The Ecological Footprint of South Australia

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Section 2 of this report includes some background material reproduced from the Victorian Footprint study (Global Footprint Network and University of Sydney 2005) and from Monfreda et al 2004. We are sincerely indebted to the Victorian EPA, Manfred Lenzen and Mathis Wackernagel for their permission to reproduce this material. Similarly, the three pictures on the cover of this report have been reproduced with the permission of their respective website owners: http://www.adelaide-connection.com, http://www.jblue.com.au, www.totaltravel.com.au.

Disclaimer

The scope of this study was determined by the project brief the main component of which was to calculate South Australia's Ecological Footprint by a methodology consistent with that recently used to calculate Victoria's Footprint. Hence, the methodology used in the latter calculation as well as the methodology used to calculate Australia's national Footprint were accepted as given foundations for the present project. Similarly, the authors used data and Excel worksheets supplied to them by the Office of Sustainability as well as a number of other sources. Every effort was made to confirm the veracity of these data and calculations, and the data sources are documented in the accompanying manual. However, the authors do not accept responsibility for any errors that are the consequence of inaccuracies in the data or worksheets that were supplied to us, or in the underlying methodologies that were accepted as the foundations for this project. Finally, this report contains commentary and views that express the authors' opinions and are not necessarily the views of either the University of South Australia, or the Office of Sustainability.

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Executive summary

The Office of Sustainability of the South Australian Government has commissioned the Centre for Industrial and Applied Mathematics at the University of South Australia to calculate and assess the Ecological Footprint of South Australia, using a method consistent with one that has recently been used to calculate Victoria's Footprint, The objectives of the task were:

- To calculate the consumption-land use matrix for South Australia;
- To compare per capita consumption and biocapacity of Victoria, South Australia and Australia;
- To assess contributions to the South Australian Footprint of broad activity categories;
- To identify key areas to focus on for Footprint reduction.

These tasks were successfully completed and the results are described in some detail in this report and the accompanying manual. The results show that South Australia's Ecological Footprint of 6.99 gha/cap is smaller than both the national Footprint of 7.7 gha/cap and South Australia/s biocapacity of 7.5 gha/cap. However, this also demonstrates that South Australia's per capita consumption is already running at approximately 93% percent of the state's biocapacity. As such, there is limited room for sustainable population increases, unless the latter are accompanied by lower per capita demand on natural resources, that is, lower Footprint.

The results also show that three groups of activities: "Food", "Goods" and "Housing" account for some 77% of the entire Footprint and, as such, represent most promising areas where reductions in the state's Footprint might be achieved. A closer examination of the components of the South Australian Footprint identified one prominent target area where, we believe, there are opportunities for significant reductions of the Footprint. That area is energy generation, both for electricity and other purposes (e.g., fuel). Greater adoption of renewable energy (e.g., solar and wind) offers exciting opportunities for reducing contributions to the Footprint across most sectors of human activities.

Preliminary optimisation analysis of a number of activities indicated that a more healthy diet also offers some opportunities for Footprint reductions. Of course, the question of how such a change of life-style might be achievable was beyond the scope of this project.

A comparison of South Australian and Victorian Footprint contributions reveals a great deal of similarity in percent terms as well as a constant trend of, somewhat, lower contributions in absolute units of global hectares per capita. Both the differences and similarities, in specific activity sectors, can yield insights for policy makers. For instance, the fact that in Victoria, with its superior public transport system, the per capita contribution to the Footprint of the "passenger cars and trucks" activity is still slightly higher than in South Australia may, once again, point to the challenge of the need to alter life-style patterns in order to achieve Footprint reductions.

Finally, in this report, we also briefly discuss some limitations of our calculations as well as some directions for future developments that would offer policy makers greater flexibility in what we call "integrated assessment" of sustainability strategies.

1. Project Purpose

The purpose of this study is to calculate and perform a preliminary assessment of the South Australia's Ecological Footprint. The South Australian Office of Sustainability commissioned the Centre for Industrial and Applied Mathematics, University of South Australia (UniSA) to perform this task.

The specific tasks to be performed included:

- calculation of the consumption-land use matrix for South Australia;
- a comparison between Victoria's, South Australia's and Australia's per capita consumption;
- a comparison between Victoria's, South Australia's and Australia's biocapacity;
- an assessment of contribution to the South Australian Footprint by broad activity category (in % and absolute terms);
- an assessment of the key areas to focus on for Footprint reduction;

In the following section, we will briefly review the concept of Ecological Footprint. However, at this introductory stage, it is sufficient to say that by calculating a region's Footprint, we are attempting to quantify - in a standardised manner - the amount of the earth's biocapacity resources that the human society in that region requires to maintain its lifestyle.

There are many insights that the Footprint analysis can provide with regard to the potential ways to lower our impact on the planet's resources. In Section 4.3 we will illustrate a methodology for employing the Footprint accounts to lower South Australia's impact. This will include preliminary suggestions on which areas of human activities might yield the greatest reductions in the Footprint, as well as indications of how optimisation techniques can be used to minimise the Footprint under a set of constraints. These constraints will reflect the capability of various sectors to lower their impact.

We emphasise that, the benefit of comparing the South Australian figures to the Australian and Victorian figures is not from calculating whose numbers are greater. Rather, it is from investigating in which categories the main differences may lie, and thus helping to identify ways in which we can lower the South Australian figure.

It must also be emphasised that the usefulness in such calculations is not in the absolute numbers that result, but in the identification of certain, preliminary, strategies that can be used to lower the South Australian Footprint[1].

[1] We note that a comprehensive exploration and analysis of various trade-offs involved in the reducing South Australia's ecological Footprint was beyond the scope of this project and would involve the consideration of a range of "performance indicators" in addition to the Footprint (see Section 7).

2. Background and Introduction to the Footprint Concept

In this section, we reproduce from the other sources, including the report of the Victorian accounts and Monfreda et al (2004), the basis for the accounting methods.

In particular, we introduce the, now standard, concepts and terminology by quoting, nearly verbatim from the Victorian study (Global Footprint Network and University of Sydney 2005, see [1])[2]. This underscores the fact the basic Footprint methodology is not due to the present authors and ensures consistency with the Victorian calculations.

2.1 Ecological Footprint Accounts

Ecological Footprint accounts track our supply and use of natural capital. They document the area of biologically productive land and sea a given population requires to produce the renewable resources it consumes and to assimilate the waste it generates, using prevailing technology.

In developing an index that reflects a particular activity, common unit of measurement is often utilised. The Footprint uses land area as a basis of measurement because to achieve long term sustainability, we must live entirely off of renewable resources and services from the biosphere, which in turn are powered by energy from the sun. The Footprint represents the portion of that solar collector necessary for maintaining given activities. This area is expressed in *global hectares*—adjusted hectares that represent the average yield of all bioproductive areas on Earth.

2.2 Ecological Footprint Results

Ecological Footprints compare, for any given year, human demand on nature's bioproductivity with nature's regenerative capacity. Recent calculations, published in the *Living Planet Report 2004* (WWF 2004), show that the average Australian resident uses 7.7 global hectares to produce the goods they consume and absorb the waste they produce. Using the common unit of global hectares makes results comparable to all regions in the world (a hectare, or 10,000 m^2, is about the size of a football field. A "global hectare" is a hectare of biologically productive space with world-average productivity). Worldwide, the average Footprint is 2.2 global hectares per person. (For more countries, see Table1)

In contrast, dividing the total amount of biologically productive land and sea on the planet by the current world population reveals that there are 1.8 productive hectares available per person. The average Australian's Footprint is approximately four times this area. This amount of area per person is even less if we allocate some to the other species that also depend on it. Providing space for other species is necessary if we

[2]We are sincerely indebted to Victorian EPA, Manfred Lenzen and Mathis Wackernagel for their permission to reproduce this material.

want to maintain the biodiversity that is essential for the health and stability of the biosphere.

In 2001, humanity's Ecological Footprint exceeded the Earth's biocapacity by over 20 percent (2.2 [gha/pers] / 1.8 [gha/pers] = 1.2. It is possible to overuse the global biocapacity. Trees can be harvested faster than they regrow, fisheries can be depleted more rapidly than they restock, and CO_2 can be emitted more quickly than ecosystems can absorb it. With humanity's current demand on nature, *overshoot* – using resources more quickly than they are provided – is no longer merely a local, but a global phenomenon.

Overshoot causes the liquidation of the biological natural capital. For example, harvesting timber faster than the forest re-grows means the forest will shrink. Efficiency gains have led our Footprint to grow more slowly than our economic activities. Still, human demand on nature has steadily risen to a level where humans have put the planet in ecological overshoot (see the Figure 1 below). We are not just living on nature's interest, but we are also depleting the capital.

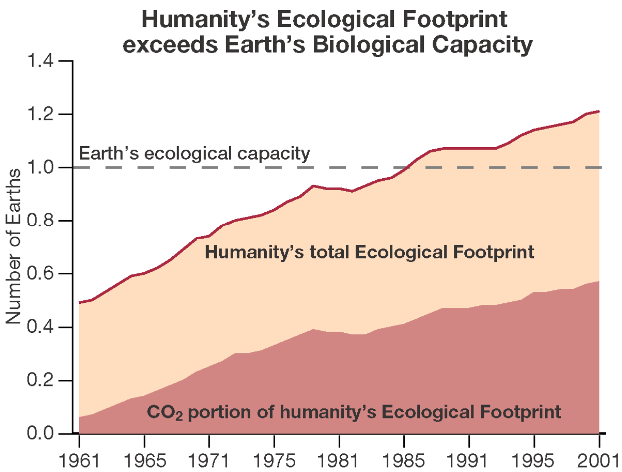


***Figure1** : The Footprint allows the comparison of human demand against the regenerative capacity of the biosphere. The global trend of the last 40 years is depicted here: an increase from using half of the biosphere's capacity in 1961 to using 120% capacity in 2001. Source: WWF 2004, see [13].*

	Population	Ecological Footprint	Biological Capacity	Ecological Deficit (-) or Reserve (+)
	[million]	[global ha/cap]	[global ha/cap]	[global ha/cap]
WORLD	6,148	2.2	1.8	-0.4
Argentina	38	2.6	6.7	4.2
Australia	19	7.7	12.7*	**11.5**
Brazil	174	2.2	10.2	8.0
Canada	31	6.4	14.4	8.0
China	1,293	1.5	0.8	-0.8
Egypt	69	1.5	0.5	-1.0
France	60	5.8	3.1	-2.8
Germany	82	4.8	1.9	-2.9
India	1,033	0.8	0.4	-0.4
Indonesia	214	1.2	1.0	-0.2
Italy	58	3.8	1.1	-2.7
Japan	127	4.3	0.8	-3.6
Korea Republic	47	3.4	0.6	-2.8
Mexico	101	2.5	1.7	-0.8
Netherlands	16	4.7	0.8	-4.0
Pakistan	146	0.7	0.4	-0.3
Philippines	77	1.2	0.6	-0.6
Russia	145	4.4	6.9	2.6
Sweden	9	7.0	9.8	2.7
Thailand	62	1.6	1.0	-0.6
United Kingdom	59	5.4	1.5	-3.9
USA	288	9.5	4.9	-4.7
Combined	4,148	2.4	1.9	-0.5

In the last column, negative numbers indicate an ecological *deficit,* positive numbers an ecological *reserve.* All results are expressed in *global hectares*, hectares of biologically productive space with world-average productivity.

Note that numbers may not always add up due to rounding. These Ecological Footprint results are based on 2001 data, the most recent available. (as published in WWF, *Living Planet Report 2004*)

*Australia's Biocapacity has been adjusted to reflect new data that became available after the publication of the *Living Planet Report 2004*.

Table 1*: The Ecological Footprint and Biocapacity of selected countries*

2.3 Robustness of the Footprint Accounts

The Ecological Footprint is a conservative measure of human demand on the planet. The National Ecological Footprint and Biocapacity Accounts, which are the foundation for regional Footprint assessments such as the one for South Australia, build on publicly available statistics from United Nations agencies. They take the UN data at face value, and since they document ecological performance of the past, they do not depend on either extrapolation or dynamic modelling.

The accounts are designed to be conservative: when data is contradictory the accounts use the data that result in a lower estimate of human demand and higher estimates for biocapacity. In addition, the accounts leave out impacts that are not conclusively documented, such as the use of freshwater with locally specific impacts, or the emission of a variety of pollutants. When there is uncertainty about the yields of a given bioproductive space an optimistic figure is used, favouring overestimation of global biocapacity. For instance, the Footprint of emitting CO_2 (mostly from burning fossil fuel) is taken as the area of world-average forest required to sequester the CO_2, after the amount absorbed by the oceans is subtracted. Other methods for calculating a CO_2 or fossil fuel replacement Footprint return larger Footprint results.

The reason we use a conservative approach is to make our claim of global overshoot as robust as possible. Still, because of the conservative nature of the Ecological Footprint measure, human demand on the biosphere is likely to be even greater than the results indicate.

2.4 Other Ecological Impacts

The Ecological Footprint does not document our entire impact on nature. It only addresses one particular question: how much of the regenerative capacity of the biosphere is occupied by a given activity. Hence, it does not directly assess degradation, risk, visual impacts or intensity of use since this is not part of the research question. Nevertheless, degradation will show up in future accounts as declining biocapacity.

Primarily, Footprint accounts include those aspects of our resource consumption and waste production that are potentially sustainable. In other words, it shows those resources that within given limits can be regenerated and broken down into waste. All activities that are systematically in contradiction with sustainability have no Footprint since nature cannot cope with them. For instance, there is no significant natural absorptive capacity for substances such as heavy metals, persistent organic and inorganic toxins, radioactive materials, or mismanaged biohazardous waste. For a sustainable world, their use must be phased out.

2.5 Ecological Footprint Assessments: Component–Based and Compound Approaches

Two distinct approaches exist for calculating Ecological Footprints: component-based and compound Footprinting (Simmons et al., 2000, [6]). The component-based approach sums the Ecological Footprint of all relevant components of a population's resource consumption and waste production. This is achieved by first identifying all the individual items, and amounts thereof, that a given population consumes, and second, assessing the Ecological Footprint of each component using life-cycle data.

The overall accuracy of the final result depends on the completeness of the component list as well as on the reliability of the life-cycle assessment (LCA) of each identified component. The challenges of this approach include: measurement boundary problems associated with LCA, lack of accurate and complete information about products' life-cycles, problems of double-counting in the case of complex chains of production with many primary products and by-products, and the large amount of detailed knowledge necessary for each analysed process. In addition, there may be significant differences in the resource requirements of similar products, depending on how they are produced. Still, judging from the hundreds of projects employing this approach worldwide, the process of detecting all components and analysing their respective resource demands has heuristic / pedagogical value.

Compound Footprinting calculates the Ecological Footprint using aggregate data. Input-output assessment is a compound approach. So are national Footprint calculations performed by Global Footprint Network. In essence, they start from a whole, before divvying up the whole into pieces, thereby making sure they are complete.

Since the national assessments are a starting point also for input-output assessments for allocating national Footprints to sectors or consumption categories, we provide here a brief introduction. More detailed descriptions of how the national Footprint accounts work can be found on Global Footprint Network's website at www.Footprintnetwork.org.[3]

The national Footprint accounts use aggregate data that captures the resource demand without requiring information about every single end use, and is therefore more complete than data used in the component-based approach. For instance, to calculate the paper Footprint of a country, information about the total amount consumed is typically available and sufficient for the task. In contrast to the component method, there is no need to know which portions of the overall paper consumption were used for which purposes, aspects that are poorly documented in statistical data collections. Similarly, the national Footprint calculation only requires the overall CO_2 emissions of a country, not a breakdown of which activity is associated with which portion of the total emissions. A compound Footprint approach yields accurate, robust results at

[3] Method paper is available at http://www.Footprintnetwork.org/gfn_sub.php?content=download.

a national scale, but does not provide information about all the details, or does not show results in categories that may be most policy relevant.

2.6 Setting the Boundaries

To make the analysis transparent and comparable, it is important to choose boundaries that ensure there is no double counting. More explicitly, if we applied the identical boundary principle to all other similar entities on earth and added up each entity's resource consumption, the sum would be equal to the total global resource consumption.

For Ecological Footprint studies, there are two standard ways of drawing boundaries:

1. *Consumption Footprint*: The Footprint of a population's final consumption. In the case of South Australia, the Footprint would include all the consumption of the region's residents, including goods and services while a resident is not physically present in South Australia, as well as consumed goods and services imported from elsewhere. This provides an insight into the resource intensity of the population's lifestyle and how it can be influenced. For example, the Consumption Footprint would include the resources used to produce the cars the population drives, the jet fuel used for their vacation travel, and the imported food they purchase, no matter whether these resources are used or originate inside or outside South Australia. Also, the Consumption Footprint would not include the energy used to power their computers at work because this energy is not part of their household consumption. Instead, this energy is assigned to the Consumption Footprint of the person who purchases the products of that office or company. Similarly, South Australia's Footprint does not account for goods produced in South Australia but exported to other regions of the world. The ecological impact of these activities will be counted towards the Footprint of residents in the region where these goods are consumed. This prevents double counting.

2. *Production Footprint*: The Footprint associated with all economic activity within a given area or population. This Footprint can be measured either at the primary production level (for example, agriculture) (the primary production Footprint), or at the stage of the commercial activities that transform primary resources and provide them to the final user (for example, the grocery store) (the secondary production or commercial Footprint). For South Australia, the commercial Production Footprint (the second possibility of the two production Footprint approaches) would include all the resources spent (and turned into waste) in producing the value added by the region's economy. This Footprint would include, for example, the timber supplied to a woodworking shop in South Australia (materials wasted in the production process and materials in the final product), the paper and electricity used by banks and offices located within South Australia, and the transportation energy for commuting to work, no matter where the products/services that they produced are consumed.

In summary, the two Footprint formulations are:

- Consumption Footprint: "Consumed in South Australia, no matter where produced"
- Production Footprint: "Produced in South Australia, no matter where consumed".

In this study, we have used the Consumption Footprint approach.

2.7 Defining the Activity Areas & Land Types

The underlying philosophy of the global ecological Footprint is that human activities place a demand on planet's available land, thereby leaving a "Footprint" on land. It is this notion that enables us to express the Footprint in terms of the appealing and universal unit of "global hectares per capita", or gha/cap.

Certainly, in the case of activities such as crop cultivation, or cattle grazing this concept has immediate meaning. However, in the case of activities such as electricity generation a conversion procedure is needed to replace, for instance, the amount of energy generated by burning coal with an equivalent area of "fossil fuel land (for electricity)". Similarly, carbon dioxide emissions generated by such burning requires land covered by vegetation to absorb it, thereby placing further demand on this type of land category. These conversions have already been developed in the seminal papers of Wackernagel et al. (see [5],[10]-[13]) and have become embedded, in a now standardised manner, in nearly all global Footprint computations. We refer the reader to [5], and [10]-[13] for further discussion of these issues.

Consistent with the above Footprint philosophy a standard set of groups of human activities that place demands on the standard set of land types have been developed[4]. These are listed in the Table 2 below.

[4] The question of whether these groups of activities or land types should be altered in any way was outside the scope of the present project.

Human Activity Group	Subcategories	Land Type	Subcategories
Food	Plant-based Animal-based	**Energy Land**	Fossil Fuel Land (Non-electricity) Fossil Fuel Land (For Electricity) Nuclear Land Hydroelectric Land Fuel Wood Land
Housing	New construction Maintenance Residential energy use	**Cropland**	
Mobility	Passenger cars and trucks Motorcycles Buses Passenger rail Passenger air Passenger boat	**Pasture**	
Goods	Appliances Furnishings Computers and electrical equipment Clothing and shoes Cleaning products Paper products Tobacco Other miscellaneous goods	**Forest**	
Services	Water and sewage Telephone and cable Solid waste Financial and legal Medical Real estate and rental lodging Entertainment Government Other miscellaneous services	**Built area**	
		Fishing Grounds	

Table 2: Groups of human activities and land types

3. Calculations of SA's Footprints and Biocapacity

The calculation of South Australia's Ecological Footprint is based on Australia's National Footprint and Biocapacity Accounts for 2001. To avoid duplication we refer the reader to the *Living Planet Report 2004* (WWF et al., 2004) for the detailed national accounts. The underlying methodology of the latter is explained in Wackernagel et al. (see [5], [10]-[13]).

The approach adopted to calculate South Australia's Footprint is based on an appropriate scaling of Australia's National Footprint. This has two advantages:

A. It simplifies the algorithm by exploiting the analogous, previously calculated, national contributions to the Footprint, and
B. It is consistent with the approach adopted in Victoria (see [1]).

A possible shortcoming of the scaling approach stems from the implicit assumption that the contributions to the Footprint of man-nature interactions in South Australia are the same in kind (if not in quantity) as the contributions of the corresponding interactions in Australia, as a whole.

3.1 Australian Consumption-Land Use Matrix

Mathematically, the ecological Footprint is a "nested-sum" of contributions from many components of the man-nature interactions.

As explained in [1] and [5], we have five **groups of human activities**: *Food (**f**), Housing (**h**), Mobility (**m**), Goods (**g**) and Services (**s**)* and **six types of land** needed to support these activities: *Energy Land (**E**), Cropland (**C**), Pasture (**P**), Forest (**F**), Built Area (**B**) and Fishing Grounds (**G**).*

Under our scaling approach for the calculation of the Footprint in a given state, we make extensive use of national, Australia, level Footprint data contained in the "consumption-land use" matrix for Australia (see Table 3, below).

Consistent with the national accounts, this table shows that the aggregated Ecological Footprint, for Australia, is 7.7 global hectares per capita. This aggregation totals contributions from the above mentioned man-nature interactions. Note that the five human activities (food, housing, mobility, goods and services) are further sub-divided into more specific sub-activities listed in the column 2 of Table 2.

Remark: It is important to note that the data in the national Footprint calculation Table 3 are taken as given in this study. No attempt was made to question these data in any way.

[gha/cap]	Energy Total	Cropland	Pasture	Forest	Built area	Fishing Grounds	Total
Food	0.5	1.1	0.7	0.0		0.3	**2.7**
.plant-based	0.3	0.3		0.0			0.6
.animal-based	0.3	0.7	0.7	0.0		0.3	2.1
Housing	1.1	0.0		0.3	0.1		1.4
.new construction	0.1	0.0		0.3	0.0		0.4
.maintenance	0.0	0.0		0.0	0.1		0.1
.residential energy use	0.9						0.9
..electricity	*0.8*						*0.8*
..natural gas	*0.1*						*0.1*
..fuelwood	*0.1*						*0.1*
..fuel oil, kerosene, LPG, coal	*0.0*						*0.0*
Mobility	0.7	0.0			0.1		**0.8**
.passenger cars and trucks	0.5	0.0			0.1		0.6
.motorcycles	0.0	0.0			0.0		0.0
.buses	0.0	0.0			0.0		0.0
.passenger rail transport	0.0	0.0			0.0		0.0
.passenger air transport	0.1	0.0			0.0		0.1
.passenger boats							
Goods	1.4	0.0	0.0	0.4	0.0		**1.9**
.appliances (not including operation energy)	0.0			0.0	0.0		0.0
.furnishing	0.0	0.0	0.0	0.0	0.0		0.1
.computers and electrical equipment (not inclu	0.0			0.0	0.0		0.0
.clothing and shoes	0.0	0.0	0.0	0.0	0.0		0.1
.cleaning products	0.0			0.0	0.0		0.1
.paper products	0.1			0.2	0.0		0.3
.tobacco	0.0	0.0		0.0	0.0		0.0
.other misc. goods	1.2	0.0		0.1	0.0		1.3
Services	0.7	0.0		0.1	0.0		**0.9**
.water and sewage	0.0			0.0	0.0		0.0
.telephone and cable service	0.0			0.0	0.0		0.0
.solid waste	0.0			0.0	0.0		0.0
.financial and legal	0.0			0.0	0.0		0.1
.medical	0.2	0.0		0.0	0.0		0.2
.real estate and rental lodging	0.1	0.0		0.0	0.0		0.1
.entertainment	0.0			0.0	0.0		0.1
.Government	0.1	0.0		0.0	0.0		0.2
..non-military, non-road	*0.1*	*0.0*		*0.0*	*0.0*		*0.1*
..military	*0.1*	*0.0*		*0.0*	*0.0*		*0.1*
.other misc. services	0.1	0.0		0.0	0.0		0.2
		0.0		0.0	0.0		0.0
Total (gha/cap)	**4.4**	**1.1**	**0.8**	**0.8**	**0.3**	**0.3**	**7.7**

Table 3: Consumption–land use matrix for Australia showing the Ecological Footprint of the average Australian resident, in global hectares per person.

In the above table, blank cells indicate that these particular man-nature interactions are either not applicable to the calculation, or in some cases that there is insufficient data to calculate the corresponding contributions to the Footprint. Cells that appear as zeroes contain actual values that are smaller than 0.005 [gha/cap]. Consequently, small discrepancies may appear in row and/or column totals.

The "consumption-land use" matrix of Table 3 plays a fundamental role in our calculation of South Australia's ecological Footprint, as it did in the corresponding calculation for Victoria.

3.2 South Australia's Consumption-Land Use Matrix

For calculation of South Australia's Ecological Footprint we have adopted the procedure of the Victoria's Ecological Footprint calculation, as in [1]. A key element of the algorithm is the calculation of per capita consumption ratios of SA and Australia.

The Australian Bureau of Statistics provides data on resource consumption and trade for Australia as a whole but that data-base is, at times, incomplete for individual states. Consequently, in order to compute the above ratios comparing South Australian and national consumption and use pattern, data were collected from a variety of sources, including the ABS (see the accompanying calculation manual for a comprehensive list of data sources). A selection of key ratios used to compare SA's and Australian per capita consumption is given in Table 4, below.

	South Australia	Australia	Ratio
DEMOGRAPHIC DATA			
Population	1,530,402	19,881,500	
Individuals per Household	2.42	2.60	
ECONOMIC DATA			
Total expenditure per week	1,177.18	1,365.00	
Total expenditure per week minus expenditure for housing, food, fuel, and transport	$ 882.22	$ 1,004.89	
Per capita expenditures per week	$ 367.59	$ 386.50	95%
TRANSPORTATION			
Road km per person travelled, 2003			
Passenger vehicles	7,542	7,632	99%
Motorcycles	42	69	61%
Airplane			
Passenger km per person	1,576	1,720	92%
Rail			
Passenger km per person	327	534	61%
ENERGY CONSUMPTION			
Residential energy consumption			
Electricity (kwh per capita)	2,412	2,375	102%
Gas (kwh per capita)	1,383	1,624	85%
direct carbon intensity of electricity (t C/Gj)	0.0568	0.0684	90%
FOOD			
Apparent per capita consumption (kg)			
Seafood	10.1	10.9	93%

Table 4: Comparison of South Australia and Australia residents' per capita consumption: Some examples.

These ratios give us some insight as to how South Australian Footprint might compare with the national Footprint. For instance, we note that most of these ratios are less than 100% with the notable exception of residential electricity consumption that, at 102%, is just barely above the national average.

Applying these ratios across the Australian consumption-land use matrix, we constructed the equivalent matrix for South Australia (see Table 5, below).

in [gha/cap]	Energy Total	Crop land	Pasture	Forest	Built Area	Fishing Grounds	Total
Food	0.5	1.0	0.7	0.0		0.3	**2.5**
.plant-based	0.2	0.3		0.0			0.5
.animal-based	0.3	0.7	0.7	0.0		0.3	2.0
Housing	1.0	0.0		0.2	0.1		1.2
.new construction	0.1	0.0		0.2			0.3
.maintenance	0.0	0.0		0.0			0.0
.residential energy use	0.8						0.8
..electricity	*0.7*						*0.7*
..natural gas	*0.1*						*0.1*
..fuelwood	*0.0*						*0.0*
..fuel oil, kerosene, LPG, coal	*0.0*						*0.0*
Mobility	0.7	0.0			0.1		**0.8**
.passenger cars and trucks	0.5	0.0					0.5
.motorcycles	0.0	0.0					0.0
.buses	0.0	0.0					0.0
.passenger rail transport	0.0	0.0					0.0
.passenger air transport	0.1	0.0					0.1
.passenger boats							
Goods	1.3	0.0	0.0	0.3	0.0		**1.6**
.appliances (not including operation energy)	0.0			0.0			0.0
.furnishing	0.0	0.0	0.0	0.0			0.1
.computers and electrical equipment (not inc	0.0			0.0			0.0
.clothing and shoes	0.0	0.0	0.0	0.0			0.0
.cleaning products	0.0			0.0			0.0
.paper products	0.1			0.2			0.2
.tobacco	0.0	0.0		0.0			0.0
.other misc. goods	1.1	0.0		0.1			1.1
Services	0.7	0.0		0.1	0.0		**0.8**
.water and sewage	0.0			0.0			0.0
.telephone and cable service	0.0			0.0			0.0
.solid waste	0.0			0.0			0.0
.financial and legal	0.0			0.0			0.1
.medical	0.2	0.0		0.0			0.2
.real estate and rental lodging	0.1	0.0		0.0			0.1
.entertainment	0.0			0.0			0.1
.government	0.1	0.0		0.0			0.2
..non-military, non-road	*0.1*	*0.0*		*0.0*			*0.1*
..military	*0.1*	*0.0*		*0.0*			*0.1*
.other misc. services	0.1	0.0		0.0			0.1
Total (gha/cap)	**4.0**	**1.0**	**0.7**	**0.7**	**0.2**	**0.3**	**7.0**

Table 5: Consumption–land use matrix for South Australia showing the Ecological Footprint of an average resident of South Australia, in global hectares per person.

Similar to the calculation for Australia as a whole, blank cells indicate that cells are either not applicable to the calculation for that land use category, or in some cases that there is insufficient data to calculate sub-categories. Cells that appear as zeroes contain actual values that are smaller than 0.05 [gha/cap]. Also, numbers may not add due to rounding.

We immediately note, from this table that an average South Australian's Ecological Footprint of **6.99 (rounded to 7.0 in Table 5) is 9% smaller** than that of an average Australian. Remarkably, South Australians have a smaller Footprint than average Australians in all five of the main human activities: food, housing, mobility, goods and services. Of course, the percentage deviations from the national average vary somewhat across the various categories of human activities.

3.3 South Australia's Biocapacity and Comparison with Victoria

South Australia's demand for land resources can be compared to what is available globally, nationally or locally. In particular, a region's "biocapacity" is now aggregated, in a standardised way, over land types: Cropland, Grazing Land, Forest, Fishing Grounds and Built-up Land.

Hence, it is now possible to compare South Australia's per capita biocapacity with those of both Victoria and Australia, as a whole. Importantly, the Footprint calculations enable us to compare the available biocapacity with that demanded by our life style. This is one measure for determining whether a society is living within

Global Biocapacity per person	1.8 global hectares				
Humanity's Footprint per person	2.2 global hectares				
Ratio of Humanity's Footprint to Global Biocapacity	121%				
Biocapacity of Australia per person					
	Area [1000 ha]	**Equivalence factor** [gha/ha]	**Yield factor** [-]	**Biocapacity** [1000 gha]	**Biocapacity per person** [gha/cap]
Cropland	47,329			81,304	4.2
primary	21,430	2.19	0.90	42,268	
marginal	25,899	1.80	0.84	39,036	
Grazing land	430,101	0.48	0.18	36,115	1.9
Forest area	164,290	1.38	0.31	69,822	3.6
Fishing grounds	212,392			52,797	2.7
marine	206,500	0.36	0.71	52,736	
inland water	5,892	0.36	0.03	61	
Built-up land	2,583	2.19	0.90	5,095	0.3
Total	856,695			245,134	**12.7**
Australia Footprint per person	7.7 global hectares				
Ratio of Australian Footprint to Australian Biocapac	61%				
Biocapacity of South Australia per person					
	Area [1000 ha]	**Equivalence factor** [gha/ha]	**Yield factor** [-]	**Biocapacity** [1000 gha]	**Biocapacity per person** [gha/cap]
Cropland	4,000	1.98	0.94	6,407	4.2
Grazing land	46,000	0.48	0.07	253	0.2
Forest area	11,015	1.38	0.06	266	0.2
Fishing grounds (assumed national average)				4,135	2.7
Built-up land	192	2.19	0.94	354	0.2
Total	61,207			11,416	**7.5**
South Australia Footprint per person	7.0 global hectares				
Ratio of SA Footprint to SA Biocapacity	93%				

Table 6: Biocapacity of South Australia and Australia, in gha/cap.

or beyond its "ecological means". The data necessary for such comparisons are supplied in Tables 6-7.

These types of comparisons produce mixed results. On the one hand, South Australia appears to be in a better situation than Victoria because its biocapacity per capita of 7.5 gha/cap exceeds its ecological Footprint of 7.0gha/cap and the latter is lower than Victoria's ecological Footprint of 8.1gha/cap by 13.6%. On the other, this "surplus biocapacity" is still much lower than the national surplus of 5.0 = (12.7 – 7.7) gha/cap; see Tables 6-7.

Furthermore, all three ecological Footprints (Australian, Victorian and South Australian) are much bigger than the worldwide (humanity's) Footprint of 2.2gha/cap. Since even the latter exceeds, the global biocapacity per capita (of 1.8 gha/cap) it could be argued that Australian society is using up global biocapacity resources at an unreasonably fast rate even though it still living within its ecological means. Undoubtedly, the surplus of 5.0 gha/cap reflects the fact that Australia possesses significant natural biocapacity resources and has a small population.

Biocapacity of Victoria					
	Area [1000	**Equivalence factor** [gha/ha	**Yield** [-]	**Biocapacit** [1000	**Biocapacity person** [gha/cap
Croplan	5,916	1.98	1.02	10,301	2.1
Grazing	7,282	0.48	1.09	666	0.1
Forest	8,295	1.38	0.30	1,050	0.2
Fishing grounds (assumed national					2.7
Built-up	449	2.19	1.02	901	0.2
Total					**5.4**
Victoria Footprint per	8.1	global			
Ratio of Footprint to	150%				
Global Biocapacity per	1.8	global			

Table 7: Biocapacity of Victoria, in global hectares per person.

Vis a vis Victoria, South Australia's biocapacity of 7.5 is 38% higher. However, it may be worthwhile to remark that the effect of, say, doubling the state's population, without changing our life style (and hence the Footprint) would reduce the biocapacity per capita to roughly 3.75 gha/cap, thereby creating an ecological deficit of 4.25 gha/cap that is greater than Victoria's current deficit.

Unlike Victoria, where approximately half of its biocapacity comes from marine areas only 36% of South Australia's biocapacity comes from fishing grounds. The greatest contributor to South Australia's biocapacity is Cropland which accounts for 56% of the state's biocapacity. Also, unlike Victoria, the ratio of South Australia's Footprint to its biocapacity is still less than 1. However, the Footprint still constitutes 93% of the state's biocapacity and hence the margin for further exploitation of natural resources is small, unless it is accompanied by more efficient use of these resources[5].

4. Evaluating the Results

We have already seen that the calculation of South Australia's overall Footprint of 6.99 gha/cap involved aggregation over many components. In order to achieve a better understanding of the implications of the Footprint it is instructive to consider the contributions to the Footprint from a range of significant man-nature interactions. From Table 8, below, we see that in South Australia, only thirteen of these components had contributions that were of 0.1 or more. In this section, we briefly discuss some features of the distribution of these contributions.

	Energy Total	Cropland	Pasture	Forest	Built area	Fishing grounds	Total Footprint, SA	% of total SA EF	Total Footprint, Australia	% of total Australia EF
	[gha/cap]	[gha/cap]	[gha/cap]	[gha/cap]	[gha/cap]	[gha/cap]	[gha/cap]		[gha/cap]	
Food	0.5	1.0	0.7	0.0	0.0	0.3	2.5	36%	2.7	36%
Housing	1.0	0.0	0.0	0.2	0.1	0.0	1.2	18%	1.4	18%
Mobility	0.7	0.0	0.0	0.0	0.1	0.0	0.8	11%	0.8	11%
Goods	1.3	0.0	0.0	0.3	0.0	0.0	1.6	23%	1.9	24%
Services	0.7	0.0	0.0	0.1	0.0	0.0	0.8	12%	0.9	11%
Unidentified	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%	0.0	0%
Total (gha/cap)	4.0	1.0	0.7	0.7	0.2	0.3	7.0		7.7	
	58%	15%	11%	9%	3%	4%	100%			100%

Table 8: Area Requirements of the South Australia Footprint

4.1 Assessment of SA Footprint by Broad Activity Categories

In particular, it is natural to consider – in percentage terms – the contributions of each group of activities and each land type to the Footprint. These are summarised in Table 9, below and in the corresponding subsequent pie charts.

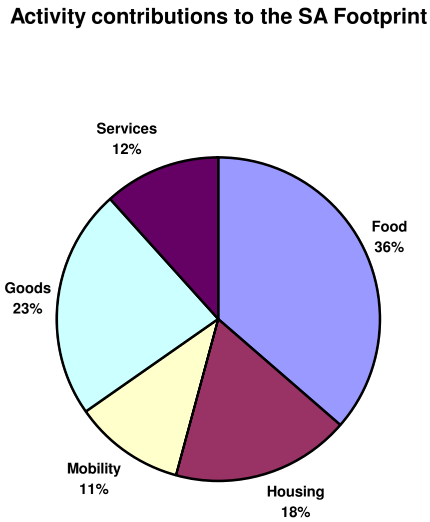
[5] Of course, an "ecological deficit" such as that which exists in Victoria is possible but it means that the state either, effectively imports natural resources, or it depletes the existing resources in an unsustainable manner.

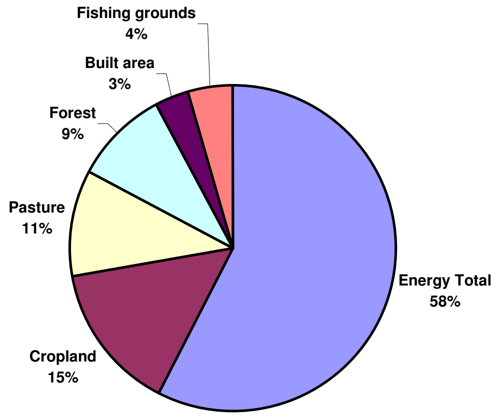
Activity Area	Percent of Total	Landuse Type	Percent of Total
Food	36%	Energy Total	58%
Housing	18%	Cropland	15%
Mobility	11%	Pasture	11%
Goods	23%	Forest	9%
Services	12%	Built area	3%
Unidentified	0%	Fishing grounds	4%
TOTAL	100%	TOTAL	100%

Table 9: Percentage contributions by activity areas and by land use type.

There can be no doubt that in, South Australia, the main human activities contributing to the total Footprint, in decreasing order, are Food, followed by Goods, Housing, Services and Mobility. Of these, Food is the dominant contributor accounting for 36% of the Footprint which is full 13% higher than next largest contributor, namely, Goods and double that of the third largest contributor: Housing. Thus it is clear that policies aimed at significantly reducing the Footprint need to focus, primarily, on these three areas that together account for 77% of contributions.

In terms of demands placed on various land types by the above human activities, there is one particular component that stands out: the 58% contribution of Energy Land. Of course, this may merely reflect the degree to which a modern society relies on energy generation to sustain itself but it also points towards certain specific Footprint reduction strategies. Incidentally, except for minor variations in contributions of Fishing Grounds and Built Areas the contributions of the dominant land areas such as Energy Land and Cropland are very similar in both South Australia and Victoria.





Area requirements of the SA Footprint by land-use area

In the remainder of this section we consider, in a little more detail, the contributions due to specific human activity groups and land types.

1. **Food (36.4% contribution to the Footprint):**

In South Australia, there are a variety of good reasons to strive for a deeper understanding of the way that food consumption activities contribute to the Footprint. Our calculations (see Table 10) merely breakdown this activity's contribution of 2.5 gha/cap into two components: plant-based food with 0.5 gha/cap and animal-based food with 2.0 gha/cap, or 7.7% and 28.7%, respectively.

Much has been written recently about healthy diets and undesirable wastage of food. In order to develop strategies that might reduce this Footprint contribution (and simultaneously bring about other benefits), it would be desirable to have a finer resolution of these activities. In Section 4.3 below, we indicate how the limited information that we already have on expenditures on various food categories (e.g., meat, fish, eggs etc.) can be exploited to design a potentially healthier diet that also reduces the Footprint. However, a more complete analysis of this interesting issue was beyond the scope of this project.

2. **Goods (23.3% contribution to the Footprint):**

This group of activities spanned a number of sub-categories related to the consumption of products and materials and their associated end-of-life disposal (see Table 10).

It is somewhat difficult to analyse this contribution because the single biggest sub-category (16.2%) corresponds to the "other miscellaneous goods" classification. Of the remaining contribution "paper products" account for 3.4% , "furnishing" for 0.9% and "clothing and shoes" for 0.7%. The latter three sub-categories may offer some, limited, opportunity for reducing the Footprint. Without, closer understanding of the dominant miscellaneous category, perhaps, the only way to influence this contribution is by "proxy" in the sense that its Footprint of 1.63gha/cap contains 1.25gha/cap from Energy Land. Therefore, it is reasonable to assume that greater use of renewable energy would reduce this contribution significantly across most sub-categories.

3. Housing (17.7% contribution to the Footprint):

This group of activities spanned a number of sub-categories related to the construction and maintenance of housing, and the residential consumption of electricity, natural gas, and other fuels (see Table 10).

The sub-category of "residential energy use" accounts for 12.1% of the overall contribution of 17.7% and, as such, constitutes the dominant component that can be targeted for reduction. Hence, once again, it is reasonable to assume that greater use of renewable energy would reduce this contribution most significantly. In particular, the presently growing contribution of wind energy to the electricity generation system in South Australia will be discussed in a subsequent section. However, in this case, other strategies, such as the use of "smart materials" in construction strengthening of the star rating system for housing, extending the proposed mandating of solar hot water heating for domestic dwellings and other initiatives could also have a significant impact on this Footprint contribution.

The only other sub-category of Housing that has a substantial contribution (4.2% out of the overall 17.7%) to the Footprint is called "new construction". A closer inspection of the demand that this contribution places on various land types reveals that the two areas that are most significantly affected are Forest and Energy Land. Thus strategies that might reduce this contribution to the Footprint may involve greater use of recycled materials in new construction and, possibly, renewable sources of energy and fuels such as bio-diesel.

4. Services (11.6%, contribution to the Footprint):

This group of activities spans quite a number of sub-categories related to the consumption of services and their associated resource costs (see Table 10). We note that only three of these sub-categories: "medical", "government" and "other, miscellaneous" account for at least 2.0% each (out of the overall 11.6%).

Of course, the operation of hospitals and government buildings (including military facilities) contribute strongly to the first two of these sub-categories. While a more detailed resolution of the contributions in various sub-categories of Services would be helpful, a quick inspection of South Australia's land use matrix indicates that the bulk of the demand that the Services activities place on land is on the Energy Land. Indeed, 0.66 gha/cap (out of 0.81 gha/ca for Services) constitutes a demand on the Energy Land. Hence, strategies that rely on alternative, renewable sources of energy generation and fuels, may offer best opportunities for the reduction of the Services Footprint.

5. **Mobility (11.1%, contribution to the Footprint):**

This group of activities spans a number of sub-categories related to the consumption of fuel for personal transport and the associated energy and built area Footprints of transport infrastructure of services and their associated resource costs (see Table 5). In this group, the sub-category “passenger cars and trucks”, in Table 10 is clearly dominant and accounts for 7.2% (out of the overall 11.1%) of the contribution to the Footprint. In Section 4.3, below, we discuss in a little more detail one strategy for reducing this component of the Footprint. However, at this point, we merely point out that Mobility’s contribution to the Footprint as a whole is not as great as might have been expected in view of the fact that South Australia is such a large, sparsely populated, state where the majority of urban dwellers commute to work in passenger cars.

6. **Energy Land (57.5%, contribution to the Footprint):**

The preceding five items focussed on contributions to the Footprint due to groups of human activities. However, one of the benefits of the Footprint calculation is that it also supplies the demands that these activities place on various land types. In the case of South Australia the largest, by far, demand is placed on Energy Land; it is equivalent to 4.02 gha/cap or 57.5% of the entire Footprint. As such, it is worthwhile to consider at least some of the constituent components of this demand. The three significant components of the latter are due to “Fossil Fuel (Non-electricity)”, “Fossil Fuel (For-electricity)” and “Wood Fuel”. Of these the first two land types account for nearly all, 3.94gha/cap, of this demand.

This finding is consistent with previous discussion of contributions due to human activities which indicated that efficient energy generation seems to underlie most of the natural Footprint reduction strategies. In this respect, the state’s strategic focus on promoting further development of renewable energy sources (e.g., wind and solar) seems well founded.

Activity	Percent of Total Footprint
Food	**36.4%**
.plant-based	7.7%
.animal-based	28.7%
Housing	17.7%
.new construction	4.2%
.maintenance	0.4%
.residential energy use	12.1%
..electricity	*10.3%*
..natural gas	*0.9%*
..fuelwood	*0.7%*
..fuel oil, kerosene, LPG, coal	*0.2%*
Mobility	**11.1%**
.passenger cars and trucks	7.2%
.motorcycles	0.0%
.buses	0.2%
.passenger rail transport	0.2%
.passenger air transport	1.7%
.passenger boats	
Goods	**23.3%**
.appliances (not including operation energy)	0.5%
.furnishing	0.9%
.computers and electrical equipment (not incl	0.2%
.clothing and shoes	0.7%
.cleaning products	0.6%
.paper products	3.4%
.tobacco	0.4%
.other misc. goods	16.2%
Services	**11.6%**
.water and sewage	0.5%
.telephone and cable service	0.5%
.solid waste	0.4%
.financial and legal	0.9%
.medical	2.6%
.real estate and rental lodging	1.3%
.entertainment	0.8%
.government	2.3%
..non-military, non-road	*1.2%*
..military	*1.2%*
.other misc. services	2.0%
Total (gha/cap)	**100.0%**

Table 10: Activity contributions to the South Australia Footprint

4.2 Comparison of SA with Victoria by Consumption Sector

In Table 11, we compare the Ecological Footprints of South Australia and Victoria, not for any pejorative purposes, but in order to help regions to understand their contributions to Footprint. In this way, it is evident that there are opportunities to lower the Footprint in both regions. How may we interpret this comparison?

Two main features are immediately apparent: (A) The distribution of the Footprint contributions across sectors is very similar in the two states, both in absolute terms of global hectares per capita and in percentage terms, and (B) The Victorian figures show a general trend of higher gha/cap values in all categories. Of the latter, some deserve further scrutiny.

For instance, household energy use is higher in Victoria, both for electricity and gas. One might expect the usage of gas to be somewhat higher in Victoria, given the more severe winter conditions, but reasons for electricity use being higher are unclear since South Australia's consumption of electricity is also slightly above the national total. Hence, this is an area that we identify as a prime area for improvement. If, for instance, the consumption of electricity were 75% of what is reported in this calculation, the Footprint of South Australia would fall to 6.8. This observation has two implications: one that this is an area for improvement, but also that there has to be a concerted effort in many areas. Since Victorian consumption of electricity is considerably higher than South Australian, even more significant gains can be made in Victoria by addressing this problem.

Another area that stands out is that of transport, not because of any significant difference between the states, but because of its absence. The prevailing belief is that Victoria's, especially Melbourne's, public transport system is significantly better than South Australia's. This may well be the case, but it does not imply that there should be significant Footprint reduction opportunities in this area without other initiatives being taken. Hence, the argument that lack of adequate public transport infrastructure is the reason for the high use of private cars may not stand up to closer inspection.

The final comment to be made from this comparison is the disparity in the contribution to the Footprint from the food sector. Whereas Victoria's contribution is above the national amount, South Australia's is below. This is, perhaps, surprising since Victoria would appear to be at least as able as South Australia to provide most of the food products for its consumption within its borders. Consumption figures in this category (as with some others) must be examined closely since they are based on expenditures, rather than literally on consumption. Expenditures act as a proxy for consumption, but they depend on prices of commodities. However, it is difficult to imagine such a discrepancy based solely on price difference per item. Is it possible that there are other factors - such as local sourcing of food, seasonal purchasing – that account for this discrepancy? If so, this could point to an area where there are opportunities for reducing the Footprint.

SA and Victoria Footprint				
Contributions across Sectors	**South Australia**	**Victoria**	**South Australia**	**Victoria**
[gha/cap]	**gha/cap**	**gha/cap**	%	%
Food	2.55	2.97	36.53	36.67
.plant-based	0.54	0.64	7.74	7.90
.animal-based	2.00	2.33	28.65	28.77
Housing	1.23	1.54	17.62	19.01
.new construction	0.29	0.34	4.15	4.20
.maintenance	0.03	0.04	0.43	0.49
.residential energy use	0.84	1.11	12.03	13.70
..electricity	0.72	0.82	10.32	10.12
..natural gas	0.06	0.22	0.86	2.72
..fuelwood	0.05	0.07	0.72	0.86
..fuel oil, kerosene, LPG, coal	0.01	0.01	0.14	0.12
Mobility	0.77	0.80	11.03	9.88
.passenger cars and trucks	0.51	0.57	7.31	7.04
.motorcycles	0.00	0.00	0.00	0.00
.buses	0.01	0.01	0.14	0.12
.passenger rail transport	0.02	0.03	0.29	0.37
.passenger air transport	0.12	0.10	1.72	1.23
.passenger boats	0.00	0.00	0.00	0.00
Goods	1.63	1.88	23.35	23.21
.appliances (not including operation energy)	0.03	0.04	0.43	0.49
.furnishing	0.06	0.07	0.86	0.86
.computers and electrical equipment (not including operation energy)	0.01	0.02	0.14	0.25
.clothing and shoes	0.05	0.06	0.72	0.74
.cleaning products	0.04	0.05	0.57	0.62
.paper products	0.24	0.28	3.44	3.46
.tobacco	0.03	0.03	0.43	0.37
.other misc. goods	1.13	1.32	16.19	16.30
Services	0.81	0.91	11.60	11.23
.water and sewage	0.03	0.05	0.43	0.62
.telephone and cable service	0.04	0.04	0.57	0.49
.solid waste	0.03	0.04	0.43	0.49
.financial and legal	0.06	0.06	0.86	0.74
.medical	0.18	0.20	2.58	2.47
.real estate and rental lodging	0.09	0.11	1.29	1.36
.entertainment	0.05	0.06	0.72	0.74
.Government	0.16	0.19	2.29	2.35
..non-military, non-road	0.08	0.10	1.15	1.23
..military	0.08	0.09	1.15	1.11
.other misc. services	0.14	0.15	2.01	1.85
Total (gha/cap)	6.99	8.10		

Table 11: Activity contributions to the South Australia and Victoria Footprint

4.3. Key Areas for Footprint Reduction

In the preceding sections we indicated how the Footprint calculation may be used to promote a higher level of sustainability. In particular, we identified the large contribution of 4.0 gha/cap due to demand on Energy Land as the key area that can be targeted for potential Footprint reduction. More specifically, we note that the bulk of the latter is made up of two finer contributions: 1.32 gha/cap due to demand on fossil fuel (non-electricity) land type and 2.62 gha/cap due to demand on fossil fuel (for electricity) land type.

Both of these could be, considerably, reduced by an appropriate mix of technological innovations and life-style changes. The latter may include a greater adoption of renewable sources of energy (e.g., solar and wind), new fuels (e.g., biodiesel) or fuel efficient vehicles (e.g., hybrids like Toyota Prius), recycling, lowering of kilometres travelled (e.g., due to telecommuting), improving home insulation, energy conservation and many other initiatives.

We do not wish to trivialise the potential difficulty in achieving significant Footprint reductions in the Energy Land component. For instance, we saw in Section 4.2 that a drop of 25% in the consumption of electricity would result in a drop in the South Australian Footprint to merely 6.8 gha/cap from the current 7 gha/cap. However, we emphasise that with the present Footprint methodology this reduction assumes that burning of fossil fuels is still the dominant method of energy generation. It is possible, even very likely, that by proper incorporation of the benefits of renewable energy sources (e.g., lowering of CO_2 emissions) into the Footprint calculations, much more dramatic Footprint reductions will be achievable.

At this stage we note that there are a number of uses of the Footprint. These include:

I. Assessment of the relative benefit of two or more actions or policies.
II. An indicator in the evaluation of the value of a proposed activity. For instance, a project's impact on the State's Footprint could be included in the decision making process in addition to, say, environmental impact estimation, employment benefits and so on.
III. Optimisation of the mix and intensity of certain activities so as to minimise the Footprint. As will be seen below, one can actually utilise the Footprint calculation worksheets to indicate the levels of activities in various sectors that would be needed to reduce the State's impact on the resources to its minimum value while still providing adequate services.

In the remainder of this section we provide a simple demonstration of item III, above. Suppose, for instance, that it is desirable to minimise the Footprint by changing the mix of modes of transport used within South Australia. We have altered the calculation spreadsheet so that the final results table appears on the same worksheet as the SA vs Aus Data. This has been done so that the inbuilt optimisation tool of

Microsoft Excel, called Solver, can be utilised to perform calculations. A simple example of such a problem is to minimise the Footprint, denoted by EF , by altering the average kilometres travelled, T_c, T_b, T_{tr}, by car, bus and train respectively. The total kilometres travelled is held constant, only the mix is changed. It is surmised that the Footprint will decrease as the optimisation routine will tend to lower T_c**,** due to the higher fuel consumption per person, per kilometre of personal vehicles. Mathematically, the problem is

$$\min_{T_c, T_b, T_{tr}} EF$$

$$\text{subject to:}$$

$$T_c + T_b + T_{tr} = C$$

$$T_c \geq L_1$$

$$T_b \geq L_2$$

$$T_{tr} \geq L_3$$

In this formulation, C is the total kilometres travelled, and the L_i are lower bounds for the different modes of travel. These bounds can be fixed by a user to reflect current thinking on the issue. An example calculation is shown in the Excel file in the link below. Basically, what it says is that if we limit travel by car to at least 7000 million km. (presently it is 11000 million km), we can lower the Footprint to 6.93 by replacing the travel by car by travel by bus and/or train. This does not necessarily mean the infrastructure is in place to support such a change, but it may point to another reason for providing such infrastructure.

If one wants to examine the optimisation, it is necessary to have the Solver add-in activated. Before opening the file, go to the **Tools** menu and if the **Solver** option does not appear, go to **Add-ins** and tick the appropriate box. Then use the link to open the file, and then access **Solver** and the description of the problem will be evident in the dialog box. The **Solver** tool uses an inbuilt algorithm to find the appropriate values of the decision variables, the amounts of the different modes of travel necessary to minimise the Footprint. To access the file, click on the link below.

SA_EF_calculationMay2005_Transport.xls

We also made a similar, preliminary, calculation concerning a potential change in the dietary habits of the populace, and its effect on the Footprint. It was observed that even though the household expenditure on food is at about 87% of the national average, expenditure on meat was at 95% and on fruit, nuts and vegetables was at approximately 80%. Thus, we have set up a minimisation of the Footprint, wherein the expenditure on meat and dairy products was lowered to below 80 and 87% respectively, while the expenditure on fruit, nuts and vegetables was raised to above 87%. As a result the Footprint was lowered to 6.71, even though we also constrained the total cost to be no more than previously. The link to the file containing this calculation is given below. We must caution that this is a preliminary examination of this type of a procedure. Indeed, it is only a simple example, but it does show the scope of what is possible.

Mathematically, we have

$$\min_{M,D,F,V} EF$$

subject to

$$123 \leq C \leq 125$$
$$M \leq 0.8$$
$$D \leq 0.87$$
$$F \geq 0.87$$
$$V \geq 0.87$$
$$C_p \leq 0.9$$
$$C_a \leq 0.9$$

In this formulation, ***EF*** is the Footprint, ***M, D, F, V*** are the South Australian percentages of the Australian expenditure on meat, dairy, fruit and nuts and vegetables respectively. The expenditure per week on food is denoted by ***C***. South Australian percentages of the Australian expenditure on plant and animal based foodstuffs are denoted by C_p and C_a respectively.

SA_EF_calculationMay2005_Food.xls

We thus see some of the possible uses of the Footprint calculation. Perhaps, its most appropriate use, in South Australia, is in the context of how much change can we effect through changes in certain activities.

5. Calculations of the Consumption Footprint

It is important to know what is behind the ecological Footprint (EF) calculations that are spread across a number of Excel worksheets embedded within the main EF calculation spreadsheet. Of course, for a comprehensive description of the guiding principles, methodology and assumptions of EF we refer the reader to the publications of its originators Wackernagel et al. [5], [10]-[13]. It must be noted that in the calculation of the South Australian Footprint a methodology analogous to that used in Victoria [1] was adopted. See also the manual

Mathematically, EF is a “nested-sum” of contributions from many components of the man-nature interactions. While the algorithm is conceptually simple, it is complex to follow in every detail, because of the wide range of interactions captured in the computation. Perhaps, the best way to explain this algorithm is to consider it at a number of successive "levels of resolution", moving from the coarse level to the very fine level, in this order.

We number the above levels 0, 1, 2, 3….etc. The exact number of levels varies with the interaction being described, however, it never goes beyond 5 in the case of South Australian calculation. At the highest level, we arrive at the stage where either raw data, or relevant figures from the national (Australian) EF calculation can be inserted. At the lower levels, the calculation is merely a formula combining the outputs from the higher levels.

Level 0: The lowest resolution (or "macro" level).

From Table 2, we have five **groups of human activities**: *Food (**f**), Housing (**h**), Mobility (**m**), Goods (**g**) and Services (**s**)* and **six types of land** needed to support these activities: *Energy Land (**E**), Cropland (**C**), Pasture (**P**), Forest (**F**), Built Area (**B**) and Fishing Grounds (**G**).*

The notational convention that we shall adopt will be that the contribution to the EF from a given land type, or from a given human activity will be denoted by the capital symbol representing that land type, and the lower case symbol representing that activity.

That is,

C = the contribution to EF capturing the global hectares of cropland per capita needed to support all five groups of human activities.

Analogous meaning is attached to ***E, P, F B*** and ***G***. Similarly,

f = the contribution to EF capturing the global hectares per capita - aggregated over all six land types - needed to support the food consumption activities.

Analogous meaning is attached to symbols, ***h, m, g*** and ***s***.

Consequently, at the coarsest, 0-level resolution, the ecological Footprint is given by the formula:

$$EF = E + C + P + F + B + G = f + h + m + g + s.$$

Important Remark: The consistency of all subsequent calculations demands that the contribution summed over the six land types is equal to the contributions summed over the five groups of human activities. That is, the second equality in the above formula must hold. This can be used as a rough check of consistency of other calculations.

In the case of South Australia, the numerical values of the above quantities (using 2003 and some prior data) were[6]

$$\mathbf{7.0 \approx 4.0 + 1.0 + 0.7 + 0.7 + 0.2 + 0.3 = 2.5 + 1.2 + 0.8 + 1.6 + 0.8.}$$

Of course, we note that at this 0-level of resolution, the interactions between human activities and land types are not yet captured. This is done at the subsequent levels, starting with level 1 that we now describe.

Level 1: The first resolution level of man-nature interactions.

The notational convention that we shall adopt will be that the contribution to the EF from a given land type due to a given human activity will be denoted by the capital symbol representing that land type with a lower case symbol subscript representing that activity. For instance,

C_f **=** the contribution to EF capturing the global hectares of cropland per capita needed to support the food consumption activities.

Hence, there is now, an array of thirty (5 × 6) such contributions at the level 1. These can be summarised in the array (see Table 8 for numerical values of these quantities for South Australia):

$$\begin{matrix} E_f & C_f & P_f & F_f & B_f & G_f \\ E_h & C_h & P_h & F_h & B_h & G_h \\ E_m & C_m & P_m & F_m & B_m & G_m \\ E_g & C_g & P_g & F_g & B_g & G_g \\ E_s & C_s & P_s & F_s & B_s & G_s \end{matrix}$$

Note that, each of the contributions to the EF at 0-level can be expressed as a sum of a column or a row of the above array. For instance,

$$\boldsymbol{E = E_f + E_h + E_m + E_g + E_s}, \text{ and } \boldsymbol{m = E_m + C_m + P_m + F_m + B_m + G_m}.$$

That is, at the 1-level, the ecological Footprint is a sum of thirty contributions captured by the formula

Remark: Based on our calculations – in South Australia – only thirteen out of the above thirty contributions are significant at the second, or higher decimal place (see Table 8 in Section 4). That is, in South Australia (in 2003), the ecological Footprint is approximately given by the simpler formula:

$$\boldsymbol{EF \approx E_f + E_h + E_m + E_g + E_s + C_f + P_f + F_h + F_g + F_s + B_h + B_m + G_f}.$$

[6] The discrepancy between 7.0 and 6.9 in the equation below is due to the round-off to one decimal place.

The higher levels of resolution in the calculation of EF tend to be specific to the particular man-nature interaction component being analysed. In what follows, we shall present details of only the food-energy land component E_f = 0.5 (see Table 8) and we refer the reader to the accompanying manual for the details of the remaining main components of the calculation.

Level 2: The first resolution level of E_f food-energy land component of EF.

We have three types of energy land needed to support these activities: *Fossil Fuel Energy Land* to generate non-electric power *(N), Fossil Fuel Energy Land* to generate electric power *(E), Nuclear Energy Land (A), Hydroelectric Energy Land (H) and Fuel Wood Energy Land (W).*

It is important to note that since Australia does not have a nuclear power industry, the component *A* is set to zero everywhere. In South Australia there is also no hydroelectric power generation and fuel wood contribution is so small as to be negligible.

Consequently, in South Australia, at this second level of resolution, the food-energy land contribution is given by the formula:

$$E_f = N_f + E_f .$$

Level 3: The second resolution level of E_f food-energy land component of EF.

We have two groups of human activities related to the consumption of food: Plant Based Food ***(p)*** and Animal Based Food ***(a)***. Hence, the total contribution of food activity on energy land is the sum of the contributions of both groups of food activities, plant based and animal based, on both types of significant energy lands in SA. These contributors are shown in the array below

$$\begin{matrix} N_f(p) & E_f(p) \\ N_f(a) & E_f(a) \end{matrix}$$

where $N_f(p)$ denotes the plant based food activity Footprint on the Fossil Fuel Energy Land (non-electricity), $E_f(a)$ denotes the animal based food activity Footprint on the Fossil Fuel Energy Land (for electricity) and similarly for others.

Thus, in South Australia, at this third level of resolution, the food-energy land contribution is given by the formula:

$$E_f = N_f(p) + E_f(p) + N_f(a) + E_f(a) .$$

In South Australia, the current estimates of the above quantities are:

$$E_f = .49 = .06 + .17 + .07 + .19 \approx 0.5.$$

The next level of resolution explains how the above four contributions were calculated.

Level 4: The third resolution level of E_f food-energy land component of EF.

We illustrate this level with the calculation of $N_f(p)=0.06$. The calculation of the remaining three contributions $E_f(p)$, $N_f(a)$, $E_f(a)$ is completely analogous.

Let $V_{SA}(f,p)$ denote the dollar value of weekly per capita expenditures, in South Australia, on plant based food activities, $V_A(f,p)$ denote the dollar value of per capita expenditures, in Australia, on plant based food activities. Hence the ratio $V_{SA}(f,p)/V_A(f,p)$ represents the fraction of the latter national expenditures generated in South Australia. The values of $V_{SA}(f,p)$ and $V_A(f,p)$ can be obtained from Household Expenditure Survey, Australia: Detailed Expenditure Items (ABS, see manual for detailed reference).

Next we refer to the national Footprint data (called the Australia matrix within the supplied spreadsheet[7]) which contains the contribution N of Fossil Fuel Energy Land to generate non-electric power. In the Australia matrix this contribution is given as $N=1.4235$ gha/cap. Note that this figure is also calculated, for Australia as a whole, via a number of resolutions into finer and finer contributions. The Australia matrix also contains the percentage contribution of each human activity to N and in particular, the percentage contribution of plant based food activities, denoted by $r(N_f(p))$, is given as 0.05%.

It is now natural, to calculate the South Australian contribution $N_f(p)$ to EF as:

$$N_f(p) = \frac{V_{SA}(f,p)}{V_A(f,p)} \times r(N_f(p)) \times N = \frac{71.15}{81.13} \times 0.05 \times 1.4235 = 0.06.$$

Remark: We refer the reader to the manual accompanying this report for further details of Footprint calculations.

[7] The data in the Australia matrix spreadsheet came from the national level calculations performed by researchers from the Global Footprint Network.

6. Limitations

There are a number of caveats one must take notice of when examining the Footprint calculation. Some have been mentioned before, such as the care one must take with respect to simply scaling the Australian results to fit the South Australian use patterns. Similarly, many assumptions are dealt with in the documents we rely on, such as Wackernagel et al. [5], [10]-[13]. However, we would like to mention some other points worthy of note, particularly regarding the South Australian interpretation, and the future calculation of the Footprint.

For a number of reasons, the data used in the calculation are derived from data for various years. This is always going to be a problem when data for different sectors has to be sourced from different agencies. These agencies collect their data for a variety of purposes, and have their own budget constraints. The latter need not be consistent with the needs of calculating the EF for a particular State.

Additionally, since the calculation is done on a per capita basis, we have to make a decision on how we account for the problem mentioned above, namely, that the data comes from various times. In the calculation for South Australia, we have used the population figure for 2003. There are two reasons for this, one that it is somewhat in the middle of the time period covered in the other data sources. More importantly, the population of South Australia is not changing at a great rate, and thus any difference from taking a different year will not be very significant.

We observe that the ratio of the ratio of populations of SA/ Australia remains nearly constant and, approximately, equal to 0.08:

SA/Aus population	1999 ratio	0.079
SA/Aus population	2001 ratio	0.079
SA/Aus population	2003 ratio	0.077

There is one important area that will need to be set up differently in future calculation of the Footprint and it must be said that it signals a significant improvement in the electricity generation mix in South Australia. Namely, we believe, a number of alterations must be made to the calculation in order to accommodate the inclusion of renewable energy in the electricity supply system. Since wind power in particular is predicted to supply between 10%-20% of the power in South Australia within the next few years, there must be a close examination of the generation mix in the calculation. This will have a number of ramifications that should be catered for. In a similar manner, it is not perfectly clear how we deal with a potential upsurge in use of solar hot water heaters, especially if there is any change in the J tariff for water heating in the wake of this.

We also believe that there is a need to investigate how the provision of water resources should be incorporated into the calculations. At present, we understand that water provision is not incorporated, and we believe that – in South Australia - it is important to understand the means by which it can be included.

7. Conclusions and Future Directions

In the project described in this report we:

- Calculated a consumption-land use matrix for South Australia;
- Compared per capita consumption and biocapacity of Victoria, South Australia and Australia;
- Assessed contributions to the South Australian Footprint of broad activity categories;
- Identified key areas to focus on for Footprint reduction.

Main Findings

Our results show that South Australia's Ecological Footprint of 6.99 gha/cap is smaller than both the national Footprint of 7.7 gha/cap and South Australia/s biocapacity of 7.5 gha/cap. However, this also demonstrates that South Australia's per capita consumption is already running at approximately 93% percent of the state's biocapacity. As such, there is limited room for sustainable population increases, unless the latter are accompanied by lower per capita demand on natural resources, that is, lower Footprint.

The results also show that three groups of activities: "Food", "Goods" and "Housing" account for some 77% of the entire Footprint and, as such, represent most promising areas where reductions in the state's Footprint might be achieved. A closer examination of the components of the South Australian Footprint identified one prominent target area where, we believe, there are opportunities for significant reductions of the Footprint. That area is energy generation, both for electricity and other purposes (e.g., fuel). Greater adoption of renewable energy (e.g., solar and wind) offers exciting opportunities for reducing contributions to the Footprint across most sectors of human activities.

Preliminary optimisation analysis of a number of activities indicated that a more healthy diet also offers some opportunities for Footprint reductions. Of course, the question of how such a change of life-style might be achievable was beyond the scope of this project.

A comparison of South Australian and Victorian Footprint contributions revealed a great deal of similarity in percent terms as well as a constant trend of, somewhat, lower contributions in absolute units of global hectares per capita. Both the differences and similarities, in specific activity sectors, can yield insights for policy makers. For instance, the fact that in Victoria, with its superior public transport system, the per capita contribution to the Footprint of the "passenger cars and trucks" activity is still slightly higher than in South Australia may, once again, point to the challenge of the need to alter life-style patterns in order to achieve Footprint reductions.

Future Directions: Integrated Assessment of South Australia's Sustainability

In the remainder of this section we put the Ecological Footprint calculation in the wider framework of "quantitative integrated assessment" of South Australia's sustainability policies. Because the Footprint and its many contributions are expressed in numerical units (gha/cap) it is a quantitative assessment method. Because its constituent man-nature interactions span a wide, often disparate, features of human activities and their impacts, it has many aspects of what, nowadays, is known in the literature as "integrated assessment".

The latter phrase covers a range of models that present a reasonably holistic view of important, complex, phenomena or activities. There is now a significant body of literature, including and an international journal of Integrated Assessment, devoted to the design, construction, analysis and uses of these types of models. An essential characteristic of these models is that they attempt to capture the interactions between constituent components of the situations modeled; thereby justifying the use of the word "integrated" in their description.

In the above context, the Ecological Footprint calculation reported here is appropriately viewed as an integrated assessment method that calculates one, very important, quantitative indicator of sustainability: the Consumption Footprint. It is a measure that is driven by the important concept of the planet's (or a region's) "biocapacity". Some of the many valuable insights and uses of the Footprint have been discussed in the preceding sections and are well documented in the literature (e.g., see [5]-[8] and [9]-[14]).

However, in a state such as South Australia that is often described as "the driest state on the driest continent" another critically important indicator immediately comes to mind when assessing strategies for sustainable development. That indicator is:

- Water (direct and embedded) measured in, say, Litres per capita.

A recent, dramatic, illustration of the importance of this indicator of sustainability was cited in the cover story of The Australian (25, May 2005) which stated that, in Australia, it takes 21,000 litres of water to produce 1 kg of rice[8]. There is clearly a need, in South Australia and Australia as a whole, to calculate the equivalent of what we might call our "Water Footprint" and compare it with our "Water Capacity". This is an urgent, and critically important problem, especially because South Australia is located at the estuarine end of Australia's single most important river system: the

[8] We wish to go on record as acknowledging that Australia's rice producers are regarded as among the most efficient in the world with regard to water usage.

Murray-Darling Basin. It is widely recognised that policies and water usage practices upstream and in other states have a profound impact on South Australia's water capacity. A Water Footprint Indicator could be a powerful tool in the assessment of these policies and practices.

Another, group of sustainability indicators that would be particularly useful in the South Australian context is that of

- Energy Footprints (direct and embedded) also measured in appealing units eg. Joules per capita and renewable Joules per capita.

We have seen in this report that demand on Energy Land is major contributor to the Ecological Footprint. Arguably, the best way to reduce this Footprint is to move away from the heavy dependence on fossil fuels. In South Australia (and elsewhere) a mix of alternative sources of energy is being developed, investigated or explored. These include solar, wind, hydrogen fuel cells, biodiesel, and "hot rocks". Some of these are already being implemented at various levels in the society (e.g., wind farms, solar water heaters and certain biodiesel powered fleet vehicles). However, we already mentioned that the current Footprint methodology does not adequately account for the impacts of these innovations.

Importantly, the above impacts may have a variety of effects on aspects of environmental sustainability not covered by Ecological Footprint as it now stands. For instance, the "hot rocks" technology if successfully implemented, in the desert regions of the state would, almost certainly, place some demand on the state's water resources[9].

Similarly, it is impossible to ignore the fact that most Footprint reduction strategies will also have economic impacts. This is, surely, the "development" aspect of the "sustainable development" phrase. To a considerable extent, this aspect can be addressed by calculating the Production Footprint in addition to the Consumption Footprint calculated in this report. Certainly, in South Australia, the Office of Sustainability, while advocating specific Ecological Footprint reduction initiatives, might be interested supplying their estimated impact on a number of economic performance indicators, such as, for instance

- Employment level, e.g., number of fully/partly employed people per 1000 in the population

- Income per capita (e.g., income or value of throughput of goods).

In this context we note the interesting, modeling work being done using input-output analyses, at the University of Sydney by a team led by M. Lenzen (e.g., see [2]-[4]).

[9] Presumably, on the finite Artesian basin reservoir.

The preceding discussion underscores the need to develop a family of performance indicators that will communicate a more comprehensive assessment of the likely impact of proposed Footprint reduction strategies. Arguably, this would help the Office of Sustainability in building consensus to support the best solutions for the state.

In principle, it is clear that a unified input-output analysis framework - conceptually consistent with the global Footprint methodology - can be used to calculate not only the ecological consumption and production Footprints but also a number of other "Footprints" representing South Australia's other priority indicators such as water, energy, waste, employment levels, income, etc. This would enable the state to perform more comprehensive, multi-criteria, integrated assessment of sustainability strategies.

Importance of Time Scales of Processes

There is one, last, important aspect that we wish to highlight in this report. We are referring here to the underlying "static nature" of both the global Footprint and the classical input-output analysis methodologies. These modelling approaches do not explicitly factor in the dependence of most human and natural processes on time. Hence they are not well suited to capture the evolution of key resources and impacts over time. They merely provide a snapshot of the situation at one particular time[10].

Of course, one can re-calculate the Footprint and other indicator values at different times "after the fact" and thereby construct a historical trend over time. Indeed, we hope that this will be done in South Australia (and other states) with respect to the Ecological Footprint. Even so, it is hard to use this framework to simulate future scenarios because the underlying dynamics of processes are not captured.

The authors of this paper argue that, ultimately, dynamic integrated assessment models of sustainable development should be our goal. This is because we believe that - at a fundamental level - most of practical sustainability strategies are about "buying time". For instance we need to buy time to extend the life of deposits of natural resources, time to allow ecosystems to recover from over exploitation, time to permit new technologies (e.g., wind/solar power) to be developed to support human activities in pollution free ways, and – equally importantly – time to support business activity in ways that maintain and grow net employment at sustainable rates. Time is what defines business cycles, recovery cycles, production cycles and life cycles of products.

Consequently, we believe that sustainability will only be achieved if these time scales are synchronised so that our human production processes are in sufficient harmony with natural processes.

[10] Of course, in the case of input-output models, this can also refer to an indefinitely long period of time when the system is an economic equilibrium. We do not propose to discuss here the, somewhat philosophical, issue of whether such periods actually exist in a dynamic world.

We conclude, by stating that we would like to see a partnership develop that includes South Australian Office of Sustainability, our Institute for Sustainable Systems and Technologies at the University of South Australia, the Global Footprint Network and the University of Sydney that will work to:

1. Extend the current Footprint model to cover other indicators of sustainability via Input-Output modeling, and

2. Extend the above static models to controlled dynamic models that capture rates of change of key physical and economic variables and sustainability indicators.

8. References

[1]. Global Footprint Network and University of Sydney (2005). 'The Ecological Footprint of Victoria: Assessing Victoria's Demand on Nature - draft version'. Prepared for EPA Victoria.

[2]. Lenzen, M. (2001). A generalised input-output multiplier calculus for Australia Economic Systems Research 13(1), 65-92.

[3]. Lenzen, M. and Murray S.A. (2001). A modified Ecological Footprint method and its application to Australia. Ecological Economics 37(2), 229-255.

[4]. Lenzen, M., Dey C. and Foran B. (2004). Energy requirements of Sydney households. Ecological Economics 49(3), 375-399.

[5]. Monfreda, C., Wackernagel, M. and Deumling, D. 2004. Establishing national natural capital accounts based on detailed Ecological Footprint and biological capacity assessments, *Land Use Policy* 21 (2004) 231–246.

[6]. Simmons, C., K. Lewis, and J. Barrett. 2000. Two feet – two approaches: a component-based model of Ecological Footprinting. *Ecological Economics* 32(3), p 375-380.

[7]. Simpson, R., Petroeschevsky A. and Lowe I. (1998). The Ecological Footprint of Australia, with a focus on the South-East Queensland Region. Preliminary Technical Report,, School of Public Health, Griffith University, Logan Campus, QLD, Australia.

[8]. Simpson, R.W., Petroeschevsky A. and Lowe I. (2000). An Ecological Footprint analysis for Australia. Australian Journal of Environmental Management 7, 11-18.

[9]. Wackernagel, M. 1998. The Ecological Footprint of Santiago de Chile. *Local Environment* 3(1), p 7-25, February.

[10]. Wackernagel, M., White, K.S., Moran, D. 2004. Using Ecological Footprint accounts: From analysis to applications, Int. J. Environment and Sustainable Development, Vol. 3, Nos. 3/4, 2004, 293-315.

[11]. Wackernagel, Mathis, and William E. Rees. 1996. *Our Ecological Footprint: Reducing Human Impact on the Earth*. New Society Publishers, Gabriola Island, BC.

[12]. Wackernagel, Mathis, Niels B. Schulz, Diana Deumling, Alejandro Callejas Linares, Martin Jenkins, Valerie Kapos, Chad Monfreda, Jonathan Loh, Norman Myers, Richard Norgaard, & Jorgen Randers. 2002. Tracking the ecological overshoot of the human economy. *Proc. Natl. Acad. Sci. USA*, Vol. 99, Issue 14, 9266-9271, July 9.

[13]. World-Wide Fund for Nature International (WWF), Global Footprint Network, UNEP World Conservation Monitoring Centre. 2004. *Living Planet Report 2004*. WWF, Gland, Switzerland.