ECOLOGICAL FOOTPRINT AND APPROPRIATED CARRYING CAPACITY: A TOOL FOR PLANNING TOWARD SUSTAINABILITY

by

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ABSTRACT

There is mounting evidence that the ecosystems of Earth cannot sustain current levels of economic activity, let alone increased levels. Since some consume Earth's resources at a rate that will leave little for future generations, while others still live in debilitating poverty, the UN's World Commission on Environment and Economic Development has called for development that is *sustainable*.

The purpose of this thesis is to further develop and test a planning tool that can assist in translating the concern about the sustainability crisis into public action. The research advances the concept of "Ecological Footprint" or "Appropriated Carrying Capacity" (EF/ACC) as a planning tool for conceptualizing and developing sustainability. To meet this purpose, I document the development of the EF/ACC concept, explore its potential use in public decision-making towards sustainability, apply the concept in a real world context, and finally, empirically analyze its usefulness to actors in the public domain.

The research shows that the EF/ACC concept can link global social and ecological concerns to individual and institutional decision-making. Though the tool needs further refinement to make it readily applicable to the planning practitioners' everyday decisions, it has proved useful as a conceptual tool for framing the sustainability challenges. More than 20 EF/ACC applications, by others and by me, range from environmental outdoor education for children to policy and project assessments for municipalities and regions. With these examples, EF/ACC has contributed to translating sustainability into concrete terms and to providing direction for planning toward sustainability.

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I. INTRODUCTION

A. THE CHALLENGE

There is mounting evidence that the ecosystems of Earth cannot sustain current levels of economic activity, let alone increased levels (Goodland 1991, Meadows *et al.* 1992:97-103, Postel 1994, Rees & Wackernagel 1992:383). However, economic activities, measured by the Gross World Product, are growing at four percent a year[1] -- which corresponds to a doubling time of under 20 years (UNDP 1993:149, Brown *et al.* 1992b:67). One factor of this expansion is the growth of the world's population, which is expected to almost double between 1990 and the year 2050 (United Nations 1991). The other ecologically significant factor is the rise in per capita consumption which, in the last 40 years, has been increasing even faster than the human population (Holdren & Ehrlich 1974, Brown *et al.* 1992b:77).

Today's form of conventional economic development was launched after the Second World War, and has become a major element of most nations' political agendas. Its aim has been to integrate local economies into the global economy, which leads to accelerated industrial production (*and* resource consumption) (Smith 1994, Ohmae 1990, Samuelson & Nordhaus 1985:870, 857-868). However, increasing economic production has neither levelled income differences, nor satisfied the basic needs of the world's poorest one billion people. While twenty percent of the world's people live in unprecedented wealth, at least twenty percent live in conditions of "absolute poverty" (UNDP 1993:12). Therefore, the conventional economic development approach has been challenged for not catering effectively to the needs of the poor (Dube 1988, Friedmann 1992, Friedmann & Weavers 1979, George 1984 & 1992, Hadi 1993, Hayter 1985, Laquian 1993).

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[1] The Gross World Product rose in 1987 dollars from $3.8 billion in 1959 to $18.8 billion in 1990. This expansion corresponds to an average growth rate of 4.1 percent. For the 1980's, the average growth rate was three percent (Brown *et al.* 1992b:67).

Now, in the face of global ecological constraints, the criticism becomes even more severe. Currently, humanity appears to deplete nature, through resource harvesting and waste generation, faster than nature can regenerate itself. By 1986, human activities were already appropriating over forty percent of nature's terrestrial net primary productivity -- or in other words, humanity was channelling through its economy over forty percent of nature's chemical energy and living matter, which are constantly being accumulated by the land-based natural processes of photosynthesis (Vitousek *et al.* 1986). If the appropriation of other functions of nature are added, such as waste absorption (e.g., biodegrading effluents or sequestering CO_2 from fossil fuel burning) and life support services (e.g., preserving biodiversity or providing climate stability), there is indication that the world may already be effectively "full" of human activity (Goodland 1991, Daly 1991, Rees & Wackernagel 1992).

The resource appropriation which has supported the last decades' economic growth and the rise of industrialized countries' standard of living has, at the same time, resulted in the degradation of forests, soil, water, air, and ecological and genetic diversity (Durning 1989, Ehrlich & Ehrlich 1970, Brown *et al.* 1984a-1994a). As the world approaches effective "fullness", the conventional economic development path has become self-destructive and a burden, particularly to the poor. Many scholars believe that continuing on this path might not only ultimately impoverish humanity but put at risk its very survival (Durning 1989, Ekins 1986 & 1992, Goldsmith *et al.* 1991, Gordon & Suzuki 1990, Meadows *et al.* 1992, Wolfgang Sachs 1992a & 1993, Shiva 1991, *The Ecologist* 22(4), Trainer 1989).

In 1987, with the release of *Our Common Future* by the United Nations World Commission on Environment and Development (WCED), discussions about the destructive social and ecological impacts of humanity's current approach to development became prominent on political agendas. The starting point for the World Commission's work was their acknowledgement that humanity's future is threatened. The Commission opened its report by declaring:

> We all depend on one biosphere for sustaining our lives. Yet each community, each country, strives for survival and prosperity with little regard for its impacts on others. Some consume the Earth's resources at a rate that would leave little for future generations. Others, many more in number, consume far too little and live with the prospects of hunger, squalor, disease, and early death (1987:27).

To confront these challenges of excessive resource consumption and persistent social misery, the Commission called for *sustainable development*, defined as "...development that meets the needs of the present without compromising the ability of future generations to meet their own needs..." (1987:43). In other words, the conventional economic development imperative of maximizing economic production must be reoriented toward minimizing human suffering today and in the future. This depends, on the one hand, on reducing ecological destruction -- mainly through lowering the resource throughput that the human economy draws from nature -- and, on the other hand, on improving many people's quality of life.

How to meet the challenge of developing sustainability[2] has stimulated much academic and political debate. Expressions of this growing interest in sustainability issues have been

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[2] In this thesis, I use the expression *"developing sustainability"* rather than *"sustainable development"* because development is often confused with growth (Daly 1991:243, Kumar *et al.* 1993:3). This becomes particularly evident when some people as William Reilly (1994) advocate "sustainable growth." Also, Brian Burrows *et al.*, in their otherwise well-informed book, write that "... the emphasis shifted from advocacy of zero growth to a recognition of the need for *sustainable development*, which would include some economic growth, but in a pattern sufficiently well balanced to minimise environmental damage and eventually to avoid the depletion of non-renewable natural resources..." (1991:9). However, as pointed out later in this thesis, developing sustainability might require a *reduction* in aggregate economic production, while at the same time providing *more* consumption to the poorest. Further, the depletion of renewable resources might be a more serious limitation than the depletion of non-renewable resources.

Also, the term "sustainable development" is semantically ambiguous: it could refer to the necessity to live sustainably (a state), to the process of getting there (a process), to the current unsustainable lifestyle (problem), or to strategies to solve the crisis (solution). Therefore, debates about "sustainable development" can be confusing since objections could be interpreted as disagreement with the problem definition, the proposed solutions, the goal of sustainability or the process of getting there. As discussed in Chapter II, there is little disagreement on the problem, but much on how to address it.

international events such as the 1992 UNCED - "Rio Conference" (United Nations Conference on Environment and Development, Rio de Janeiro, June 3-14, 1992) ; national and provincial activities such as Round Tables and government-sponsored research initiatives; and local initiatives in schools, municipalities and businesses. However, there is little common understanding across the various academic disciplines on how sustainability can be developed (Folke *et al.* 1994), and there is little indication that current sustainability initiatives are effective at reversing the ecological and social trends. On the one hand, human use of nature apparently continues to exceed global carrying capacity (nature's renewable productivity). On the other hand, social health, as indicated by a sharpening of economic and social polarization, is deteriorating, locally and globally (Kaplan 1994, Pimentel & Pimentel 1994, Postel 1994, Brown 1994, Brown *et al.* 1992b). One deficiency of current sustainability initiatives is the lack of accepted monitoring tools to measure progress toward sustainability; another is the poor public comprehension of the sustainability crisis (Peat Marwick 1993b). Without a clear and generally accepted framework of basic criteria for sustainability and without popular support, sustainability initiatives are without direction and fail to move industrial society towards critical social and ecological objectives. Therefore, planning tools which can be used to raise public awareness of the issues and dilemmas, measure progress towards sustainability, and direct action, could make an important contribution to the development of sustainability.

B. THE PURPOSE OF THIS THESIS RESEARCH

The purpose of this thesis is to further develop and test a planning tool that can assist in translating the concern about the sustainability crisis into public action. As a planning tool for conceptualizing and developing sustainability, the concept of "Ecological Footprint" or "Appropriated Carrying Capacity" (EF/ACC) is proposed.

EF/ACC is a simple, yet comprehensive tool: it provides an accounting framework for the biophysical services that a given economy requires from nature. It is calculated by estimating the land area, in various categories, necessary to sustain the current level of consumption by the people in that economy, using prevailing technology. An economy's full Ecological Footprint would include all the land whose services this economy appropriates from all over the globe to provide necessary resource inputs and to assimilate corresponding waste outputs. The EF/ACC concept thereby demonstrates the ecological dependence of economic systems. It is both an analytical and heuristic device for understanding the sustainability implications of different kinds of human activities, and serves as an awareness tool and an action-oriented planning tool for decision-making towards sustainability.

The EF/ACC concept builds on the human carrying capacity debate (e.g., Meadows *et al.* 1972, Vogt 1948, Ehrlich 1982, Pimentel & Pimentel 1990, 1994, Pearce & Barbier *et al.* 1991:114-127, Buitenkamp *et al.* 1993, Postel 1994), and originates in the teaching and research by Prof. William E. Rees, and later by myself, at The University of British Columbia (Rees 1978, 1986, 1992, Cousins & Wackernagel 1991, Wackernagel 1991, 1992, 1993a [see copy in Appendix 3.3], Wackernagel & Rees 1992, Rees 1992, Rees & Wackernagel 1992, Wackernagel *et al.* 1993).[3] The concept has already found many applications (including Wada 1993, Beck 1993, Harrington 1993, Parker 1993, Commonwealth Forum 1994, Davidson & Robb 1994, ESSA 1994, Maguire *et al.* 1994, Neumann 1994, UBC Task Force 1994, Zürcher 1994).

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[3] Related concepts include "Environmental Space" by Maria Buitenkamp *et al.* from the Dutch *Friends of the Earth* (1993), Jim MacNeill *et al.*'s "shadow ecologies" (1991), William Catton's "phantom carrying capacity" (1980), Borgstrom's "ghost acreage" (1965), Ragnar Overby's "carrying capacity demand" (1985), and William Rees' "regional capsule" (1986) and "personal planetoid" (1992c).

C. STRUCTURE OF THE THESIS' PRESENTATION

Developing a planning tool requires tasks such as: identifying and conceptualizing the sustainability problem; distilling key issues and mechanisms; clarifying and making explicit the personal motivations; values and working assumptions; identifying possible strategic intervention points; testing conceptual approaches; and then consolidating and refining them.

Therefore, before discussing the EF/ACC concept, I propose a problem statement in *Chapter II* which exposes the concerns that motivated this research and provides some context about the issues. I also explore the sustainability crisis and five of its major facets by reviewing definitions of, and perspectives on, sustainability from the literature. Particular, the "constant natural capital" principle as the ecological "bottom-line" requirement for sustainability is emphasized, while acknowledging that it is difficult to measure this capital. I also discuss socioeconomic, political, epistemological and psychological conditions for moving toward sustainability -- and analyze their implications for new planning tools.

To achieve my overall research purpose of further developing and testing a tool for planning toward sustainability, I divide it into four research objectives which are explored in the subsequent chapters. They are:

- to introduce and describe EF/ACC as a new planning tool for developing sustainability, and then to discuss its rationales and to review its intellectual context *(Chapter III)*;
- to develop a calculation procedure for concrete EF/ACC applications (*Chapter IV*);
- to apply the concept to the Canadian context and list other EF/ACC applications that have been or are being completed (*Chapter V*); and,
- to explore empirically how useful administrators and planners, business people and economists, and community activists and local politicians perceive the EF/ACC tool to

be when planning toward sustainability (*Chapter VI*).

Finally in *Chapter VII*, I draw the conclusions from the research findings and explore the findings' implications for planning.

D. SCOPE OF THE STUDY

Rather than discussing paths and strategies for developing sustainability, I explore in this thesis the usefulness of one particular tool for planning toward sustainability which could stimulate the sustainability debate, help develop strategies, and evaluate their effectiveness. EF/ACC has further evolved in the context of the work with the UBC Task Force on Planning Healthy and Sustainable Communities and their engagement with various municipalities and community groups. Also, the EF/ACC tool is meant to be applied in conjunction with other sustainability tools and processes such as for example the "Social Caring Capacity" concept that is being developed by some members of the UBC Task Force (1994, Aronson & Charles 1993). The activities and concepts of the Task Force are documented by the UBC Task Force (1994), Janette McIntosh (1993), Bob Woollard (1994b), and me (1993a, 1994). For the purpose of this thesis, I focused the research on the EF/ACC tool, its applications and its perceived usefulness.[4]

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[4] The UBC Task Force, composed of Peter Boothroyd (School of Community and Regional Planning), Lawrence Green (Health Promotion), Clyde Hertzman (Health Care and Epidemiology), Judy Lynam (Nursing), Sharon Manson-Singer (Social Work), Janette McIntosh (Task Force co-ordinator), William Rees (Co-Chair, School of Community and Regional Planning), Robert Woollard (Co-Chair, Family Practice), me (and more recently Alec Ostry and Mike Carr), started from the acknowledgement of the two key sustainability imperatives, namely the need:

a) to reduce society's (material) draw on nature, and

b) to improve society's quality of life,

and maintains that only those policies and projects that satisfy these two imperatives move us toward sustainability. Sustainability imperatives refer to the goals that initiatives or activities have to meet in order to be sustainable. The sustainability conditions, outlined in Chapter II, suggest characteristics for such initiatives that seem necessary to meet these goals: the political, epistemological and psychological conditions address the process side, while the ecological and socioeconomic conditions encompass the substantive aspects. In this thesis, I addressed mainly the first sustainability imperative.

The thesis documents one EF/ACC application that estimates the land appropriation of human consumption. Land (or ecosystems) were classified into eight land-use categories, while consumption was divided into five main consumption categories. The application relies on a simplified operational definition which permits the assessment of EF/ACC's magnitude rather than documenting the land appropriation with a percentage precision. The key is to emphasize the conceptual accuracy rather than precision in measuring the material draws on nature.[5] In the application (Chapter V), I calculated the EF/ACC example from a consumption perspective only, and used secondary data for calculating land equivalencies of consumption patterns. However, other EF/ACC application which have been completed, or are in progress, are briefly discussed too.

For exploring the tool's usefulness to the public, I conducted 21 in-depth interviews. They do not provide statistical evidence of the EF/ACC tool's public acceptance, but document the reasoning and understanding by a variety of actors in the public domain, and uncover themes and patterns that influence the psychological predisposition of these actors to plan toward sustainability. Such information is significant when testing the usefulness of the tool because it helps to identify limitations for planning toward sustainability and possible improvements of the EF/ACC tool for more effectively addressing these limiting factors.

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[5] "Accurate" refers to pointing in the right direction (or securing a consistent mean), while "precision" alludes to good reproducibility of the results (or displaying a low variance -- independent of accuracy). To take the metaphor of a gun, accuracy refers to how close the centre of the bullet-holes' cluster comes to the target, while precision indicates how dense the cluster of the bullet-holes is, regardless of the cluster's location to the target. For example, the Gross National Product (GNP) is a very precise tool and can be reproduced within a small margin of error; however, it is inaccurate as a tool for measuring national income because many activities and services, such as informal work or loss in ecosystem assets, are not included in the calculation.

E. SIGNIFICANCE OF THE STUDY

EF/ACC is a new ecological-economic tool which goes beyond comparable approaches. It draws on an over 200 year-old tradition of human ecology, including newer fields such as energetics, environmental planning, impact assessment, resource management and ecological economics, but moves further in that it:

a) reinterprets the carrying capacity concept as land per capita necessary to sustain an individual's throughput ("demand on nature"), rather than as capita per land ("supply of nature");

b) connects all competing uses of nature by translating them into exclusive land-uses as land represents a limiting factor for nature's productivity. For many uses it identifies bio-chemical energy (and the land needed to generate it) as the limiting factor for the human economy. Using such a common ecological "yardstick" makes it possible to aggregate human uses of nature including appropriated biological productivity, consumed fossil energy, absorptive capacity, and overtaxed water sources;

c) addresses cumulative impacts rather than focusing on fragmented events;

d) translates the results into (industrial) land-uses all over the globe, thereby linking global (macro) concerns related to the sustainability crisis with individual and institutional (micro) action;

e) develops (i.e., applies and quantifies) this concept into a comprehensive tool for a variety of planning tasks including communication, education, assessments, evaluations, comparisons, design, and decision-making; and

f) examines and challenges the publics' perception of sustainability and lacking support for action by using an heuristic approach.

II. THE SUSTAINABILITY CRISIS: EXPLORING ITS FACETS AND LINKING ITS THEMES

The World Commission on Environment and Development's opening statement revealed many fundamental concerns about the current human condition (1987:27). It acknowledged that humanity is not living within nature's productive capacity, thereby gradually destroying it. It also concedes that many people's basic needs are still not being met. These concerns reflect the crux of the sustainability crisis. According to the *Collins Dictionary*, a crisis is "...a situation where something, such as your confidence in someone or something, is so heavily attacked or questioned that there is serious doubt whether it will continue to exist..." (Sinclair 1987). I argue in this chapter that there is serious doubt whether those societies with high-consumption lifestyles, as enjoyed in industrialized countries over the last fifty years, will be able to maintain their current consumption level, and whether the less industrialized countries will be able to emulate the lifestyle of industrialized countries, as promised by the conventional economic development paradigm -- and analyze the implications for planning tools.

Even though human activities have ecologically "filled" the entire world, industrial societies still operate in an "empty-world" mode (Daly 1991, Meadows *et al.* 1992). Conventional economic development strategies continue to promote expansion of human activities in order to combat poverty and to tackle other social and ecological problems, many of which are actually caused by the prevailing approach to development. This expansion-oriented economic development approach is supported by most governments, by the economic branches of organizations such as the World Bank or the Organization for Economic Co-operation and Development (OECD), and even by sections of the World Commission's report (WCED 1987:213-215).

On one level, a large percentage of the people in the North and South know about the destructiveness of the current development path. For example, a comprehensive Gallup study directed by Riley Dunlap and conducted in 12 Northern and 12 Southern countries, documents the widespread concern about the future of humankind (Dunlap 1993). But this widespread concern is not translated into the action necessary to reverse the ecological trends and to improve the less fortunate people's quality of life. The lack of political action cannot be attributed to any shortage of adequate information. In fact, over the last quarter of a century, scholars, NGOs, and politicians have consistently used the same set of arguments to warn about the human predicament.[1]

Clearly, we need planning tools that go beyond delivering information in order to bridge the gap between mere concern about the sustainability crisis and effective political action. As stated, exploring such a planning tool is the purpose of this thesis. However, before addressing my main research objectives, I discuss the concerns that motivated and directed this research and explore the sustainability crisis through its ecological, socioeconomic, political, epistemological, and psychological aspects.

A. WHY WORRY? EXAMINING THE SUSTAINABILITY CRISIS

An average person from the industrialized world does not experience the immediacy of the sustainability crisis. This person typically shops in supermarkets overstocked with an overwhelming variety of goods, and watches television ads which show the newest, and

[1] Examples are: organizations such as Club of Rome or Greenpeace; reports such as *The Global 2000 Report* (Barney 1980) or *The Ecologist*'s *Blueprint for Action* (1972); conferences such the 1972 UN Conference on the Human Environment in Stockholm (UNCHE 1973), or the second conference on Environment Futures in Reykjavik in 1977 (Polunin 1980).

technologically most advanced cars dashing through lush and unpopulated landscapes. Not only is the abundance of goods overwhelming, but so is that person's purchasing power. For example, the average Canadian's income could buy over 200 times more food than he or she requires[2] -- which translates into a high level of consumption. However, sustaining such high levels of consumption has had detrimental effects: global resource stocks are being used faster then they can replenish themselves. This imbalance characterizes the *ecological crisis*.

In the meantime, poverty remains rampant. One third of the global population lives in absolute poverty (UNDP 1993:12). As discussed below, some scholars even argue that prevailing development programs have generally increased, rather than curtailed, poverty (even in the case of some low-income countries with rapid economic growth rates). The persisting poverty exemplifies the *socioeconomic crisis*. On the whole, local and global political institutions have not been successful in counteracting these trends, and future political breakthroughs in this area do not look promising. While some maintain that government institutions are a part of the problem, and that deregulation and structural adjustment would be a positive step toward sustainability (Block 1990), many others insist that effectively addressing the above crises demands the leadership of global institutions and the establishment of international agreements (WCED 1987, MacNeill 1991:74-128). It is not clear whether global economic integration strengthens or detracts from such aims. While globalization has improved communication links and stimulated economic growth, it has weakened the political institutions of nation states and

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[2] As a rough estimate: in 1991, the average Canadian earned approximately 20,740 [$US GNP/cap/year] (World Resources Institute 1994:257). In the same year, wheat prices were at 0.140 [$US/kg] (World Resources Institute 1994:262). Therefore, the average Canadian income could buy 20,740 / (0.140 * 365 [days per year]) = 406 [kg/day]. One kilogram of cereals corresponds to more than a person's daily food energy requirement (13,000 [kj/cap/day]) -- hence the average income would buy 400 times the calorie requirements for food. For a more protein rich diet like soybeans, that person could buy about 230 [kg/day], each kilogram containing approximately 220 [g] of proteins and 12,000 [kj] of available energy -- or over 200 times the daily requirements (World Resources Institute 1994:262, de Looy 1987:136 {data for dry beans}).

regional governments, thereby reducing government's potential policy choices -- a dilemma identified as the institutional or *political crisis*.

Most public science institutions, which are viewed as the official "sensory organs" of industrialized societies, have been hampered in their efforts to apprehend these crises, let alone deal with them. Science's industrial successes have fortified those parts of the scientific enterprise which concentrate on narrow and marketable studies while compromising on inquiries dealing with more encompassing concerns such as the ecological, social, and political crisis. Science's limitation is summarized as the *epistemological crisis*. In spite of the limitations of scientific inquiry, individual citizens can sense these crises all the same. Too often, however, they are unwilling to fully acknowledge them or to take appropriate action. These psychological barriers are referred to as the *psychological crisis*. In this section, I explore these five facets of the sustainability crisis. For each facet, I describe the key symptoms and trends, and assess the success of current public action to counteract these trends.

1. THE ECOLOGICAL CRISIS

The global ecological crisis is deepening. The trends paint a clear picture. Since 1984, the global fish harvest has been dropping, and so has the per capita yield of grain crops (Brown 1994:179-187).[3] Also, stratospheric ozone is being depleted; the release of greenhouse gases

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[3] The literature is not conclusive about whether the decrease in per capita grain production over the last 10 years is a long-term trend. Data from the World Resource Institute between 1970-1990 are consistent with Brown's 1950-1993 time series which show a decrease in average per capita productivity of food after 1984 (World Resources Institute 1992b, Brown 1994:186 based on USDA data). However, John Bongaarts is optimistic about the future of grain production, and claims that feeding a growing world population is technically feasible (1994:36-42). However, the "...economic and environmental costs incurred through bolstering food production may well prove too great for many poor countries. The course of the events will depend crucially on their governments' ability to design and enforce effective policies that address the challenges posed by mounting human numbers, rising poverty and environmental degradation..." (1994:42). In contrast, plant physiologist William Paddock believes that population growth rates are underestimated, while progress in plant productivity is overstated resulting in misguided optimism (1994:52-65).

has changed the atmospheric chemistry and might lead to climate change; erosion and desertification is reducing nature's biological productivity; irrigation water tables are falling; contamination of soil and water is jeopardizing the quality of food; other natural resources are being consumed faster than they can regenerate; and biological diversity is being lost -- to reiterate only a small part of a long list (Brown *et al.* 1984-1994, Burrows *et al.* 1991, Chiras 1992a, Clark & Munn 1987, Corson 1990, Goodland 1991, Myers 1984, and *Scientific American* September 1989). These trends indicate a decline in the quantity and productivity of nature's assets, or, in the language of Ecological Economists, the depletion of "natural capital" (Jansson *et al.* 1994).

At the same time, the human population and its demands on nature are growing. Between 1950 and 1990 alone, the industrial roundwood harvest doubled, fish catches increased five fold (and fell since 1989), water use tripled, and oil consumption rose nearly sixfold (Postel 1994:7, Brown 1994:179).[4] While human demands are growing exponentially, nature's sustainable productive capacity is in decline. These opposing trends show how human consumption has come to exceed the global productive capacity of nature.[5] Harvesting in excess of nature's productive

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[4] Donella Meadows *et al.* compare the increase of various human activities between 1970 with 1990, and document in most cases a doubling. For example, the world population grew from 3.6 to 5.3 billion, registered cars increased from 250 to 560 million, energy consumption nearly doubled, truck transportation in OECD countries more than doubled, and waste generation in OECD countries increased by 40 percent (1992:7). For statistical surveys on human activities (including resource harvest) and nature's productivity see Worldwatch (Brown *et al.* 1992b, 1993b), World Resources Institute (1986-1994), United Nations Human Development Report (1990-1994), World Bank (1978-1993). Other sources include the International Labour Organization (ILO), the Organization for Economic Co-operation and Development (OECD), the UN Food and Agriculture Organization (FAO), the Population Reference Bureau, and the United Nations Environmental Programme (UNEP).

[5] According to my preliminary calculations, today's human requirements in three of nature's main functions alone, namely food, forest products, and CO_2 sequestration, already exceed terrestrial carrying capacity by nearly 30 percent (see Chapter V). Also, marine carrying capacity is now fully occupied by human demands: the current global fish harvest has reached (and since 1989 fallen back from) the Maximum Sustainable Yield as estimated by FAO (in Brown 1994:179). However, according to the United Nations Industrial Development Organization (UNIDO), with current population levels the world industrial output would have to be increased by a factor of 2.6 if consumption of manufactured goods in developing countries were to rise to current levels in industrialized countries (WCED 1987:213).

capacity is possible only temporarily, at the cost of drawing down nature's assets and weakening its regenerative capacity.

Even though there is wide acknowledgement of, and concern about, the growing human demands on a limited and already overtaxed planet (Dunlap 1993), there remain some scholars who claim that this is a fabricated concern.[6] The main arguments they bring forward include:

- *the assertion of infinite substitutability*. Economists Bruno Fritsch holds that resources are a reflection of knowledge, while George Gilder maintains that resources are "...a product of the human will and imagination..." (Fritsch 1991:299, Gilder 1981 cited in Daly & Cobb 1989:109). Similarly, H. Goeller and Alvin Weinberg's biophysical resource assessment, titled *The Age of Substitutability*, argue that "...most of the essential resources are in infinite supply: that as society exhausts one raw material, it will turn to lower-grade, inexhaustible substitutes..."[7] (1976:683). While this may be true for some specific industrial inputs, such as copper which is being replaced by glass fibres, substitutability does not work for most ecological services on which human activities depend. A major flaw in these assertions about substitutability is their ignorance of

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In fact, using Daly's simplified model of global income distribution (15 % of the world population makes on average $21,000 per capita and year, the other 85 % only $1,000 [1993:54]), the required increase would rather need to be 5.3 times larger.

[6] Most of the scholarly disagreement about "sustainable development" is not so much about the symptoms of the crisis, but rather about the strategies on how to achieve it. For example, strategies are proposed to *advance* or *reverse* economic deregulation, technological efficiency, global government, privatization, consumption taxes, or trade, to name a few.

[7] They also argue that humankind would need an inexhaustible energy source such as nuclear fusion, breeder reactors or solar energy, and are positive that such sources can be developed.

human dependence on critical life-support functions of nature.[8] Human activities not only require minerals and other industrial resources, many of which are substitutable, but also renewable biological resources, waste absorptive capacity and numerous life support services for which there are no known or satisfactory substitutes. Finally, the second law of thermodynamics asserts that the biophysical availability of a resource is ultimately determined by the available chemical and thermodynamic energy (also called "essergy") of that resource rather than by human wants.

- *the belief that falling real prices indicate declining reduced resource scarcity* (Barnett & Morse 1963, Simon & Kahn 1984, Ozdemiroglu 1993 [in Pearce & Turner *et al.* 1993:6]), or that increased resource reserves would indicate reduced scarcity (Gee 1994, Fritsch 1991:101). There is strong evidence that prices reflect the scarcity of *neither* the biophysical non-marketed resources (Pearce & Turner *et al.* 1993:5) *nor* that of marketed resources.[9] Evidently, for essential process resources without a market, prices fail absolutely. Also, interpreting increases in economic reserves of non-renewable assets ignores the fact that the total stock is declining all the same, and that it may become

[8] Ignorance of what William Rees calls humanity's "...obligate dependence on nature..." (1990c) -- and in the crudest sense, on its bio-chemical flows -- is widespread in economics (see also Folke 1991). In fact, in most development oriented economics texts, nature's constraints are not even mentioned, with the exception of oil supply and prices. If "environmental concerns" are addressed, then it is only to point out that, building on economist Ronald Coase's approach for internalizing "social cost," environmental degradation is caused by lacking property rights (examples are Blöchliger *et al.* 1991, Bromley 1991, Giersch 1993:163-164, McKibbin & Sachs 1991, Jeffrey Sachs 1993). Economist Peter Kennedy argues that "...those presumed preferences [between which types of natural capital to conserve] are not consulted to examine the possibility that future generations may actually prefer substitution of manufactured capital for natural capital..." (1993:7). There are several problems with this statement. First, it does not recognize that natural capital is already in decline. Second, individual preferences and social preferences might fundamentally contradict as pointed out in the next section. And third, many essential ecological needs dependent on natural capital are not a matter of individual or social preference. For example, human bodies need *inter alia* 10,000 [kj] of healthy food per day, and that this is non-negotiable (Schmidheiny 1992:39).

[9] The section on the blindness of monetary analysis for assessing natural capital in Chapter III provides more discussion on this subject.

increasingly difficult to exploit the remaining stock for entropic reasons. In any event, focusing on marketed industrial resources is again a much too narrow interpretation of human dependence on nature, as pointed out above. Despite Marcus Gee's claim that "...by almost every measure, life on Earth is better than ever before..." (including rises in world GNP, total exports, adult literacy, food production in developing countries, and crude-oil reserves; 1994:A1,D1), there is no guarantee that these trends can be sustained -- particularly on a per capita basis -- nor is there indication that those most in need are benefitting from these increases.

- *charges of scientific fraud and misinformation* (Ray 1993)[10]. However, the claim that the use of probabilistic results amounts to scientific fraud is misleading. Science is by definition not able to predict conclusively events that cannot be replicated. Science can only interpret available data and test hypotheses to develop theory and explore probabilities. Refuting an argument on the grounds that the scientific evidence does not conclusively prove future effects is, therefore, merely a reflection on the limits of science, and cannot be interpreted as a negation of the argument.[11] In summary, these scholars' refutations of the ecological crisis are based on an incomplete model and partial analyses. Nevertheless, their argument enjoy much public and political support because they conveniently rationalize status quo and inaction.

The relationship between habitat productivity and population (including human population) has been a scientific topic for over 200 years (Martinez-Alier 1987). Biologists have

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[10] Particularly, the climate change debate has witnessed various books which deny the crisis from this perspective. Examples are Balling (1992) and Michaels (1992).

[11] This is further discussed in the section on the epistemological crisis.

documented that the population of most species examined levels out as their demands approach the productive capacity of their habitats (Krebs 1985:207-221). The upper limit at which the population can be sustained is referred to as the carrying capacity of the habitat (Kormondy 1969:66).

Invader species generally come to exceed the long-term available carrying capacity with consequent rapid population decline. William Catton calls this phenomenon "overshoot." A well-known and much cited example of overshoot is the introduced reindeer population on St. Matthew's Island which grew exponentially from 29 individuals to about 6,000 within nineteen years. Three years later, only 42 animals remained (Krebs 1985:221).[12] Alternatively, the carrying capacity of a habitat can change. Population sizes are subject to fluctuation due to climactically induced decreases in net primary productivity or limited absorptive capacities which give rise to pathogens (Krebs 1985:324-349, Fenchel 1987:19-23). Similarly, local human populations have frequently collapsed after overshooting their carrying capacity, or when resource (habitat) productivity has declined. The rapid population decline by at least one order of magnitude on the Easter Islands around 1680 (Catton 1993, Ponting:1992:1-7), plague waves in Europe[13] (Ponting 1992:228-232, Fenchel 1987:19-23), famines such as the Irish Potato Famine in 1845 (Paddock 1994:53-54, Catton 1980:247-250), the Chinese famine during the Great Leap Forward (1959-1960), and the chronic famines on parts of the African continent since the early 1980s are prominent examples of events where overshoot leading to disease, declining productivity, or other limitations on carrying capacity has contributed to human

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[12] Other examples of crashing animal populations are documented in Krebs (1985:221-223) and Stott (1994:66-69).

[13] For this decline, the limiting factor was not the available resources, but the insufficient human waste absorption. This same event could also be interpreted from the perspective of the pathogens: these pathogens invaded an area of abundant carrying capacity (dense human population). By killing their hosts off (and by their hosts acquiring resistance), the pathogens depleted their carrying capacity which resulted in the eventual crash of the pathogen population.

population collapses.

The situation today differs from these historic examples. Today, overshoot is occurring on a global scale, not just in isolated pockets of the world. One manifestation is the speed at which the globe is losing biological diversity as human beings appropriate a growing share of nature's primary productivity. Also unprecedented in human history is the yearly four percent growth in consumed goods and services over the last forty years (UNDP 1993:212, World Resources Institute 1992:246). While in 1950 there were still 3.6 hectares of ecologically productive land remaining per capita, less than 1.6 are left in 1994.[14] A global population of 10 billion - expected by 2030 - would leave humanity with only 0.9 hectares per capita, with some of it degraded.[15] This is one-fourth of the per capita area 80 years earlier (World Resources Institute 1992, Postel 1994:11).

Not many of the few countermeasures in place have been successful in addressing the conflict between increasing human demand and nature's supply. In spite of such widespread policy instruments as Environmental Impact Assessment and increasing use of environmental taxes and regulations, many important trends have not been mitigated. For example, in the two countries with arguably the most advanced environmental impact requirements -- namely, the National Environmental Policy Act (NEPA) in the USA, and the Environmental Assessment and Review Process (EARP) in Canada -- energy consumption is still on the rise, and resource

[14] See Chapter V.

[15] Over the last 45 years 1,964 million hectares of productive land were degraded, 30 percent of it through deforestation (Oldeman in Postel 1994:10). Similarly, the Union of Concerned Scientists claim that since 1945 eleven percent of Earth's vegetated surface has been degraded, which would correspond to over 1,200 million hectares, or "...an area larger than India and China combined..." (1992). Assuming continued yearly decline at the same rate, this would result in the degradation of another 900 to 1,500 million hectares or 12-20 percent of the remaining ecologically productive land.

depletion has not been curbed. The latter is evident in the North Atlantic collapse of the cod fish stock affecting the Canadian East Coast, and in the forest land-use conflicts everywhere on the North American West Coast.

No international efforts have been able either to gather the political momentum necessary to address the ecological crisis despite some partial international agreements on particular issues. Examples of those agreements: the 1989 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal; the Convention on International Trade in Endangered Species (CITES) from the 1970's, and more comprehensively, the 1992 Global Biodiversity Strategy; the 1992 UN Convention on Climate Change; and, the 1987 Montreal Protocol on the reduction of CFC and halon gases, with its 1992 London Amendment (World Resources Institute 1994:373-384, Environment Canada 1993, Corson 1990). In spite of this impressive list, ecological deterioration continues. While it might be argued that it is too early to measure significant improvements, there is much evidence to indicate that we would be unwise to rely on the promises of these agreements. Many sustainability concerns are not addressed by such agreements (including soil conservation, deforestation, resource consumption, and population), and many of the conventions lack rigorous standards, ratification or effective mechanisms to enforce them. Also, UN agencies such as the Food and Agriculture Organization (FAO) or the United Nations Environmental Program (UNEP) are limited to providing statistical and some consulting services -- rather than being more pro-active. Worse, in the case of the FAO, their promotion of monoculture, capital intensive agriculture, and export crops is considered counterproductive to sustainability by many scholars and development groups (*The Ecologist* 21(2)). UN sponsored conferences such as the UNCED conference in Rio de Janeiro (June 3-14, 1992), including its resolution (UNCED 1992), may have increased political awareness of the issues, but it is doubtful whether these events have developed effective responses (*The Ecologist* 22(3), 22(4), *New Internationalist* 246, Sachs 1993:6-66). Even the much-praised Montreal Protocol on the reduction of ozone-depleting CFCs is constantly jeopardized by circumvention (Meadows *et al.* 1992:141-160). One example which illustrates the circumvention of the Protocol was reported by *The Economist*, which stated that in December 1993:

> America's Environmental Protection Agency asked [Dupont] to continue [with their CFC production] in 1995. ... The EPA's concern with Dupont was that it might leave America's 140 million or so air-conditioned vehicles without CFCs. Car makers have found it hard to produce simple and reliable ways to refit old cooling systems to take substitutes. ... Another culprit may be some 10,000 tonnes of CFCs imported from Russia, supposedly to be cleaned up and returned, which is said to have found its way illicitly onto the European market (January 29, 1994:69).

In summary, ecological deterioration and the parallel growth of human activity mark a sharpening conflict. Many international and local efforts have tried to help mitigate this conflict without much effect; the gap between human demands and nature's supply widens.

2. THE SOCIOECONOMIC CRISIS

Even though aggregate global consumption has never been as high as today (and, as mentioned, continues to increase) poverty is not receding (UNDP 1993:149, Brown *et al.* 1992b:110-111).[16] Of the 5.7 billion people on Earth, over 1.1 billion people in the developing world are malnourished, i.e., they cannot afford the necessary daily level of calorie intake

[16] Detailed figures on the state of poverty in the world are hard to find. One reason is the difficulty of defining poverty (for example, the World Bank uses two benchmarks in defining poverty as a per capita purchasing power of less than $370 or $275 per year (1990:27)). Also, poor people work predominantly in the informal sector of the economy which lacks statistical assessments. Urbanisation and industrialization might also cause significant increases in monetary transactions, but it is questionable whether these changes translate into higher standards of living. Finally, the common monetary analyses of poverty on a country by country basis distort reality. They do not reveal distribution within the countries, and they are not sensitive to showing income increases of poor people, as their share of the GDP is negligible (the poorest quintile makes typically only 4 percent of the national income [Durning 1989:13]). In fact, a further polarization of incomes has been a general phenomenon in industrialized countries since the 1980s to the effect that the lowest quintile is worse off today than in the early 1980s -- not only in relative but also in absolute terms. It is therefore particularly disturbing that the *World Development Report 1990* of the World Bank which addressed poverty focused mainly on *per capita* GDP growth as a key strategy *and* main indicator for poverty abatement, while discounting their few head-count statistics on poverty even though they do not show a trend of poverty reduction in absolute terms.

required to function fully and in good health (Durning 1989). The poorest fifth of the world's population earns 150 times less than the richest fifth. In 1960, this relative difference in income was about half that ratio (UNDP 1993:11). Moreover, of the 1.1 billion people residing in industrialized countries, about 100 million live below the poverty line (UNDP 1993:13).

Areas of rapid urbanization are characterized by their high quota of poor people. Cities in Third World countries account for over 72 percent of the global population growth, and grow, population-wise, at about 4.5 percent per year (Leaf 1992). This means a doubling time of 16 years. By 2025, cities will house over 60 percent of the population in those regions, a trend which exacerbate current living conditions in these overcrowded environments (Laquian 1993).

Less than 60 percent of today's urban populations have access to adequate sanitation. Also, according to the WHO/UNEP Global Environmental Monitoring System, 20 out of 23 cities in developing country exceed the WHO air quality guidelines for suspended particles and sulphur dioxide emission (Laquian 1993). Waterborne diseases, smog, dust, leaching substances from hazardous waste, unsafe roads and utilities are a constant threat to urban populations leading to further impoverishment (Hardoy & Satterthwaite 1991, Leonard & Petesch 1990). Without radical improvements in education, health care and economic opportunity for the poor, these trends are likely to persist: the poor without education, health care and opportunities are impeding their own future well-being, being caught in a downward spiral of ecological destruction, high fertility, and health hazards (Leonard & Petesch 1990:37, Durning 1989).

Women bear the brunt of the problems associated with poverty. In 1970, the United Nations Commission on the Status of Women reported that women perform two-thirds of the work hours while earning 10 percent of global income and owning less than one percent of the world's property (United Nations 1970). Income figures, however, reflect only one aspect of poverty. Economic hardship is often accompanied by high mortality rates, diseases, illiteracy, and discrimination (Boucher 1992).

There is mounting evidence that conventional economic development efforts of the last forty years have not been effective in alleviating the plight of the poor, not even through "trickle down" effects.[17] In fact, an abundant literature blames conventional economic development for exacerbating poverty (Dube 1988, Durning 1989, Ekins 1986 &1992, Friedmann 1992, George 1984 & 1992, Goldsmith *et al.* 1991, Goodland & Daly 1993, Hadi 1993, Hayter 1985, Laquian 1993b, Meadows *et al.* 1992, Wolfgang Sachs 1992a & 1993, Shiva 1991, *The Ecologist* 22(4), Trainer 1989).

3. THE POLITICAL CRISIS

The rapid globalization of the world economy in the last few decades has transformed the balance of political power.Two major forces can be identified. On the one hand, the debt crisis has weakened many Northern and Southern governments (George 1992). At the same time, capital mobility has increased international tax competition and reduced the revenues of many governments. While mutual international dependence that results from global integration may reduce the danger of military conflicts, it also reduces choices in social, economic and ecological

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[17] Some possible exceptions in the South in which industrialization has led to two-digit economic growth rates include the Asian tigers, namely, Singapore, Hong Kong, Taiwan and South Korea now joined by the South of China, and Vietnam. The four Asian tigers have invested their increasing revenues in education thereby building an internationally competitive high-tech labour force (*Globe and Mail* June 4, 1994:A6). While some authorities praise the governments of these countries for their obsession with economic development and rapid modernization, others point out the irreversible social and ecological destruction that comes with it and that may ultimately outweigh the economic gains. Also, it is questionable whether these cases can be replicated by other countries. These "tigers" may just happen to be the winners of a negative-sum game in which those with the most resource-intensive high-tech economies do best, while others -- particularly those with low-throughput economies -- carry the burden (Bello & Rosenfeld 1992, Lohmann 1990, Sarangi & Sherman 1993).

policies. In particular, the global economy's "New World Order" has led to deregulating the economy and cutting back social spending in the North. Elsewhere, structural adjustment programs have been used to reduce public spending, open markets for transnational corporations (Bello & Cunningham 1994:87), and transform Southern economies into exporters of primary goods for industrialized countries. This further strains local social and ecological health and results in unilateral, rather than mutual dependence.

Clearly, these economic strategies have been successful in accelerating trade. In constant dollars, international trade increased fourfold between 1960 and 1988, and the value of all the currently traded goods corresponds to over 60 percent of the goods produced all over the world (World Bank 1990:185,189,205). As a result, production has become increasingly specialized and segregated, increasing many countries' dependence on trade relationships (UNCTC 1993). The opening of global trade is considered the key factor for the rapid and sustained economic growth over the last 45 years (Smith 1994). Indeed, it has been international and continental trade agreements such as GATT (1947 and subsequent rounds),[18] EEC, and NAFTA, the development of vast transportation and communication capacities, and the expansion of international currency markets that have made a global economy of this magnitude possible.

The abolition of the gold standard in 1976 has enabled unprecedented capital mobility. Today, daily currency trades exceed $1 trillion, or about 20 times the value added by the global economy in the same time period (*The Economist* March 27, 1993, Paul Kennedy 1993:51, World Bank 1990:183). This quantum leap in capital mobility has been a boost to those interested in international business operations and international investments, namely,

[18] For a discussion see *The Economist* (December 4, 1993:11,23-26).

transnational corporations and their shareholders. For instance, in 1990, only 56 countries were included in the world's 100 largest economies -- the other 44 were transnational corporations (calculated from UNDP 1993 and UNCTC 1993:26-27).[19] Yet, as ecological economist Stephan Viederman comments, the latter "...have none of the responsibilities of government for social welfare, education, health care and the like..." (1993:10).

The enhanced mobility of goods, capital, and business people has intensified the functional integration of territories, and has exposed economies to greater competition. The political downfall is that competition for taxes and concentration of financial strength in transnational corporations have weakened the negotiating and regulatory power of local, national and international political institutions. As a result, the law of the market ("one dollar, one vote") has gained influence at the cost of democratic principles ("one person, one vote").

The high mobility of financial capital has gained a momentum of its own, constantly refuelled by higher profit expectations.[20] To feed accelerating economic production, and to keep up with rising financial expectations, economies naturally expand their appropriation of nature's productivity, thereby depleting natural capital assets (Hall 1990). This increased pressure on biophysical resources has intensified social tension and international conflicts as exemplified by the continuous civil wars in West Africa (Kaplan 1994). Another example is the further damming of the Euphrates and Tigris rivers in Turkey to collect irrigation water, thereby

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[19] Furthermore, "...international trade of the 350 largest TNCs [or Transnational Corporations] accounts for almost 40 % of world merchandise trade...". Their sales add up to nearly one third of the combined national products of the industrialized countries (Daly & Goodland 1994:89, *New Internationalist* 1993, No.246. p18).

[20] Paul Kennedy observes that "...from one major exchange to another - Tokyo, Hong Kong and Singapore, London, Frankfurt and Zurich, New York, Chicago, Toronto - trading yen futures or General Motors stock goes on twenty-four hours a day and creates a single market..." (1993:51). However, more than 90 percent of the trading is unrelated to [merchandise] trade or capital investment (Paul Kennedy 1993:51).

reducing the water flow by about two thirds. If the project goes ahead -- and it has already been started -- this could inflame volatile conflicts not only between Turkey, Syria and Iraq, but also with the Kurdish people. In fact, according to Stephan Libiszewski from the Environment and Conflicts Project at the Swiss Federal Institute of Technology, the threat of reducing water flow has been used by the Turkish government to force Syria to relinquish their support for the Kurdish movement, and it is likely that Syria in return will use the Kurdish guerillas to retaliate against reduced water flow (1994:9). Many wars have been fought to secure oil supply, most recently, the 1991 Gulf War. Conflicts over biological resources are also on the increase. The struggles over fisheries around Iceland or on the East Coast of Canada (both having suffered from fisheries collapses which have not recovered yet), or conflicts over forestry practices all over the world including those in Brazil, India, Indonesia, Malaysia, and, much closer to home, in British Columbia, demonstrate the linkage between biophysical scarcity and social conflicts.

In the face of increasing resource competition, it is not surprising that military conflicts are still widespread -- despite the end of the "Cold War." According to the UNDP, over 60 countries are afflicted by internal conflicts, leading to over 35 million refugees in developing countries alone (1993:12). How biophysical scarcity translates into social conflicts is explained and documented by Catton (1980), Homer-Dixon (1993), Gurr (1985), Hall (1990, 1992), Kaplan 1994, and Ophuls *et al.* (1992). In fact, there is also a growing concern in UN agencies that the UN Security Council has not yet fully acknowledged non-military sources of instability such as poverty, overpopulation or degradation of ecosystems (*Globe and Mail* May 26, 1993:A8). Similarly, the root causes of these rising socioeconomic and ecological conflicts are still not being addressed. On the contrary, destructive modernization projects including damming and resource extraction still dominate development efforts and may well exacerbate social conflicts. Rather than adjust their development strategies, most governments rely on military power to keep the conflicts at bay -- often at tremendous human costs, as witnessed in Argentina, Chile, China, Indonesia, Iraq, the Philippines, Rwanda, and Turkey, to name a few. In particular, the Western world has demonstrated in the recent Gulf War a military superiority of such overwhelming proportions that the West's confidence in securing its global status through military force rather than through co-operation has been confirmed once more.

In summary, globalization has led to rapid growth in industrial production but may well have compromised local autonomy and jeopardized the social and ecological health of poorer countries. Through accelerated resource use, the potential for ecological conflicts increases, while it appears that the political institutions, as well as the community networks that could mitigate such conflicts, lose capacity and devolve. Increasingly, as economies turn more and more global, so more people will feel disempowered and become alienated. If these trends continue, decisions made in corporate headquarters and by consumers of their products and services will increase in importance compared to the formal political decisions. Also, corporate lobbying efforts within political institutions and through television might accelerate this trend. The lack of public involvement in long-range decision-making became particularly evident in the recent processes of formalizing free-trade agreements such as the Uruguay GATT agreement or NAFTA. All these agreements were arranged with minimal input from the public -- in spite of their far-ranging consequences. As long as governments persist in focusing on economic expansion, the range of possible political choices will narrow and the competition for declining resource stocks will intensify, thereby threatening geo-political stability.

4. THE EPISTEMOLOGICAL CRISIS[21]

"...We cannot regulate our interaction with any aspect of reality that our model of reality does not include because we cannot by definition be conscious of it..." commented Stafford Beer (1981). This self-referential trap is the crux of the epistemological crisis. It becomes increasingly doubtful whether dominant belief systems are adequate for addressing current socioeconomic and ecological issues. In particular, traditional science[22] and economic analysis, which are the socially accepted sensory organs of society, are incapable of comprehending the sustainability crisis (Capra 1982, Catton & Dunlop 1980, Colby 1991, Henderson 1991, Kassiola 1990:205,59-70, Maturana & Varela 1992, Milbrath 1989:115-134, Peet 1992, Reason & Rowan 1981, Rees 1990c, Rees & Wackernagel 1992:387, Steiner 1992 & 1993).

In public decision-making, traditional science (or rather the beliefs of scientific materialism) have become the dominant way of understanding issues and their context. The prominence of neo-classical economics in political decision-making serves as a perfect example of such scientific materialism. Also, at least in affluent countries, the public's faith in market-driven traditional science is alive and well. Many people believe that, through the use of science-driven technological innovations, humanity will always be able to defeat scarcity and ecological

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[21] When analyzing inquiry paradigms, Egon Guba and Yvonna Lincoln approach them in three subsequent steps. They ask the ontological question: "What is the form and nature of reality and, therefore, what is there that can be known about it?", the epistemological question: "What is the nature of the relationship between the knower or would-be knower and what can be known?", and the methodological question: "How can the knower [or would-be knower] go about finding out what he or she believes can be known?" (Guba & Lincoln 1994:108). Since I argue in this section that the scientific institutions have been unable to fully apprehend the ecological and socioeconomic crises, let alone deal with them, this issue falls mainly in the domain of the epistemological question. In fact, the essence of planning is the (epistemological) relationship between knowledge and action, to use John Friedmann's definition of planning (1987).

[22] In this context, I define "science" as systematic inquiry with transparent documentation. "Traditional science" refers here, more narrowly, to the not necessarily sequential process of identifying a clearly defined and testable question, pursuing this question in a systematic and replicable manner using quantifiable measures and statistical significance, and documenting the research process and findings in a logical order. In contrast, "scientific materialism" refers to the worldview which holds that eventually everything can be understood and mastered through scientific inquiry, and that only those things, which can be perceived by quantitative science, exist.

constraints. This belief in scientific materialism, industrial societies' implicit mainstream "religion", can be inferred from society's

- lack of alternative spiritual values or mythological beliefs (Berman 1989);
- emphasis on science which concentrates on "how" rather than on "why" questions (Berman 1981, Henderson 1977:304);
- notion that nature can be dominated and managed by "how" science (Berman 1981, Küng 1990, Milbrath 1989:1-6,17-35),[23] and with this, a wide acceptance of hierarchical androcentrism;[24]
- admiration or adoration of technological tools, and the "straight line" approach as manifest in current linear thinking, designing, managing and producing (Hundertwasser in Nørretranders 1991:466, Steiner 1993);
- pride in science's success stories, such as technological sophistication and progress, micro- and macro-space exploration, industrial mass-production and unprecedented military capabilities; and,
- promotion of an exclusive culture of professionalism (*Kettering Review* 1994).

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[23] Milbrath discusses four of the common arguments, namely "humans are clever", "we will develop unlimited energy", "markets will take care of it", and "[we can] maximize productivity from renewable resources" (1989:17-35). The debates on the ethics of genetic or nuclear technology provide good examples of some of theses arguments (Rifkin 1985). In fact, even the stewardship concept in environmental ethics is based on the principle that nature can be controlled by humans (Beavis 1991:77-81). A further discussion of the philosophical undercurrent of exploitative and instrumental relationship to nature is provided by Carolyn Merchant (1980, 1992).

An example of the view that technology and human inventiveness can continue to expand global carrying capacity is implied by the Vatican's position for the 1994 UN conference on population in Cairo. On the question of how to provide decent lives for a growing human population, rather than arguing for a radical redistribution of wealth, Bishop James McCue from the US stated in a radio program by the Canadian Broadcasting Corporation that similar to the past one hundred years, human inventiveness could increase nature's productivity (CBC 1994).

[24] This section starts from the premise that the shift from the egocentric or androcentric ("male-oriented") worldview to a truly anthropocentric perspective would already significantly contribute toward achieving sustainability. However, it might be quite conceivable that a sustainable society will adopt a more eco-centric perspective. For further discussion see also footnote 46 in this chapter.

At best, scientific inquiry is able to predict reproducible events. And this was the focus of classical science, such as Newtonian physics. For non-replicable events involving complex systems such as social or ecological behaviour, scientific inquiry can only explore probable outcomes, but never prove its predictive claims. Science's technological success, however, has fuelled the widespread public expectation that science can provide immutable answers to all challenges, for replicable events (or simple, defined and controllable "micro-realities" characterized by "mechanical" reproducibility)[25] as well as for less clearly defined and more complex issues concerning the human condition (or complex, open and undefined "macro-realities" characterized by uncertainty). In fact, many key issues about human survival, such as the long-term effect of ozone depletion, climate change, deforestation or destructive human behaviour can only be formulated as concerns. These concerns cannot be conclusively answered, but only explored through probable scenarios and simplifying models. To wait for conclusive scientific evidence before making decisions will, by definition, exclude all long-term concerns from the political agenda as such empirical evidence can only be gathered when it is too late. In other words, while science is effective and valuable when exploring concerns, it would be misleading or dangerous to wait for science to deliver definitive answers.

However, the worldview attributed to scientific materialism ignores the fact that, for macro-realities, science can only raise concerns and not answer them. In contrast, scientific materialism reflects the widespread faith in human ingenuity to manipulate and control the human condition. Science, from this perspective, is no longer a method or a collection of knowledge but, to use Lewis Mumford's words, it has become a "megamachine" (1967:199) far

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[25] And indeed, the scientific approach has led to incredible technological successes. *The Economist* identified the microprocessor, the birth control pill, the telephone network, the jumbo jet, the off-shore platform, the hydrogen bomb and the moon program as the seven modern wonders (December 25, 1993:47-51).

removed from what science purports to be.

As long as society believes that science, and particularly the more instrumental traditional science, is the only objective, systematic and comprehensive method of inquiry to generate universal knowledge, the utilized science becomes an instrument of power for those who control it. Furthermore, by excluding other approaches to knowledge, it makes society blind to many issues and impedes the debate about science's validity or limits. (Some debate on this issue can be found in the feminist critique such as Bordo 1987, Harding 1986, Keller 1985, and Merchant 1980, 1992; other aspects are presented by the socioecological critique which includes Capra 1982, Ellul 1990, Goldsmith 1992, Griffin 1988, Naess 1989, Reason & Rowan 1980, Roszak 1986, 1992, Steiner 1992, and Steiner *et al.* 1988).

When criticizing traditional science, Peter Reason and John Rowan identify 18 characteristics of the "scientific paradigm," including positivism, reductionism, quantophrenia (or focus on quantification), detachment, conservatism, bigness, low utilization, inaccessible language, cause-effect determinism, and "fairy tales" in textbooks on the characteristics of scientific research (1981:xiv-xvi). Instrumental rationality, and misleading objectivity are other characteristics that should be added to the list, which is discussed in the following paragraphs.[26]

Reductionism, or the belief that phenomena can be understood by dividing them into clearly defined observable parts, and which is driving traditional science has attracted severe

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[26] A comprehensive critique of mainstream science, and a discussion of alternative approaches to scientific inquiry is provided by Norman Denzin and Yvonna Lincoln's *Handbook of Qualitative Research* (1994) which contains contributions from over 30 leading social scientists.

criticism.[27] The strength of traditional scientific analysis lies in examining reproducible *specificities*, trying to infer some fundamental *universalities*, such as the Maxwell equations, the Newton equations, and other fundamental laws of classical physics. Such inquiries boil down to a search for the abstract and the pure, which explains some of the bias against relevant questions such as how to overcome the impediments to sustainability, or whether the current way of gathering knowledge is adequate to face the sustainability challenges. Both questions lack scientific legitimacy.

However, if society is to cope with the sustainability challenges, critical or socratic thinking is what is most needed -- not merely the accumulation of more bits of conventional scientific information[28] (Roszak 1986:216). Unfortunately, the traditional scientific approaches rooted in reductionism have a poor record of analyzing and recommending how to cope with a situation that cannot be completely understood. Evidence of the generation of specific information, which lacks a context, rather than of critical thinking on relevant issues, can be found in the vast majority of the many thousands of scientific journals to which the UBC Library subscribes. In essence, by focusing on unrelated, specific pieces that should eventually and hopefully add up to some fundamental universalities, traditional science cannot capture systemic *generalities*. For example, "the current development path is unsustainable" or "economic growth cannot be sustained" are statements which are not specific enough. Neither are they falsifiable and refutable through the study of isolated special cases. Therefore, they are not viable research

[27] Every inquiry involves the use of models or theories that simplify actual events or circumstances. Reductionism, however, is one particular way of simplifying through isolating particular aspects and systematically ignoring the significance of the linkages between the parts when analyzing an issue.

[28] Information, according to Claude Shannon *et al.*, is a quantitative concept related to thermodynamic entropy and can be measured in bits (1948 in Nørretranders 1991:56-62). This quantitative approach to information represents much of today's scientific output which is prolific, but increasingly devoid of understanding or meaning (Roszak 1986:13-14,156-176).

questions for traditional scientific inquires -- even though the overall social and ecological trends are evident, and even though pursuing such questions is fundamental for securing a healthy human condition.

Science's reductionism lends itself also to an incremental understanding, thereby losing the reference points. Slicing broad concerns into separate issues makes people blind to larger implications, and legitimizes piecemeal approaches. Those approaches quite possibly encourage disaster by seemingly insignificant increments. For example, while scientific research is successful in preparing for, and developing, industrial advances, traditional science practice is impotent to understand, or effectively to address worsening ecological and social trends. In fact, the technological knowledge, generated by traditional science, has made the social and economic world so complex that it becomes increasingly difficult to understand its dynamics. Therefore, the knowledge gap between what we need to know in order to effectively counteract the trends, and the kind of knowledge that is offered by the scientific enterprise, is growing rapidly (Elgin 1981:252-257). The International Society for Ecology and Culture states that [traditional]

> science gains its understanding of the world by isolating and studying small pieces of the interconnected continuum of nature. ... Modern technology is indeed able to manipulate the world to an almost unimaginable extent. When it comes to infinite complexity and long term frame of social systems or ecosystems, the limitations of science are particularly evident. Given these fundamental shortcomings, the status of science today is profoundly disturbing (Goldsmith *et al.* 1991:5-6).

Robert Ornstein and Paul Ehrlich believe that this focus on incrementalism and reductionism is linked to the way our minds function: slow changes, long-term implications and connections cannot easily be perceived by human brains (1990), a phenomenon called the "boiled frog syndrome." "...Frogs placed in a pan of water that is slowly heated will be unable to detect the gradual but deadly trend. ... Like the frogs, many people seem unable to detect the gradual but lethal trend in which population and economic growth threaten to boil civilization..." (Ornstein & Ehrlich 1990:74-75).

Particularly since World War II, social science has been characterized by *quantophrenia* where everything is reduced to numbers. Sociology research looks like a collection of linear regressions, and economics has become so mathematical that Elizabeth Corcoran and Paul Wallich asked in the *Scientific American* "... [are] economic principles simply obscured behind the mathematics -- or have they vanished?..." (1992:142). Economist Clifford Cobb comments that the

> tyranny of quantification leads society to conclusions about well-being which are surely wrong if one takes an overall reasonable view of the economic landscape. But such a view is precisely what is impossible because of the use of these statistical abstractions. This tyranny of quantification leads to another tyranny that shows in the epistemology that conventional economics uses. The tyranny of quantification leads to the tyranny of precision, objectivity and certainty, i.e., that of positivism. If you cannot measure it precisely in a numerical manner and with certainty, then it cannot be true (*The Human Economy Newsletter* 1992:1).

Also, traditional (and politically acceptable) scientific research and applications rely on clear *cause-effect* relationships, or linear causation. However, in macro-settings, which cannot be conclusively defined by an initial condition, cause and effect are often not distinguishable and can become meaningless concepts. In other words, by acknowledging only direct cause-effect relationships, traditional science's blindness to "chicken-and-egg" or systemic relationships becomes problematic as this blindness will conceal most critical social or ecological concerns.[29] In this context, examination of situations whose cause-effect mechanisms cannot be understood must be intensified. Clearly, philosophical debates on issues such as the precautionary principle seem to have contributed more useful guidance than traditional scientific inquiry.

The ideological mainstream of the scientific community has promoted a narrow concept

[29] A reaction to this fundamental shortcoming of traditional science is the systems thinking approach. Introductions to this epistemological approach can be found in Ashby (1956), Beer (1974), Boothroyd (1992b), Checkland (1990), Greene (1989), Hawryszkiewycz (1988), Macy (1991), Meadows *et al.* (1972, 1992), Miller (1978), Rapoport (1986), Senge (1990), Van Gigch (1978), Vester (1983), von Bertalanffy (1968), von Neumann (1944/53), Wiener (1950), and Wolstenholm (1990).

of rationality. For example, Graham Bannock *et al.* in their *Dictionary of Economics* define rational as "contain[ing] no systematic error" (1987:346). This definition hinges on its interpretation of "systematic." In economic theory, "systemic" typically refers to "internally consistent", while the assumptions (such as maximizing individual self-interest or "maximizing personal utility") do not need to be tested on external consistency. In other contexts (such as in engineering or traditional urban planning[30]), the word "systematic" seems to imply "approaches consistent with scientific materialism", while never acknowledging that the choice of the reference system determines the meaning of rational. Borrowing from traditional science, an interpretation of rationality based on self-centred scientific materialism has become a core concept of the industrialized countries' political discourse and a criterion for legitimizing goals and objectives. This particular rationality concept has proven to be highly effective in the industrial domain, but does lead to irrationalities and contradictions in the public domain from a social and ecological perspective. Such an instrumental approach to rationality (Kincheloe & McLaren 1994:140) facilitates the development of new devices, while being weak at addressing macro-realities. For example, those developments in science which try to mitigate the negative externalities (or additional costs that are not accounted for in the price and market system) of the global economy are outpaced by the negative impacts of economic expansion. Ironically, this economic expansion is stimulated by other scientific innovations, as evident with the new gigantic transport capacities and the powerful telecommunication networks.

With Francis Bacon's and René Descartes' proclamation that there was no contradiction between (instrumental) rationalism and empiricism (Berman 1981:14, Roszak 1986:212),

[30] For example, one of the *Canadian Institute of Planner*'s definitions states that "'planning' means the planning of the scientific, aesthetic and orderly disposition of land, resources, facilities and services with a view of securing the physical, economic and social efficiency, health and well-being of urban and rural communities" (CIP, Charter Bylaw, Final Proposal, September 23, 1986).

instrumental rationality became the new moral yardstick and the new "divine principle" to guide human beings (and, ever since, has been confused with reason). Philosopher Herbert Marcuse commented that the

> union of growing productivity and growing destruction; the brinkmanship of annihilation; the surrender of thought, hope and fear to the decision of the powers that be; the preservation of misery in the face of unprecedented wealth constitute the most impartial indictment - even if they are not the *raison d'être* of this society but only its by-product: its sweeping [instrumental] rationality, which propels efficiency and growth, is itself [socially and ecologically] irrational (1964 p:xii).

As noted, within the realm of traditional scientific inquiry, it is never acknowledged that "systematic" refers to a particular worldview or ideology; rather, it is silently assumed that scientific materialism (including individual self-interest) is objective or value-free. However, this claim to *objectivity* in science has been questioned by many scholars (Kassiola 1990, Milbrath 1989:132-136, Peet 1992:146-147). They conclude that a researcher's claim to be "value-free" is highly value laden and indicates that this researcher does not want to debate his or her assumptions (see also Mitroff in Reason & Rowan 1981:37*ff*).

A further obstacle to holistic research on (irreproducible, complex and uncertain) macro-realities is the politics of science funding which favours established reductionist disciplines. For example, evidence seems to suggest that traditional scientific institutions such as universities have avoided integrative (or truly interdisciplinary) research on macro-realities. In fact, in the case of sustainability, most of the literature, debate and studies seem to be generated by private or semi-private institutes,[31] or by dissident voices within mainstream organizations[32]

[31] Examples are the World Resources Institute, the Worldwatch Institute, Institute for Local Self-Reliance, Wuppertal Institute, Friends of the Earth, Elmwood Institute, Rocky Mountain Institute, Planet Drum Foundation, New Alchemy Institute, Carrying Capacity Network, David Suzuki Foundation, Öko-Institutes in Germany, Greenpeace, Sierra Club, International Union for the Conservation of Nature, World Wide Fund for Nature (WWF), and many other environmental organizations with research branches. In addition, there are many individual activists and writers such as Hazel Henderson, Barry Commoner (?), Wendel Berry, and Murry Bookchin. Also in Switzerland, most leading edge research on sustainability is conducted outside the universities. Examples are Ellipson, Öko-Zentren (Langenbruck and Schafweid), Infras, Arras und Bierter, Karthago, Verkehrs Club der Schweiz (VCS), Greenpeace, WWF Switzerland,

(Viederman 1994:7). The fact that scientific institutions primarily focus on micro-realities, rather than addressing the larger picture, would not be worrisome if society did not expect answers on macro-problems from these institutions. Certainly, it is true that many of these micro-reality studies which are embedded in a single academic discipline do not add up to an understanding of macro-realities, and are not even compatible with studies from other disciplines. In traditional academic institutions, there are few examples where natural science and social science are integrated. Witnesses are the rift between economics and human ecology; or the diverse academic fields which identify with an ecological approach, but where definitions of ecology are not only different but incompatible.[33]

In summary, rather than being just one tool for society to assist public debate and to contribute to public decision making, instrumental or traditional scientific analysis has become the undebated but dominant worldview and apologist for modern society's destructive expansionism. Thus, the weaknesses of the scientific process have become the weaknesses of public decision-making. The "megamachinery" of traditional science has become a paralysing political force which, by failing conclusively to prove complex issues, legitimizes inaction. The CO_2 debate provides a prominent example. As in so many other cases, the lack of complete scientific certainty supports the politics of "business-as-usual" rather than promoting precautionary action (Schneider in Reichert 1993:189).

Daniel Wiener, Kulturprojekt Silvania, Duttweiler Institut, Institut de la Durée, etc.

[32] Prominent examples of such voices are Herman Daly and Robert Goodland at the World Bank. Academics who work outside their job descriptions include Paul Ehrlich, Garrett Hardin, Franz Moser, John Peet, David Suzuki, and Robert Woollard; in Switzerland Jean Ziegler, Pierre Fornallaz, Hans Christof Binswanger, Theo Ginsburg (†) and Max Thürkauf (†).

[33] Many "ecological studies" from various disciplines either exclude human beings from the ecosphere (biological ecologists), do not acknowledge the humansphere as embedded in, and dependent on, the ecosphere (economists), or understand the "environment" barely as a socio-cultural construct (social scientists).

5. THE PSYCHOLOGICAL CRISIS

The psychologically rooted social behaviour is perhaps the most fundamental and influential barrier to sustainability.[34] However, the low number of scholarly publications concerning the psychological facet of the sustainability crisis suggests that it is a largely neglected area.

Two major psychological phenomena stand out. They can be summarized as the "active promotion" and the "passive tolerance" of the current condition. The active promotion includes the positive portrayal of unsustainable lifestyles through, for example, advertising (Durning 1992: 117-135). The passive tolerance is manifested in the social denial of the current crisis as evident in industrialized countries' perseverance in *planning for more* -- be it cars or economic growth -- rather than *planning for sustainability*.

The **active promotion** of unsustainable lifestyles shows many faces. It is reflected in the values of the dominant worldview which have been summarized under names such as scientific materialism, economic expansionism, Pareto efficiency fixation, frontier ethics, industrialism, individualism, or globalism (Catton and Dunlop 1980:34, Chiras 1992b:107, Colby 1991:193-213, Deveall & Sessions 1985:18,41-48, Kassiola 1990:205, Milbrath 1989:119, Peet 1992:16-26, Sachs 1988:33-39, Sbert 1992). These beliefs and values are promoted not only within many academic disciplines -- as commerce and economics -- but even more so through "fraudulent and incessant advertising" (Sale in Kassiola 1990:6, Ewen 1988). This becomes particularly evident when analyzing society's self-destructive "love for the automobile" (Sachs 1992b, Freund & Martin 1993, Nadis and MacKenzie 1993).

[34] Also, it might be interesting to analyze whether the rise in incidence of mental illness, drug abuse, physical abuse and suicide is a symptom of this psychological crisis.

Western-style billboards with English slogans have penetrated to every corner of the world. This consumer culture has been promoted particularly aggressively in Eastern Europe. As a result, waste production has increased by magnitudes rather than percentages. The promotion of cars has begun to undermine the energy efficient public transport systems. Also, the commercial success of heavily publicised Western packaged foods is destroying local food producers (Weller 1993).

Another factor in active promotion is television, which portrays the unsustainable lifestyle as a desirable and achievable dream for everybody. Apart from consumption-promoting commercials, of which the average North American has seen about 350,000 by age 20 (Wachtel 1989:287), also regular television shows re-confirm the desirability of lavish lifestyles, justify dreams of material wealth and glamour, and foster misplaced "Disneyesque" images of nature.[35] Commercial television rarely conveys any sense of limits or "enoughness", nor does it establish intellectual connections between issues, people(s) and ecosystems (Durning 1992, Mander 1991:75-96, McKibben 1992, Wilson 1974).[36]

On the other hand, abstraction of thought is hailed by intellectuals as a great achievement of Western civilization. This fascination with abstract thought and the contempt for the visual,

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[35] The magazine *Adbusters Quarterly* published by the Vancouver *Media Foundation* regularly features discussions on that subject. Also remarkable is their production of anti-television and anti-consumption spots for commercial television stations.

[36] Another aspect of television was envisioned by George Orwell in his novel *1984*. By separating people and providing simplistic fast-paced and emotional messages, television can feed into the politics of mistrust and hate, which undermines cooperative approaches. For example, in an article on television and fundamentalism, *The Economist* commented that "...print isolates individuals, sponsoring rational, dispassionate analysis, [whereas] spoken words [and television in particular] encourage group thinking, sometimes mob-thinking. ... Scholars offer many learned explanations [as to why religious enthusiasts can challenge social order and political power]. One that they largely neglect is the impact of audio-visual technology. The magic potency of the oral word and the encapsulated message by the visual icon are dethroning the written word..." (August 21, 1993:36).

which characterizes the academic community, has helped to create the context where commercial television is able to monopolize people's audio-visual experience. By not generating alternative (visual) visions, academia has missed the opportunity to challenge the television vision of consumerism, stereotypes and hate.

The active promotion of unsustainable lifestyles does not apply only to the industrialized world. In fact, Helena Norberg-Hodge, former Director of the Ladakh Project, identifies *psychological pressure to modernize* as the most important reason for the breakdown of traditional societies, and points out that this psychological dimension is a much neglected aspect in the development debate (Goldsmith *et al.* 1991:81).

The **passive tolerance** of ecological destruction and social malaise has been captured by different names. Some call it social, societal or shared denial. Others call this behaviour self-censorship, learned helplessness, ignorance, reality avoidance, alexithymia,[37] the mismatched "old mind", numbing,[38] self-deception, or the "unperceived realities of the consumer life" (Baron & Byrne 1987:132-139, Baum & Aiello 1978, Catton 1980:183-197, Chiras 1992b:95, Edelstein *et al.* 1989, Goleman 1986, Macy 1983, Ornstein & Ehrlich 1989, Wachtel 1989:48, Wolfe 1991).[39]

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[37] Alexithymia is a disorder which causes people to behave in a pre-programmed manner and take a cynical attitude toward wanted information, explored by David Wolfe (as one example) when analyzing executives' denial of unpleasant news about market developments (1991:40-44).

[38] In his preface to *Overshoot*, William Catton writes that "...my own exposure to population pressure, a major indicator of the common source of our mounting frustrations, has been sufficiently marginal and intermittent to permit me to see it in relief. Constant exposure to it would have prevented me (as it has prevented so many others) from seeing its real nature. Complete insulation from it would have precluded awareness and concern. Even with my advantageous situation, it took me years to see what I was looking at..." (1980:viii).

[39] It is surprising that there is little literature available on that subject. The few publications that address social denial, analyze group behaviours in controlled experimental contexts; fewer discuss non-experimental social crises such as the Holocaust or the threat of nuclear annihilation (Edelstein *et al.* 1989, Macy 1983, Suefeld *et al.* 1992:96-100). In fact,

Societal denial is widespread. One example is our blind faith in redemption through scientific progress. Another is "...the further development of entertainment industries based on reality-avoidance..." (Slaughter 1993). Also, it becomes evident in situations when the victims are blamed, as was done by IMF Managing Director and Chairman of the Executive Board, Michel Camdessus. He claims that poverty [and not the high consumption of industrial societies or the global economy], is the prime reason for environmental destruction (Camdessus 1992). A similar assertion can be found in the World Commission on Environment and Development's report which states that, "...the cumulative effect of [the poor's impact on the ecosphere] is so far-reaching as to make poverty itself a major global scourge..." (WCED 1987:28). More widespread is the addiction to the illusion of permanent economic and infrastructure growth (Chiras 1992b:95, Wachtel 1989:16-22,50, Sanders 1990, WCED 1987:213-215),[40] or the common response of not wanting to see the self-evident, as typified by flood victims all over the world who rebuild their homes in the same old place (Salholz 1993). "Accusing the Cassandras" is another variation on the theme (Ray 1993, Simon & Kahn 1984, and many critiques of the *Limits to Growth* report). Albert Hirschman writes that the

> "...denial of reality that is practised testifies to the *power* and *vitality* of the disappointment experience. We engage in all kinds of ingenious ruses and delaying actions before admitting to ourselves that we *are* disappointed, in part surely because we know that disappointment may compel us to a painful reassessment of our preferences and priorities..." (in Kassiola 1990:34)

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the UBC library on-line catalogue shows 23 entries under the subject heading "nuclear warfare -- psychological aspects." However, social denial in the context of the ecological crisis lacks discussion in the literature, even though the crisis is so tightly linked with individual behaviour. The foreword to the Touchstone edition of Goleman's *Vital Lies, Simple Truths* is one of the few exceptions (1986:11-14); another one is Sandra Postel's introductory chapter to the *State of the World 1992* called "Denial in the Decisive Decade" (Brown *et al.* 1992a). Clearly, research about the psychology of societal denial in the context of the sustainability crisis needs to be conducted urgently. At this point, we can only speculate whether such denial is rooted in ignorance, naive optimism, or suppressed knowledge, and whether it is individually or culturally rooted, etc.

[40] The current debate on replacing Vancouver's Lions Gate Bridge or the Greater Vancouver Regional District's *The Livable Region Strategic Plan* of 1993 typify such societal denial by not addressing sustainability implications of the presented choices.

In summary, it is widely acknowledged in academic literature that the current ecological decline is worrisome and the persistence of social misery in the world is distressing. Moreover, the dissenting voices are not able to dispel these concerns. However, it seems that mainstream science, our official sensory organ, is limited in its understanding and capacity to act upon these challenges. Further, there is much indication that a major stumbling block to action is the enormity of the issue which feeds in a sense of hopelessness, fear or denial. Effective action toward sustainability therefore requires, first. the establishment of the connections between the facets of the sustainability crisis, and second, to explore the mechanisms that have perpetuated unsustainable lifestyles.

B. MAKING THE CONNECTIONS: THE COMMON THEME OF THE SUSTAINABILITY CRISIS

It is widely acknowledged that the above facets of the sustainability crisis are tightly linked (Boothroyd 1992a, Brown *et al.* 1984a-1994a, Burrows *et al.* 1991, Chiras 1992a, Clark & Munn 1986, Corson 1990, Durning 1992, Kumar *et al.* 1993, *The Ecologist* 22(4)). For example, increased human demand can accelerate ecological deterioration, thereby exacerbating poverty. Poor people often economically depend on high reproduction rates which further entrenches poverty. Higher human demands and local ecological deterioration increase the dependence on carrying capacity of distant places thereby impacting the social and ecological fabric in other places of the world.

In fact, the facets of the sustainability crisis are not only linked, but they suffer from a similar dynamic, the "Tragedy of the Commons", or rather, to be more accurate, the "Tragedy of Free Access." Ecologist Garrett Hardin reiterated in 1968 the wisdom of Aristotle that, "...what is common to the greatest number gets the least amount of care..." (1973/1993:145). In contrast to Aristotle, he emphasized its tragic social implications. To illustrate how gains to the individual can ultimately be outweighed by the aggregate losses to society, Hardin uses an agricultural example. He compares the individual shepherd's benefits of increasing his or her herd size to the individual share of the resultant costs. Since the benefits will always seem greater to the individual shepherd, each has an incentive to add animals to the pasture, thereby ruining it by overuse (1973/1993:132). And, this tragedy is precisely the mechanism of the global ecological downward spiral.

However, as mentioned, the "Tragedy of the Commons" should rather be called the "Tragedy of Free Access." Hardin misinterpreted the historic meaning of "commons" in his classic analysis (as Hardin himself later acknowledged). He was not, in fact, describing a commons regime in which rights and authority are vested in members of the community, but rather an open or free access regime in which ownership and authority are vested nowhere (Aguilera-Klink 1994:223-227, Berkes 1989a [particularly Berkes & Farvar 1989], Ophuls *et al.* 1992:193, *The Ecologist* 22(4):127). Ironically, and as will be discussed later, Hardin advocated resolving the tragedy through a social contract, or by "...mutual coercion, mutually agreed upon...," to use his words, in itself a definition of a "commons" regime (Aguilera-Klink 1994:222-223, Berkes 1989b:85).

This "Tragedy of Free Access" is also widely discussed in various fields under different names. In 1950, researchers at the RAND Corporation described a similar phenomenon as the "Prisoner's Dilemma" which is now commonly discussed in game theory (Poundstone 1992). Economists refer to "externalities" and study their impact on market failures. Daly and Cobb also identify this tragedy as a key mechanism causing the sustainability crisis, but name it "pervasive externalities." However, as they point out themselves, "externalities" is a misleading term when describing vital issues such as the destruction of life-support services. They ridicule the concept, if used in the sustainability context, by calling it an "ad hoc corrections introduced as needed to save appearances, like the epicycles of Ptolemaic astronomy" (Daly & Cobb 1989:37,141-146). Some economists also call the "Tragedy" a "public good problem", and Michael Jacobs labels it graphically "Invisible Elbow" (1993:22). Common property management is studied by resource economists and scholars in resource management, and has got its own literature and conferences (Berkes 1989a).

The "Tragedy of Free Access" characterizes the mechanisms of the key conflicts in each facet of the sustainability crisis.

From the **ecological perspective**, this tragedy is particularly obvious. Maximizing the personal use of nature's services (including resource supply and waste assimilation) is beneficial to the individual, but can lead to an over-exploitation of nature which negatively affects society at large -- to say nothing of other species. Prominent examples of such negative impacts are the accumulation of greenhouse gases, the depletion of atmospheric ozone, the generation of acid rain, the decimation of whale populations, the overharvesting of fisheries with consequent collapses, and rapid deforestation. Natural capital stocks everywhere are drawn down and global absorptive sinks are filled to over-flowing (Rees & Wackernagel 1992). As humanity's levels of resource throughput are the product of population size and average per capita resource consumption, these trends are exacerbated by growth in both consumption and population.[41]

In effect, our global safety net is being shredded as the "Tragedy of Free Access" is played out on a global scale. All countries now face the same potentially limiting factors simultaneously (e.g., ozone depletion, exhausted fisheries, potential climate change) in a geopolitically uncertain world. In fact, the micro-economic conditions reinforce such unsustainable behaviour patterns as investment is directed into ventures that increase economic productivity, thereby closing a positive feedback loop (Wackernagel & Rees 1992).

From the **socioeconomic perspective**, the population crisis is a clear example of the "Tragedy of Free Access." In this case, the tragedy is not only manifest in the contradicting interests of individuals and society, but also in the conflict between various social groups and humanity as a whole. The first conflict between individuals and society is obvious. Reproductive decisions are taken by individuals, while the cumulative ecological and social effects of the aggregate population is carried by everybody, independent of their reproduction. Economic conditions might make it necessary for poor families to have a large number of offspring, even though this becomes a stumbling block for the wellbeing of their local society (Li 1992).[42] In fact, fast growing populations with over 50 percent of their people under the age of 15 will

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[41] This does not suggest that one percent growth in population has necessarily the same impact as one percent growth in consumption. One percent growth of an already high per capita consumption (or of an affluent population) has obviously a larger impact than one percent growth of low per capita consumption (or of a less affluent population). Also from an ethical perspective, growth of consumption for those with low consumption seems more necessary and defensible than growth in affluent consumption.

[42] In contrast, for affluent families, *low* reproduction rates might be economically beneficial: low numbers of offsprings help to maintain a high concentration of wealth and allow large investments into each offspring's education. Also, with increasingly long education spans, the time horizon for potential economic pay-back to the parents becomes so long that its net present value at the time of conception might be negligible in comparison to the investment costs of child raising.

never be able to afford effective health care or adequate education (Catley-Carlson 1994).

The affluent parts of humanity might have the means to help slow down population growth. They could provide funds for education, health care and social programs (particularly for women) (Burrows *et al.* 1991:321), but they might see reducing population growth as being in conflict with their economic short-term interests. This conflict between various social groups and humanity manifests various dimensions. For instance, in industrialized countries, people and governments seem less worried about local overpopulation than about the aging of their societies for fear of reduced pensions once they retire. Indeed, to keep their population younger, some industrialized countries even encourage local population growth. In addition, affluent sectors of society might perceive growing poor populations as an opportunity, rather than as a threat: poor people are a cheap source of industrial and domestic labour, as for example evident in many South East Asian countries (Hadi 1993), in the sex trade in Thailand (*The Vancouver Sun*, August 6, 1994:B2), and in the manual workforce of (sometimes illegal) immigrants in industrialized countries. At the same time, in the face of the unprecedented superiority of Western military power, these rising populations might not be seen as a serious security threat to high-income countries. This disincentive structure points toward another "Tragedy of Free Access" situation, in which those who have the means of making the changes are not willing to, thereby perpetuating or even exacerbating the human suffering of others.

From the **political perspective**, the "Tragedies of Free Access" phenomenon arises from the distancing between actions and their effects. The increased distance between action and effects, which handicaps corrective feedback, characterizes not only the globalizing economy but also the political decision-making within nation states.

In the political domain, most rights and responsibilities are separated. Not only in representative democracies, but also in direct democracies such as Switzerland, where those who vote are not always those who will carry the burden of the decision. This becomes particularly evident when local groups defend their own interests at the cost of other groups or parts of society (sometimes identified as the NIMBY syndrome). A local example are the residents of the neighbourhoods around the Arbutus corridor in Vancouver who oppose higher density for fear of increasing local traffic, thereby augmenting transportation pressures in the entire Fraser Basin. Another example are communities who oppose the treatment of hazardous waste, while not opposing the local production of such waste.

Military build-ups constitute another dimension of this "Tragedy of Free Access." In fact, much of the writing about the "Tragedy of Free Access" phenomenon was motivated by the Cold War grid-lock situation (Axelrod 1984, Poundstone 1992). Nevertheless, since the end of the Cold War, local arms races and trade in military equipment have continued to feed into this tragedy: those selling or operating this military equipment are hardly affected by the economic burden of arm races, or by the physical and psychological hardship of war, while the suffering is inflicted on others.

In the macro-economic domain, globalization has entrenched the "Tragedy of Free Access" as economic activities and their social and ecological impacts are further and further separated. The design, advertisement, production, distribution, consumption and disposal of products gets spread over countries, if not continents. Food products are no exception: "...One fourth of the grapes eaten in the United States are grown 11,000 kilometres away, in Chile, and the typical mouthful of American food travels 2,000 kilometres from farm field to dinner plate..." (Brown *et al.* 1991a:159). The social and ecological externalities that are consequences of the expanding global market -- such as rapid urbanization, pollution, or community breakdowns -- become pervasive. In other words, impacts are no longer locally confined but become systemic. This obscures the consequences and side-effects of most economic actions (Daly & Cobb 1989:141-146). The increased complexity of the global economy and the devolution of nation states make remedial action an ever bigger challenge.

From the **epistemological perspective**, the focus of generating knowledge which benefits a particular group rather than society as a whole (because such knowledge pays back those who financed the research) is another example of the "Tragedy of Free Access." While market-driven knowledge generation seems to be highly adaptive to individual economic needs and "wants", it also accelerates the expanding spiral of production and consumption. However, other concerns of humanity as a whole, such as ecological limits, social equity, community vitality or spiritual well-being, lose out. Since today's economic activities are dictated by those who introduce them first ("primacy of action"), society as a whole cannot decide on whether it wants these new technologies, but must bear the costs of its side effects (see also Steiner 1993:51). Examples include the introduction of nuclear power, genetic engineering, telecommunication and television, automobiles, video-games, the "Green Revolution", air traffic, and military technology.

At least since the end of the Second World War, under the leadership of the industrialized countries, economic research and technological breakthroughs in communications and transportation capacities have backed the globalization of a world economy. Economic agreements have consciously been put in place to accommodate economic and technological innovations in support of the globalization evident today. In consequence, aggregate economic production has skyrocketed, thereby accelerating resource consumption to such an extent that it has now exceeded nature's carrying capacity. In other words, the scientific model behind conventional economic development can be identified as a root cause of the sustainability dilemma (Peat Marwick 1993b, Chiras 1992a). In those cases where individual and societal interests are at odds, this instrumental approach will exacerbate the "Tragedy of Free Access" by amplifying selfish human traits such as greed and acquisitiveness.

Our scientific machinery has not been successful in addressing this crisis. Science's strength is its "micro" approach (i.e., developing specific, sophisticated, technological gadgets in a lab), while failing to address "macro" concerns (i.e., understanding the connected global issues, thinking about the implications of the "unknowability" of complex systems, or at least acknowledging the impossibility of ecological or global "management"). The scientific reductionist approach, in both analysis *and* application constitutes the epistemological dimension of the "Tragedy of Free Access" phenomenon.

From the **psychological perspective**, the "Tragedy of Free Access" becomes particularly apparent. On the one hand, individuals in today's Western society feel insignificant, overwhelmed and powerless when confronted with the global dimensions of the sustainability crisis. As the benefit of individual or even national sustainability efforts accrue to humanity as a whole, such action feels like martyrdom. Also, the globalizing cash nexus alienates and commodifies, thereby further separating the individual from a sense of community. On the other hand, the social and ecological crises are denied partly because the implications are too intimidating and require profound change in the way people live. Such change might require that the rich give up some of their material wealth so that the suffering of the poor could be mitigated and long-term productivity of nature would not be further compromised.

The emotion-laden environmental debates document the anxieties of people when faced with such fundamental dilemmas and challenges. The consequent knee-jerk reactions often lead to further protection of the immediate self-interests of a particular group while hindering co-operative behaviour, thereby exacerbating the conflict. Realizing the implications of the global issue can lead to despair and various forms of social denial. This translates into the low priority of sustainability issues on political agendas.

C. REACTING TO THE CRISIS: EXPLORING THE NECESSARY CONDITIONS FOR SUSTAINABILITY

So far, this chapter has discussed why humanity's current way of living is *not* sustainable. Building on the last section, I discuss what the characteristics or necessary conditions are for developing a sustainable way of life.

Sustainability is a simple concept: living with each other within the means of nature. This is the essence of WCED's widely accepted definition of this concept (1987:43).[43] But it is a startling, even alarming, concept - and that explains why progress is so slow. Sustainability shocks because it reminds the wealthy part of humankind of some bleak realities: the needs of the poor are not being met today and the current demands on nature are undermining the future capacity of nature to meet the needs of future generations. It is also alarming because it implies

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[43] This is also the underlying message of the 10 sustainable development definitions listed in Rees (1989) and the over 20 definitions listed in Pearce *et al.* (1989:Annex). And, there is much academic agreement on the symptoms of the crisis. However, interpretations of this message, or its implications for action, are contradictory (Lélé 1991). Sharachchandra Lélé acknowledges that these various interpretations are not caused by a lack of understanding the issues, but rather by the reluctance to acknowledge the implications of the underlying message (1991:618). In other words, and in contrast to the view that we are witnessing a "...clash of *plural rationalities* each using impeccable logic to derive different conclusions..." (Thompson in Redclift 1987:202), the deliberate vagueness of the concept is merely a reflection of the distribution of power in the political bargaining. It is not a manifestation of sustainable development's insurmountable intellectual intricacy (see also Milbrath 1989:323). "...Unless *we are prepared* to interrogate our assumptions about both development and the environment and *give political effect* to the conclusions we reach, the reality of unsustainable development will remain..." (emphasis added, Redclift 1987:204).

that the human race cannot continue on its current path: profound changes are required. In particular, high income earners in industrialized societies must significantly reduce their resource consumption and waste production if everybody is to be able to live decently.

In spite of the simple message carried by "sustainability", the concept suffers from semantic ambiguity stemming from the fact that it refers to a state as well as to a process (see also footnote 2 in Chapter I). On the one hand, it refers to a state in which human consumption does not exceed nature's productivity, and on the other hand, to the process of achieving this state. The first three facets of the sustainability crisis discussed above inform about the state of sustainability, while the last three indicate conditions for the development of sustainability.

As explained later in this section, the state of sustainability depends simultaneously on the health of three spheres (Figure 1.1). These spheres are:

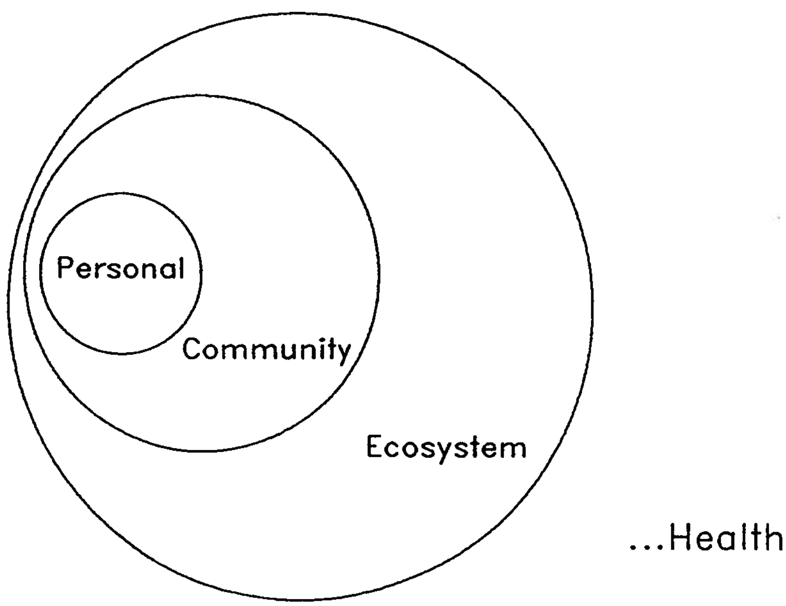

Figure 1.1: **Three spheres of health**
Personal health is embedded in community health, which is embedded in ecosystem health. (Source: UBC Task Force 1994).

a) *Ecological health*: Using of nature's productivity without damaging it (ecological condition for sustainability).

b) *Community health*: Fostering social well-being through the promotion of fairness, cooperation, inclusion, equity, and connectedness (political condition for sustainability).

c) *Individual health*: Strengthening individual well-being through the provision of food, clothing, shelter, education, health care, leisure and so forth (socioeconomic condition for sustainability) (Wackernagel 1993a).

To develop sustainability, society needs tools to understand and communicate about the sustainability challenges (epistemological condition for sustainability). It must acknowledge and accommodate the debilitating fear of change (psychological condition for sustainability) and finally, devise decision-making processes that include people and re-establish the links between rights and responsibilities (political condition for sustainability).

1. THE ECOLOGICAL BOTTOM-LINE FOR SUSTAINABILITY: A CASE FOR STRONG SUSTAINABILITY[44]

Sustainability requires living within the productive capacity of nature. Therefore, we need to know how to identify and measure nature's productivity. Human societies depend not only on labour and human-made capital, but also on nature, or "natural capital" (Costanza & Daly 1992). Even though the concept of natural capital has not yet been developed into an operational definition, various interpretations of natural capital have been advanced. The narrowest definitions identify natural capital mainly as commercially available (industrial) renewable and non-renewable resources (Barbier 1992). However, a more complete definition of natural capital

[44] This section draws from Wackernagel & Rees (1992).

must not only include all the biophysical resources and waste sinks that are needed to support the human economy, but also the relationship among those entities and processes that provide life support to the ecosphere.

In short, natural capital is not just an inventory of resources; it includes those components of the ecosphere, and the structural relationships among them, whose organizational integrity is essential for the continuous self-production of the system itself.[45] Indeed, it is this highly evolved structural and functional integration that makes the ecosphere the uniquely liveable "environment" it is. In effect the very organisms it comprises produce the ecosphere (Rees 1990c, 1992a). Geoclimatic, hydrological, and ecological cycles do not simply transport and distribute nutrients and energy but are among the self-regulatory, homeostatic mechanisms that stabilize conditions on Earth for all contemporary life-forms, including humankind.

When debating the ecological conditions for sustainability, the question arises whether natural capital itself has to remain constant ("strong sustainability"), or whether a loss in natural capital is acceptable if compensated through an equivalent accumulation of human-made capital ("weak sustainability") (Costanza & Daly 1992, Daly 1989:250-252, Pearce *et al.* 1989, Pearce & Turner 1990, Pezzey 1989, Rees 1992a). As natural capital cannot be substituted by human-made capital (Daly 1992:250), but rather remains a prerequisite for human-made capital, "strong sustainability" becomes the criteria for judging whether humanity lives within nature's means.

Therefore, the ecological bottom-line of sustainability is met if each generation inherits

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[45] "Organization" signifies those properties and relationships that must be present for a thing to exist. Maturana and Varela (1992:39-52) refer to the unique self-producing and self-regulating properties that define living systems as "autopoietic organization".

an adequate *per capita* stock of essential biophysical assets *alone* -- independent of the human-made capital stock. This biophysical stock, or natural capital, must be no less than the stock of such assets inherited by the previous generation.[46]

However, some scholars do not subscribe to the strong sustainability criterion. A few, such as Pearce and Atkinson (1993), use the weak sustainability criterion as their analytical approach, but without providing convincing arguments for its ecological validity.[47] The most forceful contestants of the strong sustainability perspective can be divided into two camps. The first interprets the ecological crisis only as an issue of pollution, and not of resource scarcity. This position is common in environmental economics (e.g., Dasgupta & Heal 1979), but can no longer be maintained in the face of such widespread phenomena as the loss of biodiversity, deforestation, and the collapse of fisheries. The second camp consists of people who deny or ignore the ecological crisis altogether, as discussed in the first section of this chapter (Gee 1994, Simon & Kahn 1984, McKibbin & Sachs 1991, Giersch 1993), a position that is barely defensible (Homer-Dixon 1994). However, as pointed out later, the major debate is not about the validity of the strong sustainability criterion but rather about how to organize human activities, still maintaining our natural capital stock. In fact, within the field of Ecological Economics there is wide support for the strong sustainability interpretation, from the ecological as well as the economic perspectives represented in the field (Jansson *et al.* 1994, in particular

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[46] However radical the constant stocks criterion might appear, it still reflects anthropocentric values. Emphasis is on the pragmatic minimum biophysical requirements for *human* survival. However, the preservation of biophysical assets essential to humankind does imply the direct protection of whole ecosystems and thousands of keystone species, and thousands more will benefit indirectly from the maintenance of the same systems upon which humans are dependent. In short, the most promising hope for maintaining significant biodiversity under our prevailing value system may well be ecologically enlightened human self-interest. Of course, should humankind shift to more ecocentric values, its own survival might be assured even more effectively. Respect for, and the preservation of, other species and ecosystems for their intrinsic value, would automatically ensure human ecological security.

[47] For a brief discussion see footnote 7 in Chapter III.

Turner *et al.* 1994).

2. THE SOCIOECONOMIC CONDITIONS FOR SUSTAINABILITY

As a minimum, sustainability requires that everybody's basic needs be satisfied. However, ecological limits and the poor record of wealth distribution through the "trickle-down" effect of conventional economic development suggest that continued economic growth will not be able to achieve this goal. And there is increasing evidence that economic success is actually undermining ecological integrity as, generally speaking, those who can access the largest amount of resources (and have the entrepreneurial spirit to transform them effectively into demanded goods and services) perform best in the global economy.

However, securing basic needs for everybody is not enough. It also requires an improvement in quality of life. In fact, people will be reluctant to plan for sustainability if this path is not seen as an improvement to their lives. Many scholars believe that if society chooses wisely, such options still exist, particularly for industrialized societies (Roseland 1992). For example, carefully designed settlement patterns which promote aesthetics, density, community interaction, greenspaces and non-motorized transportation have the potential massively to reduce industrial societies' resource consumption and waste generation while significantly improving quality of life. Indeed, only those policies and projects that satisfy these two imperatives can move us toward sustainability. In particular, municipalities could play an increasingly important role in planning for sustainability. And they could start today: through community economic development as well as transportation and land-use planning (Roseland 1992, Harrington 1993, Parker 1993, Beck 1993).

3. THE POLITICAL CONDITIONS FOR SUSTAINABILITY

As long as competition remains a major organizing force of society, nobody will ever be satisfied with what they have got. In fact, as Fred Hirsch pointed out, once our basic needs are met, people start to focus on relative and not absolute wealth (1976). Such systemic and constant dissatisfaction keeps people on a never ending spiral of wanting more (Wachtel 1989). Consequently, "enoughness" becomes an alien concept (Durning 1992).

Therefore, to meet everybody's basic needs and to improve people's lives requires more co-operative forms of interaction. Co-operation does not depend on altruism, but rather on reciprocity, as pointed out by Robert Axelrod's simulation games with its winning "Tit for Tat" strategy (1984). In fact, there might be an evolutionary advantage to co-operative behaviour (Berkes 1989b:72-76). Constructive reciprocity is only possible if the participants trust each other. Without social justice and mutual respect such trust cannot be established, but might lead to devastating situations such as social collapses, conflicts and civil war (Gurr 1985, Homer-Dixon 1993, Kaplan 1994, Ophuls *et al.* 1992). Failing to build trust between the members of a society will encourage a competitive mode of interaction which will further erode mutual trust, and which will feed into the never-ending and ultimately self-destructive race to generate more.

Increased cooperation depends on transparent and inclusive decision-making processes (WCED 1987:65). This requires forums for political debate, an acknowledgement of conflicts within society, but also an awareness and understanding of the sustainability dilemma and of the implications of "business-as-usual".

Reconnecting rights and responsibilities, therefore, becomes a key requirement for dealing with the "Tragedy of Free Access" (*The Ecologist* 22(4):195-204). In fact, this follows

Garrett Hardin's own proposition of instituting "...mutual coercion, mutually agreed upon..." (1968/1993:139) -- which means, as pointed out earlier, to establish a commons regime (Berkes 1989b:85). Such an endeavour depends primarily on the wide and authentic participation of people affected by the decisions. It requires the rebuilding of what Fikret Berkes and Carl Folke call, "cultural capital", namely, guarding cultural diversity, recognizing traditional ecological knowledge, building institutions, organizing collective action, and supporting cooperation (1994:139-146). Building cultural capital and developing inclusive decision-making will cost a lot of people's time. For example, such decision-making requires time for developing and participating in the political processes as well as for improving literacy in scripture, numbers, and ecological understanding (Orr 1992) -- but there is no democratic alternative. Furthermore, to link actions and effects, to reduce the international pressures on local communities, to strengthen local communities, and to allow a greater range of options might also require the gradual decoupling of local economies from the global economy rather than strengthening the links (Daly 1993).

4. THE EPISTEMOLOGICAL CONDITIONS FOR SUSTAINABILITY

Planning for sustainability hinges on society's broad understanding of the sustainability dilemmas. Promoting this understanding demands a profound change in the way people picture knowledge, particularly as the popular belief that "reductionism and fragmentation can generate universal answers to all human challenges" is such a debilitating and paralysing illusion.

It no longer suffices to merely acquire knowledge. Instead, people might need to learn to ask questions. Thinking about the present human condition and its implication for the future should include questions such as: whether current decisions open or close opportunities for future generations; whether the models that guide our decision-making acknowledge or are compatible with the fact that human activities depend on nature's productivity; whether their view of quality of life is compatible with ecological integrity, or whether there are ways to rethink priorities to make personal "success" compatible with sustainability; and finally, who loses and who wins from the status quo, and from particular sustainability initiatives. Also, knowing about how to cooperate with people holding other values, beliefs, and worldviews become skills on which constructive planning approaches depend. Furthermore, rather than understanding parts and details, the exploration of connections and systemic relationships must be emphasized (Vester 1983). Capacity must be built for conducting interdisciplinary, collaborative, action-oriented research on relevant issues (Friedmann 1987:389-412).

Acknowledging the limits of scientific inquiry and the implications of an increasing knowledge deficit becomes a first step toward understanding the constraints for action. Similarly, recognizing the precautionary principle, rather than using uncertainty as a legitimization of business-as-usual, becomes a precondition for developing sustainability (Reichert 1993, Turner *et al.* 1994:270,276, Costanza 1994). In fact, this is consistent with the several thousand years old basic principle of the medical profession: *primum non nocere* (usually attributed to Hippocrates [460-377 BC], but it might stem from Asclepiades [124-? BC], according to Robert Woollard [1994a]). To envision and to plan requires developing concrete and positive images that can compete with the images from advertising and television (Steen-Jensen 1994, The Media Foundation 1993). This will also improve and stimulate communication between people and make the debates more accessible.

5. THE PSYCHOLOGICAL CONDITIONS FOR SUSTAINABILITY

Social denial must be overcome for society to move effectively toward a more sustainable lifestyle.[48] This means dealing with deep-rooted fears and taboos. Everybody must be encouraged, first, to reflect upon what matters to them, and second, to listen to what they already intuitively know -- rather than repressing it. This also means acknowledging and celebrating that human beings are a part of nature (Rees 1990c), even though people have, in contrast to other living beings, the innate ability to reflect and to transform their environment.

Overcoming social denial requires trust on various levels: decision-making processes must become transparent enough to make them trustworthy, social trust must be built through social justice and mutual connectedness. Also, people must perceive choices and options, and must learn to trust themselves. At the same time, feeding into social denial must be stopped. Blaming the messengers for the message about ecological limits, encouraging inaction due to lack of "scientific evidence" about the causes of the sustainability crisis, or only providing selected information about the sustainability crisis to children and high school students to "protect" them, detracts from moving toward sustainability.

On the political level, developing sustainability should become an attractive choice rather than a moral obligation. Moral pressures will only produce resentments and will not be able to sustain long-lasting transformation. In fact, most likely they are counterproductive.

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[48] For the lack of literature on overcoming social denial, insights from the psychology of individual denial might be used. For example, Esther Kübler-Ross' stages of coping, which are "denial, rage and anger, bargaining, depression and finally acceptance," as proposed in her widely respected book *On Death and Dying* (1969), might be helpful parallels for understanding social processes (1975:10). Of course, social denial is more complex: some parts of society profit from the denial while others pay for it. Also, in contrast to individual health or addiction-related denial, many social transformation processes do not take leaps and are far from homogeneous.

D. DEVELOPING SUSTAINABILITY: THE NEED FOR PLANNING TOOLS THAT CAN TRANSLATE SUSTAINABILITY CONCERNS INTO EFFECTIVE ACTION

These multiple facets of the sustainability crisis demonstrate the constraints and opportunities of the challenge. Understanding these facets and their connection becomes a first planning step toward sustainability. In other words, without prior "...recognition of necessities..." society will not be successful in establishing "...mutual coercion, mutually agreed upon...", the social contract for achieving sustainability (Hardin 1968/93:139). To develop such a new social contract, new planning tools are needed that capture these sustainability concerns and help translate them into public action. To be productive and successful, such planning tools have to address all the facets of the sustainability crisis simultaneously. They have to:

- promote ways of living that can be supported within the ecological constraints;
- ease the socioeconomic tension. As many scholars have pointed out, poverty alleviation is one of the essential conditions for ecological sustainability, and *vice versa* (Goodland & Daly 1993) -- even though it is quite conceivable that not everybody can reach the standard of living presently characterizing industrialized societies;
- develop transparent, engaging and participatory decision-making processes which can cope with the pressures of the global economy and the hurdles of local institutions, and which can build and maintain mutual coercion, mutually agreed upon;
- include and build on a wide scope of knowledge and stimulate critical thinking. These tools must sharpen the debate between conflicting assumptions and beliefs, and help cope with uncertainty, generality, and systemic relationships; and
- provide mechanisms to overcome fear, social denial, inertia and other psychological stumbling blocks in the way of moving toward sustainability.

Clearly, the process of developing sustainability depends on a successful integration of ecological, economic and social policies in which economic success, social well-being and ecological integrity become compatible (UBC Task Force 1994, Folke & Kåberger 1991b). In contrast, addressing only one facet of the sustainability crisis while disregarding the others could be counterproductive to the cause. For example, programs which aim at increasing nature's productivity, but do not take into account socioeconomic or political concerns have been failing painfully as in the case of large damming projects, nuclear power programs or "Green Revolution" policies.

Developing a planning tool for sustainability is the challenge that this dissertation is taking on. A tool that can guide society from concern to action must help to understand the constraints, frame the issues, allow transparent and authentic communication, and monitor progress toward sustainability. As daunting as this task appears, there is already much literature available that covers various aspects of such a planning tool. On the one hand, there is burgeoning literature on sustainability from a substantive perspective (for references see above). On the other hand, a growing amount of literature discusses processes of social learning, change and transformation. These procedural aspects can be found in the areas of planning theory, organizational theory and social activism (Carnall 1989, Carson 1990, Christensen 1985, Coover *et al.* 1977/85, Forester 1989, Friedmann 1987, Meadows *et al.* 1992, Milbrath 1989, Theobald 1987). The task now is to connect the parts.

III. ECOLOGICAL FOOTPRINT OR APPROPRIATED CARRYING CAPACITY: DEVELOPING A TOOL FOR PLANNING TOWARD SUSTAINABILITY

Planning tools assist society in translating concerns into public action (Boucher 1993). This chapter presents the Ecological Footprint or Appropriated Carrying Capacity concept (EF/ACC), a new tool for planning toward sustainability.

A. THE CONCEPTUAL FOUNDATION OF EF/ACC

The EF/ACC concept analyzes human activity from a biophysical perspective and starts from a recognition that human activities depend on the productivity of natural capital. It is motivated by the concern that natural capital is limited and that this capital's draw-down reduces its productive capacity (Folke *et al.* 1994:5). The primary task of the EF/ACC tool becomes to measure natural capital and the flows that we draw from it. However, its use goes well beyond the mere measurement of these constraints, as discussed below. Also, it draws on a rich history of biophysical assessments and builds on parallel concepts that measure ecological constraints.

1. ASSESSING NATURAL CAPITAL

As noted, "strong sustainability" requires that each generation must inherit an adequate *per capita* stock of essential biophysical assets no less than the stock of such assets inherited by the previous generation (see Section II.C.2). Now, the question arises how this stock of essential biophysical assets can be measured.

David Pearce *et al.* identify three possible approaches to measuring natural capital -- physical inventory, present valuation of stocks, and market prices (income flows). They finally settle for monetary measures on grounds that constant physical capital would "...be appealing for renewable resources, but, clearly, has little relevance to exhaustible resources since any positive rate of use reduces the stock..." (Pearce *et al.* 1990:10). This view needs to be challenged. Using money values as a measure for natural capital depletion can be misleading, not only because money is confused with material and social wealth (Vogt 1948:64), but also for the six following reasons:[1]

First, biophysical scarcity is hardly reflected in market prices (Hall 1992:109-110). And even if it was, it might not be useful to assess constancy of natural capital stocks. According to neoclassical theory, the marginal price of increasingly scarce resource commodities should increase. If this neoclassical premise is correct, rising prices (which should indicate increased scarcity) could hold the income from a particular natural capital stock constant, while the stock is actually in biophysical decline. Thus, constant money income may foster the illusion of constant stocks while physical inventories actually shrink. Or in contrast, prices might fall (suggesting resource abundance) while the stock is being reduced in biophysical terms as illustrated by timber or fossil fuel prices in the last twenty years (World Resources Institute 1992:242). A prominent example of interpreting such declining prices with resource abundance is Harold Barnett and Chandler Morse's study (1963).

However, market prices do not describe absolute biophysical scarcity, but rather the commodity's scarcity on the market.[2] This market scarcity is only partially determined by the

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[1] What follows is not an argument against monetary analysis *per se*. Monetary analysis is crucial when developing budgets, or when deciding whether to build a school, a hospital or a theatre. Cash-flow strategies and a number of other business decisions are unthinkable without sound monetary analysis. The point is, however, that monetary analysis is not suitable for analyzing the ecological facet of sustainability.

[2] This confusion is also well illustrated by the well-publicized bet between Paul Ehrlich and Julian Simon in which both committed the error of confusing biophysical and market scarcity (Tierny 1990).

biophysical resource scarcity. More influential factors are the state-of-technology, the demand, the level of competition, extraction, processing and transaction costs etc.[3] In fact, the impact of biophysical scarcity on market prices is still small.[4] Prices are therefore not a reliable yardstick for measuring sustainability.

Second, monetary analyses are systematically biased against future values -- discounting makes nature's assets of the future look less valuable the farther away in time they are (Hampicke 1991:127, Harvey 1993:5, Price 1993). For example, while land portrays future production potentials, monetary wealth contains little information about long-term income and ecological productivity.

Third, another factor that diminishes the usefulness of monetary indicators for long-term assessments are the distortions from market fluctuations. Monetary wealth is subject to

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[3] David Pearce *et al.* show a partial agreement with the position presented. In spite of citing Ozdemiroglu's paper on *Measuring Natural Resources Scarcity: A Study of the Price Indicator* (1993) and concluding that "...marketed natural resources do not show evidence of any scarcity...", they say earlier that "economists like to use prices as indicators of scarcity, although there are technical disputes about the suitability of the indicator" (1993:6). They also state that "...those who object to a preoccupation with sustainability also tend to be 'resource optimists' ... [who] tend to point to evidence of expanding resource discoveries and to declining trends in resource prices. But this evidence relates to resources that are marketed, and these are not the focus of concern. So, while it *may* be comforting (only may be, since the evidence is not conclusive) to observe no scarcity in some resources, it is hardly reassuring..." (1993:5). In addition, I would argue that not only the biophysical scarcity of non-market resources (such as air, climate, biodiversity) are of concern but also the deterioration of market resources such as witnessed with the collapse of fish stocks, deforestation, decline of fossil fuel stocks etc.

[4] For example, of the 50 cents per litre payed for gasoline at the Vancouver gas station, less than four cents go toward royalty payments (or payments for resource depletion). Assuming an oil prices of 15 dollars a barrel (159 litres), this can be calculated by detracting the exploration costs of about six to eight dollars per barrel, and extraction and the processing costs of approximately two to four dollars per barrel (typical Canadian figures according to Boriana Vitanow, financial analyst of a Calgary oil company [1994]). In fact, in Canada, the resource royalties charged by the government amount to about 15 to 30 percent of the gross production's value, depending on the quantity of oil extracted and the age of the operation -- or between two and five dollars per barrel (Vitanow 1994). Hence, the average Canadian motorist, driving 24,000 kilometres a year with a car which uses 12 litres per 100 kilometres, would contribute a mere $35 to $90 a year to resource royalty payments -- very little compared to the total yearly operating costs of $7,400 (Canadian Automobile Association, reported in *The Vancouver Sun*, August 3, 1994).

exogenous fluctuations of world market prices, while biophysical wealth such as ecologically productive land in a region represents an endogenous factor of long-term food and resource security. Money reflects the economic strength of one region as compared to that of the world economy, but does not reveal the ecological integrity of the natural capital underlying this economy.

Fourth, monetary analysis cannot distinguish between substitutable goods and complementary goods.[5] In the monetary balance sheet, all prices are added or subtracted as if goods that are priced the same would be of equal importance to human life, or as if they were substitutable. However, many services from nature are essential and therefore not commensurate with some human-made gadget of equal dollar value. In other words, once nature is over-exploited, a loss of nature's services cannot be compensated by a gain in manufactured goods (Daly & Cobb 1989:72).

For example, to get fish on one's dinner plate, a fish stock *and* fishing equipment are needed. And, even though the fish stock might be worth the same amount of dollars as seven Rolls Royces, seven Rolls Royces and the best fishing equipment would not generate any fish. In fact, natural services and human-made goods are not fully complementary either, in contrast to what Herman Daly and John Cobb (1989) suggest, because human-made goods depend on natural services, while the opposite is not the case.

Fifth, the potential for growth of money seems unlimited which obscures the possibility that there might be biophysical limits such as a global carrying capacity. To use Herman Daly's

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[5] H. Goeller and Alvin Weinberg's claim that resources are infinitely substitutable is discussed in Chapter II.

metaphor, monetary assessments do not recognize the boat's Plimsoll line, an indication of the maximum loading capacity of the boat. Pareto efficiency[6] -- the current measure of macro-economic health -- ensures only that the ship sinks optimally and does not counteract the sinking itself (Daly 1992).

Sixth, an even more serious objection is that monetary measures say nothing at all about nature's critical stocks and processes such as hydrological cycles, the ozone layer, CO_2 absorption, ecological thresholds, irreversibilities, or the health of whole ecosystems for which there are no markets (Harvey 1993:5, Rees 1992a, Stirling 1993:97-103, Vatn *et al.* 1993, Wackernagel 1992:30-36).

In summary, monetary approaches are blind to critical biophysical realities. The stock of essential biophysical assets can be assessed meaningfully only in biophysical terms.[7] The essential natural capital needs of an economy must, therefore, be understood as the biophysical stocks required to produce the biophysical "goods and services" that this economy consumes from global flows to sustain itself without compromising future production. Building on Salah El Serafy's monetary argument (1988), this should also include the non-renewable energy

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[6] Pareto efficiency assumes that the optimizing principle must be "utility maximization" rather than minimizing human suffering or future regrets as proposed by Karl Popper (in Afrane 1991:6). Clearly, the adoption of Popper's "negative utilitarianism" would lead to a radical shift in political priorities.

[7] In spite of these arguments, David Pearce and Giles Atkinson rank various nations' sustainability from the neoclassical assumption that natural and human-made capital are substitutable (1993:104). They claim that "...an economy is sustainable if it saves more [in monetary terms] than the depreciation on its man-made and natural capital..." (1993:106). As a result, Japan, the Netherlands, and Costa Rica head the list of sustainable countries, while the poorest countries in Africa lead the list of the unsustainable economies. Apart from the authors' fallacious assumption of substitutability, they also ignore that rich countries depreciate other countries' natural capital stock, thereby preserving their own as demonstrated in the case of Japan or the Netherlands. Clearly, this study becomes another illustration of the absurdity to assess sustainability from a monetary perspective. Nevertheless, the authors conclude obliviously that "...we argue strongly that efforts to monetise the values of those functions advances the development of an ecologically based economics..." (1993:106).

resources which can be used sustainably only if, in compensation, an entropically equivalent amount of biophysical capital is being accumulated. In other words, the biophysical capital to sustain a given material standard of living can be defined as the minimum per capita stock required to provide all the resources and waste sinks necessary, while simultaneously maintaining the functional integrity and productivity of the stocks themselves. It follows that, rising material standards or increasing population levels necessarily require corresponding increases in available aggregate natural capital stocks, something difficult to achieve in a "full" world.

2. DEFINING EF/ACC

Putting the "strong sustainability" principle to work hinges on finding a meaningful biophysical measurement unit for aggregating the various biophysical stocks or carrying capacity needs of an economy. For this purpose, this thesis further advances an ecological accounting concept that uses land area as its biophysical measurement unit[8]. This approach starts from the assumption that every major category of consumption or waste discharge requires the productive or absorptive capacity of a finite area of land or water (ecosystems). Adding up the land requirement of all these categories provides an aggregate or total area which we call the "Ecological Footprint" of a defined economy on Earth.[9] This area represents the carrying capacity which is "appropriated" (or occupied) by that economy for providing the total flow of goods and services. Another name for the Ecological Footprint is, therefore, the "Appropriated Carrying Capacity" of the economy. More formally, this concept is defined as:

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[8] See also Rees (1992), Rees & Wackernagel (1992), and Wackernagel (1991, 1992).

[9] This metaphor, first suggested by William Rees, was chosen to capture and extend our conception of the human impact on the ecosphere, and to build upon related concepts in planning such as the urban or infrastructure footprints, meaning the land area directly occupied by a particular structure. Robert Cahn also used this metaphor for his 1978 book *Footprints on the Planet: A Search for an Environmental Ethic*.

Definition: The *Ecological Footprint* or the *Appropriated Carrying Capacity* (EF/ACC) is defined as the aggregate land (and water) area in various categories required by the people in a defined region

a) to provide continuously all the resources and services they presently consume,[10] and

b) to absorb continuously all the waste they presently discharge

using prevailing technology.[11] In other words, the EF/ACC of a population is the land which is needed to exclusively produce the natural resources and services it consumes and to assimilate the waste it generates indefinitely under present management schemes.[12] It is the land that would be required now on this planet to support the current lifestyle forever.

Conventionally, carrying capacity is defined as the "...maximal population size of a given species that an area can support without reducing its ability to support the same species in the future..." (Daily & Ehrlich 1992:762). However, it is problematic to apply this definition to human beings living in a global economy, because regions are no longer isolated -- people consume resources from all over the world. Indeed, economists regard trade flows as one way to overcome the constraints on regional carrying capacity imposed by local resource shortages.

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[10] Consumption refers to all the goods and services consumed by a household, as well as those goods and services which were consumed by government and businesses to provide that household's goods and services.

[11] This definition can be expanded for other sustainability assessments. For example, EF/ACC, analyzed from the perspective of industrial production, can reveal how much carrying capacity a region gives up to produce the exports that are required to pay for the imports.

[12] EF/ACC encompasses the consumption of renewable resources and of fossil energy as well as the human impacts which reduce biological productivity. A complete EF/ACC analysis would therefore include the additional land (and water) area required to compensate for the loss of biological productivity due to pollution, contamination, radiation, erosion or salination. Also, it would incorporate non-renewable, non-consumed resources (such as aluminum or iron) insofar as it accounts for their processing energy and for the pollution effects that their use and production entail. However, as explained in Chapter IV, the current approach is still leaving out some of these functions of nature to simplify the calculation procedure. This makes the results underestimate the land-area actually required -- without compromising the tool's heuristic value.

Furthermore, in contrast to animals, resource consumption by people is not fixed by their biology. While most animals do not consume much beyond their food, the bulk of people's material consumption consists of non-food items such as energy or forestry products. This leads to individual consumption levels that can vary by many orders of magnitude: the farm helpers in rural India might represent the lower extreme of the scale, board members of transnational companies the upper echelon.

For these reasons, the definition of EF/ACC is based on two modifications of the conventional conception of carrying capacity. The EF/ACC concept

- does not just count people. Instead, it stands for the impact on nature of the aggregate consumption by a population. After all, it is the total ecological impact (= population * per capita ecological impact) that counts, not population alone (Holdren & Ehrlich 1974); and,
- is not based on "maximum yield" of a geographically fixed resource stock, but rather on the current total consumption of nature's services by a given population.

3. THE ECOLOGICAL FOOTPRINT AND ITS CONCEPTUAL ANCESTORS

Biophysical assessments of human needs and human dependence on nature have a long history. Certainly, there must be several thousand year old oral tales about the relationship between people and land. David Durham traces the concept of carrying capacity back to Plato's *Laws*, Book V, where the latter stated that a:

> ...suitable total for the number of citizens cannot be fixed without considering the land and the neighbouring states. The land must be extensive enough to support a given number of people in modest comfort, and not a foot more is needed (in Durham 1994:4).

According to William Ophuls and Stephen Boyen, early Christian and Chinese scholars also worried about the destruction of habitat (1992:12-13). The first scholarly book on sustainable practice in the English language might be John Evelyn's *Sylva: A Discourse of Forest Trees and the Propagation of Timber* from 1664 (Garbarino 1992:9). In North America however, George Perkin Marsh's study *Man and Nature*, from 1864, was most influential in increasing the awareness of nature's limited capacity to provide for human demands.

Ecological accounting can be traced back to at least as early as 1758. In that year, François Quesnay published his *Tableau Economique* in which the relationship between the productivity of land and wealth creation is discussed. Since then, many scholars have developed conceptual approaches and accounting procedures to analyze the relationship between people and nature. Some have focused on an analysis of energy flows within the economy (e.g., Jevons 1865, Podolinsky 1880, Sacher 1881, Boltzmann 1886 [the last three in Martinez-Alier 1987], Lotka 1925, Georgescu-Roegen 1971, 1980). Others have examined economies from the perspective of carrying capacity or land-use requirements (e.g., Malthus 1798, Jevons 1865,[13] Pfaundler 1902, Wahlen 1945, Vogt 1948:18-45, Osborn 1953, Stamp 1958, Borgstrom 1965, 1973, Urban & Rural Land Committee 1973, Bishop *et al.* 1974, Rees 1977, Schneider *et al.* 1979, Catton 1980, Hare 1980, Ehrlich 1982, Higgins *et al.* 1983 (or FAO 1984), Hodge

[13] Apart from analyzing the role of energy in society, Jevons also described the concept underlying EF/ACC in his 1865 classic *The Coal Question*:

> The plains of North America and Russia are our corn-fields; Chicago and Odessa our granaries; Canada and the Baltic are our timber-forests; Australasia contains our sheep-farms, and in Argentina and on the western prairies of North America are our herds of oxen; Peru sends her silver, and the gold of South Africa and Australia flows to London; the Hindus and the Chinese grow tea for us, and our coffee, sugar and spice plantations are all in the Indies. Spain and France are our vineyards and the Mediterranean our fruit garden, and our cotton grounds, which for long have occupied the Southern United States, are now being extended everywhere in the warm regions of the earth (1865/1965:411).

McCoid 1984, Mahar 1985, Overby 1985, Harwell & Hutchinson 1986).[14]

With Rachel Carson's *Silent Spring* (1962), Paul Ehrlich's *The Population Bomb* (1968), and the MIT team's *Limits to Growth* report to the Club of Rome (Meadows *et al.* 1972), these concerns reentered the public debate and have not vanished since.[15] Today, the debate on how to make human activities sustainable is shaped by two camps: the "Limits to Growth" advocates and the "Growth of Limits" advocates. The latter position is probably best represented by Julian Simon and Herman Kahn who claim that:

> ...because of increases in knowledge, the earth's "carrying capacity" has been increasing throughout the decades and centuries and millennia to such an extent that the term "carrying capacity" has by now no useful meaning (1984:45).

Julian Simon and Herman Kahn are not alone. In fact, there is a large literature, including parts of the Brundtland report that translates sustainable development into the self-contradictory notion of "sustainable growth" (WCED 1987:206-234, Block 1992, Reilly 1994).

4. THE ECOLOGICAL FOOTPRINT AND ITS CONCEPTUAL SIBLINGS

There are a growing number of biophysical approaches that try to measure human impacts in order to understand the ecological constraints and to measure progress toward sustainability (Callenbach 1990, Herendeen 1994, Stead & Stead 1992). These assessments are increasingly prominent in the political debate, but have not yet been able to successfully challenge the decision-makers' monetary focus. This section provides a brief overview of the

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[14] Agro-economist Juan Martinez-Alier (1987) provides a fascinating history of this debate spanning from 1865 (Jevons' *The Coal Question*) to the 1940's.

[15] For a discussion of the impact of this debate on social theory and political ideology see Redclift (1987:7-12,37-51) or Paehlke (1989).

nine major biophysical approaches and compares them to the EF/ACC concept.

i) Human carrying capacity studies analyze the capacity of regions to support human activity. Examples are studies by Gretchen Daily and Paul Ehrlich (1992), David Pearce (1987:259, *et al.* 1991:114-134), Gonzague Pillet (1991), David and Marcia Pimentel (1990, 1994), Sandra Postel (1994) and Peter Vitousek *et al.* (1986). Particularly interesting is Philip Fearnside's probabilistic approach on ecosystem viability for supporting human activity in the Amazon forest (1986).

These studies are useful to assess whether particular activities can be sustained by local ecosystems. However, to understand the linkage between the global ecology and a regional economy, this traditional carrying capacity concept can be misleading. An example is David Pearce's perspective, which attempts to analyze the relationship between economic performance and the resource base by, similar to Daily and Ehrlich's perspective (1992), measuring "...the maximum number of people or families that could be supported on the basis of the known resource base..." (1987:259). However, in general, explaining the urgency and scale of a resource problem from this perspective ignores the global context of present economic systems. Therefore, Pearce's approach, which equates poverty and famine in the Sahel Zone with exceeded local carrying capacity, would be too simplistic to describe many economies. Hongkong, Singapore, Japan, Switzerland, and the Netherlands, to name only a few, exceed by far their carrying capacity, while belonging to the economically most prosperous countries on Earth.

ii) Resource accounting or environmental accounting was pioneered by the Norwegian government in 1974, and followed by the French government in 1978 (Pearce 1989:95, Theys

1989:40-53). Resource accounts require an annual inventory and statistical analysis of a vast array of resources including minerals, biochemical stocks, fluxes (solar radiation, hydrological cycles, wind) and space (Friend 1993). However, these accounts do not suggest an interpretation of the data. Also, it is not evident which aspects of nature should be included in these accounts and which are, or can be left out. On the one hand, it is not feasible (nor possible) to account for everything, and on the other hand, not all life-supporting functions of nature are known or understood. Therefore, "...the use to which these [accounts] can be put, in terms of economic analysis that has policy relevance, is unclear..." (Pearce *et al.* 1989:99).

iii) Energy analyses have been propagated through ecological (E.P Odum 1959/71, H.T Odum 1971, 1983, with the "eMergy" concept; Lieth & Whittaker 1975, Vitousek *et al.* 1986, with net primary production) as well as through technical studies (Hannon 1975, Thomas 1977, Costanza 1980, Mitsch *et al.* 1981, Cleveland *et al.* 1984, Hall *et al.* 1986, Pimentel 1974, 1991, Giampietro *et al.* 1990, 1991, 1992, 1993, O'Connor 1991:95-122, Pillet 1991, Smil 1991, Ruth 1993). While today, the latter approach is referred to as "energetics", it was called "net energy analysis" in the 1970's and 1980's. Most of these studies are motivated by the fact that, as direct energy costs constitute only a minute percentage of industrialized countries' GNP, the crucial role of energy to society is underestimated by monetary analysis. Clarifying the dependence of human activities on energy inputs is the major strength of the energy analysis. Therefore, this approach has also regained some interest in the CO_2 debate, particularly when analyzing potentials for CO_2 emission reductions (Hofstetter 1991, Smith 1993).

However, more general economic analysis based on energy might struggle with problems similar to those of monetary analysis. Herman Daly points out that "...just as the economists' assumption of infinite substitutability of capital, labour, etc., is unrealistic, the energy theorists' assumption that energy is the proper common denominator of all resource scarcity is likewise unrealistic..." (Daly & Umaña 1980:167). Moreover, those studies that trace all energy flow back to solar radiation (as for example done "with eMergy") focus on a factor that is not itself limiting. The key limiting factor for human life is the biochemical energy that can be accumulated by the (living) ecosphere, not the sun-light that falls on Earth. For example, one little plant that might be the only organism growing on one hectare of the Sahara desert is probably ecologically as well as economically less "significant" than one hectare of tropical forest, even both receive the same solar input.

iv) Environmental impact assessments (EIA) evaluate whether the ecological impact of a new project is acceptable. Over the past 20 years, EIA has grown to become the major proactive environmental policy instrument in North America, though, it has arguably had little success in stopping environmental deterioration. This failing can be attributed to weaknesses such as EIA's:

- one-shot, short-term structure at the end of the planning stage rather than one which monitors or evaluates the projects on an ongoing basis;
- project by project approach which generally ignores cumulative effects in a regional or global context; and
- fragmented and often discretionary self-assessments (that at best have followed guidelines and are now being instituted by law) as opposed to having transparent assessments conducted according to ecologically informed procedures by third parties (Rees 1980, 1990d).[16]

v) State-of-Environment indicators (or sustainability indicators, as they are sometimes

[16] For a more generous formulation of the same criticism, see David Lawrence (1994).

called) document the state and trend of various quantifiable environmental variables such as DDT accumulation in egg yolk, amount of waste generated, or total land area protected. Indicators based on scientific measurements enjoy widespread public credibility even though the pollution standards and benchmarks are often not scientifically determined and are set by political choice (Genoni 1993).

Many environmental initiatives of international organizations such as the Group-of-Seven (G-7) or OECD encourage the development of state-of-environment indicators.[17] Both Canada's and British Columbia's *State of the Environment Report* are fruits of these initiatives (Environment Canada 1991, Ministry of Environment, Lands and Parks 1993).[18]

However, state-of-environmental indicators have serious limitations. First, they focus on "the dangers of the environment to human health" rather than "the threats of human activities to the integrity of the biosphere." Second, by providing various sets of indicators on a multitude of aspects, they fragment the issues related to sustainability. This could weaken a more comprehensive and systemic understanding of the sustainability crisis.

vi) Ecological efficiency refers to the ratio of services received to ecological impact caused. This impact includes the service's embodied resource input as well as the capacity for

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[17] The G-7 initiative to develop such indicators was put forward by Brian Mulroney at the meeting in Paris in 1989.

[18] There are many more organizations working on sustainability indicators, including: Statistics Canada; the Canadian National Round Table; the Ontario Round Table; the World Resource Institute; the Worldwatch Institute; the federal government of the Netherlands; the Oregan Progress Board;and various UN organizations (Peat Marwick 1993). Literature on sustainability indicators include Anderson (1991), Brown *et al.* (1992b), Caracas Report 1990, Daly and Cobb (1989), Davis (1993), Gosselin (1992), Henderson (1992), Lawson (1991), Onno *et al.* (1991), Victor *et al.* (1991). Beckerman (1980), Carley (1981), Innes (1990), MacRae (1985) and Miles (1985) discuss more generally the role of social indicators.

absorbing the corresponding waste[19] accumulated over the entire life cycle. Many studies identify improving ecological efficiency as a key strategy for achieving sustainability (WCED 1987:215-216, Schmidheiny 1992:37-39, Koechlin & Müller 1992:36-39). To measure ecological efficiency, various approaches have been developed. One is the increasingly common "life cycle analysis" (e.g., Cole & Rousseau 1992, Fecker 1990, Frischknecht *et al.* 1991, Fritsche 1989, Hofstetter 1992, Ledergerber *et al.* 1991, Müller & Hanselmann 1993, Öko-Institut 1987, Stahel 1991, Suter & Hofstetter 1989, Tötsch & Polack 1992). Another approach is the "Material Intensity per Service Unit" (MIPS) developed by Friedrich Schmidt-Bleek at the Wuppertal Institute (*Fresenius Environmental Bulletin* 1993, Schmidt-Bleek 1993, Weizsäcker 1994).

Ecological efficiency is useful for comparing similar technologies on their ecological impacts, but it is not sufficient for determining the sustainability of a technology *per se*. After all, the total impact depends not only on the impact per unit but also on the number of units consumed. Other weaknesses of this method include the dependence on detailed data that become obsolete quickly due to fast changes in production technologies. Also, the comparison between the results of such studies can be hampered by incompatible and poorly defined analytical systems boundaries (Bringezu 1993). However, these studies are helpful for informing EF/ACC analyses.

vii) Regional metabolism studies trace the stocks and flows of resources within a region. Studies include (Newcombe *et al.* 1978, Baccini & Brunner 1991, Wallner & Narodoslawsky 1994). Ken Newcombe *et al.* trace the "...flow and end-use of energy and other materials in

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[19] Typically, the capacity for waste absorption is measured in terms of "critical mass (or volume)" of air, water, and soil. This refers to the amounts of air, water and soil that would be polluted up to the legal standards by the release of that product's or service's waste.

Hong Kong...", and conclude that "...the extrapolation [of the study] to a global future, show[s] that rapid urbanization is a resource-expensive process..." (1978:3). The purpose of Peter Baccini and Paul Brunner's study is primarily to better understand heavy metal cycles and their future pollution potentials, while Peter Wallner and Michael Narodoslawsky developed their study to facilitate the closing of material cycles within regions, thereby creating "Islands of Sustainability" (1994, 1994) Closing resource cycles would become a practical attempt to reduce a region's Ecological Footprint.

viii) Regional models, often computer aided, such as *World3* (Meadows *et al.* 1972, 1992) simulate the interaction between key variables such as resources, population, pollution and consumption patterns, and calculate trends under different scenarios. Further studies include Mesarovic and Pestel (1974), ROBBERT Associates (1990/1992), Robinson *et al.* (1990-1994) and Shaw (1993). Educational software packages such as SIM CITY™ or SIM EARTH™ from Maxis Software use similar approaches to provide players with an opportunity to experiment with complex systems. However, these computer models' high level of sophistication depends on large quantities of data, on a precise understanding of the mechanisms and connections, and an explicit declaration of the working assumptions for the models to produce a meaningful output -- conditions which are seldom met. Furthermore, this level of sophistication can compromise on the model's transparency and flexibility which are both essential to engage people and to gain the public's political support.

ix) Ecological space studies translate ecological impacts into a land-use area. This approach is closest to that of the EF/ACC concept. Some studies only focus on agricultural land appropriation (Gerster 1987:159, Thiede in Redcliff 1987:93). Others are more comprehensive, including Wouter de Groot (1992:273-282), Giampietro and Pimentel (1991), and Overby

(1985). Jim MacNeill and his colleagues acknowledge that industrialized countries "...breath, drink, feed, and work on the ecological capital of their 'hinterland,' which also receives their accumulated waste..." and call it a country's "shadow ecology" (1991:58).

Closely related to the Ecological Footprint concepts are the Sustainable Process Index (SPI) by Anton Moser and Michael Narodoslawsky (Moser *et al.* 1993, Narodoslawsky *et al.* 1994), or the concept of "Environmental Space" developed by the Dutch *Friends of the Earth* (Buitenkamp *et al.* 1993). In contrast to EF/ACC, the Sustainable Process Index only looks at industrial processes and not at entire economies. Environmental Space, however, is similar to EF/ACC in its scope, but does not aggregate all of the human demands on nature into an one land use area, but provides separate indicators for various aspects such as agricultural land and forestry, fossil energy, and non-renewable ores. Also, it focuses on resource availability rather than on resource appropriation. And, by specifying the limits in resource flows, rather than in areas which are necessary to produce these flows, this Environmental Space approach might get exposed to criticism from technological optimists who claim a potential for increasing ecological productivity.

B. THE FIVE RATIONALES FOR EF/ACC

1. ECOLOGICAL RATIONALE

A meaningful portrayal of natural capital must be the starting point of any tool for planning toward sustainability. Such a tool must adequately represent key functions of the biosphere and their role for human life. The EF/ACC tool uses land area as a proxy for many important forms of natural capital. As discussed below, land is used as it represents the ecosystems and their photosynthetic productivity, and thereby the essence of natural capital. In particular, measuring natural capital in terms of land areas is appropriate as it captures Earth's finite nature, and as its capacity to support photosynthesis reflects the two basic thermodynamic laws and other ecological principles.

i) **Liebig's Law and the competing uses of nature:** In any system and process, there are always some necessary factors in limited supply that prohibit further expansion or production. This fundamental ecological insight is called "Liebig's Law"[20] and led originally to the use of industrial fertilizers in agriculture. For example, if plant growth is stunted by the lack of potash, fertilizing with potash alone will boost plant growth. The crop can now continue to grow and to access more of all its required nutritive substances until some other factors become limiting; the next limiting factor for this crop might be water, so still higher production will need irrigation, etc.

Similarly, if available supplies of one factor or service are committed to one thing, they cannot be used for something else. For example, a city that draws water from the adjacent eco-systems might compromise productivity in these ecosystems, as witnessed in the conflict between agricultural and residential water-use in California. Or, the effluent of a city might compromise the fishing in that area. Air pollution can compromise the use of water for human consumption, as observed in Chilliwack BC. In essence, this shows that the various uses of nature are in competition. One use of a source, or a sink, may prohibit another use of that source or sink. Particularly, pollution and contamination issues have demonstrated that the over-use of natural capital sinks may destroy their potential as sources.

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[20] In the middle of the last century, the German agro-chemist Justus von Liebig postulated the "Law (or Doctrine) of the Minimum" for plant growth. He observed that every field will contain a variety of concentrations of various plant nutrients ranging from superabundant to undersupplied. He found that "it is by the minimum that the [growth of] crops are governed" (Liebig 1863:207).

To establish an account of these competing and mutually exclusive uses of nature, EF/ACC converts individual uses into a land area equivalent. Having various kinds of different human uses and activities converted into land areas makes the ecological impacts of these uses comparable and permits us to add them up. This cumulative impact approach illustrates how the various ecological concerns add further stress onto the ecosphere, and that these concerns are linked. In other words, all the different human uses and functions of nature -- such as: providing water, food and fibres; maintaining biodiversity (out-crowding of species and the reduction of wild life habitat); absorbing waste; or, providing living space for human beings -- are in competition with each other; they are not fragmented independent activities.[21] Accounting for the land areas that are used exclusively for one purpose avoids double counting of land areas. This means that the total Ecological Footprint can be calculated by simply adding up the parts.

Some of the competing uses of nature can be sustained by the present carrying capacity of the globe. Other uses draw down nature's assets. However, to the consumer of goods and services, it is not clear whether these goods and services were produced from the interest of natural capital (or the natural income) or from depleting the principal. Examples are the harvests from overexploited fisheries and forests, agricultural products from land that is being degraded by its use (erosion, salination, etc.), and the draw down on fossil fuels. Living on the principal can be interpreted as living on illusionary or "phantom" carrying capacity (Catton 1980:28-

[21] Of course, not all uses of nature are in absolute competition with each other. Many traditional agricultures have developed growing systems that allowed various uses of the same space. And indeed, this is also the intention of newer management regimes. Clearly, the current linear approach of using land to feed people in the city, and then use another ecosystem to absorb the corresponding human waste could be improved if the ecological cycles were closed and the human waste (in some sterilized form) would be brought back to the agricultural land. In fact, this would be one way of reducing our Ecological Footprint. This shows how the EF/ACC concept also represents the difference between linear and circular ecological and material flows in the biosphere.

30,34,278).[22] Living on illusionary carrying capacity could make people assume that nature's productivity is higher than it actually is. An example is the buffalo hunting in the North American prairies that drove a seemingly abundant resource into sudden and unexpected near-extinction (Ponting 1992:174-175), or, more timely, the recent collapse of the East Coast cod fishery.[23]

Today, less land is actually used to provide all of nature's services than if they were provided on a sustainable basis because the current harvest of many resources exceeds the sustainable yields of the land and is based in part on natural capital liquidation. In other words, the Ecological Footprint is larger than the land that is currently in production. However, future generations (starting from right now) will have to pay dearly for the temporary transgression of local and global long-term carrying capacity: not only will they have to satisfy the needs of an increased population, but also they will be endowed with reduced ecological productivity of the Earth's degraded carrying capacity.

ii) **The first and second law of thermodynamics, and the role of photosynthesis.** Using land area as its measurement unit makes EF/ACC consistent with the first and second law of thermodynamics. In fact, compared to energy flux (or even Odum's solar income), land is a more appropriate indicator to reflect both energy constancy (first law), by accounting for the solar energy income of a particular area, and energy quality (second law), by the qualitative and quantitative bioproductivity of that area. In contrast, energy accounting only encompasses energy

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[22] Catton defines "phantom carrying capacity" as "...illusory or extremely precarious capacity of an environment to support a life form or a way of life. [The phantom carrying capacity refers to] that proportion of a population that cannot be permanently supported when temporarily available resources become unavailable..." (Catton 1980:278).

[23] For a history of similar events see Ponting's chapter on "The Rape of the World" (1992:161-193).

constancy.

As the availability of biochemical energy has become the limiting factor for economic activities, it must become the focus for accounting, not embodied solar energy. For example, Anil Agarwal and Sunita Narain suggest that indicators for national wealth or income should move from the GNP to the Gross Natural Product, because, "...for the human population, biomass production is the basis for survival, main source of income and the protector of the environment..." (in Carley *et al.* 1992:45, see also Agarwal & Narain 1992:72-74). In other words, what counts is the solar flux onto the land multiplied by the photosynthetic net efficiency of land, which averages about 0.3 percent (Smil 1991:324).[24] The attributes of land, however, go even beyond the two laws of thermodynamics. Land also represents life and can be seen as a proxy for certain life-support functions such as rain collection, exchanges of gases, waste absorption, biogeochemical cycling, self-production and renewal, or link between and nutritional basis for organisms. In short, land supports photosynthesis which is the basis of all food chains of the fauna, and thereby suspends the ecosphere, which is "...a highly improbable, far-from-equilibrium, self-producing, dynamic, steady-state system, ... [far] above thermodynamic death..." (Rees 1994c:10).

For this reason, airsheds are not accounted for in this calculation model because air is mainly a carrier facilitating energy and matter flows, but not a source of primary ecological production. In fact, all life in the air feeds on food chains which originate in water or land based photosynthesis.

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[24] Ecosystems' photosynthetic efficiency can be anywhere between zero and 2 percent, while the peak field efficiency could reach as high as 5 percent (Smil 1991:324).

iii) **The finiteness of the planet**. In contrast to (solar) energy or money, land is finite,[25] and its total amount can easily be measured. Therefore, land is a good representation of planet Earth's finite nature. Indeed, the surface of the Earth is 51 billion hectares, and cannot be expanded.[26] In total, 17 billion of them are terrestrial, only 8.9 of them being ecologically productive (Wright 1991:293, World Resources Institute 1992:262). Actually, the total amount of ecologically productive land on the globe has been in steady decline, by approximately one half percent in area since the end of the 1970's (World Resources 1992:262), and probably more in productive capacity.

iv) **Human dependence: "no planet, no profit"**. The finite character of land reflects more realistically the biophysical wealth (or capital) on which humanity has to live than energy or money can. Because the EF/ACC concept provides a measure to contrast current ecological production with current economic consumption, it indicates whether there is ecological room for economic expansion, and if not, how economic expansion might affect the natural capital stock. The concept also underscores the need for adequate stocks of renewable and replenishable natural capital as a necessary condition for a humane existence; in other words, for sustainability.

More particulary, EF/ACC helps to determine the ecological constraints within which society operates, to set political benchmarks to avoid further ecological overshoot, and to monitor progress towards becoming sustainable. EF/ACC provides a measure of current (or

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[25] With the notable exception of the Dutch. However, they have abandoned the project. On Nevertheless, it would be interesting to analyze how many years it takes for that re-claimed land with its new ecological productivity to pay back the invested resources required to establish this land (the lost productivity of the sea should be deducted too).

[26] The Earth's diameter is about 12,700 [km] (or 40,000 [km] / π). Hence, its surface comes to π * (diameter)^2 = 510 million [km^2] or 51 billion hectares.

expected future) economic consumption against which to contrast current (or likely future) ecological production, thereby revealing a "sustainability gap" or the overshoot of local (and global) carrying capacity by industrialized societies (Rees & Wackernagel 1994).

2. SOCIOECONOMIC RATIONALE

The Ecological Footprint not only represents ecological constraints but can also inform on socioeconomic conditions of, and conflicts within, a population. Three areas are explored; namely, EF/ACC as a "yardstick," as a tool to analyze and anticipate ecologically induced social and economic conflicts, and as a concept to link ecological and economic understanding.

i) **An ecological yardstick.** Similar to monetary currencies, EF/ACC permits us to compare different activities on the same scale. In fact, it provides a yardstick for measuring the natural capital requirement of various activities, processes or technologies. This yardstick can be applied to any level of analysis, be it a single activity, an individual, a household, a city, a region, a country or the entire globe. However, in contrast to monetary currencies, the ecological yardstick only focuses on the ecological aspects and does not provide a comparison of ecological impacts with social or economic ones. Focusing on the ecological constraints separately is consistent with the "strong sustainability" interpretation which maintains that the natural capital stock must be maintained *independent* of social or economic capital formation. The EF/ACC yardstick becomes a way to measure ecological efficiency (how much of natural capital's income is necessary to provide a given service), and ecological dependence (how much natural capital is necessary to support an economy), but does not illuminate social preferences. Or, the EF/ACC could be interpreted as an ecological camera that takes (static) pictures of current practices and bio-chemical flows.

EF/ACC's yardstick can help to determine whether the decoupling of the economy from biophysical resource throughput (or qualitative growth, how some call it) is taking place (see Chapter VII). It can also test whether economic and technological efficiency gains have decreased or increased a particular economy's Ecological Footprint.

ii) **Social and economic conflicts**. Analyzing the relationship between an economy and its resource requirements from the EF/ACC perspective enables people to understand not only ecological but also socioeconomic impacts of current economic activities, and allows them to explore the forces and mechanisms that are threatening to liquidate global resource assets. By demonstrating that natural capital has become the limiting factor for resource dependent human activities, it shows how certain economic activities by one group preempt other group's activities, now or in the future. EF/ACC reveals the extent to which wealthy people and countries have already "appropriated" the productive capacity of the ecosphere through both commercial trade and unaccounted demands on open access source and sink functions. This points to potential conflicts between and within societies.

By putting economic development in the context of ecological constraints, it also challenges the most basic assumptions of growth-oriented international development models as exemplified by the Hong Kong, Japanese or Swiss post-war development paths, which other countries so desperately try to imitate. By showing that Pareto efficiency might not necessarily be the limiting factor for future economic development, and that societies may already have run out of "elsewheres" that can compensate for their ecological deficits, EF/ACC analyses put light on the need to shift policy priorities from economic growth to equity and quality of life considerations.

In a global economy, where exponentially increasing demands are competing for dwindling resources, it is in the self-interest of any economy to analyze its current and future resource requirements and to compare them with the productivity of the resource stocks to which it has jurisdiction or permanent access. In other words, the question is whether the people of an economy will be able to continue to appropriate enough carrying capacity to satisfy their resource needs in the future, a constraint with which any economy will have to cope in the long run.

iii) **Ecological economics.** The EF/ACC concept can inform efforts to link ecological and economic understanding. Most importantly, EF/ACC highlights the ecological and thermodynamic basis of economic processes. It does this not only within a theoretical framework, but also in practical applications as is shown in Chapter V. EF/ACC recognizes productive natural capital as the basis or pre-condition for human-made wealth. More specifically, by distinguishing between available and total appropriated productivity from nature, EF/ACC can distinguish between sustainable natural income and non-sustainable natural income which is used as the economic input -- a distinction that conventional economic analysis does not provide, but which is essential for maintaining natural capital.[27] In other words, EF/ACC adds an understanding of the functioning and throughput requirements of society's respiratory and digestive system, while economic analyses of circular flows (such as System of National Account approaches) only inform about society's cardio-vascular system (Daly 1993:56).

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[27] Neoclassical economist John R. Hicks provided a useful definitions of sustainable income, saying that "the purpose of income calculation in practical affairs is to give people an indication of the amount which they can consume without impoverishing themselves" (1946:171). Economists have used this definition to determine the maximum level of monetary income flows that can be maintained without diminishing the monetary capital stock. Similarly, to determine the sustainable natural income from a "strong sustainability" perspective, Hicks' perspective must be applied to natural capital.

The EF/ACC concept is complementary to, and compatible with, many economic analyses. EF/ACC analyses can provide an account of the embodied services from nature at any stage in the circular flow of money. In other words, they estimate how much of nature's biophysical productivity (or carrying capacity) is necessary to provide all the consumed goods. Or, if the economy is analyzed from a production perspective rather than the consumption perspective, it reveals how much of nature's productivity is necessary to generate the value added to pay for the consumed goods.[28] EF/ACC can also cover blind spots of monetary analysis when effects of biophysical scarcity, long range discounting, unsustainable harvests, or resource dependence need to be interpreted. Thereby, EF/ACC analysis promotes the necessary shift from unsustainable consumption *of* to investment *in* natural capital, a key requirement for developing sustainability.

Furthermore, EF/ACC gives economic stability a new ecological dimension: it helps people realize that uninterrupted access to the required "carrying capacity" (the continuity of resource flows and waste sinks) is a precondition for any stable economy. Also, EF/ACC encourages the extension of traditional economic cost/benefit and marginal analyses to the macro level. Recognition of the economy's biophysical requirements and constraints forces consideration of the cumulative effects of growth, the notion of optimal scale, the ecological impact of trade and particular technologies, and the implications of ecological inequities at the regional, national, and global levels.

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[28] An example would be to analyze how much bioproductivity a staple economy gives up through exports to pay for their industrial imports (which in return represent embodied bioproductivity, but of course, much less per dollar than staple goods).

3. POLITICAL RATIONALE

The Ecological Footprint assists political-decision making in two ways. It provides explicit information about ecological constraints which highlight important ethical questions. Further, as explained in section *ii*, it assists in conceptualizing the dilemmas and conflicts, fostering a common understanding of the issues, and providing a means to monitor progress toward sustainability, thereby helping to build agreement on, and support for, action.

i) **Ethical questions.** EF/ACC emphasizes the material and energy dependence of human beings on Earth's "web of life." EF/ACC shows how the human economy is inseparable from those of other species and fundamentally depends on the continuity of various resource stocks, waste sinks and life support services from all over the world. Further, by communicating the existence of biophysical limits and the realization that people's uses of nature are competing, it raises pertinent social and economic questions. For example, it forces over-consumers to face the otherwise hidden trade-off made between their own consumption levels and the poverty and human suffering that results somewhere else.

By making these trade-offs visible, it questions whether the biophysical limits mean that not everybody in the world can have a decent life, or whether equity and redistribution should take precedence over economic efficiency and expansion. By quantifying both intra- and inter-generational inequities and showing that not everyone can become as materially rich as today's average North Americans or Europeans without undermining global life support systems, this should impose greater accountability on the wealthy and give the poor greater leverage in bargaining for development rights, technology transfers, and other equity measures. EF/ACC assessments might therefore strengthen the case for international agreement on how to share the Earth's productive capacity more equitably and how to use it more carefully.

Apart from the socioeconomic dilemma, the EF/ACC perspective also challenges the predominant extensionist perspective about humanity's right to appropriate a large percentage of nature's bio-productivity[29] while being only one of several million species living on the planet.

The way that people perceive nature (i.e., their worldview or value system) influences how nature's services are being used. For example, in the context of the global economy, people (and many jurisdictional systems) assume that land belongs to people. This was not always the case. In fact, in Europe, it was not until about 1100 AD that land became a commodity (Ponting 1992:154). In contrast, many hunting-gathering, and agricultural societies live "in place," consider a particular place as their home, or feel that they belong to the land, rather than the reverse. For example, in the case of the Quichua in Eastern Ecuador, the Maasai and the Samburu of Kenya, and the Tribal Filipinos, Davis Shelton summarizes the relationship of these peoples to the land as follows:

> Indigenous peoples -- in contrast to the Western economists and development planners -- do not view the land as a "commodity" which can be bought and sold in impersonal markets, nor do they view the trees, plants, animals and fish which cohabit the land as "natural resources" which produce profits or rents. To the contrary, the indigenous view -- which was probably shared by our ancestors prior to the rise of the modern industrial market economy -- is that land is a substance endowed with sacred meanings, embedded in social relations and fundamental to the definition of a people's existence and identity. Similarly, trees, plants, animals and fish which inhabit the land are highly personal beings (many times a "kinship" idiom is used to describe these beings) which form part of their social and spiritual universe. This close attachment to the land and the environment is the defining characteristics of indigenous peoples; it is what links together, in a philosophical and cosmological sense, numerous geographically disparate and culturally diverse peoples throughout the world (Shelton *et al.* 1993).

Maintaining that they belong to the land and that this land is the origin of life reflects

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[29] As a reminder: Peter Vitousek *et al.* suggested in 1986 that human activities appropriated over 40 percent of the terrestrial Net Primary Productivity. As pointed out in Chapter V, this figure might actually be over 100 percent if further functions of nature are included.

these peoples' respect for and commitment to living within local carrying capacity. However, when people think that land belongs to them, local carrying capacity constraints become irrelevant to their decision-making as they can expand their land base or can start to appropriate extraregional carrying capacity. For this task, economic purchasing power or military force is used. Many of the "great civilizations" such as Rome, the Ottoman Empire, the European colonial empires, as well as today's China (in Tibet), Morocco (West Sahara) and Indonesia (in East Timor) -- to name a few -- are prominent examples of military based extraregional appropriators of carrying capacity, while modern industrial countries (and past and modern city states) rely mainly on appropriation through purchasing power.

While revealing important relationships and dependences, EF/ACC's ethical position remains anthropocentric -- similar to the "constant natural capital" criterion (see footnote 45 in Chapter II). It demonstrates that it is in humanity's best self-interest not to over-exploit nature. Such an enlightened form of self-interest is in itself a significant step toward sustainability. Even though some people argue for other species' intrinsic right to exist, using this anthropocentric perspective might be more effective because it reflects the common denominator of today's industrial societies, thereby facilitating communication. Nevertheless, it provides for other species to the extent that their maintenance reduces risks to human(e) survival.

ii) **A transparent and simple framework for planning toward sustainability.** The EF/ACC concept provides a simple framework for understanding the ecological bottom-line of sustainability. Putting sustainability in simple and concrete terms helps to build common understanding, and sets a framework for action. For example, EF/ACC gives decision-makers a physical criterion for ranking policy, project, or technology options according to their impact on ecological sustainability.

Making the sustainability challenges more transparent by providing explicit objectives, spelling out the assumptions, and providing a reproducible method, stimulates the public debate. This shows EF/ACC's potential as an awareness and communication tool between people which could assist planning tasks and the willingness to support change toward sustainability. Without feedback and monitoring, planning is doomed to fail. Until now, there were no clear yardsticks to measure progress in ecological terms when planning toward sustainability. However, the EF/ACC tool, and its procedure for assessing natural capital consumption, can be used as a proxy for measuring progress towards ecological integrity, a pre-condition for sustainability.

Furthermore, EF/ACC underscores the global imperative for local action. It demonstrates an inter-regional ecological multiplier effect of industrial levels of consumption on the welfare of human populations and other species everywhere. By exploring the contribution of both population and material consumption to global ecological decline, EF/ACC emphasizes the need for policies to control both, and provides a tool to assess the success of particular technologies to alleviating this dilemma.

4. EPISTEMOLOGICAL RATIONALE

The EF/ACC concept organizes and interprets information without getting lost in insignificant details. As explained in the following sections, it does this by using land as an accounting unit, by making links between issues rather than fragmenting them, and by providing interpretations of the constraints rather than developing deterministic predictions.

i) **Accounting**. EF/ACC provides a simple accounting model for ecological services. For most accounting purposes money is used because, being fully convertible, it is the limiting factor[30] for many of people's activities.[31] Also the constancy of monetary units (i.e., they do not change spontaneously over time) allows us to keep track of capital stocks and flows by simply adding incomes and subtracting expenditures. However, because monetary approaches are not suitable for sustainability assessments, as discussed above, EF/ACC uses land areas as the accounting unit. Fortunately, in this context, land has similar qualities as money. In a "full" world, ecologically productive land is also a limiting factor, and land areas remain constant over time (even though its productivity might decline or improve); and in fact, as mentioned above, for the last 45 years, approximately half a percent of the ecologically productive land area was degraded per year [Oldeman in Postel 1994:10]).

In contrast to money, land accounts for only the ecological services on which human life depends, not for social and economic necessities. When planning for sustainability, this limitation might actually be interpreted as an advantage over monetary convertibility, because the ecological condition for strong sustainability must be met independently of the other sustainability conditions. In fact, convertibility might tempt the human mind to see prospects for trading off one objective for another one.

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[30] This might be regarded as an application of Liebig's Law of the Minimum to theory building. However complete a theory or model purports to be, it cannot include everything about reality. By definition, every model is nothing but a simplification or interpretation of a more complex reality. However, to be effective at conveying the essence of reality, models must incorporate the limiting factor which determines the behaviour of that particular reality in that particular context. Good theory finds a balance between inclusiveness and effective simplification. Effective models are simple to apply, but are "good enough" to capture the essence. For example, the human body temperature is a good variable to describe the health of the human body. The theory that "temperatures over 36.7 Celsius are bad" is an enormous simplification, but a highly operational one -- i.e., the theory is for most cases "good enough."

[31] While humanity's activities as a whole are limited by natural capital, the individual's apparent constraint is his or her purchasing power.

ii) **Connection of issues.** Land connects most of the ecological issues that humanity is facing. Land-use conflicts and out-crowding of other species is one obvious manifestation. But also, pollution and contamination have an impact on land. Milder forms of pollution and contamination make the harvest from such land less desirable for human consumption, while heavy contamination could significantly harm any kind of life on that and adjacent land. Water shortages might lead to salination of agricultural land, wind erosion or desertification. Also, increased UV_B radiation due to ozone depletion might stunt photosynthetic productivity, which then would increase the EF/ACC if consumption remains constant (see Chapter IV). CO_2-induced climate change might lead to a flooding of productive land close to the shore and destroy ecosystem productivity through desertification or through rapid changes in average temperatures and climatic patterns. This shows why EF/ACC comprehensively covers and connects these various threats to ecosystem health -- even cumulative impacts.

The EF/ACC approach is also conservative: it underestimates the amount of nature that is required to sustain a given lifestyle with prevailing technology. First, it assumes an industrial mode of land-use,[32] and assumes that this land-use is sustainable, which it is not (see Chapter V). Second, EF/ACC leaves out many of nature's functions, due to conceptual difficulties and lack of data. This shows why EF/ACC underestimates the actual carrying capacity appropriation.

iii) **Interpreting data and trends.** The EF/ACC concept does not extrapolate current trends or predict future paths of society. And it does not advocate determinism. In fact, EF/ACC

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[32] The EF/ACC concept is useful to compare lifestyles between people in either agricultural or industrial societies. It is particularly apt to understand the ecological dependence of urban people. However, the concept becomes less meaningful when comparing, for example, a Vancouver citizen with a traditional Innuit, because their consumption stems from incomparable land uses. The former receives most products from intensively and industrially-exploited ecosystems, while the latter lives extensively on fragile and low-yield ecosystems.

provides a coarse ecological picture of what is happening today in light of prevailing technology and management regimes. This means that EF/ACC is descriptive rather than prescriptive. A descriptive approach helps to acknowledge constraints and to stimulate development of realistic options and choices. The tool does not predetermine whether it is possible to decouple economic activities from ecological throughput because of improved technology. But it provides a yardstick to test the claims and asks necessary questions. This simple yardstick makes EF/ACC a heuristic tool for understanding issues and their connections to other concerns. By providing a framework for comparisons, it assists practitioners and activists to judge sustainability strategies and to prepare for public action.

In contrast to traditional research approaches, the EF/ACC concept does not require new data but provides a new interpretation of old data. Rather than building an understanding of the whole by adding up detailed specificities of distinctive issues, EF/ACC starts from the macro perspective, and becomes more detailed in the further steps. Key is to frame the issues and understand the magnitude or scale of the concerns. EF/ACC does not focus primarily on precise estimates, but on conceptual accuracy that is measured with sufficient precision. In the first place, the concept should help us to think about, and conceptualize the implications of, human impacts rather than provide us a technical tool to manage them. By focusing on accuracy rather than precision, EF/ACC depicts macroscopic and systemic relationships rather than singled-out cause-effect correlations. However, whether the EF/ACC concept is either too simplistic to be sufficiently accurate in visualizing the magnitude of the issue and to support the heuristic value of the tool, or too complex to be effectively utilizable, can only be concluded after testing various applications.

5. PSYCHOLOGICAL RATIONALE

To make the EF/ACC concept useful for getting people interested in sustainability and motivating them to actively participate, it must reach out and cater to the psychological needs of the audiences and actors. This means it must stimulate active and engaging education. It must also be in resonance with people's experiences and encourage inter-active communication.

i) **Education.** A major purpose of the EF/ACC concept is to provide an educational tool to enhance people's understanding of their fundamental dependence on nature's services, including resources, waste absorption and life-support services. Furthermore, it underscores temporal and spatial interdependence of all living things, adding a practical plank to the extensionist platform for granting moral standing to non-human species.

By using an heuristic approach for communicating the sustainability concept, it aggregates complex information into a single, easily understood ecological indicator: ecologically productive land. With land as a measurement unit, the finite reality of the biosphere can be translated into concrete everyday experiences, such as sizes of city blocks, football fields and parks. It can also link the experiences of personal consumption to more abstract concepts such as global limits.

ii) **Communication.** Also, EF/ACC tries to bring forward the sustainability dilemmas in a non-threatening way, and much effort has been put into effective communication for various audiences through the use of graphics and appropriate language. Also, it should help people to realize that sustainability is first of all about one-self, not about what others should do. Certainly, much more needs to be done to make the concept even more accessible. Possible strategies might be to use other modes of communication (including experiential learning), develop new angles and examples of the concept, simplify the images and concepts, or present it in an uplifting tone.

In conclusion, the EF/ACC concept addresses all five facets of the sustainability crisis simultaneously and points the way to positive choices. EF/ACC is not a doomsday concept in which society is condemned to collapse because of ecological overshoot. On the contrary, this tool attempts to help society to avoid collapse and to move towards sustainability. EF/ACC is a tool that allows people to compare and rank development options according to their ecological impact. It assists in choosing those technologies or policies which can perform a certain task (or service) with the smallest Ecological Footprint -- or better, within the available natural capital budget. By contrast, prevailing analyses ignore ecological constraints, and development policy decisions are informed (at best) by cost/benefit and other monetary considerations alone. In these circumstances, currently introduced technologies or policies might well increase resource consumption per capita, rather than decrease it.

IV. DEVELOPING A CALCULATION PROCEDURE FOR ASSESSING EF/ACC OF AN ECONOMY

This chapter introduces a calculation procedure for applied EF/ACC assessments. The purpose is to document the procedure, to ensure reproducibility and to show why the results underestimate the actually required land areas.

A. ESTABLISHING AN OPERATIONAL EF/ACC DEFINITION

An economy's EF/ACC can be obtained by calculating how much of Earth's ecological services (measured in land area) the people in that economy must appropriate to provide continuously for their present consumption using prevailing technology. Clearly, if all the details of consumption items and ecosystem functions were included into the assessment, the volume of information and the data processing required would make such venture impractical if not impossible. Therefore, for applications, the concept is simplified:

- The calculation starts from the conservative assumption that the current industrial harvest practices (i.e., agricultural and forestry) are sustainable, which they are not. In other words, current EF/ACC assessments *underestimate* land requirements for human activities.[1]
- Nature's services that are included in the calculation encompass direct and indirect

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[1] Assuming sustainable farming and forestry underestimates the required land area for nature's resource production. For example, agricultural soils in North America are depleted up to 20 times faster than they can reproduce (Giampietro *et al.* 1990a:171). In other words, in order to compensate for the soil loss, agricultural land farmed under current practices should be left fallow for up to 20 years for each year of cultivation. This would increase the appropriated area of agricultural land by a factor of 20. Similarly, current forestry may not be sustainable: it is questionable if the planned 70 year rotation periods can be kept up for more than two to three harvests (Diem 1992:263). Also, these assumed sustainable yield can be maintained only if the forest growth is not slowed down by pests or fires.

The ratio of the land area, which would be required under sustainable land-use and harvest practices, to that land area, which is required today according to current productivity estimates, is called "sustainability factor." These factors suggest the extent to which we presently overestimate ecological long-term productivity.

appropriations of nature's services through human activities; such as, harvest of renewable resources, extraction of non-renewable resources, waste absorption, paving, fresh water consumption, contamination, pollution, and ozone depletion.[2]

- Ecological productivity is classified into eight land (or ecosystem) categories five of which are available for human use (see Section 3 below).

For the time being, the appropriated marine areas are left out of EF/ACC calculations. Cynically, one could claim that the oceans are used primarily as a dumping ground for waste, a function which cannot be translated into a well-defined appropriated area.[3] On the other hand, fresh-water and marine ecosystems presently produce only a small fraction of the resources used by the human economy. Also, it is unlikely that under current practice, the resource yield from oceans, lakes, and rivers can be much expanded; for example, wild fish stocks, the main renewable resource from fresh-water and marine ecosystems, provide less than two and a half percent of the human food requirements,[4] and most fisheries are already over-harvested. FAO estimates that the global harvest of marine food approaches 90 percent of the theoretical maximum yield, if it has not reached it already (Hibler 1992:34, Brown 1994:179). In fact, "...the per capita seafood supply, which peaked at 19 kilograms in 1989, will be back down to

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[2] At this point, our research has focused on the ecological impact of the first four activities. We intend though to include the impact of the other activities in subsequent EF/ACC research. Nevertheless, leaving out some of these functions underlines, once more, that this approach underestimates the human impact on nature.

[3] The currents of the oceans lead to a significant material and heat exchange between the various areas of the oceans. Therefore, it is next to impossible for most cases to determine the area that corresponds, for example, to a given absorptive capacity for degradable waste. Furthermore, EF/ACC might not be a useful concept for illustrating the ecological impact of non-degradable organic waste (such as DDT and PCBs) or non-organic waste (such as heavy metals or radioactive substances) as this waste accumulates and is not being recycled or transformed by nature's services. Such non-degradable waste might only be reflected in Ecological Footprint consideration to the extent that heavily contaminated areas become unavailable for human consumption, thereby reducing the available carrying capacity to human beings (see also Weber 1994:41-60).

[4] These 2.5 percent refer to the food's nutritional energy content. This corresponds to about 16 percent of globally consumed animal proteins (Weber 1994:43, FAO 1990:tbl106).

11 kilograms..." by 2030, comments Lester Brown (1994:180).[5]

This simplified EF/ACC approach might be criticized for not considering a variety of biophysical life-support services, particularly those which are not directly associated with land-based renewable resource production. However, this omission does not weaken the EF/ACC analysis. First of all, ecological models should not include all aspects of the ecosphere functioning, but only the essential and critical ones. In other words, to be effective, they need to focus on the limiting factors of the modeled system.[6] For example, one insight of the more recent sustainability debate is that, in contrast to the 1970's focus on non-renewable resources, the more worrisome concern today is the depletion of renewable resource stocks (Robinson 1993). Non-renewable resources are included to the extent that they impact the ecosphere, namely through their energy requirement for extraction and processing, and through their occupation of built-up areas.

Indeed, even though the EF/ACC approach underestimates the actual land requirements, or is conservative, this simplified EF/ACC approach still provides a valid comparison between nature's productivity and human consumption -- the crucial ecological issue for sustainability. Including in the calculations more of the other life-support services of nature which are performed by aquatic systems and ecologically productive land (such as wilderness areas), would complicate the analysis as these services cannot be assigned as clearly to specific human

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[5] Fish-farming would not necessarily overcome the ecological scarcity, but only shift the scarcity to agriculture which produces the feedstock for these farms.

[6] See footnote 30 in Chapter III.

activities without improving the tool's heuristic value.[7]

B. OUTLINING THE CALCULATION PROCEDURE

Central to the EF/ACC concept is the notion that for every significant type of material or energy consumption, a certain amount of land in various ecosystem categories is required to provide the consumption-related resource flows and waste sinks. This section explains how to link consumption categories and land areas, and shows how this information assists EF/ACC calculations.

1. THE LAND-USE OF CONSUMPTION

To determine the total land area to support a particular pattern of consumption, the land-use implications of each significant category of consumption must be understood. Since it is not feasible to assess land requirements for the provision, maintenance, and disposal of every single consumption good, the calculations are confined to major categories. This helps to avoid the gigantic task of assessing the impact of each of the several hundred thousand purchaseable consumption goods on the hundreds of land categories that can be distinguished.

Estimating EF/ACC is an iterative process. Rather than starting with the analysis of a particular household's consumption, it is simpler and more effective to assess first the EF/ACC of a region's or nation's aggregate consumption flows, such as the national fossil fuel, food or

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[7] If it was required to roughly assess humanity's impact on the remaining life-support services, one could suspect that the *per capita* impact would be proportional to the *per capita* land area appropriated for resource production. However, as explained later, in the present EF/ACC approach, some areas that provide life-support services (such as biodiversity and carbon storage) are deducted from the total land that is available for direct human use, rather than adding individual shares to the individual Footprints.

timber consumption. Most data for preliminary assessments of the aggregate quantities consumed can be obtained from national statistics.[8] For more sophisticated, focused or detailed analysis, it is necessary to estimate the land-uses associated with the various consumption categories and subcategories, as well as of smaller consumer units such as municipalities or households. Adding up the land-uses of these disaggregated consumption items then provides a means to check this result against the first assessment of aggregate consumption flows and their land-use. Going back and forth from the disaggregate consumption analysis to that of aggregate consumption helps eliminate data gaps, errors and apparent contradictions which are the inevitable hurdles of any EF/ACC assessment.

2. CONSUMPTION CATEGORIES

To keep the EF/ACC quantification manageable, consumption are divided into main categories only. To simplify data collection, it is advisable to adopt the classifications used by official statistics. On the most general level, it seems useful to separate consumption into five main categories (Table 4.1).

Table 4.1: The five main consumption categories

1. food
2. housing
3. transportation
4. consumer goods
5. services

[8] For many consumption categories, national statistics provide economic production and trade figures. From that, "apparent consumption" can be assessed: *apparent consumption = production + imports - exports.*

For more refined analysis, these categories can be subdivided. For example, food could be divided into vegetable and animal-based products. Transportation could be separated into public and private transportation. These sub-categories should be defined strategically in order to answer effectively the policy questions of interest. Each category encompasses all the embodied resources[9] that go into the production, use and disposal of its functions and processes. For example, even though "services" are considered to be "non-material," they require material flows to make them happen. In the case of money transactions at a bank, such physical energy and resource requirements include the building and maintenance of bank infrastructure, the generation of bank statements, and the use of computers.

Numerous sources can be used to quantify consumption and its embodied resources. Statistics on waste streams, household and national expenditure, metabolic rates, diet information, trade figures, and resource flows can be consulted -- and checked, one against the other.

3. LAND AND LAND-USE CATEGORIES

Similarly, for the purpose of these calculations, land (including available and non-available land) is divided into categories. For the purpose of EF/ACC calculations, the following eight main land categories have been identified (Table 4.2). They are similar to the classification used by The World Conservation Union (IUCN 1991:34,126,186).

The first category is called "phantom land" in accordance with William Catton (1980:44-

[9] Embodied energy and resources of a commodity are the energy and resources that are used during the entire life-cycle of the commodity for manufacturing, transporting and disposing of the commodity, while "energy intensity" refers to the embodied energy per unit of a good or service. Similarly, embodied EF/ACC is the contribution to EF/ACC which is needed to produce, and later absorb, the waste of this commodity.

46) who points out that humanity is using some of nature's productivity without nature being able to replace or compensate for it. For example, by using fossil fuel today we put a burden on future generations, as less fossil fuel will be available to them. In particular, they will have to cope with elevated CO_2 levels in the atmosphere. In other words, this use of nature does not correspond to a natural income but leads to the depletion of natural capital stocks.

Table 4.2: The eight main land and land-use categories

I) phantom land:	a.	land equivalent for fossil energy	(NON-RENEWABLE RESOURCES) **Note: in a sustainable economy, this would depend on land in category *c*, *d*, *e* or *f*.**
II) consumed land:	b.	built environment	(DEGRADED LAND)
III) currently used land:	c.	gardens	(REVERSIBLY BUILT ENVIRONMENT)
	d.	crop land	(CULTIVATED SYSTEMS)
	e.	pasture	(MODIFIED SYSTEMS)
	f.	managed forest	
IV) land of limited availability:	g.	untouched forests	(PRODUCTIVE NATURAL ECOSYSTEMS)
	h.	non-productive areas	(DESERTS)

Only five of these land categories are available to human use in the long run, namely land categories *b-f*. As discussed below, the land associated with fossil fuel use (category *a*) would have to be accommodated by available productive land (in categories *c-f*). Furthermore, some of the Earth's ecologically productive land is not available either (category *g*). These are the virgin ecosystems whose harvest would lead to a net CO_2 release which the ecological production on this land would not be able to compensate before 200 years (Wellisch 1992:4, Harmon *et al.* 1991, Marland & Marland 1992). Also, these areas are indispensable biodiversity refuges that should not be disturbed. The only direct human use of such ecosystems would be their sink function for sequestering CO_2, but of course, only in those cases where these virgin systems still accumulate carbon. The other category of land with limited availability or "usefulness" is the land that is ecologically not highly productive (category *h*). This includes high and low-latitude deserts such as Antarctica or the Sahara.

These land categories encompass a multitude of nature's services in support of human activities: namely, the provision of commercial energy, water and space for human infrastructure, the absorption of waste, and the preservation of biodiversity.

i) **"Carrying capacity requirements" for commercial energy:**[10] Commercial energy consumption can be translated into land areas. This section discusses the land use implications of consuming fossil fuel, hydroelectricity and some other renewable energy sources. The energy-land equivalence ratio reports how much energy per year could be provided by one hectare of ecologically productive land. The units used are Gigajoules per hectare and year (or 10^9 [joules/ha/yr] = 1 [Gj/ha/yr]).

There are three approaches to convert the consumption of **fossil energy** into a land area equivalent. Each of them follows a different rationale, but they come up with about the same land area equivalent. All approaches conclude that the consumption of 80 to 100 [Gj] of fossil fuel per year corresponds to the service appropriation of approximately one hectare of ecologically productive land. Appendix 1 explains in more detail the rationales for, and

[10] Most energy on which human life depends comes from the sun. In fact, life on Earth is powered by a solar flux of about 175,000 [TW] (or Terawatt), while the commercial energy of the human economy amounts to "only" 10 [TW] (or 310,000 [Pj/yr] according to the World Resources Institute 1992:314).

calculations of, these three approaches.

The first method involves calculating the land required to grow the ethanol equivalent of present fossil fuel consumption. The rationale for this approach is the notion that a sustainable economy must not tap into fossil capital, but produce continuously the energy it consumes. Ethanol is a potentially renewable energy carrier that is technically and qualitatively equivalent to fossil fuel as it is a homogeneous, concentrated fuel that can easily be stored and transported, and that can fuel many human-made processes.[11] From this perspective, the equivalence ratio of fossil energy into a land area can be calculated by estimating how much ecologically productive land would be required to produce the biomass input and the processing energy for producing the same amount of ethanol. As documented in Appendix 1.1, the most optimistic estimates for ethanol productivity suggest a net gain of 80 [Gj/yr] per hectare of ecologically productive land.[12]

The second method involves estimating the land area needed to sequester the CO_2 from fossil fuel burning. The rationale for this approach is the argument that, in a sustainable society, people who use fossil fuel should at least be responsible for sequestering the CO_2 that their

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[11] Instead of ethanol, methanol could have been another fuel choice for this approach. Calculations by Yoshihiko Wada (1994a) based on Barnard (1984) and Smith (1982) suggest a methanol productivity of 10.5 to 13.5 [Mj] per kilogram of wood input. For New Zealand tree plantations (reaching one of the highest timber productivities in the world with about 23 [m^3/ha/yr]), this would translate into an energy-land equivalence ratio of 120 to 150 [Gj/ha/yr]. However, for timber productivities typical for Canada, Russia, or Scandinavia, the figure would drop to 17 - 30 [Gj/ha/yr], or approximately 55 - 68 [Gj/ha/yr] for the US (New Zealand Forest Owner Association 1994:1).

[12] On the one hand, there are more efficient ways of using biomass energy than converting it first into ethanol. However, burning ethanol reflects the current wasteful consumption of fossil fuel: for example, in many low-temperature applications such as domestic warm water or space heating, high-quality (or low-entropy) energy fuels are used where low-quality (or high-entropy) fuels would suffice. On the other hand, it seems likely that due to the ecological impacts of modern agriculture such as erosion, and due to the removal of crop residues (which is necessary to achieve the high ethanol yields) the estimated output could not be sustained. In fact, the sustainable yield of ethanol could be about one magnitude smaller than the estimated 80 [Gj/ha/yr] -- which underlines once more the conservative nature of the current EF/ACC calculations (see Appendix 1.1).

activities release into the atmosphere. This assumes that humanity is worse off with every additional CO_2 molecule added to the atmosphere. Forest ecosystems and peat bogs are among the natural systems that can absorb CO_2 over longer time frames, such as the next 50 to 80 years -- forests having the highest accumulation rates. As documented in Appendix 1.2, average figures suggest that average forests[13] can accumulate approximately 1.8 tonnes of carbon per hectare and year (Wada 1994a). This carbon absorption rate suggests that one hectare of average forest can sequester annually the CO_2 emission generated by the household consumption of 100 [Gj] of fossil fuel (including the CO_2 released for extraction and refinement).

The third method involves assessing the land area required to rebuild a natural capital stock at a rate that is equivalent to the consumed fossil fuel. The rationale for this approach builds on a biophysical interpretation of an argument put forward by economist Salah El Serafy (1988). In essence, he proposes that a sustainable society can use non-renewable resources if it replenishes, at the same rate, an equivalent renewable resource asset. Replenishing what is used would address inter-generational equity, a precondition for sustainability. Calculations, documented in Appendix 1.3, show that one hectare of average forest could accumulate about 80 [Gj] of chemical energy per year. In other words, the energy-land equivalence ratio, from the perspective of restocking renewable natural capital at the rate that fossil fuel stocks are depleted, amounts to approximately 80 [Gj/ha/yr]. However, this ratio overestimates the forest productivity for available energy, as the stock of forest biomass would be of considerably lower technical value for powering human-made processes than fossil fuel.

Methodically, the CO_2 approach is the most conservative one and, therefore, shows the

[13] Average forest productivity corresponds to an average calculated from the typical forest productivities of temperate, boreal and tropical forests weighed according to their land area on the globe.

highest energy-land equivalence ratio. Reviews and discussions showed that this approach received the highest acceptance. Therefore, **100 [Gj/ha/yr]** was chosen as the energy-land equivalence ratio for fossil fuel, and is used in all current EF/ACC assessments. Choosing a somewhat arbitrary figure for this fossil energy-land ratio does not compromise the usefulness of EF/ACC assessments for three reasons. First, it still illustrates the appropriated carrying capacity's order of magnitude. Second, the EF/ACC assessment can easily be adjusted if a modified energy-land equivalence ratio or a more detailed energy analysis would be available. Third, as long as the same equivalence ratios are applied, EF/ACC remains a sufficiently precise common sustainability yardstick that can compare the relative merits of various options.

For **hydro-electricity**, the land requirements can be estimated by adding up the land that gets flooded by the damming, and dividing it by the annual electricity production. Furthermore, one could add the pasture claimed from forest land which is necessary to provide corridors for high voltage power lines. Vaclav Smil suggests productivities of 160-480 [Gj/ha/yr] for lower-course dams (50-200 [MW] size), 1,500-5,000 [Gj/ha/yr] for middle and upper-course dams (including a 50% load factor), and 15,000 [Gj/ha/yr] for alpine high-altitude dams (1991:193-194). In contrast, David Pimentel *et al.* assess hydroelectric productivity at only 280 [Gj/ha/yr] (Pimentel *et al.* 1984 in Pimentel *et al.* 1994:208). Michael Narodoslawsky *et al.* estimate the productivity of typical hydro power stations at about 1,500 [Gj/ha/yr] (1993:4.2) which still excludes the space requirements for power lines. Including the powerlines in the Canadian case would reduce Narodoslawsky *et al.*'s productivity for hydroelectricity to approximately 1,000 [Gj/ha/yr].[14] This energy-land equivalence ratio of 1000 [Gj/ha/yr] which still leaves out other

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[14] Canada's electrical transmission lines measure about 153,000 kilometres (Energy, Mines and Resources, Canada 1992:68). However, only 62 percent of the electricity production is hydro-electrical (Energy, Mines and Resources, Canada 1992:38). Assuming corridors of 50 metre widths and a total primary electricity production of 1,304 [Pj/yr] (Statistics Canada 1992:tbl1b), the total land area appropriated would add up to (1,304E6 [Gj/yr] / 1,500 [Gj/ha/yr] +

impacts, such as impact on fisheries, could be used for EF/ACC calculations. The corresponding appropriated land areas would fall in the categories of built environment (flooded areas) and pasture (transmission corridors). However, at this point of the EF/ACC research, electricity consumption is not yet included in the EF/ACC assessments.

For **fossil fuel produced electricity**, the current EF/ACC approach uses the United Nations Statistical Office's 30 percent efficiency assumption which translates the above equivalency ratio into a productivity of 30 [Gj/ha/yr] (World Resource Institute 1992:324).

In comparison to fossil fuel, **renewable energy** sources promise high productivities. Preliminary analysis suggests for photovoltaic electricity a productivity of 100 to 500 [Gj/ha/yr] (Winter *et al.* 1988 and calculations by Wada & Wackernagel, in Wada 1994), 430 [Gj/ha/yr] according to Michael Narodoslawsky *et al.* (1993:4.2), or 1,300 [Gj/ha/yr] according to David Pimentel *et al.* (Pimentel *et al.* 1984 in Pimentel *et al.* 1994:208). Other examples of renewable energy production include sustainable selective stem cutting in moist areas which would produce about 50 [Gj/ha/yr] (Smil 1991:191), while wind generation in America's windiest places might score up to 550 [Gj/ha/yr] (Smil 1991:196-197). According to Vaclav Smil, well-designed low-temperature solar collectors (for domestic hot water applications) could achieve 10,000 to 30,000 [Gj/ha/yr] (1991:198-199), while Michael Narodoslawsky and his colleagues estimate their productivity at 3,600 [Gj/ha/yr].[15]

62% * 153,000,000 * 50 /10,000 [ha] = 870,000 + 470,000 [ha] =) 1,340,000 [ha]. This reduces the productivity for electricity to (1,304E6 [Gj/yr] / 1,340,000 [ha] =) 970 [Gj/ha/yr].

[15] Note that many of these applications such as photovoltaic cells, windmills or hot water solar collectors do not necessarily require ecologically productive land.

Nuclear energy is not incorporated in current EF/ACC assessments. According to Vaclav Smil, nuclear energy has low space requirements. In fact, including the complete fuel cycle (mining, processing of uranium ores, uranium enrichment, production of fuel elements, reprocessing of spent fuel, and storage of radioactive wastes), and assuming no accidents, it produces an astonishing 500,000 to 750,000 [Gj/ha/yr] (Smil 1991:195-196), or 53,000 [Gj/ha/yr] according to David Pimentel *et al.* (Pimentel *et al.* 1984 in Pimentel *et al.* 1994:208).[16] Whatever the right figure might be, the productivity of well-functioning nuclear power plants seems to exceed that of the most efficient ethanol production by two to three magnitudes. However, the shattered popular trust in nuclear safety, the fact that peaceful use and military applications are interwoven, and the seemingly unsolvable problem of radioactive waste -- which becomes an irresponsible burden for future generations -- suggest that nuclear power is not a viable energy option today (Buitenkamp *et al.* 1993:25).

ii) **Provision of built-up land.** Paved-over, built upon, badly eroded or otherwise degraded land is considered to have been "consumed", as it is no longer biologically productive. This means that productivity is reduced for the future. To secure "no net loss", another area somewhere on the planet that was degraded should be made productive again to compensate for the lost ecologically productivity of the built-up land. Also, an additional debit could be charged against such degraded lands by estimating the time, energy and material that would be required

[16] In the case of the Chernobyl plant, however, the productivity decreases to less than 20 [Gj/ha/yr]. The "back of the envelope" calculation is as follows:

Electrical production: with an assumed output of 1,000 [MW] electrical energy for the period of 20 years, the life cycle production adds up to 631 million [Gj].

Land occupation: the 1986 meltdown-induced contamination might have made unfit for human consumption 10 percent of that year's agricultural production in Europe. This would translate into 34 million hectares of agricultural land (or 10 percent of Europe's and 2 percent of the Soviet Union's agricultural land [one fifth of the Soviet Union was in Europe]) (World Resources Institute 1992:263).

Result: the resulting productivity is 631E6 [Gj] / 34E6 [ha*yr] = 18 [Gj/ha/yr], which does not yet include long-term damages and damages to human beings.

to restore productivity. However, current EF/ACC assessments do not include this step.

iii) **Provision of water.** In many regions of the world, the consumption of water for one human use compromises on another possible use of that water. Or it may be shipped in. Depending on where the water comes from, the EF/ACC analysis could either count the additional land requirements to supplement productivity that dropped due to the lack of water; or calculate the energy requirements for transporting the water, and translate this energy into an equivalent land area. Catchment areas for water should only be included in EF/ACC assessments if water collection is the only economic function this catchment area is used for; otherwise, it would lead to double counting.

iv) **Absorption of waste products.** Nature has a limited capacity to absorb human-made waste. What is not degraded and absorbed accumulates locally or is carried away by water or air, and might finally end up in the sea. Contaminated soil or polluted water and airsheds may reduce nature's productivity, or contaminate nature's products to an extent that they are not fit any more for human consumption. Or, the depletion of the atmospheric ozone layer might reduce bioproductivity through increased UV_B radiation levels (Rees 1990a, *The* UV_B *Impacts Reporter* 1994). For that loss of biological productivity, one could calculate a corresponding EF/ACC area. However, at this point of the EF/ACC research (and with exception of CO_2 sequestering) waste absorption and pollution are not included in the calculations. Even though there are some studies available on the impact of pollution, they concentrate primarily on its associated monetary costs and can therefore not be generalized to biophysical damages (UPI 1991, GVRD 1994).

v) **Securing of biodiversity.** As pointed out by conservation biologists, biodiversity is threatened by the loss of wilderness area as well as by its fragmentation. There is an ongoing debate on how much wilderness area must be set aside to secure ecological stability. Ecologist Eugene Odum suggests that a third of all eco-systems should be preserved to secure biodiversity. The Brundtland commission also proposed that at least 12 percent of the Earth's land area should be set aside with the explicit purpose of conserving ecosystems and species (WCED 1987:147,166).[17]

Category *h* in the above land classification refers to the about 1.5 billion hectares of untouched forest ecosystems or forests that are close to their original state (Postel & Ryan 1991:75). These ecosystems should not be harvested for the very reason that such harvests would lead to a net release of CO_2. A second reason for preserving these ecosystems is their function as biodiversity sanctuaries. In fact, these 1.5 billion hectares correspond to just 9 percent of the Earth's terrestrial area -- about 17 percent of the ecologically productive land -- while providing habitat to probably the bulk of the Earth's biological diversity (Wright 1991:293, World Resources Institute 1992:262).

4. THE MATRIX

Once the main consumption and land-use categories are defined, the connection between each of the five (or more) consumption categories and each of the six land-use categories that are available (categories *a* to *f* in Table 4.2) must be established. For this purpose, a matrix is used that links the human consumption (rows) with the land-uses (columns). Table 5.1 shows an example of this Land-Use - Consumption Matrix (Chapter V). Each of the 30 (=5*6) basic cells in the matrix converts a particular consumption item into its corresponding "appropriated"

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[17] This corresponds to about 2 billion hectares or 23 percent of the Earth's ecologically productive land.

land area.

The rows are numbered from 10 to 60 -- of which the 10s are food, the 20s housing, the 30s transportation, the 40s consumer goods, and the 50s, the services received. The 60s correspond to the totals. The categories contain not only the immediate land-use of these goods and services, but also the land needed to produce, maintain, and (where the data are available) absorb them. This amounts to (simplified) life cycle analyses of all major consumption items. For example, the housing category encompasses the land on which the house stands (including the necessary urban infrastructure), the land necessary to grow the house's timber, and the land required for producing its heating energy.

In correspondence with the classification in Table 4.2, the columns of the matrix are identified with the letters **"A"** to **"F"**, each representing a type of land-use. More specifically, column **A** details the fossil energy consumed in the form of a land-equivalent. As discussed above and in Appendix 1, an energy-land equivalence ratio of 100 [Gj/ha/yr] is used. Column **B** indicates the amount of degraded land or built environment that is occupied. Column **C** contains the garden area which is mainly used for vegetable and fruit production. Typically, this land features the highest ecological productivity. Column **D** subsumes the crop land, and column **E** the pastures for dairy, meat and wool production. Finally, column **F** includes the prime forest area necessary to provide all the forestry products. The column **TOTAL** summarizes the land consumption for each consumption category.

For translating consumption into land-use, the global averages of ecological productivity-per-hectare are used as standardized measurement units. This provides various advantages. First, it reflects realistically the link between local economic consumption and global ecological production on which they draw. In fact, industrial urban communities only live to a small extent from local ecological productivity. Most of their goods and services are imported from other regions on the globe. Second, having a globally-adjusted measurement unit makes international comparisons possible and meaningful. Such comparisons are necessary as ecological sustainability in the context of the current global economy can no longer be achieved regionally, but has become a global concern. And third, it makes accounting easy while not distorting the aggregates. When comparing a population's Ecological Footprint with locally available land, this local land area must be adjusted to represent the land area according to the global average in ecological productivity. For example, if the local region contains land twice as productive as the world average, then this land would count for double its area. If productive agricultural land with double the average productivity is paved, then double the area (measured in average land) is lost for ecologically productive functions. Adding up all these regionally-adjusted available land areas will add up to an area equal to the total available land on Earth.

This calculation approach is static and does not depict the mechanism of accelerated land appropriation by industrial activities. As explained in the preceding chapter, EF/ACC is merely an ecological snapshot. However, when the task comes to analyzing changes over time, the EF/ACC of various points in history can be reconstructed which then will trace this development. Also, in contrast to many other approaches, EF/ACC assessments do not start from detailed analyses that are dovetailed to a whole, but begins by analyzing aggregate data that only later are divided into more specific sub-components. This helps to get the magnitudes right and to capture the indirect effects of consumption; factors which many of the more detailed approaches have methodological difficulties incorporating.

These calculations do not disregard the possibilities for technological improvements that might substitute for some resource requirements. In fact, the Ecological Footprint of a population could be reduced by either decreasing the amount of their consumption (and thereby decreasing the embodied resource and services flow drawn from natural capital) or by using a technology that allows the production of the same consumption with fewer of nature's resources and services. The latter one is described as "decoupling" economic activity from natural capital requirements. This emphasizes that EF/ACC does not extrapolate future dependences on natural capital flows of an economy, but rather becomes a yardstick for monitoring the progress of an economy's dependences on nature's resource services, either through a reduction in consumption, or through decoupling from these material flows.

C. ADOPTING THE CALCULATION PROCEDURE TO SPECIFIC APPLICATIONS

As EF/ACC can be applied to various scales (individual, household, region, nation, world), the first task is to define the population for which the carrying capacity appropriation should be calculated. To make the results useful, they need to be compared to other EF/ACC results. In some applications, an interesting comparison might be the difference between the size of a population's EF/ACC and the land area that is available in the local region, or the difference among Ecological Footprints associated with various lifestyles of that population.

Estimating the Ecological Footprint of policies means to reveal the policy's implications on the resource consumption and waste generation practices of the affected population. For example, policy implications could be documented in terms of the additional (or reduced) Ecological Footprint that this policy makes necessary. To assess the EF/ACC increase due to a particular policy, the first step is to establish a list of all the policy's possible direct and indirect effects on resource consumption and waste generation. A useful question for thinking about these issues is how this policy might alter the lifestyles of the affected people. The next step is then to quantify each of these impacts. Adding up all the quantified impacts then gives the increment in Ecological Footprint which is induced by this policy.

This shows that EF/ACC assessments procedures still need to be adjusted for every new application. In particular, new applications require the selection of systems boundaries and the identification of indirect effects, both of which are subject to personal judgement and values. However, such assessments force the analysts to declare their judgements and values, and to reflect upon the magnitude of possible impacts.

Also, the described calculation procedure has been left as simple as possible in order to communicate about magnitudes, rather than to obfuscate the analysis with percentage range considerations. On the other hand, there might be a concern that EF/ACC's focus on quantitative analysis might detract from qualitative issues. An EF/ACC analysis however, just provides a framework to point out the magnitude and connection between issues and does not substitute for further and more detailed qualitative analysis of these various issues.

Alternatively, an input-output model could have been used to trace the embodied natural capital flows through various sectors of the economy. This might be a useful approach for more refined analysis and for gaining a better understanding of the intersectoral resource flows. However, such a detailed analysis is not necessary at this stage when the main purpose of the EF/ACC approach still is to visualize the impact of *aggregate* resource consumption and waste generation on the future availability of natural capital.

In summary, this EF/ACC framework and its calculation procedure are still coarse and general, and have the potential to be methodologically refined, if deemed necessary.

V. ASSESSING THE IMPACT OF PEOPLE, THEIR CONSUMPTION AND THEIR TECHNOLOGY: EF/ACC APPLICATIONS

The purpose of this chapter is to show how the EF/ACC concept can be translated into reproducible numbers, and how available official statistics and handbooks support such calculations. To achieve this, I document in this chapter one detailed EF/ACC calculation and describe other EF/ACC applications.

A. THE APPROPRIATED CARRYING CAPACITY OF AN AVERAGE CANADIAN[1]

1. THE PURPOSE OF THIS CALCULATION

This application is to demonstrate the feasibility of EF/ACC calculations. The case of calculating the average Canadian's Ecological Footprint is chosen because this application:

- can test the basic premises of the EF/ACC analysis. By comparing the Canadian's Ecological Footprint to globally available ecological productivity, it can expose whether, or to what extent, natural capital is limiting the scale of human activities on the globe;
- can be executed with data that are available and can be found in sources such as international and national statistics, and agricultural, forestry and engineering handbooks; and,
- is a stepping stone for further analyses as key relationships and baseline data are identified.

This application provides a conservative approximation of how much of the Earth's available land (in six exclusive land-use categories) is needed to produce the natural resources and services which the average Canadian presently consumes and to assimilate the waste which

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[1] This application is based on my research for the UBC Task Force on Healthy and Sustainable Communities; in particular, the work undertaken in conjunction with the Richmond Planning Department (Wackernagel *et al.* 1993).

he or she presently generates using prevailing technology.

In other words, this EF/ACC application is calculated from the consumption perspective. This includes: direct household consumption, such as the items purchased by the consumer; indirect consumption, such as the goods and services received for free, or the consumption by businesses and government to provide the household's direct consumption. These received services include schooling, policing, governance or health care. Statistics on GNP and household expenditure patterns are used as data source for resource throughput.

2. THE CALCULATION PROCEDURE

Establishing the land-use - consumption matrix builds on two tasks. First, the yearly consumption in all the five categories must be estimated, and second, the ecological productivity for the six land-use categories must be determined. To keep the task manageable, this can be done in an initial round of rough estimates of economic consumption and ecological productivity. To encourage other applications, to make the calculations transparent and transferable, and to allow comparisons with other areas in the world, World Resources Institute data are used where ever possible.

The average Canadian's consumption is impressive: his or her food consumption amounts to about 3,450 [kcal/cap/yr] of which 1,125 are animal products (FAO 1990b:tbl106). According to the World Resources Institute, Canadians occupy a total of about 55,000 km^2 built-up land (World Resources Institute 1994:285). Also, the average Canadian drives a car 18,000 [km] per year, uses approximately 200 [kg] of packaging, spends around $2,700 on consumer goods and another $2,000 on services (Statistics Canada 1989:36).

Every year, approximately 321 [Gj] of commercial energy[2] are required per average Canadian to provide all these goods and services (World Resources Institute 1992:314). Most government statistics provide a break-down of energy consumption by economic sector. However, using these statistics distorts the direct and embodied energy requirements of households, because the industrial sectors do not produce for domestic consumption only, and some of the consumption goods are not produced within the country. In the current EF/ACC applications, import-export balances are only analyzed for the primary products of the forestry, agriculture, and commercial energy sector. For the other sectors, such as manufacturing and service industries, an ecologically balanced trade is assumed. In other words, it is assumed that apart from these primary sectors, the embodied resources and energies exported are equal to those imported, and that therefore the errors would cancel out.[3]

To assess productivity, various sources are used. The trade and productivity figures of the UN Food and Agriculture Organization (FAO) are used to determine global average productivity for various crops. For ranching, the carrying capacities for pastures suggested by agricultural handbooks are used as productivity figures. The average forest productivity is assumed to be 2.3 [m^3/ha/yr] which corresponds to the average productivity of Canadian forests. This estimate is also close to the one used by the Dutch *Friends of the Earth* in their study on *environmental space*, which assumes a global average of 2 [m^3/ha/yr] for timber productivity

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[2] In current EF/ACC assessments, energy is accounted at the consumption level rather than at the level of primary production.

[3] A more in depth EF/ACC study, however, will have to include an analysis of the trade balance in embodied carrying capacity. Such a study could build on Robert Smith's ecological-economic input-output analysis which shows that the exported embodied CO_2 corresponds to about 20 percent of the national CO_2 emission (1993:85). Another example is provided by Patrick Hofstetter who calculated a simplified energy trade balance for Switzerland (1992a).

(Buitenkamp *et al.* 1993:82).[4] As discussed above and in Appendix 1.1, CO_2 sequestration corresponds to an energy productivity of 100 [Gj/ha/yr]. However, at this point, absorptive capacities for waste and pollution (with the exception of CO_2) are not yet included in the EF/ACC calculation. This underestimates the land-use requirements. Appendix 2 documents in detail the data sources and the calculations for each cell of the matrix.

3. EXAMPLES OF TRANSLATING CONSUMPTION INTO LAND-USE

To explain the mechanics of translating consumption into land-use this section provides three examples.

a) Example 1: fossil energy consumption

Question: How much ecologically productive land would be required per average Canadian to sequester all the CO_2 released by their consumption of fossil energy? This corresponds to cell **"a60"** in the consumption - land-use matrix (Table 5.1). **"a"** stands for the matrix's land-use column, **"60"** for its consumption row.

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[4] On the one hand for Canada, the average mature forest contains 163 [m^3/ha] of timber. Assuming a harvest rotation period of 70 years, this would result in a productivity of about 2.3 [m^3/ha/yr]. This productivity corresponds also to typical figures for the Annual Allowable Cut in Canadian public forests (Canadian Council of Forest Ministers 1993:7-13). On the other hand, data compiled by Gregg Marland suggest that the world timber productivity would average 4.1 [m^3/ha/yr] (1982:39). This is calculated from boreal productivities of 2.3 [m^3/ha/yr] (corresponding to 33% of the global forest area), 3.3 [m^3/ha/yr] for temperate forests (25 % of the area) and 6 [m^3/ha/yr] for tropical forests (42 % of the area). However, these estimates are questionable, particularly those for the tropical forests. As of today, no reliable productivity data have been collected for these forests. In fact, a study for the International Tropical Timber Organization concluded that less than 0.1 percent of tropical logging was done on a sustained yield basis (Postel & Ryan 1991:79). Another way to calculate average timber productivities is the use of carbon accumulation data. Yoshihiko Wada's survey of the literature suggests a carbon absorption rate of 1.8 [t/ha/yr] (Wada 1994a). This corresponds to about 4 [t/ha/yr] dry biomass of which a maximum of 25 percent might be merchantable timber. With an average density of approximately 500 [kg/m^3]), this would correspond to about 4*0.25/0.5 = 2 [m^3/ha/yr], which is precisely the figure of global average productivity of "working" forests used by the Dutch *Friends of the Earth* study (Buitenkamp *et al.* 1993:82).

Canada's commercial fossil fuel consumption amounted to approximately 7,269 [Pj] in 1989.[5] In 1989, 26.3 million people lived in Canada (World Resources Institute 1992:246). The energy-land equivalence ratio for fossil fuel is 100 [Gj/ha/yr] (Chapter IV and Appendix 1). Therefore, each Canadian would require...

$$\frac{7{,}269\ [Pj/yr] * 1{,}000{,}000\ [Gj/Pj]}{26{,}300{,}000\ [Canadians] * 100\ [Gj/ha/yr]} = 2.76\ [ha/capita]$$

for sequestering the CO_2 released by this fossil fuel.

b) Example 2: forest area for paper consumption

Question: How much forest area is dedicated to providing fibres for paper that an average Canadian consumes? This corresponds to the cells **"f10"**, **"f40'"**, **"f43"** and some of **"f20"** in the matrix.

Canadians consume about 244 kilogram of paper every year (Appendix 2.1:**"x43"**). Currently in Canada, the production of each metric tonne of paper requires 1.8 [m^3] of wood, in addition to all the recycled paper that reenters the processing input (Appendix 2.1:**"f72"**). For EF/ACC analyses an average productivity of 2.3 [m^3/ha/yr] is assumed. Therefore, the average Canadian requires...

$$\frac{244\ [kg/cap/yr] * 1.8\ [m^3/t]}{1{,}000\ [kg/t] * 2.3\ [m^3/ha/yr]} = 0.19\ [ha/capita]$$

of forests in continuous production to provide the fibres for his or her consumed paper.

[5] Here, it is assumed that the consumed commercial energy in Canada consist of fossil fuel (f) and electricity (e). The World Resources Institute claims a commercial energy consumption of 8,414 [Pj/yr] (= e+f) in 1989. The same source lists Canada's energy requirements in "Conventional Fuel Equivalent" as 11,087 [Pj/yr] (= 3.333e + f) (1992:316). This translates in an apparent electricity consumption of e=1,145 [Pj/yr] and an apparent fossil fuel consumption of f=7,269 [Pj/yr].

c) Example 3: urban environment

Question: On how much built-up land do Canadians live (including roads, residences, commercial and industrial areas, residential gardens and parks)? This should correspond to cell **"b60"**.

The World Resources Institute reports 5,500,000 hectares of build-up land in Canada (1994:285). Therefore, the average Canadian occupies...

$$\frac{5{,}500{,}000 \text{ [ha]}}{26{,}300{,}000 \text{ [Canadians]}} = 0.21 \text{ [ha/capita]}$$

of built-up land for housing, roads, commercial and industrial areas, residential gardens and parks.

4. RESULTS AND COMPARISONS

The figures in the consumption - land-use matrix (Table 5.1) report the land area (in hectares or [ha]) occupied to provide the current lifestyle of the average Canadian. The Canadian average *per capita* requirements add up to at least 4.28 [ha] of land, (2.34 [ha] of them for fossil energy alone)[6] -- which becomes the personal Ecological Footprint on which the average Canadian citizen lives.

[6] As pointed out, hydro-electrical energy is not yet included in this calculation. A preliminary estimate for Canada could be calculated as follows: Canada produced in 1991 1,111 [Pj] of hydro-electricity (World Resources Institute 1994:333). At an equivalence ratio of 1,000 [Gj/ha/yr] (se Chapter IV) this would lead to an additional per capita appropriation of (1,111E6 [Gj] / 1,000 [Gj/ha/yr] / 26.5E6 [Canadians] =) 0.04 [ha/cap/yr], which only includes flooded land and transmission lines, but no other environmental impact (such as on fisheries etc.).

Table 5.1: The consumption - land-use matrix for an average Canadian (1991)

in [ha/capita] ecologically productive land	a ENERGY	b DEGR.	c GARDEN	d CROP	e PASTURE	f FOREST	TOTAL
10 FOOD	**0.33**		**0.02**	**0.60**	**0.33**	**0.02**	**1.30**
11 vegetarian	*0.14*		*0.02*	*0.18*		*0.01?*	*0.35*
12 animal products	*0.19*			*0.42*	*0.33*	*0.01?*	*0.95*
20 HOUSING	**0.41**	**0.08**	**0.002?**			**0.40**	**0.89**
21 constrn./maint.	*0.06*					*0.35*	
22 operation	*0.35*					*0.05*	
30 TRANSPORTAT'N	**0.79**	**0.11**					**0.90**
31 motorized private	*0.60*						
32 motorized public	*0.07*						
33 transp'n of goods	*0.12*						
40 CONSUMER GOODS	**0.52**	**0.01**		**0.06**	**0.13**	**0.17**	**0.89**
40' packaging	*0.10*					*0.04*	
41 clothing	*0.11*			*0.02*	*0.13*		
42 furniture & appli.	*0.06*					*0.03?*	
43 books/magazines	*0.06*					*0.10*	
44 tobacco&alcohol	*0.06*			*0.04*			
45 personal care	*0.03*						
46 recreation equip.	*0.10*						
47 other goods	*0.00*						
50 SERVICES REC'D	**0.29**	**0.01**					**0.30**
51 gov't (+ military)	*0.06*						
52 education	*0.08*						
53 health care	*0.08*						
54 social services	*0.00*						
55 tourism	*0.01*						
56 entertainment	*0.01*						
57 bank/insurances	*0.00*						
58 other services	*0.05*						
60 TOTAL	**2.34**	**0.21**	**0.02**	**0.66**	**0.46**	**0.59**	**4.28**

(0.00 = less than 0.005 [ha] or less than 50 [m^2], blank = probably insignificant; ? = lacking data)

ABBREVIATIONS (for calculations and data sources see Appendix 1 and 2)

a) ENERGY = **fossil energy consumed** expressed in the land area necessary to sequester the corresponding CO_2.
b) DEGR. = **degraded land** or built-up environment.
c) GARDEN = **gardens** for vegetable and fruit production.
d) CROP = **crop land.**
e) PASTURE = **pastures** for dairy, meat and wool production.
f) FOREST = prime **forest.** An average roundwood harvest of 163 [m^3/ha] {= Canadian average} every 70 years is assumed.

These land requirements also illustrate how much hinterland the dweller in industrialized regions appropriates to maintain his or her consumption. The Lower Fraser Valley, which surrounds Vancouver BC, can illustrate this insight. This region extends over 4,000 [km^2] and houses 1,700,000 people, which results in an average population density of 4.25 [people/ha]. Assuming average Canadian consumption patterns and average ecological productivity, people in this region use over 18 times more land than there is within the region for food production (22,000 [km^2]), forestry products (10,000 [km^2]), and energy (40,000 [km^2]).[7]

The Netherlands offer an interesting comparison. The Lower Fraser Valley and the Netherlands share a similar population density. With an area of 34,000 [km^2] and a population of 15,000,000, the Dutch population density reaches 3.7 [people/ha]. The average Dutch person consumes fewer resources than the average Canadian. But still, for food, forestry products and energy alone, the Netherlands uses over 13 times more land than there is within the country, approximately 5,380 [km^2] built-up area, 230,000 [km^2] for food and forestry products, 210,000 [km^2] for energy (World Resources Institute 1994:269,285,333-335, Buitenkamp *et al.* 1993, for calculations see "**t60**" in Appendix 2.1). These two examples demonstrate that industrial regions extend much beyond the area of their immediate geography.

As long as there is enough ecologically productive land available, local consumption that exceeds local ecological production can be sustained by the productivity of other regions. This raises the question, however, whether there are other regions that can still accommodate those consumption demands which are not covered locally. According to the World Resources Institute, Earth provides 13.1 billion hectares of land uncovered by ice or water. Only 8.9 billion

[7] Even if land in the Lower Fraser Valley was doubly as productive as that of the world average, the people in this region would still require nine times more land than there is locally available.

hectares of them are ecologically productive. They are composed of cropland, permanent pastures, forests and woodland. Of the remaining 4.2 billion hectares, 1.5 billion hectares are occupied by large deserts (not including Antarctica) and 1.2 billion hectares by sparsely wooded, mostly semiarid areas (World Resources Institute 1992:262,286,292, Wright 1991:303). The remaining 1.5 billion hectares include "uncultivated land, grassland not used for pasture, built-on areas, wetlands, wastelands, and roads" (World Resources Institute 1992:268).[8] However, as pointed out in Chapter IV, the 1.5 billion hectares of ecologically productive land that have been left untouched so far (various sources in Wada 1994a) should not be harvested because this interference would threaten biodiversity and would lead to a net release of CO_2. This means that only 7.4 of the 8.9 billion hectares of ecologically productive land are actually available for human use.

Since the beginning of this century, the ecologically productive land that is available on a *per capita* basis has decreased from close to 5 hectares to only 1.4 hectares in 1990, or 1.3 today in 1994. In other words, the available *per capita* space is shrinking. At the same time, the Ecological Footprint of people in many industrialized countries has expanded to over 4 hectares. This illustrates the fundamental conflict that humanity is facing: the ecological footprints of average citizens in rich countries are exceeding the average available land by a factor of three (Table 5.1 and World Resources Institute 1992:262). In other words, if everybody on Earth lived like today's Canadians, it would require three Earths to provide for that lifestyle. Consequently, due to biophysical constraints, not all of the 5.7 billion people on Earth today will ever be able to live like today's Canadians -- let alone the 10 billion people expected by the year 2030.

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[8] Assuming an average of 0.05 hectares of built environment (settlements and roads) *per capita*, this would add up to 0.3 billion hectares.

A rough assessment also shows that the current appropriation of nature's resources and services has exceeded Earth's carrying capacity. The human requirements in four of nature's functions alone exceed nature's carrying capacity. Current agriculture occupies 1.5 billion [ha] of crop land and 3.3 billion [ha] of pasture. To continuously provide the current roundwood harvest (including fire wood) would depend on a productive forest area of 1.7 billion [ha]. To sequester the CO_2 released by today's fossil fuel combustion, an additional 3.0 billion [ha] of ecologically productive land would have to be set aside for this function alone (World Resources Institute 1992:262,288,314-316, Wada 1994a). This adds up to a requirement of 9.5 billion [ha] as compared to 7.4 billion [ha] of available ecologically productive land. In other words, these four functions alone exceed nature's carrying capacity by close to 30 percent. This means that the current throughput associated with human activities depends on depleting the natural capital stock.

5. THE PRECISION OF EF/ACC ESTIMATES

Because the EF/ACC concept is a new approach, there are no data sets available which already contain all of the required information. Therefore, the data collection in Appendix 2 relies on a wide variety of sources. When analyzing consumption items, often only monetary statistics are readily available while biophysical information is lacking. Further, there is little known about the life cycles of consumer products; and when data on issues such as amounts consumed or embodied energy and resource content are available, they are often not reliable as they provide conflicting information. In fact, data in the literature can vary by orders of magnitudes rather than merely by a few percentages.

There remain a few weak spots in the data provided in Appendix 2. For example, the energy use of cars does not add up to the claimed energy consumption in the transportation sector; energy intensities of consumer goods and services rely solely on estimates of one other study (Hofstetter 1992a); the data on built-up environments in Canada are vague and contradictory; and the crop areas listed in the FAO statistics (1990b), for producing the main agricultural products in Canada, add up to only about half of the available Canadian crop land. Timber consumption for furniture relies on guesses. Clearly, the presented data set is only a beginning and needs to be improved. Every subsequent Ecological Footprint project will therefore expand and improve these data.

For every application, the necessary level of precision and disaggregation can be chosen by the user of the EF/ACC tool. It depends entirely on the effort put into developing the statistical framework and gathering the data. A rough EF/ACC estimate can already be attained with existing data, and might be sufficiently sophisticated for preliminary analyses.

As explained in Chapter IV and above, this approach is a simplified calculation of the average Canadian's EF/ACC and provides conservative results, or a low estimate, of the total area necessary to sustain the current consumption patterns. We call this a "conservative simplification." This means that however startling these results appear, they are actually consistently conservative estimates of the resource flows and the productive land "appropriated" to sustain a given lifestyle.

B. OTHER EF/ACC APPLICATIONS

The EF/ACC concept not only analyzes people's average Ecological Footprint, but can answer many other questions. This section introduces some other EF/ACC applications that are now being undertaken, or that have already been completed. These applications include:

technology comparisons; issues pertaining to local, regional, national and international decision-making; social equity; and finally, public education and social behaviour. The purpose of this section is to show how the EF/ACC has been adopted and applied by other scholars, which indicates the tool's versatility, growing acceptance, increasing popularity and efficiency as an heuristic tool for planning toward sustainability.

1. TECHNOLOGY ASSESSMENT

EF/ACC calculations can assess whether a new technology is more resource intensive than the one it replaces. In other words, EF/ACC can compare the resource requirements of a new technology to the one being replaced for producing the same good or service.

For example, EF/ACC can compare the total land requirements of two different agricultural methods for producing a given quantity of food. The total area would include the directly farmed land as well as the land equivalent necessary to produce all the agricultural inputs including heating. In fact, using the EF/ACC concept, Yoshihiko Wada compared two agricultural technologies for tomato production -- namely, hydroponics and open-field growing. In contrast to the popular belief, hydroponic tomato growing does not increase ecological productivity, but currently requires, in British Columbia, 10 to 20 times *more* Ecological Footprint per kilogram harvested than does conventional open-field production (1993).

Another example is the technology comparison of cars, buses and bicycles. An EF/ACC assessment documents that the land requirements of one person living five kilometres from work requires 125 [m^2] of ecologically productive land for bicycling, 300 [m^2] for busing or 1520 [m^2] for driving by car (Wackernagel *et al.* 1993:48-49, adapted for CO_2 approach). Most of the ecologically productive land calculated for the cyclist is needed for growing extra food, while most of the bus passenger's and car driver's land is required for CO_2 sequestration.

Currently, architecture student Hijran Shawkat at UBC uses the Ecological Footprint concept for comparing housing options with different design, construction, operation and urban location (1994).

2. LOCAL AND REGIONAL DECISION-MAKING

Similarly to technology assessments, EF/ACC analyses can evaluate the ecological impact of new projects and policies. For example, it can determine whether the introduction of new projects, programmes, polices or budgets will reduce the population's Ecological Footprint or increase it.

An obvious application is the calculation of municipal Ecological Footprints. In the Canadian context, multiplying the land-use of an average Canadian by the number of people living in a particular municipality, is a crude method for understanding the magnitude of its Ecological Footprint. This assumes, however, that the average resident of that municipality lives the same lifestyle as the average Canadian. A more accurate, but more time-consuming analysis of municipal EF/ACC requires understanding the differences between the lifestyle of the people in the particular municipality and the average Canadian. This difference is largely determined by municipal income distribution and housing prices. Housing prices influence density, which directly affects transportation requirements. For example, people in rural areas might earn lower incomes than their urban peers. However, each dollar earned in a rural area represents substantially higher purchasing power as far as housing is concerned. Also, geographic peculiarities such as climate, remoteness, and settlement patterns influence people's expenditures in the area of heating, food, and transportation.

While the above analysis is more focused on household choices, EF/ACC could also be used for assessing institutional choices. Economic development, transportation infrastructure, or zoning can have long-ranging impacts on the consumption of nature's services. For example, one aspect of economic policies could be illuminated by looking at the resource intensity of production: the EF/ACC tool could analyze the Ecological Footprint requirements per dollar income that is locally generated as compared to a national average. On the infrastructure side, two EF/ACC assessments were conducted by students of the Simon Fraser University, Burnaby. They measured the EF/ACC impacts of proposed bridges. One study, conducted by Gavin Davidson and Christina Robb, analyzed the implications of widening the Lions Gate bridge from three to five lanes (1994). This study, using conservative assumptions, concluded that due to a change in the settlement pattern induced by expanded transportation capacities, the appropriation of at least an additional 200 km^2 of ecologically productive land would be prompted by the five lane options. The second study, by David Maguire, Calvin Peters and Marcy Saprowich (1994), investigated the possible EF/ACC impacts of the proposed bridge to the Prince Edward Island. It concluded that such a bridge might lead to the additional appropriation of approximately 16,000 ha or 160 km^2 of ecologically productive land, an assessment which was based on economic projections from the Federal Environmental Assessment Review Office in Ottawa.

The question of how transportation, settlement and community economic development initiatives impact on a municipality's carrying capacity appropriation, and which municipal policies could be used to reduce this appropriation, has been explored by Graham Beck (1993), Tony Parker (1993), and Molly Harrington (1993) for the UBC Task Force on Healthy and Sustainable Communities (1993). UBC student Susan Petersen analyzes the potential of urban gardening as a strategy for reducing Ecological Footprints (1994). In 1994, the Task Force is building on that research, and is exploring the impact of urban density on the Ecological

Footprint by studying various municipalities in the lower Fraser Basin (Walker 1994).

Even though the ratio between the Ecological Footprint area and directly occupied (urban) land is higher for densely inhabited settlement patterns, these dense settlements can lead to considerably lower *per capita* carrying capacity requirements. This is due not only to more efficient land-use for housing and urban infrastructure, but also to the reduced need for transportation and residential heat (Roseland 1992:111-115). For example, a recent study of the San Francisco region found that the doubling of residential density cuts private transportation by 20 to 30 percent, while Newman reports differences in heating energy consumption between grouped and free-standing housing of up to 50 percent (Holtzclaw, and Newman in Roseland 1992:122,113).

In other ongoing research of the UBC Task Force on Healthy and Sustainable Communities with the City of Richmond, a framework for analyzing the social, economic, and ecological sustainability implications of specific policies is being developed. The goal for this research was to expand the often narrow impact assessments, and show the connections between the issues, rather than fragmenting them, or only concentrating on a few aspects. Key questions were established to capture the main social and economic issues, while the EF/ACC has been proposed to address the ecological implications. This framework could become a framework in which sustainability impacts could be reported to City Council. Therefore, this generic report structure could be a useful tool for Council as it helps them link a variety of potential policy implications. This framework builds on the potential key dilemma of sustainability: on the one hand, human(e) survival has to be secured (which requires ecological health and is measured by EF/ACC), while on the other hand, local livability needs to be enhanced (which requires social health and economic health and might ultimately be conceptualized by the Social Caring Capacity

(SCC) tool). Using such a framework might stimulate ideas how both of these goals could be achieved simultaneously -- even though they are in conflict in most conventional policy decisions. The first test case dealt with the issue of large scale home improvement retail markets (UBC Task Force & City of Richmond 1994).

Two groups in Europe are embarking on Ecological Footprint studies. One is housed at the Institute for European Studies at the University of Trier, Germany. As an initial project, Ingo Neumann is developing an Ecological Footprint assessment of the Trier Region (1994). Others who have adapted the concept to their region include Dieter Steiner *et al.* at the Swiss Federal Institute of Technology (1993), Dieter Zürcher with Infras (1994), and Beat von Scarpatetti with Kulturprojekt Silvania (1994), all from Switzerland. Also, the Commonwealth Human Ecology Council held a seminar on this topic in Manchester on July 23, 1994.

3. NATIONAL AND INTERNATIONAL DECISION-MAKING

An obvious application for the EF/ACC concept is its use as a sustainability indicator for ecological health. For example, the Canadian *State of the Environment Report* (SOER) team is reconsidering a shift in its conceptual approach away from an environmental indicators framework (as prominently used in the 1991 report) towards a more integrated human ecology perspective. For that purpose, they commissioned Colin Duffield to develop and outline ideas for incorporating the EF/ACC concept into the 1996 report (1993). Moreover, in separate reports for the Canadian Council of Ministers of the Environment and the Fraser Basin Management Board in Vancouver, which were both prepared by Peat Marwick Stevenson and Kellogg, the measurement of carrying capacity appropriation is proposed as a way to "assess sustainability from an ecological worldview" (1993a:13, 1993b:22).

EF/ACC assessments enable policy decision-makers to better understand long-term constraints that national and international economies will have to face as the population and its *per capita* consumption increases. For example, a comparison of a region's size with the carrying capacity demand of its population, illustrates the sustainability gap which is presently being bridged by imports. This understanding raises questions about the role of trade, and the ecological and political security of those places from which carrying capacity is being appropriated.

Rather than analyzing trade from a monetary perspective, EF/ACC provides a means to compare the exported carrying capacity flows with the imported ones. This provides a framework for analyzing the long-term costs and benefits of trade and the potential sources of conflict. Monetary analyses do not reveal anything about carrying capacity leakages, i.e., countries' net losses in biological productivity. EF/ACC estimates, however, can disclose the balance of traded carrying capacity and whether a country is running an ecological deficit. A first rough comparison of these biophysical trade balances is being assessed by a research project of the UBC Task Force on Healthy and Sustainable Communities (Thomas 1994). Also, Nick Robins at the International Institute for Environment and Development is developing a similar study for analyzing the impact of international trade and its implications for national policy (1994).

Ecological deficits will become of increasing concern for those participants in the global economy (typically low-income countries with resource industries) whose carrying capacity is being appropriated increasingly by other economies, i.e., whose carrying capacity leakages are encouraged by current terms of trade (Catton 1980:158, Rees & Wackernagel 1992, Rees 1994a). However, trade in carrying capacity may also become a concern to those economies that have become dependent on others' carrying capacity and can shed light on the potential intensification of local and global resource conflicts (see for example Arden-Clarke 1991, Homer-Dixon *et al.* 1993, Ophuls *et al.* 1992, Pimentel *et al.* 1992, and Ponting 1992).

Such considerations challenge conventional economic development models (as promoted by the World Bank, the International Monetary Fund or the Harvard Institute for International Development[9]) on the ground that there might simply not be enough biophysical assets to provide for such development; and that these models actually promote dangerous illusions and hide the conflict or competition between the consumption of the rich and that of the poor.

4. SOCIAL EQUITY

Conventional economic development wisdom suggests that there is no material limit to economic expansion, and that poverty can be alleviated by increasing economic production. According to this perspective, people enjoying a high level of consumption would not have to compromise their lifestyle in order that the poor improve their lives. In fact, some even claim that the consumption of the rich could be beneficial to the poor as it would cause the economic growth to be accelerated.[10] However, the biophysical perspective challenges this view. In today's context of a global carrying capacity that has already been exceeded, the use of nature's productivity by one person preempts other people from using this same productivity. This means that the consumption by the rich can undermine the prospects for the poor.

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[9] For example, in a letter to *The Economist*, Michael Roemer from this institute writes that "economic growth is the only mechanism through which the welfare of the poor can be improved in a sustainable way" (June 4, 1994:6), while not mentioning -- and probably ignoring -- that, in a "full" world, such a strategy would require from rich countries to give up a large share of their resource consumption.

[10] For example, World Bank Vice President Lawrence Summers uses the phrase "rising tides do raise all boats" (in Goodland & Daly 1993:88). An early and influential advocate of this perspective was Walt Rostow with his book *The Stages of Economic Growth* (1960).

EF/ACC assessments demonstrate the competing uses of resources and their implications for the future resource productivity of a given stock. With a given resource flows, one person's use of the flow preempts the next person from using that same flow. In monetary terms, this constraint does not become apparent because monetary expansion does not seem to be bound by any biophysical limits. In the current global economy with increasingly interwoven international monetary systems, those with strong financial assets gain easier and faster access to the limited resource stocks of the world. The resulting conventional economic growth only leads to an accumulation of human-made wealth, often in fewer and fewer hands, but does not replenish in any significant way the natural capital base on which this former wealth creation depends.

Analyzing these economic inequities from the perspective of EF/ACC can provide useful comparisons of consumption internationally, as well as intra-nationally. It is useful because it compares those aspects of consumption that are in direct competition with each other. It also reveals the ecological constraints and socioeconomic effects of any future social contract regarding the distribution of ecological services.

For the purpose of illustrating the socioeconomic differentiation in carrying capacity appropriation, I analyzed the differences in Ecological Footprints of various Canadian income groups with the help of a simple spreadsheet-based calculation model. As a first cut, this model assumes a) that there is no difference between net income and the expenditures, b) that a dollar spent in a given category would always appropriate the same amount of land, and c), that the income is spent according to the average expenditure patterns of the corresponding income category, or that Canadian consumption patterns are similar for a given income group. Therefore, this estimate reflects only the average Ecological Footprint of a particular income category, while the Footprint of the individual household might vary according to that household's specific consumption pattern. Clearly, this is a coarse model, but it provides an initial illustration of the differences in Ecological Footprints of various lifestyles within an industrialized country.

Preliminary results showed that in Canada the average person in the lower income quintile uses about 3 hectares of ecologically productive land, while the average in the upper income quintile consumes the ecological production of over 13 hectares per capita (Wackernagel 1993a). These differences within Canada alone show how the carrying capacity appropriation by individual consumption levels can vary considerably. However, people at the higher income level have more control over the size of their Ecological Footprint by choosing how to spend their money. People with the same income can either live on the suburban fringe, where they can afford larger houses but need to commute long distances. Or, they can live in a denser situation closer to where they work themselves, thereby cutting down on heating and transportation energy. Also, by buying locally produced and seasonal food, by shopping for organic food, by investing in insulation rather than spending on heating for their accommodation, or by paying for music lessons rather than financing fast cars, the Ecological Footprint per dollar spent can be decreased. Some of these aspects are being analyzed by Lyle Walker (1994).

5. SOCIAL BEHAVIOUR AND PUBLIC EDUCATION

The simple and heuristic aspect of the EF/ACC tool makes the ecological requirement of sustainability accessible. This underlines the concept's potential for public debate and education. In fact, the concept has been presented to a variety of audiences ranging from high school children to environmental ministers. The *Sea to Sky* outdoor school in Gibsons BC has integrated the concept into its programs. Participatory outdoor activities include: experiencing one hectare of ecologically productive land and roughly assessing its productivity; visualizing the relationship between human consumption and ecological production; tracing back the origin of food and goods; facing the competing uses of nature and the socioeconomic determination of EF/ACC sizes; and, experimenting with low-Footprint lifestyle choices. Another educational initiative was prepared by ESSA and the BC Ministry of Environment, Lands and Parks in the form of a teacher's guide to the State of the Environment report (1994). An entire chapter is devoted to the EF/ACC concept. Calculation examples focus on the food section of the Ecological Footprint.

The EF/ACC concept has been integrated into various professional and academic education efforts, including various planning and resource management courses (PLAN 504, PLAN 425 at The University of British Columbia, and REM 642 at the Simon Fraser University, Burnaby, BC). There has been a growing demand for a simple documentation of the concept that caters to community activists and planners. This was addressed by the UBC Task Force's development and production of a visually supported, simply worded and action oriented brochure explaining the concept (Wackernagel 1993a). Also, the New Society Publishers have asked William Rees and me to write an upbeat, accessible and richly illustrated book on the EF/ACC concept (1994 forthcoming).

Various events and institutions have used the concept as an integrative framework. For example, the *New Catalyst* newsletter, which was published for the Vancouver *Greening our Cities* conference, opened its discussion on sustainable communities with a lead article on the Ecological Footprint concept (1994). The *David Suzuki Foundation* introduced in its newsletter the Ecological Footprint as a framework for the institute's activities (1992). Similarly, the EF/ACC concept was an integral part of the successful UBC application for Tri-Council Green Plan Funding of which the UBC Task Force on Healthy and Sustainable Communities is a member. On the more artistic side, the *Precipice Theatre* from Banff Alberta, is planning to use the EF/ACC concept in their performances on Eco-Restoration and Exchange (Funk 1994).

Many of the presented applications were initiated by the UBC Task Force on Healthy and Sustainable Communities. However, more and more of them are being developed independently of the UBC Task Force, mainly in Europe and North America.

VI. EXPLORING EF/ACC'S USEFULNESS FOR PLANNING TOWARD SUSTAINABILITY

The primary purpose of this chapter is to explore how various actors in the public domain perceive the usefulness of the EF/ACC tool. Usefulness of a planning tool means that people want to use it. More specifically in the context of sustainability, it refers to the tool's qualities of communicating sustainability challenges, assisting in framing the debate, inspiring people's interest (and participation) in the debate, and finally, allowing researchers to analyze people's perception and understanding of sustainability issues. In short, the EF/ACC tool is useful if it makes people more effective in their task to plan toward sustainability.

Testing the usefulness of the EF/ACC tool is achieved by interviewing those in the public domain all of whom, by their daily decisions, influence society's sustainability. The secondary purpose of this chapter involves determining the utility of this questionnaire-based interview series as an heuristic device to raise people's understanding of the sustainability crisis and its dilemmas, to identify their blockages against required action, to encourage public and private action, and to challenge people's behaviour. Thereby, this research becomes in itself yet another EF/ACC application.

A. MEASURING "USEFULNESS"

1. CHOOSING INTERVIEWING AS THE RESEARCH METHOD

Evaluating a planning tool cannot be based entirely on theory but must be grounded in empirical testing. Even though sound theory may build on synthesized experience, it cannot legitimize the utility or prove the effectiveness of practical applications. It merely provides a framework for organizing thoughts and for supporting design processes through the provision of information about possible mechanisms and barriers -- and warnings about potential difficulties. Therefore -- and this is further explained in Section 3 -- this research used the theory about planning tools only to inform the development of the EF/ACC tool. In contrast, testing a planning tool requires not only applying it to examples as done in Chapter V, but also exposing it to potential users so they may examine the effectiveness of the tool. Ultimately, the tool is only useful if the public and practitioners perceive it as such.

Such research requires tapping into people's experiences and conceptions, and examining the meanings that they attach to these experiences. Methods to do this could include reviewing literature, assessing institutional and personal documents, observing behaviour or surveying population samples. However, if the purpose is to explore how people interpret their experiences, how they come to their conclusions and how they translate these conclusions into action, interviews become a necessary avenue of such an inquiry (Seidman 1991:4). Not to ask people directly would impoverish the research because people can talk and think. In fact, Daniel Bertaux points out that unlike a star, a molecule or a lever, "...if given a chance to talk freely, people appear to know a lot about what is going on..." (in Seidman 1991:2). Clearly, interviews are much richer than observations, as the interview participants not only expose their own behaviour and thought, but can reflect and report on experiences of many other people that influenced and shaped their own thinking.

However, this interview research is not the first empirical test of the EF/ACC tool. Throughout the research, many aspects of the tool were adapted to accommodate suggestions which I gathered through evaluation questionnaires after lectures (UBC, Simon Fraser

University, Sustainable Communities Workshop #2 1993),[1] and other comments received during my work with, *inter alia*, the UBC Task Force on Healthy and Sustainable Communities (background research, review of the draft handbook[2]), the City of Richmond (presentations, workshops, tool development), the Indonesian Ministry of Population and Environment (workshops and seminars), Sea to Sky outdoor education (curriculum design), and various public presentations. Now, the task is to examine the matured version of the EF/ACC tool more systematically.

2. ESTABLISHING TWO SCALES

To assess the usefulness of the EF/ACC tool for potential users the interview needs a measurement procedure that can determine people's understanding of, and commitment to, the

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[1] The reactions that I received orally or those voiced in the various written workshop and presentation evaluations that I collected over the last four years include concerns about:

the concept of nature and its role for supporting human activity (misconception due to too narrow interpretation of "resources" referring mainly to commercial industrial inputs such as mercury, aluminum, or fossil fuel rather than including all material requirements that support human activity / ignoring the connections between nature's "resource" production, waste absorption and maintenance of life-support services / confusion between use of nature and degradation of nature / narrow interpretation of "environmental impact" as pollution or urban air quality / confusion between space and productivity);

the ambivalence of the concept's name (the term "appropriated" is confused with "appropriate" / the claim that "carrying capacity" is an outdated concept / "ecological footprint" is interpreted as the land that is destroyed rather than the land that is used. In our presentations, William E. Rees and I have also experimented with other names such as: human pasture; an economy's pasture, land base or habitat; Hicksian capital; personal planetoid);

weaknesses of the tool's method (level of aggregation / global applicability, e.g., comparability to other lifestyles such as the traditional Innuit culture / inclusion of fossil energy / definition of a region / inadequate representation of mineral resources / exclusion of wilderness, the sea, fresh water resources, pollution and environmental destruction / promotion of anthropocentrism and "resourcism" / approach static rather than dynamic);

the choice of the measurement unit (using a biophysical unit is no different than using monetary units / land does not represent human preferences / why choosing land and not energy, eMergy or essergy as measurement units / land can have double functions which will lead to double-counting / and the ecological productivity of land varies a lot -- some not being productive at all);

the disconnection between the EF/ACC tool and "real world" planning (OCPs do not support global thinking / EF/ACC consideration are outside of the planning mandate / does not address the incentive to become sustainable -- or, reverse, how to overcome the "Tragedy of Common Pools" / is a naive interpretation of economic constraints / provides no direct link to local planning / is an ivory tower concept); and,

the interpretation of the implications (EF/ACC represents a doomsday scenario / is normative / ignores technological potentials and human ingenuity / supports parochialism).

[2] See Appendix 3.1.

tool -- in essence, their support for the tool. Determining people's support for the tool also requires knowing where people stand in the sustainability debate as compared to the sustainability interpretation which I proposed in Chapter II of this thesis. To measure people's support of the tool and perspective on sustainability, I established two simple, progressive scales. These scales map people's perception of sustainability and support for the EF/ACC concept, and are summarized in Table 6.1. Both scales are organized along a list of statements each of which is a more stringent subset of its preceding statement (the statement with lower ordinal value, i.e., *i* is a subset of *i-1*). The scale measures at which point the participants disagree for the first time with one of the increasingly narrow and specific statements. The participants are classified at the scale point of the statement with which they agreed last.

Table 6.1: Scales for measuring people's perspectives on sustainability and support for the EF/ACC concept

Scale for measuring people's "interpretation of sustainability" 1. I am interested in sustainability 2. sustainability is important 3. sustainability requires that natural capital not decrease 4. some regions are not sustainable (e.g., the South, a particular local region, etc.) 5. humanity as a whole is not sustainable (i.e., global carrying capacity is exceeded) 6. industrial countries must significantly reduce their resource consumption 7. sustainability is about me 8. I try to 'live' sustainability
Scale for measuring people's "support for the EF/ACC concept" 1. I understand the EF/ACC concept 2. EF/ACC is a first step, but it is not comprehensive or accurate enough[3] 3. EF/ACC might be useful for some applications 4. EF/ACC should be used by governments, agencies, scholars or others 5. I intend to use the EF/ACC concept as an argument in discussions 6. I intend to promote, present or write about the EF/ACC concept 7. I intend to apply the EF/ACC concept

[3] The negation of this statement could mean that the EF/ACC concept is perceived either to be neutral in its impact or misleading in its representation of reality. In fact, the key informant from my interview series classified in this category felt that the EF/ACC concept was misleading.

One scale plots the participants' concordance with the biophysical interpretation of sustainability perspective as outlined in Chapter II. The scale starts from the most general sustainability concerns (which corresponds to people showing interest in sustainability issues) and becomes gradually more specific by testing whether people accept the "strong sustainability" criterion, whether they acknowledge global overshoot and finally, whether they assume personal responsibility. The higher the number, the better the participant's concordance with the sustainability perspective presented in Chapter II. For example, a person would be at scale point "4" ("some regions are not sustainable") if he or she felt that sustainability is important, that it requires preserving natural capital, and that indeed some regions are not sustainable as they over-exploit their natural capital; however, he or she would not perceive the sustainability crisis as a global problem, but might identify it as a problem pertinent *only* to the overpopulated South, or to a particular region they know.

The second scale represents the participants' level of support for the EF/ACC tool and builds on a simple classification of the learning process: encountering the concept, learning it, understanding it, accepting it, supporting it and, finally, committing to it. Table 6.1 documents the various levels of support for the EF/ACC tool, "1" indicating no and "7" the strongest support.

3. IDENTIFYING POTENTIAL BARRIERS TO THE EF/ACC TOOL

Once the participants' perceptions of sustainability and support for the EF/ACC tool is mapped, the second task is to explore their reasoning for reaching these conclusions, so as to understand their motivation and to assess their effectiveness in translating this knowledge into action. Discovering how people arrive at their conclusions and how their thinking is influenced by the EF/ACC concept reveals shortcomings of the EF/ACC tool, which is valuable information for making the tool more effective.

Many of the potential shortfalls or necessary key characteristics of such a planning tool could be similar to those of indicators whose potential weaknesses are identified by the indicator literature. These potential weaknesses and key characteristics include various *procedural* and *substantive* aspects:

Substantive requirements of indicators mentioned in the literature include the necessity for relevance and accuracy (Bregha *et al.* 1993, Gosselin *et al.* 1993, Henderson 1991:146-190, Hodge & Taggart 1992:19-21,Appendix 1, Peat Marwick 1993a:50-53). Applying these insights to planning tools means: effective tools for sustainability should address key concerns and adequately represent ecological realities and economic structure. For example, in the case of EF/ACC, the planning tool must show how the over-use of ecological productivity is a key factor in sustainability and how this relates to economic activities. Also, the tool must build confidence in its accuracy when representing the ecological constraints for human activities. Chapter III addresses these questions on a theoretical basis by discussing EF/ACC's compatibility with thermodynamic and ecological principles (laws of thermodynamics, Liebig's law of the minimum, food chain efficiencies and energetic flows, photosynthetic conversion) and with economic conditions (household, government and firm consumption, natural capital requirements, definition of economic and ecological efficiency).

Process requirements of indicators addressed in the literature include the need for consistent, simple and clear data gathering and processing methods, and for easy and accessible presentation, all of which are preconditions for building trust and encouraging participation (Anderson 1989, Bregha *et al.* 1993, Carley 1981, Carr-Hill & Lintott 1986, Davis 1993, Gosselin *et al.* 1993, Henderson 1991:146-190, Hodge & Taggart 1992:19-21,Appendix 1, Innes 1990, Lawson 1991, Peat Marwick 1993a:50-53, Simonis 1990:77-95).[4] Johan Galtung put the process requirements for indicators simply by stating provocatively that "...an indicator which anyone with five years of schooling cannot understand within five minutes is not an indicator, but an instrument of control..." (in Simonis 1990:90). Similarly, to be effective and useful, planning tools must communicate well, and need to be clear and sufficiently simple. Also, to be effective, such tools need to find acceptance from across different political camps and academic perspectives in order to facilitate the "cross-paradigm" communication. By only speaking to one worldview and excluding another one, it would become a counter-productive tool as it would entrench the differences.

However, rather than testing the EF/ACC tool according to a pre-defined set of evaluation criteria identified by the literature, the approach chosen here is to expose the concept directly to potential users and let them decide. These people then can judge how useful the tool is for them, independent of predefined narrow categories that might constrain their thinking and may not be relevant for this case. On the other hand, if the theory on substantive and procedural requirements covers the ground effectively, the interview participant might come up with the same criteria. In fact, looking back, the participants addressed similar points as the literature, but also came up with concerns that more narrow criteria might have missed -- such as the need to provide more examples, to explicitly discuss the tool's assumptions, and to be more careful about the tool's psychological implications. In short, rather than measuring whether the tool fulfils pre-defined, specific, theoretically derived requirements (such as clarity, inclusiveness,

[4] Further literature that examines the usefulness of indicators for political decision-making include Beckerman (1980), and Daly and Cobb (1989) who analyze surveyed indicators in essay form, and the Caracas Report (1990), Choo (1980), Hardoy (1980), Innes (1980) who evaluate their usefulness by examining case studies.

data availability or compatibility), this approach for testing the planning tool is more open and comprehensive by documenting key informants' reaction and exploring the reasons that lead them to their conclusions.

4. SELECTING KEY INFORMANTS

The purpose of this qualitative interview research is to document EF/ACC usefulness as judged by decision-makers and potential users. This approach provides a probabilistic exploration of dominant thinking about, and reactions, to the EF/ACC tool and the questions it raises. To ensure the documentation of a wide range of perspectives and experiences, key informants for the interviews are selected in accordance with what Janice Morse or Michael Patton call *critical case sampling* (Morse 1994:229, Patton 1990:174). This means a deliberate selection of diverse people in order to cover a broad spectrum of possible perspectives.

To cover the dominant perspectives held by people who shape public decision-making and to capture their views and insights on the usefulness of the EF/ACC tool, I targeted seven key informants in three main groups for my interview research (or a total of 21 participants). These groups who represent major actors in the public domain are:

a) administrators and planners,

b) business people and economists, and

a) community activists and local politicians.

"*Administrators and planners*" includes those who work for a government institution. This first group of administrators and planners is chosen because an important original intention when developing the tool was to support municipal governance bodies in their planning toward sustainability. Interviewing this group reveals whether the EF/ACC concept could assist them in their daily tasks and shows how they would use the tool. Interviews with this group also should point out how the tool could be improved to make it more suitable for municipal planning.

"*Business people*" refer to those who make their living selling products or services; while "*economists*" are those who teach economics or provide economics advice. Business people and economists are an important target group because they are one of the most influential professional groups in the political decision-making process. Many business people see themselves as proponents of sustainability. The Club of Rome, environmental initiatives by the World Bank (as reported by their *Environment Bulletin*), the UN based Business Council for Sustainable Development (chaired by Swiss industrialist Stephan Schmidheiny, who summarized the Council's findings in the 1992 report *Changing Course*) or the bi-annual Vancouver GLOBE conferences (initiated in 1990) are manifestations of this perspective. Also, many economists point proudly to the fields of resource and environmental economics, which claim to promote sustainability. In fact, many in this group identify the lack of economic mechanisms as a root cause of environmental degradation (*The Economist*, Block 1990, Pearce *et al.* 1989:153-172, Weder 1994).

On the other hand, mainstream economists and business people are often attacked by those outside their community for promoting a worldview which supports unsustainable lifestyles (Suzuki 1994, Jacobs 1993, Daly 1977/1991, Rees 1990b). This stark contrast makes the group of "business people and economists" particularly interesting when analyzing sustainability. This may help explore whether the EF/ACC concept can actually bridge the paradigm "moat" between the ecological (or biophysical) worldview and the economic (or monetary) worldview, i.e., between the "limits to growth" and the "growth of limits" paradigms (Rees & Wackernagel

1992). It may also help to identify where understanding of sustainability diverges and whether there is room for fruitful communication about possible sustainability objectives between this group and other sectors of society.

Furthermore -- and perhaps most importantly -- rather than preaching to the converted, the EF/ACC concept should be able to engage those with the expansionist "growth of limits" perspective in the biophysically oriented sustainability debate. This is possible if the concept can successfully and constructively challenge these people's assumptions about wealth creation and development strategies. Only if EF/ACC assists in constructively engaging this segment of society will it be truly effective in building consensus and fostering the necessary wide support for developing sustainability.

Finally, "*community activists and local politicians*" are interviewed, because they lead the political debate at grass-roots level and often initiate social change. Therefore, this research needs to explore how the EF/ACC tool could assist them in conceptualizing the sustainability dilemmas and in explaining the necessity for change. Also, such research allows us to estimate their interest in applying the tool for monitoring progress toward sustainability or assessing development and policy options on their sustainability impact.

However, the most important consideration is that testing the tool with these diverse groups provides an opportunity to identify common ground and could reveal whether the tool has the potential to ease communication between these groups or whether each of these groups, by identifying a separate set of the tool's weaknesses, would demonstrate a mutually exclusive and irreconcilable perspective on sustainability.

In addition to interviewing well-informed and articulate people from three different but influential groups, further selection criteria for ensuring a broad variety of views consisted of:

- diversity in academic backgrounds, job positions and responsibilities;
- gender representation (at least two female key informants in each group);
- varying levels of previous exposure to the EF/ACC concept ranging from people who I had worked with (or who had attended UBC Task Force on Healthy and Sustainable Communities workshops) to others we had not contacted before and, most likely, had not heard about the EF/ACC concept before the interview; and,
- ethnic representation.

As geographic boundaries, I chose those of the UBC Lower Fraser Basin Ecosystem Study, since my research with the UBC Task Force on Healthy and Sustainable Communities was a component of this Ecosystem Study. Further, to build bridges with other research in the Ecosystem Study, and to use my interviews as a means of involving potential community participants in the Ecosystem Study, I asked Michael Healy, Principal Investigator of the study to provide me with contacts. In fact, over half of my interview contacts were suggested by him.

I approached a total of 26 people for the interviews. Only five of them were not able to join, which left me with 21 participants, or seven for each group. Those five who could not participate were either too busy, out of the country, retired, or felt that somebody else in their organization would be better suited for the interview. However, three of these five people suggested another person to approach. Recruiting women was difficult as they occupy fewer senior positions than men, and I was unable to achieve any significant ethnic representation. In fact, 19 of the 21 key informants were of European descent, and two-thirds were born in Canada. This lack in ethnic representation could be seen as a weakness of this interview process, particularly when it is a widely held concern that ethnicity influences the way environmental issues are perceived -- a concern which was also addressed by some of the key informants (see also Pau 1994, *Greening Our Cities* conference 1994).

To test whether the sample led to a certain saturation which would be indicated by recurring themes, I interviewed seven (rather than five) in each of the three groups, with two women in each group. The 21 key informants interviewed are listed in Appendix 3.2.

The key informants represented a large variety of backgrounds such as architecture, banking, biology, community development, economics, engineering, geography, law, planning and political science. They work for federal, provincial and municipal agencies and governments, private consulting firms, industries, developers, universities, foundations, non-governmental organizations (NGOs), "think tanks", or farms. Most of them hold senior or executive positions in their organizations. All of them were familiar with the sustainability debate. Eight of them had never heard of the EF/ACC concept before, but only one of the eight was from the community activist group. Five had already referred to the EF/ACC concept in their work; four independently, that is, uninvolved with me or the UBC Task Force on Healthy and Sustainable Communities, before the interview.

5. DEVELOPING AN INTERVIEW QUESTIONNAIRE

To capture the key informants' understanding of sustainability and support for the EF/ACC tool, and to identify how the EF/ACC tool could assist them in more effectively translating their sustainability concerns into action, the interview process must be carefully designed. On the one hand, it needs structure to cover all the necessary issues in a reasonable amount of time, but on the other hand it should also provide enough flexibility for discussions initiated by the key informants.

To test the participants' understanding of sustainability and the support for the EF/ACC concept, a series of questions was developed that gradually moves from more general statements and issues to more specific ones. Both understanding and support were explored from different perspectives throughout the interview.

The interview was simply structured. In the first part, I established a short personal profile of the participant. This profile documented formal educational background, extent of political concerns, familiarity with the sustainability debate, job responsibility and social context. I explored the scope of political concern by asking them to rate the "importance" of 14 national political issues (interview question 1.3, Appendix 3.3). Three of these 14 issues covered ecological concerns, while six were social and five economic. Furthermore, to test the participants' level of altruism, the last two issues covered political concerns which could directly benefit them.

The questions about the participants' personal profile led into the second part of the interview which focused on their understanding of sustainability and their support for the EF/ACC tool. This included asking about direction for sustainability action and research steps, and how to overcome social barriers. To do this, the interview proceeded along the two scales introduced above and advanced on both simultaneously to maintain a logical flow. Table 6.2 shows this parallel progression. Appendix 3.3 contains a copy of the questionnaire used for the interviews. In the following, I will briefly explain the intent behind this series of questions.

Table 6.2: Structure of the interview

Supporting the EF/ACC concept:	Understanding sustainability:
Testing whether the key informant...	
	knows about sustainability
	has participated in sustainability initiatives
understands the EF/ACC concept	
	accepts the ecological condition of sustainability
	accepts the socioeconomic condition of sustainability
accepts the EF/ACC concept	
supports the EF/ACC concept	
	has identified strategies for achieving sustainability
	assumes responsibility for achieving sustainability
shows commitment to apply the EF/ACC concept	

Do they know about sustainability, and have they participated in sustainability initiatives?

I explored the participants' familiarity with sustainability by asking about the books, articles or TV programs that influenced their thinking on sustainability issues, and about activities towards achieving sustainability in which they have participated.

Do they understand the concept?

After giving the participants time to read a popular explanation of the EF/ACC concept consisting of the first four pages of the UBC Task Force's brochure on "How Big Is Your Ecological Footprint?" (Wackernagel 1993a, copy in Appendix 3.3), I asked them to evaluate the brochure, and to re-phrase the concept (question 2.1). Re-phrasing the concept allowed me to test the participants' factual understanding of the concept. In case of misinterpretation, I clarified the Ecological Footprint definition. This had two purposes. On the one hand, it made sure that the participant started the interview with a clear understanding of the concept. On the other hand, it documents possible misunderstandings and indicates how well the brochure communicates the EF/ACC concept.

Do they accept the ecological and the socioeconomic condition of sustainability?

I then tested in the interview, how participants interpreted sustainability and whether they felt that nature is being overused (question 2.2), whether they spontaneously recognized human dependence on nature (question 2.3), and whether they agreed with the "strong sustainability" interpretation (question 2.4a). In addition, I asked whether they perceived industrialized countries to be massive overconsumers with an obligation to reduce their resource consumption (question 2.4b). As a cross-check, I later asked the question whether they believed that in spite of the current debt load, Canada could afford "sustainability" (question 2.6).

Do they accept the concept?

Next, I asked the participants to judge EF/ACC's effectiveness in representing the ecological dimension of the sustainability dilemma (question 2.5 and 2.8). The first question focused on the concept's method and its capability to communicate, while the second one addressed its conceptual accuracy. I used both questions to stimulate more open discussions in which a wide variety of concerns could be addressed, rather than focusing on the actual question asked. To examine how the concept supports the conversation about sustainability and whether it is a helpful learning tool, I asked the participants if the interview changed their perspective on sustainability (question 2.10).

Do they support the concept?

I tested the participants' passive support for the EF/ACC concept by exposing them to six different applications (question 2.7). These EF/ACC applications included: communicating sustainability to the general public, informing about sustainability impacts of individual lifestyle and business decisions, supporting sustainability oriented community activism, analyzing sustainability impacts within municipal planning, indicating national sustainability, and framing sustainability education. If required, I gave examples of such applications.

Have they identified strategies for achieving sustainability?

In section 2.9, I explored a series of issues. First, by asking about strategies for society to achieve sustainability, I cross-checked the participants' interpretations of sustainability and tested to what extent the participants have thought already about the sustainability crisis' implication for action. By exploring perspectives on how to achieve sustainability, I hoped to shed light on possible connections between personal commitment to promote sustainability and the feeling that there are options and choices for this. I also hoped to generate insights about how the EF/ACC concept could assist in overcoming social and perceptual barriers to sustainability (as defined in this thesis), and would give participants another opportunity to bring up other issues about sustainability or the EF/ACC concept which were not covered elsewhere in the interview.

Do they assume responsibility for achieving sustainability?

In the second part of section 2.9, I turned the discussion to the personal level of the sustainability debate. I asked whether the participants thought that society can become sustainable, and what they could do about it. This informed us about the respondent's personal motivation and commitment to sustainability.

Do they show commitment to apply the concept?

To test the participants' confidence in the EF/ACC tool, I asked in question 2.11 how they would consider using the concept in the next year. In contrast to question 2.7, where I explored the participants' passive support for the concept by making them choose from a list, I did not provide any ideas or options in this question. This allowed me to check the participants' ability to generate possible EF/ACC applications on their own, and to test their active understanding of the concept and interest in using the tool.

I ended the interview with an open question soliciting other comments. After having been exposed to the concept, this provided participants an opportunity to point out unresolved issues or concerns not covered. Additionally, during the interview process, I provided other opportunities to indirectly test the concept on potential shortcomings and key concerns identified in the indicator literature -- such as reaction time of the concept to real world changes, clarity of the method, flexibility, accuracy and relevance, simple communication, user-friendliness, or inclusiveness of the public (questions 2.1.1, 2.5, 2.7, 2.8, 2.10, and 2.11).

6. THE PROCESS OF THE QUESTIONNAIRE-BASED INTERVIEW RESEARCH

The interview followed the requirements established by the UBC Ethical Review Committee:

- the questionnaire was submitted to, and approved by, the Ethical Review Committee;
- the key informants were initially approached by letter rather than by phone, and the letter explicitly stated that participation is voluntary;
- the key informants had a choice of where to meet to ensure a "safe" environment; and
- all participants signed a consent form prior to the interview that informed them about the

interview process and their rights, including the right to terminate the interview process at any time, the assurance of anonymity of their statements in the research text apart from their names being listed in the appendix of the research document (Appendix 3.2).

For the interview, I provided a questionnaire form and an EF/ACC brochure (see Appendix 3.3) to all participants so they could follow the process more easily. However, the participants did not have to fill in the questionnaire as I took notes for them. As a back-up, and with permission of the participants, I taped the interviews. Using my notes and the tapes, I produced a written summary of each interview.

I sent the summarized transcript of the conversation to each participant and invited them to review it. Quotes used in this research document draw solely from these revised statements. For this report, I generalized the specific geographical locations mentioned in the original statements of the participants to secure their anonymity. In other cases, where the statements might indirectly reveal the source, I asked the key informants for special permission to use their quotes.

While the collection of data followed this interactive process, I interpreted the interviews and classified the key informants (as represented in Figure 6.1) without consulting them.

7. LIMITATIONS OF THIS INTERVIEW RESEARCH

The purpose of these structured interviews was to learn about the usefulness of the EF/ACC tool by exploring which aspects of the concept are difficult to understand, how it motivates people to act, and which applications are considered most useful. This required exposing psychological and social mechanisms which enable, and barriers which obstruct, people's efforts to plan toward sustainability, and to reveal how the EF/ACC tool could enhance these mechanisms or remove these barriers.

Although these interviews provide a probabilistic exploration of people's perceived usefulness of the EF/ACC concept, they do not reveal with statistical significance the level of support for the EF/ACC tool within these three groups. However, they provide insights into how the concept works for practitioners and how it could be strengthened. In other words, this interview series should rather be considered as a pilot for an in-depth study into EF/ACC's usefulness and public interpretation of sustainability. After all, documenting people's support for the EF/ACC tool with any statistical significance would require conducting over 380 interviews.[5]

However, the variety in perspectives and ideologies represented by the selected key informants and the depth of interviews (which expose the reasoning behind the answers) become more relevant than knowing the level of support within a population. After all, to convince in a debate and sharpen one's argumentation, it is more significant to understand the various perspectives and perceptions brought to the debate, rather than knowing how many people support one's side.

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[5] For example, the Gallup study on environmental perception interviewed 1000 people per country to document people's perspectives (Dunlap 1993).

For binary answers and large sample sizes, the Central Limit Theorem suggests that these answers would be normally distributed with N(p, p*q/n). N stands for normal distribution; n would be the sample size, p the probability of an affirmative answer, q (= 1-p) of a negative one. Hence, the minimal sample size (n_{min}) for a confidence interval (i) of ± 5 % (i.e., the interval is 10%) reaching a significance level of 95 %, can be calculated by using the formula $i/2 = x(sign.=95\%) * (p*q/n)^{1/2}$, x being the parameter for the unit normal distribution (Rosner 1986:section 6.6.2). For a significance of 95 %, x = 1.690, which means that 95 % of the distribution is within ±1.690 times the distribution's standard error. In the worst case, p*q reaches 0.25. Therefore, $n_{min} = p*q*x^2*(i/2)^{-2} = 384$.

(According to Bernard Rosner, this sample satisfies the condition of size required for applying the Central Limits Theorem as long as $p \geq 0.0132$. This follows from Rosner's assertion that the Theorem can be applied if $p*q*n \geq 5$. For a sample size of n=384, one can calculate that $p_{min} = 1.32$ percent.)

The original plan was to interview five people in three groups (=15 participants). However, as explained above, over the course of the interviews the sample was expanded to 21 in order to ensure a large enough variety. The similarities in the emerging themes suggests that this sample covers sufficiently well the reasoning patterns typical within these three particular groups; only small marginal gains could be expected from larger samples.[6] It is conceivable that interviewing a larger group of people might only reveal the limits of the interviewing process rather than furthering the understanding of the participants' psychological incentives for, and barriers to, planning toward sustainability.

Limitations for testing the usefulness of the EF/ACC concept through this interview research include:

- the rigid structure of the interview. This focused interview approach could reduce the topics that can be explored by the participants. However, without structure and focus it would be more difficult and more time consuming to recognise common themes.
- the choice of questions. The set of questions used may not be the most effective one to better understand emerging themes. Therefore, in a second step, rather than just increasing the sample size, the questionnaire would need to be fine-tuned from a substantive and a procedural perspective to focus more effectively on the themes that emerged in this first study.

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[6] For effective qualitative research, the selection of the participants, the context and the interview process is more significant than the number of participants (Patton 1990). The number of required participants for such research changes with the purpose of the research. In psychological or special education studies, one participant might suffice, while some sociological studies might require over 100 participants (Morse 1994:225). J.Douglas suggests 25 participants, if he had to pick a number (in Seidman 1991:45). In Janice Morse's typology, the testing of the EF/ACC tool is probably closest to what she calls "ethnography" which refers to exploring "cultures of understanding" and for which she suggests approximately 30-50 interviews, depending on saturation (1994:229).

The similarity of the participants' answers in my interview research to the ones collected over the last two years in evaluation forms from planning classes, workshops and seminars suggests that this sample of 21 captured a fair representation of the key concerns. The apparent saturation within the collected set of answers indicates that the sample of 21 participants was sufficiently large.

- the vested interest of the interviewer in the concept. My vested interest in the EF/ACC tool might deter criticism as participants may not articulate their full reservations about the tool in order not to offend me. Having me conduct the interviews, rather than a third person, cannot be avoided at the initial stage of the research, essentially to interact more effectively and to discuss issues with the participants. It seems unlikely that somebody less familiar with the EF/ACC concept could lead debates about the tool with participants as effectively. However, for further research, an impartial researcher, supported by an improved questionnaire, might be more effective.
- the focus on these three groups which might systematically omit mechanisms, barriers and concerns prevalent in other influential groups such as engineers, teachers, lawyers, or media people.
- the voluntary participation in the interview, which will lead to bias toward participants who are already sympathetic to the sustainability cause.
- the previous exposure of the participants to the sustainability debate which might make them judge the EF/ACC concept more favourably. Therefore, further interview research should be conducted with those not yet engaged in the sustainability debate.

B. DOCUMENTING THE INTERVIEW RESULTS

This section summarizes the key informants' interpretation of sustainability and their support for the EF/ACC tool. To make the progression of the answers coherent and logical, the discussion in this section does not follow the original order from the questionnaire (see Appendix 3.3), but is arranged according to the two progressive scales in Table 6.1 An extensive selection of the participants' answers is provided in Appendix 3.4.

1. THE KEY INFORMANTS' UNDERSTANDING OF "SUSTAINABILITY"

All the key informants were familiar with the term "sustainability." Eighteen of the 21 participants told me they had read or knew about the Brundtland report, while the remaining three had heard about sustainability through the media and had read professional reports on sustainability issues. When asked about the sources that shaped their understanding of sustainability, 11 showed a bias toward a biophysical interpretations by mentioning books and reports that focus on biophysical manifestations of the sustainability crisis (such as presented by the Worldwatch Institute, World Resources Institute, or *Limits to Growth* [Meadows *et al.* 1972]). Only three, all from the "business people and economists" group, showed a bias toward a monetary sustainability interpretation. From this perspective, the sustainability crisis is perceived to be a symptom of a deregulated market; the environment is viewed as an external factor to the economy with a particular dollar value (such as represented by environmental economics). There was only one participant (from the group of "community activist and local politicians") who showed a good understanding of the monetary as well as the biophysical sustainability interpretation.

Ten participants felt their organizations were committed to promoting "sustainability" (as interpreted by the participant), while another eight saw themselves as promoters of sustainability within an organization which took sustainability challenges not very seriously. Two thirds of the participants said their personal view on sustainability did not conflict with ideas and responsibilities at work -- in the group of "business people and economists," all felt that way with exception of one of the two environmental consultants.

In the following section, the summarized answers are organized according to the progression of the sustainability scale introduced in Table 6.1. Figures in brackets "()" provide the frequency counts of the participants' answers.

Do you think nature is being overused? (question 2.2)

(17) Yes (2) No (2) Don't know

Most participants felt that nature is being overused, or that, as I often rephrased it, the world's biomass harvest exceeds regrowth. However, particularly in the group of "business people and economists," not everybody was sure whether this was a local or a global phenomenon. Reservations mentioned included "...I do not know whether [this is the case] ... However, some areas are certainly overused. When I fly, I can still see huge land-areas that seem unused...". Or, "...it is mainly in poverty-stricken countries that biomass is being harvested faster than it regrows...".

Describe what would happen if nature is overharvested year after year? (question 2.3)

(15) spontaneously pointed out human dependence on nature

(3) acknowledged human dependence on nature once asked about the potential impact on society

(3) avoided talking about human dependence on nature even when specifically asked

Over two thirds of the participants pointed out spontaneously the dependence of human beings on nature. In fact, they provided graphic descriptions of how human life in an overused ecosystem would look. They said that "...we'll be left with a barren wasteland...," and "...either nature will correct the situation through starvation, or man will correct the situation...". One participant explained that continuing over-harvesting nature "...would simply destroy the Earth. As a minimum scenario, this would lead to a decrease in livability -- as a maximum scenario, this could mean that humanity does not survive as a species. Reality would probably be in between. Some small groups might survive and would have to dramatically restructure their way of life...". Somebody else concluded that "...if we take biomass to its most abused state, then our survival is very much in doubt. If people understand that? No!...".

Some of the "business people and economists" persistently swayed the discussion toward possible solutions such as developing solar technology or adjusting prices, but five explicitly mentioned that depleting nature would erode human welfare.

Maintaining nature's capacity to regenerate and reproduce is a necessary requirement for achieving sustainability. (question 2.4a)

(20) I agree with the statement (1) I disagree with the statement

All but one participant, who was firmly entrenched in the monetary interpretation of sustainability, agreed with this statement -- most participants did not even feel the need to comment on it. However, one community activist added that "...this does not mean that everything has to be left untouched...".

To become sustainable, industrialized countries need to massively reduce their resource consumption. (question 2.4b)

(14) I agree with the statement (3) I disagree with the statement

(4) n/a as the question was not included in the first four questionnaires

This statement about industrialized countries' obligation to reduce resource consumption was the most contentious one and stimulated many comments. A key objection to the statement was not necessarily its validity, but the psychological implications of the statement. For example, a planner/administrator said that the statement "...has to be qualified. If we tell it this way we scare people and they do not want to believe. So we should find examples about what will happen if we do not act, and how good it could be if we act...". Somebody else from the same group said "...I think that this is one of the scary sentiments or statements that get put out which terrify people or which make people feel quite helpless. The reason is that the degree by which we have stepped over the line, is quite scary...". Also, another participant in the group of "business people and economists" felt that "...as a goal now, the vision would be too narrow, too petty and would be counterproductive. It sounds too moralistic. And it is a negative goal rather than a positive goal...". Many participants provided suggestions on how this overwhelming task could be presented in a more manageable form. However, some also suggested that the shock value of this statement was necessary to get people to understand the dilemma that society is facing.

The three participants who disagreed with the statement felt that humanity has the capacity to overcome nature's limitations by inventing or further developing new sources of energy; in fact, two of them mentioned the yet untapped potential of nuclear energy. They did not see the decline of natural capital *per se* as a barrier to sustainability, but identified the cause with social constraints such as irrational or uninformed decision-making, lack of property rights, and uncontrolled population growth.

Qualifications by people who essentially agreed with the statement included questioning whether the reduction has to be "massive", the proposition that through recycling society's high resource throughput could still be maintained; and the faith that human inventiveness will allow society to cope with these challenges. Only one participant felt that "...biophysical scarcity does not have any meaning -- and by the way, food has been mushrooming. There is no question that locally, some areas have food problems, but globally, we have huge surpluses of food...".

Considering the enormous public debt, implementing sustainability measures is a luxury that Canada cannot afford right now. (question 2.6)

(0) Yes, I agree (0) Yes, I somewhat agree (3) No, I somewhat disagree (18) No, I disagree (0) Don't know

All the participants believed that developing sustainability and resolving the debt crisis were not fundamentally at odds. In fact, some said that "...if we do not do anything about sustainability, public debt is not going to mean anything. Reducing public debt has to run hand in hand with advancing sustainability...". Another participant said that "...if we want to know what debt is and what poverty is, we should just keep going on our course...".

In your opinion, can society become sustainable? (question 2.9)

(9) Yes (3) Maybe (2) No (4) Don't know (3) Not answered

Less than half of the participants were confident that society can become sustainable. Most participants felt that the public has not acknowledged the sustainability dilemma and concluded that education is most urgent. Some felt that crises or shocks might be needed to develop a public consciousness while many saw the current materialistic value system to be a major stumbling block to achieve sustainability. The perception of jobs and environment being in competition was a recurring theme. For example, somebody mentioned that "...the limiting factor for change today is the bleak economic outlook, including the debt and the loss of jobs. Therefore, we might need economic growth to achieve sustainability. Economic growth could well be in conflict with sustainability, and requires careful management to avoid this. The money generated by economic growth should consciously be redirected towards sustainability...". In contrast, others felt that the roots of the sustainability crisis need to be addressed and that "...Western and other wealthy societies must reorient their understanding of needs and wants away from materialistic consumerism...".

In these discussions about barriers to developing sustainability, we often touched the topic of social denial. Issues that came up included fragmentation of people's perception, the lack of options or positive role models, the difficulties to think about future needs, and the reluctance to give up a lifestyle into which people have invested much of their lives. "...Children are more flexible and are not yet entrenched in a path, but they have no status and no power. [Therefore,] the vulnerable point is the parent's love for their children...". said one participant. Also, many participants felt that the general population does not understand the crisis. In fact, "...there was some reverse learning we went through in the oil crisis. So people are left confused, and the crisis seems not real...". And many who realize the sustainability conundrum do not accept it as their personal challenge. "...We always mean other people but never us...".

Television's impact on human perception was brought forward by several participants. "...It fragments people's experiences and understanding, discounts any sense of time and disconnects them from their surrounding..." said one person, while another participant pointed out that "...by pretending that life can be lived like on TV is debilitating... Similarly, in human rights violations or environmental abuse, the more disconnected (e.g., through TV) you are, the easier it is to abuse...".

2. THE KEY INFORMANTS' SUPPORT FOR THE EF/ACC CONCEPT

This part summarizes the participants' answers regarding the usefulness of the EF/ACC tool. Again, for the discussion in this section, the order of the questions follow the progressive scale on public support for the EF/ACC concept (see Table 6.1), rather than the order by which they appeared in the questionnaire (see Appendix 3.3).

Does this brochure explain the concept well? (question 2.1.1)

(18) Yes **(0) Barely** **(0) No** **(3) Question not asked**

All participants liked the style of the brochure and felt that it communicated the concept well. In fact, all but one (with whom the question was not discussed) were able to rephrase the EF/ACC concept. Most mentioned explicitly in some form that this concept is about nature's resources and services necessary to provide household consumption; that it is attributed to population, rather than region; that it is not a projection but an analysis of the current situation; and that the measurement unit is land area. When rephrasing the concept, five of the six women, and two of the 15 men used the pronouns "we", "our", "I", or "me." This may indicate that these seven participants acknowledged the concept's relevance to their own consumption -- not only to that of other people.

As far as the brochure was concerned, the use of graphics was particularly appreciated. The participants provided many helpful suggestions on how the brochure could be improved such as including more white space, use the front and the back of the document more effectively (like a newspaper), use bullet lists, adapt it to various audiences and link it to their experiences. Many pointed out that producing brochures does not suffice as many people do not read, and suggested other modes of communication.

Community activists liked the brochure's action orientation. However, some of the "business people and economists" did not agree with the recommendations. They particularly objected to the brochure's "localism" and said "...I have indicated that some of your theories such as 'buy items made or grown locally rather than far away' represents the kind of thinking that moves us away from finding a solution. This disintegrates rather than integrates communities. If you want the Mexicans to clean up their environment, trade with them, and then use that trade as a leverage point to make them clean up their environment...". Somebody else commented that "...maybe local needs should not be secured. Maybe local communities should be wound up and absorbed in a larger and more sophisticated urban community... It does not work that we put unproductive regions on welfare programs as done in Eastern Quebec and most of the Maritimes...". However, another participant in this group was less concerned about the recommendations and said that "...one way we can achieve [sustainability] is by putting this quantifiable stuff out for people to see. This [brochure] shows me right away in a quantifiable form what I intuitively know. That is the bridge and that's exciting...".

Does the Ecological Footprint concept describe the ecological bottom-line accurately?

(question 2.5)

(15) Yes, it is simple, but sufficiently accurate.

(2) Yes, but it is rather complex.

(0) No, it is too simplistic.

(0) No, it is too complex.

(2) Other comment: the concept seems simple, but the application might be complex; the concept is misleading.

(2) Not answered.

The themes that emerged in the discussion about EF/ACC's ability to represent the ecological bottom line of sustainability addressed the role of models and the difficulty to apply the concept. Many made the point that although models can never be completely precise, they do not need to be completely precise because they are approximations of reality. For example, one participant said that "...the concept is an interesting first cut. It quantifies a lot of issues that were kind of vague in my mind. Any research or statement about knowledge [you need to] simplify when you communicate. So, somebody can always say that it is too simplified. We are always in search of truth. But that is elusive. We are just seeing one slice of reality and say this is one possible vision of it. As long as that is made clear, I do not have a problem with it...".

Similarly, one participant mentioned that the brochure "...should emphasize the state of ignorance, and that we cannot fully know how ecosystems work...".

Participants also indicated how crucial it is to declare the assumptions behind the model upfront. One commented, "...it is always the assumptions that make people doubt the model. Therefore, it is important to accompany such studies with a clear discussion of the assumptions, and a sensitivity analysis with alternate assumptions...". Some assumptions behind the concept were contested. One planner stated "...I feel that the Footprint concept is quite intuitive, in the sense that if I would do something I think I would know what its sustainability impact is and probably also in which direction the Footprint would go...". A business person said that "...there is potential for misunderstanding. Also, as some of the issues mentioned in the brochure are counter-intuitive, this suggests to me that there is a bias behind the model...".

One participant also cautioned about the methodological difficulties that any resource accounting faces. "...There is a long history of resource accounting (e.g., the technocracy movement), but by translating everything into land-use the level of abstraction in [the EF/ACC's] accounting procedure is even one level higher than in energy accounting. Also, the quality of such accounting has not a very good track record...". The participant continued that "...the concept is OK, but measurements would be rather unreliable. It does not include labour, and it ignores the role of water. It should demonstrate that land and water can be competitors. But how would we compare California (which lacks water) with Bangladesh (where water is in surplus with all the floods)?...".

The participants understood the concept's validity for framing the challenges. One said that "...it assists common-sense logic and is necessary to stimulate discussion and understanding of complex issues. Complete accuracy is not necessary...". However, many found the difficulty in applying the EF/ACC concept was the weakest point of the tool.

Evaluate how reliable the Ecological Footprint concept is [for illustrating the ecological crisis]. (question 2.8)

Does the Ecological Footprint concept demonstrate humanity's competing demands on nature's productivity?

(8) Absolutely (6) To a large extent (1) Barely (1) Not at all (5) Don't know

Many participants appreciated the ability of the concept to show systemic effects and connections between human uses of nature's services. "...It is one method to show that we are not here alone..." a community activist said. "...Yes I agree, if something comes from Indonesia, it is used by us and cannot be used by them...". Some pointed out that since the concept was more spatially oriented, issues of pollution, biodiversity or ozone depletion were not well covered by the concept. For example, one remarked that "...the model is static rather than dynamic. It does not explicitly address issues of water and air, or ozone depletion...". One of those two participants who felt that the EF/ACC tool did "barely" or "not at all" represent humanity's competing demands told me that the tool was not yet developed far enough; the other that the tool was fundamentally misleading. Both were from the "business people and economists'" group.

A common concern was the scale of the application. Most participants acknowledged the concept's usefulness for illustrating global resource conflicts, but many did not see its relevance to the local scale (see also below). For example, one participant remarked that the concept "...is probably not enough for decision-making regarding development. It is very much a global approach and you also have to look at the local social, environmental and economic situation...".

In fact, many participants felt that the EF/ACC concept did not adequately address the social aspects of society such as society's capacity to accept new ideas or social and spiritual conditions for sustainability -- and, in fact, these are the aspects that we on the UBC Task Force on Healthy and Sustainable Communities try to capture with the "Social Caring Capacity" tool (UBC Task Force 1994). However, one community activist concluded that "...the enormity of the [EF/ACC concept's] implications cannot be grasped by many people. In fact, the tool illustrates how everything is connected. This concept is extremely important but breathtaking and scary. It also allows [people] to start at any point, but to grasp its entirety might be hard...".

How useful do you think the Ecological Footprint concept is for:

- the general public to understand the sustainability dilemmas? (question 2.7a)

(14.5)[7] Very useful (4.5) Useful (0) Marginally useful (0) Not useful (1) Don't know (1) positively harmful

There was almost unanimous consensus between the participants that the EF/ACC concept would be useful for the public to understand the sustainability dilemmas. One community activist put it this way: "...It is essential. If the general public does not understand it, they will not buy it... And even if it meant tightening their belts, and they really understood, they would absolutely insist on [becoming sustainable]...". However, one business person who classified the concept for this purpose as "very useful," warned that the concept also has the potential to "...be very misleading when used by propagandists who do not explain their assumptions...".

[7] Fractions indicate that some participants chose in between the marks of the original scale.

● individuals to reconsider lifestyle or business decisions? (question 2.7b)

(5) Very useful (10) Useful (4) Marginally useful (0) Not useful (1) Don't know (1) positively harmful

The suggestions to use the EF/ACC concept for reconsidering lifestyle and business decisions generated the least enthusiasm of all six propositions. "...It is very difficult to influence individuals to do anything without some economic coercion..." said one participant. Essentially, the participants pointed out that the EF/ACC tool is only useful for evaluating their lifestyle if they have "bought into" the concept in the first place.

● community activists in their sustainability campaigns to make their point more effectively? (question 2.7c)

(13) Very useful (5) Useful (1) Marginally useful (0) Not useful (1) Don't know (1) positively harmful

Even though many participants perceived the tool to be useful for community activists, some business people were concerned about potential misuse of the concept. One said that community activists "...are the ones who can most abuse this concept by oversimplifying the issues, or not declaring their assumptions...". Another business person felt that "...to assume that everybody here in Canada should only consume on the world average level does not work. There is no absolute standard. Population growth becomes a vicious circle. We in Canada should not change our lifestyles just because other populations are growing at a fast pace. Otherwise they will just outgrow our sustainability gains...".

● planning departments and municipalities as a planning tool? (question 2.7d)

(10.5) Very useful (4) Useful (2.5) Marginally useful (2) Not useful (1) Don't know (1) positively harmful

The opinions about the usefulness of the EF/ACC tool for municipal planning were clearly divided between the various groups. Particularly, the group of administrators and planners rated the tool's usefulness for municipal planning low. In fact, the typical answer of the administrators and planners was between "useful" and "marginally useful" (or at 2.3 points, with very useful = 1, useful = 2, marginally useful = 3), while that of the other two groups combined scored between "very useful" and "useful" (or at 1.7 points). A planner said that "...probably on the national or provincial level, it is quite a useful thing. But for municipalities it could be difficult to apply...". However, another planner felt that "...we are on a slippery slope, and today there seems to be no interest in planning for sustainability. If [municipal planners] were concerned about our future and our children's future it would be very useful, but in the current conditions, it is marginally useful...".

Most of the community activists identified municipalities as major actors for moving society toward sustainability. In fact, "...we have to appreciate the effect of municipal decisions and all the cumulative effects of all the small things that come with it. I suspect that municipal things are far more important than an awful lot of people give credit for...". However, many said that although this depends on appropriate planning tools, public support from within the municipality is essential. One community activist added that "...a main thing for local government is to make [the decision process] simpler so people can understand it. This tool might be helpful to get information out to the public and increase their understanding of the constraints. Municipalities have a duty to lead toward sustainability...". However, another participant maintained that quality of life issues might actually be a more compelling motivation for people to move toward sustainability than facts about the Ecological Footprint.

- political decision-making as a sustainability indicator (similar to the GDP)? (question 2.7e)

(10) Very useful (9) Useful (0) Marginally useful (1) Not useful (1) Don't know (0) positively harmful

In general, the participants liked the idea of a national Ecological Footprint indicator.

However they cautioned about the national scale of analysis, which seems to be too large for individuals to identify with. Another warning they gave was that an EF/ACC indicator might not change much as political decision making is not a rational process driven by careful analysis.

- students and scholars to generate positive choices for sustainability? (question 2.7f)

(12.5) Very useful (5) Useful (0.5) Marginally useful (0) Not useful (2) Don't know (1) positively harmful

Some of the participants were not clear about how the concept could assist students and scholars to generate positive choices for sustainability. However, after I explained the concept's potential to provide a framework for sustainability and a criterion for evaluating policy and design ideas, many expressed support.

Has this interview changed your perspective on sustainability? (question 2.10)

Many indicated that the interview was useful to rethink the sustainability impacts of everyday issues, or as one community activist put it "...it is always good to be reminded of the larger policy context...". What the participants seemed to appreciate most was the concept's ability to communicate ecological constraints to the public. One participant said the interview discussion "...has been complementary to my understanding. I learned that you came up with a tool that can show our impact on nature in a graphical format, and ways to demonstrate figuratively fairly complicated concepts to people whose minds don't perceive those concepts particularly easily....". Another one said that "...I think, finally, I have a clearer definition of sustainability, and one that I like to use myself. I think it is a better one than the one of the Brundtland report, even though the Footprint does not say it is about 'sustainability'...".

Would you consider using the Ecological Footprint concept during the next year? (question 2.11)

(14) Yes (2) No (5) Don't know

Two thirds of the participants felt they would use the EF/ACC concept as an argument in discussions with friends, colleagues or clients. Eight expressed active support to promote the concept by using it in public presentations, in their writing or by distribution brochures to people they know. One participant indicated interest in applying the concept.

Any other comments? (question 2.12)

Implications of perceptual differences between the Euro-Canadian and the Chinese-Canadian culture in the Vancouver area came also up in the discussions. The concern was raised that "...because of demographic shifts through the immigration of people from Hong Kong (where sustainability is not much of a consideration as they import all their resources and nature's services), the interest in these issues is diminishing as they do not mean much to the new immigrants...". Another participant felt that "...the Asians understand much more their place in nature [than Western culture], because of Buddhism, Zen, Taoism and the philosophy of Asian history. What happened with the new immigrants coming here is that you are dealing with a very small sector of *nouveau riche* which in the case of Hong Kong consists mainly of urban people without rural history or context... [However], I do not think that Canadian society's view on sustainability is turning around one way or the other because of the Asian population's view on this matter...".

In their final remarks, participants from all three groups showed appreciation for the concept and felt that it has potential to link "...these broad goals with the specific decisions, as it addresses global issues and then links them to the decisions in an individual's life...".

However, one participant warned about the danger of promising too much and said the concept seemed "...a bit over-sold as a planning tool. I think it is good as an advocate tool, but it is difficult in the links to everyday planning tasks such as approvals, policy recommendations, etc...". Finally, many expressed interest to see more applications of the concept, and saw the current shortage in EF/ACC examples as the main stumbling block for receiving a larger support for the tool.

C. ANALYZING THE INTERVIEW RESULTS

Interviewing key informants most of whom are practitioners in a variety of fields was a fruitful process for pinpointing weaknesses of the tool and for better understanding of sustainability issues with which these people are struggling. The interviews allowed me to identify the areas on which further tool development should focus, in order to make the EF/ACC concept more useful and relevant for them. In the first part of this section, I will interpret the participants' comments and infer from these how participants felt about the tool's ability to support their work. In the second part, I will draw lessons from this interview process: how future processes should be designed to test more effectively people's sustainability understanding, and to identify the limiting factors for public action promoting sustainability.

To analyze the interviews, I categorized the answers of the participants in a matrix, which made common patterns and themes visible. The rows of the matrix represented the participants (aggregated in their respective groups), while the columns represented the coded questions. For example, I listed which of the following elements they mentioned when rephrasing the EF/ACC concept, namely using the first person singular, mentioning resource allocation, expressing it in terms of *per capita* consumption, referring to the present situation (rather than to future prediction), identifying land as a measurement unit, and using the word "sustainable" in their definition. Or, I classified their main objections to the tool which the participants put forward in question 2.5 and 2.8, which included the tool's neglect of biodiversity, water resources, pollution, social factors, hidden assumptions, ignorance of market forces, and technological pessimism. For other questions with multiple choice answers, I coded the answers with an ordinal number according to the checked box. However, to keep the statements anonymous, the matrix is not reproduced here, and the results are directly reported in the text.

Classifying the participants according to the developed scales was simple and straightforward. Because answers from three participants seemed contradictory, I had to go back to the transcript before making a decision in their scale point with respect to perspective on sustainability. Two of these were classified in between two scale points as they wavered on that question during the interview.

1. EVALUATING EF/ACC'S USEFULNESS

Figure 6.1 plots the key informants' agreement with the sustainability perspective outlined in Chapter I, and their level of enthusiasm for applying the EF/ACC concept themselves. The distribution in this graph shows the interviewed "administrators and planners" (A), "business people and economists" (B), and "community activists and local politicians" (C), according to their perspective on sustainability (x-axis) and their support for the EF/ACC concept (y-axis). The distribution of these perspectives suggests two lessons: first, there is no tight correlation between people's sustainability interpretation and their judgement about the usefulness of the EF/ACC tool. For example, participants who said that they intend to use the EF/ACC concept as an argument in discussion (five on y-axis) vary from people who understand the sustainability

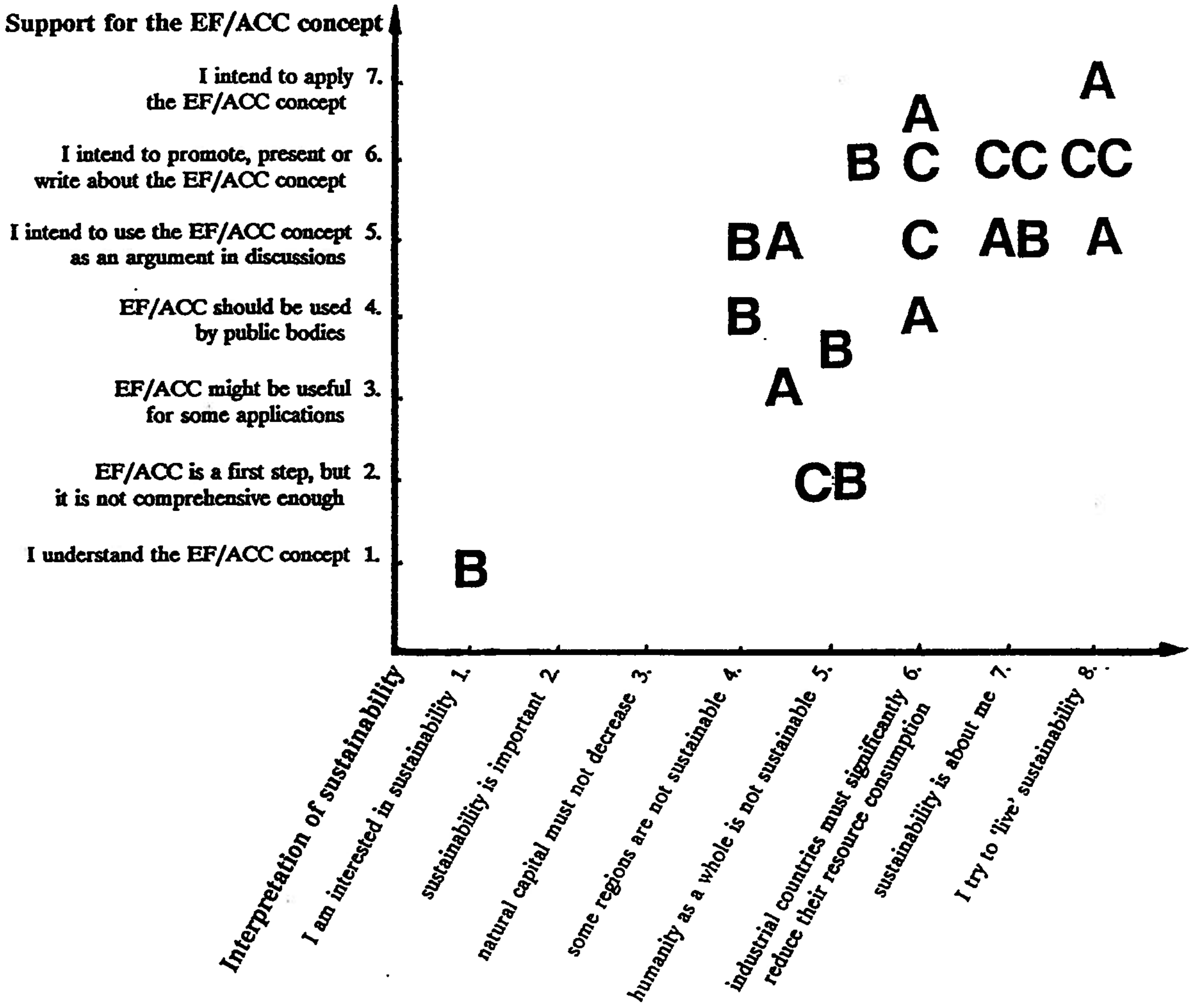

Figure 6.1: **The participants' perspective on sustainability and support for the EF/ACC concept**
This graph shows the participant's agreement with the sustainability perspective outlined in Chapter I, and their level of enthusiasm for applying the EF/ACC concept themselves. The scale on the x-axis indicates where they disagreed with my interpretation for the first time. The scale on the y-axis shows how far their support for the EF/ACC tool goes.

A: administrators and planners

B: business people and economists

C: community activists

crisis only as a local phenomenon (four on x-axis) to people who live the "sustainability principles" in their lives (eight on x-axis). In fact, out of the nine key informants who do not advocate a major responsibility for industrialized countries to reduce their resource consumption (below point six on the x-axis), three showed interest all the same in applying the EF/ACC concept in the future when discussing sustainability.

On the other hand, people who have become advocates for sustainability and who actively explore possibilities to reduce Canada's resource consumption massively all liked the EF/ACC concept. However, they did not necessarily identify EF/ACC as a tool that they intend to introduce to their work. The reason might be that these people are already overcommitted in their current sustainability activities and may see the use of this tool as an additional task rather than as a relief.

A second conclusion could be drawn from this graph. The fact that there is no clear-cut segregation in perspectives between these three interviewed groups suggests a significant overlap among their sustainability interpretations. In fact, the cluster of "administrators and planners" in graph 6.2 intersects significantly with the cluster of "business people and economists" as well as with that of "community activists and local politicians". Even the group of "business people" and "community activists" overlap. This indicates that there might be more potential for cooperation between these groups than the members of these groups may think. Also, this implies that, since the EF/ACC tool communicates with various people of different perspectives, it might be a useful tool for bridging communication gaps between disparate groups.

Quite possibly, the EF/ACC concept might be more useful to support constructive communication than the conventional sustainability model with the three intersecting circles of "economy, society and environment" (see for example Sadler & Jacobs 1990:9). Through its ambiguity, the three circle model feeds into a vague initial consensus. This obscurity hides the various perspectives' conflicting interpretations of what those three concepts mean and how they are linked. In contrast, the EF/ACC tool proposes a concrete and measurable condition for sustainability and might thereby facilitate a more constructive and concise communication between these various perspectives. Such communication could disclose these different interpretations and check them against each other. This was confirmed by the revealing discussions triggered by the concept during the interviews -- what sustainability means, what the barriers are and how they could be overcome. Even though the concept questions common assumptions and places the challenges of overconsumption in industrialized countries quite openly on the table, it still received support from people in all three groups (see Figure 6.1).

The **substantive** grasp of the EF/ACC concept by the participants was remarkable. In the past, many informal conversations with those previously exposed to the EF/ACC concept initiated significant re-interpretation according to what appeared to be their main concept of "environmental concerns" -- re: pollution, waste recycling or fossil fuel consumption. However, the interview participants could easily rephrase it, and many had no difficulty in pointing out implications for the human economy. Also, the overwhelming majority had a clear recognition of human dependence on nature, once asked about the consequences of continued degradation of nature. They acknowledged that maintaining nature's capacity to regenerate and reproduce is a necessary requirement for achieving sustainability. However, fewer of them supported the statement that industrialized countries need to reduce their resource consumption massively as to become sustainable. This statement helped to identify those who accepted the sustainability challenge and its associated responsibilities, and those who were reluctant to acknowledge it -- or did not feel that these challenges would translate into responsibilities for public action beyond traditional environmental policy interventions. An example of the second category was a business person who maintained that "...a relatively wealthy society is doing a relatively good job...".

It was surprising that none of the key informants agreed with the statement about sustainability not being affordable now when Canada faces an enormous public debt. This was intended to test the participants' bias toward a monetary interpretation of sustainability, and represents an opinion often voiced in business oriented media such as *The Globe and Mail* from Toronto or *The Economist* from London. From my experience with earlier EF/ACC evaluations that I collected in various workshops where many with monetary sustainability interpretations seemed to agree with the statement, I expected that at least some in the group of "business people and economists" would agree with the statement. But none did. However, some mentioned in other contexts that more affluent societies become environmentally conscious, or that, as one person from the group of "business people and economists" put it "...the only likely solution to pollution is growth...".

A reason why those business people with a more monetary oriented perspective disagreed with the statement (or agreed that reducing debt and developing sustainability are not at odds) reflected a reaction to the statement's government focus. They felt that governments had much shorter time horizons than businesses which made them less effective agents for sustainability. In other words, by spending money, government would not promote sustainability; to put it another way, by not spending money, they would not detract from sustainability.

However, it might also be that the question needs to be improved. It is quite conceivable that people with a monetary sustainability interpretation perceive debt as the central sustainability problem. "Considering the hardship of economic recession, can we afford to invest in the development of sustainability?" might be a more illuminating question for this task.

The interviews showed that most participants acknowledged that the various human uses of nature are in competition, and that therefore the various ecological issues are linked. Everybody but one from the group of "business people and economists" and who displayed consistently a monetary bias, accepted that availability of bioproductivity is a core sustainability requirement. Seventeen also explicitly acknowledged that, given the way we live now, this condition is not satisfied. The two who negated it were both in the group of "business people and economists." Nobody disputed the size of the Ecological Footprint, or argued that, in contrast to the claims of the brochure, everybody on the planet could eventually live as Canadians do today. This is remarkable, and would probably not be a shared perspective all across the Canadian society. On the other hand, this interview did not explore whether the participants would have brought forward this perspective on their own, or if they were guided by interview questions and chose the answers out of convenience. In either case, this could be interpreted in favour of the EF/ACC tool: if they had not proposed these perspectives on their own, the tool was able to make the argument in a non-threatening and convincing way; or, if they already believed in this perspective, the tool is fully compatible with how these groups understand sustainability and could therefore be adopted as a sustainability measure.

However, where the EF/ACC concept became more personal, it encountered more resistance in the interviews. For example, some participants did not appreciate the graph that depicts the Ecological Footprint of various income groups. One business person said that "...this incredible large Footprint of the professional couple bothered me. My wife and I happen to be such a couple. But this relationship makes no sense and the assumptions are not obvious. This could be very misleading, because for example, we put mostly energy efficient appliances in our house etc...". Also when testing the passive support for various applications, those that showed potential for applications in the participant's sphere scored lower. For example, the proposition to use the EF/ACC for reconsidering lifestyle or business decisions did not receive much support. Rather than talking about their own experience, those participants who felt less supportive of that option avoided the issue and argued that people were not yet ready for such ecological self assessment (even though that was not the interview question). Also, when asked about the usefulness for municipal planning, administrators and planners were the least enthusiastic (with the exception of those who had worked previously with the UBC Task Force on Healthy and Sustainable Communities). For example, one person of the "administrators and planners" group who was well versed in the sustainability literature and had followed it over three decades rejected the idea that municipalities should and could actively plan toward sustainability. In fact, this person felt that responsibilities should be removed from municipalities rather than added. However, such reactions might illustrate a general reluctance to acknowledge personal responsibilities while continuing to delegate these to others.

EF/ACC received the highest rating for being able to link global constraints with individual or local decision-making in a simple, comprehensible way. However, many found it hard to imagine concrete applications of the concept in a municipal context. This underlined the need for more tangible local examples relevant to the practitioner's everyday work, and which could easily be replicated in similar contexts. Providing more small scale applications might also address the commonly expressed concern that the EF/ACC concept would only apply to larger scales but would be less relevant to household or municipal concerns.

When discussing how to achieve sustainability (or how to reduce industrialized countries' Ecological Footprints), many identified the lacking public understanding as the limiting factor to more effective public action. Participants pointed out that people know about issues, but that everyday life -- including professional responsibilities, commuting, TV or shopping -- stimulates a fragmented worldview and invites people not to make the mental connections between the various issues and their effect on the future. This might feed into society's further denial of the sustainability crisis which in itself becomes a major barrier to developing sustainability.

Also, it was pointed out that people are caught in a lifestyle that is painful to abandon. The psychological and financial investment in lifestyles reduces willingness to change and many are puzzled about how they could change without having to carry the whole burden themselves. For example, one participant pointed out a "Tragedy of Free Access" phenomenon saying that "...everybody can see that cars are a problem. But people do not know how to give them up. We need alternative transportation policies such as tolls or inconveniences for personal cars. But the problem is that not even the advocates for this change have changed...".

To make the interviews more personal and interactive, I should have invited the participants to analyze their strategies according to their impact on carrying capacity appropriation. For example, a planner remarked that "...we could not completely shut down our resource industry. ... [However,] government's pull-out from supporting high-tech research is a sign of moving in the wrong direction...". When this idea that the restructuring of the economy from a resource to a service industry would make Canada more sustainable was put forward, it would have been interesting to observe whether the EF/ACC concept could have been effective for allowing the participant to evaluate the strategy. If the concept is effective, it should have enabled the participant to realize that this strategy of economic restructuring might not necessarily reduce Canadians' resource consumption, but only increase Canada's competitiveness in the global economy.

Some scholars claim that the sustainability debate ignores the social dimensions of the issue and is led from an assumption of "universal affluence" within Canada (Schrecker 1994:36). However, this concern seemed not to be confirmed in these interviews. In fact, the sustainability advocates showed a much stronger concern for social issues when asked about their political perspectives or when talking about how society can become sustainable, than those participants less committed to promoting sustainability. Many of the committed community activists explicitly mentioned the need for social sensitivity. For example, one community activist said that "...any righteousness that rubs people out of the picture is counter-productive...". Also, a business person said that "...the brochure does not give people the feeling that you understand their problem. For example, by saying that people should live closer to where they work might not feel like a possible choice to them...". Some participants pointed out that affluent groups can have a strong voice in protecting their unsustainable lifestyles. One example mentioned are groups in Vancouver's Arbutus Corridor, all "...intelligent and well-informed people...," who fight densification for fear of local traffic congestion, and voice their objections through community organized protest drives and simulated traffic congestions.

In fact, many participants put forward the concern that the EF/ACC concept lacks the social and spiritual dimension of sustainability. This supports the strategy pursued by us on the UBC Task Force on Healthy and Sustainable Communities to complement the EF/ACC tool with a social equivalent, the "Social Caring Capacity" tool.

The EF/ACC concept received also much support for its **procedural** strength when exploring the tool's methodological strengths and weaknesses in question 2.5 and 2.8. Most participants expressed the view that the concept was sufficiently simple, even though they felt that applications might be more demanding and the method not yet obvious. Surprisingly, the need for reliability and accuracy did not cause much concern to the participants. In contrast, some explained that models should be concise and to the point rather than obfuscating through sophistication, thereby supporting my intent of visualizing generalities rather than specificities (see Chapter I). They acknowledged that models are approximations of reality, should epitomize our experiences and must facilitate communication.

Much discussion focused on how the communication of the concept could be improved. On the one hand, the discussion focused on the mechanics of effective communication including an accessible writing style, the use of multi media modes, jingles, or strategic brochure distribution. On the other hand, ideas were generated on how to make the communication of the concept empowering rather than frightening or intimidating. Suggestions included ignoring negative goals (such as 'reduce consumption') and focusing on positive ones (such as 'liberate yourself from the yoke of consumption,' 'have fun with bicycling or walking' or 'build a funky compost heap'), to acknowledge people's constraints and living situations, to avoid moralizing and guilt-tripping or to use attractive and uplifting communication modes such as music and jingles.

Many participants appreciated the EF/ACC tool's action orientation and the focus on clear and accessible communication. However, some participants felt that the assumptions behind the EF/ACC calculations need to be spelled out in more detail to increase the confidence in the tool. But nobody suggested that the analysis should be more detailed or more sophisticated. This contrasts with views of academics gathered informally, many of whom have suggested translating the EF/ACC concept into a computer model or developing it into a more detailed input-output analysis. The academics suggested that such a detailed model could illustrate the resource flows within the anthroposphere, could show dynamic effects and might allow researchers and practitioners the instantaneous testing of scenarios. However, none of the participants (who were mainly practitioners) proposed the idea of translating the concept into such a computer application. Rather than questioning the calculation procedure, they suggested including more components of the biosphere such as water or air. This suggests that those issues which the EF/ACC concept includes indirectly (such as biodiversity, water use, ozone depletion) should be addressed more explicitly. In short, the tool's generality and effectiveness to communicate was perceived to be more crucial than the structure of the calculation procedure and its conceptual sophistication.

Finally, the reasoning of participants in two particular clusters requires special attention. The first cluster encompasses those three participants who did not accept the need for industrialized countries to reduce their resource consumption massively (No.4 on the sustainability scale, or lower). In fact, they presented the view that free markets and human inventiveness would automatically take care of the ecological crisis. They felt that deregulating the market and privatizing public goods would lead to full-cost pricing. Ecological destruction would then be reflected in higher prices, which would later stimulate adequate technical responses. Also, they were optimistic that human inventions could overcome ecological scarcity. For example, as mentioned above, two pointed out that nuclear power could substitute fossil fuel. One said that we need to "...find new resources such as atomic energy...". Two others mentioned the increase in agricultural productivity, and one told me that

> ...since I grew up, the productivity of a farmer has increased fivefold. This is due to higher yield varieties and better farming techniques (e.g., 2.5 inch tillage rather than 6 inches which allows the soil to retain more moisture, slows down erosion and leaching, and conserves tractor energy). Now they produce on a sustainable basis -- when I was young they were mining the soil and did not know how to take care of the land.

The second cluster includes four participants who did not actively support the use of the EF/ACC tool in its current form (No.4 on the "support for EF/ACC" scale, or lower). Participants in this cluster exhibited much more diverse reasoning. The planner in this cluster did not recognize the profound implications of the ecological crisis and argued that EF/ACC

> ...is not very helpful for local planning. Perhaps, I might use it internally to win an argument. But it cannot be incorporated in OCPs (Official Community Plans)... The Ecological Footprint is helpful for global education, but the GVRD (Greater Vancouver Regional District) concepts of environmental management and regional management are more helpful when planning at the at the local level. It might be that the Ecological Footprint can get further developed for municipal applications. But at this point, I cannot see its specific relevance for municipalities. Municipal planning is related to land-use or to management of the land. Therefore, the Ecological Footprint is not specially useful as it also includes other land than that immediately within the municipal boundaries (e.g the fossil fuel use as a land component of the Ecological Footprint). But, it helps as a background orientation.

The community activist's had similar technical concerns about the tool, even though he recognized the challenge set by the ecological crisis. He felt the

> ...Ecological Footprint concept to be an elegant means of represent consumption of resources, aggregated at a municipal or regional level. I do not, however, consider the Ecological Footprint to be more than marginally useful as a planning tool. By *planning tool*, I mean anything that I would use for analysis, plan and policy formulation, or plan implementation. [The Ecological Footprint] is appropriate to get the issue of over-consumption on the political agenda. But beyond that it is not useful because it does not link with the rest of the daily planning activities. There is no municipal act saying "Thou shall pay attention to the global context." The Footprint does not describe the human system but only why we should change the way we operate today and helps us set very broad objectives. Personally, I suspect it is equally compelling to work with localized issues such as "do you like living here?" and make people think about their quality of life. Basic principles of quality in design and quality of life are as compelling and as a legitimate motivation to do what we would consider planning for sustainability.

One of two people in the cluster from the "business people and economists" group believed that the EF/ACC tool was fundamentally misleading as it ignored economic principles; the other still wanted to see further development of the tool before judging its utility, as he was sceptical about the methods of any economic tool that tried to measure non-monetarized quantities. He said that

> ...if the Footprint is used in the public domain, it will suffer from the same problems as cost-benefit analysis. If a politician does not like the conclusion, then some assumptions will be attacked thereby killing the whole analysis.

The portraits of the seven people in these two clusters (one participant in both) shows how people with perspectives not congruent with the sustainability interpretation of Chapter II or with less support for the EF/ACC concept could be engaged in the debate. People in the first cluster need to understand that even though their technological optimism might be correct, the EF/ACC tool could be used as a yardstick to verify these claims. For people in the second cluster, more pertinent EF/ACC applications need to be developed in order to convince them. It appears that people do not feel comfortable translating an abstract concept into real applications on their own but need examples to gain confidence about specific approaches.

2. EVALUATING THE INTERVIEW PROCESS AS AN EF/ACC APPLICATION

Interviewing the participants was not only a research project for validating the EF/ACC tool, but also a test of an application of EF/ACC in itself. In this application, I used the concept as a conversation piece to explore people's understanding of sustainability and their commitment to action. The purpose of such explorations is to identify the limiting factors hampering the translation of sustainability concerns into action.

This test application showed that the EF/ACC concept can stimulate lively discussions about the barriers to developing sustainability, reveal to participants and others their attitudes toward possible strategies for overcoming them. The support that the concept received from a large variety of people with, at times, opposing sustainability perspectives suggests that the tool could contribute to consensus building, make the sustainability concept more concrete, and bring it closer to people's experiences.

The interview process with a systematic progression of questions focused the discussion and helped make the participants' answers comparable with those of other participants. This eased the analysis. The two progressive scales provided a simple but useful categorization of participants' understanding. A similar one could be developed for social denial, once its key mechanisms are identified. These scales assisted in quickly assessing the participants sustainability perspectives, not in absolute terms, but certainly in relative or comparative terms.

During the interview process, the questionnaire was slightly changed to incorporate some of my acquired knowledge and experiences during the interviews. Rather than merely asking whether maintaining nature's capacity to regenerate and reproduce is a necessary condition for achieving sustainability (in question 2.4a), I added a second question about industrialized countries' need to reduce their resource consumption massively (question 2.4b). This question pointed at a sensitive area of the sustainability debate and was therefore effective in fathoming participants' sustainability perspective. Particularly, the word "massively" prompted much interesting discussion. On the one hand, people acknowledged that current consumption levels in Canada have much exceeded what can be sustained by Earth. However, on the other hand, the word "massively" seemed to remind them of the necessity to reduce resource consumption, an unpleasant thought about which they would rather not be reminded of. Another change suggested to me by a participant was to improve the wording in the scale of question 2.7. Rather than having people pick from the scale "Very useful - *Quite* useful - Marginally useful - Not useful - Don't know," I dropped the ambiguous word "quite" and changed the scale to "Very useful - Useful - Marginally useful - Not useful - Don't know."

Considering the social taboos around age, sex and race, asking about the social situation of the participants always felt awkward. Nevertheless, these questions were necessary because there is much evidence that gender, age and ethnicity influence how sustainability is perceived.

To be honest about the information gathered, I decided to include the questions rather than "secretly" categorize the participants myself according to age, sex and ethnicity. In further interviews, this section might be improved by explaining first to the participant what the information is used for and also by re-stating their right to skip questions.

In addition to the limitations described at the outset, the interview process has led to insights on how further research on the usefulness of the EF/ACC tool and people's interpretation of sustainability may be improved. Two aspects of the interview process would need particular attention: first, the interview needs to test whether the participant's understanding of sustainability has changed because of their exposure to the EF/ACC concept. Second, further interview research on the role the tool has in helping researchers comprehend the phenomenon of societal denial (or disjunction between concern and action) could be undertaken.

To explore the EF/ACC tool's impact on the participants' sustainability interpretation, question 2.10 asked whether the interview had changed their perspective on sustainability. However, it turned out that this question was ineffective, and merely reflected the participants' consciousness about their continuous learning. Also, the question could be perceived as either psychologically degrading since an affirmative answer might be interpreted as previous ignorance or successful manipulation of the participant. A more useful question might be "how has the EF/ACC tool affected your understanding of sustainability?" Even better might be to begin and end the interview with a quick assessment of the participant's sustainability interpretation in order to detect changes. For example, one of the questions in the beginning could be "what are the key ingredients of sustainability?" with a similar one at the end such as "how would you summarize the main conditions for sustainability?"

To make further applications more productive, some questions need to be added, rephrased, or dropped. The questions in section 2.7 on possible applications were too abstract for many participants and would gain from an explanatory sentence illustrating a concrete application. Further, questions would be particularly useful that explore the sustainability implications on a more personal and engaging level. For example, question 1.4.4 on "does your personal view on sustainability conflict with ideas and responsibilities at work?" should be changed to "*how* does your personal view on sustainability conflict with ideas and responsibilities at work?"

To streamline the process, the scope of questions can be reduced, and some could be dropped entirely. For example, question 2.1.1 on "does this brochure explain the concept well?" is not necessary. Question 2.3 could be rephrased to "describe *in a few words* what would happen if nature is harvested faster than it can regrow, year after year." The discussion on the method of the EF/ACC concept (question 2.5) could be merged with question 2.8, as question 2.5 seemed to be too technical and specific anyhow. However, the comment line "which essential component(s) are left out by the concept? Please list?" in question 2.8 should be changed to "what is useful about the Ecological Footprint, what should be improved, or what is misleading?"

Another addition to future interview series would be to expand the variety of participants, maybe even by interviewing a random sample of the local population. This could show whether the gathered answers and the pattern in which this group reacted was particular to well informed professionals in executive positions all of which had participated in activities toward achieving sustainability before or whether a random sample would generate similar results. Clearly, a second generation interview should also test the general public's understanding of sustainability and identifying their particular barriers to developing action toward sustainability. Nevertheless, these first 21 interviews have contributed to a significant step in that direction.

In essence, this EF/ACC application in the form of an interview process has shown the potential of the EF/ACC concept as a tool for stimulating thinking about sustainability on many levels, analyzing people's understanding of sustainability, and documenting their commitment to action. This might be a particularly useful application as a tool for planning toward sustainability. Today, much action toward sustainability is condemned to failure by being perceived as unnecessary, nuisance, or worse, oppression. However, by helping to improve understanding of the constituency's thinking, and to develop strategies for action toward sustainability that are supported -- or at least accepted -- by the public, EF/ACC can make a contribution to developing effective action toward sustainability.

VII. CONCLUSION

The purpose of this thesis was to report on research undertaken to further develop and test the EF/ACC concept as a tool for planning toward sustainability. In this last chapter, I draw the research conclusions from three perspective: conclusions with respect to the research findings; suggested areas for further research; and, implications for planning.

A. CONCLUSION WITH RESPECT TO THE RESEARCH OBJECTIVES

To test EF/ACC's usefulness as a tool for planning toward sustainability, I performed four research tasks:

- First, I provided an introduction to the EF/ACC concept by defining the concept, comparing it to other sustainability assessment methods and discussing its relevance to ecological, socioeconomic, political, epistemological and psychological considerations related to the sustainability crisis (Chapter III).
- Second, I described how the various competing uses of nature can be translated into a calculated area of land-use and how this allows to assess the Ecological Footprint of a human activity (Chapter IV).
- Third, to make this calculation procedure more applicable, I illustrated it with the example of the average Canadian Footprint, and gave additional examples of a variety of other EF/ACC applications from many other places (Chapter V).
- Finally, I explored how administrators and planners, business people and economists, and community activists and local politicians perceive the usefulness of the EF/ACC tool for planning toward sustainability (Chapter VI). I achieved this through an interview process which in itself was a test of the usefulness of the EF/ACC concept.

I started this research with the assumption that sustainability can be achieved only if human consumption does not exceed nature's surplus production (the natural income). In other words, the scale of the economy must not overshoot global carrying capacity if nature's long-term productivity should not be compromised. This condition I called the "ecological bottom-line for sustainability". Respecting the ecological bottom-line means that the world's social and economic problems must be addressed within nature's self-productive capacity. Traditionally, these problems have been addressed by facilitating economic expansion. Therefore, the first question becomes how much the human activities can still be expanded until global carrying capacity is exceeded.

Peter Vitousek *et al.* calculated in 1986 that by then, humankind was appropriating over forty percent of the globe's terrestrial net primary productivity. However, if other services of nature are included, such as waste absorption (e.g., biodegrading effluents or sequestering CO_2 from fossil fuel burning) and life support services (e.g., preserving biodiversity, protecting from UV_B radiation or providing climate stability), there is increasing evidence that the world may already be effectively "full" (Goodland 1991, Daly 1991). In fact, as Chapter V pointed out, current agriculture, roundwood harvest and fossil fuel burning together have an Ecological Footprint that exceeds the available ecologically productive land by close to 30 percent. In other words, we would need at least a 30 percent larger (or more ecological productive) Earth to accommodate sustainably present material flows through the human economy. In fact, the overshoot might be much larger if other competing services of nature were included -- particularly the effect of soil erosion which, since World War II, has reduced the productivity of about 11 percent of the globe's vegetated area (World Resources Institute 1992:111-119). This indicates that the ecological crisis is caused by the quantity consumed -- not only by the quality of human consumption. If we assume that the 20 percent of the world's population which lives in industrialized countries consumes about 80 percent of the world's resources, that would translate into the industrialized world *alone* occupying an Ecological Footprint larger than global carrying capacity:

80% [of the world's resource consumption] of

130% [humanity's Footprint as compared to the global carrying capacity]

= 0.8*1.3 = 104% [industrial countries' Footprint / global carrying capacity].

Ecological overshoot is also indicated by the global degradation of forests, soil, water and ecological and genetic diversity. Such trends and data demonstrate the ecological constraints humanity is facing, the responsibilities of industrialized countries, and the challenges for future generations whose well-being depends first of all on adequate, functional natural assets. These natural assets are essential because most lost life-support systems cannot be substituted by human-made systems.

By showing the link between the various competing uses of nature and available ecological space, the EF/ACC concept provides a framework to visualize and communicate the phenomenon of overshoot as applied to human activity. In contrast to what such concepts as "Limits to Growth" might suggest, expanded human activities do not crash into the limits of nature as a car would crash into a wall. In fact, the natural limits are "fuzzy" and can be temporarily exceeded at the cost of drawing down nature's assets. As the limits are crossed, no explicit warning signs light up -- we have only the depletion of natural capital to indicate that human impact has exceeded carrying capacity. Moreover, this degradation can be difficult to detect because the visible differences between ecosystems that have been altered by human use (such as through agriculture) and those that are being degraded are subtle. By converting resource and waste flows to their land equivalents, EF/ACC graphically underscores global ecological constraints and provides such a "warning light". In fact, EF/ACC's conceptualization of the global ecological challenges and linking them to local decision-making was an aspect of the tool which was particularly appreciated by the interview participants.

The EF/ACC concept can be taken a step further by linking these global constraints to local action. Its various applications to technology assessment, local and regional decision-making, national and international decision-making, inter- and intra-national social equity, and education and behavioral analysis provide venues for pertinent policy responses. Even though there remains much scope to improve the technical aspects of the EF/ACC tool and there is a need for more concrete examples and applications to encourage wider use of the tool, the tool's potential to translate global ecological constraints down to the individual and institutional decisions, and the tool's various applications, have been clearly appreciated by the participants of the interview research and the reviewers of the handbook. It has attracted much interest by practitioners and academics, and was received favourably by the majority of the interviewed key informants. Also, the international interest which the tool has received, and the many applications it has found, confirm the tool's heuristic value for addressing sustainability issues. The interviews seemed to suggest that EF/ACC's ability to translate the ecological aspect of sustainability into a concrete common yardstick could bridge communication between people with conflicting political perspectives and dissimilar sustainability interpretations.

Moreover, the EF/ACC addresses not only the ecological side of the sustainability crisis, but also integrates the other four facets. EF/ACC's full potential to address simultaneously all these facets is best realized in combination with the parallel concept on livability, the "Social Caring Capacity" concept being developed by the UBC Task Force on Healthy and Sustainable Communities (UBC Task Force 1994). Most importantly, EF/ACC facilitates the "...recognition of necessities...", which, according to Garrett Hardin, is the precondition for overcoming the "Tragedy of Free Access" (1968/93:139). By acknowledging concrete ecological constraints and illustrating the meaning of natural income within which humanity has to live, EF/ACC helps us to think more effectively about the social, economic and political adjustments needed to live within them. At present, we exacerbate our problems by ignorant action.

As the interviews confirmed, the EF/ACC tool provides various features that make it attractive and assert its potential as a tool for planning toward sustainability. Clearly, some aspects of the tool still need to be further developed, as pointed out by the interview participants. Their main concern was that: EF/ACC is not yet applicable to practitioners' everyday decision-making; in particular, potential users still lack sufficient examples and calculation procedures -- also for establishing more confidence into the model; further, more effective communication is necessary to make EF/ACC considerations and implications more accessible to the public. Only one participant felt that the tool was misleading, mainly because of the briefing brochure's suggestions for action (Wackernagel 1993a, or Appendix 3.3). This participant's main criticism of EF/ACC as a concept was the tool's neglect of market prices.

However, in spite of these concerns, most participants appreciated the tool, particularly as it addresses a wide variety of sustainability issues identified in Chapter II, frames them, and directs according action as:

- it translates global ecological constraints down to the local scale and demonstrates the need for appropriate local socioeconomic adjustment. Today, when global carrying capacity is being overused, ecological productivity has become a limiting factor for aggregate human activity. EF/ACC analysis shows that the carrying capacity appropriated by one person or group diminishes the carrying capacity that can be appropriated by other people; in short, human uses of nature compete against each other. This has fundamental implications for global development strategies (see later);

- it links social and ecological concerns raised in the sustainability debate as it illustrates how competing uses of nature can translate into social conflicts, and how conventional economic development strategies are at odds with preserving ecological integrity, thereby compromising future well-being. In fact, EF/ACC applications show that ecological efficiency is not congruent with ecological efficiency (Wada 1993). EF/ACC becomes a tool to visualize these conflicts and provides a framework for alternative approaches to economic development which contributes to the goal of living within global carrying capacity;
- it facilitates political decision-making as it offers a relatively simple, transparent approach for comparing sustainability impacts of human activities. This can be done on the municipal level (as pursued by the UBC Task Force together with the City of Richmond [1994]) or on larger scales (as proposed in the *1993 Environmental Scan* [Peat Marwick 1993b:24]). By raising ethical question and translating them into concrete terms, EF/ACC could make the trade-offs of decisions more visible -- from the local scale when making consumer choices at the household level, up to the global scale when it might assist Southern countries in their negotiation for more ecological space;
- it presents an heuristic tool that builds on present knowledge, stimulates future oriented thinking, and is action-oriented. Even though EF/ACC is a scientifically based tool, it can deal with generalities rather than getting lost in specificities. By starting from explicit assumptions (such as "human beings depend on nature"), the EF/ACC concept translates these assumptions into concrete implications. Thereby, it helps to sharpen the debate between conflicting assumptions and beliefs around such issues as decoupling, ecological efficiency, growth management and impact assessment; and,

- it respects the psychological reluctance and anxiety of people to accept sustainability challenges by providing a non-threatening communication tool. At the same time it enables people to visualize the cumulative effect of incrementalism and illustrates its potential destructiveness, a precondition for overcoming the "boiled frog syndrome". For this reason, the example of the Lions Gate bridge (Davidson & Robb 1994) always caught the participants' interest when I told them about it. In other words, EF/ACC provides the "bigger picture" about the impacts of people's individual decisions without alienating the individual -- rather than pointing fingers, it shows the connections of life and the human dependence on nature. Also, as noted, the conducted interview research seems to indicate that EF/ACC has the potential to improve the cross-paradigm communication.

The research met its objectives outlined in Chapter I by developing and testing a planning tool for translating sustainability concerns into action. By addressing all these aspects, the EF/ACC concept ties together multiple facets of the sustainability crisis rather than fragmenting it into seemingly separate issues. This inherent holism most likely enhances the effectiveness of the tool for planning toward sustainability.

B. SUGGESTED AREAS FOR FURTHER RESEARCH

To make EF/ACC more applicable and useful to the practitioners and community groups (NGOs), more examples of its use are needed. The results from applications will help illustrating the concept and its relevance to sustainability, while the documentation of these examples will provide guidance for other researchers and practitioners who would like to apply the EF/ACC concept to a new context. Developing more concrete examples was the most common suggestion that I received from the EF/ACC handbook reviewers and the participants in the interview research. Further research ideas that could make the EF/ACC tool more widely applicable and user-friendly are categorized into five topic areas.

1. TOOL IMPROVEMENTS: INCLUDING ALL COMPETING USES OF NATURE

The existing EF/ACC assessment would gain from a more comprehensive treatment of consumer goods and from an inclusion of competing uses of nature which are still left out. Such research would involve the development of more reliable data sets and would require:

- calculating EF/ACC assessments for renewable energy options that could substitute for fossil fuel use such as ethanol, methanol, photovoltaic generated hydrogen, oil-seeds, hydrogen, and wood. EF/ACC research on energy options could build on studies conducted by Mario Giampietro, Michael Narodoslawsky, David Pimentel, Vaclav Smil, Yoshihiko Wada and me;
- including hydroelectricity into EF/ACC calculations. This requires more detailed biophysical data about the land requirements for production (such as area for power lines, area for hydro reservoirs, impact on river [and ocean] fisheries) as well as data about the direct and indirect consumption of electricity;
- clarifying forest productivities as the reported yields are still scattered over a wide range;
- reviewing literature on estimates for the minimum area of wilderness necessary to protect ecological stability. After determining the land area that should remain untouched, one can calculate how much of Earth's area would be available to accommodate humanity's Ecological Footprint. At this point, as discussed above, we assume the existence of 1.5 billion [ha] of untouched ecosystems and believe that the ecosystems should be left in their present state for reasons of rising atmospheric CO_2 levels and threatened

biodiversity -- and believe this to be a defensible minimum requirement;

- assessing the land and water area requirements for providing a given assimilative capacity (for sewerage, solid waste, air pollution and soil contamination);
- providing an account of degraded areas due to soil erosion, salination, urbanization and transportation, including estimates of energy, time and resources that would be necessary to restore them;
- comparing the EF/ACC tool to other ecological assessment methods such as life cycle analysis, environmental space, SPI, and MIPS (see Chapter III), to clarify the compatibility between these approaches, identify data transferability, and resolve differences between these approaches;
- developing a calculation procedure (and rationale) to translate the use of fresh water into a land area. This could start from assessing the potential losses in agricultural productivity due to lacking fresh water supply, or the energy requirements to transport or desalinate the necessary water for agricultural production; and,
- improving the existing data collection. Much of the data on embodied energy and resources, national consumption and ecosystem productivity should be checked against other studies, and need updating. Also, consumption by government and business needs better documentation.

2. LOCAL APPLICATIONS: ANALYZING THE IMPACT OF SETTLEMENT PATTERNS AND CONSUMPTION

To develop more concrete illustrations of the EF/ACC concept, additional local, small scale examples need to be developed. These could include the:

- documentation of the Ecological Footprint sizes for households in various income classes. The main parameters would include settlement patterns, housing types (with their implications for construction and maintenance requirements), transportation patterns, shopping facilities and consumer choices. Preliminary research on this topic, with a particular focus on housing density, is being pursued by Lyle Walker (1994);

- analysis of transportation strategies such as new roads, bicycle strategies, bridges or public transportation options on their EF/ACC (including their impact on settlement patterns and lifestyles). Such research could build on the preliminary work by Gavin Davidson and Christine Robb (1994), Anthony Parker (1993), and Graham Beck (1993);
- estimations of EF/ACC impacts of concrete development proposals such as golf courses, shopping centres, pedestrian zones, highways, public transportation, and zoning. This could also be applied to technologies or budgets. Assessing large scale retail development is one application that is being analyzed from this perspective by the UBC Task Force on Healthy and Sustainable Communities and the staff of the City of Richmond (1994);
- comparison of the Ecological Footprints of a dollar spent on different goods in the same consumption category. Examples could include cheap versus expensive clothing, cheap versus luxury cars, organically grown versus conventionally grown food, vegetarian versus omnivore diet, or processed and packaged food versus unprocessed bulk food;
- account of the Canadian EF/ACC availability thorough developing a land inventory (agriculture, forests) with their respective ecological productivities. This could build on Yoshihiko Wada's assessment of the available carrying capacity of the Lower Fraser Basin (1994b). Further, the sustainability gap between available and actually occupied EF/ACC could be documented, and various scenarios could be tested on how to close the gap;
- link and integration of the EF/ACC tool with the Social Caring Capacity concept to develop ways how they can mutually support the planning toward sustainability;
- development of more business oriented applications such as product labelling (Stead & Stead

1992:145-152. More meaningful eco-labelling could go beyond eco-efficiency reporting by conceptually linking the consumption at the individual micro-level with the ecological macro-constraints. The EF/ACC model could improve traditional ecological product labelling by indicating how many days of ecological production a particular good or service would occupy on the globe's average carrying capacity (which amounts today to about 1.3 hectares per capita). For example, 0.2 hectares could be set aside for producing a healthy (close to vegetarian) diet, which would leave the remaining hectare for providing housing, transportation, goods, and services. A compact disk or shampoo could then be labelled with the statement: *"It took (..) hours ecological production of the average person's available 1.1 hectares to provide this product"*, thereby suggesting that the purchaser should wait for (..) hours until engaging in the next resource consumptive activity if he or she wants to live within global carrying capacity. This would enable individuals to budget their share of natural income; and,

- documentation of the calculation procedures for various EF/ACC applications (technical processes, policy assessments, national statistics, etc.) to improve the concept's replicability and assist other researchers in their EF/ACC applications.

3. LARGER SCALE APPLICATIONS: ANALYZING THE IMPACT OF REGIONAL AND NATIONAL POLICIES

The EF/ACC tool lends itself to analyzing potential sustainability impacts of policies, trade issues, natural capital depletion, public budgets, or technological innovations. Possible applications include:

- a study of traded carrying capacity. Building on existing EF/ACC applications, this application would entail a more detailed tracing of a region's or nation's carrying capacity leakages into global trade relations (Rees &Wackernagel 1992, Rees 1994a, Thomas 1994). The carrying capacity leakages which leave one region and get appropriated by a second region illuminate the ecological imbalance of trade that monetary balances cannot reveal. Such studies could also document the dependence of urban regions and the leakages in rural (or resource extracting) areas. These studies become particularly relevant as in the current context of globalization and export driven economies, industrialized countries' Ecological Footprints have become footloose and economies all over the world are forced to expand their appropriation of nature's productivity in order to compete successfully in the global market;

As a complementary task to the EF/ACC analysis that only points out some of the social implications of trade relationships, appropriated labour could be analyzed. The appropriated labour of a person would be that share of the world's available labour necessary to provide this person's consumed goods and services (per year), while the available labour would correspond to all the hours of work (including domestic work) performed all over the world during the same time span. This could indicate whether a particular, more "ecologically friendly" lifestyle was only made possible by the appropriation of more cheap labour, or whether this lifestyle is also socially more just (see also Giampietro *et al.* 1993). For example, cheap labour might be substituted for the use of commercial energy (as apparent in feudal systems or when exploiting slave labour), which might reduce EF/ACC at the cost of an unacceptable social burden. Such an analysis would not only reveal social inequities but also physical policy constraints in terms of people's time: clearly, not everybody can depend on cheap labour, as the average per capita appropriated labour is always equal to the average per capita labour contributed;

- an evaluation of national policies regarding their impact on EF/ACC. This could include transportation, employment, international development, or resource development policies;

- a documentation of the distribution of the available EF/ACC all over the world which includes developing an account of the areas of ecologically productive land as well as collecting estimates of their ecological productivity. As a frame of reference, this would also require an assessment of the average global ecological productivities;
- a comparison of the relationship between "quality of life" indicators and the EF/ACC of various lifestyles all over the world. The results will give an indication about how, and to what degree, quality of life can be improved while EF/ACC is decreased; and,

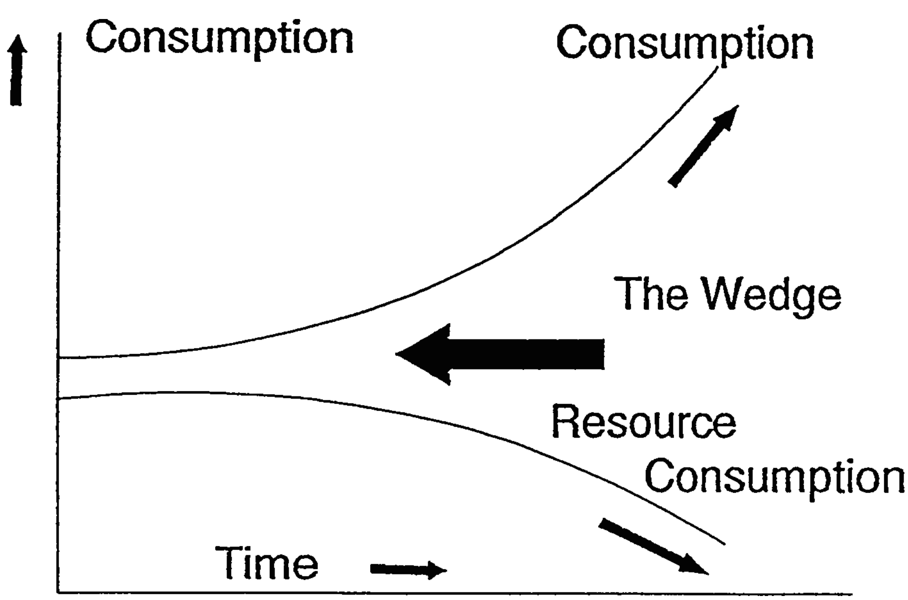

Figure 7.1: **David Pearce's "policy wedge" to decouple consumption from resource throughput** David Pearce believes that policy wedges can be found that allow consumption of goods and services to rise while resources consumption would fall at the same time. In other words, he believes in decoupling "consumption" from "resource consumption." The EF/ACC tool could be used in further research to measure whether decoupling is happening. (Source: Pearce 1994)

- a study of historical paths and potential trends in the EF/ACC of various countries. Such an analysis could test many scholars' claim about the human economy's ability to "decouple" from its material dependence on the ecosphere, and about the possibility of economic growth without increasing EF/ACC ("qualitative growth") (Isenman 1991).[1] For example, David Pearce claims that "...consumption can rise while the ratio of resources to consumption can fall at the same time. The extent to which *total resource use* rises then depends on whether the ratio falls faster than the level of consumption rises..." (1994:1). He then calls for the "policy wedges" that can help to decouple "consumption" from "resource consumption" (1994:3, Figure 7.1). Tracing the per capita EF/ACC over time could reveal whether household consumption in particular regions has indeed "decoupled" from its dependence on nature. Cases that show decreasing EF/ACC while they were actually increasing their consumption might inform about how "decoupling" could be achieved (if such cases exist). A better understanding of "decoupling" (or the lack of it) will indicate the potential for economic growth within Earth's carrying capacity.

4. COMMUNICATION: MAKING THE TOOL AND ITS IDEAS MORE ACCESSIBLE

EF/ACC's strength is not its sophistication for "environmental management", but its ability to communicate the ecological constraints and its implication for policy choices in a simple and illustrative way. To make the tool more effective further research could:

- adapt the EF/ACC information to various professional or public audiences by using their language, including examples (and data) relevant to their experience, and developing graphics and tables that illustrate these effectively. Potential audiences could include

[1] Indeed, the main caption in an advertising brochure for William Reilly's *Environment Strategy America 1994/95* reads "...effective environmental strategies are vital to sustainable growth as economic recovery gathers pace..."

community activists, municipal politicians, municipal planners, artists, teachers, public engineers, architects, business people, lawyers, and journalists.

- develop data-base or spread-sheet supported calculations that make the use of the gathered data more flexible and allow easier updating.
- devise educational software applications that show graphically and in a playful way the sensitivity of EF/ACC estimates to lifestyle choices.
- produce board games, role playing and outdoor exercises for schools, workshops, or other entertainment that illustrate the sustainability dilemma, using EF/ACC and the Social Caring Capacity concepts as tools.
- design curriculums, simple case studies, and other preparatory material for workshops and courses, which could build on existing educational applications (ESSA 1994, Griggs *et al.* 1993, Kool 1994).

5. BEHAVIORAL ANALYSES: EXPLORING THE SOCIAL PSYCHOLOGY OF THE SUSTAINABILITY CRISIS

An interesting application of the EF/ACC tool that still needs further refinement is its use in exploring and analyzing public perception of sustainability, and identifying limiting factors for action toward sustainability. This could build on the research documented in Chapter VI. Such research could be highly valuable for designing more effective strategies toward developing sustainability.

Key to such research is the study of societal denial, particularly on how and where it occurs. The purpose would be to document the mechanics that lead to the disjunction between people's stated goals and values about the necessity to become sustainable which are revealed in many opinion polls and government documents (Dunlap 1993) and, on the other hand, the lack of corrective public action.

Therefore, as a first step, further research on the social psychology of sustainability could focus on societal denial by pointing out potential inconsistencies between values, interpretation of biophysical measurements and actions, and the collection of people's reactions to these contradictions. In fact, such studies could be instrumental in identifying leverages for change, as pointing out such inconsistencies could be used to feed into people's cognitive dissonance. After all, according to social psychology, it is cognitive dissonance that leads to attitudinal change (Baron & Byrne 1987:132-146).

C. IMPLICATIONS OF THE EF/ACC TOOL FOR PLANNING ACTION

This research about the EF/ACC concept has shown how the global ecological constraints to human activities can be documented and how these constraints can direct decision-making toward sustainability on the institutional and individual level. Accepting the global ecological constraints has fundamental implications for the way we should organize human activities, and provides some insight into the planning tools needed for assisting such a transformation.

The EF/ACC tool demonstrates that we no longer live in a world with abundant, unused ecological capacity (or with ecosystems whose production has not yet been modified according to human demands). As noted, there is evidence that human carrying capacity has already been exceeded. This puts forward fundamental challenges for public policy: how can the ecological impact of human activity be decreased while at the same time providing for everybody's needs? Who should reduce their Ecological Footprints, and who should be allowed to still increase theirs to meet their needs? How can people be convinced to reduce their Ecological Footprint? How can a social contract be devised that makes sure the weakest will not carry the greatest burden of the sustainability crisis -- but that humanity can live with these challenges in the most humane way?

The EF/ACC tool not only points out the limits at the macro scale, but also can translate these global constraints to smaller scales such as the level of individual decision-making. In spite of the many attempts which conventional planning has used to address "environmental" constraints, the results have, arguably, been poor. Zoning, growth management or impact assessment all lack the link to the macro-scale of global ecological constraints. Thereby, they accommodate rather than prevent, the destructive incrementalism of conventional economic development. Indeed, the EF/ACC tool could assist society (and planners) in developing sustainability, if society wanted this. This indicates implications for three public policy domains: 1) creating public awareness, 2) planning for sustainable national and international policies, and 3) planning sustainable communities.

In the face of the ecological and socioeconomic constraints that become more and more apparent, sustainability must become the new organizing principle for planning. And indeed, there are encouraging signs that this is happening as evident by: the Canadian Institute of Planners' renewed interest in sustainability (Canadian Institute of Planners 1990, 1993, 1994); planning schools' various activities in that area (SCARP 1994:1, Wackernagel 1993b); National and Provincial Round Tables with strong focus on planning issues; provincial initiatives such as the CORE (Commission on Resources and Environment) process in British Columbia; and, the hiring of "environmental planners" by various municipalities here in the Fraser Basin.

1. CREATING PUBLIC AWARENESS

Effective action requires public support. However, there is little evidence that a large enough segment of the public acknowledges the profound nature of the sustainability crisis. From public opinion polls, it becomes clear that most people know about the challenges (Dunlap 1993), but few understand the implications of, and connections between, these challenges. Therefore, informing people about these implications is the first step toward a more sustainable society.

It might well be that economic constraints force all levels of decision-making to choose unsustainable options. However, this unhealthy situation should not be silently accepted, but should be used as an opportunity to explain the trade-offs between the short-term gains and the long-term costs which the current socioeconomic context forces us to make. The EF/ACC concept is a helpful tool to illustrate this conflict. Rather than privately sighing about the "constraints of real-life decision-making" that impose slow but incremental ecological destruction, planners must point out this conflict publicly and show why the current negative-sum game will be detrimental for everybody in the long run. It is a negative-sum game, rather than a zero-sum game, because in a "full" world, overconsumption by one person compromises future options for everybody -- the losses outweigh the gains. Often, the argument is put forward that economic growth and the subsequent expansion in aggregate consumption is inevitable, or that every development option has to be seized because "otherwise somebody else will do it." These arguments are no longer defensible, but are an indication of society accommodating the destruction of its future. By using the EF/ACC tool, policy analysts could more persuasively point out the disastrous cumulative impact of perpetuating conventional economic development. Even though economic constraints might force communities to accommodate such economic development today, decision-makers should be informed that accepting such development now might be financially attractive today, but devastating in the long run. Decision makers must realize how profound and serious the sustainability crisis is if destructive development is supposedly "inevitable". In fact, "inevitable destruction" should be recognized as a warning bell indicating the urgent need for forceful public action.

The EF/ACC concept provides planners with a tool that can communicate these challenges. This concept underscores the fact that human life is dependent on, and embedded in, nature and that consumption is indeed limited by nature's reproductive capacity. Realizing the resource constraints raises questions about how humankind is to consume resources in the future. If human consumption continues to exceed nature's capacity to regenerate, future generations will have even less "natural capital" (or reproductive capacity) available and will therefore be even more likely to erode the remaining stock as they meet their consumption needs. Therefore, life on Earth (including that of human beings) can only be sustained within the limits of nature's dividends which can be measured by EF/ACC. In other words, EF/ACC demonstrates that excessive consumption today means reduced life-support services for future generations.

Clearly, palliative policy responses to the sustainability crisis are unhealthy in this context, because they detract from reacting to the crisis and feed into societal denial. Rather than continuing with palliative policies, the question becomes how the culture of societal denial can be dismantled. Perhaps, it requires a spear group with enough self-confidence to accept the sustainability challenges and to resist the attraction of consumption and the seductive messages about economic (or financial) success with which people are bombarded by the media (and their peers). Or, as an interview participant said, "...now there is a certain sexiness about an expensive lifestyle that going without just does not have...". In response, the EF/ACC tool might be a helpful interactive research tool for visualizing the sustainability conflicts, exposing palliative approaches and challenging the assumptions of the palliative denial culture. Probing the palliative denial culture could clarify whether the barriers are lack of information, inadequate worldviews (or paradigms), fragmented and inconsistent value systems, or external social constraints (such as social demands, physical structures and misleading economic incentives which would limit individual choice). In other words, this should shed light on the question whether the limiting factor in motivating people for sustainability is ignorance about the issues, disbelief, fear, carelessness or desperation.

The need to avoid palliative responses also has implications for planning education. Planners must be prepared for the present challenges with effective substantive knowledge and procedural approaches. The EF/ACC tool could assist the learning about the cumulative impacts of incremental decisions ("boiled frog syndrome"), and about how this can be communicated to the public and to government. The tool could help planners in realizing that the world is "full", which has profound implications on how people and institutions must reorganize themselves to live a good life with a shrinking resource base. Therefore, EF/ACC also becomes a tool that assists planners in the most important task, building broad public support rather than developing sophisticated policies, which may be planners' greatest contribution to a more sustainable future.

The message that needs to be disseminated is simple: developing sustainability requires that human activities must remain within global carrying capacity. Because currently global carrying capacity is already overshot, and industrialized countries use significantly more than their share, these industrialized countries need to significantly reduce their resource consumption.[2] Here, the EF/ACC tool can be of considerable help analyzing which policies are

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[2] Of course, also within many industrialized countries, consumption is inequitably distributed too. Therefore, a reduction in resource consumption cannot be universal, but must also respect the needs of those groups lacking already an adequate supply of consumption goods.

effective in achieving sustainability. For example, it could monitor whether efficiency measures alone would reduce the EF/ACC of an economy, or whether, in addition, this economy would need to modify its tax system to divert the economy's efficiency gains into natural capital investments (Wackernagel & Rees 1992, Rees 1994b).

However, a reduction in resource consumption can only be achieved if people feel that such a reduction will improve their lives including aspects of health, survival, autonomy and identity (Miles 1992:293). Clearly, the judgement about how such a reduction will affect people's quality of life has to be left to the affected people as quality of life is subjective and depends on their worldviews. If a reduction in resource consumption is not seen as a desirable step, it will most likely encounter unsurmountable resistance rather than the necessary support and good-will.

To successfully develop sustainability we must demonstrate to the public that reducing our Ecological Footprint while improving our quality of life is still possible. And, as mentioned above, this becomes the criterion for sustainability. When testing a technology, project, program or policy on its sustainability impact, two questions must be asked:

(1) Will this decision or activity reduce people's Ecological Footprint?; and

(2) Will this decision or activity improve our quality of life?

Only those decisions or activities that satisfy these two imperatives can move us toward sustainability; all others are conscious choices against sustainability.

2. PLANNING FOR SUSTAINABLE NATIONAL AND INTERNATIONAL DEVELOPMENT

The findings that the EF/ACC concept has generated, fundamentally challenge the assumptions which drive economic globalization, international development and population policies. Industrialized countries still do not encourage a reduction in their population size (as one factor of the impact equation [Holdren & Ehrlich 1974]), but are more worried about aging of society. Recognizing that humanity must live within ecological limits means that aggregate consumption must not increase beyond present levels. Excessive consumption of natural capital by one group will compromise the opportunities for consumption by others; present or future. However, a large part of humankind needs to increase consumption in order to live decently -- but the conventional approach of raising the standard of living of poorer segments of society by increasing economic production no longer works. Any increase in economic production that depends on more of nature's services will exacerbate the "natural capital deficit". Such a deficit in wealth-generating resources, however, is even more difficult to overcome than a financial deficit (such as those which our governments are currently running up at the expense of future generations) because these natural processes cannot be replaced.

While we must continue to pursue environmentally-sound technologies, we cannot use this as an excuse to avoid questions of distribution and overconsumption. The process which will move humankind towards sustainability could use, as a first step, the two sustainability imperatives outlined above. On the one hand, this evolutionary plan towards sustainability must protect those assets which all future generations of humanity will need for their survival. On the other hand, for ethical and practical reasons this plan of action should not deprive members of the present generation from meeting their basic needs. Otherwise, increasing social conflicts could significantly decrease quality of life for everybody. Although this process will constrain some economic choices today by limiting total consumption of the affluent, it will keep more options open for people in the future -- including the option of not suffering from deprivation and ecological deterioration.

As shown by EF/ACC analyses, in most cases (and Canada might be a lucky exception with its extensive land base), the way industrialized countries operate cannot be supported by local carrying capacity alone. Maintaining present industrial lifestyles leads not only to a draw-down of nature's biological renewable and non-renewable assets such as soils, forests, fisheries, fossil fresh water and fossil fuel, but also relies on the continuous exploitation and appropriation of ecological carrying capacity of other places - especially Third World countries. This raises major ethical and moral issues about our lifestyles.

Under existing economic exchange rules, our resource hunger threatens to liquidate the globe's ecological assets -- the very basis of life. The establishment of global markets has facilitated the appropriation of carrying capacity from all over the globe and has accelerated its destruction. For example, Malaysia is cutting down its forests to satisfy Japanese timber hunger; Russia has opened its fisheries, forests and fossil fuel stocks to Western markets; and British Columbia is exploiting its forests to furnish the worldwide lumber and paper demand. More and more people start living on ecological carrying capacity from *somewhere else*. How long will it take before we run out of *somewhere else*?

If the industrialized countries continue to promote a lifestyle that requires two more planets (as EF/ACC analyses point out), they are, in effect, blindly planning for their own collapse. If the industrialized world wants to make a true contribution to sustainability it should massively reduce its resource consumption. It should promote living simply -- so others can simply live.

But industrial countries are still proceeding the other way. By removing trade barriers, the global economy opens access to new resource stocks and feeds into exponentially rising consumer expectations while drawing down the global resource stocks at an accelerated pace. At the same time the incentive vanishes to conserve local resources. The global economy provides us temporarily with some glorious and seemingly resource rich years at the cost of aggravating the dilemma between increasing human demands and a declining productivity of nature.

There are already some initiatives in place that try to deal with these conflicts, the British Columbia CORE (Commission on Resources and Environment) process being one of these. Their comprehensive approach in Goal setting is impressive (Chess 1994), even if this process has not yet been effective in making people understand their dependence on healthy natural capital and in inspiring compassionate approaches to address the sustainability dilemmas. For those processes, the EF/ACC tool may be of assistance in the future.

The EF/ACC tool could provide direction for an ecologically more sensitive and therefore more humane and future oriented development path. As pointed out earlier, planners do not lack in sustainability strategies. Rather, society lacks the intellectual and emotional acceptance of the facts that humanity is materially dependent on nature, and that nature is limited in its biological productivity. The EF/ACC tool might be useful to help explore the implications that these realities entail.

3. PLANNING SUSTAINABLE COMMUNITIES

Local planning offers significant leverages for action toward sustainability. In the municipal context, innovative changes in transportation and land-use patterns can significantly reduce resource consumption and, at the same time, improve local quality of life. Furthermore, as these more sustainable land-use and transportation policies mainly influence the way people are housed, how they commute, and how they spend their recreational time (but not the structure of the local economic production), these changes will not threaten the economic competitiveness of the municipality. EF/ACC could assist in analyzing policies on their global ecological impact, in assessing progress toward sustainability -- and, if used in a more refined form -- in identifying those actions which would result in the greatest sustainability impact per dollar spent.

Of course, the positive effect of well designed urban form can be greatly enhanced by people's lifestyle changes. The challenge is clear: people should focus on living locally, rather than on consuming globally. Also, they must re-discover that meeting some friends while bicycling home is more fun and less ecologically damaging than spending lonely hours in highway congestions on the way to the suburb.

The calculations in Chapter V show that it would take about 4.3 hectares of ecologically productive land to support the average Canadian's current lifestyle. This is by one to two magnitudes more land than there is typically available within urban Canadian municipalities. On the one hand, this local overshoot shows the challenge of being truly sustainable. However, it also demonstrates the multiplier effect of municipal action: if the Ecological Footprint exceeds the regional carrying capacity 20 times (as in the case of the Lower Fraser Basin in BC), a 5 percent cutback in resource input and waste generation will reduce the Ecological Footprint by the size of the entire region.

Municipalities are under a lot of pressure to deliver more services with fewer resources. A fierce tax competition reduces revenues, thereby making conventional economic development opportunities look even more attractive to local governments. However, as the EF/ACC tool can illustrate, this negative-sum game will be destructive for everybody in the long run. And this must be emphasized -- in fact, the first step toward sustainability might be to become more conscious about the negative-sum game in which humanity is caught. Explaining this to citizens in their communities might be the most effective action for courageous municipal planners and community activists. Hopefully, the EF/ACC tool can help them to communicate the cumulative effects of the destructive power of seemingly benign incremental development. In the case of single resource towns, EF/ACC might assist in framing the debate on options of the community's future, thereby making a positive contribution to more careful planning for the inevitable transition of these communities. Without such careful planning, they will otherwise repeat the painful experiences of other busting resource towns.

In summary: In the context of a "full" world and growing populations with rising material expectations, the question of how to provide everybody with essential resources becomes a major challenge. EF/ACC is a tool that can facilitate the comparison of policy choices society inevitably must face (or nature will react first with a less attractive response). EF/ACC analysis becomes an essential planning tool to secure the ecological stability upon which social and individual health depends, by raising questions about long-term sustainability, by enabling assessment of choices, and by monitoring progress towards closing the dangerous and widening gap between human consumption and nature's production.

In essence, the Ecological Footprint or Appropriated Carrying Capacity (EF/ACC) tool makes it clear that every future decision that results in the appropriation of more resources by those who consume more than their fair share (economically viable as this may seem) is a *conscious* choice *against* ecological, social and economic sustainability.

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APPENDICES

APPENDIX 1

LAND AREA EQUIVALENT FOR FOSSIL FUEL:

THREE CALCULATION APPROACHES[1]

This appendix provides three independent approaches for estimating an energy-land equivalence ratio for fossil fuel. The first approach calculates the energy-land equivalence ratio for fossil fuel by assessing how much ecologically productive land would have to be set aside to produce the same amount of ethanol. The second approach estimates the ratio by calculating how much land would be required to absorb the CO_2 which is released by fossil fuel combustion. Finally, the third approach calculates the ratio from the perspective of how much land would have to be reserved to increase the biochemical energy stock by an amount that is equivalent to the biochemical energy of the burnt fossil fuel.

The CO_2 approach proves to be the most conservative one, that is, the approach that suggests the lowest land requirement. Its energy-land equivalence ratio is **100 [Gj/ha/yr]**. The current EF/ACC calculation use this ratio for translating fossil fuel consumption into a land area.

[1] The references for Appendix 1 are listed in the bibliography.

APPENDIX 1.1: ENERGY-LAND EQUIVALENCE RATIO BASED ON ETHANOL PRODUCTION

1. Why Ethanol?

When estimating the EF/ACC of a given population, one must know how much land is necessary to sustain its current level of consumption. This is a simple task for consumption goods that are produced from renewable resources. In the case of fossil energy, however, it becomes more complex because it is not being reproduced, but mined from limited stocks. Therefore, fossil energy consumption could be translated into appropriated land area by calculating how much land is necessary to produce an equivalent renewable substitute.

Ethanol is the most obvious renewable[2] substitute for liquid hydrocarbons. It exhibits similar physical properties, such as heating value or homogeneity, and can as easily be transported or stored as fossil fuel. Ethanol could also be considered as an equivalent substitute for natural gas as this energy carrier is also a high quality fuel (low entropic value), but probably it is superior to coal (see Appendix 1.3). However, in the first approximation, solid fossil fuels such as coal can be neglected in EF/ACC assessments as they account for only 2.6 percent of the fossil fuels consumed in Canada in 1990. Natural gas, on the other hand, constitutes 45.3 percent of the consumed fossil fuels (Statistics Canada 1990:tbl1b).

2. Comparing Ethanol Studies

The purpose of this appendix is to clarify how much ethanol can be produced per hectare of arable land. At first glance, this question appears simple and straightforward, but the literature offers a wide array of answers. Some scholars claim that current ethanol production results in a massive net loss in available energy (Pimentel 1991, David *et al.* 1978, Kendrick *et al.* 1978, Stout 1990:361), while one source implies net yields as high as 101 [Gj/ha/yr] (Kirk-Othmer 1980:V9:356,358). Most of this divergence can be explained by the various assumptions. For example, all of the studies which assume that the processing of biomass into ethanol would be powered by fossil fuel come to the conclusion that ethanol production amounts to a net loss. Other studies assume that this process energy would be supplied by agricultural waste -- and these are the studies that document the highest net yields.

Ethanol productivity depends on two factors: the biological productivity of biomass on given land, and the technological efficiency for converting biomass energy into ethanol. Table A1.1 summarizes these factors and the resulting ethanol productivity for various studies. The results of the quoted studies are standardized to make them comparable as they all use different measurement units and propose incompatible definitions of efficiency or net gains. In the

[2] Or at least it is potentially renewable. For a discussion see section 4 of this appendix.

standardized format which reports the results from all of these studies in [Gj/ha/yr], the processing is assumed to be powered by agricultural waste.

The conversion efficiency listed in Table A1.1 compares the biological productivity (i.e., the Net Primary Productivity of the crop) to the net gain in ethanol. In all cases it is assumed that the farming and harvesting energy is powered by high quality (low entropy) energy inputs such as ethanol, while, as mentioned above, the heat energy for the ethanol processing is provided by agricultural waste. This means that only the energy for agricultural production is subtracted from the gross ethanol gain. Therefore, many studies that assumed fossil fuel-powered ethanol processing, and consequently reported a net loss, now show a net gain in low-entropy energy. Formally, the conversion efficiency is defined as:

$$\text{Conversion Efficiency} = \frac{\text{net low entropy energy produced [per hectare \& year]}}{\text{Net Primary Productivity [per hectare \& year]}}$$

$$= \frac{\text{net ethanol output [in Gj/ha/yr] - commercial energy input [in Gj/ha/yr]}}{\text{Net Primary Productivity [in Gj/ha/yr]}}$$

Table A1.1 relates biological productivity (column 1), conversion efficiency (column 2) and net gain in ethanol (column 3) as follows:

Biological Productivity * Conversion Efficiency = Ethanol Productivity

3. Choosing an Energy-Land Equivalence Ratio for Fossil Fuel

Each of the cited studies were prepared for different purposes and are, therefore, either cautious or more optimistic in their assessments. For example, while Pimentel tries to demonstrate bio-energy's limited potential for securing current energy consumption levels, the National Renewable Energy Laboratory (NREL 1992) in Golden, Colorado, provides more optimistic estimates in its endeavour to lobby for the expansion of bio-energy programmes.

To keep EF/ACC assessments conservative, the most optimistic scenario for ethanol production is chosen for the energy-land equivalence ratio. The study from the National Renewable Energy Laboratory proposes the highest yields. This prediction for a state-of-the-art process that depends on fast growing poplar trees as its biomass input claims a net ethanol productivity of 80 [Gj/ha/yr].[3]

4. Sustainability and the Environmental Impact of Ethanol Production

Even though an ethanol economy could reduce atmospheric CO_2 accumulation and (with the appropriate technology) lower NO_x and HC emissions in comparison to the equivalent consumption of fossil fuels, ethanol production is not inherently sustainable or ecologically benign. An ethanol economy could be sustainable or ecologically benign only if the agricultural input was produced without soil loss and soil contamination, and if the by-products were reused as fertilizers for the fields (and the workers were paid fairly). In this case, the ethanol technology would be CO_2 neutral and could be sustained over a long period of time. More likely however, the agricultural production per hectare would drop, decreasing the net ethanol productivity (even in the most optimistic scenarios) to less than 50 [Gj/ha/yr] (Giampietro 1992).

However, the current rate of topsoil erosion, and loss of farmland due to waterlogging or salination suggests that current agricultural production is unsustainable (Pimentel 1987:277). Machine and resource-intensive farming techniques produce high yields in the short-run, but lead to massive soil loss and soil contamination. Particularly in the case of crop production for ethanol rather than for food markets, a higher dosage of pesticides might applied. In addition, removing all the biomass from the fields, as in the use of farm waste for fuelling the ethanol processing, can deplete the soil structure. This process causes more run-offs, allows the leaching of nutrients and leads to a fast loss of organic matter. Further, to keep the crop yields up, more aggressive and energy-intensive farming techniques which could damage the soil might be used.

Also, when an ethanol economy relies on a biomass input whose agricultural production has caused a substantive soil loss, such ethanol production could become a net CO_2 source. The reason is that some of the eroded soil decomposes and thereby releases CO_2 into the atmosphere.

[3] The only study reporting net gains beyond these 80 [Gj/ha/yr] is the *Kirk-Othmer Encyclopaedia* (Mark *et al.* 1980) which implies a net production of 101 [Gj/ha/yr]. At one point they state that it takes 202 square kilometres of farm land to produce a [gross] output of 265,000,000 litres of ethanol (1980:V9:356). Later they show that 65 percent would be necessary to power the agricultural production which results in a net productivity of 101 [Gj/ha/yr] (1980:V9:358). However, this study does not provide a reliable documentation of these results.

TABLE A1.1: Comparing Results of Various Ethanol Productivity Studies

authors of study type of biomass	**biological productivity** [Gj/ha/yr]	**conversion efficiency** [%]	**net ethanol production** [Gj/ha/yr]
A) **Ahmed and Morris** (1992)			
corn	320	9	29
cellulosic crop	242	22	53
B) **David *et al.*** (1978)			
corn	214[1]	12	26[1]
C) **Giampietro** (1992)			
sustainable sugar cane	103	31	32
D) **Giampietro and Pimentel** (1990)			
sugar cane	436[1]	15[1]	65
sugar cane (U.S.A.)	436[1]	12[1]	52
sugar cane (Brazil)	436[1]	13[1]	57
E) **Kendrick *et al.*** (1978)			
corn	214[1]	1.4	3[1]
F) **Kirk-Othmer** (Mark *et al.* 1980)			
sugar cane	436[1]	23[1]	100
corn	300[1]	19	57[1]
G) **Lightfoot** (& Kirk-Othmar) (1992)			
corn	229	8	18
H) **Narodoslawsky *et al.*** (1993)			
sugar beet (today)	868	4	39
sugar beet (best technology)	868	9	81
I) **NREL, Golden** (1992)			
fast growing wood	395	20	79
J) **Pimentel** (1991)			
corn	297	5	15
K) **Stout**[2] (1984)			
sugar beet			34-66
Other Scenarios			
L) corn, commercial energy input = 0	326	22	73

[1] Includes estimates from other sources. For example, Zaborsky reports a typical sugar cane yield (total biomass) of 436 [Gj/ha/yr], while its sucrose content adds up to only 90 [Gj/ha/yr] chemical energy (1981:V2:216).

[2] Includes total energy inputs to produce and process crops. Sugar beet is the only plant for which this study shows a net gain. However, this result seems overly optimistic. Zaborsky reports for sugar beet a gross gain of sucrose which is equivalent to 60 [Gj/ha/yr] chemical energy (1981:V2:143).

APPENDIX 1.2: ENERGY-LAND EQUIVALENCE RATIO BASED ON CO_2 ABSORPTION[4]

1. Why CO_2?

The purpose of this appendix is to estimate the land area necessary to sequester the CO_2 released by fossil fuel burning. From this perspective, the energy-land equivalence ratio would indicate the level of fossil fuel consumption in [Gj/yr] whose corresponding CO_2 can be sequestered by one hectare of global average forest.

Appendix 1.1 described various estimates of the "energy land" associated with current consumption that would be required to produce ethanol from biomass as a substitute for fossil hydrocarbons. This approach assumes CO_2 emission and not the size of fossil fuel reserves as the limiting factor for fossil fuel consumption. Therefore, estimating the energy-land requirements of fossil fuel burning involves calculating the area of growing forest necessary to absorb and store the released CO_2.[5] Since the mining and burning of fossil fuels results in the continuous and rapid injection of carbon from an historically inactive pool into the atmosphere, potentially hazardous accumulations of CO_2 are inevitable unless some form of semi-permanent carbon sink can be found.

2. Forests as Carbon Sinks

The most obvious and direct solution is to use contemporary photosynthesis to capture the newly emitted fossil CO_2. Indeed, tree planting and the maintenance of "carbon sink" forests is the only currently practical means of soaking up excess atmospheric carbon. With this approach, the risk of atmospheric and climate change is reduced by continuously sequestering the excess carbon in growing forests and long-lived wood products. Such semi-permanent storage keeps the accumulating fossil carbon out of active circulation. In effect, we would be shunting the carbon through the economy from an ancient inactive pool to a modern one.

While the deliberate use of forests as a carbon sink is a relatively new idea, the fact is that enormous quantities of carbon are already held in the world's biomass and soils. The remaining vegetation and soils contain in excess of 2000 billion metric tonnes of carbon -- three times the amount in the atmosphere (Brown *et al.* 1988:93, CE 1991:Ch22). Indeed, land mismanagement and deforestation have been major contributors to greenhouse gas accumulation in the recent past. Since 1860, forest clearing and burning alone has contributed 90-180 billion

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[4] This Appendix builds on Yoshihiko Wada's literature review on CO_2 absorption of forest ecosystems (1994a) and William E. Rees' summary statement on CO_2 sequestration (Wackernagel *et al.* 1993).

[5] This assumes that nonrenewable hydrocarbons will remain the main energy source for industrial societies in the foreseeable future.

[t] of carbon to the atmosphere (as compared to 150-190 billion [t] from fossil fuels) (Brown *et al.* 1988:94). The current contribution from deforestation is 1.0-2.6 billion [t] annually (20-50% as much as from burning fossil fuels).

3. Land Use Implications

The CO_2 sequestration of forests are based on the estimates reported in Table A1.2

TABLE A1.2: CO_2 Sequestering by Forest Ecosystems

Forest type	**CO_2 absorption**[6]	Percentage of global forest area[7]
Average boreal forest	0.5 [t carbon/ha/yr]	33 %
Average temperate forest	1.5 [t carbon/ha/yr]	25 %
Average tropical forest	3.0 [t carbon/ha/yr]	42 %
Average global forest	1.8 [t carbon/ha/yr]	100 %

Forest ecosystems are by one magnitude more effective in the long-term absorption of CO_2. According to a literature review by Yoshihiko Wada (1994a:8-10), the global average of grassland adds up to about 0.12 [t carbon/ha/yr], most of it in the soil.

Knowing the global average of CO_2 absorption allows a straightforward calculation of the energy-land equivalence ratio. Siegenthaler *et al.* report that every year about 5.4E9 [t] of carbon are released by fossil fuel combustion. This corresponds to a fossil fuel consumption of 300,000 [Pj].[8] In other words, including all the CO_2 releases of mining and refining, one [Gj]

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[6] This table is based on an extensive literature review by Yoshihiko Wada that he conducted for the UBC Task Force on Healthy and Sustainable Communities (1994a). The chosen figures stem mainly from Apps *et al.* (1993), Dixon *et al.* (1994), Birdsay *et al.* (1992), and Marland (1988).

[7] Dixon *et al.* (1994) in Wada (1994a).

[8] The global commercial fossil fuel in 1989 which was consumed directly or through the use of electricity can be estimated from the World Resources Institute figures (1992:316). It reports 298,258 [Pj] of commercial energy consumed, while 346,931 [Pj] in Conventional Fuel Equivalent. Hence, one can calculate the fossil fuel component as follows:

(1) *directly consumed f(ossil) + e(lectrical) = 298E18 [j]*, and

(2) $f + 3.333e = 347E18$ *[j]*.

This results in f= 277E18 [j] and e= 21E18 [j]. Of the consumed electricity, 14E18 [j] were generated by nuclear or hydro power (1992:314). This means that the remaining electricity (6.5E18 [j]) was generated by fossil fuel. Therefore, the global commercial fossil fuel in 1989 that was consumed directly (277E18 [j]) or through the use of electricity (3.333*6.5E18 [j]) adds up 299E18 [j].

of fossil fuel emits about 18 [kg] of carbon into the atmosphere. According to the average sequestering capacity of forests, this shows that one hectare of average forest could annually sequester the CO_2 of 100 [Gj] of fossil fuel (100 [Gj/yr] * 18 [kg/Gj] = 1.8 [t/yr], or one hectare's capacity). In the current EF/ACC assessments, this fossil energy-land equivalence ratio of **100 [Gj/ha/yr]** is being applied.

In summary, while dedicated carbon sink forests could make a major contribution to slowing atmospheric change, it would require dramatically improved land management generally and a massive international commitment of forest land and other resources for the full benefit to be realized. One should also keep in mind that since wood is impermanent (eventually decaying or burning and returning its carbon to the atmosphere), and since there is twice as much carbon stored in fossil fuel reserves (mainly coal) as is held in contemporary biota and soils, a large reduction in fossil fuel consumption is also necessary.[9] In short, as potentially useful as they might seem, carbon sink forests are at best a partial, stop-gap solution to atmospheric and possible climatic change. They would, however, provide a few decades of breathing space while we search for more permanent solutions.

[9] Neither condition is likely to be met in the foreseeable future. Indeed, deforestation continues apace and much of the developing world is only entering the fossil fuel age.

APPENDIX 1.3: ENERGY-LAND EQUIVALENCE RATIO BASED ON CREATION OF RENEWABLE SUBSTITUTES

1. Why Renewable Substitutes?

World Bank Economist Salah El Serafy proposes that a sustainable society can consume non-renewable resources only if it replenishes an equivalent (monetary) stock (1988). A biophysical interpretation of this assertion would require replenishing an equivalent renewable resource asset at the same rate as fossil fuel is being consumed. Such creation of an equivalent renewable substitute would address the principle of constant natural capital,[10] thereby ensuring inter-generational equity, a precondition for sustainability. Estimating the land necessary to create renewable substitutes for the depleted non-renewable resources becomes the third rationale for translating current fossil fuel consumption into land areas. In other words, fossil fuel consumption could be translated into the land area which must be set aside to accumulate a resource stock equivalent in biochemical energy to the depleted amount of fossil fuel.

2. Forests as Substitutes of Depleted Fossil Fuel Stocks

Forests are the only renewable resource that can accumulate large quantities of biomass over a long period of time such as one to several human generations.[11] Therefore, this approach is based on growing forest biomass as the renewable resource substitutes for the drawn down fossil fuel stocks. To develop an equivalent between forest biomass and fossil fuel, their possible use must be compared first. To power human-made processes, high quality energy carriers are necessary. Therefore, one could argue that only the timber biomass of the forest should be counted. However to enable life, the soil biomass of the forest is much more valuable. Therefore, two approaches for measuring forest biomass are proposed. The first approach assesses the timber productivity of forests in terms of their exergetic (or essergetic) value; the second, the entire forest productivity in terms of their biochemical value. These two estimates -- the first one cautious, and the second one more optimistic -- provide a range of defendable measurements for average forest productivity.

3. The First Approach: The Exergetic Forest Productivity for Timber

As a first approximation, one could postulate that one [kj] of timber is equivalent to one [kj] of coal. On the one hand, coal is, in exergetic terms, more effective than wood, i.e., the combustion of coal can generate higher temperatures than that of timber. On the other hand,

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[10] This corresponds to the "strong sustainability" interpretation which is elaborated in Chapter I.

[11] Peat bogs also accumulate carbon over even longer time spans, but at a substantially lower rate (Wada 1994a).

timber is more versatile than coal, because it can be used for heating as well as for construction purposes. From an exergetic perspective, some engineers suggest that one [kj] of oil (or gas) is as valuable as two [kj] of coal (McKetta 1984:7). In other words, they consider it to be a gain if 2 [kj] of coal are converted into 1 [kj] of liquid fuel. For many purposes, gas can be counted as if it was of the same quality as liquid fuel, even though it is slightly less versatility (however for many stationary applications, such as domestic heating or gas turbines, it is superior to liquid fuel). Therefore, the exergetic conversion ratio between timber, coal, oil and gas can be crudely postulated as:

$$2 \text{ [kj timber]} = 2 \text{ [kj coal]} = 1 \text{ [kj liquid fuel]} = 1 \text{ [kj gas]}$$

Assuming an average timber productivity of 2.3 [m^3/ha/yr] (Chapter IV), an average timber density of 520 [kg/m^3 dry wood] with an energy content of 20 [Mj/kg dry wood] (see Appendix 2.2), one hectare of Earth's average forest would be able to accumulate:

$$\frac{2.3 \text{ [m}^3\text{/ha/yr]} * 520 \text{ [kg/m}^3\text{]} * 20 \text{ [Mj/kg]}}{1000 \text{ [Mj/Gj]}} = 24 \text{ [Gj/ha/yr]}.$$

Furthermore in exergetic terms, these 24 [Gj/ha/yr] of timber are worth only 12 [Gj/ha/yr] of liquid fuel. This energy productivity or energy-land equivalence ratio is much less than the assumed **net** energy productivity of 80 [Gj/ha/yr] for ethanol, or 100 [Gj/ha/yr] calculated through the CO_2 approach.

4. The Second Approach: The Biochemical Energy Productivity of Forest Ecosystems

Once the carbon accumulation of forest ecosystems is known, this can be translated into equivalent biochemical energy. Appendix 1.2 showed a carbon accumulation rate of 1.8 [t/ha/year] for average forests. For most forests, one [kg] of carbon corresponds to about 44 [Mj] of biochemical energy (Appendix 2.2). Hence, the biochemical energy accumulation of average forests adds up to (1.8 [t/ha/year] * 44 [Gj/t] =) 79 [Gj/ha/yr], which is quite similar to the ethanol productivity calculated in Appendix 1.1.

5. Discussion

This calculation illustrates that for a sustainable economy it might be ecologically more efficient to produce the energy requirements on a renewable basis (such as direct solar, hydro, wind or biomass energy) rather than to take El Serafy's route: compensating for the consumed non-renewable resource stocks by accumulating equivalent renewable substitutes.

APPENDIX 2

BACKGROUND DATA FOR THE CONSUMPTION - LAND USE MATRIX OF AN AVERAGE CANADIAN

This appendix contains the data material and supporting tables for calculating the average Canadian Ecological Footprint the result of which are presented in the consumption - land-use matrix (Table 5.1). Appendix 2.1 documents the calculations for every relevant cell of the matrix. Appendix 2.2 includes supporting tables on food consumption and embodied energy. Appendix 2.3 gives the references for all these data, and Appendix 2.4 summarizes abbreviations and units used in this section.

Tables

<u>APPENDIX 2.1:</u> DATA FOR CALCULATING THE AVERAGE CANADIAN ECOLOGICAL FOOTPRINT

X - CONSUMPTION

<u>x10 FOOD</u>

REFERENCES:

The food expenditure per capita in Canada, 1986 was (FE 1989:34):
5,013 [$] / 2.72 [cap/household] = 1843 [$/cap/yr].
{75 % of the purchases are from stores, 25 % from restaurants}.

The food supply per capita in **Canada**, 1986-88 was (FAOb 1990:tbl106):
2325 [kcal/cap/day] vegetable products {i.e., 67%}, and
1125 [kcal/cap/day] animal products {i.e., 33%}.

{The food supply per capita in the **world**, 1986-88 was (FAOb 1990:tbl106):
2253 [kcal/cap/day] vegetable products {i.e., 84%}, and
419 [kcal/cap/day] animal products {i.e., 16%}}.

Milk consumption: 8,229,000 [t] of milk was produced in Canada in 1989 (FAOb 1990:tbl99) which amounts to 313 [l/cap/yr], while consumption {?} in 1989 was 278 [l/cap/yr] (CY 1992:367). The 278 [l] corresponds to 89 % of the total production of 313 [l], i.e., the remaining 35 [l] would be net trade and/or statistical discrepancies.

Meat consumption: 2,423,453 [t/year] was consumed in Canada in 1989. This corresponds to 2,423,453 [t/year] * 1000 [kg/t] / 26.3E6 [Canadians] = 92 [kg/cap/year].
1.26 times more meat is produced (i.e., 3,055,521 [t]) (Table 8).

The consumption of grain by human beings and livestock:
In Canada, 79 % of the consumed grain is fed to livestock (WR 1992:276).

The food waste: (Corson 1990:75)

pre harvest agricultural loss:	5-40 percent (worldwide),
losses from harvest to retailing:	15 percent (in US),
purchased food discarded by restaurants and households:	15 percent (in US).

Meadows *et al.* report a 40 % food products loss from farm to consumer (Meadows *et al.* 1992:48).

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<u>x20 HOUSING</u>

x21 housing construction and maintenance

REFERENCES:

The construction and maintenance expenditure in Canada, 1986 was (FE 1989:34):

rented living quarters:	1720 [$] / 2.72 [cap/household] =	632 [$/cap/yr], and
owned living quarters:	2510 [$] / 2.72 [cap/household] =	923 [$/cap/yr].
	TOTAL =	1,555 [$/cap/yr]

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x22 operation of housing

REFERENCES:
The operational expenditure in Canada, 1986 was (FE 1989:34):
water, fuel and electricity: 1092 [$] / 2.72 [cap/household] = 401 [$/cap/yr], and
household cleaning and paper and plastic household supplies:
230+231 [$] / 2.72 [cap/household] = 169 [$/cap/yr].
TOTAL = 570 [$/cap/yr]

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x30 TRANSPORTATION

x31 motorized private transportation

REFERENCES:
The private transport expenditure in Canada, 1986 (FE 1989:36):
4235 [$] / 2.72 [cap/household] = 1557 [$/cap/yr].

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x32 motorized public transportation

REFERENCES:
The public transport expenditure in Canada, 1986 (FE 1989:36):
421 [$] / 2.72 [cap/household] = 155 [$/cap/yr].

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x40 CONSUMER GOODS

x40' packaging

REFERENCES:
The packaging in the US, 1984 (Selke 1990:4) amounted to:
(US tons converted into metric tonnes, assuming 249E6 [Americans])

29.5 million tons =	26.8E6 [t] paper packaging	= 108 [kg/cap/yr]
5.4 million tons =	4.9E6 [t] steel packaging	= 20 [kg/cap/yr]
2.0 million tons =	1.8E6 [t] aluminum packaging	= 7 [kg/cap/yr]
6.3 million tons =	5.7E6 [t] plastic packaging (1987), increased from 5.0E6 [t] in 1984	= 23 [kg/cap/yr]
12.8 million tons =	11.6E6 [t] glass packaging	= 47 [kg/cap/yr]
2.0 million tons =	1.8E6 [t] wood packaging	= 7 [kg/cap/yr]
58 million tons =	52.7E6 [t] TOTAL PACKAGING	= 212 [kg/cap/yr]

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x41 clothing

REFERENCES:
The clothing expenditure in Canada, 1986 was (FE 1989:36):
2215 [$] / 2.72 [cap/household] = 814 [$/cap/yr].

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x42 furniture and appliances

REFERENCES:
The furniture and equipment expenditure in Canada, 1986 was (FE 1989:36):
1278 [$] / 2.72 [cap/household] = 470 [$/cap/yr].

= =

x43 books and magazines

REFERENCES:
The reading material and other printed matter expenditures in Canada, 1986 were (FE 1989:38):
205 [$] / 2.72 [cap/household] = 75 [$/cap/yr].

The paper consumption in the US is:
317 [kg/cap/yr] which is the world's highest consumption rate according to (Meadows *et al.* 1992:63).
317 [kg/cap/yr] in 1988 according to (Kroesa 1990:41).

The paper consumption in Canada is:
6,201,000 [t] paper products consumed in 1990, which amounts to 242 [kg/cap/yr]. Of these 6,201,000 [t], 1,089,000 [t] are newsprint, and 5,112,000 [t] are other paper and paperboard (PED 1992:73) {see also **f43**}. (In 1990, Canada produced 2.7 times more paper than it consumed, i.e., 16,465,000 [t/yr] (PED 1992:52), i.e., approximately 63 % for export).
247 [kg/cap/yr] paper consumed in Canada, 1988 (Kroesa 1990:41).

The Canadian paper consumption inferred from world consumption:
World's yearly paper production between 1987-89 adds up to 223,012,000 [t/yr] (WR,1992: 288).
Rule of thumb: people living in OECD countries (Organization for Economic Co-operation and Development) {i.e., people in highly industrialized countries} use typically 4-5 times that of the World's per capita average (various, e.g., Barry Commoner in Ekins 1992:108).
223,012,000 [t/yr] / 5.5E9 [people] * 5 [OECD factor] = 203 [kg/cap/yr]

Paper waste:
In Ontario (CE 1992:25-6):
1,474,000 [t/yr] private paper waste (55 % of total),
1,221,000 [t/yr] commercial paper waste (45 % of total).
Therefore, the per capita waste adds up to
(1,474,000+1,221,000) [t/yr] / 9.1E6 [Ontarians] = 296 [kg/cap/yr].

priv.(55%)	**commerc.(45%)**		**total (100%)**	**in absolutes**
62%(=34%)	64%(=29%)	63%	for reading	= 186 [kg/cap/yr]
11%(= 6%)	36%(=16%)	22%	for packaging	= 65 [kg/cap/yr]
14%(= 8%)	–	8%	for food pack	= 24 [kg/cap/yr]
13%(= 7%)	–	7%	for household	= 21 [kg/cap/yr]
100%(=55%)	100%(=45%)	100%		296 [kg/cap/yr]

Municipal Waste in Canada in 1989 contained (WR 1992:319):
228 [kg/cap/yr] cardboard,
29 [kg/cap/yr] plastic,
41 [kg/cap/yr] glass,
41 [kg/cap/yr] metals, and
266 [kg/cap/yr] organic.
625 [kg/cap/yr] TOTAL.

RESULT:
The per capita paper consumption:
317 [kg/cap/yr] per US-American,
296 [kg/cap/yr] paper waste per Ontarian,
242-247 [kg/cap/yr] per Canadian, **in this EF/ACC calculation, 244 [kg/cap/yr] of paper is used**
228 [kg/cap/yr] cardboard and paper in Canadian municipal waste, or
203 [kg/cap/yr] per Canadian (inferred from world production).

==

x44 tobacco and alcohol

REFERENCES:
The tobacco and alcohol expenditure in Canada in 1986 was (FE 1989:38):
518 + 610 [$] / 2.72 [cap/household] = 415 [$/cap/yr].

==

x45 personal care

REFERENCES:
The personal care expenditure in Canada in 1986 was (FE 1989:36):
679 [$] / 2.72 [cap/household] = 250 [$/cap/yr].

==

x46 recreation

REFERENCES:
The recreation expenditure in Canada in 1986 was (FE 1989:36):
equipment, vehicles, home entertainment: 1,771 - 630 [$] / 2.72 [cap/household] = 503 [$/cap/yr], and
other accommodation - traveller accommodation (from 'Shelter', i.e., in Statistics Canada's statistic this item is classified under 'Shelter'): 358 - 180 [$] / 2.72 [cap/household] = 65 [$/cap/yr].
TOTAL = 568 [$/cap/yr].

==

x47 other goods

REFERENCES:
The dollars spent on gifts in Canada in 1986 were (FE 1989:38):
381 [$] / 2.72 [cap/household] = 140 [$/cap/yr].

==

x50 RESOURCES NEEDED FOR SERVICES PROVIDED

x52 education

REFERENCES:
The education expenditure in Canada in 1986 was (FE 1989:38):
296 [$] / 2.72 [cap/household] = 109 [$/cap/yr].

==

x53 health care

REFERENCES:
The health care expenditure in Canada in 1986 was (FE 1989:36):
648 [$] / 2.72 [cap/household] = 238 [$/cap/yr]
{of the 648 [$], 430 [$] are direct costs and 218 [$] are health insurance premiums}.

==

x54 social services

REFERENCES:
The unemployment and government pension contributions in Canada in 1986 were (FE 1989:36):
468+372 [$] / 2.72 [cap/household] = 309 [$/cap/yr] .
{Benefits received (in dollar terms) are approximately the same amount in all income groups}.

==

x55 tourism (without transportation)

REFERENCES:
The tourism expenditure in Canada in 1986 was (FE 1989:36):
traveller accommodation (from 'Shelter,' i.e., in Statistics Canada's statistic it is classified under 'Shelter')
180 [$] / 2.72 [cap/household] = 66 [$/cap/yr], and
package travel tour ('Recreation' in Statistics Canada's statistic)
180 [$] / 2.72 [cap/household] = 66 [$/cap/yr].
TOTAL =132 [$/cap/yr].

==

x56 entertainment

REFERENCES:
The recreational services expenditure in Canada in 1986 was (FE 1989:36):
('Recreation' category in Statistics Canada's statistic)
630-180 [$] / 2.72 [cap/household] = 165 [$/cap/yr].

==

x57 banks and insurances

REFERENCES:
The interest on personal loans in Canada in 1986 was (FE 1989:38):
315 [$] / 2.72 [cap/household] = 116 [$/cap/yr].
The life insurance premiums (in 'Security') were: 270 [$] / 2.72 [cap/household] = 99 [$/cap/yr].
The retirement and pension fund payments (without government pension plan (in 'Security' in Statistics Canada's statistic)
were: 791-372 [$] / 2.72 [cap/household] = 154 [$/cap/yr].
TOTAL = 369 [$/cap/yr].

==

x58 other services

REFERENCES:

The communication expenditure in Canada in 1986 was (FE 1989:36):

486 [$] / 2.72 [cap/household] = 179 [$/cap/yr].

The child care and pet expenditure cost: ('Household Operation' in Statistics Canada's statistic)

198+147 [$] / 2.72 [cap/household] = 127 [$/cap/yr].

The dues to union and professional organizations ('Miscellaneous' in Statistics Canada's statistic)

135 [$] / 2.72 [cap/household] = 50 [$/cap/yr].

On the government run lotteries, the average household spends ('Miscellaneous' in Statistics Canada's statistic)

146 [$] / 2.72 [cap/household] = 54 [$/cap/yr].

Other expenditures were: ('Miscellaneous' in Statistics Canada's statistic)

899-315-135-146 [$] / 2.72 [cap/household] = 111 [$/cap/yr].

Contributions for religious and other charitable organizations were: ('Gifts and Contributions' in Statistics Canada's statistic)

227+83 [$] / 2.72 [cap/household] = 114 [$/cap/yr].

TOTAL = 635 [$/cap/yr].

==

a10 FOOD

REFERENCES:

Energy in the food system:

According to a study by the US Federal Energy Administration in 1976, the food system uses 16.5 percent of the national energy:

(In percent of total energy consumption):

3.4% in the residential sector	(residential sector uses	19% of US energy)	
3.2% in the commercial sector	(commercial sector uses	14% of US energy)	
5.5% in the industrial sector	(industrial sector uses	43% of US energy)	
4.4% in the transportation sector	(transport. sector uses	24% of US energy)	
16.5% of the U.S. energy consumption for food		100%	(Stout 1984:14).

In other words, 16.5 % of the total US energy consumption is for food production and preparation.

Based on 1963 data, each person, from food production to consumption, uses 34.5 [Gj] of food energy per year. Eric Hirst estimates that

18 % goes into agricultural production
33 % goes into food processing
3 % goes into transportation {low compared to statistics above}
16 % goes into whole sale
30 % goes into home preparation
100 % (Stout 1984:15).

According to Corson, 6 % of commercial energy consumption in the US is used by food processing and packaging. This would add up to 295 [Gj/cap/yr] * 6% = 18 [Gj/cap/yr] (WR 1992:316).

Typically, 10-15 % of the total national energy goes into the food system (Spedding 1989:3-table 3). Stout (1984:15) states that some studies report values from 12-20 % of the total energy consumption depending on the boundaries given, the food system, and the extent to which indirect energy usage (machinery, buildings, etc.) is charged to the food system. For example, in Switzerland, 14 % of the total commercial energy goes into the food system (Hofstetter 1992a:12). In Switzerland, this corresponds to 7971 [kWh/cap/yr].

The Canadian agricultural sector in 1989 used 2 % of all of the commercial energy consumed in Canada (WR 1992:318). The energy intensity in the Canadian agricultural sector amounted to 9 [Mj] per [US$] agricultural income generated, i.e., per 1 [US$] agricultural GDP in Canada (WR 1992:318).

Fuel composition: In 1970, 50 % of the energy used in the US food system was liquid petroleum, 30 % was natural gas, 14 % was electricity, and the remainder was coal and residual fuel oil (USDA in Stout 1984:15).

CALCULATIONS:

Energy in average Canadian food chain:if we assume 14 % of national energy consumption to be used for the food system this would add up to 234 [Gj/cap/yr] * 14% = 33 [Gj/cap/yr] (see **a60**).

According to USFEA (1976 in Stout 1984:14), these 33 [Gj/cap/yr] can be attributed to

7 [Gj/cap/yr] from home production	{=> **a22**}	(= 3.4%/16.5% * 33 [Gj/cap/yr]),
9 [Gj/cap/yr] from transportation	{=> **a30**}	(= 4.4%/16.5% * 33 [Gj/cap/yr]),
11 [Gj/cap/yr] from industrial processing		(= 5.5%/16.5% * 33 [Gj/cap/yr]),
of which 2% * 234 = 5 [Gj/cap/yr] are from agriculture, and the remaining 6 [Gj/cap/yr] are deducted from consumer goods, and	{=> **a40**}	
6 [Gj/cap/yr] from commercial	{=> **a50**}	(= 3.2%/16.5% * 33 [Gj/cap/yr]),
33 [Gj/cap/yr].		

234 [Gj/cap/yr] * 14% / 100 [Gj/ha/yr] = **0.33 [ha/cap]**
(for the 100 [Gj/ha/yr] energy-land conversion ratio, see Appendix 1.2).

RESULT:
0.33 [ha/cap]

==

a11 vegetarian products

REFERENCES:
Assumptions:
For the agricultural production of 1 [j] of animal products, 8 times more energy is needed per 1 [j] of animal based food products than for vegetarian food products (see **d12**). Agricultural fossil energy adds up to 5 [Gj/cap/yr] / 33 [Gj/cap/yr] = 15 % of the energy embodied in food.

Processing animal products might be twice as energy intensive as processing vegetarian food. Processing food requires approximately (100%-15%=) 85 % of the energy used in the food system.
Therefore, animal based food requires approximately 8*15% + 2*85% = 2.9 times more energy per 1 [j] of food than does a vegetarian food product.

CALCULATIONS:
Every average Canadian eats approximately 2325 [kilocalories] vegetarian food products and 1125 [kcal] animal products per day (see **x10**). Assuming a ratio between energy intensity of vegetarian food and animal based food of 2.9 (see above), one can calculate the ratio between the total energy spent on vegetarian food as compared to that spent on animal based food by using the equation: 2325x + 2.9*1125x = 33 [Gj/cap/yr].

From this equation follows x = 33 / (2325 + 2.9*1125) = 0.0059, and therefore, 13.7 [Gj/cap/yr] would be required for the vegetarian products and 19 [Gj/cap/yr] for the animal products.
This leads to 13.7 [Gj/cap/yr] / 100 [Gj/ha/yr] = **0.14 [ha/cap]** of land.

RESULT:
0.14 [ha/cap]

==

a12 animal products

REFERENCES AND CALCULATIONS:
(see **a11**): 19 [Gj/cap/yr] / 100 [Gj/ha/yr] = **0.19 [ha/cap]**

RESULT:
0.19 [ha/cap]

==

<u>a20 HOUSING</u>

REFERENCES:
The total life cycle energy of a "standard house" is 10,469 [Gj]. The operating energy over a 40-year life span of the building was 86 % of the total, the embodied energy comprised approximately 14 % (Sheltair 1991:31). Furthermore, we assume that 79 % of this energy is fossil fuel (see **a60**).

CALCULATIONS:
1st calculation:
79% * 10,469 [Gj] / 2.72 [cap/house] / 40 years / 100 [Gj/ha/yr] = 0.76 [ha/cap] {However, this is a "standard house,"

which is probably bigger than the average dwelling}. Construction and operation would come to 0.76 * 14% = 0.11 [ha/cap], and 0.95 * 86% = 0.65 [ha/cap] respectively.

2nd calculation:

0.06 [ha/cap] (from **a21**) + 0.35 [ha/cap] (from **a22**) = **0.41 [ha/cap]**.

RESULT:

0.41 [ha/cap] range: 0.41...0.76 [ha/cap]

==

a21 housing construction and maintenance

REFERENCES:

The material requirement to build an average Canadian house includes 23.6 [m^3] of wood (CE 1991:10-11). In this study, we assume that other residences require the same amount of wood per household.

The building sector requires 18 % of Canadian energy demand (Sheltair 1991:1). {This percentage figure seems high, because it is unlikely that building houses requires as much energy as operating them}.

The life span of an average Canadian house is assumed to be 40 years (same assumption in Sheltair 1991).

The embodied production energy in lumber is 10 [Mj/kg] (Brown 1985:61 and Table 10).

The construction energy per house corresponds to approximately 10 % of the energy embodied in the building materials (Cole 1992).

The estimated total embodied energy for an average Canadian home is 844 [Gj] (Sheltair 1991:29), or including the entire life cycle of all components, it rises to 1,310 [Gj].

CALCULATIONS:

1st calculation:

The energy requirement for wood processing and construction is:

(100 % {embodied energy} + 10 % {construction energy}) * 23.6 [m^3] * 600 [kg/m^3] * 10 [Mj/kg] / 40 [yr] / 2.72 [cap/household] = 1.43 [Gj/cap/yr]; corresponds to 1.43 / 100 [Gj/ha/yr] = 0.014 [ha/cap] {close to Sheltair's estimate (1991)}.

2nd calculation:

The total energy requirement is:

844 [Gj/house] / 2.72 [cap/house] / 40 years / 100 [Gj/ha/yr] = 0.08 [ha/cap].
Or: 1,310 [Gj] / 2.72 [cap/house] / 40 years / 100 [Gj/ha/yr] = 0.12 [ha/cap].

3rd calculation:

Assuming a 86% / 14% split between operation and construction energy (Sheltair 1991), energy for construction would add up to 0.35 (from **a22**) * 0.14 / 0.86 = **0.06 [ha/cap]**. This corresponds to 0.07 [ha/cap] * 80 [Gj/ha/yr] = 5.6 [Gj/cap/yr] {to be deducted from **a40**}.

RESULT:

0.06 [ha/cap] range: 0.06...0.12 [ha/cap]

==

a22 housing operation

REFERENCES:
The energy consumption in the residential sector in Canada in 1989 was 18 % of the total commercial energy consumed (WR 1992:318).

CALCULATIONS:
1st calculation:
(18% * 234 [Gj/cap/yr] - 7 [Gj/cap/yr] {cooking energy, already accounted for in food category, see **a10**}) / 100 [Gj/ha/yr] = **0.35 [ha/cap]**

RESULT:
0.35 [ha/cap]

==

a30 TRANSPORTATION

REFERENCES:
The direct energy consumption in the transportation sector in Canada, 1989: 26 % of commercial energy (WR 1992:318).

The indirect energy consumption of cars:

Estimates range between 20 % (Matsumoto 1984 in (Environment Canada 1993:4)) {for car production only} and 50 % (Pimentel in (Giampietro and Pimentel 1990:223)) {for car production plus maintenance} in addition to direct gas consumption.

If we assume 2E6 [cars/yr] are sold in Canada, at 1050 [kg] each (middle-size car, Hofstetter 1992:19) with an embodied energy of 100 [Mj/kg], this would add up to 8 [Gj/cap/yr]. If a car lasts for 6-7 years, this would correspond to 16 [Gj/yr] for construction related embodied energy, while the average consumption rate of fuel per car is 73 [Gj/yr], i.e., an additional 22 % of a car's direct petroleum consumption would be required for its construction. For car maintenance and road construction, Hofstetter adds another 8 % and 15 %, respectively (1992:21). In comparison, Spreng estimates that apart from the direct energy consumption of cars, an additional 9 % is needed for road construction, another 9 % for car repair and 13 % for car production (Pillet 1992:100).

In this study, we assume that 8 additional percent stems from the service sector for car maintenance and 37 % from the industrial sector {i.e., 22 % for car construction plus 15 % for road construction}. These results are applied to all motorized modes of road transportation.

As a comparison: 25 [l] of gas {or 875 [Mj] of chemical energy equivalent} are needed to produce one single tire (Schäublin 1992:7.14).

CALCULATIONS:
(26% * (100% + 8% + 37%) * 234 [Gj/cap/yr] - 9 [Gj/cap/yr] {already in food category, see **a10**}) / 100 [Gj/ha/yr] = 79 [Gj/cap/yr] / 100 [Gj/ha/yr] = **0.79 [ha/cap]**

37% * 26% * 234 [Gj/cap/yr] = 23 [Gj/cap/yr] deducted from industrial sector {see **a40**},
8% * 26% * 234 [Gj/cap/yr] = 5 [Gj/cap/yr] deducted from commercial sector {see **a50**}.

RESULT:
0.79 [ha/cap]

==

a31 motorized private transportation

REFERENCES:

Number of cars and trucks in Canada:

13,300,000 cars, i.e., 2 Canadians per car (WR 1992:266).

8,157,000 cars in Canada, i.e. 3.2 Canadians per car (CE 1991:12-13) {difference might be explained by the assumption that the lower number corresponds to the private cars only, while the higher one includes public + private + commercial cars}.

12,086,000 cars and taxies in Canada, 1988, i.e. 2.2 Canadians per car (IRTU 1990:132).

3,700,000 trucks in 1988 (IRTU 1990:132).

Kilometres driven:

4411E9 [cap*km/yr] in the US in 1988 (IRTU 1990:181) = 18,000 [km/cap/yr].

Energy consumption of cars:

2,087 [l/yr] gasoline consumed per car (CE 1991:12-13).

35 [Mj/l] energy content of gasoline (Beitz *et al.* 1983:1359).

21.4 [Mj/l] energy content of ethanol {Lower Heating Value applies to comb. engines} (Beitz *et al.* 1983:1359).

4.2 [Mj/car/km] typical energy use by car {corresponds to 12 [l] / 100 [km]} (CE 1991:13-21).

100 [Mj/kg] embodied energy in car/machinery (Hofstetter 1992b:Anhang-4).

Pimentel estimates that it requires 3667 [l/yr] ethanol to fuel a car, 5556 [l/yr] including construction and maintenance, i.e., 50 % more (Pimentel in (Giampietro and Pimentel 1990:222)).

20.92 [miles per gallon] was the average fuel rate of cars sold in the US in 1990 (EIA 1992:53). This corresponds to 11.25 [l/100km]. With an average gas consumption per car of 2,087 [l/yr], this amounts to an average distance driven per car of 18,500 [km/yr].

{To be more accurate, the embodied energy in cars should be calculated as the difference between embodied energy in gross car production minus embodied energy in net imports. The embodied energy in the gross car production should be deducted from the industrial sector's energy consumption}. For the materials used for car construction see (CE 1991:14-22, Greenpeace 1992:42, or Environment Canada 1993:3).

In Canada, 63 % of the petroleum consumed was used for transportation (1986), 80 % of which was for car fuel. Therefore, (63%*80%) = 50.4 % of all petroleum is used by cars (CE 1991:14-20).

CALCULATIONS:

1st calculation:

Direct energy consumption for car use in Canada:

12E6 [cars] / 26.5E6 [cap] * 2087 [l/car/yr] * 35 [Mj/l] * 0.001 [Gj/Mj] / 100 [Gj/ha/yr] = 0.33 [ha/cap]

In comparison, Pimentel's ethanol estimate:

12E6 [cars] / 26.5E6 [cap] * 3667 [l/car/yr] * 21 [Mj/l] * 0.001 [Gj/Mj] / 100 [Gj/ha/yr] = 0.35 [ha/cap]

TOTAL (including indirect consumption): 0.33 [ha/cap] * (100% + 8% + 37%) = 0.48 [ha/cap]

This corresponds to 0.48 [ha/cap] * 100 [Gj/ha/yr] = 48 [Gj/cap/yr].

2nd calculation:

79 [Gj/cap/yr] direct plus indirect (fossil) energy is consumed for transportation (see **a30**). Transportation of goods uses approximately 13 [Gj/cap/yr] (see **a33**). Hence, private transportation would consume (79-13 =) 66 [Gj/cap/yr]. In Canada, 10 % of passenger transport costs are spent on public transport, 90 % on private transport. Assuming the same energy intensities, 59.5 [Gj/cap/yr] would be required for private transportation {rather than the estimated 48 [Gj/cap/yr] (see above in 1st calculation)}, and 6.5 [Gj/cap/yr] for public transportation. 59.5 [Gj/cap/yr] / 100 [Gj/ha/yr] = **0.60 [ha/cap]**

RESULT:

0.60 [ha/cap] range: 0.48...60 [ha/cap]

a32 motorized public transportation

REFERENCES:

Specific energy consumption for public transportation (Hofstetter 1992:19-28, if not mentioned otherwise):

long distance flights:	2 - 2.5	[Mj/cap/km]
long distance flights:	2.7	[Mj/cap/km] (SW 1993:121)
medium distance flights:	2.5 - 3.5	[Mj/cap/km]
long distance buses:	0.5	[Mj/cap/km]
short distance buses:	0.9	[Mj/cap/km]
bus:	0.5 -1.0	[Mj/cap/km] (CE 1991:13-21)
intercity train:	0.948	[Mj/cap/km] (SW 1993:121)
commuter train:	1.3	[Mj/cap/km] (SW 1993:121)
urban rail:	1.2	[Mj/cap/km] (SW 1993:121)

Other public transport figures:

512 public airports in Canada (WR 1992:266),
20 [km^2] land is occupied by Mirabelle airport alone,
60,000 buses and coaches in Canada, 1988 (IRTU 1990:132).

Kilometres flown per Canadian:

50,400E6 [pass*km/yr] by air in Canada (WR 1992:266) = 1970 [km/cap/yr]
48.7E9 [pass*km/yr] air traffic in Canada, 1988 (IRTU 1990:133), corresponds to 48.7E9 [pass*km/yr] / 26.5E6 [Canadians] = 1837.74 [km/cap/yr].
433E9 [pass*km/yr] air traffic in the US, 1989 (IRTU 1990:183), corresponds to 433E9 [pass*km/yr] / 247E6 [US Americans] = 1753.04 [km/cap/yr].

CALCULATIONS:

1st calculation:

Energy requirements for air travels:

1837.74 [km/cap/yr] * 2.5 [Mj/km] * 0.001 [Gj/Mj] = 4.59 [Gj/cap/yr]

Energy requirements for bus travels:

60,000 [buses] * 40 [seats] * 200 [km/day] * 200 [operating days/yr] / 26.5E6 [Canadians] * 0.7 [Mj/km] * 0.001 [Gj/Mj] = 2.54 [Gj/cap/yr]

TOTAL: (4.59 + 2.54) [Gj/cap/yr] / 100 [Gj/ha/yr] = 7.13 [Gj/cap/yr] / 100 [Gj/ha/yr] = 0.07 [ha/cap]

2nd calculation:

(see **a31**, 2nd calculation) => 6.5 [Gj/cap/yr] / 100 [Gj/ha/yr] = **0.07 [ha/cap]**

RESULT:

0.07 [ha/cap]

==

a33 transportation of goods

REFERENCES:

Energy requirements for transportation	(Fritsche 1989:151) and	(Pimentel, 1980:55):
truck:	2.5 [Mj/t/km]	0.83 [kcal/kg/km]= 3.5 [Mj/t/km]
train:	0.1 [Mj/t/km]	0.12 [kcal/kg/km]= 0.5 [Mj/t/km]
inland navigation:	0.5 [Mj/t/km]	0.08 [kcal/kg/km]= 0.3 [Mj/t/km]
maritime navigation:	0.05 [Mj/t/km]	
pipelines:	0.07 [Mj/t/km]	
air fright:		6.63 [kcal/kg/km]= 27.8 [Mj/t/km]
	(SW 1993:121):	

intercity freight by truck: 2.3 [Mj/t/km] {which is over 8 times more than trains need}
older trucks: 1.5-2.5 [Mj/t/km].

Goods transported:
0.261807E12 [t*km] transported by train in Canada, 1987 (IRTU 1990:132).
1.028E12 [t*km] transported by trucks in USA, 1988 (IRTU 1990:181).
78.9E6 [t] goods unloaded in Canadian ports, 1988 (IRTU 1990:133) {here we assume that these goods travel an average distance of 10,000 [km]}.

CALCULATIONS:
1st calculation (using Fritsche's figures):
Energy requirements for Canadian goods transported by train: 0.261807E12 [t*km/yr] * 0.1 [Mj/t/km] * 0.001 [Gj/Mj] / 26.5E6 [Canadians] = 0.99 [Gj/cap/yr].
Energy requirements for Canadian goods transported by sea: 78.9E6 [t/yr] * 10,000 [km] * 0.05 [Mj/t/km] * 0.001 [Gj/Mj] / 26.5E6 [Canadians] = 1.49 [Gj/cap/yr].
Energy requirements for US goods transported by trucks: 1.028E12 [t*km/yr] * 2.5 [Mj/t/km] * 0.001 [Gj/Mj] / 243E6 [US Americans] = 10.58 [Gj/cap/yr] {here we assume that this figure is the same for Canada}.
TOTAL: (0.99 + 1.49 + 10.58) [Gj/cap/yr] = 13.06 [Gj/cap/yr]
13.06 [Gj/cap/yr] / 100 [Gj/ha/yr] = **0.13 [ha/cap]**

2nd calculation (using Pimentel's figures):
Energy requirements for Canadian goods transported by train: 0.261807E12 [t*km/yr] * 0.5 [Mj/t/km] * 0.001 [Gj/Mj] / 26.5E6 [Canadians] = 4.94 [Gj/cap/yr].
Energy requirements for Canadian goods transported by sea: 78.9E6 [t/yr] * 10,000 [km] * 0.05 [Mj/t/km] * 0.001 [Gj/Mj] / 26.5E6 [Canadians] = 1.49 [Gj/cap/yr].
Energy requirements for US goods transported by trucks in: 1.028E12 [t*km/yr] * 3.5 [Mj/t/km] * 0.001 [Gj/Mj] / 243E6 [US Americans] = 14.81 [Gj/cap/yr].
TOTAL: (4.94 + 1.49 + 14.81) [Gj/cap/yr] = 21.24 [Gj/cap/yr]
21.24 [Gj/cap/yr] / 100 [Gj/ha/yr] = 0.21 [ha/cap]

RESULT:
0.13 [ha/cap] range: 0.13...0.21 [ha/cap]
{Due to rounding errors and to make it add up, it is reported as 0.12 [ha/cap] in Table 5.1}

==

a40 CONSUMER GOODS

REFERENCES:
37 % of the total commercial energy is used by industry in Canada, 1989 (WR 1992:318). {Embodied energy of net imported consumer goods should be added (an indirect contribution to Canadian energy consumption) and 23 [Gj] for car production subtracted (is already included in section on private transportation)}.

Energy intensity per dollar in industrial sector is 15 [Mj/US$ in industrial GDP] (WR 1992:318). This figure can also be calculated (for 1989):

total GDP: GDP = 123,198E6 [US$] / 0.222 = 555E9 [US$] (WR 1992:240),

industrial GDP is 34.8 % of total = 193E9 [US$] (WR 1992:236),

industrial energy consumption is 37 % (WR 1992:318) of 8,414 [Pj] (WR 1992:316) = 3113 [Pj], hence industrial energy intensity is 3113 [Pj]/ 193E9 [US$] = 16 [Mj/US$] {rather than the recorded 15 [Mj/US$]}.

CALCULATIONS:

(0.37 * 234 [Gj/cap/yr] - 6 [Gj/cap/yr] {already in food category (see **a10**)} - 5.6 [Gj/cap/yr] {from residential construction (see **a21**)} - 23 [Gj/cap/yr] {already in transportation (see **a30**)}) / 100 [Gj/ha/yr]
= **0.52 [ha/cap]**

RESULT:

0.52 [ha/cap] {Table 5.1 lists 0.52 [ha/cap] due to rounding???}.

==

a40' packaging

REFERENCES:

For the embodied energy in various materials see Table A2.5.

CALCULATIONS:

(from **x40 packaging**)

paper packaging:	108 [kg/cap/yr] * 50 [Mj/kg] * 0.001 [Gj/Mj]	= 5.4 [Gj/cap/yr]
steel packaging:	20 [kg/cap/yr] * 30 [Mj/kg] * 0.001 [Gj/Mj]	= 0.6 [Gj/cap/yr]
aluminum packaging:	7 [kg/cap/yr] * 240 [Mj/kg] * 0.001 [Gj/Mj]	= 1.7 [Gj/cap/yr]
plastic packaging:	23 [kg/cap/yr] * 65 [Mj/kg] * 0.001 [Gj/Mj]	= 1.5 [Gj/cap/yr]
glass packaging:	47 [kg/cap/yr] * 20 [Mj/kg] * 0.001 [Gj/Mj]	= 0.9 [Gj/cap/yr]
wood packaging:	7 [kg/cap/yr] * 10 [Mj/kg] * 0.001 [Gj/Mj]	= 0.1 [Gj/cap/yr]
	TOTAL	= 10.2 [Gj/cap/yr]

10.2 [Gj/cap/yr] / 100 [Gj/ha/yr] = **0.10 [ha/cap]**

RESULT:

0.10 [ha/cap]

==

a41 clothing

REFERENCES:

Energy intensity of clothes and shoes refers to the energy embodied in {or total energy needed for} one dollar worth of clothes and shoes. All energy intensities in the **a40**s and **a50**s are taken from a study by Hofstetter (1992b:35). They are only first approximations and used in relative terms rather than absolute ones. From Canadian energy statistics we know that the energy spent on consumption goods (not including cars) is approximately 52 [Gj/cap/yr]. In Table 11, Hofstetter's figures are used to examine whether the expenditure pattern multiplied with Hofstetter's energy intensities adds up to the 52 [Gj/cap/yr] from the energy statistics. As shown, this is not the case. It overshoots by approximately 9 [Gj/cap/yr]. The figures in Table 11 are then proportionally adjusted so that the total adds up to 52 [Gj/cap/yr] or 0.66 [ha/cap] (last column).

For clothes and shoes the energy intensity is assumed to be 7.2 [Mj/Fr] (Hofstetter 1992b:35). As these figures are only best guesses, and as the Swiss Franc is approximately at parity with the Canadian dollar, 7.2 [Mj/Fr] corresponds to 7.2 [Mj/$].

CALCULATIONS:
See Table A2.6

RESULT:
0.11 [ha/cap]

==

a42 furniture and appliances

REFERENCES:
The energy intensity of furniture, carpets, household equipment, and electric and electronic appliances is assumed to be 7.2 [Mj/$] (Hofstetter 1992b:35). {For explanation, see **a41**}.

CALCULATIONS:
See Table A2.6.

RESULT:
0.06 [ha/cap]

==

a43 books and magazines

REFERENCES:
The energy intensity of books and magazines is assumed to be 10.8 [Mj/$] (Hofstetter 1992b:35).
The embodied energy for paper is:

61 [Gj/t] or 0.061 [Gj/kg] for producing paper (SEF 1991:223);
23.6 [Gj/t] or 0.0236 [Gj/kg] for producing paper in an integrated paper mill (Brown 1985:78).

CALCULATIONS:
1st calculation:
240 [kg/cap/yr] * 0.0236 [Gj/kg] / 100 [Gj/ha/yr] = **0.06 [ha/cap]**

2nd calculation:
240 [kg/cap/yr] * 0.061 [Gj/kg] / 100 [Gj/ha/yr] = 0.15 [ha/cap]

3rd calculation: {With population and consumption figures from Ontario (see **x43** and Table A2.1:General Data)}
(1.474+1.221) * 1E6 [t] / 9.1E6 [cap] * 61 [Gj/t] / 100 [Gj/ha/yr] = 0.18 [ha/cap]

RESULT:
0.06 [ha/cap] range: 0.06...0.18 [ha/cap]

==

a44 tobacco, alcohol, coffee and cocoa

REFERENCES:
The energy int. of alcohol and tobacco is assumed to be 5.4 [Mj/$] (Hofstetter 1992b:35). {For explanation, see **a41**}.

CALCULATIONS:
See Table A2.6.

RESULT:
0.06 [ha/cap]

a45 personal care

REFERENCES:
The energy intensity of washing and toilet articles is assumed to be 7.2 [Mj/$] (Hofstetter 1992b:35). {For explanation, see **a41**}.

CALCULATIONS:
See Table A2.6.

RESULT:
0.03 [ha/cap]

==

a46 recreational equipment

REFERENCES:
The energy intensity of recreational equipment is assumed to be 7.2 [Mj/$] (Hofstetter 1992b:35). {For explanation, see **a41**}.

CALCULATIONS:
See Table A2.6.

RESULT:
0.10 [ha/cap]

==

a47 other goods

REFERENCES:
The energy intensity of watches and jewellery is assumed to be 1.8 [Mj/$] (Hofstetter 1992b:35). {For explanation, see **a41**}.

CALCULATIONS:
See Table A2.6.

RESULT:
0.00 [ha/cap]

==

a50 RESOURCES REQUIRED FOR SERVICES RECEIVED

REFERENCES:
14 % of the total consumed commercial energy was used by the commercial sector, 1989 (WR 1992:318).
3 % of the total consumed commercial energy was used by the remaining sectors (neither agricultural, commercial, industrial, residence, or transport), 1989 (WR 1992:318).
12 % of Swiss commercial energy is consumed by public institutions (Hofstetter 1992a:12).
The energy intensity of services sold in Canada was 2.9 [Mj] per 1 [US$] (WR 1992:318). This figure can also be calculated (for 1989):
GDP = 650E9 [$] (Statistics Canada 1991a:3), services in GDP = 61.8 % => (0.618*650 =) 402E9 [$] (WR 1992:236), commercial energy consumption is 14 % (WR 1992:318) of 8,414 [Pj] (WR 1992:316) =

1,178 [Pj], hence industrial energy intensity is:
1,178 [Pj]/ 402E9 [$] = 3.4 [Mj/Cdn$] {as opposed to the listed 2.9 [Mj/US$]}. This does not include the materials which are used for/by the services.

CALCULATIONS:
((14% +3%) * 234 [Gj/cap/yr] - 6 [Gj/cap/yr] {already in food category (see **a10**)} - 5 [Gj/cap/yr] {for car services, already in transportation category (see **a30**)}) / 80 [Gj/ha/yr] = **0.29 [ha/cap]**

RESULT:
0.29 [ha/cap]

==

a52 education

REFERENCES:
The energy intensity of education is assumed to be 0.45 [Mj/$] (Hofstetter 1992b:35). {For explanation, see **a41**}.

CALCULATIONS:
See Table A2.6

RESULT:
0.08 [ha/cap]

==

a53 health care

REFERENCES:
The energy intensity of health insurances, dentists, medicines, hair dresser assumed to be 1.8 [Mj/$] (Hofstetter 1992b:35). {For explanation, see **a41**}. {Multiply private expenses by 3 to include health care expenditures of the government}.

CALCULATIONS:
See Table A2.6

RESULT:
0.08 [ha/cap]

==

a54 social services

REFERENCES:
The energy intensity of social services (including old age pensions) is assumed to be 0.45 [Mj/$] (Hofstetter 1992b:35). {For explanation, see **a41**}.

CALCULATIONS:
See Table A2.6

RESULT:
0.00 [ha/cap]
==

a55 tourism

REFERENCES:
The energy intensity of hotels and camping is assumed to be 5.4 [Mj/$] (Hofstetter 1992b:35). {For explanation, see **a41**}.

CALCULATIONS:
See Table A2.6

RESULT:
0.01 [ha/cap]

==

a56 entertainment

REFERENCES:
The energy intensity of movies, concerts etc. is assumed to be 7.2 [Mj/$] (Hofstetter 1992b:35). {For explanation, see **a41**}.

CALCULATIONS:
See Table A2.6

RESULT:
0.01 [ha/cap]

==

a57 banks and insurances

REFERENCES:
The energy intensity savings, life insurance, private pension plans is assumed to be 0.45 [Mj/$] (Hofstetter 1992b:35). {For explanation, see **a41**}.

CALCULATIONS:
See Table A2.6

RESULT:
0.00 [ha/cap]

==

a58 other services

REFERENCES:
The energy intensity of mail, phone, repairs is assumed to be 7.2 [Mj/$] (Hofstetter 1992b:35). {For explanation, see **a41**}.

CALCULATIONS:
See Table A2.6: 0.058 [ha/cap].

RESULT:
0.05 [ha/cap]

a60 TOTAL (estimated)

REFERENCES:

10,000 [km²] would be required for the James Bay hydroelectric dam project alone (CE 1991:5-7).

80 [Gj/ha/yr] is the maximum net ethanol productivity for ecologically productive land (see Appendix 1).

321 [Gj/cap/yr] is the Canadian commercial energy consumption per capita (WR 1992:316). If expressed in conventional fossil fuel equivalent, the Canadian energy requirement expands to 426 [Gj/cap/yr] {with 1 [W in fossil fuel] = 0.3 [W electric]} (WR 1992:316).

234 [Gj/cap/yr] is the Canadian commercial fossil energy consumption per capita (see below). In this study, only fossil energy consumption is considered. However, it is assumed that the sectoral distribution of fossil energy consumption is the same as the sectoral distribution of the total commercial energy consumed.

Apparent energy consumption in Canada (net supply)

(Statistics Canada 1992b:tbl1b) (in petajoules = 1,000,000 [Gj]).

a) commercially available primary energy		
coal		57
natural gas		2,583
gas plant NGL's		173
primary electricity		1,304
steam		21
SUBTOTAL a)	(Stat. Canada)	4,134
	(added up)	4,138
b) secondary energy		
coke		107
coke oven gas		33
petroleum		3,184
secondary electricity		377
SUBTOTAL b)		3,701

TOTAL a+b (Stat. Canada)	7,840
FOSSIL FUEL ONLY	6,159

per capita (1990: 26.3 million Canadians)

total consumption: 298 [Gj/cap/yr] (100 %) {as opposed to 321 claimed by (WR 1992:316)}.

fossil fuel consumption: 234 [Gj/cap/yr] (79 %). Of these 234 [Gj/ca[/yr] (100%), 2.6% are solid 53.1% liquid, and 45.3% gas.

CALCULATIONS:

Personal extrasomatic (or non-food) power requirement in fossil fuel equivalent in Canada:

426E9 [j/yr] / 365.25 [days/yr] / 24 [h/day] / 3600 [s/h]= 13.5 [kW/cap]

If only fossil fuel is counted: 7.5 [kW/cap].

Total land requirement for replacing all the fossil fuel consumed by the average Canadian by ethanol:

234 [Gj/cap/yr] / 100 [Gj/ha/yr] = **2.34 [ha/cap]**

If all energy was counted in fossil fuel equivalent:

426 [Gj/cap/yr] / 100 [Gj/ha/yr] = 4.26 [ha/cap].

As a reminder: James Bay hydroelectric dam alone (without all other dams, and the land used to transport electricity) would require 1,000,000 [ha] / 26.5E6 [Canadians] = 0.04 [ha/cap], 4 times the size of an average single family house.

RESULT: 2.34 [ha/cap] range: 2.34...4.26 [ha/cap]

B - DEGRADED LAND: BUILT ENVIRONMENT

b20 HOUSING

REFERENCES:

In Canada, there is 2,650,000 [ha] of settlements (calculations in **b30**), or (2,650,000 [ha] /26.5E6 [Canadians] =) 0.10 [ha] per capita. Here, it is assumed that 0.08 [ha/cap] is used for housing, 0.01 [ha/cap] for industrial purposes, and 0.01 [ha/cap] for commercial and service activities.

RESULT:

0.06 [ha/cap]

= =

b30 TRANSPORTATION

REFERENCES:

Length of roads:

27 [km] paved road per 1,000 [km^2], in Canada, 1988 (WR 1992:266); with Canada's total land area being a 9,970,000 [km^2] (CE 1991:5-8), this adds up to 27[km]/1000[km^2] * 9,970,000 [km^2] = 270,000 [km] road.

280,251 [km] roads in Canada, 1986 (excluding municipal roads) and of which 160,864 [km] are paved (IRTU 1990:132).

841,411 [km] road in Canada (CE 1991:14-20/21).

879,530 [km] highway in Canada (CE 1991:12-13).

6,230,000 [km] of public roads in the USA, 1988, of which 654,000 are principal roads (IRTU 1990:180).

34 [m] is the typical width of Canadian highways (CE 1991:14-20/22).

The US contains 21.5 million [acres] {=8.7E6 [ha]} of highways and 7 million [acres] {=2.8E6 [ha]} of rail roads (Corson 1990:181). Renner estimates 60,00 [square miles] {or 38 million [acres] = 15.5 million [ha]} of road space in the US (Greenpeace 1992:48).

CALCULATIONS:

1st calculation: (Canadian figures)

road area: (270,000 [km] * 34[m] + (879,530 - 270,000) [km] * 10 [m]) / 26.5E6 [Canadians] = 1,527,330 [ha] / 26.5E6 [Canadians] = 0.06 [ha/cap] of roads

Typically, 1/3 of the settlement space in North America is devoted to streets. The settlement space in Canada would be (see above and **b60**) (5,500,000 [ha built-up area] - 1,527,330 [ha roads] =) 4,000,000 [ha] settlements, 1/3 of which (or 1,350,000 [ha]) are streets, 2,650,000 [ha] are settlements. Therefore, the total road and street space is (1,527,330 [ha roads] + 1,350,000 [ha streets] =) 2,850,000 [ha] space for transportation. Per Canadian:

2,850,000 [ha] / 26.5E6 [Canadians] = **0.11 [ha/cap]** of roads

2nd calculation: (road area, a comparison with the US)

(654,000 [km] * 34 [m] + (6,230,000 - 654,000) [km] * 10 [m]) / 245E6 [US Americans] = 0.03 [ha/cap] in the US, or:

(38E6+7E6) [acres]/ 2.47 [acres/ha] / 245E6 [US Americans] = 0.074 [ha/cap] in the US

RESULT:

0.11 [ha/cap]

b40 CONSUMER GOODS

REFERENCES:

Less than 0.03 % of total land is used directly for mining; "an oil or gas drill site typically occupies only about 0.015 [km^2], excluding storage area" (CE 1991:5-7). However, "despite these seemingly insignificant figures, mining and energy industries can have considerable impacts upon the land resource. Arctic landscapes are particularly susceptible to damage and slow to recover from even minor disturbances related to oil and gas exploration or development" (CE 1992:5-7).

These 0.03 % correspond to 300,000 [ha]. However, about 5,000,000 [ha] mineral exploration claims were recorded (exclusive of claims for coal) (CE 1991:11-5). In addition to mining, consumer goods need built environment for storage, manufacturing, selling, transportation and waste deposition.

Only approximately 20 percent of the mining is for domestic consumption (CE 1991:11-6).

CALCULATIONS:

0.03% * 997.1E6 [ha] * 20 % / 26.5E6 [Canadians] = 0.002 [ha/cap]. Furthermore, other industrial activities are assumed to occupy 0.01 [ha/cap] built environment (see **b20**). 0.01 [ha/cap] + 0.002 [ha/cap] = **0.01 [ha/cap]**.

RESULT:

0.02 [ha/cap]

==

b50 RESOURCES NEEDED FOR SERVICES PROVIDED

REFERENCES:

(see **b20**): 0.01 [ha/cap]

RESULT:

0.01 [ha/cap]

==

b60 TOTAL (estimated)

REFERENCES:

72,000 [km^2] = 7,200,000 [ha] built environment in the 25 major metropolitan areas of Canada; 7,900,000 [ha] urban and industrial land in Canada (CE 1991:5-8).

55,000 [km^2] = 5,500,000 [ha] built-up environment in Canada (WR 1994:285).

0.2 % of Canada is urban (CE 1991:13-4) = 0.002 * 997.1E6 [ha] {Total Land Area in Canada} = 20,000 [km^2].

0.6 % of Canada is built environment (HA 1986:174) = 0.006 * 997.1E6 [ha] = 60,000 [km^2].

Typical urban densities: For example, Vancouver with approximately 36 people per hectare uses about 0.03 [ha/cap] locally. In lower density settings, such as rural towns and villages, or suburban areas of metropolitan areas have typically population densities below 10 [people/ha]. This density corresponds to 0.1 [ha/cap]. Some of the built environment is not located within the municipal boundaries; for example, people in a municipality use land from elsewhere for transporting resources, mining, and providing other services.

CALCULATIONS:

5,500,000 [ha] / 26.5E6 [Canadians] = 0.21 [ha/cap]
6,000,000 [ha] / 26.5E6 [Canadians] = 0.23 [ha/cap]
7,900,000 [ha] / 26.5E6 [Canadians] = 0.30 [ha/cap]

RESULT:

0.21 [ha/cap]　　　range: 0.21...0.30 [ha/cap]

c11 vegetarian food (includes c10 FOOD)

REFERENCES:
Assumption: area for growing vegetables and fruits is considered to be garden area.
Aggregated production and trade figures for vegetables:
1,924,000 [t] vegetables are produced in Canada.
145,000 [t] of tomatoes are imported for 102,623,000 $ (FAOa 1990:tb51).
2,290,850,000 $ - 478,920,000 $ = 1.8 billion $ is the value of Canadian vegetable and Fruit net import, 1989 (FAOa 1990:tb14).

For this simplified rough estimation of garden space, the assumed average yield for vegetables (and fruits) is 15 [t] per hectare (Table A2.2). {Van Bers *et al.* (1992) predict organic crop yields for Canada: 18,339 [kg/ha] for vegetables, 8,131 [kg/ha] for fruits}.
The average Canadian consumes approximately 70 kg of vegetables per year (Table A2.4).

The appropriated garden area by Canadian consumers:
added up from FAO statistics {underestimates area because FAO misses out on some produces}: 354,000 [ha] of garden area appropriated (FAOa, FAOb 1990) (see Table A2.2).
added up and adjusted by a fruit factor (for missing fruit that do not add up in the FAO statistics) and vegetable factor (for missing vegetables that do not add up in the FAO statistics) 417,000 [ha] of garden area appropriated (Table A2.2).

CALCULATIONS:
An estimate of the imported quantities are: {assuming tomato being an average vegetable}. 1.8E9 [$] * 145,000 [t tomatoes] / 102,623,000 [$] {using data for tomatoes} = 2,540,000 [t] vegetables imported per year.

Per capita consumption of vegetables:
2,540,000 [t/yr] imported + 1,924,000 [t/yr] homegrown = 4,470,000 [t/yr]; 4,470,000 [t/yr] * 1000 [kg/t] / 26.5E6 [Canadians] = 169 [kg/cap/yr] {which is much higher than the reported 70 kg. However, this figure includes processing waste}.

Three calculations for the per capita appropriated gardening area for fruit and vegetables:
4,470,000 [t/yr]/ 15 [t/ha/yr] / 26.5E6 [Canadians] = 297,600 [ha] / 26.5E6 [Canadians] = 0.011 [ha/cap].
354,000 [ha] / 26.5E6 [Canadians] = 0.013 [ha/cap] (see Table A2.2) {underestimate}.
417,000 [ha] / 26.5E6 [Canadians] = **0.016** [ha/cap] (see Table A2.2).

RESULT:
0.02 [ha/cap]   range: 0.01-0.02 [ha/cap]

==

c20 HOUSING
It is assumed that the garden area per capita is approximately 200 [m^2] = 0.002 [ha/cap] {i.e., it is much smaller than 0.01 [ha/cap]}.

==

D - CROP LAND: CULTIVATED SYSTEMS

d10 FOOD

REFERENCES:

Crop land in Canada and its agricultural production:

45,900,000 [ha] cropland is available in Canada. This corresponds to 1.73 [ha] cropland per Canadian, 1990 (WR 1992:274).

2,200 [kg/ha] is the average cereal yields in Canada (1988-90) (WR 1992:272).

47,355,000 [t] cereals produced on average in Canada (WR 1992:272).

Cereal production equivalent: 45,900,000 [ha] * 2,200 [kg/ha] * 0.001 [t/kg] = 100,980,600 [t] = 1.01E8 [t].

Therefore, the percentage of crop land used for cereal production 47,355,000 [t] / 100,980,600 [t] = 47 %.

Some data characterizing Canadian agricultural practice {not used in these calculations}:

47 [kg/ha/yr] of fertilizer used on average in Canada (WR 1992:274).

54,767 [t/yr] of pesticide active ingredients used in Canada (WR 1992:274).

725,000,000 [Cdn$] are the cost for the annual Canadian pesticides (CE 1992:9-22).

756,300 tractors are used in Canada (WR 1992:274).

156,700 harvesters in Canada (WR 1992:274).

For soil degradation see (WR 1992:290).

Trade figures for cereals:

22,469,000 [t] net annual cereal export 1987-89 (WR 1992:278);

341,699 [t] net annual vegetable oils export 1987-89 (WR 1992:278);

392,909 [t] net annual pulses export 1987-89 (WR 1992:278).

CALCULATIONS:

1st calculation:

see FAO-data in Table A2.2

d11+d12 = 0.60 [ha/cap]

2nd calculation:

percentage of cereals for domestic consumption:

1 - (22,469,000 [t/yr] / 47,355,000 [t/yr]) = 53 %

If this percentage is also assumed to be the percentage for all other Canadian agricultural production, then the crop land for domestic consumption would add up to: 1.73 [ha/cap] * 53 % = 0.92 [ha/cap].

RESULT:

0.60 [ha/cap] range: 0.60...0.92 [ha/cap]

=======================================

d11 vegetarian products

REFERENCES:

12,254,000 [ha] cropland is used for cereal production (Table A2.2).

21 % of crop for direct human food consumption, i.e., for the vegetarian portion of the human diet (WR 1992:276).

19,090,000 [ha] is the total appropriated farm land for providing all the food consumed in Canada (Table A2.2).

17,150,000 [ha] is the appropriated land for food that is shared by animals and people (Table A2.2).

1 [bushel] of corn = 25.45 [kg] of corn (Zaborsky 1980:40).

CALCULATIONS:
1st calculation:
see FAO-data Table A2.2
0.183 [ha/cap]

2nd calculation:
(19,090,000 [ha] - 79%*17,150,000 [ha]) / 26.5E6 [Canadians] = 0.21 [ha/cap]

RESULT:
0.18 [ha/cap]   range: 0.18...0.21 [ha/cap]

======================================

d12 animal products

REFERENCES:
20.7 % of meat produced in Canada is exported (Table A2.3).
79 % of the grain consumed in Canada is fed to livestock (WR 1992:276).
The food supply in Canada in 1986-88 per capita is (FAOb 1990:289) (see also **x10**):
2325 [kcal/cap/day] of vegetable products;
1125 [kcal/cap/day] of animal products.

17,150,000 [ha] is the appropriated land area for food that is shared by animals and people (Table A2.3).
13,068,000 [ha] is the appropriated area for feed stock (Table A2.2).
2.65 [t/ha/yr] is the average cereals yield in Canada (Table A2.2, row #15).
13,020 [kj/kg] is nutritional energy content of cereal or flour (de Looy 1987:132-136).

CALCULATIONS:
Comparison of the energy content of the feed and the energy content of the produced meat:
ACC for feedstock = 13,068,000 [ha] which corresponds to about 13,068,000 [ha] * 2.65 [t/ha/yr] = 34,577,928 [t/yr] of cereals. The cereals contain (34,577,928,000 [kg/yr] * 13,020 [kj/kg]) = 4.5E17 [j] nutritional energy.
Energy in animal products corresponds to 5.5899E16 [j], i.e., on average it requires 8 [j] feedstock to produce 1 [j] of animal products. In fact, for beef this ratio is 16; for pork, turkey, chicken and eggs it is 6; for milk it is 5 (Corson 1990:74, de Looy 1987:132-136).

1st calculation:
see FAO-data Table A2.2
0.42 [ha/cap]

2nd calculation:
79% * 0.60 [ha/cap] = 0.47 [ha/cap]

3rd calculation:
0.18 [ha] provides 2325 [kcal/day]. Therefore, 1125 [kcal/day] of animal products consumed per average Canadian {which needs 8 times more input per [kcal]} would require 0.18 * 8 * 1125 / 2325 = 0.70 [ha/cap].

4th calculation:
The percentage of crop consumed in Canada which is exported through meat trade:
79 % of crop consumed in Canada is fed to cattle. 20.7 % of the meat is exported.
Hence: 79%*20.7% = 16 % of crop consumed in Canada is exported through the meat trade.

13,068,000 [ha] * (100% - 16%) / 26.5E6 [Canadians] = 0.41 [ha/cap]. However, FAO statistics explains only 26,000,000 [ha] out of the total of 45,977,000 [ha] crop producing land = 56 %. Therefore, extrapolating the 0.41 [ha/cap] {presumably = 56%} to 100% would amount to approximately 0.41 [ha/cap] * 100% / 56% = 0.73 [ha/cap].

5th calculation:

Extrapolating from the individual's consumption:
92 [kg/cap/yr] meat, plus 12 [kg/cap/yr] of eggs, plus 313 [l/cap/yr] of milk correspond to 2.12E9 [j/cap/yr] (see Table A2.3).
This would require 8 * 2.12E9 [j/cap/yr] / 13,020 [kj/kg] = 1.70E10 [j/cap/yr] / 13,020 [kj/kg] = 1305 [kg/cap/yr] of cereals. To produce this amount of cereals would require 1305 [kg/cap/yr] / 2646 [kg/ha/yr] = 0.49 [ha/cap].

RESULT:

0.42 [ha/cap] range: 0.42...0.73 [ha/cap]

= =

d41 CLOTHING

REFERENCES:

Cotton production:

236 [kg/ha/yr] was the average US harvest, 1977 (Zaborsky 1980:Vol2:117).

The harvest of cotton ranges from 255 - 560 [kg/ha/yr] for dry land to 560 - 1685 [kg/ha/yr] for irrigated land.

700 [kg/acre/yr] = 1730 [kg/ha/yr] is reported by Coote as a good field harvest in Tanzania. This is considerably more than typical US or Australian harvests (Coote 1992:41).

431 [kg/ha/yr] world average yield of cotton (Rechcigl 1982:Vol2:289).

593 [kg/ha/yr] US average yield of cotton (Rechcigl 1982:Vol2:289).

The apparent cotton consumption in the US in 1977 was 2,559,000 [t/yr] (Rechcigl 1982:Vol2:289). With a US population of 223E6 [Americans in 1977], the per capita consumption becomes 2,559,000,000 [kg/yr] / 223E6 [Americans] = 11.5 [kg/yr].

CALCULATIONS:

1st calculation:

11.5 [kg/cap/yr] / 236 [kg/ha/yr] = 0.05 [ha/cap]

2nd calculation:

11.5 [kg/cap/yr] / 431 [kg/ha/yr] = 0.026 [ha/cap]

3rd calculation:

11.5 [kg/cap/yr] / 593 [kg/ha/yr] = **0.019 [ha/cap]**

4th calculation:

0.008 [ha/cap] (Table A2.2)

RESULT:

0.02 [ha/cap] range: 0.01...0.05 [ha/cap]

= =

d44 tobacco, alcohol, cocoa and coffee

REFERENCES:
Land uses:

16,000 [t/yr] out of 74,000 [t/yr] tobacco harvest exported from Canada (FAOb 1990:tb82 and FAOa 1990:tb98).

151,930 [t/yr] of wine is imported to Canada (FAOa 1990:tb96), and 57,000 [t/yr] produced in Canada (FAOb 1990:tb66).

7 [t/ha/yr] are typical wine yields (FAOb 1990:tb66).

280,000 [ha] of agricultural land are required for hops production in Canada (FAOb 1990:tb81).

CALCULATIONS:
1st calculation:
see FAO-data Table
0.04 [ha/cap]
2nd calculation:

land for tobacco:	40,000 [ha] / 26.5E6 [Canadians]	= 0.001	[ha/cap]
land for wine:	(151,930 + 57,000) [t/yr] / 7 [t/ha/yr] / 26.5E6 [Canad.]	= 0.001	[ha/cap]
land for beer:	280,000 [ha] / 26.5E6 [Canadians]	= 0.011	[ha/cap]
land for tea:	5,050 [ha] / 26.5E6 [Canadians]	= 0.0002	[ha/cap]
land for cocoa:	437,284 [ha] / 26.5E6 [Canadians]	= 0.016	[ha/cap]
land for coffee:	200,389 [ha] / 26.5E6 [Canadians]	= 0.008	[ha/cap]
	TOTAL	= 0.0372	[ha/cap]

RESULT:
0.04 [ha/cap]

==

d60 TOTAL (estimated)

REFERENCES: see Table A2.2 and **d41**.

CALCULATION:
0.02 [ha/cap] (see **d41**) + (0.652-0.008) [ha/cap] (see Table A2.2) = **0.66 [ha/cap]**

RESULT:
0.66 [ha/cap]

==

e12 animal products

REFERENCES:
Of the cattle in Canada:
12,195,000 are meat cattle, and
1,421,000 are milk cattle (FAOb 1990:tb89,tbl99).

Milk and meat consumption in Canada:
89 % of milk is consumed locally (see **x10**).
The net consumption of meat corresponds to 79.3 % of total meat production in Canada, 1989 (Table A2.3).
The area required for cattle:
average carrying capacity is approximately 1 animal unit for half a year per acre = 2.47 [cattle/ha] * 0.5 [yr] = 1.24 [cattle/ha] (Ensminger 1978:593-637).

CALCULATIONS:
1st calculation:
Milk production: 1,421,000 [milk cattle] / (1,421,000 + 12,195,000) [cattle] = 10.4 %, i.e., 10.4 % of the Canadian cattle is milk cattle. Hence: 89% * 10.4% * 32,500,000 [ha] {Canadian pasture} / 26.5E6 [Canadians] = 0.11 [ha/cap] for locally consumed milk.
Meat production: 79.3% of meat is consumed locally; 79.3% * (100% - 89%*10.4%) * 32,500,000 [ha] {Canadian pasture} / 26.5E6 [Canadians] = 0.88 [ha/cap] for meat.
TOTAL = 0.99 [ha/cap]

2nd calculation:
Area needed for cattle {multiplied by percentage locally consumed}:
(1,421,000 * 89% + 12,195,000 * 79.3%) [cattle] / 1.24 [cattle/ha] / 26.5E6 [Canadians] = **0.33 [ha/cap]**

3rd calculation: (for calculating the average productivity of land for meat)
Land needed to produce 1 [kg/yr] of meat:
pasture:
(79.3% * 12,195,000 [cattle] / 1.24 [cattle/ha]) / 2,423,435,000 [kg meat consumed/yr] = 0.00322 [ha*yr/kg]
crop land:
92 [kg meat/cap/yr] / 0.42 [ha crop land for feed stock/cap] (see **d12**) = <u>0.00457 [ha*yr/kg]</u>
TOTAL: 0.00779 [ha*yr/kg]
or 129 [kg/yr/ha] of meat.

RESULT:
0.33 [ha/cap] range: 0.33...0.99 [ha/cap]

==

e41 clothing {wool}

REFERENCES:
The world's average wool production:
1,940,989,000 [kg/yr] of wool, produced by 1,175,524,000 [sheep] (Table A2.3);
1,940,989,000 [kg/yr] / 1,175,524,000 [sheep] = 1.7 [kg/sheep/yr];
US average: 1.9 [kg/sheep/yr], French average: 1.1 [kg/sheep/yr] (Rechcigl 1982:Vol2:297).

The average meat production of sheep: 5.5 [kg/yr] (Table A2.3).
5 sheep correspond to 1 animal unit, i.e., pasture requirement for 5 sheep is 1.24 [ha] (Ensminger 1978:593-637, or see **e12**).

CALCULATIONS:

Wool production:

1.7 [kg/sheep/yr] * 5 [sheep/animal unit] * 1.24 [animal units/ha] = 10.5 [kg/ha/yr] of wool

Meat production:

5.5 [kg/sheep/yr] * 5 [sheep/animal unit] * 1.24 [animal units/ha] = 34 [kg/ha/yr] of meat

Net wool production:

34 [kg/ha/yr] corresponds to (34 [kg/ha/yr] /129 [kg/ha/yr] {see **e12** 3rd calculation} =) 26 % of average meat production. This means that 26 % of a sheep's pasture requirement is used for meat production, the rest is for growing wool. Therefore, the net wool production after deducting the meat production us 10.5 [kg/ha/yr] /(1-0.26) [ha] = 14.2 [kg/ha/yr] net wool production.

World average and Canadian average wool consumption:

1,940,989,000 [kg/yr] / 5.2E9 [people in 1989] = 0.373 [kg/cap/yr]

However, Table A2.3 suggests that Canadian consume only 0.080 [kg/cap/yr]. This low figure seems to be an unlikely estimate, because typically people in OECD countries consume 5 times the amount of the world average (see **x43**). This adds up to

5 [OECD factor] * 0.37[kg/cap/yr] = 1.8 [kg/cap/yr].

Land requirement:

1.8 [kg/cap/yr] / 14.2 [kg/ha/yr] net wool production = **0.13 [ha/cap]**

RESULT:

0.13 [ha/cap]

==

e60 TOTAL (estimated)

REFERENCES:

32,500,000 [ha] of permanent pasture are available in Canada (WR 1992:262).

CALCULATIONS:

1st calculation:

79.3% * 32,500,000 [ha] / 26.5E6 [Canadians] = 0.97 [ha/cap]

2nd calculation:

e12 + e41 = 0.46 [ha/cap]

RESULT:

0.46 [ha/cap] range: 0.46...0.97 [ha/cap]

==

Forest productivity estimates:
The quantity of wood fibres in various forest types in Canada is estimated at (CE 1991:10-6:tbl10.1):

350 [m^3/ha] overmature forests in B.C. (only 0.18 % of B.C. forest area).

255 [m^3/ha] mature forests in B.C. (B.C. average).

163 [m^3/ha] mature forest (Canadian average). For this handbook, 163 [m^3/ha] is used as the typical amount of average harvests.

107 [m^3/ha] average forest in Canada.

Average forest productivity:

70 years rotation assumed (personal communications Faculty of Forestry, UBC). *The State of Canada's Environment* states cutting cycles of 50-80 years (CE 1991:10-15).

Therefore, we assume in this study a sustainable yield on forest land of 163 [m^3/ha] / 70 [yr] = 2.33 [m^3/ha/yr] roundwood.

CALCULATION AND RESULT:
The average productivity of Canadian forests would be 163 [m^3/ha]/70 [yr] = 2.3 [m^3/ha/yr]. {This is more than 2 [m^3/ha/yr] that Maria Buitenkamp ***et al.***'s study *Action Plan Sustainable Netherlands* uses as world average (1993:82, see also Chapter V). However, for international comparisons, the Dutch figure should be used. It might also be advisable to confirm this figure with a literature review because often much higher forest productivity are cited (which mostly turn out to be optimistic productivity estimates of forest plantations).}

= =

f10 FOOD

REFERENCES:
For all paper related land use calculations, we assumed that the Canadian paper consumption average is 244 [kg/yr/cap] (see **x43**). The break-up for the various paper uses such as printing (63%), packaging (22%), food wrapping (8%), and household operation (7%) is taken from the Ontario statistic in **x43**. For this entire section a wood to paper conversion ratio of 1.8 [m^3 wood/t paper] is assumed (see **f60**, in calculations).

CALCULATIONS:
244 [kg/cap/yr] * 8% * 1.8 [m^3 wood/t paper] / 1000 [kg/t] * 70 [yr] / 163 [m^3 harvest/ha] = **0.015 [ha/cap]**

RESULT:
0.02 [ha/cap]

= =

f21 housing construction and maintenance

REFERENCES:
Material requirement per house: 23.6 [m^3] of wood required to build an average Canadian house (CE 1991:10-11), family residencies are assumed to be the same.

40,000 [acre] of prime forest contain wood enough to build 100,000 homes (US Forestry Service in Mt.Helen exhibit, Washington State).

Canadian household size: 2.72 people per household (see Table A2.1:General Data, FE 1989:32).

The average home contains (Sheltair 1991a:28)

15,035 [kg] lumber and timber,
7,443 [kg] veneer and plywood,
2,870 [kg] woodwork, and
2,524 [kg] building paper.

The assumed life span of average Canadian house is 40 years (consistent with Sheltair 1991).

CALCULATIONS:

1st calculation:

1.5 {see Brown in **f60**} * 23.6 [m^3] / 163 [m^3/ha] * 70 [yr] / 40 [yr] / 2.72 [cap/house] = 0.14 [ha/cap] {only residential}

Or, with US figures on wood requirements for residential homes: 40,000 [acres] / 2.47 [acres/ha] / 100,000 homes * 70 [yr] / 40 [yr] / 2.72 [cap/house] = 0.11 [ha/cap] {only residential}.

2nd calculation:

Lumber consumption 16,204,000 [m^3] corresponds to 1.29 (see **f60**) * 16,204,000 [m^3] = 21,000,000 [m^3] of logs.

Shingles and shakes consumption corresponds to 5,000,000 [m^3] of logs.

26,000,000 [m^3] / 26.5E6 [Canadians] * 70 [yr] / 163 [m^3 harvest/ha] = 0.42 [ha/cap] {includes operation and construction}.

3rd calculation:

One House contains

15.035 [t] / 0.6 [t/m^3] * 1.5 (see Brown in **f60**)		= 38 [m^3] wood for lumber and timber {might be an over-estimate (see Sheltair 1991)}
7.443 [t] / 0.6 [t/m^3] * 1.5		= 19 [m^3] wood for veneer and plywood
2.870 [t] / 0.6 [t/m^3] * 1.5		= 7 [m^3] wood for woodwork
2.524 [t] * 1.83 [t/m^3]		= 5 [m^3] wood for building paper
	TOTAL	69 [m^3] of roundwood equivalent.

69 [m^3] / 163 [m^3/ha] * 70 [yr] / 40 [yr] / 2.72 [cap/house] = 0.27 [ha/cap] {only residential}. If the ratio between residential construction and commercial construction is the same as in the GDP distribution, then the commercial construction adds up to another 18%/60% = 30 % of the residential construction. Therefore, we assume that the total construction requires 130% * 0.27 [ha/cap] = **0.35 [ha/cap]**.

The remaining 0.42-0.35 [ha/cap] = 0.07 [ha cap] (see 2nd calculation) could be composed of 0.04 [ha/cap] for maintenance and 0.03 [ha/cap] for furniture. 0.04 [ha/cap] for maintenance would mean that (0.04/0.35 =) 11 % of the wood of a house would be replaced over its entire life span.

RESULT:

0.35 [ha/cap] range: 0.11...0.42 [ha/cap]

==

f22 housing operation

REFERENCES:

(see **f10**)

CALCULATIONS:

244 [kg/cap/yr] * 7% * 0.0001 [t/kg] * 1.8 [m^3/t] * 70 [yr] / 163 [m^3 harvest/ha] = 0.013 [ha/cap]

TOTAL: 0.01 [ha/cap] + 0.04 [ha/cap] {for maintenance (see **f21**)} = 0.02 [ha/cap]

RESULT:
0.05 [ha/cap]

=======================================

f40' packaging

REFERENCES:
Note: there is a contradiction in the data on paper packaging. On the one hand, 113 [kg/cap] (in US) {see **x40 packaging**} versus 244 [kg/cap/yr] * 22 % = 53.6 [kg/cap] for Ontario figures (see **f10**) {discrepancy of factor 2!}.

CALCULATIONS:
Consumption of non writing/reading paper, paperboard, and other paper, minus export: 2,695,000 + 1,027,000 - 616,000 - 944,000 + import [t/yr] (FF 1990:46,47) = 6,197,000 [t/yr] (PED 1992:220).
6,197,000 - (1,493,000 + 2,656,000 - 761,000) [t/yr] = 2,809,000 [t/yr] of packaging material
2,809,000 [t/yr] * 1.8 [m^3/t] / 26.5E6 [Canadians] * 70 [yr] / 163 [m^3 harvest/ha] = 0.082 [ha/cap].

244 [kg/cap/yr] * 22% * 0.001 [kg/t] * 1.8 [m^3 wood/ t paper] * 70 [yr] / 163 [m^3 harvest/ha] = **0.041 [ha/cap]**.

RESULT:
0.04 [ha/cap] range: 0.04...0.08 [ha/cap]

=======================================

f42 furniture and appliances

REFERENCES:
It is assumed that every Canadian buys on average 40 [kg/cap/yr] of wooden furniture per year.

CALCULATIONS:
40 [kg/cap/yr] * 0.001 [t/kg] / 0.6 [t/m^3] * 70 [yr] / 163 [m^3/ha] = **0.03 [ha/cap]**.
(see also **f21**)

RESULT:
0.03 [ha/cap]

=======================================

f43 books and magazines

REFERENCES:
17-30 trees are saved per 1 [t] of recycled paper (CE 1991:10-22).
2 [t] of wood are required per one [t] of paper produced (SEF 1991:223).
1.8 [m^3] of wood are required per [t] of paper produced in Canada (see **f60**).
1,474,000 + 1,221,000 [t] of paper waste are generated in Ontario per year (CE 1991:25-6).
Paper consumption: 1,493,000 [t] newsprint, 1989 (PED 1992:220), 2,656,000 - 761,000 [t] of book and writing paper, 1986 (FF 1990:46,47).
(see also **f10**)

CALCULATIONS:
244 [kg/cap/yr] * 63% * 0.001 [kg/t] * 1.8 [m^3 wood/ t paper] * 70 [yr] / 163 [m^3 harvest/ha] = 0.12 [ha/cap].
Newsprint consumption: (1,493,000 + 2,656,000 - 761,000) [t/yr] * 1.8 [m^3/t] = 6,098,400 [m^3/yr]
6,098,400 [m^3/yr] / 26.5E6 [Canadians] * 70 [yr] / 163 [m^3 harvest/ha] = **0.099 [ha/cap]**.

RESULT:
0.10 [ha/cap]   range: 0.10...0.12 [ha/cap]

==

f60 TOTAL (estimated)

REFERENCES:

The Canadian roundwood industry, 1986:

177,097,000 [m^3] of roundwood was harvested (on 930,000 [ha] (FF 1990:30)), of which 124,953,000 [m^3] was processed into logs and bolts, and 42,527,000 [m^3] into pulp (FF 1990:30). This produces 21,512,000 [t] of wood-pulp (PED 1992:221). 14,157,000 [t] of pulp (PED 1992:220) produces 15,259,00 [t] of paper products. {Note: it would be double counting to include pulpwood as well as paper products in the aggregate statistics, because both are merely a stage in the process of producing paper}.

Consumption estimates:

In 1986, the Canadian forest industry produced 53,059,000 [m^3] of lumber out 68,701,000 [m^3] roundwood {this corresponds to a loss of (68,701,000 - 53,059,000) [m^3] / 68,701,000 [m^3] = 22.8 %; or, 1 [m^3] of lumber requires (68,701,000 / 53,059,000 =) **1.29** [m^3] of roundwood}. 16,204,000 [m^3] of the lumber was for Canadian (domestic) consumption; 38,274,000 [m^3] was for export {1,400,000 [m^3] imported} (FF 1990:35).

48,000,000 [m^3] shingles and shakes were produced, of which 43,000,000 [m^3] were exported.

The 1986 domestic consumption of plywood {1,936,000 [m^3]}, particle board {1,008,000 [[m^3]}, and wafer board {741,000 [m^3]} adds up to a total of 3,685,000 [m^3] (FF 1990:37-39), while all domestically processed lumber was recorded to be 5,700,000 [m^3], 1987 (FF 1990:7).

Newsprint consumption in Canada, 1989: 1,493,000 [t] (PED 1992:220).

Other paper board and paper production in Canada, 1987: 6,378,000 [t] of which 4,506,000 [t] (or 70.6 %) were consumed in Canada.

FOREST PRODUCTS, in Canada, the US, and the World

(in 1987, FF 1990:5,7)	CANADA	U.S.A.	WORLD
HARVEST			
industrial softwood roundwood	174,789,000 [m^3]	319,408,000 [m^3]	1,133,953,000 [m^3]
softwood, lumber	61,045,000 [m^3]	88,320,000 [m^3]	377,272,000 [m^3]
woodbased panels	6,776,000 [m^3]	33,991,000 [m^3]	121,995,000 [m^3]
woodpulp	23,035,000 [t]	54,058,000 [t]	145,732,000 [t]
newsprint	9,673,000 [t]	5,300,000 [t]	30,672,000 [t]
other paper and paperboard	6,384,000 [t]	62,232,000 [t]	182,165,000 [t]
CONSUMPTION			
softwood, lumber	20,370,000 [m^3]	116,201,000 [m^3]	374,370,000 [m^3]
woodbased panels	5,700,000 [m^3]	36,808,000 [m^3]	122,962,000 [m^3]
woodpulp	14,602,000 [t]	54,068,000 [t]	145,126,000 [t]
newsprint	901,000 [t]	13,135,000 [t]	31,172,000 [t]
other paper and paperboard	4,524,000 [t]	61,639,000 [t]	80,888,000 [t]

Canadian consumption	in 1990 (PED 1990:219,73)
softwood, lumber:	19,895,000 [m^3]
woodbased panels:	5,541,000 [m^3]
woodpulp:	15,524,000 [t]
newsprint:	1,183,000 [t]
other paper and paperboard:	5,075,000 [t]

Statistics on the aggregate Canadian forest:

216E6 [ha] stocked productive forest in Canada (CE 1991:10-4).

23.1E9 [m^3] standing biomass in Canada (CE 1991:10-6).

243.7E6 [ha] inventoried timber-productive land in Canada (PED 1992:xx) with a standing biomass of 20,700E6 [t] (PED 1992:2). 20.7E9 [t] / 0.6 [t/m^3] / 243.7E6 [ha] = 142 [m^3/ha] standing biomass, 40 % to 50 % of which is presumably wood (Ajtay *et al.* 1979:165).

191.4E6 [m^3] of roundwood was harvested in Canada in 1989, 9 % hardwood and 91 % softwood (PED 1992:xx).

Wood loss in value adding processes (Brown 1985):

1.2 [t] trees per 1 [t] logs (p60).

1.5 [t] logs per 1 [t] lumber (p62) {Canadian average is 1.29, see above}.

2.5 [t] wood chips per 1 [t] fiberboard (p65).

2.3-5 [t] logs per 1 [t] market pulp (p66-73).

1.1 [t] market pulp per 1 [t] paper (p76, 83).

4.6-4.9 [t] logs per 1 [t] paper (p78, 86).

CALCULATIONS:

Wood loss in Canadian pulp and paper industry:

42,527,000 [m^3] of roundwood for pulp (FF 1990:30) produces 21,512,000 [t] woodpulp => loss factor = 1.98 [m^3/t]; 14,157,000 [t] of pulp produces 15,259,00 [t] of paper products => loss factor = 0.93 [t/t]; combined factor: 1.98 * 0.93 = 1.83 [m^3/t]. In other words, **to produce one [t] of paper, 1.83 [m^3] of wood are required.**

The total Canadian consumption of forest products per year in [m^3] roundwood:

lumber consumption: 16,204,000 [m^3] * 1.29 for roundwood equivalent	=	21,000,000 [m^3] of roundwood
shingles and shakes consumption:	=	5,000,000 [m^3] of roundwood
newsprint consumption: 1,493,000 [t] * 1.83 [m^3/t]	=	2,732,000 [m^3] of roundwood
other paper consumption: 4,506,000 [t] * 1.83 [m^3/t]	=	8,245,000 [m^3] of roundwood
	TOTAL:	36,977,000 [m^3] of roundwood

36,977,000 [m^3/yr] / 26.5E6 [Canadians] * 70 [yr] / 163 [m^3 harvest/ha] = **0.62 [ha/cap]**

RESULT:

0.62 [ha/cap]

==

T - TOTAL

t60 TOTAL

REFERENCES:

In 1991, there were 15,050,000 people living in the Netherlands which has an area of 33,920 [km^2] (WR 1994:269,285).

The build-up land in the Netherlands amounts to 538,000 [ha] (WR 1994:285).

The commercial energy consumption in the Netherlands in 1991 was 3,197 [Pj] or 212 [Gj/cap/yr] (WR 1992:317). In this calculation, 212 [Gj/cap/yr] is used to represent the fossil fuel consumption. However, a "back-of-the-envelope" calculation shows that this might underestimate the true fossil fuel consumption. Assuming that 17 percent of commercial energy consumption consisted of electricity (OECD average, Flavin & Lenssen 1994:5), and 36 [Pj] of electricity were produced by nuclear plants (WR 1994:333), it follows that the remaining (3,197*0.17 - 36 =) 507 [Pj] were thermically produced within the Netherlands (or imported). Assuming that all the remaining electricity was thermically produced at an average efficiency of 33 %, the total fossil fuel consumption would add up to (3,197*0.83 + 3*507 =) 4,174 [Pj]. With a population of 15 million, the per capita consumption of fossil fuel would then add up to 277 [Gj/cap/yr].

CALCULATIONS:

forest: assuming a consumption of 1.1 [m^3/cap/yr] and a forest productivity of 163 [m^3/ha] every 70 years, this consumption corresponds to (1.1 * 70 / 163 =) 0.47 [ha/cap] of forest land.

fossil fuel: 212 [Gj/cap/yr] corresponds to (212 [Gj/cap/yr] / 100 [Gj/ha/yr] =) 277 [ha/cap].

RESULT:

food:	cropland	0.45 [ha/cap]*
	rangeland	0.61 [ha/cap]*
forest:	1.1 [m^3/cap/yr]* corresponds to	0.47 [ha/cap]
fossil fuel:	212 [Gj/cap/yr] corresponds to	2.12 [ha/cap]
forgone natural productivity (settlements and roads):		
	(538,000 [ha] / 15E6 [Dutch people])	0.04 [ha/cap]
footprint:		**3.69 [ha/cap]**

* from Buitenkamp *et al.* (1993:60,83).

For the entire country, this adds up to an Ecological Footprint of (15E6 [Dutch people] * 3.69 [ha/cap] * 0.01 [ha/km^2] =) 550,000 [km^2]. Assuming average ecological productivity in the Netherlands, this is 16 times more than the 33,920 [km^2] of land that are locally available.

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APPENDIX 2.2: SUPPLEMENTARY TABLES ON FOOD CONSUMPTION AND ENERGY CONTENTS

TABLE A2.1 General Data: Population, Land Area, and Finances

1. Population Statistics {for Canadian demographic statistics see report 91-209}

Canada
The Canadian population in 1990: 26,520,000 + 228,000 [per yr] (WR 1992:246).
There were:
26,452,000 Canadians, 1990 (HA 1991:14);
27,296,859 people living in Canada on Thursday, April 15, 1993 (from Statistics Canada, tel: (604) 666-3691);
8,849,370 families in Canada, 1986 (HA 1991:99);
8,991,670 total occupied private dwellings in Canada, 1986 (HA 1991:76).
Canadian household size: 2.72 people per household (FE 1989:32).

British Columbia
3,282,061 people living in British Columbia on Thursday, April 15, 1993 (from Statistics Canada, tel: (604) 666-3691).

Ontario
There were:
9,100,000 people in Ontario, 1986 (HA 1991:19);
10,084,885 people living in Ontario on Thursday, April 15, 1993 (from Statistics Canada, tel: (604) 666-3691).

United States
US population, 1990: 249,220,000 + 1,988,000 [per yr] (WR 1992:246).

Earth
World population, 1990: 5,292,200,000 + 90,000,000 [per yr] (WR 1992:246).

2. Land Area Statistics

Earth
(FAOb 1990:tb1) for 1988
13,382,469,000 [ha] total terrestrial area {including fresh water bodies}
13,069,253,000 [ha] land area
1,475,426,000 [ha] arable and permanent crop land
thereof 1,373,404,000 [ha] arable land, and 102,022,000 [ha] permanent crop
3,211,959,000 [ha] permanent pasture
4,049,041,000 [ha] forest and woodland
4,332,825,000 [ha] other land.

Canada	(PED:3)	Canada (FAOb 1990:tb1)
	997.1E6 [ha]	991.6E6 [ha] Total Area in Canada
	75.5E6 [ha]	75.5E6 [ha] water
	453.3E6 [ha]	356E6 [ha] forest
	67.8E6 [ha]	46E6 [ha] arable + 32.5E6 [ha] pasture (agricultural land)
	400.4E6 [ha]	481E6 [ha] other.

United States (FAOb 1990:tb1) for 1988
937,261,000 [ha] Total Area
916,660,000 [ha] land area
189,915,000 [ha] arable and permanent crop land
thereof 187,881,000 [ha] arable land, and thereof 2,034,000 [ha] permanent crop
241,467,000 [ha] permanent pasture
265,188,000 [ha] forest and woodland
220,090,000 [ha] other land.

Major Ecosystems of the World and their Surface Covering (for the period 1970-1990) (in 1,000,000 ha)

TERRESTRIAL ECOSYSTEMS	**14,400-14,796**
Evergreen forests	2,704
Deciduous forest	1,213
Evergreen forests	687
Deciduous woodlands	624
Shrubland/thicket (chaparral, maquis, brush)	1,207
Grassland	2,691
Arctic/alpine tundra	743
Desert	1,555
Ice/glaciers	1,640
Cultivated area (agriculture/pasture)	1,400
Human occupied area (built environment)	332
AQUATIC ECOSYSTEMS	**530**
Wetlands	330
Lakes and streams	200
MARINE ECOSYSTEMS	**36,100-36,236**
Close to shore	4,000
Open ocean	33,200

(de Groot 1992:305)

3. Financial Statistics

Canadian national statistics

500,337E6 [US$] Canadian GNP in 1989 (WR 1992:236).
451,839E6 [$] Canadian GDP in 1986 (HA 1991:84).
123,198E6 [US$] Canadian Government expenditures 1988 (WR 1992:240).
26,000 [$] direct expenditures of average Canadian household in 1986 (HA 1991:99).
46,659 [$] average family income in Canada in 1991, resulting in a 42,612 [$] after-tax and transfer income. Average family received 6,372 [$] in cash transfer and paid 10,519 [$] in income tax (Globe and Mail, May 4, 1993:A1).
16,316 [$] is the average income of families in the lowest 20 percent income group in 1991 (after tax and transfers). 9,692 [$] or 57.1 % of their income is received through cash transfer (Globe and Mail, May 4, 1993:A1).
79,381 [$] is the average income of families in the top 20 percent income group in 1991 (after tax and transfers). Their pre-tax income was 102,999 [$] (Globe and Mail, May 4, 1993:A1).

Canadian consumer price index (from Statistics Canada, tel: (604) 666-3691, see also catalogue 62-001).

1986	100
1987	104.4
1988	108.6
1989	114.0
1990	119.5
1991	126.2
1992	128.1
1993 (February)	130.0
1994 (May)	129.9

TABLE A2.2: CANADIAN CROP PRODUCTION AND CONSUMPTION

source: FAO production and trade statistics (FAOa, FAOb 1990)

FAO#	name	WORLD yield kg/ha	WORLD prodn 1000t	WORLD ACC 1000ha	CANADA area 1000ha	CANADA prodn 1000t	CANADA import 1000t	CANADA export 1000t	CANADA consum 1000t	CANADA ACC 1000ha	FAO#
15	**CEREALS**	2646	1864852	704782	21935	47955	1067	16597	32425	12254	15
16	wheat	2381	538056	225979	13638	24383	2	11487	12898	5417	16
17	rice	3350	506291	151132			147		147	44	17
18	Coarse Grain, and others	3000	15645	5215							18
19	barley	2348	168964	71961	4701	11672	1	3897	7776	3312	19
20	corn	3627	470318	129671	1014	6400	898	31	7267	2004	20
21	rye	2095	34893	16655	364	835	6	157	684	327	21
22	oats	1821	42197	23172	1705	3549	0	945	2604	1430	22
23	millet + other cereals	814	30512	37484			12	92	-80	-98	23
24	sorghum	1305	57976	44426							24
25	**ROOT CROPS**	12606	590176	46817	112	2754			2754	218	25
26	potatoes	15315	276740	18070	112	2754	203	390	2567	168	26
27	sweet potatoes	14408	133234	9247							27
28	cassava	9842	147500	14987							28
29	yams	9239	23459	2539							29
30	taro	5379	5814	1081							30
31	**PULSES** 32-36,39 (?)	828	57985	70030	382	482	26	357	151	182	31
32	beans, dry	588	15872	26993	49	77			77	131	32
33	broad beans	1270	4058	3195	40	25			25	20	33
34	peas, dry	1631	16447	10084	178	274			274	168	34
35	chick-peas	747	7429	9945							35
36	lentils	737	2242	3042	115	105			105	142	36
37	soybeans + soya cake	1841	107350	58311	540	1219	785	225	1779	966	37
38	ground nuts	1124	22594	20101			66		66	59	38
39	castor beans	759	1155	1522							39
40	sunflower seeds	1405	21867	15564	56	69	26	15	80	57	40
41	rapeseed + oilseed trade	1239	22302	18000	2908	3058	590	442	3206	2588	41
42	sesame seed	336	2352	7000			3		3	10	42
43	linseed	497	2121	4268	640	531			531	1068	43
44	safflower seeds	720	908	1261							44
45	seed cotton	1525	49085	32187							45
46	cottonseed	1000	30703	30703			1		1	1	46
	olives	1000	9134	9134							
	olive oil	1000	1726	1726							
47	coconuts + copra	1000	38091	38091			32		32	32	47
48	palm kernels	1000	3014	3014							48
	palm oil	1000	10165	10165							
49	**VEGETABLES AND MELONS**	15000	433940	28929		1924			1924	128	49
	FRUITS WITHOUT MELONS	7000	336073	48010		748			748	107	
	TREENUTS, TOTAL	1000	4418	4418							
50	cabbages	21620	36640	1695	5	135			135	6	50
51	artichokes	9694	1289	133							51
52	tomatoes	25096	68328	2723	15	548	145	3	691	28	52
53	cauliflower	13642	5548	407	3	48			48	4	53
54	pumpkins, squash, gourds	11207	6568	586							54
55	cucumbers + gherkins	14512	12774	880	4	85			85	6	55
56	eggplants	13287	5746	432							56
57	chili peppers, green	8292	8766	1057	2	26	6		32	4	57
58	onions, dry	13796	29319	2125	4	131	70	4	197	14	58
59	garlic	6143	3012	490							59
60	beans, green	6883	3104	451	9	51			51	7	60
61	peas, green	6083	4734	778	18	54			54	9	61
62	carrots	22235	13684	615	7	276			276	12	62
63	watermelons	14716	28423	1931							63
64	cantaloupes + oth. melons	14108	8907	631	0	2			2	0	64
65	grapes + dried raisins	7023	59158	8423	7	63	300		363	52	65
	{wine 29,055,000 [t], whereof in Cda 57,000 [t]. raisins 988,000 [t]}										
66	dates	7000	3113	445			6	1	5	1	66
67	sugar cane + sugar trade	60229	1007184	16723			701	4	697	12	67
	{Less Developed Countries' (LDC) average: 13 [kg] of sugar canes produce 1 [kg] of sugar}										
68	sugar beets	35573	305882	8599	23	805			805	23	68
	{6 [kg] beets produce 1 [kg] sugar}										

FAO#	name	WORLD yield kg/ha	WORLD prodn 1000t	WORLD ACC 1000ha	CANADA area 1000ha	CANADA prodn 1000t	CANADA import 1000t	CANADA export 1000t	CANADA consum 1000t	CANADA ACC 1000ha	FAO#
69	apples	7000	40226	5747		495	90	75	510	73	69
70	pears, peaches, plums	7000	24779	3540		78	97		175	25	70
71	oranges, mandarins, lemon	7000	65593	9370			376		376	54	71
72	grapefruit, citrus fruits	7000	6300	900							72
	apricots	7000	2162	309		3			3	0	
73	avocados, mangos, pineap.	7000	26313	3759			52		52	7	73
74	bananas, papayas, planta	7000	72523	10360			322		322	46	74
75	strawb., raspb., currants	7000	3319	474		44			44	6	75
76	almonds, pista., hazelnuts	1000	2053	2053							76
77	cashew, chestnuts, walnuts	1000	1933	1933							77
78	COFFEE	514	5775	11235			108	5	103	200	78
79	COCOA beans, excl. import	464	2467	5317			203	0	203	437	79
80	TEA	2673	2475	926			15	2	14	5	80
81	hops + malt trade	1408	112038	79572	280	450	1	0	451	320	81
82	TOBACCO	1469	7293	4965	32	74	1	16	58	40	82
83	flax fibre + tow	575	769	1337							83
84	hemp fibre + tow	658	217	330							84
85	jute and alike fibres	1551	3331	2148			0		0	0	85
86	sisal	884	430	486							86
87	cotton lint	1000	18106	18106			47		47	47	87
	other fibre crops	1000	449	449		70			70	70	
	natural rubber	1000	4777	4777			92		92	92	

CROSS CHECKING AND DATA ANALYSIS OF CANADIAN AGRICULTURAL ACC

sum of cereal area in Canada	21,422,000 [ha] rather than 21,935,000 [ha]
sum of crop area in Canada (###)!	26,469,000 [ha] rather than 45,980,000 [ha] arable and permanent crop land (FAOb 1990:tb1)

ACC cereal area	12,821,000 [ha] rather than 12,254,000 [ha]
ACC for potential animal food	16,542,000 [ha]
ACC for all crop, excl coffee etc.	17,878,000 [ha]
ACC for vegetarian crop	4,810,000 [ha] or 5,075,000 [ha] (prop. to veg/animal product intake)
ACC for feedstock	13,068,000 [ha] or 12,803,000 [ha]
ACC FOR GARDENS, total	354,000 [ha] or 417,000 [ha] if adjusted by fruit and veg. factor
weight of garden produces	2,039,000 [t]
weight of VEGETABLES AND MELONS	1,924,000 [t] of produces require 128,000 [ha] ACC
weight of vegetables produced	1,354,000 [t] of produces require 90,000 [ha] ACC
weight of FRUITS produced	748,000 [t] of produces require 107,000 [ha] ACC
weight of fruits produced	683,000 [t] of produces require 276,000 [ha] ACC
ACC for coffee, cocoa, tea and tob	1,003,000 [ha]
ACC for fibres and rubber	209,000 [ha]
TOTAL CROP LAND OF CANADIAN ACC	19,090,000 [ha]
TOTAL CROP LAND ACC adjusted	17,150,000 [ha] or 17,189,000 [ha] assuming that 20.7 % of produced meat was exported (see Table 8)

ACC PER AVERAGE CANADIAN FOR CROPS IN [ha] {based on world average yields, and 26.3 million Canadians (in 1989)}

c11 vegetarian products	**0.016 [ha]**	
d11 vegetarian products	**0.183 [ha]**	
d12 animal products	**0.423 [ha]**	
d41 clothing	**0.008 [ha]**	
d44 tobacco and alcohol	**0.038 [ha]**	**{wine not included}**
d60 TOTAL	**0.652 [ha]**	

IN COMPARISON: **THE WORLD'S AGRICULTURAL ACC (WITHOUT PASTURES)**

	(added up)		(FAOb 1990:tb1)
World's total crop area	1,273,144,000 [ha]	rather than	1,475,426,000 [ha]
CEREALS	705,696,000 [ha]	rather than	704,782,000 [ha]
ROOT CROPS	45,924,000 [ha]	rather than	46,817,000 [ha]
PULSES	74,883,000 [ha]	rather than	70,030,000 [ha]
VEGETABLES AND MELONS	14,936,000 [ha]	rather than	28,929,000 [ha]
in weight	236,842,000 [t]	rather than	433,940,000 [t]
FRUITS WITHOUT MELONS	45,380,000 [ha]	rather than	48,010,000 [ha]
TREENUTS	3,986,000 [ha]	rather than	4,418,000 [ha]

TABLE A2.3: CANADIAN ANIMAL PRODUCTS AND THEIR CONSUMPTION

source: FAO production and trade statistics (FAOa, FAOb 1990)

FAO#	LIVESTOCK	WORLD [heads]	CANADA alive [heads]	CANADA slaut./yr [heads]	CANADA import [heads]	CANADA export [heads]
88	horse	60,461,000	33,800			
	mule and asses	57,925,000	4,000			
89	cattle	1,281,472,000	12,195,000	3,775,000	54,598	434,679
	{average slaughtered cattle weighs 261 [kg]}					
90	pigs	846,174,000	10,635,000	15,550,000	630	1,204,400
	{average slaughtered pig weighs 76 [kg]}					
	sheep	1,175,524,000	728,000	381,000		
	goats	526,440,000	27,000			
91	chickens	10,574,000,000	108,000,000			
	ducks	527,000,000	1,000,000			
	turkey	234,000,000	6,000,000			

FAO#	MEAT	WORLD prodn [t]	CANADA prodn [t]	CANADA import [t]	CANADA export [t]
92	beef and veal meat	49,436,000	985,000		
93	buffalo meat + fresh meat trade	1,487,000	0	177,100	402,450
94	mutton & lamb + salted meat trade	6,473,000	8,000	1,271	14,867
95	goat meat + canned meat trade	2,365,000	0	21,318	8,854
96	pig meat + exported meat (alive)	67,460,000	1,180,000	14,294	204,815
97	horse meat	482,000	25,000		24,545
	poultry meat	37,817,000	667,000		
	TOTAL MEAT	168,860,000	2,871,000		
	x-check, sum of 92-96	165,520,000	2,865,000		
98	indigenous beef, sheep and pig meat	125,935,000	2,304,000		
	x-check, sum of 92-96 + live export	125,734,000	2,377,815		

FAO#	OTHER ANIMAL PRODUCTS	WORLD prodn [t]	CANADA prodn [t]	CANADA import [t]	CANADA export [t]	CONSUMPTION PER CANADIAN [kg/yr]
99	milk animals IN HEADS	222,846,000	1,421,000			
	milk production	474,020,000	8,250,000	466	91	313
100	milk,other	57,319,000	0			
101	cheese	14,475,276	291,000	20,618	10,739	12
	butter	7,611,826	110,000	108	2,327	4
	evaporated or condensed milk	4,624,429	107,450	2,474	16,375	4
102	milk,dry	2,224,407	10,000	4,563	42,903	
	skim and butter milk	3,928,039	108,400			4
	dry whey	1,601,697	61,350			2
103	hen eggs + egg trade	34,714,112	310,650	10,503	1,818	12
	honey	1,108,776	28,100	636	21,016	1
104	wool, scoured	1,940,989	728	1,347	16	
105	leather	8,645,054	95,709			

DATA ANALYSIS OF CANADIAN ANIMAL PRODUCTS

TOTAL MEAT PRODUCED in Canada in [t]	3,055,521	in %	100.0
TOTAL MEAT CONSUMED in Canada in [t]	2,423,453	in %	79.3
{per capita consumption 92 **[kg/yr]**, assuming 26.3 million Canadians in 1989}			
NET MEAT EXPORT from Canada in [t]	632,068	in %	20.7

FOOD ENERGY IN ANIMAL PRODUCTS IN CANADA

	meat	milk	eggs
nutritional energy in meat, milk, eggs in [Mj/t]	13,000	2,720	6,120

nutritional energy in animal products consumed per capita: 5,823 [kj/cap/day] {= 1,391 [kcal/cap/day]}

TABLE A2.4: FOOD SUPPLY AND CALORIC VALUES FOR AN AVERAGE CANADIAN

FOOD SUPPLIES MOVING INTO CONSUMPTION PER AVERAGE CANADIAN IN 1988

	food energy content [kj/kg]	amount [kg]	total [kj]	percent [%]
cereals	13,020	77	1,001,238	20
sugar	16,800	41	685,440	14
pulses	11,590	4	45,201	0
nuts	23,000	3	73,600	1
oils and fats	32,000	21	656,000	13
fruit (uncanned)	2,000	110	220,200	4
fruit canned	4,000	8	31,200	1
vegetables	300	70	21,030	0
mushrooms	300	3	,750	0
potatoes	3,200	68	218,560	4
meat	11,000	71	781,000	16
eggs	6,000	11	68,400	1
poultry	8,000	28	226,800	5
fish	5,000	7	34,000	1
milk prod.	2,720	288	783,360	16
alcohol beverages	2,000	60 ?	120,000	2
		TOTAL	4,954,678	100

sources: (food energy content: de Looy 1987, apparent food consumption: CY 1992:364-366).

ANALYSIS:

daily vegetarian products:	1,782 [kcal/cap/day]	as opposed to	2,325 [kcal/cap/day]	(FAOb 1990:tbl106)
daily animal products:	1,465 [kcal/cap/day]	as opposed to	1,125 [kcal/cap/day]	(FAOb 1990:tbl106)
	3,247 [kcal/cap/day]	as opposed to	3,450 [kcal/cap/day]	(FAOb 1990:tbl106)

TABLE A2.5: EMBODIED ENERGY IN VARIOUS MATERIALS AND PRODUCTS

paper: embodied production energy
- 61 [Gj/t] of paper produced (SEF:223) **{a43}**
- 30 [Mj/kg] (Hofstetter 1992:Anhang-3)
- 23.6 [Mj/kg] for paper produced in an integrated paper mill (Brown 1985:78)

steel: embodied production energy.
- 25 [Mj/kg] (Hofstetter 1992:Anhang-3) and (WR 1992:149/150)
- 31.1 [Mj/kg] (Cole and Rousseau (1992: average of four figures)
- 30 [Mj/kg] (Fritsche 1989:238)
- 27.7 [Mj/kg] steel from Blast Furnaces and Steel Mills (Brown 1985:268)

aluminum: embodied production energy.
- 100 [Mj/kg] (Hofstetter 1992:Anhang-3)
- 145.0 - 261.7 [Mj/kg] (Cole and Rousseau 1992)
- 260 [Mj/kg] {=72,000 [Kwh therm./t]} (Thomas 1977:11)
- 250 [Mj/kg] (Fritsche 1989:238).

"plastic:" embodied production energy.
- 50 [Mj/kg] (Hofstetter 1992:Anhang-3)
- 49.3 - 122.8 [Mj/kg] (Cole and Rousseau 1992)
- 62 [Gj/t] PE plastic production (SEF 1991:223) **{a40}**
- 65 [Mj/kg] (Fritsche 1989:238)
- 12 [Mj/kg] Plastic Materials and Resins (LDPE) (Brown 1985:148)
- 20.4 [Mj/kg] Miscellaneous Plastic Products (Brown 1985:243)
- 44 - 171 [Mj/kg] (Baird and Aun 1983)

glass: embodied production energy.
- 10.2 - 21.6 [Mj/kg] (Cole and Rousseau 1992)
- 20 [Mj/kg] (Fritsche 1989:238)
- 14.2 [Mj/kg] Flat Glass (Brown 1985:246)
- 17.6 [Mj/kg] Glass Containers (Brown 1985:249)
- 8.4 - 29.3 [Mj/kg] (Baird and Aun 1983)

wood: embodied production energy.
- 2 [Mj/kg] (Hofstetter 1992:Anhang-3)
- 34 [Mj/kg] for fibreboards requiring 2.5 [kg] chips and sawmill waste (Brown 1985:64)
- 10 [Mj/kg] lumber requiring 1.5 [kg/kg] roundwood (Brown 1985:61)

cement: embodied production energy.
- 4 [Mj/kg] (Fritsche 1989:238)
- 8.2 [Mj/kg] Cement, Hydraulic (Brown 1985:255)
- 4.2 [Mj/kg] Brick and Structural Clay Tile (Brown 1985:258)
- 28.2 [Mj/kg] Mineral Wool (Brown 1985:266).

TABLE A2.6: CONSUMPTION ENERGY CONVERSION FOR CONSUMER GOODS AND SERVICES

consumption category	expenditure per category [$ 1993/cap]	energy intensity [Mj/$]	embodied energy [Gj/cap/yr]	land appropriation (adjusted) [ha/cap]
40 GOODS	6,677		45.0576	52
40'packaging				10 {see a40'}
41 clothing	1,887	7.2	13.5864	11
42 furniture	1,089	7.2	7.8408	6
43 books and magazines	173			6 {see a43}
44 tobacco & alcohol	962	7.2	6.9264	6
45 personal care	579	7.2	4.1688	3
46 recreational equipment	1,660	7.2	11.952	10
47 other goods	324	1.8	0.5832	0
50 SERVICES	6,934		21.6189	29
51 government (& military)	1,162	3.6	4.1832	6
52 education	1,593	3.6	5.7348	8
53 health care	1,669	3.6	6.0084	8
54 social services	482	0.45	0.2169	0
55 tourism	206	3.6	0.7416	1
56 entertainment	252	3.6	0.9072	1
57 bank/insurances	576	0.45	0.2592	0
58 other services	991	3.6	3.5676	5

Comment:

This table shows a best estimate for the embodied energy in the various consumption categories. Only category **40'** (packaging) and **43** (books and magazines) are assessed separately. For all other categories, dollars spent in those categories (average *per capita* expenditure over a year) are multiplied by their respective energy intensities. The applied energy intensities were suggested by Hofstetter (1992b:35). To make the assessed embodied energy compatible with the macro data for consumer goods (52 [Gj/cap/yr] for **40**) and services (29 [Gj/cap/yr] for **50**), these results are adjusted by a multiplication factor. This adjustment factor was 0.8 for the consumer goods and 1.35 for the services.

TABLE A2.7: SPECIFIC ENERGY CONTENT[1]

	Energy Content[2]	Density	Source
fossil fuels			
crude oil	38.5 [Mj/l]		(HA 1991:ii)
motor gasoline	34.7 [Mj/l]		(HA 1991:ii)
		680 [kg/m^3] (20 degree C)	(Tuma 1983)
coal anthracite	28.0 [Mj/l]		(Francis & Peters 1980:33 HHV)
diesel	38.8 [Mj/l]		(Francis & Peters 1980:249 HHV)
		850 [kg/m^3]	(Barnard 1984:176)
plant and solar based fuels			
hydrogen	120 [Mj/kg]		(Enc. of Chem. Tech. 1978:337 LHV)
		8.99E(-2)[kg/m^3] (0 degree C = 1 atm)	(Tuma 1983:379)
methanol	17.8 [Mj/l]		(Frances & Peters 1980:287 HHV)
		800 [kg/m^3]	(Barnard 1984:176)
ethanol	23.5 [Mj/l]		(Francis & Peters 1980:287)
		790 [kg/m^3]	(Barnard 1984:176)
veget. oils (average)	34.6 [Mj/l]	900 [kg/m^3]	(Barnard 1984:176)
Soybean oil	35.8 [Mj/l]	910 [kg/m3]	(Barnard 1984:176)
Coconut oil	32.2 [Mj/l]	880 [kg/m3]	(Barnard 1984:176)
primary forest products (measured in dry mass)			
wood	19.8 [Mj/kg]		(Risbrudt & Ellis in Zaborsky 1981:529)
		680 [kg/m^3]	(Tuma 1983:394-395)
bark	20.9 [Mj/kg]		(Risbrudt & Ellis in Zaborsky 1981:529)
solid wood waste	18 [Mj/kg]		(HA 1991:ii)
dry biomass	21 [Mj/kg] = 5 [kcal/g]		(Vitousek *et al.* 1986)
primary agricultural products (measured in dry mass)			
corn	?		
sugar cane	?		
sugar cane bagasse	19.1 [Mj/kg]		(Larson *et al.* 1989:702 in Johanson?)
sugar beet	17.6 [Mj/kg]		(Spedding *et al.* 1981:109)
carrot	17.4 [Mj/kg]		(Spedding *et al.* 1981:109)
wheat	18.4 [Mj/kg]		(Spedding *et al.* 1981:78)
rice	18.0 [Mj/kg]		(Spedding *et al.* 1981:78)
cereal straws	17.8 [Mj/kg]		(Spedding *et al.* 1981:189)

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[1] The data for this table was compiled by Yoshihiko Wada.

[2] In most cases, the source did not reveal whether the energy content referred to the Lower Heating Value (LHV) or the Higher Heating Value (HHV).

TABLE A2.8: APPROXIMATE CONVERSIONS RATIOS FOR BIOMASS PRODUCTIVITY[3]

Typical timber density: timber volume [m^3] to timber weight [tonne] (Marland 1988:39)	* 0.52
Oven dry wood [kg] to heat [MJ] (Barnard 1984:247)	* 20
Oven dry biomass [kg] to carbon [kg] (calculated from Table 2 in Schroeder 1992:35)	* 0.45
Carbon [kg] to heat [Mj] (calculated from above)	* 44.4
Maximum mean annual growth of forest to maximum net primary productivity (NPP) (Farnum *et al.* 1993)	* 2.5

[3] The data for this table was compiled by Yoshihiko Wada.

APPENDIX 2.3: DATA REFERENCES (FOR DATA IN APPENDIX 2)

(Note: [ ] indicates call number at the University of British Columbia libraries)

Ajtay, G.L., P. Ketner, and P. Duvigneaud, 1977. "Terrestrial Primary Production and Phytomass," in Bolin, B., 1977. *The Global Carbon Cycle*. John Wiley and Sons, New York. [QH344 W67 1977 Wood].

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APPENDIX 2.4: ABBREVIATIONS AND UNITS

TABLE A2.9 **Abbreviations and Units**

k	kilo (1000 or 1E3)
M	mega (1E6)
G	giga (1E9)
T	tera (1E12)
P	peta (1E15)
E	exponent of 10, e.g., 2.36E4 = 2.36 * 10*10*10*10 = 23,600
*	multiplied by
/	divided by
()	references
[]	units of measurement
{}	comments
range	refers to the range of results calculated in that section. The figures chosen for the land-use - consumption matrix (in **bold**) are the most realistic estimates, or where the results remain ambiguous, the most conservative ones.

The measurement units follow the metric system, where possible.

1 [cap]	capita, one person
1 [t]	= 1 [metric tonne] = 1,000 [kg] {1 [pound] =0.454 [kg]}
1 [Mj]	= 1E6 [j or joules] = 1E6 [W*s or Watt seconds] = 1/3.6 [kWh] = 1,000/1.05506 [btu] = 947.8 [btu] = 1,000/4.187 [kcal] or [kilocalories] = 238.8 [kcal] {4187 [j] = 1 [kcal], 1.05506 [kj] = 1 [btu], 1 [quad] = 1E15 [btu], 1 [W/m^2] = 315.6 [Gj/ha/yr]}
1 [ha]	= 1 [hectare] = 10,000 [m^2] = 2.472 [acres]
1 [m^3]	= 35.314 [ft^3] = 28.4 [bushels] = 6.292 [barrels] = 0.415 [cord] = 0.221 MBF (or thousand board feet)] {1 [barrel] = 42 [gallons] = 0.15893 [m^3], 1 [gallon] = 3.785 [l or litres]}
1 [yr]	= 1 [year] = 365.24 [d or days] = 8,766.8 [h or hours] = 31.558E6 [s or seconds]

APPENDIX 3

INTERVIEW RESEARCH

Appendix 3.1 summarizes comments from reviewers of the EF/ACC Handbook (Wackernagel *et al.* 1993). Appendix 3.2 provides the names of the key informants that were interviewed. Appendix 3.3 contains a copy of the questionnaire and of the brochure "How Big Is Our Ecological Footprint" (Wackernagel 1993a) which I used for briefing the participants. Finally, Appendix 3.4 lists answers that the key informants gave during the interviews.

APPENDIX 3.1: SUMMARY OF DRAFT HANDBOOK REVIEWS

Over 100 draft handbooks titled *How Big Is Our Ecological Footprint* (Wackernagel *et al.* 1993) were sent out to academics in related fields. The names of these reviewers are identified below. The close to 20 reviews that we received were encouraging. Suggestions were made that more practical examples relevant to municipal planning be included, that it be more action oriented, that the writing style and wording be more accessible rather than academic, that the structure of the document be more inviting, and that electrical energy and the use of fresh water also be included. One reviewer felt that considering only flows in chemical energy might be misleading, as photosynthesis amounts to only about 100 TW while the powering of the Earth's hydrological cycles requires 44,000 TW of solar energy. (However, the counter argument is that the hydrological cycles are a precondition for photosynthesis. Therefore, photosynthetic production is a good indicator for ecosystem health, including hydrological cycles, temperature distributions, soil condition, solar radiation, UV_B etc.).

More general comments about the concept included: "The concept is very lucid. It is able to provide a very drastic picture of the consequences of our lifestyle that can hardly fail to impress those willing to work with it or at least to be informed by it." "Your research has been ambitious and breathtaking in scope. You have moved the central notion of carrying capacity to a whole new level of discussion. Even with all of the qualifications to your conclusions, we can put now some of our numbers up against their (classical economists) numbers!" "This is one of the most interesting and important pieces of work that I have seen in quite a while."

Suggestions of these reviewers were used to improve various aspects of the tool. The major change that resulted from the review was to choose another approach for converting fossil fuel use into land. Rather than using an ethanol equivalent, now the tool approaches this conversion ratio from the perspective of CO_2 absorption.

Reviewers of the Draft Handbook

Lester Brown, Worldwatch Institute, Washington DC, USA
Maria Buitenkamp, Friends of the Earth, Amsterdam, The Netherlands
William Catton, Graham, WA, USA
John Cobb, Jr., Claremont, CA, USA
Rudolf de Groot, Center for Environment and Climate Studies, Wageningen, The Netherlands
Ronald Doering, National Round Table on the Environment and the Economy, Ottawa, ON
Mario Giampietro, Cornell University, Ithaca, NY, USA
Ragnar Overby, Eco-matic, Arlington, VA, USA
Sandra Postel, Worldwatch Institute, Washington DC, USA
John Robinson, Sustainable Development Institute, University of British Columbia, Vancouver
Mark Roseland, School of Resource and Environmental Management, Simon Fraser University, Vancouver
Matthias Ruth, University of Boston, Boston, MA, USA
Dieter Steiner, Swiss Federal Institute of Technology, Zürich, Switzerland
Tim Turner, Sea to Sky, Gibsons, BC
Stephen Viederman, Jessie Smith Noyes Foundation, New York, NY, USA
Andrew Whittaker, Northern Forest Forum, Groveton, NH, USA
Walter Zingg, Stevensville, ON

<u>APPENDIX 3.2:</u> LIST OF INTERVIEWED KEY INFORMANTS

(a) administrators and municipal planners

Pat Anderson, Head of Engineering, Township of Langley
Suzanne Carter, Senior Planner, City of Richmond
Peter Cave, Director of Planning, Fraser Cheam Regional District
George Colquhoun, Chief Executive Officer, North Fraser Harbour Commission
Julie Glover, Commissioner and Vice Chair, BC Land Commission
Otto Langer, Head of Habitat Planning, Fraser River Action Plan, DFO
Peter Scales, Environmental Manager, Township of Langley

(b) business people and economists

Robin Allen, Vice President Finance, Parklane Homes
Julia Gardner, Principal, Dovetail Consulting
John Howard, Vice-President, McMillan Bloedel
Bill Hyslop, President, NovaTec Consultants Inc.
Tony Scott, Resource Economist, UBC
Bing Thom, Principal, Bing Thom Architects
Michael Walker, Executive Director, Fraser Institute

(c) community activists

Herb Barbolet, Board Member, Farm Folk City Folk
Stephen Connolly, Coordinator, BC Naturalists, Land for Nature Initiative
Al Grant, Member, Langley Environmental Organization
Joy Leach, Chair, BC Round Table on Environment and Economy
Moura Quayle, Landscape Architect, UBC, Member of Vancouver's Urban Landscape Task Force
David Suzuki, Biologist, David Suzuki Foundation
Bill Woodall, Council Member, Fraser Cheam Regional District

APPENDIX 3.3: THE QUESTIONNAIRE

This appendix contains the questionnaire as I used it for my last 15 interviews. As explained in Chapter VI, I improved it slightly over the course of the first interviews by add in question 2.4b, and by adjusting the wording of the scales.

Also attached is a copy of the brochure which I used for briefing the participants about the EF/ACC concept.

INTERVIEW - QUESTIONNAIRE

Sustainability and Ecological Footprints

Thursday, April 7, 1994

Mathis Wackernagel, PhD Candidate
UBC Centre for Human Settlements
2206 East Mall
Vancouver, B.C. Canada
V6T 1Z3
tel: (604) 228-9363
fax: (604) 822-6164

The purpose of this 30 to 45 minutes interview is to explore people's perception of the "Ecological Footprint" as a planning tool for sustainability (see brochure). This is part of my PhD research.

These interviews should answer two questions:
a) is the "Ecological Footprint" concept helpful in understanding the sustainability dilemma? And,
b) is this concept useful for planning toward sustainability?

Participation in these interviews is voluntary. The interviewed persons are free to ask questions, withdraw, and/or refuse to answer questions at any time. All the information gathered through this interview will remain anonymous: neither names nor job positions will be mentioned in the research report, apart from listing the interviewed people in the appendix.

If the interviewed person permits, the conversation will be taped. I will provide all participants with a summarized transcription of their interview. This will give them an opportunity to eliminate, change, or add comments and statements.

1. INTERVIEWED PERSON'S PROFILE (10 minutes)

1.1 Identification

Name:____

Contact address: ______________________________
(for reviewing ______________________________
interview summary) ______________________________

Phone number: (home) ______________ (work) ______________

1.2 Educational Background

Your educational background is:

( ) Administration
( ) Agriculture
( ) Architecture
( ) Arts and Humanities
( ) Biology
( ) Chemistry
( ) Commerce and Business admin.
( ) Computer sciences
( ) Economics
( ) Education
( ) Engineering
( ) Forestry
( ) Health care
(medicine, dentistry, nursing ...)
( ) Human geography
( ) International relations
( ) Landscape architecture
( ) Law
( ) Physical geography
( ) Physical planning
( ) Political science
( ) Religious studies
( ) Services (office, tourism, food ...)
( ) Social planning
( ) Social work
( ) Sociology
( ) Technical crafts
( ) Other:____________________

(Please expand, if necessary): ________________________________
____
____

1.3 Political Perspective

For national politics, which of these issues do you think need attention?
(3 = very important, 2 = important, 1 = marginally important, 0 = not important at all)

( ) Abating pollution
( ) Reducing the public debt
( ) Supporting art and culture
( ) Alleviating poverty
( ) Providing daycare
( ) Counteracting the economic recession
( ) Reducing unemployment
( ) Controlling health care costs
( ) Slowing down resource depletion
( ) Reducing income disparity
( ) Preserving wilderness
( ) Eradicating illiteracy
( ) Reducing income taxation
( ) Stopping crime
( ) Other:____________________

(Please explain, if necessary):________ ____________________
____________________ ____________________
____________________ ____________________

1.4 Familiarity with "Sustainability"

1.4.1 Are you familiar with the term "sustainability"? ( ) Yes ( ) Barely ( ) No

If yes:

1.4.2 Have you read books or articles about sustainability? (or have your heard lectures/TV programmes etc?) ( ) Yes ( ) No

(Please name some, if you can): ______________________________
____
____

1.4.3 Have you participated in activities towards achieving sustainability? ( ) Yes ( ) No

Which?

- ______________________________
- ______________________________
- ______________________________
- ______________________________

1.4.4 Does your personal view on sustainability conflict with ideas and responsibilities at work? ( ) Yes ( ) Sometimes ( ) Rarely ( ) No

(Please explain, if necessary):______________________________
____
____

1.4.5 Have you heard about the "Ecological Footprint" concept before? ( ) Yes ( ) No

If yes, where:______________________________

1.5 Social Situation

1.5.1 Sex: ( ) male ( ) female

1.5.2 Age:__________

1.5.3 Ethnic background or country of origin:______________________________

1.5.4 Job responsibility and position (Please describe):______________________________
____
____
____

1.5.5 Community involvement: ____ ______________________________
______________________________ ______________________________
______________________________ ______________________________

2. QUESTIONS ON THE USEFULNESS OF THE "ECOLOGICAL FOOTPRINT" CONCEPT

(30 minutes)

Please read page 1-4 of the "How Big Is Our Ecological Footprint" brochure.

2.1 **2.1.1 Does this brochure explain the concept well?** (1) Yes (2) Barely (3) No

2.1.2 Could you explain the concept in one or two sentences? ____________________

(2.1.3 If the concept is misunderstood, clarifications by Mathis:)____________________

(2.1.4 Second attempt after oral clarifications:)____________________

2.2 **Do you think nature is being overused?** (1) Yes (2) No (X) Don't know
(Please explain, if necessary):____________________

2.3 **Describe what would happen if nature is overharvested year after year?**____________________

2.4 **Maintaining nature's capacity to regenerate and reproduce is a necessary requirement for achieving sustainability.**

(1) I agree with the statement (2) I disagree with the statement

Please explain your answer:____________________

To become sustainable, industrialized countries need to massively reduce their resource consumption.

(1) I agree with the statement (2) I disagree with the statement

Please explain your answer:____________________

2.5 **Does the Ecological Footprint concept describe the ecological bottom-line accurately?**

(1) Yes, it is simple, but sufficiently accurate.
(2) Yes, but it is rather complex.
(3) No, it is too simplistic.
(4) No, it is too complex.
(5) Other comment:____________________

Please explain your answer: ____________________

2.6 Considering the enormous public debt, implementing sustainability measures is a luxury that Canada cannot afford right now.
(1) Yes, I agree (2) Yes, I somewhat agree (3) No, I somewhat disagree (4) No, I disagree (X) Don't know
Please explain your answer: ______

2.7 How useful do you think the Ecological Footprint concept is for:

- the general public to understand the sustainability dilemmas?
  (1) Very useful (2) Useful (3) Marginally useful (4) Not useful (X) Don't know
- individuals to reconsider lifestyle or business decisions?
  (1) Very useful (2) Useful (3) Marginally useful (4) Not useful (X) Don't know
- community activists in their sustainability campaigns to make their point more effectively?
  (1) Very useful (2) Useful (3) Marginally useful (4) Not useful (X) Don't know
- planning departments and municipalities as a planning tool?
  (1) Very useful (2) Useful (3) Marginally useful (4) Not useful (X) Don't know
- political decision-making as a sustainability indicator (similar to the GDP)?
  (1) Very useful (2) Useful (3) Marginally useful (4) Not useful (X) Don't know
- students and scholars to generate positive choices for sustainability?
  (1) Very useful (2) Useful (3) Marginally useful (4) Not useful (X) Don't know

(Please explain, if necessary): ______

2.8 Evaluate how reliable the Ecological Footprint concept is.
Does the Ecological Footprint concept demonstrate humanity's competing demands on nature's productivity? (1) Absolutely (2) To a large extent (3) Barely (4) Not at all (X) Don't know

Which essential component(s) are left out by the concept? Please list: ______

2.9 In your opinion, can society become sustainable? (1) Yes (2) Maybe (3) No (X) Don't know

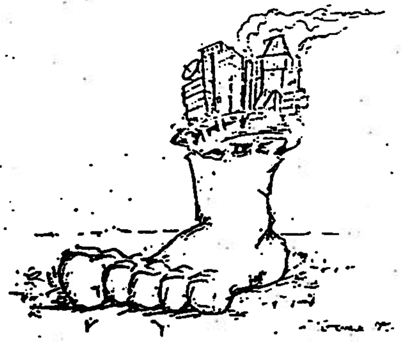
If yes, what can society do: ______

What can you do? ______

2.10 Has this interview changed your perspective on sustainability? ______
What have you learnt? ______

2.11 Would you consider using the Ecological Footprint concept during the next year?
(1) Yes (2) No (3) Don't know
If you answered "yes," what would you use it for? ______

2.12 Any other comments? ______



HOW BIG IS OUR ECOLOGICAL FOOTPRINT?

Using the Concept of Appropriated Carrying Capacity for Measuring Sustainability

by

MATHIS WACKERNAGEL

with The Task Force on Planning Healthy & Sustainable Communities, The University of British Columbia

People depend on nature, which provides a steady supply of the basic requirements for life. Energy is needed for heat and mobility, wood for housing and paper products, and we need quality food and clean water for healthy living. Through a process called "photosynthesis" green plants convert sunlight, carbon dioxide, nutrients and water into plant matter, and all the food chains which support animal life – including our own – are based on this plant matter. Nature also absorbs our waste products, and provides life-support services such as climate stability and protection from ultra-violet radiation. Further, nature is a source of joy and inspiration. Figure 1 shows how very tightly human life is interwoven with nature, a connection we often forget or ignore. Since most of us spend our lives in cities and consume goods from all over the world, we tend to view nature as a collection of commodities or a place for recreation, rather than the very source of our existence.

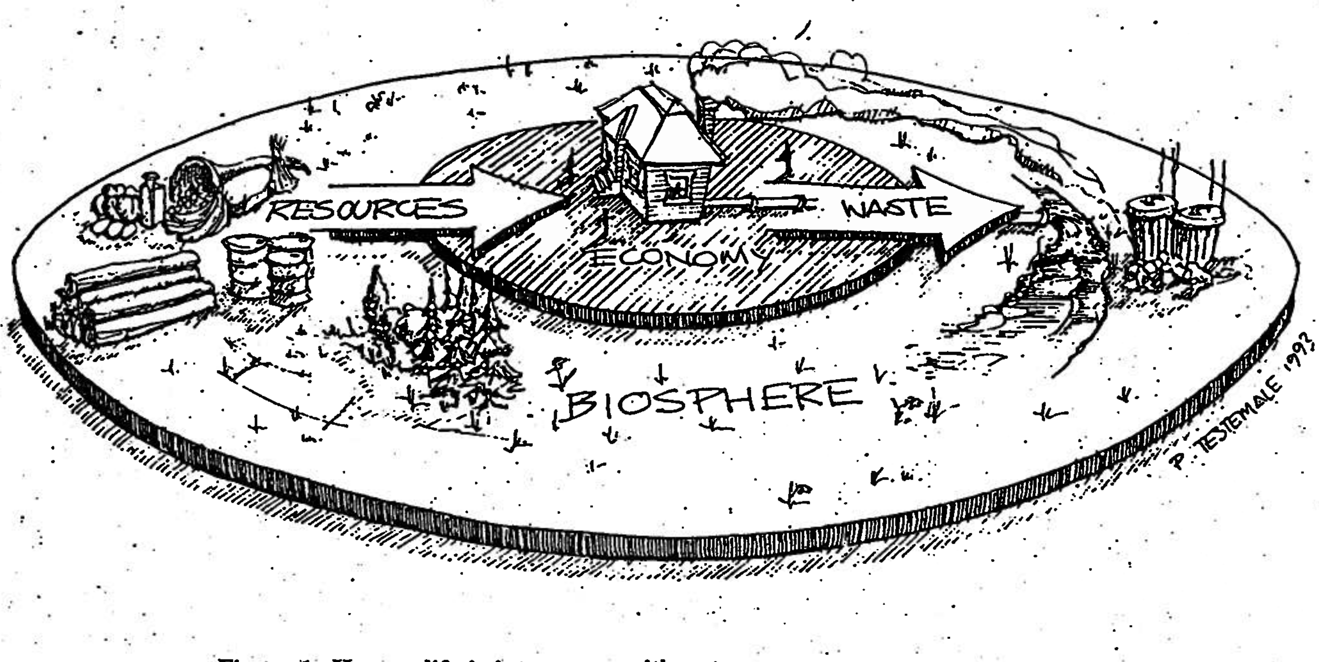


Figure 1: Human life is interwoven with nature

"The Ecological Footprint is the land that would be required on this planet to support our current lifestyle forever."

If we're to continue to have good living conditions, we must ensure that nature's productivity isn't used more quickly than it can be renewed, and that waste isn't discharged more quickly than nature can absorb it. We know from the increasing loss of forests, soil erosion and contamination, fishery depletion, loss of species and the accumulation of greenhouse gases that our current overuse of nature is compromising our future wellbeing.

To find out whether nature provides enough "resources" to secure good living conditions for everyone in a community, the Task Force on Planning Healthy and Sustainable Communities at the University of British Columbia has developed an ecological accounting tool that uses land area as its measurement unit. Various categories of human consumption are translated into the areas of productive land required to provide those items. From that, the area of land required by a given group of people (household, city or country) to provide its resources and assimilate its waste products can be calculated. This land area is known as the Appropriated Carrying Capacity or, more simply and graphically, the group's **ecological footprint** (figure 2). It's the land that would be required on this planet to support our current lifestyle forever.

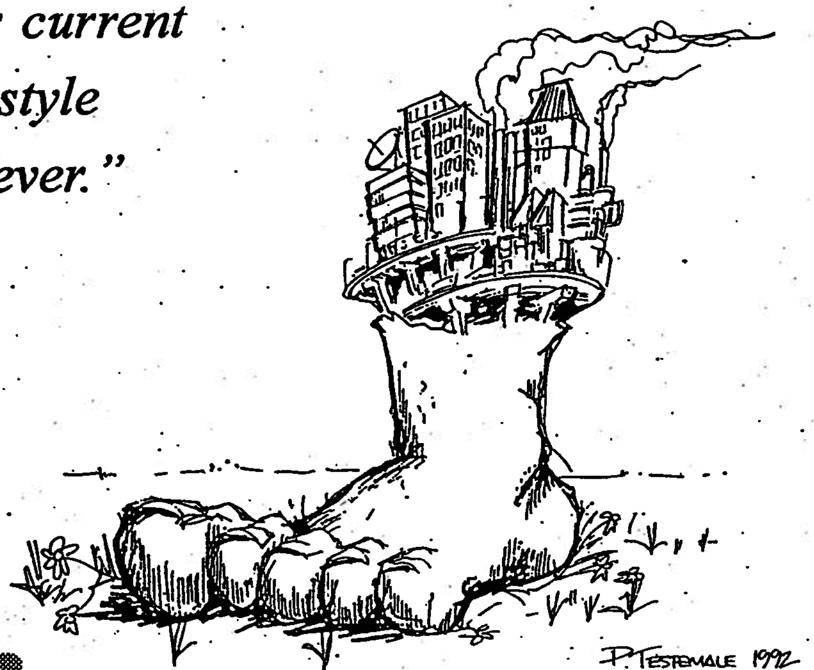


Figure 2: The Ecological Footprint

Our current economy has given rise to increasing demands which compete for dwindling supplies of life's basic necessities such as food, clean water, etc. A group's **ecological footprint** can be used to measure its current consumption against projected requirements and point out likely shortfalls. In this way society as a whole can compare the choices we need to make in the near future about our demands on nature – or else nature will make our choices for us. We'll have to look at issues like long term ecological sustainability as they relate to future economic health.

Table 1 shows the **ecological footprint** of an average Canadian, i.e. the amount of land required from nature to support each individual's present consumption. This adds up to over 4.8 hectares, or an area 220 metres long by 220 metres wide – roughly comparable to three city blocks. The column on the left shows various consumption categories, and the headings across the top show land use categories.

"Energy" as used in the table means how much land would be necessary for the long term provision of a biological substitute for fossil fuels (coal, oil and natural gas). "Built Environment" means land that's no longer available for nature's production because it's been paved over or used for building. Examples of what's included in "Resources in Services" are the fuel needed to heat a hospital, or the paper and electricity used to produce a bank statement.

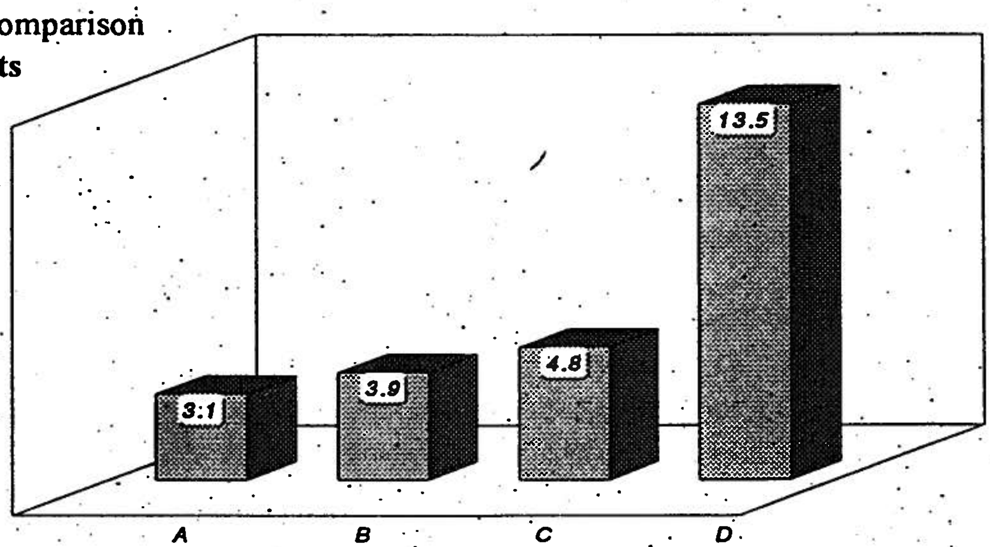
To use the table to find out how much agricultural land is required to produce the average Canadian's food for instance, you'd read across the "Food" row to the "Agricultural Land" column, and find that 0.9 hectares of land is needed.

"This adds up to 4.8 hectares... roughly comparable to three city blocks."

Table 1: The ecological footprint of the average Canadian, in hectares per capita.

	Energy	Built Environment	Agricultural Land	Forest	TOTAL
Food	0.4		0.9		1.3
Housing	0.5	0.1		0.4	1.0
Transport	1.0	0.1			1.1
Consumer Goods	0.6		0.2	0.2	1.0
Resources in Services	0.4				0.4
TOTAL	2.9	0.2	1.1	0.6	4.8

In figure 3 there's a comparison of the ecological footprints of various Canadian households.



A: SINGLE PARENT WITH CHILD - ANNUAL HOUSEHOLD EXPENDITURE $16,000
B: STUDENT LIVING ALONE - ANNUAL HOUSEHOLD EXPENDITURE $10,000
C: AVERAGE CANADIAN FAMILY, 2.72 PEOPLE - ANNUAL HOUSEHOLD EXPENDITURE $37,000
D: PROFESSIONAL COUPLE, NO CHILDREN - ANNUAL HOUSEHOLD EXPENDITURE $79,000

Figure 3: Examples of ecological footprints of various Canadian households in hectares per capita

"...we'd need at least three Earths..."

The ecologically productive land available to each person on Earth has decreased over the last century (figure 4). At the moment there is, on average, 1.6 hectares (about one city block), or one-third of the area which each Canadian is currently using according to table 1. In contrast, the land appropriated by richer countries has increased.

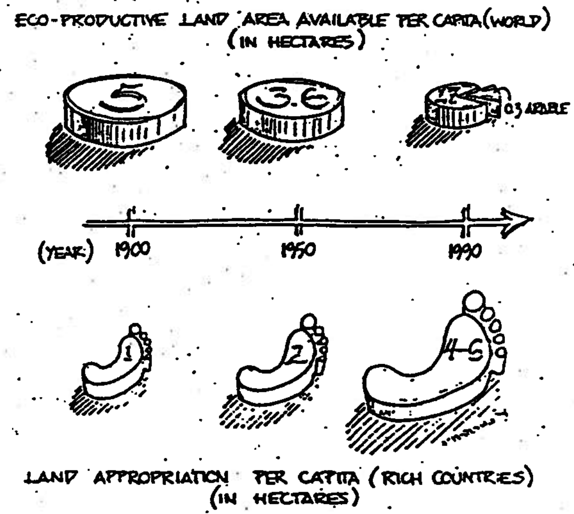


Figure 4: A historical look at the ecologically productive land available to each person and our ecological footprints

This means that if everyone on Earth lived like the average Canadian, we'd need at least three Earths to provide all the material and energy essentials we currently use (figure 5).

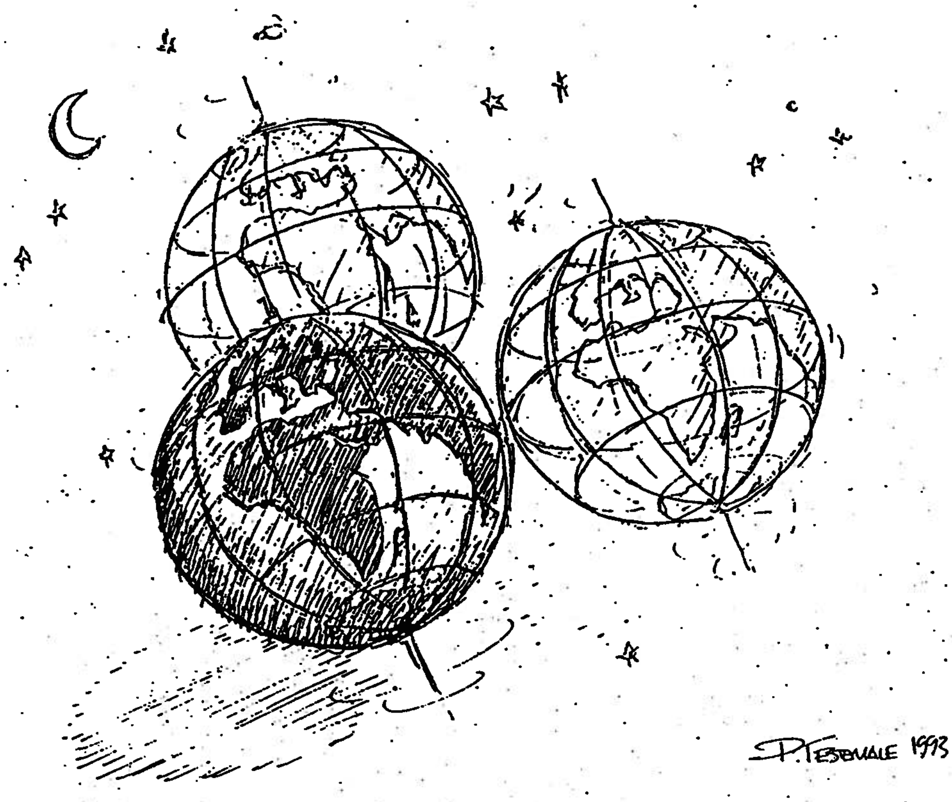


Figure 5: Wanted - two phantom planets!

If the world's population continues to grow as anticipated, by the year 2030 there will be 10 billion people, each of whom will have an average of only 0.9 hectares of productive land available, assuming there's no further soil degradation. This shows the pressure of population size on nature's productivity.

The numbers become really interesting when you look at the land area that people in North America actually use. Figure 6 shows the **ecological footprint** for the Lower Fraser Valley, the area east of Vancouver, which contains 1.7 million people or 4.25 people per hectare. The area is far smaller than that needed to supply the resources for its population. If the average Canadian needs 4.8 hectares as shown in table 1, then the Lower Fraser Valley needs an area 20 times larger than what's actually available for food, forestry products and energy.

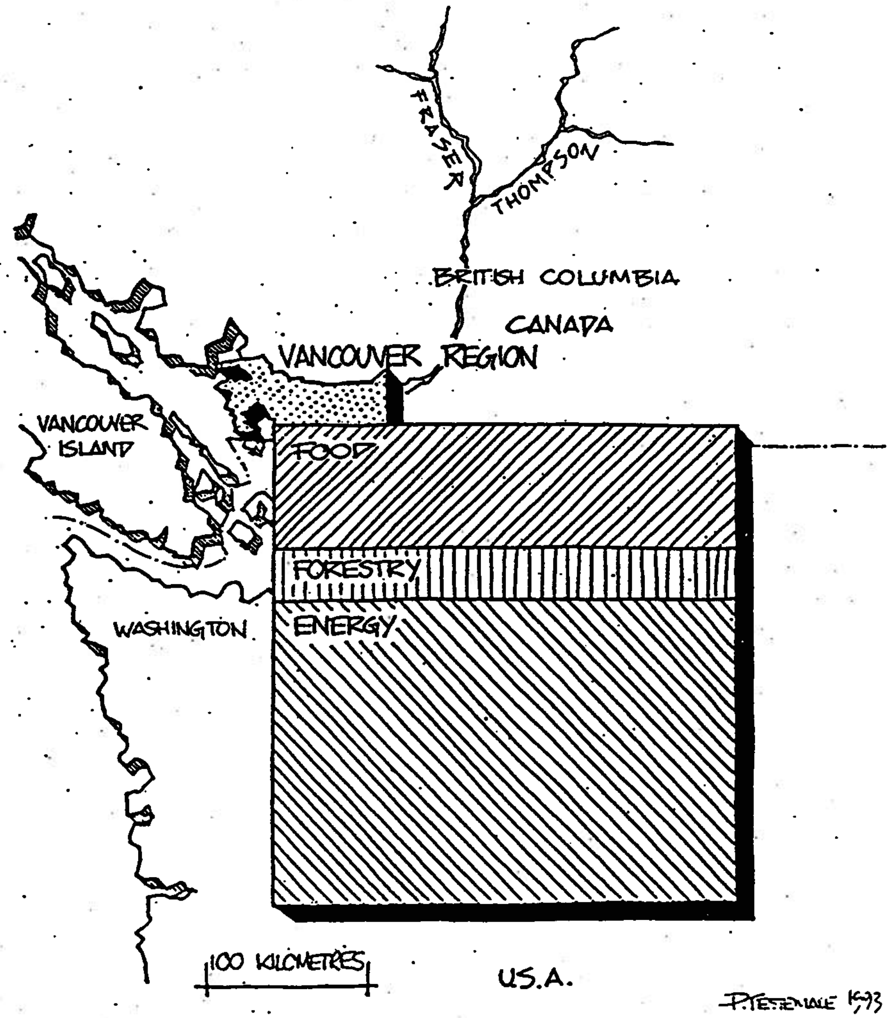


Figure 6: The ecological footprint for the Lower Fraser Valley

Holland has a population of 15 million people, or 4.40 people per hectare, and although Dutch people consume less than Canadians on average, they still require more than 15 times the available land for food, forest products and energy. In other words, **human settlements don't affect only the area where they're built**.

Increasing density in cities can lead to lower land use requirements, not only because of a reduction in the built environment, but also because of lifestyles which are less energy-intensive. For example, a recent study of the San Francisco area found that when residential density was doubled, private transportation was reduced by 20 to 30 percent. It's also been shown that residential heating requirements can be reduced significantly if housing is grouped rather than free-standing.

Our challenge is to find a way to balance human consumption and nature's limited productivity in order to ensure that our communities are sustainable locally, regionally and globally. We don't have a choice about *whether* to do this, but we can choose *how* we do it. In fact, many people concerned with these issues believe that if we choose wisely now, there's still time for us to make our communities more sustainable,

"...if we choose wisely now, there's still time..."

"Buy items made or grown locally rather than far away."

and at the same time improve our quality of life.

There are three key requirements for developing a sustainable community:

(a) Ecological health. Use nature's productivity without damaging it.

(b) Community health. Foster social wellbeing through the promotion of fairness, equity and cooperation.

(c) Individual health. Secure food, shelter, health care, education etc. for everyone.

This means working to integrate environmental, economic and social policies so that economic success, ecological integrity and social health become compatible.

In order to make our communities more livable and sustainable we can work towards change at the personal, urban and commercial levels.

AT HOME WE CAN:

- start composting
- use more energy-efficient light bulbs, shower heads etc
- switch to forms of recreation and tourism which have a low impact on the environment
- grow some of our own food
- live closer to work (or the other way around)
- use bicycles and public transport rather than cars
- buy items made or grown locally rather than far away

Households can start by reducing their resource consumption. At the urban level we must develop an **infrastructure** that leaves options open, rather than one which dictates resource-intensive lifestyles for our own and future generations. Along with these lifestyle changes, there must be changes in our **economies**

CITIES AND TOWNS CAN:

- plan attractive increased population-density areas such as town centres and urban villages instead of accommodating further sprawl
- offer living, working and shopping spaces in integrated neighbourhoods
- reallocate urban space to encourage decreased use of cars (e.g. reduce road and parking space) and increased use of public transport, bicycles and walking (e.g. build bicycle speedways and attractive pedestrian areas)
- encourage the planting of trees and greenspaces
- establish urban land-trusts to give the community more control over land use
- promote various kinds of affordable high-density housing such as secondary suites and cooperatives
- introduce housing construction guidelines which minimize the consumption of resources
- develop comprehensive waste reduction systems which include municipal resource reuse and reduction schemes

This approach differs from today's global economy which favours urban industrial centres, and requires the support and involvement of people in each sector of society.

We can all make a difference. Influential groups are:

- **Politicians** (MPs, MLAs, City Councillors, etc), who can initiate or support sustainability programs and projects, particularly at the infrastructure level. They can set up screening processes which will take ecological impact into account when assessing a budget

IN DOING BUSINESS WE CAN:

- rely on using locally available resources rather than imported ones
- regain local control over production and distribution of those resources
- secure local needs so that the long term livelihood of a region can be protected without compromising the livelihoods of other people in other regions
- charge the true costs for private transportation, pollution and resource use
- support community-based non-cash, volunteer and mutual aid networks
- encourage ecologically sound businesses
- offer tax breaks and other incentives for encouraging sustainable lifestyles, and tax and regulate unsustainable behaviour.

or project, and they can encourage the use of the concept of sustainability by the government. They can persuade their parties to develop sustainability strategies, involve the public, and discuss the dilemmas being faced. They can support community groups working towards sustainable societies.

- **Administrators and planners,** who can help politicians write appropriate legislation and ensure that existing policies are followed. They too can involve the public, present them with the dilemmas and invite input. They can encourage people to participate in shaping the future of their community, and support and assist community groups making positive contributions to society.
- **The general public,** which is all of us – possibly the most important group! We can look at our life styles, think about what's important to us, and start family and friends thinking too. Let's get involved and participate in community and municipal groups. Write and talk to politicians at a local, regional or national level, and let them know we want to work with them to develop our communities sustainably.

All of us – including politicians and planners – are consumers of nature's productivity. We must work together to achieve a more sustainable way of living now in order to ensure that resources continue to be available not only for ourselves, but also for future generations.

"We must work together...to ensure that resources continue to be available ...for future generations."

If you're interested in finding out more about the issues raised in this pamphlet, we suggest the following reading material:

General:

"For the Common Good: Redirecting the Economy towards Community, the Environment and a Sustainable Future" by Herman E Daly and John B Cobb, 1989. Beacon Press, Boston.

"Toward Sustainable Communities: A Resource Book for Municipal and Local Governments" by Mark Roseland, 1992. Available free of charge from the National Round Table on the Environment and the Economy, Ottawa - phone (613) 992-7189.

Ecological Footprint:

"Ecological Footprints and Appropriated Carrying Capacity: What Urban Economics Leaves Out" by Bill Rees, 1992. Environment and Urbanization Vol 4, No 2, pages 121-130.

"Ecological Footprints and Appropriated Carrying Capacity: Measuring the Natural Capital Requirements of the Human Economy" by Bill Rees and Mathis Wackernagel, 1993. Forthcoming in Investing in Natural Capital, edited by C Folke, M Hammer, A-M Jansson and R Constanza.

"How Big is our Ecological Footprint? A Handbook for Estimating a Community's Appropriated Carrying Capacity" by Mathis Wackernagel et al, 1993. A discussion draft prepared for the Task Force on Planning Healthy and Sustainable Communities, Vancouver.

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<u>APPENDIX 3.4:</u> ANSWERS OF THE KEY INFORMANTS

The answers of the participants are organized according to the progression of questions outlined in Table 6.1. The first part focuses on the participants' interpretation of sustainability and the second part addresses the participants' acceptance of the EF/ACC tool. The round brackets () provide the frequency counts of the participants' answers.

1. THE KEY INFORMANTS' UNDERSTANDING OF "SUSTAINABILITY"

Do you think nature is being overused? (question 2.2)
(17) Yes (2) No (2) Don't know

administrators and planners said:

I find it difficult to judge whether nature is being overused on the global level as I have only access to 2nd or 3rd hand information. In fact, it is hard for anybody to know. There are many examples of non-sustainable activities. However, we do not know how to account them.

business people and economists said:

In some cases we are harvesting faster than what nature can reproduce (and these are the cases where we do not have any property rights, i.e., common properties as witnessed in some fisheries, and in some pollution examples). In other cases we don't (privatized fisheries, or where pollution is not common property any more like in some cases in the US), but of course, there is a great debate about what the impact of pollution really is.

I do not know whether the biomass of the world is harvested faster than it regrows. However, some areas are certainly overused. When I fly, I can still see huge land-areas that seem unused.

Oil and gas is not used sustainably, and we tend to overuse it. France is a great exception. Realizing that they have no fossil fuel, they got into producing their electricity through modern nuclear power plants.

It is mainly in poverty stricken countries, that biomass is being harvested faster than it regrows. Particularly, forests are overused there. I believe that worldwide close to 60 percent of the wood consumed is firewood. And this has devastating effects (e.g., China, Nepal, Brazil, many African countries). Of course, the problem is overpopulation. In these countries the population is out of control, and if we do not deal with that, then all other possible solutions are put into question.

We are "resource pigs" here in North America as you rightly point out. In industrialized countries we use a large part of the world's resources. But that's because we are very productive; we can afford to buy and use them.

I am not sure that nature needs to be overused. We could use nature a lot more if we did it differently.

community activists said:

Knocking down Brazilian jungles and burning off African savanna far exceeds the rate at which these ecosystems get reestablished. We see what has been done to the cod fish on the East coast, and we know what is happening to the forest in many places in BC. It is no longer sustainable at present levels and how to best address this is the difficult question.

Describe what would happen if nature is overharvested year after year? (question 2.3)

(15) spontaneously point out human dependence on nature
(3) acknowledge human dependence on nature once asked about the potential impact on society
(3) avoid talking about human dependence on nature even once asked

administrators and planners said:

We'll be left with a barren wasteland. The Earth surprises me with its resilience, but I do not know how long it can go on to (positively) surprise us. [what is the implication for society?] Diseases and death rates will increase. Earth's carrying capacity will decline, and we will not win this one.

To live on the principal rather than on the interest will lead to collapse.

It would simply destroy the Earth. As a minimum scenario, this would lead to a decrease in livability -- as a maximum scenario, this could mean that humanity does not survive as a species. Reality would probably be in between. Some small groups might survive and would have to dramatically restructure their way of life.

Either nature will correct the situation through starvation, or man will correct the situation.

business people and economists said:

The price of nature will change. This will change behaviour and lead to a new stable equilibrium.

We have barely harnessed wind or solar energy. Ever since the oil crises have tapered off, all that research has died. And yet, there are enormous potentials. I still have confidence that through a political will and a harnessing of our collective wisdom we should be able to do it. ... Maybe nature is able to sustain us and give us a lot more than we give nature credit for. ... The farming of seaweeds or fish is just one of many, many things that we can do better before we can claim that nature cannot sustain us any more. I am still an optimist -- maybe naively. But I have not given up on the human potential to organize themselves.

I feel that a lot about the ecological issues is wrongly defined. The big question is rather: what will happen with technology. I guess I have some faith and am an optimist. We have seen technology more as a threat than as a tool. In other words, we are more worried about the damage of new technologies than seeing its potential benefits.

The standard of living would fall eventually.

Ultimately, this leads to a decrease in the standard of living.

You'll have exactly what is happening in the Sahel and other areas. They get overpopulated, they overuse nature, which then leads to social chaos and social destruction. See Kaplan's article (1994). Everybody should read that. That's what the world is coming to.

Nature will lose its capacity to regenerate itself. And, the life-support systems are compromised. We all would be impoverished.

Without any invention or creation, and everything else constant, we are finished. There is no question about that. The good news is that nothing is ever constant. So we might be finished as a species, but the planet (that is GAIA) will continue to live and will figure a way to get rid of us. We human beings are really visitors here. But now we are behaving as if we were not integrated. The whole notion of property rights shows this.

community activists said:

The cod fisherman can no longer earn a living. Few mature trees are left to cut [here] and a lot of people are going to go hungry if things do not change. People could have to go somewhere else, but it will get harder to find a somewhere else.

The quality of life of human beings will diminish in direct proportion to how other organisms are affected.

What is happening now: But the public does not clearly understand because of the vastness of this country. If we fly over Canada, there is so much land down there, and scarcity can hardly be perceived. But eventually we would witness a social systems break-down, because of lacking food, shelter etc.

We are going to suffer degradation and depletion. If we take biomass to its most abused state, then our survival is very much in doubt. If people understand that? No!

We would lose options and abilities necessary for our survival and well-being.

We are depleting the system. This might cause a lower level of complexity and the ecosystems will degrade or bust. In other words, the systems that we depend on will fail.

It depends for how long and how badly nature is overused. However, in the long-run, this would mean the destruction of life on Earth (apart from some insects...)

Maintaining nature's capacity to regenerate and reproduce is a necessary requirement for achieving sustainability. (question 2.4a)
(20) I agree with the statement (1) I disagree with the statement

business people and economists said:

Whether ecological factors are limiting factors is questionable: they are just a reflection of the prices. As Julian Simon's bet with Paul Ehrlich showed quite clearly, the amount of energy we have got and how we produce it, the amount of food we have got and how we produce it are not independent of how far we are from ecological sustainability. The finiteness of the resources is dependent on the given prices.

The main issue of sustainability is not so much maintaining nature's capacity, but rather have the appropriate pricing to insure that all costs are internalized.

This is a self-evident truth. However, I also consider nuclear power to be a part of nature, and part of the balance. Of course, there is always some entropy, but essentially you do need to maintain nature's capacity in the long run.

community activists said:

As a kid I had an aquarium, and when things got out of balance all fish died. The same is true for us. Without the ecology in all forms being roughly intact, human survival is in jeopardy. Of course, we can modify ecosystems, and they do not automatically collapse, but essentially, we cannot pave the whole world and not expect to suffer for it.

But this does not mean that everything has to be left untouched.

To become sustainable, industrialized countries need to massively reduce their resource consumption. (question 2.4b)
(14) I agree with the statement (3) I disagree with the statement
(4) n/a as the question was not included in the first four questionnaires

administrators and planners said:

But it has to be qualified. If we tell it this way we scare people and they do not want to believe. So we should find examples about what will happen if we do not act, and how good it could be if we act. At this point, they do not realize the conundrum.

The way we live right now cannot work for the global ecology. Even if we in industrialized countries would cut our consumption in half, and the third world would double its consumption, we would still have a problem. Even though everybody agrees with Brundtland, I have not seen any consumption in industrialized countries going down. We are all on a treadmill, from which we do not know how to get off.

Yes, in the long run it requires a significant change in the way we use resources. Sustainability requires a reduction in the amount of resources which we take from nature, but through recycling and reusing we could keep the resource flows within society still on a high level.

I think that this is one of the scary sentiments or statements that get put out which terrify people or make people feel quite helpless. The reason is that the degree by which we have stepped over the line is quite scary. If we can make changes that help, as for example such things as reduce our resource consumption or pollution that would be great. But we are just trying to change our thinking about it. So it will take 10 to 20 years until we get to make any truly effective changes regarding the amount of resources we use and the extent we deteriorate them. It is similar to smoking. We only stop once we realize how disgusting it is. Also with smoking, it took a lot of time and people did not anticipate it. [When you say you feel helpless, do you mean that you do not see choices?] No, a statement like this about the need to massively reduce resource consumption sounds like such an overwhelming task that it seems impossible. But when it starts to be rephrased in smaller actions and things, such as that we have to reframe our values, seems so much more manageable. And these are steps that you can start from and go somewhere. But otherwise, I think that the statement is good, because you need to open your eyes.

We in rich countries are taking more than our share. ... We probably need to reallocate resources and find new resources such as atomic energy. We have arguably unlimited energy even though I agree that it has some potential dangers.

business people and economists said:

The amount of fossil fuel is not decreasing but increasing. There is more energy supply available today than there was in 1979 when the Federal Government declared a major energy crisis. We have more oil in Canada today than we had in 1979. We have more natural gas by a large amount. Mankind will only find the resources it needs. There is no point in finding oil that we are going to burn in 40 years time. In 200 years, there will still be oil for 40 years, but the uses will be different. At some point oil will only be used to be put in eye drops because oil will be so expensive. And energy will be generated with something we have not even thought of. And there is no reason for us to develop alternatives or even think about it because this is too far ahead. Higher fossil fuel prices will be an incentive to find alternatives. That is why [Julian] Simon made the bet [with Paul Ehrlich about the future price of resources, and which Ehrlich lost], and he would bet again, and so would I. If we go back 4000 years, the real price of resources have been falling. Biophysical scarcity does not have any meaning – and by the way, food has been mushrooming. There is no question that locally, some areas have food problems, but globally, we have huge surpluses of food. And we will even have more so, for example, once Ukraine privatises agriculture.

The only energy crisis we have is a human energy crisis. If the human beings would do a little but more rather than being lazy, this would go a long way [toward sustainability]. ... We [in industrialized countries] just give lip-services *[to sustainability].*

Of course, some substitution between human-made capital and natural capital would be possible, but complete substitution is not possible.

To be sustainable, consumption of resources in industrialized countries would have to be reduced. I do not know whether the reduction should be massive. However, because we in Canada have been living in a bountifully environment, much is squandered.

I do not think that we should conserve just for the sake of conserving. For example, why should areas of old growth forest be preserved if the trees are going to fall down and rot eventually anyway? Rather, we should use these areas effectively, efficiently and environmentally responsibly and not wait until the trees decompose on their own. The same is true for coal that happens to be located in a park. This coal should not be preserved: it adds nothing to the functional ecological integrity of that park and it would not be rational to preserve it jut for the sake of preserving it. Of course, as you rightly pointed out in the brochure, nature is also a source of joy and inspiration. Therefore, we should keep <u>some</u> virgin parks and <u>some</u> intact old growth forests.

We in industrialized countries might be doing the rational thing such as control population and higher education. As long as overpopulation is not controlled, there is little hope for sustainability. Therefore, developing countries need education. Industrialized countries can help to pay for this education and we do it already in a massive way. However, it is extremely tough to change values and basic social conflicts (such as religious conflicts).

Yes, but it is a bit more complex. For example, in 2024 if we are sustainable we will have witnessed a massive reduction in resource consumption. But, as a goal now, the vision would be too narrow, too petty and would be counterproductive. It sounds too moralistic. And it is a negative goal rather than a positive goal. In my experience it works better to set visions that go beyond a singled out task, so everybody's energy is on board. So the smaller goal gets achieved without [anybody] even noticing it. [Moral issues and small goals] only end up in pettiness and negative sum games.

Also, we might figure out ways that we can still have the consumption but we could reduce our resource throughput. ... The world is not static and there will always be new inventions. The bottom-line is, that reducing consumption just for a goal in itself is not good enough. It also has to be fun. Otherwise it does not lead to health. Sustainability is a qualitative question, not a quantitative one in the first instance. We measure success and can set goals by using quantitative targets. But I do not believe that sustainability is a quantitative issue.

community activists said:

If industrialized countries get resources from other places they might be able to carry on for a while. I do not equate sustainability with drastic reduction in quality of life. But quality of life is not necessarily connected to resource consumption. I believe we have most things too cheaply. And people complain about their tax burden, but they do not realize how much they use and how cheaply they get everything compared to other areas.

I suspect that we do have to. But I am not sure that a reduction in the use of all resources is necessary. There are priorities for some resources. But we should not artificially intrude on reducing resources of which alternatives exist (e.g., copper being replaced by glass).

Considering the enormous public debt, implementing sustainability measures is a luxury that Canada cannot afford right now. (question 2.6)

(0) Yes, I agree (0) Yes, I somewhat agree (3) No, I somewhat disagree (18) No, I disagree (0) Don't know

administrators and planners said:

If we do not do anything about sustainability, public debt is not going to mean anything. Reducing public debt has to run hand in hand with advancing sustainability (which includes economic, social, and environmental issues). And if any nation can do it, it is Canada.

Prevention is much less expensive and more effective than restoration. But we are reluctant to prevent because it costs money now. But preventing is what stewardship is all about.

Sustainability is not a luxury.

At this point, we cannot afford to give up everything. For example, we could not completely shut down our resource industry. We have to redirect government toward sustainability. However, this is not done. Government's pull-out from supporting high-tech research is a sign of moving in the wrong direction.

The public debt results from huge unfunded liabilities. The reason is that we never had sustainable programmes: examples are UIC [unemployment benefits] or our infrastructure (water systems). Solving the debt problem means working toward sustainability. They are not opposites. Public debt is the most obvious manifestation of social unsustainability.

I do not think it is a luxury. It is a necessity.

business people and economists said:

The very question contains the answer. The enormous debt is in fact the fiscal pollution that we are leaving for the next generation. Why do we expect that the government apparatus that is responsible for that fiscal pollution is going to solve the problem of other kinds of pollution? The political process does not care about future generations; if it did it would not have accumulated this enormous debt. And, as sustainability is about intergenerational equity, the manifestation of deficit and debt accumulation is a positive proof that we should not rely on the government sector for promoting sustainability.

We cannot not afford it. On the other hand, I think that there is a reality to how much corporations can afford to become more sustainable on their own. Society in general has an obligation, unless we say that we do not care whether corporate Canada survives.

Whether the national debt is in direct competition with sustainability measures is doubtful.

To continue the rape and pillage of our resources in order to get rid of the public debt will not work. The reality is that if government decided to deplete our resources only to pay for the debt, ultimately this money would not used for paying the debt, but rather for other things such as for the padding of our safety net.

Since I grew up, the productivity of a farmer has increased fivefold. This is due to higher yield varieties and better farming techniques (e.g., 2.5 inch tillage rather than 6 inches which allows the soil to retain more moisture, slows down erosion and leaching, and conserves tractor energy). Now they produce on a sustainable basis – when I was young they were mining the soil and did not know how to take care of the land. In short, sustainability is not a luxury. It is something that we have to try to achieve.

community activists said:

Inaction is drawing down on the assets that do not even belong to us. So if we want to know what debt is and *what poverty is we should just keep going on our course.*

If we cannot afford it right now, when can we? Putting sustainability off is misleading.

Sustainability is not a luxury. The public debt is a problem too. Those two issues are not necessarily at odds.

In your opinion, can society become sustainable? (question 2.9)

(9) Yes (3) Maybe (2) No (4) Don't know (3) Not answered

administrators and planners said:

It seems that there has to be a big crisis before people react. And, the decline of the cod fishery in Newfoundland presents itself already as a looming example. Key is education, for adults and for children. I am glad to see that kids today in primary school learn much more about ecology than I did. Also prices have to include the true pollution and resource costs. But how to create the critical political mass to move society toward sustainability, I do not know.

We have to talk more about sustainability. Then we have to set goals and objectives with which to guide government. ... Indeed, there are conflicts between government institutions, as their mandate tells them to achieve opposite ends. ... The limiting factor for change today is the bleak economic outlook, including the debt and the loss of jobs. Therefore, we might need economic growth to achieve sustainability. Economic growth could well be in conflict with sustainability, and requires careful management to avoid this. The money generated by economic growth should consciously be redirected towards sustainability.

Full cost accounting would solve a lot. Unfortunately, there is no commitment to market economy. Maybe, the market economy does not provide the best ethics, but it is good for allocating resources. Also, it produces predictable and reasonable outcomes.

Education is the biggest priority. Also, we need to empower people that they feel that they have a part in it.

We have to use more science in our environmental decisions and less emotions.

business people and economists said:

The task is to get full-cost pricing. The struggle for mankind is to recognize where internalization of cost is not occurring and cause that to happen. Government could be one instrument for this, but there are lots of other and probably superior ways of achieving it.

The only likely solution to pollution is growth. And anybody who has been to China realizes that they are not going to be satisfied with where they are. And, according to Summers' work, once they get rich enough (and we are not very far from that point), they will start to worry about the environment too. ... Trade builds mutual interests. And this is exactly the instrument that environmentalists want to do away with. This is why environmentalists should be for NAFTA, because it gives a leverage point to make others comply with environmental standards. An example is how Germany has reacted with boycott threats to the BC forest practices. A lot of what Greenpeace does is regrettable, but they are like the custodians of common property. But first, you need an affluent society that becomes interested in financing institutions like Greenpeace. This will effect an internalization of costs associated with economic growth.

The issue is that the individual must take more responsibility for his own action and rely less on what government can do for us. I think that is where schooling is required. This schooling must start at early ages and also include learning about responsible behaviour (such as not to throw waste in the streets that other people then have to pick up). Education is key, and key to education is to realize that individual rights have got to such an extreme that we have *forgotten the fact that there is an individual responsibility too.*

We need a few more crises. People only react to Chernobyls. The nature of our society is to respond to crises. ... I think people are aware, they just do not know what to do.

I grew up in a generation where we believed that the rich are getting richer, and the poor are getting poorer. But now in my older age, I see that the richer are getting richer, but that the poor are getting richer, too. It is not so simplistic as when I was younger and thought that the poor of the world are going to rise up and create a new social order.

Vote for the right party. But of course, sustainability does not begin at home. One should do something there where each dollar has the highest impact. For example, Greenplan money might be better spent in Brazil than in Canada, not because I worry for the Brazilians, but because that might be the most effective thing I can do to preserve nature (thereby securing the future of my children). The numbers of hours needed to save the world are a hell of a lot more than we are going to get by voluntary efforts. If you rely only on voluntary efforts you are not serious about sustainability. Moving towards sustainability will require a lot of suffering. And therefore, the best way to reduce the suffering is to get the biggest effect for each dollar invested into sustainability.

A relatively wealthy society is doing a relatively good job already. The poor societies struggle with population growth. Canada is doing fairly well. Most important features are population control, education and economic incentives. If people are not charged true costs, they do not react. And it works: you see already some people making some dollars picking up empty beer cans.

Permanently redistribute income, live in an ecologically sustainable way, and try to convince people that sustainability matters.

Western and other wealthy societies must reorient their understanding of needs and wants away from materialistic consumerism.

If the way we present sustainability intimidates people, looks like a reduced quality of life or makes them fearful, nobody will want to work towards it. It is like war time that is motivated by fear. I believe that the human spirit functions almost naturally from a sustainable basis, and the way we have set up our politics, economics and religion, we have stripped that natural harmony. The accumulation of goods and services has almost become a substitute of what is inherent in the human spirit. So, how do we shift back to a psyche of sustainability that is much more joyful, empowering, cooperative which is also more natural.

Through having fun and showing that there are positive choices, and treating sustainability as a process. And we have to acknowledge that it is not going to be smooth.

community activists said:

Key is public understanding. But if you do not want to wait for a generation, you got to find a way to train the adults. And, they need different approaches than children. Adults need to be treated as individuals, otherwise they tune you out.

The challenge is to massively reduce resource consumption in industrialized countries. In terms of per capita consumption we are far beyond what is sustainable. We cannot afford any more to use our resources so wastefully. We have to be much more careful.

If we all start to deal with it, it will be possible. We have to talk a lot about it. We have also to include the media, even though they are reluctant.

I have changed my tramp of life, which needs time. The current pace of life really makes it more difficult. But since I bicycle [to work] I feel much more connected and come here relaxed and in tune. Before with the car, I always felt disconnected. These changes improved my quality of life.

The constant challenge is to figure out how to cause people to understand that this is something important. And in what other ways can you do it than face to face. I actually call this the "Back Fence Revolution," one person telling another person, telling another person etc. Schools are particularly key.

Any righteousness that rubs people out of the picture is counter-productive. Time and money have to be allocated for this profound change. People cannot be rushed. They have to understand first why. The logical consequences have to be explained. People have to realize how much it will cost and how it will affect their lives if we stay on today's course. We do not have to look at Africa: California is a good case study. ... But we cannot do it by saying it is too late. If you want action you have to inspire people to take it because it matters, otherwise they "enjoy the party but dance near the door..." We have to gain focus and develop timetables. Otherwise we feed into knee-jerk reactions.

Local governments need to think about the sustainability priorities. They need to be prepared to legislate change. For example preventing sprawl through urban containment boundaries. Remove subsidies for cars, and transfer road subsidy to mass transit. Urban containment would force new design.

Live the example

There are thousands of thing that society could do (if it wanted).

Hopefully we can improve society a bit that the muddling can continue for a while. However, fundamentally, I believe that deep ecologists are right. Needed change is so radical in the extreme (or revolutionary) that it is not going to happen. There is no sufficient public willingness to change. We cannot make sufficient changes without enormous upheavals.

on social denial:

I do not think that right now the public understands the challenges in any meaningful way. When they came out with these concepts such as The Population Bomb 20 years ago, I think that this idea got enough exposure that people started to realize that a huge number of people could suddenly be around. And that concept needs to be used (or some of its marketing methods) to bring these other ideas into real focus. There was some reverse learning we went through in the oil crisis. So people are left confused, and the crisis seems not real.

I have thought about [social denial] for the last 30 years. Once we realize that we are in trouble there are essentially 3 possible reactions:

a) tuning out and denying the crisis;

b) believing that nothing can be done, withdraw from society and live one's own life; or

c) saying "I do not know whether we can turn it around, but there is no choice. So, let's at least try."

I know that sustainability is not going to be achieved in my lifetime. But it has always been the case that people who acted upon a long-term vision have been able to get things going.

The worst thing about social denial is TV. It fragments people's experiences and understanding, discounts any sense of time and disconnects them from their surrounding.

If there was one thing that would do most for sustainability, it is to turn off the TV. ... TV gives an illusion of connection, but alienates. ... By pretending that life can be lived like on TV is debilitating. ... Similarly, in human rights violations or environmental abuse, the more disconnected (e.g., through TV) you are, the easier it is to abuse.

In particular, it is difficult to change adults, because they have invested so much in what they are (physically, and emotionally). Children are more flexible and are not yet entrenched in a path, but they have no status and no power. The vulnerable point is the parent's love for their children. And if they do not love their children, then it is pretty dismal. They need to understand that by living the way we live right now they deny their children a future.

We need good tools to make points clearly. For example, ... in the Arbutus land, I see how intelligent and well-informed people interpret the GVRD livability report to promote unsustainable lifestyles. I think that this GVRD report is therefore even counterproductive.

There is only an uneasiness in the population, but not a clear understanding that we need to change. We always mean other people but never us. Often people only want to see the population crisis and point their fingers at immigration. And this is just a cheap and dirty trick.

Everybody can see that cars are a problem. But people do not know how to give them up. We need alternative transportation policies such as tolls or inconveniences for personal cars. But the problem is that not even the advocates for this change have changed. For example many advocates live on the Gulf Islands and want their ferries subsidized. There are lots of barriers to change, and they would be simple enough like living in a denser area close to work.

Withstanding the fact that I work towards [sustainability], I am not convinced that we can [achieve it]. However, I am not yet ready to abandon the field. So, why do I "waste" so much time and energy on these issues? Perhaps I might jokingly say that I have a religious, missionary drive. Or, it is the hope and expectations when you come to certain conclusions that you can pass those on, for which missionaries get in trouble too, I suppose. Or, sheer orneriness. And, this shows the acceptance that not a whole lot of people are going to agree with you. ... I guess for the most part, people are motivated by fear and immediate necessities. What ever it is, long-term considerations make a lot of people uncomfortable. ... [Self-confidence] is absolutely a factor [for overcoming social denial]. You can impose some pressure on yourself and are not that exposed to the pressure to consume. It is important to get a public acceptance of the challenges.

2. THE KEY INFORMANTS' ACCEPTANCE OF THE EF/ACC CONCEPT

Does this brochure explain the concept well? (question 2.1.1)

(18) Yes (0) Barely (0) No (3) Question not asked

administrators and planners said:

It is well presented, and I like the graphics which I have used for overheads myself. The brochure gives more substance to the concept and gives some scientific basis to it.

I like the brochure because the language is simple, the diagrams are good, it includes a "what to do" section, and is not academic in its style. It is good for a community or a political audience. Planners might prefer more detail.

The brochure is good and fairly accessible to people. But my mother would not pick it up because it is too much. Perhaps reshaping it to a similar format as the GVRD brochures might help where every page would be complete in itself (because people feel that they can stop somewhere or they can read backwards as many people do). Or, adopt a newspaper style where the most important stuff is on the front page and some juicy things (like the horoscope) on the back. To popularize it more, you would need to market it, and have songs etc.

I feel that the brochure is about the right length. Any longer, and nobody would read it. But if it was only one page you could not get your point across.

business people and economists said:

I have indicated that some of your theories such as "buy items made or grown locally rather than far away" represents the kind of thinking that moves us away from finding a solution. This disintegrates rather than integrates communities. If you want the Mexicans to clean up their environment, trade with them, and then use that trade as a leverage point to make them clean up their environment.

Let me comment on some points in the brochure's section on In doing business we can...:

Gain local control sounds good, but can be silly. This usually means control certain jobs in the local community, even though this might be the most irrational way to produce [resources].

Secure local needs: this has a local planning bias, which is understandable with your academic background. But this can become quite silly again. Maybe local needs should not be secured. Maybe local communities should be wound up and absorbed in a larger and more sophisticated urban community. ... It does not work that we put unproductive regions on welfare programmes as done in Eastern Quebec and most of the Maritimes.

Charge the true costs: but you should make clear that this does not only refer to business but also to households who cause the largest part of the air pollution problems through car use, for example.

In figure 3, this incredible large Footprint of the professional couple bothered me. My wife and I happen to be such a couple. But this relationship makes no sense and the assumptions are not obvious. This could be very misleading, because for example, we put mostly energy efficient appliances in our house etc. If you assume that they are yuppies with big houses and big cars, and drive to Whistler every weekend etc., I guess you are right, but I guess you would find also that yuppies are very ecology conscious. Therefore, this aggregation in figure 3 illustrates what I call the abuse of a model. By simplifying so much, you also exaggerate and perhaps ultimately misrepresent the case.

Apart from the map, that shows the coast as an edge (as if we had cliffs..), I like the graphics, also for their character. They are not too childish, I like their humour. The bar graph does not need to be three dimensional. For an analytical mind, it makes the cross comparisons more difficult. The language is, as I can remember, at the right pitch.

One way we can achieve [sustainability] is by putting this quantifiable stuff out for people to see. This [brochure] shows me right away in a quantifiable form what I intuitively know. That is the bridge and that's exciting.

The brochure might improve if you start with a sustainability definition. It is fundamental to keep remembering that moving toward sustainability does not have to be hard or painful, or that it necessarily has to be a trade-off. It is not about denial of somebody's needs. Somewhere, if possible you should show in the brochure that it is challenging, exciting, and laudable. Now there is a certain sexiness about an expensive lifestyle that going without just does not have. In our culture (with our idols), we seem to link an expensive lifestyle with being "really cool."

The brochure does not give people the feeling that you understand their problem. For example, by saying that people should live closer to where they work might not feel like a possible choice to them. The brochure should say: "we know that housing is expensive and that you have to drive sometimes" in order not to alienate these people. One thing that could move us more toward sustainability would be through changes in the workplace. So for example people could start to work more from their home. We have to integrate what we do at home, at work and in the community. But, these bridges have not been built yet. ... People need a positive vision of where to go, but they do not have to get there today. We must take one step a time to move towards sustainability.

community activists said:

The abstract figures have to be translated into some visual statistics. The map on figure 6 might be too abstract. It should illustrate energy, food and forestry. It should speak to an 8 year old. Figure 4 (the historical trends) and figure 5 (wanted: two other planets) are attractive enough to make my eye look at them. It is important to have some variety in the brochure, because different people like different things.

To make it more attractive use more pictures and less words. The style of the pictures is good; computer *graphics would rather put me off. ... Many people who are on boards and councils might be in awe of computers, but many are not particularly impressed. It is like advertising: advertising with names like California or New York puts me off entirely. So I think your line drawings are fine. Tables are too academic. Figure 3 is better for me than table 1. Perhaps you should show how many Canadian Footprints could fit into Stanley Park. Also, "embodied" energy might be too complex and needs more explaining. But it is an essential concept. Uncovering real costs and connections is very valuable.*

The problem is that people do not read. Putting out a brochure such as this one is all based on the assumption that people act rationally. But this is not the case.

It is in plain English and uses a minimum of jargon. Also, the comparisons are helpful (like for example comparing 4.8 hectares to three city blocks). Furthermore, explaining the categories of consumption and land-uses is important to understand on what parts of the ecology we depend. I also like figure 3, that starts to look at the different impact of different kinds of people.

Perhaps it is good to leave a high density city on the Footprint picture in order not to alienate people who own sub-urban sprawl houses. Perhaps the best would be to add highways and skyscrapers (like in Metropolis).

The brochure is not confusing at all. The only problem with written material is that people are not reading any more. So it does visually not inform as quickly as it ought to. On the technical level, some of the words are still too complex. It should be at about grade 8 level. The paragraphs are too long. Don't use block form because people's eyes get tired and just run down the margins. More white space is necessary. Graphics are not used well enough to concentrate the central message. Graphics need to be very clear. The three planets for example, are not clear at all: it leads the mind to fantasy.

Some people are too busy to read, so they just read the marginal notes. And they need to be more visible. A good example of such communication is the anti-Greenpeace add of MacMillan Bloedel. With bullets and lots of blank space, they list facts and draw a simple conclusion. And this is very effective and powerful. Use bullets as much as you can.

At this point, the brochure looks like more stuff, or literature. It does not help to get people anywhere. For catching people's attention, focus on the central thought. Perhaps two pages would be good enough, if the "MacMillan" style is adopted.

It might also be a good idea to develop such papers for different sectors and adapt them to their language. Municipal council members, for example, want sophisticated publications to please their ego (they should be called "executive reports"). And the graphics which are used right now are too unsophisticated (perhaps you might want to consider computer graphics). And the only thing they would read would be margin notes. For council members, it has to look executive like and must avoid looking childish. On the back page, there should be actions that could be taken immediately. The actions described in the current brochure are on the right level of sophistication. And then refer to other available documents for the different audiences (planning departments, neighbourhood groups, etc.)

The Naturalists might think that this is far too simplistic. But because they use complex terms, they have never been able to effectively connect with the local politicians.

For me it seems simple, probably because of my education and background. Graphics help to make it simple and accurate. Even without reading the text, the brochure would be helpful.

It covers the issues really well, is action oriented (which is rather rare in academics), and examples make concept useful and vice versa.

Does the Ecological Footprint concept describe the ecological bottom-line accurately? (question 2.5)

(15) **Yes,** it is simple, but sufficiently accurate.
(2) **Yes,** but it is rather complex.
(0) **No,** it is too simplistic.
(0) **No,** it is too complex.
(2) Other comment: the concept seems simple, but the application might be complex; the concept is misleading.
(2) Not answered.

administrators and planners said:

The presentation of the concept seems simple, but I guess the derivation is not as simple and there are always error factors. And this has to be made known in the Footprint presentation. It is a good concept, but there might be a number of other ways to present the dilemma.

More or less. I would have to see a much more involved analysis. But I would say that you are going in the right direction. I would not say that it is too complex, because you could go on ad infinitum, with all these computer models. Concentrating on individual organisms or details always leads to an rationalization of incremental habitat destruction.

I think it does. My concern is more about how to use it. And the current applications (or the table/matrix in the brochure) do not tell how accurate it is.

Even if the gathered information is not completely accurate, exploring these issues is meaningful. ... It assists common sense logic and is necessary to stimulate discussion and understanding of complex issues. Complete accuracy is not necessary.

It works really well. It is a really good concept. For me, where I have always lost it is when I have to apply that concept myself and I am responsible for acting on it. ... Reading about it and understanding it reinforced my belief and helped me to fill it out and make it more manageable for me. But I think you have to believe in it to use it. If you do not you would just be left with it and would not know where to go from here. [In which way do you not know how to apply the concept?] I think the concept tries to deal with the whole giant issue of sustainability. When I think of the Ecological Footprint, I think about me taking up so much space. So the jump is: how do I make my Footprint smaller. The brochure has other pieces of information in it that help to bring the concept home. But generally the situation gets so confusing for people because they do not know which actions are useful for the environment: for example the media now reports only on how all the collected recycled materials from the blue-box programme are not being recycled and that the municipalities do not know where to put all that stuff. So people thought that they would do good, but now they think it was in vain, and they are confused.

I feel that the Footprint concept is quite intuitive, in the sense that if I would do something I think I would know what its sustainability impact is and probably also in which direction the Footprint would go, but not in a numerical sense. The concept is good because it helps structure the problem (even without knowing or applying all the details). And, the more specific Footprint tools that are lacking are those by definition which will have to be identified by the users, so you cannot come up with a definitive set of tools.

I thought the Footprint was interesting and a novel approach to resource allocation.

business people and economists said:

The tool is very badly flawed. The brochure communicates very well, but is very misleading: it conveys a sense of relationship between people and ecology which is highly misleading and, I think, is dangerous. First it does not take into account new prices and new technology. How much nature is used is not relevant. If people see this Footprint concept, they might think that we need this land right here in the Fraser Valley to grow food on. The fact of the matter is that we do not need any land to grow food on. In fact, we should grow zero food in the Fraser Valley because the land *is too valuable, and should be used for housing -- and I know that from looking at the prices: housing prices have increased, and food prices have decreased. [Second], we have got a surplus of food. Therefore, the whole Footprint concept is misleading if people start to follow the Footprint rather than the prices. And the supply of all these things is not finite. It is countably infinite and responsive to pricing. The Ecological Footprint is the shadow of Paul Ehrlich. The world is not physically finite: the mathematical theory of fractal analysis has shown that "finite" has no conceptual meaning any more, particularly as resources are concerned.*

It is a good beginning. The concept is an interesting first cut. It quantifies a lot of issues that were kind of vague in my mind. Any research or statement about knowledge [you need to] simplify when you communicate. So, somebody can always say that it is too simplified. We are always in search of truth. But that is elusive. We are just seeing one slice of reality and say this is one possible vision of it. As long as that is made clear, I do not have a problem with it.

Judging impacts is always difficult due to indirect effects. If we can apply a systems approach towards analysis of problems, sometimes we make an a priori judgement on where the boundaries of that system are and then we analyze. But maybe, the a priori assumptions on the boundaries of our system were not accurate.

The concept is ok, but measurements would be rather unreliable. It does not include labour, and it ignores the role of water. It should demonstrate that land and water can be competitors. But how would we compare California (which lacks water) with Bangladesh (where water is in surplus with all the floods)?

The sheer number of the Ecological Footprint is only of shock value, but to become meaningful it has to be compared to something. And this comparison could run into difficult measurement problems. Statistical difficulties for measuring the concept are overwhelming. It is not obvious what should be measured. This is similar to the problem that people face in economics when measuring the value of women's work in the house, or biological diversity. There is a long history of resource accounting (e.g., the technocracy movement), but by translating everything into land-use the level of abstraction in this accounting procedure is even one level higher than in energy accounting. Also, the quality of such accounting has not a very good track record. For example, the poor assessment of agricultural land is frightening.

The Footprint is only one way of assessing ecological sustainability.

It is a useful concept. But there is potential for misunderstanding. Also, as some of the issues mentioned in the brochure are counter-intuitive, this suggests to me that there is a bias behind the model. However, overall it seems to be useful. Imagery is always helpful.

One assumption that should be stated is that these 4.8 hectares per capita are industrially used, productive areas. And please remember, only 40 percent of the land area in BC is productive, 30 percentage points of this 40 percent are productive forest areas. Only 10 percent of BC's land can be used for agriculture (and is also used for housing and infrastructure). Another assumption which is not clearly stated concerns the calculation of the land area for energy. It seems counter-intuitive to me that you seem to advocate biomass energy. This would increase the pressure on forests. To keep the forests healthy, a good percentage of the forest biomass should be left on the forest floor to decompose and build the humus for the next generation of trees.

It is always the assumptions that make people doubt the model. Therefore, it is important to accompany such studies with a clear discussion of the assumptions, and a sensitivity analysis with alternate assumptions.

Other people argue against the Ecological Footprint concept by saying that:

> *"of course we are going to use resources from outside our political boundaries. This might also be ecologically more sensitive, because otherwise we would manage our resources too intensively and have a negative ecological impact."*

What they miss is that in total, there is not enough available, given the size of our current Footprints. Probably, to make the brochure more effective, you should address this issue to preempt this critique that seems to come up all the time.

community activists said:

This is something I am not totally clear on. Whether you can make these inductive leaps as illustrated by your table, I do not know and I cannot follow. There is a direct relationship between the use of the land and what the land will produce. And to people who live on the 42nd floor of a high-rise building, that directness can be lost. I am soundly in favour of any way to put real values onto concepts so that they become understandable to people. Similarly, to make things more real, we should ask ourselves: how many hours do we have to work to get this, rather than getting stuck with nominal dollar values. This Footprint concept graphically represents the impacts in a way that the average person can understand. That's where the value of this concept lies and I think it is of considerable value. Also the term "Footprint" is familiar because it is used in many other contexts such as building footprints. So, when I read through your brochure, I thought that this is a public education tool. And this is apparently quite useful. And what I would emphasize is that columns and graphs have not nearly the impact with the general public and the tax payers who are not familiar with the issue. Making difficult concepts understandable to the average guy in the street is very important.

I do not feel that human knowledge is adequate to understand ecology, and it probably never will be. For example, if you just take one teaspoon of soil, 1000 scientists could spend all their lives trying to figure out this community of living beings, and they would never understand it. ... The Ecological Footprint concept is great, but you should emphasize the state of ignorance, and that we cannot fully know how ecosystems work. I have problems with people who want to computer-model these interactions, and simulate or backcast ecological behaviour. We have to be humble and acknowledge our ignorance.

Sustainability is a complex issue. But if it is not explained simply enough, the audience will be lost. The brochure starts from the constraints and then explores what to do. So, it becomes not gloomy, but empowering. It is an important start.

The concept is good. Maybe you do not even want to use the term carrying capacity because it is too academic.

The chambers of commerce are afraid if a cut down in resource consumption is advocated (essentially, this would be identified as a communist plot). But the Ecological Footprint puts forward this imperative in a non-frightening way.

The accuracy depends on the application. I found it an excellent metaphor. When you talk about carrying capacity you have a lot of trouble describing that. The Footprint gets through the concept of carrying capacity and does it in an unambiguous and effective manner. I quite like it from that point of view. It is not particularly simple, but accurate for the context it is used for.

Evaluate how reliable the Ecological Footprint concept is. (question 2.8)
Does the Ecological Footprint concept demonstrate humanity's competing demands on nature's productivity?
(8) Absolutely (6) To a large extent (1) Barely (1) Not at all (5) Don't know

administrators and planners said:

I think it demonstrates the competing demands, however, it does not address the ability of society to accept a new idea.

The concept seems quite general, so probably a lot of things are left out. At this point, it includes more of these spacial things that are more measurable.

It does not address how to motivate people. Also, the problem of loss of biodiversity is not well represented.

The Ecological Footprint is a common currency: not dollars but acreage. It is inevitable that certain aspects cannot be quantified. But this does not matter, because it is an educational and analytical tool, not a regulatory one. Similarly, not everything can be reduced to money either.

The difficulty is that when you start to change the variables then it has an impact somewhere else. So it demonstrates the systemic effects. It demonstrates very clearly these competing demands. ... To make the tool effective it should not focus so much on the global scale but also translate it to the small scale of everyday life. Anyhow, the big scale is only useful for decision-making of large-scale government bodies. But sustainability has to come from the bottom up, otherwise people will resist it rather than support it.

It depends on the application. It is probably not enough for decision-making regarding development. It is very much a global approach and you also have to look at the local social, environmental and economic situation.

business people and economists said:

Environmentalists are a product of affluence. There are no environmentalists springing up in the Amazon. Environmentalists declare that Canada should not grow any more and even China should not grow any more (while we should share what we have with them). If this came true, this would reduce the yearly income of Canadians to about $800. And at that income level nobody would have the slightest interest in preserving environmental amenities.

Well, I do not understand the concept yet. I understand the global context, but I am not sure how exactly it is applied and what it includes, or how you get to these 4.8 hectares per capita. You show a correlation between income and Footprint. Have you found any reversible trends?

It is only a base number. As a concept it is ok, but not in the way it is translated into numbers. For example, water use is not incorporated effectively. Historical comparisons are difficult. Also comparison of industrial lifestyles with subsistence lifestyles might not be possible in a meaningful way. For example, what is the Footprint of innuit people in the North West Territories as compared to South Canadians.

If the Footprint is used in the public domain, it will suffer from the same problems as cost-benefit analysis. If a politician does not like the conclusion, then some assumptions will be attacked thereby killing the whole analysis.

I have the feeling that the concept (as any other one) could be misused to legitimize some wrong decisions. But I cannot think of any right now. But I would love to hear your thesis defence, and I am sure that some examiners would come up with challenging questions I did not think of before.

I would have to read the concept more carefully to understand how consumption is translated into a land-use. Also pollution aspect is not yet incorporated. Perhaps you might want to expand your concept into the 3rd dimension (by including the entire biosphere) rather than restrict yourself to land.

Tools like this [Ecological Footprint concept] might be needed to catalyze this process where people could actually see the impact, but not from the perspective that they are doing something wrong or bad. It should show that this is how the system is set up, and we are born into it. And we were told that we could consume like this. In fact, it was desirable [for the economy]. So [people] are not wrong, it is just not working they way we thought it should work in the 1940's and 1950's.

The graph on the professional couple without children is fascinating. But to work towards sustainability requires that we work toward a greater standard of living for everyone. I do not believe that sustainability is about taking this limited pie and just dividing it up more evenly. When you get the cognitive motivation from a joyful point toward sustainability, the creativity that arises from that is phenomenal. So you can in fact expand the material productive potential of this planet without necessarily depleting resources in the process. The psychological mind-set of a culture from a positive and not-fear based perspective is that the wealth (and not only the material one but also well-being, *psychological and spiritual and physical) generated from that is so significant that it will transform what we produce, how we produce and who gets it. I really do see sustainability about alleviating poverty and expanding the level of wealth and well-being.*

The model is static rather than dynamic. It does not explicitly address issues of water and air, or ozone depletion.

It all depends on the assumptions stated and whether alternate assumptions are tested.

community activists said:

It is one method to show that we are not here alone. Yes I agree, if something comes from Indonesia, it is used by us and cannot be used by them.

Such a tool is so crude, and we know so little. So we should not take models too seriously. There might be several other ways to approach this, too. Two major things that are left out are the social conditions, and most importantly the spiritual part.

I have a bias towards wanting to make connections between the people and their land. Therefore, I welcome any tool that can help doing that. This is necessary that people realize that they should be stewards of the land. I would like to see more debate about the rights and duties of citizenship towards land.

The essential thing that is left out by the Footprint concept are not the present capabilities of the land but its actual uses, such as the existing flora and fauna, and the benefits that accrue from that biological diversity.

Reliability is not necessarily an issue for the Footprint concept. And I am always sceptical of large comprehensive models, because the world is much more complex. Humility with ones tools is always important. And of course, there are very large generalizations there. By definition, demonstrating competing demands on nature is at best an estimate. [The Ecological Footprint] sets the global imperative very well, but for regional planning it just sets the imperative, but does not tell how to do it. The Footprint only works to evaluate, or show people why certain solutions might not be that good after all from a global perspective. But it is a very elegant tool to demonstrate excessive consumption. However, I had difficulties using this tool at a regional scale, except to lay out the imperative to change. ... On the city level [ecological thinking] becomes very basic: does it protect biodiversity?, does it protect the capacity of ecosystems to continue to be self-organized and complex? Those two principles I use a lot in these situation, and the Footprint does not address these issues effectively. ... It is to help the acceptance of an approach, but once it is accepted there are other tools that are more effective.

My concern is that the enormity of the implications cannot be grasped by many people. In fact, the tool illustrates how everything is connected. This concept is extremely important but breathtaking and scary. It also allows people to start at any point, but to grasp its entirety might be hard.

How useful do you think the Ecological Footprint concept is for:

- the general public to understand the sustainability dilemmas? (question 2.7a)

(14.5) Very useful (4.5) Useful (0) Marginally useful (0) Not useful (1) Don't know (1) positively harmful

administrators and planners said:

Does not deal with the motivation of the individual. Money is a big motivator. If resources were priced more fairly and included externalities such as pollution costs and the true value of resources, then the behaviour of people would become more sustainable.

business people and economists said:

It is a difficult concept and has to be explained all the time. But this might be good: it becomes a good conversation piece to talk about sustainability measures. Many measurements are quite shaky, but they open opportunities for public discussion on that particular topic.

It is very useful, but it can be very misleading when used by propagandists who do not explain their assumptions.

We develop measurements when we find that it is a nice way to provide a shorthand. An example is the use of mathematics, or any measurement units such as yards and inches. And I think that this [Ecological Footprint] is a measurement tool to very effectively accomplish something that we are trying to show.

community activists said:

It is essential. If the general public does not understand it, they will not buy it. If the general public had a real grasp of what the public debt means and what it is costing them, they would be beating on the doors of every government office in the country. And even if it meant tightening their belts, and they really understood, they would absolutely insist on it. And that is equally true for the ecological debt, forestry and other issues.

If the audience is interested in trying to understand these issues, this tool is the best that has come along so far. But I despair about how many people are interested. It is a particularly helpful tool because it reaches out to people, particularly through the use of graphics. It is more accessible than anything that I have seen. The format is great; the cartoons (such as the foot with the city on top) or the tables really help.

- individuals to reconsider lifestyle or business decisions? (question 2.7b)

(5) Very useful (10) Useful (4) Marginally useful (0) Not useful (1) Don't know (1) positively harmful

But it is very difficult to influence individuals to do anything without some economic coercion. However, if you are raised with a certain mentality, you do continue with it (i.e., composting).

Businesses have a lot of ability to discount the need to move toward sustainability, and therefore I see the Ecological Footprint at this point for this task only moderately useful. That is the highest you can hope for at this stage. All the same it is a good tool.

The greater the body using this, the greater ability these bodies have to capture the "spill over effects" or externalities, and therefore the more useful the tool. For example, private business still thinks that it only has to worry about its bottom line and cannot do anything to affect something else out there. So they cannot understand the benefit of such a tool.

It depends on how much people buy into the Footprint concept.

- community activists in their sustainability campaigns to make their point more effectively? (question 2.7c)

(13) Very useful (5) Useful (1) Marginally useful (0) Not useful (1) Don't know (1) positively harmful

This Ecological Footprint is nothing but a doomsday scenario. If Greenpeace uses this and gets people really upset and was really effective in getting people to cut their consumption to $800 a year, as David Suzuki seems to think, the end result would be total calamity. People need to read what it was like when the average income in the world was $800.

If I had a particular axe to grind, I would show how my issues would impact other people at other places. This goes towards real cost accounting, and that is what the Footprint is all about. It has to come back to public understanding, and that is key.

This concept can also be misused. It is not the only answer. Particularly, to assume that everybody here in Canada should only consume on the world average level does not work. There is no absolute standard. Population growth becomes a vicious circle. We in Canada should not change our lifestyles just because other populations are growing at a fast pace. Otherwise they will just outgrow our sustainability gains. However, it would be a positive step, if we could reduce our Footprint by being more knowledgeable about what we do.

Probably, this tool is very useful for community activists. However, they are the ones who can most abuse this concept by oversimplifying the issues, or not declaring their assumptions.

It depends on the message being presented. For example for me, it only gives me marginally more leverage in my work, even though it is complementary to what I do. [In my work], we start already from the assumption that the Footprint addresses. In my particular work, it does not add any new emphasis to it. It is a nice to have it in the back pocket to pull out useful metaphors to make the "global over-consumption" argument.

- planning departments and municipalities as a planning tool? (question 2.7d)

(10.5) Very useful (4) Useful (2.5) Marginally useful (2) Not useful (1) Don't know (1) positively harmful

administrators and planners said:

We are on a slippery slope, and today there seems to be no interest in planning for sustainability. If they were concerned about our future and our children's future it would be very useful, but in the current conditions, it is marginally useful.

It has potential to be useful, but I would like to see first some more applications.

This tool is not very helpful for local planning. Perhaps, I might use it internally to win an argument. But it cannot be incorporated in OCPs. ... The Ecological Footprint is helpful for global education, but the GVRD concepts of environmental management and regional management are more helpful when planning at the at the local level. It might be that the Ecological Footprint can get further developed for municipal applications. But at this point, I cannot see its specific relevance for municipalities.

Municipal planning is related to land-use or to management of the land. Therefore, the Ecological Footprint is not specially useful as it also includes other land than that immediately within the municipal boundaries (e.g the fossil fuel use as a land component of the Ecological Footprint). But, it helps as a background orientation.

The concept seems to be ok on an issue to issue basis, but for general applications it becomes more difficult. The tool still needs to be adapted to every new situation (e.g., how is the council going to apply it to sewers?). Education is a big part of "inching" with people along and getting them involved. ... We have to get people on board. So it is not only people at city hall that have to figure out how to apply the concept in our daily work, but it is all the institutions (like the GVRD) and the public. The level at which people do not understand and have fragmented perspectives is amazing. The fragmentation in our understanding and in organizing our lives is similar to an alcohol problem: let's just have one little drink... but we cannot stop. If we can take the Ecological Footprint and turn it into the tools with numbers attached to it that planning departments or engineers are using, that would help. Perhaps this would depend on having a handbook with the necessary statistics, so when engineers have to calculate whether their project reaches a certain percentage of efficiency so they would also have to account the amount of land and pollution and all these kind of things rather than the much more narrow way we do it now. But that needs still a lot of ground work to turn it into something.

Probably on the national or provincial level, it is quite a useful thing. But for municipalities it could be difficult to apply.

business people and economists said:

the concept could be misused. I think that academics are often respected too much, even though they have not done much "real-life" work. ... Perhaps, on this same "advisory research team" on municipal sustainability, there should be a development consultant to include a broader picture rather than only focusing on the narrow sustainability concerns.

We should not pave over the fertile farmland for urban sprawl (as it has happened in Richmond), and we should support higher urban density, because transport capacities for more and more cars are not feasible. Also, rather than upgrading Lions Gate Bridge, we should build a subway system to link the nodes in the region. But nobody wants to face the enormous initial costs. Five lanes on the Lions Gate Bridge only will increase car use and will have a drastic negative impact on the environment. Not talking about it is just assuming away the real issues. If we continue like this we will become like the typical American city. The Ecological Footprint could be useful for supporting this task but you have to be very honest about the assumptions.

community activists said:

There could be good applications. ... A main thing for local government is to make [the decision process] simpler so people can understand it. This tool might be helpful to get information out to the public and increase their understanding of the constraints. Municipalities have a duty to lead toward sustainability.

Exercises like this one are good. We have to appreciate the effect of municipal decisions and all the cumulative effects of all the small things that come with it. I suspect that municipal things are far more important than an awful lot of people give credit for. And consequently they do not get involved in the municipal affairs. Therefore, we have to work towards the public acceptance of this sort of an approach and embrace it on the municipal level. Only then will the local population adopt it as a municipal strategy.
Perhaps [the municipal planners] do not see how exactly to apply it to every day planning rather than not wanting to apply it. Some argue that there should be some larger planning bodies, but until such time, if there ever is, the municipalities have to make these judgements.

I wish they would introduce it in [our municipality].

I consider the Ecological Footprint concept to be an elegant means of representing consumption of resources, aggregated at a municipal or regional level. I do not, however, consider the Ecological Footprint to be more than marginally useful as a planning tool. By planning tool, I mean anything that I would use for analysis, plan and policy formulation, or plan implementation.

[The Ecological Footprint] is appropriate to get the issue of over-consumption on the political agenda. But beyond that it is not useful because it does not link with the rest of the daily planning activities. There is no municipal act saying "Thou shall pay attention to the global context." The Footprint does not describe the human system but only why we should change the way we operate today and helps us set very broad objectives. Personally, I suspect it is equally compelling to work with localized issues such as "do you like living here" and make people think about their quality of life. Basic principles of quality in design and quality of life are as compelling and as a legitimate motivation to do what we would consider planning for sustainability. In local communities, quality of life arguments are as effective a means of getting into action toward sustainability. There are situations where this direct experience might not point towards sustainability. But with emphasis on quality, in 9 out of 10 cases it will point toward sustainability.

● political decision-making as a sustainability indicator (similar to the GDP)? (question 2.7e)
(10) Very useful (9) Useful (0) Marginally useful (1) Not useful (1) Don't know

The nation is a too large unit for analysis. It might be useful. But people in their day to day life think of their own communities. They look at the local situation and compare it with some other places. So, the area for the Footprint analysis should be smaller.

Political decision making is so irrational and there are so many variables involved that I cannot see how the Ecological Footprint is going to assist political decisions, because they will not be honest about their assumptions. As politicians they do not want to go out to talk about the alternatives but rather preach one solution.

● students and scholars to generate positive choices for sustainability? (question 2.7f)
(12.5) Very useful (5) Useful (0.5) Marginally useful (0) Not useful (2) Don't know (1) positively harmful

I do not trust government to generate information. That is why universities are important for thinking about alternatives or for presenting various perspectives and kinds of information. ... But I also believe that above anything else, academics have to divorce themselves from single issue interest groups and act like scholars who look at alternatives across the spectrum. That is why we give scholars tenure.

Has this interview changed your perspective on sustainability? (question 2.10)

administrators and planners said:

No, but it has added something. I think, finally, I have a clearer definition of sustainability, and one that I like to use myself. I think it is a better one than the one of the Brundtland report, even though the Footprint does not say it is about "sustainability."

I do now better understand how the Ecological Footprint could be applied, and I am interested in seeing more examples and applications.

No, but I am supportive of this research work. Also, our conversation has again pointed out the sustainability dilemma.

The most interesting thing I had not thought of before was to use the Ecological Footprint as a complement to GDP. This could be very useful.

Yes, you have put forward a concept that I can understand. It is not the only way of doing it, but it has some nice facts in it such as "a Canadian is using up so many hectares" whereas "somebody in the Indian subcontinent uses that much."

business people and economists said:

If Michael Healy had sent me the brochure, I probably would have filed it without reading it. So talking about it has made me think about it. ... I certainly have thought a little further on some issues.

It has added to my understanding and, in our discussion, I have learnt a lot too.

community activists said:

It has been complementary to my understanding. I learned that you came up with a tool that can show our impact on nature in a graphical format, and ways to demonstrate figuratively fairly complicated concepts to people whose minds don't perceive those concepts particularly easily.

It is always good to be reminded of the larger policy context.

Would you consider using the Ecological Footprint concept during the next year? (question 2.11)

(14) Yes (2) No (5) Don't know

I believe in test cases. It would be nice to find a community that can embrace this idea and run with it. And then to study this community and see how it did would be insightful.

Any other comments? (question 2.12)

administrators and planners said:

The Ecological Footprint is really important work. Through my involvement in the CORE process I have realized that it is quite easy to get general agreements on broad goals. But as soon as you work your way down to specific goals -> objectives -> policies -> on the ground decisions (such as drawing lines on maps, or agreeing on annual allowable cuts), it becomes really difficult. Perhaps, the Ecological Footprint is helpful in linking these broad goals with the specific decisions, as it addresses global issues and then links them to the decisions in an individual's life.

I would like to see more examples of Footprint applications.

business people and economists said:

It is an interesting concept and I will certainly think about it.

The concept has come a long way. I am glad you are doing this and ask all these questions. But the concept still needs a lot of work.

community activists said:

I think that the Ecological Footprint is a tool that we need: a simple communications tool that causes people to say "I see."

My concern at the Richmond meeting was that the Ecological Footprint was a bit over-sold as a planning tool. I think it is good as an advocate tool, but it is difficult to see the links to everyday planning tasks such as approvals, policy recommendations, etc.

I would like to see an ongoing public report and evaluation on the progress of the footprint tool. This should discuss attempts to use it and recent developments of the tool. It could be in a bulletin form and should help to build a constituency. Also, I would like to see the concept in audiovisual fashion (e.g. video) and why not in a song of a rock group. It would be nice if there were other methods to get the concept into popular culture.

two comments about the impact of ethnicity:

I think that, from a pure ethnic Asian culture point of view, the Asians understand much more their place in nature [than Western culture], because of Buddhism, Zen, Taoism and the philosophy of Asian history. What happened with the new immigrants coming here is that you are dealing with a very small sector of "nouveau riche" which in the case of Hong Kong consists mainly of urban people without rural history or context. But if you looked at the entire Asian society you would have a much easier time communicating the concept of sustainability, because 90 percent of Asia is still agrarian. For now, looking at what Canada has to tackle, the opinion of the Asian community is insignificant. As many are new immigrants, they do not have a strong political voice anyhow. And, they have many other problems before this one. I do not think that Canadian society's view on sustainability is turning around one way or the other because of the Asian population's view on this matter.

Also because of demographic shifts through the immigration of people from Hong-Kong (where sustainability is not much of a consideration as they import all their resources and nature's services), the interest in these issues is diminishing as they do not mean much to the new immigrants.