.2 Discussion

Global ecological challenges coupled with the global urban transition position cities, particularly high-consuming cities, as an important locus for change towards a more sustainable future (Rees 2012; Seitzinger et al. 2012; Wackernagel et al. 2006; Satterthwaite 1997). Within cities, Lombardi et al. (2011) observe that setting goals and targets for sustainability and using performance metrics to track progress are political decisions that reflect the values of governing regimes and their networks. However, political resistance to adopting scientifically informed targets and measurable indicators of sustainability is a barrier at both national and local government levels (Sussmann 2012; Giddens 2011; Astleithner et al. 2004). While staying within global ecological carrying capacity is identified as an important criteria of urban sustainability (Rees 2010; Newman and Jennings 2008; Downton 2007; Portney 2003; Beatley 2000), few North American cities measure the impacts of their planning and policy initiatives from this vantage point. Many cities pursue energy and resource efficiency improvements (Roseland 2012; Joss 2010; Beatley 2000), but most lack hard targets that orient their activities to ecological carrying capacity (Birch and Lynch 2012; Sussmann 2012; Giddens 2011; Victor 2008). Indeed, a recent guide to “planning for a sustainable future” published by the US Environmental Protection Agency (EPA 2010) makes no mention of ecological thresholds, thereby reinforcing the notion that incremental improvements towards efficiency gains and/or waste reductions are sufficient. In committing to the goal of one-planet living, Vancouver’s council acknowledges that living within ecological carrying capacity is an important consideration.

Portney (2003) argues that cities that are “getting serious” about sustainability are measuring their impact on ecological and social systems and developing and implementing plans to reduce that impact. Specifically, cities in high-consuming societies that are seeking ways to reduce their ecological footprints to reflect global ecological carrying capacity, i.e., toward a fair Earthshare, can be said to be more serious about sustainability than those that do not (Rees 2010; Portney 2003; Haughton 1999). From this perspective, Vancouver can be identified as a city that is on track to taking sustainability seriously, as one of only a handful of cities that has committed to the goal of one-planet living.[142] Vancouver's *Greenest City 2020 Action Plan* demonstrates a willingness to publicly wrestle with the question of how the City can reduce its per capita EF to a fair Earthshare. Indeed, the willingness to explore whether and how Vancouver can reduce its ecological footprint to a level commensurate with one-planet living may be the most important element of the City's commitment to sustainability.

Of course, getting one-planet living on the political agenda is only the first step towards making a city ecologically sustainable. The next and more important challenge is embedding needed changes into planning policy and practice as well as the daily activities of citizens (Giddens 2011). Vancouver, like most cities in high-consuming cultures, demands vastly more ecosystem services, i.e., dissipates more energy and materials, than its fair Earthshare. My research demonstrates that at least a 58% reduction in Vancouver's EF would be needed to achieve one-planet living.[143] More than half of this is directly influenced by personal lifestyle choices of Vancouver residents. For example, 65% of Vancouver's EF comprises food and consumable products, areas over which the City has very limited jurisdiction. The remaining 35% of Vancouver's EF is attributable to buildings, transportation, and water, areas over which the City has jurisdiction. Therefore, although there is much that the City can do to influence the EF, citizen engagement is essential to achieving the one-planet living goal. This finding corroborates claims that changes to urban morphology are not sufficient on their own to achieve sustainable cities (Newman 2010; Register 2006; Lenzen et al. 2004, Hoyer and Holden 2003; James and Desai 2003).

[142] Other examples include: Cardiff, UK; Sutton, UK; and Middlesbrough, UK.
[143] An even larger reduction is actually needed if the impacts of senior government services are taken into consideration.

Whether Vancouver's citizens are willing to participate in changing their lifestyles to accommodate one-planet living remains unclear. As noted in chapter 2, Vancouver is characterized by a diverse citizenry including a segment of the population who resist even modest efforts towards more compact, transit-oriented development. The dramatic nature of lifestyle changes that would be needed to reach the fair Earthshare of 1.8 gha/ca means that virtually all aspects of lifestyle would need to change from the food Vancouverites eat, to where and how they live and travel, to what they purchase (or more importantly do not purchase).

Giddens (2011, 108) is "hostile" to a focus on changes in lifestyle, arguing that it is unrealistic to assume that most people are willing to adopt "self-induced deprivations." Citing surveys over the past decade, he notes that "a majority of citizens in most countries will support national and international initiatives designed to cope with global warming as long as these initiatives do not demand a significant alteration of lifestyle" (Giddens 2011, 103).[144] Rees (1995, 359) concurs that "sacrifice is a hard sell." Nevertheless, many see a focus on changing individual behaviour at the household level as critical to the success of sustainable city endeavours (Newman 2010; World Bank 2010a; World Bank 2010b; Victor 2008; Rees 1995). Newman (2010) notes that the power of social networks to mobilize community members in ways that build social cohesion can create transformative changes in short order if a whole systems approach that comprises urban design and infrastructure services, regulation, and tax incentives/disincentives are also introduced to support the sustainable lifestyles objective.

[144] Ironically, people in the developing world are the most concerned about climate change, and they have the highest levels of personal commitment to action (Giddens 2011).

Where Giddens (2011) and Newman (2010) and others (Seyfang 2009; Victor 2008; Rees 1995) agree is on the necessary pursuit of systemic change that engages government authorities in the use of regulation and tax incentives aimed at shaping more sustainable economic processes and lifestyle choices. Such an approach would address the infrastructures of provision that underlie urban ways of life (Seyfang 2009; Van Vliet et al. 2005; Southerton et al. 2004). Indeed, global urbanization can be viewed as a means of establishing infrastructures of provision that now lock half the global population in unsustainable patterns of consumption. Seyfang (2009, 17) believes that citizens, in their role as "(c)onsumers are effectively trapped within … lifestyle practices by the over-arching social structures of markets, … urban planning and development." Therefore, strategies that simply focus on green consumerism are insufficient. Victor (2008) believes that for systemic change, grass roots efforts must overcome opposition by those wealthy and powerful elites in Canada, and other countries, who benefit tremendously from the status quo.

My research demonstrates that changing infrastructures of provision is essential to achieving one-planet living. The issue of whether and how to address lifestyle changes that support one-planet living touches ground in Vancouver most apparently with regard to food. Food comprises the largest component in Vancouver's EF, and one-planet living would necessarily entail changes in diet (e.g., reducing by half the consumption of red meat) and reducing by half the amount of food that is wasted post-purchase. This finding about the importance of food – and red meat in particular - is generally corroborated in the sustainability literature (Nordgren 2012; Foley et al. 2011; Steinfeld et al. 2006) as well as Ecological Footprint analyses (Scotti et al. 2009; Collins and Flynn 2005; Best Foot Forward 2002). However, neither of the proposed changes is being pursued through the *Greenest City 2020 Action Plan*. For example, despite the fact that citizen feedback in the “Talk Green to Us” public engagement campaign supported vegan food choices as the most popular initiative, dietary choices are considered to be a very personal matter that lies outside the domain of the City’s jurisdiction and for which there are no policy tools (A. Reimer 2012, personal communication, September 19, 2012). Similarly, with regard to food waste, the City is pursuing diversion of food waste from landfills; however, the push up-stream to address behaviours that generate food waste is not “on the table” (pun intended) (M. Kosmak, personal communication, September 4, 2012).

Reticence to address personal behaviour and lifestyle change stems from liberal democratic traditions that identify personal pursuits which do not directly cause harm to others as outside the domain of government interest (Giddens 2011; Dresner 2002). However, in a “full world” (Daly 1991, 29 cited in Rees 1995), the question of whether and how to address personal pursuits that cumulatively yet indirectly cause harm to others becomes a question worthy of political attention. Of further interest is a seeming reticence to address issues of dietary choice and food waste while the City simultaneously encourages people to “buy in-season, organic and locally produced food” (COV 2012l). Choices about what to purchase seem in this instance to be fair-game for City directives, revealing a cultural biases that permits some topics to be approached but not others. Further probing may reveal that the orientation to enabling (i.e., expanding the scope of possibilities) rather than disabling (i.e., reducing the scope of possibilities) underlies this distinction. In other words, it is culturally acceptable to present opportunities (buy this instead of that) but not to restrict opportunities (do not buy this) (Maniates 2012; Giddens 2011). Yet, framing lifestyle change in the context of expanding the scope of opportunities may be a challenge if alternatives cannot be readily identified or presented as desirable choices. This situation points to the value of a communicative planning approach. Communicative planning focuses on interactive governance processes aimed at developing collective approaches to resolving conflicts and mobilizing for action (Healey 1999). For example, framing lifestyle choices as judicious trade-offs may present a point of entry. This means presenting the facts about the impacts of specific behaviours and/or products, presenting less impactful alternatives (if any can be identified), and engaging in dialogue about the challenges associated with changing behaviours/products (and the risks of not). Providing people with the rationale for making such a choice and the benefits associated with such a choice can expand the scope of engagement in one-planet living. For example, explaining that the intensive use of cropland to produce animal feed is what contributes to the large EF of red meat, and choosing exclusively range-fed beef or substituting with other sources of proteins including legumes in one's diet can significantly reduce one's EF. A deliberate engagement that directs people to a range of solutions in which they can participate still represents an expansion of choice (even if that includes substituting, curtailing or abstaining from certain behaviours/products) if the ultimate goal is a sustainable future. As Healey (1999, 115) astutely observes, "identifying which relations really make a difference… which ones cause major problems through the conflicts they generate… and where mutual benefit could be achieved … requires governance capacity to act as a strategic relational node… and a locus for the development of shared understandings."

There is broad agreement within the urban sustainability literature that high-consuming societies should take the lead to reduce their consumption in order to allow developing societies to increase their consumption as they develop (Renner 2012; Giddens 2011; Rees 2010, 1995; World Bank 2010a; Seyfang 2009; Victor 2008; Portney 2003). This approach is commonly termed "contraction and convergence" and is predicated on the ethical notion that everyone should be allowed equal access to the global commons and that this access must in total not exceed global ecological carrying capacity (Nichols and Meyer 2012). However, in a full world, i.e., a world in ecological overshoot, where global demand for energy and resources already exceeds global ecological carrying capacity, ecological space can only be created through absolute reductions in existing ecological demand by high-consuming societies (Nichols and Meyer 2012; Giddens 2011; Renner 2010; Victor 2008). Placing onus on the developed countries follows the principle of polluter pays (Giddens 2011). It aligns with notions of consumer responsibility as well as sustainable modes of consumption and production. It is ultimately predicated on the acceptance of ecological limits (Giddens 2011; Victor 2008; Rees 1995).

While it is beyond the scope of this research project to delve into theories of social change, planning theory and practice can provide several relevant examples and insights. Recall Newman's (2010) observation that social transformation in support of sustainable lifestyles can be achieved in short order through the power of social networks coupled with a whole systems approach that encompasses urban design, infrastructure management, regulation, tax incentives and disincentives. Education is also essential (Newman 2010) and usually begins with an awareness campaign to explain why change is needed coupled with social-marketing

(McKenzie-Mohr 2011)[145] to foster interest and participation in desired behaviour changes. This prepares people for subsequent introduction of incentives and disincentives (e.g., taxes) and regulations (e.g., bylaws) that require compliance over time. This holistic approach is practiced under the banner of "demand management" (Newman 2010, 135) also known more commonly in Vancouver as "demand side management." The terminology reflects a shift in public policy orientation from an emphasis on supply to meet growing demands for services (e.g., public utilities' provision of electricity, water, transportation road infrastructure) to shaping and curtailing demand for these services.

A comprehensive approach to the strategic shaping of demand for services creates the incentives and disincentives that influence decisions and behaviours of individuals and whole sectors of the economy with regard to the use of energy and materials in both production and consumption activities. As such, it can be affiliated with insights from "Structuration Theory," first articulated by Giddens (1984) that explores how "institutions structure values and behaviour within society" (Wheeler, 2004, 33) and the "multi-dimensional interaction between social constraint and human invention" (Healey 2007, x). Many planning theorists agree that sustainability requires policy development based on demand-side management (Roseland 2012; Newman and Jennings 2008; Portney 2003; Beatley 2000; Carly and Spapens 1998).

Planners in Vancouver have employed this approach to shape demand for land use (e.g., SmartGrowth), water (e.g., introduction of metering and summer lawn watering restrictions),

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[145] Social marketing is a communication strategy that systematically builds engagement through: i) establishing early commitments (e.g., to learn more, come to a meeting, make a simple pledge) and then ii) reinforces desired behaviour changes over time through the use of prompts (e.g., stickers placed on doors or next to switches as reminders to turn-out the lights) and personal accountability (e.g., self-reporting during campaigns), and positive reinforcements (e.g., celebrations of success).

and transportation (e.g., transit, cycling, and pedestrian oriented development coupled with employer trip reduction programs that include: Go Green, TravelSmart, Clean Air Day, and Bike-to-Work Week). In this latter example, collaboration with regional and provincial agencies such as TransLink and the BC Lung association has also proven effective. Additional examples include introduction of a green building program (i.e., Leadership in Energy and Environmental Design (LEED)) through collaboration with Metro Vancouver and the Province of British Columbia and initiatives to manage electricity (e.g., PowerSmart campaigns) led by BC Hydro, the provincial electrical utility. Examples of successful regulatory campaigns include seat-belt, motor cycle and bicycle helmet laws, waste disposal bans, and bylaws to prohibit smoking in public places.[146] In all cases the City either had jurisdiction to act (e.g., installation of water meters) or collaborated with an agency that did. As noted in chapter 5, a challenge to pursuing demand side management with regard to dietary choice is the City's lack of jurisdiction and perception that it is inappropriate to venture so far into the personal lives and habits of individuals. Nevertheless, the City has experience with shaping demand of travel choice, for example, and there are multiple agencies with shared interests in public health who may be willing to work with the City to promote heart-smart, or other healthy orientations to diet, that coincide with low-footprint food choices to support one-planet living.

The ecological footprint and one-planet living metrics contribute to articulating the contraction and convergence framework. My research uses these tools to quantify the magnitude of the

[146] The example of bylaws to prohibit smoking in public places provides an important example of a profound change in personal behaviours that was achieved across the entire City in a relatively short period of time. This demonstrates that the City can collaborate with other agencies to establish jurisdictional authority to act in ways that affect personal behaviour when it is deemed necessary and appropriate. It serves as an important reminder and provides a pathway that the City could follow in order to achieve further behaviour changes conducive with one-planet living (R. Woollard, personal communication, August 12, 2013).

sustainability gap between Vancouverites average per capita consumption and what it would be if the City's population were living on their equitable Earthshare. However, my research also reveals that even if the City and its citizens acted within the full scope of their powers to reduce their consumption to a fair Earthshare, they would still not achieve one-planet living. Part of the reason rests with the sheer energy intensity of the global economy upon which Vancouver depends (see chapter 4). The other part rests with the energy and materials consumed through senior government services that occur outside the City but from which all Canadians (and Vancouverites) benefit (see chapter 5). These factors direct attention towards technical solutions to de-materialize the economy and improve the efficiency with which senior government services are delivered.

Several authors have explored the potential for dematerialization in the economy, most notably von Weizsäcker et al. (2009; 1997) who explore technologies and policy measures capable of achieving 75-80% reductions in energy and material throughput in high-income countries. This level of reduction is increasingly accepted as the level of reduction required for ecological sustainability, including by such notable, mainstream heavy-weights as the International Energy Agency (IEA 2011) and World Bank (2010a). Historical supporters of such radical dematerialization include the Advisory Council for Research on Nature and Environment, World Conservation Union, United Nations Environment Program, Worldwide Fund for Nature, and the World Business Council for Sustainable Development (Rees 1995).

Strategic focal areas include: energy efficiency in buildings (e.g., high performance appliances and the Passive House standard), energy efficiency in transportation (e.g., performance standards, fuel switching, transit-oriented development), materials recycling (e.g., steel, aluminum, paper and plastics), industrial process manufacturing (e.g., materials substitution, electric arc furnaces), agriculture (e.g., organic and low/no-till practices, anaerobic digesters and other forms of on-site energy production) (von Weizsäcker et al. 2009). Indeed, Lombardi et al. (2011) observe that a majority of effort is placed on technical solutions. This is problematic. Technologies "are always embedded in wider political, economic and social frameworks, which are likely to govern both how they develop and what their consequences are" (Giddens 2011, 130). In a growth-oriented society, a confounding factor of efficiency gains through technology innovation is the rebound effect (Renner 2012; Newman 2010; Rees 2009, 1995; Victor 2008; von Weizsäcker et al. 2009, 1997). As efficiency improves, cost per unit of manufactured product goes down (presumably because less material is used in its manufacture). Lower costs stimulate greater consumption of the product, resulting in increased net consumption. The rebound effect was first articulated by Jevons in 1865 (Rees 2009). Weizsäcker et al. (2009) observed that a survey of sixty-five studies in North America demonstrate that the rebound effect accounts for up to 30% of consumer expenditures. This helps explain why resource and energy demand in most of the world's developed countries has increased in absolute terms over the past forty years despite simultaneous efficiency gains of 50% in materials and 30% in energy use respectively (von Weizsäcker et al. 2009).

These observations lend themselves to interpretation through a lens of complexity theory. Indeed, Giddens' (1984) theory of structuration is arguably predicated on observations compatible with complexity theory (Innes and Booher 2010; Scheffer et al. 2002). Giddens recognizes the autonomy of agents to act and therefore produce indeterminate outcomes within systems. Nevertheless, agents operate within structural constraints (i.e., rules and regulations) that they themselves help, in-part, to create and reinforce and that limit the scope of their potential actions (Giddens 1984; Innes and Booher 2010).[147] Addressing these systemic conditions necessitates planning (Giddens 2011; Filion 2010; Healey 1999; Rees 1995). Viewing Vancouver as a city-system, nested within a broader socio-economic system, which is in-turn nested within the ecosphere, one can interpret Vancouver City Council's willingness to acknowledge ecological limits and the value of one-planet living as "positive agency," i.e., system's adaptation to stay within a "window of vitality." However, there is little evidence that City officials are choosing to challenge societal memes that assume continued economic growth as the norm. Furthermore, reticence to address citizen behaviours pertaining to diet, for example, reveals the power that societal norms still exert with regard to constraining the City's agency. In chapter 1 I explored the lifecycle of systems, noting that as a system evolves structure its flexibility to adapt diminishes (Gunderson and Holling 2002). This insight could be applied to the socio-cultural norms and the institutional structures that restrict the adaptive capacity of Vancouver to respond to exogenously imposed threats such as energy scarcity, impacts from climate change, increasing food insecurity, etc. In this regard, Vancouver's vulnerability to collapse aligns with what is predicted for most high-consuming cities (Victor 2008; Downton 2007; Kunstler 2006; Diamond 2005; Odum and Odum 2001). It is therefore important to consider where the City is situated in its lifecycle with regard to capacity to respond to ecological challenges that could trigger its collapse. Equally important is

[147] I extracted this observation directly from reading Giddens (1984); however, after subsequently reading Innes and Booher (2010), I note that they also draw upon these observations from Giddens' work to explain the relationship with complexity theory.

consideration of the City's ability to respond to such challenges. This requires an internal assessment of the City's structure and current governance regime. As Joss (2011) observes, governance and sustainability are inherently intertwined. The power of structure is most forceful in the "taken for granted assumptions people implicitly draw upon" (Healey 1999, 114 citing Lukes 1974).

While Vancouver has aspirations to achieve one-planet living, its primary orientation is to the endogenous factors that influence the city-system rather than the exogenous factors that threaten its eventual collapse. Citizen resistance to change can persist in the absence of feedback that stimulates a felt need to adapt. Without an immediately apparent need to adapt, official actions that could contribute the most to achieving one-planet living are stymied. Unfortunately, many of the global ecological processes that threaten Vancouver, and cities generally, are slow to emerge. This creates an illusion of system stability when system thresholds may have already been crossed, making irreversible changes imminent (Giddens 2011; Rees 1995; Moore 1994; Prigogine and Stengers 1984; Meadows et al. 1972).

As previously noted, the City of Vancouver can play an important role to enable lifestyle choices commensurate with one-planet living, but it is not equipped with the jurisdictional authority to implement the full scope of measures needed to reduce Vancouverites' average EF to the one-planet living target of 1.8 gha/ca. Senior government intervention would also be needed. That said, senior governments are themselves impeded by the inertia of a political economy predicated on power through growth (UNDES 2011; Victor 2008; Rees 1995). Nevertheless, net consumption cannot increase indefinitely. Therefore, the need to acknowledge limits to growth coupled with absolute reductions in levels of consumption globally becomes a question of when, not if (Giddens 2011; Victor 2008; Rees 1995; Meadows et al. 1972). This reality holds even in the face of powerful interests throughout global, socio-economic and political systems that remain vested in maintaining the status quo (Renner 2012; Victor 2008; Rees 1995).

The extent to which one-planet policy and planning measures are pursued is ultimately tempered by the perception of necessity to act. As risks of societal collapse due to ecological degradation become more apparent, perceptions of the need to act may be strengthened to such a degree that rationing will be pursued, e.g., in the form of cap-and-trade for greenhouse gas emissions or other limits set on personal consumption. This would not be something that is wanted but, as Kuhn's (1962) theory of scientific revolutions reveals, it may become necessary in the absence of pro-active measures taken sooner to pre-empt anticipated changes.

6.3 Limitations of the Research

The countries selected for international profiles in the lifestyles archetype were primarily determined based on Menzel's (1994) field studies. This work was a starting inspiration for my research. Although Menzel (1994) studied 34 countries spanning the range from one-planet to three-plus-planet consumption profiles, his selection criteria included countries that are considered to be either allies or adversaries to the Unites States of America. It is unclear whether this biases my research findings, but it should be noted as a potential limitation because starting with a data set of consumption profiles for countries without the criteria could yield different results.

In chapter 4, I used data for selected countries already at one-planet living to build the international profile for the lifestyles archetype. Most of these are located in warm climates; however, Vancouver has a temperate climate. This difference was not taken into consideration in the analysis. Therefore, the analysis does not address the local bioregional context which could be an important consideration. Also in chapter 4, I used a composite of different consumption patterns from different communities to build the intentional communities profile, also part of the lifestyles archetype research. In so doing, I selected the lowest level of consumption achieved per component by any intentional community. This approach relies on a limited set of data comprising only the intentional communities for which an ecological footprint had been completed. Within this set, there were variations in the way that consumption was assessed, including time-limited surveys that ask participants to report on their consumption for a given week, rather than a full year. This can lead to underestimates of consumption if the week in question was one in which the participants did not make any significant purchases or trips. This limitation is compounded by my method which selected the lowest consumption by any community for each component. Therefore, I believe that the intentional community profile represents an underestimate of actual consumption.

The use of national statistics for the food component in my ecological footprint analysis may also bias the findings. While food is commonly found to be the most significant component in EF studies (Sotti et al. 2009; Newman and Jennings 2008; Collins and Flynn 2005), basing the Vancouver food footprint on local data might have yielded a lower estimate. For example, a BC Ministry of Agriculture (2006) study of BC food consumption for the year 2001 indicates that the BC population consumes more fruits and vegetables (38%) than Canadians on average

(23%). Similarly the BC population consumed more dairy (33%) than average Canadians (18%). I chose not to modify the national food consumption data used in my EF analysis in order to avoid mixing data between study years. For example, the national food consumption statistics represent 2006 data, the base year used in the EFA. However, the most recently available local consumer survey data and BC food consumption data were collected for the year 2001. Lack of data about domestic transportation of food (i.e., food miles) further reduces accuracy.

The use of lifecycle assessment data to estimate the embodied energy and materials of consumer goods was limited to what could be gleaned from the literature. This could result in underestimates of the total EF for some items.

6.4 Potential Applications of the Research Findings

The ecological footprint analysis developed in this research using 2006 data could be repeated using 2011 data. Such a comparison could reveal trends in consumption and EF to further inform the City's efforts to reduce its EF through implementation of the *Greenest City 2020 Action Plan*. Subsequent analyses using 2016 data could then show whether the City's implementation of the *Greenest City 2020 Action Plan* is having the desired effect. Policy adjustments to adapt existing efforts could also be derived. The EF reduction potentials identified in baseline 3b as well as the policy proposals aimed at achieving those EF reductions (see chapter 5) could also be considered for implementation by the City, either in part or in whole as part of an ongoing effort to move towards the goal of one-planet living. The greenhouse gas emissions inventory of consumption could also inform a comparative analysis of how policies aimed at reducing greenhouse gas emissions based on the territorial protocol prescribed by the Partners for Climate Protection program (FCM 2008) could be augmented through a more holistic approach that considers a broader range of emissions sources. Such an approach can also help identify those aspects of lifestyle choice that contribute the most to greenhouse gas emissions generation, including consideration of trans-boundary sources, meaning emissions generated outside the City that benefit, through end-use consumption, those living within it.

The research findings could also be used in a comparative analysis, if the research project were repeated using 2006 data for a different city, or multiple cities. Such an approach could reveal insights about the ways that urban morphology and household behaviours, including cultural preferences, affect the overall EF and policy options for reducing the sustainability gap.

6.5 Ideas for Future Research

This research represents a preliminary exploration of the potential to achieve one-planet living in Vancouver. Future research could refine both the ecological footprint analysis and the policy levers aimed at reducing it for any of the five components studied: food, buildings, consumables and waste, transportation, water.

The research also identifies the important role that senior governments play in affecting EF outcomes. However, I did not take a component approach to assessing the EF of senior government services and this represents an important opportunity for future work. A study that attempts to identify and build an EF estimate of senior government services using actual energy and materials consumption data would be an important contribution to knowledge. Such a study could begin with a comparison of Vancouver's EF for 2006 using the compound method contrasted with the findings from this research. The difference theoretically would represent the senior government services component. Subsequent bottom-up data collection and analysis could then attempt to determine what energy and material flows constitute this EF component, and what aspects of the senior governments' services footprint component could be reduced. Finally, future research could explore the role that senior governments could play in support of local government efforts to reduce their ecological footprints.

The Vancouver case examined here could be the basis for future comparative studies. For example, the energy and materials flows data collected in this research can be compared directly with other urban metabolism data. Component ecological footprint studies following the present method could also be undertaken for cities in Canada or elsewhere for comparative purposes, including over multiple years. Future studies could also investigate what changes to planning policies and practices in those cities could contribute to achieving a one-planet living target. Comparative investigations such as these could yield important insights about differences and similarities among cities respecting lifestyle and consumption and the ways that land use and development patterns, including built form and infrastructure systems, affect ecological footprint outcomes over time. Comparisons among policy frameworks that either enable or hinder one-planet living could also be considered.

The lifestyle archetype research uncovered several anomalies within the international case studies profiles that challenge assumptions about direct links between consumption characteristics and ecological footprints on the one hand and human development index numbers on the other. Exceptions within and between societies comprising the one-planet and three-planet profiles reveal important opportunities for further investigation. For example, several of the countries in the three-planet archetype, e.g., Germany and Japan, have a higher standard of living than countries in the three-plus archetype. While some countries in the one-planet archetype, e.g., Ecuador and Cuba, achieve a high human development index despite low per-capita consumption levels. Whether these anomalies can be accounted for through socio-cultural factors, such as national safety-net policies and/or universal education policies, or whether they are due to something else could present an intriguing avenue for future research.

The research findings represent a starting point for further analysis about whether and how changes to policy and urban management practices at the local government level can enable citizens to make choices in support of one-planet living. For example, could more specific information about how lifestyle and related consumption patterns across the components that comprise Vancouver's EF inspire citizens to make changes or is reduction in the EF predominantly associated with regulatory and financial incentives? Could open-data initiatives that engage individual residents in understanding what constitutes the average Vancouverites' ecological footprint inspire change or is an approach that utilizes social networks more effective?

6.5 Final Conclusions

This research demonstrates that one-planet living poses a tremendous challenge that requires a comprehensive effort by the City and its citizens, as well as senior governments. The challenge is far greater than what the City has contemplated to date. It presents what I believe is both a story of hope and a story of – dare I say - despair. Hope, because a pathway to one-planet living can be identified, the technological capability exists, and there are many people in Vancouver who have consistently demonstrated through the decades their willingness to strive for a sustainable future. Despair, because over this same time span, global indicators of ecosystem health, income disparity, and total economic throughput reveal that sustainability is moving farther out of reach.

As noted above, tremendous global forces remain vested in the status quo. To effect changes in the way the City is planned and managed at the level required to achieve one-planet living may indeed prove too great a challenge given this macro socio-economic context. This is further compounded by the reality that even within the City sustainability is not embraced by everyone. Indeed, it could be argued that there is a significant population within Vancouver who do not believe in or share the Greenest City vision, let alone a notion of sustainability predicated on the concept of one-planet living. And, as the research shows, even if the City were successful in implementing the policies proposed herein, much of the responsibility for getting to one-planet living remains at the personal discretion of citizens as they pursue their every-day lives.

The scientific evidence that the world is, indeed, in ecological overshoot and that much of the global population is at risk from the threats of ecological stress compels many, myself included, to continue to investigate pathways towards a globally just and ecologically secure, i.e., a more sustainable, future. To this end, I believe this research serves a valuable purpose. It quantifies Vancouver's sustainability gap and explores a potential pathway to closing it. If knowledge is power, then for those that are still willing to try, this result can help inform what getting serious about sustainability in Vancouver entails. Whether Vancouver achieves one-planet living may not affect the global situation, and whether Vancouver fails in its bid to become the Greenest City may not deter those who have retained a commitment to sustainability through the decades. However, what is important is that those who would choose to promulgate a story about sustainability in Vancouver understand the evidence that supports and refutes such claims. What is even more important is that those who seek to achieve sustainability, whether in Vancouver or in another part of the world, have access to research that can help light the way. It is to this endeavor that I believe this research makes its most important contribution.

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APPENDIX A: List of Countries Selected for the Research

Country Name	Ecological Footprint (gha/ca)
THREE-PLUS-PLANETS (> 6 gha/ca)	
United States of America	7.99
Canada	7.00
Australia	6.83
Kuwait	6.33
THREE-PLANETS (6<>4 gha/ca)	
Sweden	5.88
Norway	5.55
Mongolia	5.53
Spain	5.42
Germany	5.09
Italy	4.98
United Kingdom	4.90
New Zealand	4.89
Israel	4.82
Japan	4.71
Russia	4.44
TWO-PLANETS (4<>2 gha/ca)	
Chile	3.23
Mexico	2.99
Brazil	2.90
Bosnia and Herzegovina	2.76
Argentina	2.60
Thailand	2.36
South Africa	2.30
China	2.21
One-Planet (< 2gha/ca)	
Mali	1.93
Ecuador	1.88
Cuba	1.84
Guatemala	1.78
Uzbekistan	1.74
Viet Nam	1.40
Iraq	1.35
Philippines	1.30
Ethiopia	1.11
India	0.91
Haiti	0.67

APPENDIX B: Detailed Profiles of Intentional Communities

a) By Ecological Footprint

Component (unit of measure)	Toarp (gha/ca)	BedZed (gha/ca)	Quayside (gha/ca)	Findhorn (gha/ca)	Average (gha/ca)
Food (t/ca) Daily caloric supply	0.93	1.22	1.11	0.42	0.92
Buildings (kWh/ca) and Built Area (m2/ca)	1.15	0.77	0.31	0.29	0.63
Consumables and Wastes (Paper t/ca)	0.19	0.79	0.23	0.30	0.38
Transportation (VkmT/ca)	0.42	0.75	0.94	0.37	0.62
Water (l/ca) % domestic	n/a	n/a	n/a	n/a	n/a
Other/Government	0.09	1.15	n/a	1.33	0.21
Total	**2.78**	**4.68**	**2.59**	**2.71**	**2.76**

b) By Consumption

Toarp, Municipality of Malmo, Sweden

Component	Consumption (unit/ca/yr)	Carbon Emissions (t/ca/yr)	Ecological Footprint (gha/ca/yr)	Comments
Population				Total population is 144 people.
Area				Site area is 4.2 hectares.
Food			0.93	
Buildings and Built Area	30 m^2		1.15	An average of 3.9 people per household live in 37 houses. Approximately 50% of electricity is hydro-power. Rely mostly on firewood for heating.
Consumables and Wastes			0.19	Approximately 0.15 gha/ca/yr associated with consumption and 0.04 gha/ca/yr associated with waste.
Transportation			0.42	
Water			n/a	
Other/ Government			0.09	Services only.
Total			2.78	

Source: (Heraldsson et al. 2001.)

BedZED, Burrough of Sutton, London, England

Component	Consumption (unit/ca/yr)	Carbon Emissions (t/ca/yr)	Ecological Footprint (gha/ca/yr)	Comments
Population				Total population is 222.
Area				Site area is 3.5 acres. Brownfield redevelopment.
Food	n/a	n/a	1.22	Approximately 25% of food consumed is organic.
Buildings and Built Area	3,139 kWh Comprising: Electricity: 3.4 kWh/ca/day Space Heating 5.2 kWh/ca/day	0.88	0.77	An average of 2 people per household live in studios and apartments ranging from 1 to 4 bedrooms. Buildings are 3 story row-houses with adjacent two story live-work loft spaces. Approximately 20% of electricity is provided by 777 m2 of photovoltaic panels. Additional energy savings are achieved through passive solar and passive ventilation design with green roofs
Consumables and Wastes	234 kg	n/a	0.79	Approximately 50% of waste is recycled, and another 10% is composted. Therefore, only 104 kg/ca/yr is disposed to landfill or incineration.
Transportation	0.3 vehicles 2,318 VkmT 10,063 AkmT	1.9 tCO2	0.75	Five minute walk to commuter train service. Car co-operative on-site.
Water	87 litres	n/a	n/a	Rainwater and grey water recycling provide 15 litres/day, thereby reducing total demand on water utilities to 72 l/ca/day.
Other/ Government	Business Infrastructure Government	n/a	0.54 0.24 0.37	This footprint study was compiled using REAP which apportions private services (i.e. business) and infrastructure separately from buildings and built area. NB: These would be included within the Buildings and Built Area component under my method, assuming the businesses and infrastructure are located within the community. However, given the small neighbourhood scale of BedZed, it is likely that these services reside in the surrounding community..
Total		9.99	4.68	

Source: (Bioregional 2009)

Quayside, North Vancouver, Canada

Component	Consumption (unit/ca/yr)	Carbon Emissions (t/ca/yr)	Ecological Footprint (gha/ca/yr)	Comments
Population				Total population is 38 people.
Area				n/a
Food			1.11	A mostly vegetarian diet with occaisional poultry, fish and dairy. Animal protein accounts for 0.9 gha/ca. Shared kitchen and dining facilities.
Buildings and Built Area	80m2 2,336 kWh 21 GJ	 0.06 tCO_2e 1.05 tCO_2e	0.31	An average of 2 people per household live in 19 residential units plus common area (240 m2) and commercial space that is leased. Total site area is 0.1 ha comprising a four story walk-up building with commercial at grade.
Consumables and Wastes	 0.11 tonnes (waste)		0.23	Recreational and sports equipment comprise largest share of consumables followed by audio-visual equipment, followed by appliances.
Transportation	Transity na/ VkmT n/a AkmT n/a	0.11 tCO_2e 1.13 tCO_2e	0.94	Air travel was not included in the EF estimate for transportation. Additional travel includes: train 3,055 kmT/ca, and bus 127 kmT/ca.
Water			n/a	
Other/ Government			n/a	
Total			2.59	

Source: (Giratalla 2010)

Findhorn, Scotland

Component	Consumption (unit/ca/yr)	Carbon Emissions (t/ca/yr)	Ecological Footprint (gha/ca/yr)	Comments
Population				Total population is 345 people.
Area				n/a
Food			0.42	Almost exclusively vegetarian. Shared kitchen and dining facilities.
Buildings and Built Area			0.29	Approximately 181 households live in 138 buildings. Wind energy supplies 100% of electricity demand.
Consumables and Wastes	0.76 tonnes (recycled) 0.084 tonnes (waste)		0.3	Recreational and sports equipment comprise largest share of consumables followed by audio-visual equipment, followed by appliances.
Transportation	539 VkmT 8,439 AkmT		0.37	Air travel was not included in the EF estimate for transportation. Additional travel includes: train 3,055 kmT/ca, and bus 127 kmT/ca.
Water			n/a	
Other/ Government			1.33	This component comprises private services (0.35 gha/ca), government services (0.47 gha/ca) and capital investment in infrastructure (0.51).
Total			2.71	

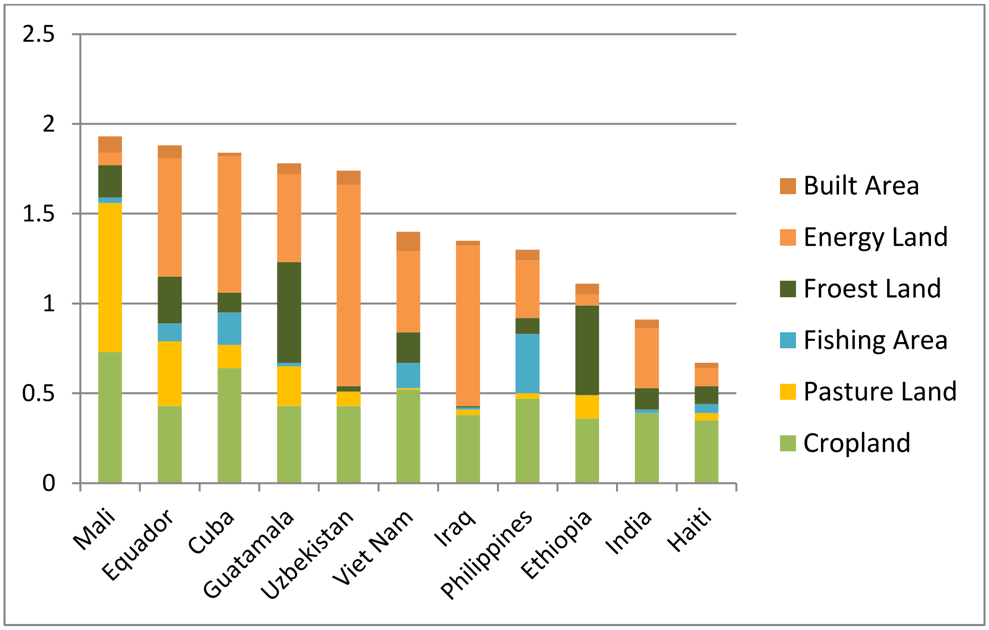
Source: (Tinsley and George 2006)

APPENDIX C: Lifecycle Factors for Consumable Materials EF Conversion

Type of Material	Energy LCA Factor gha/tonne	Materials LCA Factor gha/tonne	Total LCA Factor (gha/tonne)
Paper			
Printed Paper	0.18	1.29	1.47
News Print	0.21	1.13	1.34
Cardboard and Boxboard	0.17	1.47	1.64
Telephone Directories	0.21	1.13	1.34
Other	0.21	1.29	1.34
Plastic			
Film (bags)	0.85		0.85
PET	1.23		1.23
HDPE	0.73		0.73
PVC	0.5		0.50
Other	0.85		0.85
Organic Waste			
Food waste (not to include in the EF)			
Yard and Garden			0.59
Wood Waste	0.18	0.41	0.59
Textile	3.76	3.14	6.90
Rubber	1.6	1.83	3.43
Other		0.05	0.05
Metals			
Ferrous Food/Drink Packaging not Recycled	0.45		0.45
Ferrous Other	0.45		0.45
Non-Ferrous and Bimetallic	3.21		3.21
Glass			
Food/Drink Packaging	0.16		0.16
Other	0.16		0.16
Household Hygiene			
Diapers	0.80	0.36	1.16
Sanitary Napkins/Tampons	0.80	0.36	1.16
Other	0.80	0.36	1.16
Hazardous material Container	3.21		3.21
Electronic waste	0.85		0.85

APPENDIX D: EF of International Case Studies in One-Planet Archetype

Ecological Footprint of Countries that Represent the One-planet Archetype



One-Planet Archetype	Cropland	Pasture Land	Fishing Area	Froest Land	Energy Land	Built Area	Total
	gha/ca/yr	gha/ca/yr	gha/ca/yr	gha/ca/yr	gha/ca/yr	gha/ca/yr	gha/ca/yr
Mali	0.73	0.83	0.03	0.18	0.07	0.09	1.93
Equador	0.43	0.36	0.1	0.26	0.66	0.07	1.88
Cuba	0.64	0.13	0.18	0.11	0.76	0.02	1.84
Guatamala	0.43	0.22	0.02	0.56	0.49	0.06	1.78
Uzbekistan	0.43	0.08	0.00	0.03	1.12	0.08	1.74
Viet Nam	0.52	0.01	0.14	0.17	0.45	0.11	1.40
Iraq	0.38	0.03	0.01	0.01	0.89	0.03	1.35
Philippines	0.47	0.03	0.33	0.09	0.32	0.06	1.30
Ethiopia	0.36	0.13	0.00	0.50	0.06	0.06	1.11
India	0.39	0.00	0.02	0.12	0.33	0.05	0.91
Haiti	0.35	0.04	0.05	0.1	0.1	0.03	0.67
Average	***0.47***	***0.17***	***0.08***	***0.19***	***0.48***	***0.06***	***1.45***

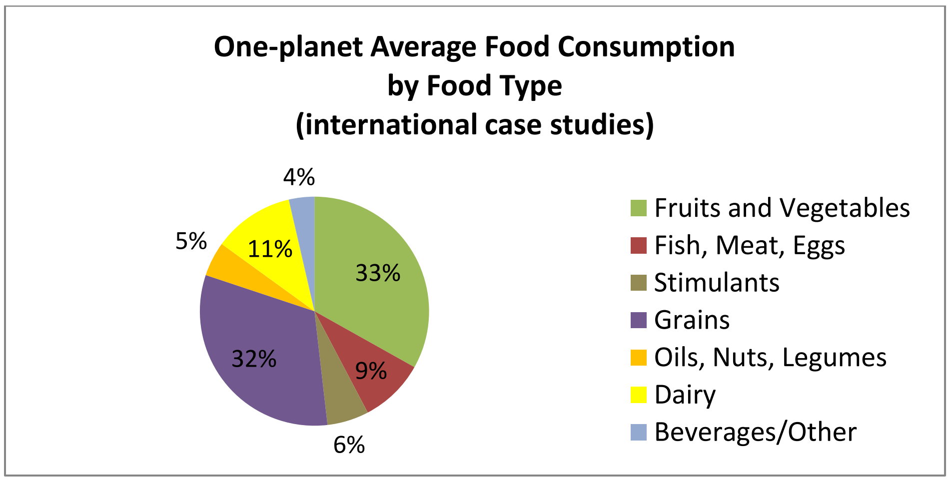
(Source: WWF 2010b)

APPENDIX E: Food Consumption of International Case Studies in the One-Planet Archetype

FAO Nutrition Country Profiles for Countries Representing the One-planet Archetype

	Mali	Ethiopia	Equador	Cuba	Guatemala	Philippines	Viet Nam	Haiti	Average	Average	Average
	g/ca/day	g/ca/day	g/ca/day	g/ca/day	g/ca/day	g/ca/day	g/ca/day	g/ca/day	g/ca/day	kg/ca/yr	t/ca/yr
Fruits and Vegetables	252	227	542	723	321	195	208	534	375	137	0.14
Fish, Meat, Eggs	99	30	145	133	82	178	96	68	104	38	0.04
Stimulants	34	12	118	155	123	19	3	68	67	24	0.02
Grains	547	384	315	298	342	318	429	260	362	132	0.13
Oils, Nuts, Legumes	63	44	74	75	63	25	10	88	55	20	0.02
Dairy	155	63	301	260	137	63	0	55	129	47	0.05
Beverages/Other	19	35	55	75	33	22	44	44	41	15	0.01
Total	1169	795	1550	1719	1101	819	790	1118	1133	413	0.41

(Source: FAO 2010b, 2008, 2003a, 2003b, 2001a, 2001b, 1999a, 1999b.)



Vancouver at One Planet	One Planet t/ca/yr	Scaled EF gha/t	EF gha/ca/yr
Fruits and Vegetables	0.14	0.72	0.10
Fish, Meat, Eggs	0.04	6.71	0.25
Stimulants	0.02	0.67	0.02
Grains	0.13	1.30	0.17
Oils, Nuts, Legumes	0.02	1.93	0.04
Dairy	0.05	1.32	0.06
Beverages/Other	0.01	0.14	0.00
Total	0.41		0.64

APPENDIX F: Calculations Pertaining to Closing the Sustainability Gap for Buildings

Table 4.10 in chapter 4 reveals that Vancouver's total residential CO_2 emissions are 604,984 tCO_2, comprising 44,728 tCO_2 from electricity consumption and 560,256 tCO_2 from other energy sources including natural gas, heating oil and propane (MOE 2010). Table 4.02 in chapter 4 reveals that residential emissions for those living at a one-planet level are 0.2 tCO2/ca.

I estimate Vancouver's residential buildings emissions if they were equivalent to the one-planet level (i.e., 0.2 tCO_2/ca*578,041 = 115,608 tCO_2), this would result in a reduction of 489,376 tCO_2 (i.e., 604,984 – 115,608 tCO2).

Following equation 6 in chapter 3, I convert a reduction of 489, 376 tCO2 to an equivalent EF reduction of 121,365 gha.

Table 4.10 reveals that the EF for the buildings component is 386,752 gha. I subtract from this the estimated amount of EF reduction (i.e., 386,752 gha – 121,365 gha = 265,387 gha). This gives me the new EF for buildings if Vancouverites produced CO2 in residential buildings commensurate with the one-planet level of 0.2 tCO2/ca.

Next I convert the revised EF value for the buildings component into a per capita value (i.e. 265,387 gha/578,041 = 0.46 gha/ca). I subtract this from the original per capita EF for the buildings component to calculate the potential reduction that could be achieved (i.e., 0.67 – 0.46 = 0.21 gha/ca.) Therefor, I estimate the potential reduction to be 0.21 gha/ca.

Appendix G: Names of Research Interviewees

Amy Fournier, City of Vancouver, Sustainability Office, Program Coordinator

Andrea Reimer, City of Vancouver Council Member

Brent Toderian, City of Vancouver, Director of Planning

Christine De Marco, Metro Vancouver, Division Manager, Regional Development

David Cadman, City of Vancouver Council Member

David Ramslie, City of Vancouver, Program Manager

James O'Neil, City of Vancouver, Social Planner

Jerry Dobrovolny, City of Vancouver, Director of Transportation

John Tylee, Vancouver Economic Commission, Senior Policy Advisor

Johnny Carline, Metro Vancouver, Chief Administrative Officer

Karis Hiebert, City of Vancouver, Planner

Lindsay Cole, City of Vancouver, Greenest City Planner

Mark Hartman, City of Vancouver, Sustainability Office, Program Manager

Monica Kosmak, City of Vancouver, Zero Waste Planner

Peter Judd, City of Vancouver, Director of Engineering

Sean Pander, City of Vancouver, Sustainability Office, Climate Action Manager

Tamim Raad, Translink, Director, Strategic Planning

Theresa Duynstee, Metro Vancouver, Food Systems Planner

Appendix H: Interview #1
Preliminary Identification of Policy Interventions

Introduction:

The purpose of this interview is to identify policy interventions or changes to management practices that could enable reductions in energy and materials consumption by Vancouver's residents. The goal is to identify opportunities to enable Vancouverites to live within the earth's ecological carrying capacity. A phrase often used to describe this concept is "one planet living." It represents the average material standard that, if extended to everyone on Earth, would be a sustainable and equitable sharing of the earth's ecological and economic output.

To achieve one planet living in Vancouver would require that we reduce average levels of energy and material consumption by about 75%. While seemingly extreme, it is at least theoretically possible to achieve such reductions while simultaneously maintaining or enhancing quality of life. Identifying policies that could stimulate the necessary changes in institutional and consumer behaviour is the major challenge associated with this research project.

We can estimate any specified population's demand on the Earth's ecosystems using ecological footprint analysis (EFA). EFA converts a study population's material consumption and waste production into the area of ecosystems required to produce the resources the population consumes and to assimilate its (carbon dioxide) wastes. To facilitate comparisons, population eco-footprints are estimated in terms of hectares of global average productivity, termed a "global hectare."

The largest components of Vancouver's ecological footprint are: food, transportation and buildings (construction, maintenance and operation). While Vancouver has made important advances in reducing the energy and materials consumption associated with its built environment, continued reductions in energy and materials consumption associated with consumables and their associated wastes, and to a lesser degree water also remain important. Compared to best practice in other communities, the following "sustainability gaps" emerge as opportunities for Vancouver to improve its performance.

<table>
<tr><th>Component</th><th>Vancouver</th><th>One Planet*</th><th>Sustainability Gap</th><td rowspan="8">*One Planet values reflect ecological footprint results achieved in the eco-village of Findhorn, Scotland for food, buildings and transportation, and Toarp, Sweden for consumables and wastes as well as other services.</td></tr>
<tr><td>Food</td><td>2.13 gha</td><td>0.42 gha</td><td>1.71 gha</td></tr>
<tr><td>Buildings</td><td>0.66</td><td>0.29</td><td>0.37</td></tr>
<tr><td>Consumables and Wastes</td><td>0.57</td><td>0.19</td><td>0.59</td></tr>
<tr><td>Transportation</td><td>0.81</td><td>0.37</td><td>0.44</td></tr>
<tr><td>Water</td><td>0.00</td><td>N/A</td><td>0.00</td></tr>
<tr><td>Other Services</td><td>N/A</td><td>0.09</td><td>- 0.09</td></tr>
<tr><td>TOTAL</td><td>4.18</td><td>1.36</td><td>3.02</td></tr>
</table>

Preamble:

The City has adopted the *EcoDensity Charter* which cites a commitment to move toward becoming an EcoCity and setting "environmental sustainability" as "a primary goal (COV, 2008, 4). The "Greenest City Action Team," established by the Mayor of Vancouver, has prepared a report: *Vancouver 2020: A Bright Green Future* that includes an objective for Vancouver to achieve a "one-planet ecological footprint" (Boyd, 2009, 14). Given that Vancouver has an average per capita ecological footprint of gha and a one planet target is approximately 2 gha, this would require a 75% reduction in the consumption of energy and materials that comprise Vancouver's ecological footprint (Boyd, 2009, 46). The report cites a short-term target of 33% reduction in Vancouver's ecological footprint by 2020, achieved in-part through efforts to reduce greenhouse gas emissions and consumption of water (Boyd, 2009, 47) and cites technological improvements and behaviour change as means by which to achieve the longer term 75% reduction goal (Boyd, 2009, 46).

Questions:

1. Reflecting on the following characteristics of an ecocity, which Vancouver neighbourhood do you believe best reflects urban sustainability and why?

   Characteristics of an ecocity neighbourhood:

   - walkable area with pedestrian oriented amenities, e.g. 160 acres (approximately 7x7 city blocks) with foot and cycle paths and transit service, i.e. no cars in the urban centre;
   - compact and mixed use built environment, e.g. buildings ranging from six to twenty-five stories with a density of no-less than 50 people per hectare (i.e. Vancouver's average density);
   - solar-oriented design that maximizes penetration of natural daylight, passive ventilation;
   - open space suitable for conversion to agriculture, community and rooftop gardens;
   - protection of natural features such as creeks, wetlands, forests suitable for natural habitat.

   (Adapted from: Girling and Kellett, 2005, 12; Register, 2006, 248)

2. What are some examples of City policy or management practices in this neighbourhood that enable people to reduce their consumption of energy and materials?

   Prompts: Policy or management practices could affect land use and buildings, transportation, food, water, consumables and waste (including organic waste), or services.

3. a) Reflecting on the components that comprise Vancouver's Ecological Footprint, and what appear to be the most significant sustainability gaps relative to documented best practices

elsewhere, what are some policy interventions or changes to management practices the City could make in order to enable people to reduce their energy and materials consumption toward the goal of One Planet Living?

Prompts: Present the “sustainability gaps” research outputs.

Interventions or changes could affect land use and buildings, transportation, food, water, consumables and waste (including organic waste), or services.

b) Which of these policy interventions or changes to management practices do you believe is most important in terms of moving towards the One Planet Living goal?

4. What changes to City policy or management practices are you or colleagues working on at the moment that enable people to reduce their consumption of energy and materials? Alternatively, is there a change you wish you could make?

   Prompts: Interventions or changes could affect land use and buildings, transportation, food, water, consumables and waste (including organic waste), or services.

5. What specific policies or sections of text therein, regulate municipal functions that prevent or impede efforts to reduce energy and materials consumption as they relate to the Ecological Footprint components?

   Prompts: Components include: food, buildings and built area, consumables and waste (including organic waste), transportation, water, and services.

6. Are there policies, regulations, or other factors (e.g. cost-hurdles or market conditions) that are outside the City’s control that prevent or impede efforts to reduce energy and materials consumption as they relate to the Ecological Footprint components? If so please explain?

7. Can you suggest anyone else whom you think it is important I interview for this research, either working within the City or in a different government, non-government or private sector organization?

8. My I contact you again prior to the second interview for further clarification of any answers provided to questions herein?

9. Do you have any questions for me?

Appendix I: Interview #2
Reflective Assessment of Proposed Policy Interventions

Introduction:

The purpose of this interview is to explore whether policy interventions or changes to management practices identified through the research to date pose challenges from a technical or regulatory perspective, and what changes to existing policy could enable their implementation. The goal is to identify opportunities to enable Vancouverites to live within the earth's ecological carrying capacity. A phrase often used to describe this concept is "one planet living." To achieve one planet living in Vancouver would require approximately 75% reductions in energy and materials consumption below existing levels of an average Vancouverite's lifestyle. Exploring how to maintain quality of life while simultaneously achieving this level of energy and materials consumption reductions is a challenge associated with this research project.

Preamble:

The City has adopted the *EcoDensity Charter* which cites a commitment to move toward becoming an EcoCity and setting "environmental sustainability" as "a primary goal (COV, 2008, 4). The "Greenest City Action Team," established by the Mayor of Vancouver, has prepared a report: *Vancouver 2020: A Bright Green Future* that includes an objective for Vancouver to achieve a "one-planet ecological footprint" (Boyd, 2009, 14). Given that Vancouver has an average per capita ecological footprint of 7 gha and a one planet target is approximately 2 gha, this would require a 75% reduction in the consumption of energy and materials that comprise Vancouver's ecological footprint (Boyd, 2009, 46). The report cites a short-term target of 33% reduction in Vancouver's ecological footprint by 2020, achieved in-part through efforts to reduce greenhouse gas emissions and consumption of water (Boyd, 2009, 47) and cites technological improvements and behaviour change as means by which to achieve the longer term 75% reduction goal (Boyd, 2009, 46).

To date the research has identified the following policies and management changes as having potential to either directly reduce energy and materials consumption by the City's residents or to enable them to pursue One Planet Living: (see report or presentation delivered prior to interview and summarized as an attachment to this questionnaire for your reference).

Questions:

1. Reflecting on the policies and/or changes to management practices identified through the research thus far, which, if any, pose challenges from a technical or regulatory perspective (e.g., which rely on un-proven technologies, constitute an undue burden of risk, contravene

existing City policy or contract agreements, or contravene policy of other government bodies that limit municipal jurisdiction)?

2. Of the policies and/or changes to management practices identified in question one above, can you identify appropriate changes to municipal policy or changes to senior government policy or multi-government agreements that could enable its implementation?

3. Are there other challenges that you can identify that would impede the feasibility of implementing any of the identified policies and/or changes to management practices? If so please explain?

   Prompts: Examples include cost-hurdles, market conditions, cultural bias.

4. Which of the identified polices and/or changes to management practices identified through the research thus far do you believe represent the most significant opportunity to reduce energy and materials consumption by the City's residents and/or enable One Planet Living?

5. Are there policies and/or changes to management practices that have not been identified or are not presented here-in that you believe should be considered? If so please explain.

6. Can you suggest anyone else whom you think it is important I interview for this research, either working within the City or in a different government, non-government or private sector organization?

7. My I contact you again for further clarification of any answers provided to questions herein?

8. Do you have any questions for me?

Appendix J: Procedural Steps to Calculate EF Adjustments for Baseline 1

Steps:

1. Divide total consumption of fish, meat and eggs (88,067 tonnes) by 6 which is the number of remaining food categories in the food component. This equals 14,678 tonnes. Add this amount to each of the remaining food categories. Recalculate the food footprint by assuming the ratio increase in consumption of each food type is equally reflected in its footprint. Example: Fruits and vegetables was 166,227 tonnes, plus 14678 tonnes now equals 180,905 tonnes. This is an 8.11% increase. Therefore increase the fruits and vegetables footprint by 8.11%.
2. Assume zero emissions associated with production and transportation of fish, meat and eggs.
3. Assume equivalent increases in production and transportation of EF of all remaining food categories in proportion to increases in tonnage consumed. Example: If consumption of Fruits and Vegetables increases by 8.11% then assume that CO2 associated with production and transportation of Fruits and Vegetables also increases by 8.11%.

Appendix K: Vancouver Landfill Carbon Dioxide Coefficient per Tonne of Municipal Solid Waste

A. Calculate total landfill gas (LFG) from the Vancouver Landfill for the year 2007: assuming a 67% efficiency rate for LFG recovery (CH2M Hill 2009) resulting in 41,488,424 m^3 of LFG recovered (COV 2007b).

If 67% efficiency recovery results in 41,488,424 m^3LFG, calculate the amount of total LFG, e.g., that could be recovered through 100% efficiency recovery, where x is total m3 LFG:

$\frac{41{,}488{,}424 m^3 LFG}{x} = \frac{67}{100}$ therefore total landfill gas = 61,923,021 m^3

B. Assuming LFG comprises 50% methane and 50% CO_2, calculate the amount of each gas comprising the total LFG recovered of each gas.

$\frac{61{,}923{,}021}{2} = x$ therefore CO_2 = 30,961m^3 and CH_4 = 30,961m^3

C. Calculate the amount of escaped methane if a total of 33% LFG was not recovered.

(.33)(.50)(61,923,021)=10,217,298 $m^3 CH_4$

D. Calculate the escaped CO_2, the utilized methane (100% of which is converted to CO_2 when it is combusted) and the utilized CO_2. In other words, subtract the escaped methane from the total landfill gas.

(0.835)(61,923,021) = 51,705,723 $m^3 CO_2$

Crosscheck: 61,923,021 – 10,217,29 = 51,705,723 $m^3 CO_2$

E. Convert m^3CO_2 to tonnes (t) CO_2. Assume 1.977 kg_{CO2}/m^3_{CO2}.

$$\frac{1.977\ kgCO_2}{1\ m^3CO_2}(51{,}705{,}723\ m^3CO_2) = 102{,}222{,}214\ kg\ CO_2 \text{ or } 102{,}222\ tCO_2$$

F. Calculate the CO2 emissions factor per tonne of municipal solid waste.

$$\frac{102{,}222\ tCO2}{510{,}135\ t_{MSW}} = 0.2\ t_{CO2}/t_{MSW}$$

Following this same method, I can now scale the carbon dioxide emissions coefficient factor to reflect a 75% landfill gas recovery rate. Therefore, increasing the recovery rate by 8% (from 67% to 75%) results in an equivalent reduction in the CO_2 emissions factor, from 0.2 t_{CO2}/t_{MSW} to 0.184 t_{CO2}/t_{MSW}.

The total amount of municipal solid waste generated by Vancouverites and disposed in the Vancouver Landfill in 2006 was 204,680 tonnes (COV 2007b). At a 67% landfill gas recovery rate, with a carbon dioxide emission factor of 0.2 t_{CO2}/t_{MSW} this generated a total of 40,936 tCO_2. At a 75% landfill gas recovery rate, with a carbon dioxide emission factor of 0.184t_{CO2}/t_{MSW} this would have generated a total of 37,661 tCO2. The difference, 3,275 tCO2 is equivalent to 812 gha or 0.0014 gha/ca.

Appendix L: Additional Baselines

Greenest City 2020 Action Plan with Intensive food production and conservation as well as zero emissions

	Vancouver EF (gha/ca)	a) Greenest City 2020 with 25% local vegetables and eggs (gha/ca)	b) Greenest City 2020 with 100%, local vegetables, eggs, pork, poultry and eggs, no red meat, and no food waste (gha/ca)	c)Greenest City 2020 with 50% local food production and low emissions (gha/ca)	d)Greenest City 2020 with 50% local food production and zero emissions (gha/ca)
Food Potential Reduction:					
Produce 25% of vegetables in city		-0.01			
Produce 25% of eggs in city		-0.01			
Produce 100% of vegetables and eggs in city			-0.08		
Produce 100% of Pork and Poultry in city			-0.18		
Produce 50% of Pork and Poultry in city				-0.04	-0.04
Produce 50% of vegetables and eggs in city				-0.09	-0.09
Abstain from eating red meat (with substitutes)			-0.65		
Abstain from consuming dairy (with substitutes)			-0.08		
Reduce red meat by 50% (with substitutes)				-0.34	-0.34
Reduce dairy consumption 50% (with substitutes)				-0.04	-0.04
Allocate all grain production to local consumption			-0.01		
Eliminate consumption resulting in food waste			-0.52		
Reduce consumption resulting in food waste 50%				-0.39	-0.39
Food	2.13	2.11	0.61	1.23	1.23
Transportation Potential Reduction:					
Make 66% of trips by walking, cycling and transit		-0.29	-0.29	-0.29	
Make 86% of trips by walking, cycling and transit					-0.38

Make 50% private vehicle fleet zero emissions				-0.07	
Make 50% commercial vehicle fleet zero emissions				-0.04	
Make 100% private vehicle fleet zero emissions					-0.05
Make 100% of commercial fleet zero emissions					-0.08
Reduce private vehicle ownership 25%				-0.04	
Reduce private vehicle ownership by 50%					-0.07
Transportation	0.81	0.52	0.52	0.39	0.23
<u>Buildings Potential Reduction:</u>					
Improve energy efficiency 20%		-0.11	-0.11	-0.11	
Improve energy efficiency 40%					-0.21
Implement 5 district energy systems		-0.17	-0.17	-0.17	
Make 50% commercial buildings zero emissions				-0.07	
Make 50% residential buildings zero emissions				-0.07	
Make 100% of commercial buildings zero emissions					-0.17
Make 100% of residential buildings zero emissions					-0.17
Buildings	0.67	0.39	0.39	0.25	0.12
<u>Consumables and Waste Potential Reduction:</u>					
Increase landfill gas capture at VLF to 75%		-0.006	-0.006	-0.006	-0.006
Reduce waste to landfill by 50%		-0.064	-0.064	-0.064	-0.064
Consumables and Waste	0.58	0.51	0.51	0.51	0.51
Water N/A					
Water	0.02	0.02	0.02	0.02	0.02
TOTAL	4.21	3.55	2.05	2.40	2.11