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Sustainable and Secure Food Systems for Victoria

What do we know? What do we need to know?

VEIL Research Report: No. 1 | April 2008

The Victorian Eco-Innovation Lab is a Victorian Government Initiative through *Our Environment Our Future - Victoria's Sustainability Statement 2006*

Sustainable and Secure Food Systems for Victoria: What do we know? What do we need to know?

VEIL Research Report No.1

April 2008

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The Victorian Eco-Innovation Lab (VEIL)

The Victorian Eco-Innovation Lab (VEIL) seeks to identify and promote emerging technical and social innovations that could form part of future sustainable systems. VEIL also creates conditions to explore emerging ideas and stimulate new ones.

VEIL was established through *Our Environment Our Future – Victorian Sustainability Statement 2006* and is funded through the Victorian Government's Sustainability Fund. The project is a partnership between the University of Melbourne, Monash University and the Royal Melbourne Institute of Technology (RMIT) and is led by Professor Chris Ryan. The VEIL project is part of the Australian Centre for Science, Innovation and Society, in the Faculty of Land and Food Resources, University of Melbourne.

Workshops involving policy officers from across the Victorian Government were held in early 2007 to identify priority areas for eco-innovation in Victoria. A key theme arising from these workshops was concern about the sustainability (and security) of the food system in Victoria and consequent possibilities for innovation. The need to understand the environmental impacts of food and the risks that these present to food security set the directions for the first 'policy challenges' research project for VEIL.

This report forms part of a larger work program envisaging sustainable systems for Victoria – see www.ecoinnovationlab.com and www.sustainablemelbourne.com for more information.

Both the summary document and the full report are available online at:
www.ecoinnovationlab.com/pages/library.php

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TABLE OF CONTENTS

1. OVERVIEW ... 2

1.1. SCOPE AND STATUS OF THIS REPORT ... 3
1.2. STRUCTURE ... 3
1.3. WHY FOOD? ... 4
1.4. KEY CHALLENGES FOR THE FOOD SYSTEM ... 6
1.4.1. Reduce environmental impacts (and risks) while keeping food available and affordable ... 6
1.4.2. Continual adaptation to complex change ... 7
1.4.3. Engaging innovation ... 7
1.4.4. Consumers driving change ... 8
1.5. DIRECTIONS FOR INNOVATION IN THE FOOD SYSTEM ... 9
1.6. THE VICTORIAN FOOD SYSTEM ... 10
1.6.1. Production ... 10
1.6.2. Processing ... 14
1.6.3. Distribution ... 15
1.6.4. Consumption ... 15
1.6.5. Prices ... 16

2. ENVIRONMENTAL RISKS AND IMPACTS ... 18

2.1. CLIMATE CHANGE ... 18
2.1.1. Direct Impacts of Climate Change ... 18
2.1.2. Energy, Greenhouse Emissions and Responses to Climate Change ... 25
2.2. RESOURCE CONSTRAINTS ... 41
2.2.1. Water ... 42
2.2.2. Oil, Biofuels & Agricultural Inputs ... 51
2.2.3. Land and Soil ... 55
2.2.4. Depleted Stocks (eg. Fish) ... 63
2.3. BIODIVERSITY ... 65
2.3.1. Native Biodiversity ... 65
2.3.2. Agricultural Biodiversity ... 71
2.4. WASTE ... 73
2.5. HEALTH AND NUTRITION ... 76

3. RESPONSE STRATEGIES ... 79

3.1. EMERGING TECHNOLOGIES ... 81
3.1.1. Technological Possibilities ... 82
3.1.2. Consumer concerns ... 83
3.2. NEW PRODUCTION STRATEGIES ... 84
3.2.1. Environmental Management ... 85
3.2.2. Diversification ... 89
3.2.3. Reducing Reliance on Inputs ... 92
3.3. DISTRIBUTION STRATEGIES ... 103
3.3.1. Localisation ... 104
3.3.2. Farmers' markets ... 108
3.3.3. Community supported agriculture ... 109
3.3.4. Urban Agriculture ... 111
3.4. CONSUMER CHOICES ... 118
3.4.1. Fair Trade ... 119
3.4.2. Waste Reduction ... 120
3.4.3. Eating in Season ... 121
3.4.4. Choosing a Sustainable Diet ... 122

4. REFERENCES ... 129

1. Overview

This report provides an overview of our food production and consumption system, its impacts on the environment and its vulnerability to environmental problems and resource constraints. The aim of the report is to identify any significant challenges to the future security of the food system in Victoria that arise from environmental and resource issues, and the risks, constraints and social or political responses to these. The report also considers a range of response strategies being developed and explored at various points across the food system.

Upon completion, this work will be circulated as a discussion paper to researchers, government policy officers, and other stakeholders. This is intended to inform and stimulate:

- Clarification (confirm or modify) the set of expected policy challenges;
- Policy responses and program development where sufficient evidence exists;
- More detailed studies (further research) where evidence or further investigation is needed; and
- Collaboration across complex issues in the food system.

The '*food system'* includes the interdependent parts of the system that provides food for local consumption and for export. It includes all the components and processes by which food is produced (grown and/or processed), stored and distributed, delivered to end-consumers and consumed (including further processing and storage) – as well as all the processes that deal with waste along the 'food chain'.[1]

'*Food security'* has been described as "the state in which all persons obtain nutritionally adequate, culturally acceptable, safe foods regularly through local non-emergency sources."[2] The Victorian Government's investment in food security focuses on regular access to healthy eating, noting that access is fundamentally dependent on secure food supplies.[3] The policy objective of food security requires attention to potential risks and challenges to the ongoing security of food supplies for all Victorians, where 'security' refers both to 'provision' and to 'access'.

As highlighted in Cribbs' discussion paper, which attracted wide publicity in Melbourne in January 2008, food security is being increasingly challenged by resource constraints (eg. water, energy, land, oil, agricultural inputs) and environmental risks such as climate change.[4] Significant concern about food security and supply in the UK has stimulated numerous investigations, including scoping papers such as *UK Food Supply: Storm Clouds on the Horizon?*[5] and the Prime Minister's Strategy Unit investigation into food.[6] The possible impacts of resource constraints and environmental risks on the Victorian food system and food security, are examined throughout this report, guided by reference to research and policy development occurring in other comparable economies.

Policy responses to environmental risks and the need to reduce the environmental impacts of the food system, will also present challenges. For example, the impacts of climate change are already (and will continue to be) a significant driver for change in production of food. But the

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[1] Cornell University (2008), *Discovering the Food System - Glossary*, accessed 1 February 2008, http://foodsys.cce.cornell.edu/glossary.html.

[2] Community Food Security Coalition (1995), cited in VicHealth (2005a), *Healthy Eating - Food Security: Investment Plan 2005 - 2010*, Victorian Health Promotion Foundation, accessed 1 February 2008, http://www.vichealth.vic.gov.au/assets/contentFiles/VicHealth%20Food%20Insecurity%20Investment%20paper.pdf.

[3] VicHealth (2005a), *Healthy Eating - Food Security: Investment Plan 2005 - 2010*, Victorian Health Promotion Foundation, p2

[4] Cribb, J. (2007), *The Coming Famine: Constraints to Global Food Production in an Overpopulated, Affluent and Resource-Scarce World: The Scientific Challenge of the Era*, Julian Cribb & Associates Discussion Paper, October 2007, http://www.apo.org.au/linkboard/results.chtml?filename_num=190252.

[5] Chatham House (2008), *UK Food Supply: Storm Clouds on the Horizon?*, Chatham House UK, http://www.chathamhouse.org.uk/publications/papers/view/-/id/593/.

[6] To report to the Prime Minister in Spring 2008, see UK Cabinet Office (2008), *Food: An Analysis of the Issues*, The Strategy Unit, London, http://www.cabinetoffice.gov.uk/strategy/work_areas/food_policy.aspx

social and economic adjustments aimed at mitigating climate change (e.g. emissions trading) will themselves become pressures for the food system.

There are other non-environmental pressures on the existing food system for Victoria with possibly significant consequences such as the health and wellbeing of the community. The role of food production systems, consumption patterns and food-processing, on diet and nutrition, have been the subject of interdisciplinary research in Victoria and are under further investigation elsewhere. This area is addressed briefly in this document, but only to identify possible intersections of the health and environmental implications of the food system.

1.1. Scope and Status of this Report

This report is primarily a 'mapping' of information sources across the food system, to provide a sense of "what we know" and "what we need to know". Research has involved literature scans, selective interviews and correspondence with researchers and research groups, as well as some consultative workshops. It has also drawn on secondary sources including general media to map social concerns and awareness about food sustainability issues.

1.2. Structure

The report is structured with three main sections

Section 1 is an overview of the document. It provides an overview of the background to the report, its scope and structure, why the food system is the focus of study. It outlines the key challenges and possible directions identified in the course of doing this work.

Sections 1 also describes the current state of the food system in Victoria, summarising data and analysis already well understood and regularly reviewed in the course of government economic and agricultural research and analysis.

Section 2 discusses the most significant environmental challenges relating to the food system, both:

- The **impacts** of the food system on the environment; and
- The **risks** and **vulnerabilities** of the food system to environmental change and associated technical, social and structural responses.

Section 2 provides an overview of issues relating to: direct impacts of climate change; energy, greenhouse emissions and responses to these; resource constraints such as water, land, oil and agricultural inputs and depleted stocks (eg. fish); biodiversity (ecological and agricultural); waste; and health and nutrition.

Section 3 presents an overview of strategies being developed or employed to manage environmental risks to the food system and reduce impacts on the environment. It considers the extent of their potential contribution (identifying any empirical evidence that exists) and opportunities for further investigation or support.

This includes an overview of some emerging technologies, the result of well-funded and directed research and development programs in Governments and corporations worldwide. It summarises the possible contributions of information and communications technologies (ICT), biotechnology, nanotechnology and the convergence of these developments.

Section 3 also surveys strategies being adopted by individuals and small groups of food producers, distributors and consumers, as they seek to reduce their own risk or environmental impact, and examines the potential contributions of these innovations and movements. This section includes strategies such as low-input production, farmers' markets, preference for local and seasonal food and changing consumer preferences.

Each chapter in Sections 2 and 3 has a summary that outlines the key points, along with subject specific 'recommendations'

In these chapter summaries, three types of 'recommendation' have been identified:

!	*Significant policy challenges*
🕮	*Lack of evidence or knowledge – further research or work suggested*
⚡	*Innovation opportunity*

There is separate summary document that contains most of Section 1 (the overview) along with the chapter summaries of each section of the full report. It can be read as a standalone document with this more detailed analysis as a reference.

1.3. Why Food?

Food production is a significant part of the Victorian economy, with a direct value of $8.9 billion in 2005-6. Even more economically significant are the flow-on benefits of this production – the food processing / manufacturing industry had a value of $21.4. billion in 2005/06, the food retailing sector turned over $20.9 billion in 2005/06 and exports of agricultural commodities and value-added food products were approximately $6.8 billion (2005/06) – 36% of Victoria's total exports.[7] Altogether the food sector generates approximately 20% of Victoria's gross state product.[8]

In 2004, approximately 15% of the total Victorian labour force were employed in the food sector: 3.2% in agriculture; 2.3% in food & beverage manufacturing; 5.4% in food retailing and 4.3% in accommodation (eg. hotels), restaurants and cafes,[9] – about 370,000 people in total.[10] These figures have decreased recent years – in November 2007 only 2.7% of the population was employed in agriculture and 2.1% in processing.[11] Employment in the food sector is vital in regional areas, accounting for over 35% of jobs in Mallee, Western District and the Wimmera regions – over 20% in every other region except Barwon and Melbourne.[12]

The 'normal' dynamics of growth within this sector create challenges that are well recognised and understood by industry and government. Such challenges are essentially economic, social and technological, affecting decisions about land allocation and use, production processes and distribution, markets, labour, skills, demographics and so on. Many of those issues are essentially similar to other areas of production and consumption within the economy. However, this sector of the economy fundamentally depends on (and impacts on) the state of the environment and our natural capital (water, soil, nitrogen, sunlight, biodiversity and so on). It also involves goods and services with immediate impacts on human health and wellbeing. This makes managing the impacts of and risks to this sector critical to our economy, environment and society.

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[7] VCEC (2007), *Simplifying the Menu: Food Regulation in Victoria*, Victorian Competition and Efficiency Commission, accessed 21 January 2008, http://www.vcec.vic.gov.au/CA256EAF001C7B21/0/9822EDC9789AB06CA2572AE001CEAA8?OpenDocument.
[8] This figure is an estimate based on various figures from a range of sources as included in Figure 1.1
[9] ACIL Tasman (2004), cited in VCEC (2007), *Simplifying the Menu: Food Regulation in Victoria*, Victorian Competition and Efficiency Commission, p89
[10] VCEC (2007), *Simplifying the Menu: Food Regulation in Victoria*, Victorian Competition and Efficiency Commission, p65
[11] Taylor, M. (2008), *Victorian Agriculture, Forestry and Fishing Industries: At a Glance 2007 (Version 3.3)*, Victorian Department of Primary Industries, pp 6 &11
[12] ACIL Tasman (2004), cited in VCEC (2007), *Simplifying the Menu: Food Regulation in Victoria*, Victorian Competition and Efficiency Commission, p89

The food sector is particularly vulnerable to environmental constraints and to social concern and action in response to environmental and resource constraints, a vulnerability that could undermine its future economic contribution to the State. Most commonly, this vulnerability is expressed as concerns over energy and water usage, pre and post farm-gate. These concerns have been further sharpened by flow-on effects of water shortages, potential carbon costs and projections of climate change and oil scarcity. Food and drink have been found to account for 20-30% of the various environmental impacts of private consumption when the full production and distribution chain 'from paddock to plate' is counted and much more in some impact categories (eg. 59.7% of eutrophication).[13] Food production and consumption has been estimated to account for approximately 37% of Victoria's ecological footprint, compared to goods 23%, housing 19%, services 11%; and mobility10%.[14]

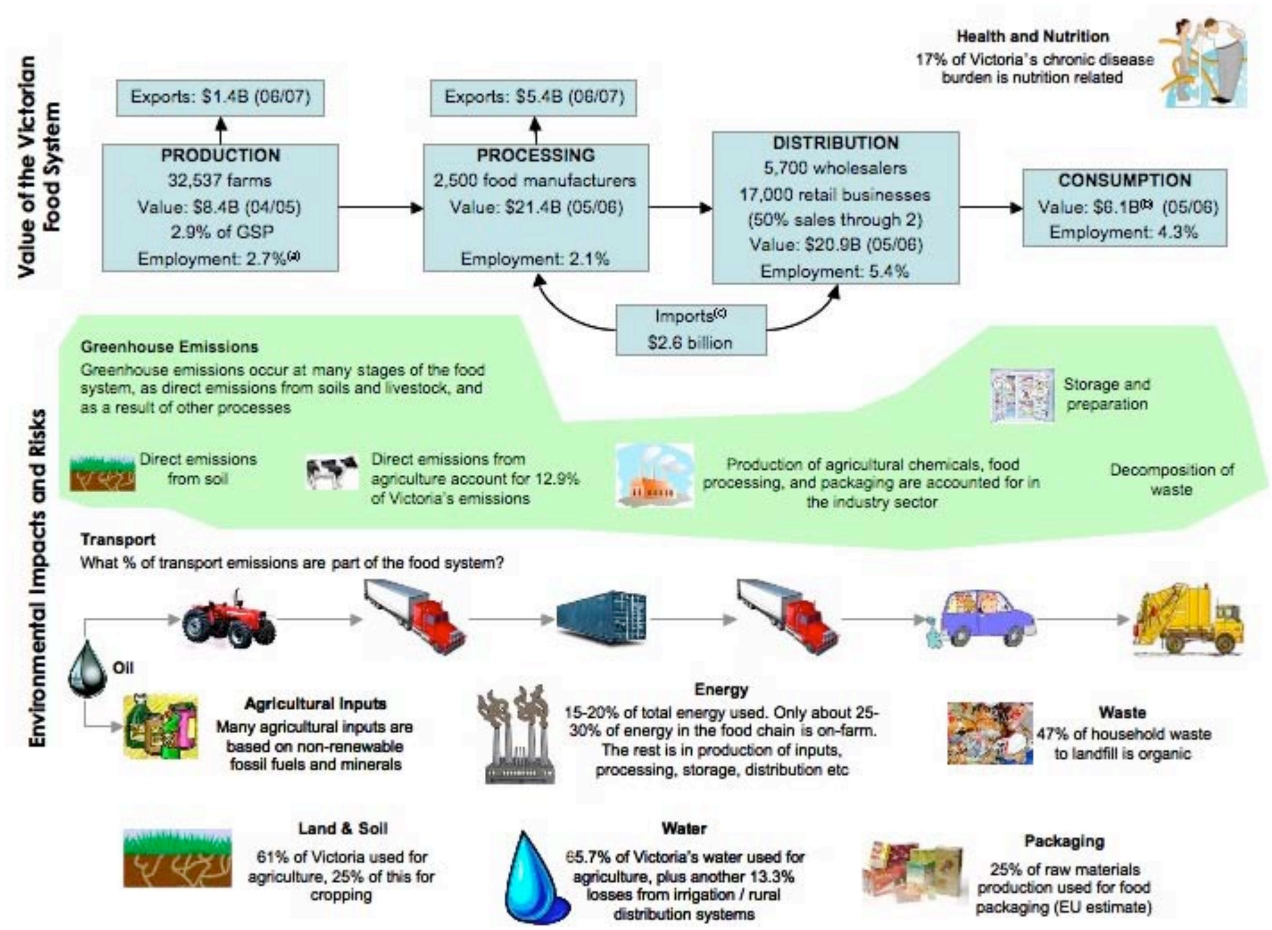
Food is essential and will inevitably have an embedded environmental impact through its reliance on land, water and energy. However, a sustainable food system would have to be one that continues to supply the nutritional demands of the population without diminishing the stock of natural capital on which it relies. That will only be possible if there is relevant knowledge on the life-cycle impacts of the food system and if investment and policy is framed with sufficient foresight regarding environmental, technological and social trends.

Figure 1.1 maps some key statistics from throughout this report to provide an overview of the economic, social and environmental significance of the food system in Victoria. This report is intended as a contribution to maintaining a secure and sustainable food supply.

[13] European Science and Technology Observatory and Institute for Prospective Technological Studies (2006), *Environmental Impact of Products (EIPRO): Analysis of the Life Cycle Environmental Impacts Related to the Total Final Consumption of the EU25, Full Report*, http://ec.europa.eu/environment/ipp/identifying.htm, p106

[14] EPA (2005), *The Ecological Footprint of Victoria: Assessing Victoria's Demand on Nature*, Global Footprint Network & University of Sydney, October 2005 – note figures are approximate because of small differences in the methods used to calculate the eco-footprint; relativities do not change with any significance.

Figure 1.1: Victorian Food System



NB. Figures in this diagram come from throughout this report – they are drawn from a range of sources and cover different years (and different countries where Australian data is not available). Figures in the blue boxes are drawn mainly from Taylor 2008 and VCEC 2007. Values fluctuate from year to year and are intended as indicative only, not as exact proportions.

(a) Percentage of Victorian total employment, these averages are much higher in regional areas eg. employment in food production accounts for up to 22% of total employment in some areas

(b) Includes cafes, bars and restaurants, as well as turnover by hotels and clubs

(c) Reports in early 2008 state that imports have surged due to drought shortages, the strong dollar and subsidised international production - see *1.6.1 (Global Competition)*

1.4. Key Challenges for the Food System

There are four overarching challenges for the food system and food security in Victoria that have been identified; these are outlined below.

1.4.1. Reduce environmental impacts (and risks) while keeping food available and affordable.

The current food system is highly vulnerable to environmental change and resource constraints, and also has a significant impact on the environment.

Complex interactions of environmental effects and resource constraints can have significant and sometimes rapid impacts on food availability and price. Food production and prices are currently being directly affected by water shortages, climate change, oil prices, and competition for agricultural inputs and land – as well as international supply and demand.

While global food shortages and increasing international demand for food products benefit some producers and raise the value of exports, they are also making food more expensive. Access to healthy and affordable food is already a problem for some disadvantaged groups and increasing food prices (along with housing and transport costs) will exacerbate this.

Increasing market internalisation of environmental costs will affect food prices as the food system has a significant impact on the environment. This will inevitably impact on some foods more than others, possibly reshaping the types of foods produced and consumed in Victoria. CSIRO analysis has suggested that "beef is undervalued in money terms by a factor of 5-10, if the value of the ecosystem goods embodied in its production chain are included."[15]

1.4.2. Continual adaptation to complex change

Uncertainty surrounds how, where and when the impacts of climate change, international or local emission control policies, resource constraints or ecological system breakdowns, will affect our food production and consumption capability. Environmental and resource challenges will impact on food systems in different ways and at different times, most likely with unexpected systemic impacts.

Ensuring a secure food supply and viable food industries under these circumstances will require attention to how the entire food system, and the productive eco-systems that underpin it, adapt to complex and often unpredictable change. Strategies to reduce risk need to encourage ongoing innovation and adaptation to new circumstances, and support *the development of flexible and resilient food systems.*

It is very difficult, but important, to consider multiple risks and uncertainties to the food system together. Separation of issues may lead to 'solutions' that are vulnerable to other risks. For example, increasing energy use to irrigate and manage water efficiently could increase energy costs and exposure to future carbon pricing. Systems that assume ongoing availability and access to cheap oil for inputs, on-farm energy, transport, packaging etc, or other non-renewable inputs, will remain vulnerable to changes in resource supply.

Individual food producers (farmers) are very adaptable – they are already responding to changing climate and resource constraints by changing what they produce and how they produce it. They are also moving out of food production altogether (a trend that may escalate if current global patterns of investment in bio-fuels continue). Many farmers are under high levels of stress from prolonged drought conditions.[16]

For all food production, there are tradeoffs between essential contributions to human diets, the energy and water demands of the product and the farm gate price.[17] Responding to new markets (eg. biofuels or almonds) can be good for individual farmers now, but could reduce the overall security of future food supply in the face of emerging risks.

1.4.3. Engaging innovation

To reduce the vulnerability of the food system to environmental (and other) challenges, all possible contributions should be explored. The scale of environmental impact reduction required (in energy, transport, emissions, water, packaging, biodiversity, land, soil etc) calls for careful consideration of every existing and emerging technology, technique and/or social and organisational innovation that might reduce risk and vulnerability, and contribute to a more sustainable food system.

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[15] Foran, B., Lenzen, M., and Dey, C. (2005), *Balancing Act - A Triple Bottom Line Analysis of the Australian Economy*, CSIRO Sustainable Ecosystems, accessed 10 October 2007, from http://www.cse.csiro.au/research/balancingact/
[16] BeyondBlue (21 March 2007), *Don't Beat About the Bush! Beyondblue and Rural Doctors Tackling Depression Together*, accessed 1 February 2008, from http://www.beyondblue.org.au/index.aspx?link_id=9.234&oid=906
[17] Foran, B., Lenzen, M., and Dey, C. (2005), *Balancing Act - A Triple Bottom Line Analysis of the Australian Economy*, CSIRO Sustainable Ecosystems, p54

There are new and emerging technological applications from the fields of ICT, biotechnology and nanotechnology and there is a convergence between these areas. These hold out promise for sustainable food and agriculture. However, we must maintain careful and measured scrutiny of the science even when there appear to be immediate benefits. The possibility of increased environmental or health risks, or side-effects leading consumers to reject other possible solutions, call for careful handling and governance of emerging technologies. The ongoing application of ICT will undoubtedly continue revolutionising all systems, however promising advances in some other areas may not be practically (or safely) useful for 10-15 years or more.

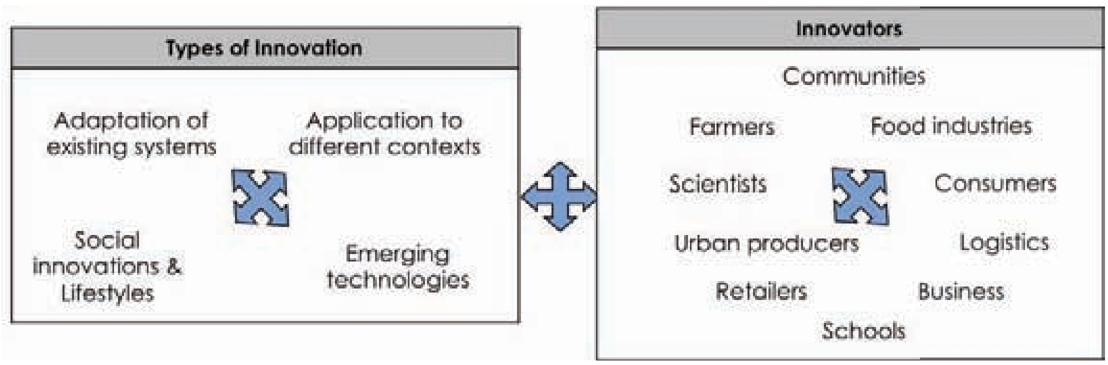
There are social, technological and organisational innovations emerging from individual and community efforts to reduce environmental impact and risk, such as diverse, low-input agriculture systems, re-designed distribution systems to reduce processing, storage and transport impacts and urban food production. Innovations in these areas also present new areas of opportunity for Victoria, with potential for broader application and further development.

There is great potential in 'evolutionary innovation' – the exponential increase in usefulness as each new scientific finding, commercialised technology, pattern of behaviour and community or individual experiment is shared, applied and developed by other people in unforeseen ways. This can be facilitated by: building individual and community capability, supporting experimentation and collaboration, and developing effective systems for knowledge exchange.

Furthermore, much of what is needed already exists. For example, a lot is known about regenerative agricultural techniques (those that restore the natural resources – particularly soil – upon which production relies), but often this research and existing knowledge isn't considered innovative, or is difficult to access and doesn't reach farmers.

Development of future food systems should seek to make use of all possible participants and types of innovation – and to emphasise capability and knowledge exchange between them all.

Figure 1.2 - What is innovation – who innovates?



1.4.4. *Consumers driving change*

The biggest impact that most individuals have on the environment is through the food we eat – food choices could make a much bigger difference to household sustainability than direct water and energy use. 50% of an Australian urban household's water use has been estimated to be through their food[18]; 28% of greenhouse emissions,[19] and 47% of municipal waste to landfill is organic (food and green waste).[20]

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[18] Lenzen, M (2002), cited in Watermark Australia (2007), *Our Water Mark: Australian's Making a Difference in Water Reform*, The Victorian Women's Trust, Melbourne.
[19] ACF (2007a), *Consuming Australia - Main Findings*, Australian Conservation Foundation, p5
[20] EcoRecycle Victoria (2005), *Information Sheet 2 - Waste Facts*, last modified March 2005, from http://www.sustainability.vic.gov.au/www/html/2039-waste-and-recycling-information-sheets.asp

There are emerging consumer trends in response to concern about the food system and environmental issues, for example interest in organic, locally produced and seasonal foods. In some countries, notably the UK, this consumer interest is being 'amplified' by the actions of retailers who are investing substantial funds in carbon labelling, local fresh food and origin labelling, systems to reduce or eliminate packaging and so on. So whilst these consumer trends still comprise a relatively small market segment in Australia, they are increasing fast and are likely to be bolstered by the changes in international markets.

There is a lack of information for Australian consumers wishing to make food choices to reduce their environmental impact. There are general (high-level) conclusions about the environmental benefits of organic / low-impact, local and seasonal foods, changing dietary composition, and reducing levels of processing and packaging. However, product and location specific factors mean few simple conclusions or recommendations can be made. Other considerations – like health, yield and wastage – also need to be taken into account to analyse overall food systems.

Australian / Victorian specific analysis and information is needed in a range of areas to underpin informed consumer choice and correctly guide producers and other food industry participants. Without robust information that is accessible, consumers will increasingly opt for simple - and even simplistic – indicators (such as 'food miles') to make their decisions.

1.5. Directions for Innovation in the Food System

There are six overarching messages about how and where innovation is occurring in relation to food that derive from the information in this report. These could form the basis for actions to accelerate the pursuit of sustainable and secure food systems in Victoria.

Broaden the perception of what 'innovations' are worth investing in.
New technologies will play an important part in developing more sustainable systems, but so will individual, social and cultural innovations. It is probable that systems innovation will be based on new configurations and new applications of existing knowledge and technologies. Broad experimentation has to be encouraged and supported.

Two tracks - parallel paths.
Incremental improvement to existing systems is essential to reduce their impacts and vulnerabilities and this approach will have to accelerate. However the extent of the change required (80% reduction in greenhouse emissions in 40 years) means that future food systems will be vastly different from today. So, incremental improvements and the exploration of significant systems redesign (including consideration of ideas that may seem unrealistic or radical) will need to happen in parallel.

Priority research areas
There is a lack of Victorian / Australian data in many areas of importance in the food system and these have been identified in the chapter summaries. There are three areas that could be considered as priorities to underpin policy design and action for the food system:

- Lifecycle analysis of key food products (particularly around greenhouse emissions and water): to enable measures to correct market failure and support modeling of the impacts of policy interventions throughout the food system
- Measure the actual effectiveness of innovations and existing known agricultural techniques in Victoria: test claims of innovative (and existing) agricultural techniques; analyse their effectiveness in different conditions; and conduct controlled trials to determine the most beneficial techniques and systems
- Extend information on ecosystems, especially the quality and condition of soils

There's a lot we don't know, but a lot we do
Where information is available, ensure that producers, food industries and consumers can easily access and make sense of it. There is also a need to drive application and uptake of knowledge and systems that exist and are ready to use – as more people use them they will continue to evolve and improve.

Catalyse change and support the 'culture of innovation'
Innovation will come from many players in the system. There is value in looking to and supporting people and organisations that are already engaged in the process of redesigning systems and experimenting with new ideas. They can be supported through access to research, information systems and promotion; as well as the removal of policy barriers to experimental activity. The successes and failures of innovative experiments should be valued and shared to foster knowledge exchange and 'evolutionary innovation'.

The food system is a complex interaction of economic, social, health and environmental issues
Issues concerning the food system cross portfolios, communities and industries. They are wicked problems and will require coordinated responses. Identification and management of conflicting objectives in the food system will be necessary, along with consideration of roles and alignment between different players.

1.6. The Victorian Food System

1.6.1. Production[21]

Victoria has diverse agricultural production, including small horticultural farms as well as large properties mainly devoted to sheep, cattle or cereal production. Victoria has an estimated 32,000 'establishments with agricultural activity', which includes all those with an estimated value of agricultural operations (EVAO) of over $5,000[22] – this includes both sub-commercial and commercial operations.[23]

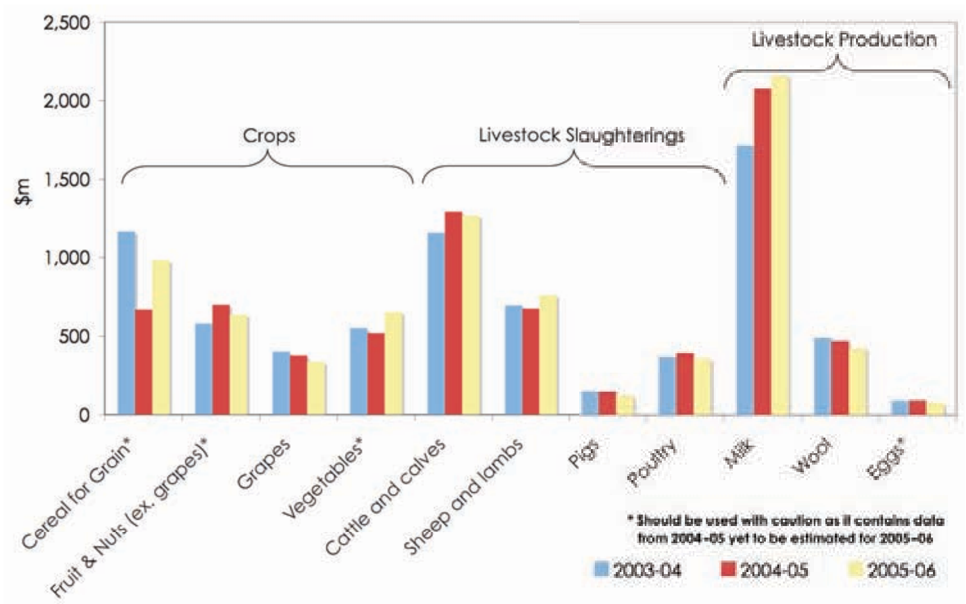
Table 1-1: Victoria's Food Production

Most significant products[24]	% of National production[25]
Broadacre crops such as wheat and barley for grain	15% grain crops
Cattle for beef and dairy production	20% beef, 65% dairy
Sheep for meat and fine wool	40% lamb
Apples, pears, citrus and stone fruit	26% of all fruit (2003-04)
Vegetable crops include potatoes, tomatoes and carrots	26% of all fruit (2003-04)

The value of Victoria's agricultural commodity production has varied over recent years, with some sectors maintaining good performance despite difficult conditions, although others have declined (Figure 1.3).

[21] 2004-05 figures used in this section are confirmed, figures for 2005-06 are preliminary figures and should be read with caution.
[22] ABS (2006a), *Agricultural State Profile, Victoria, 2004-05,* Cat. No. 7123.2.55.001, Australian Bureau of Statistics, Canberra.
[23] The ABS defines commercial as EVAO greater than $22,500, and sub-commercial as EVAO between $5,000 and $22,499.
[24] ABS (2006a), *Agricultural State Profile, Victoria, 2004-05,* Cat. No. 7123.2.55.001, Australian Bureau of Statistics, Canberra.
[25] DPI (2006a), *Victorian Food Industry Fact Sheets,* Department of Primary Industries, accessed 15 December 2007, http://www.dpi.vic.gov.au/dpi/nrenti.nsf/LinkView/2969C33369DFA832CA256BC20016E3933EAE47A0DB5D4984CA25727A00781A83.

Figure 1.3 – Value of Agricultural Commodity Production for Victoria[26]



The value and conditions of Victoria's agricultural production have been affected by changing conditions, including the drought. Dairy cattle (which made up 32% of the value of Victoria's agricultural commodities in 2005)[27] are increasingly relying on irrigated pastures rather than rainfed,[28] and on purchase of feed produced off farm.[29] The value of crops (including pastures and grasses) decreased between 2003-04 and 2004-05 primarily due to varying climatic conditions.[30]

Figures representing the value of food products reflect the price being paid. The value of food production, and particularly exports, may be kept high by increasing global demand for some commodities and foods, particularly dairy and grains (see *2.2.1 Water* for further discussion of dairy and grain prices). The increase in value for some products shown in Figure 1.2 may not be fully representative of an increase in actual production – the increased value of livestock slaughtering is partially due to farmers reducing numbers of dairy cattle and sheep that they cannot feed. The increased value of milk is at least partially due to high international prices. The producer debt that underpins continuing production is not reflected in these figures.

Exports

$1.4 billion of Victorian agriculture production was directly exported in 2006-07, making up 6.9% of Victoria's total merchandise exports.[31]

Victoria's food exports (ie. value-added products rather than direct agricultural commodities) are worth significantly higher amounts, with $5.35 billion worth of Victorian food exported in 2006-07 (this includes beverage and tobacco exports).[32]

The majority of value of Victoria's food exports is from dairy, meat, wine and grains.

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[26] Taylor, M. (2008), *Victorian Agriculture, Forestry and Fishing Industries: At a Glance 2007 (Version 3.3)*, Victorian Department of Primary Industries, State of Victoria, p7
[27] Ibid, p7
[28] Cork, S. and Delaney, K. (2005), *Thinking About the Future of Australia's Landscapes*, Land and Water Australia, p54
[29] Ibid.
[30] Taylor, M. (2008), *Victorian Agriculture, Forestry and Fishing Industries: At a Glance 2007 (Version 3.3)*, Victorian Department of Primary Industries, State of Victoria, p7
[31] Ibid, p6
[32] Ibid, p17

Increasing Farm Size, Intensification and Specialisation

The top third of Australian farms (by gross value of production) have been achieving productivity gains greater than the decrease in terms of trade,[33] and the top fifth of Australian farms generate a long-term positive return on capital.[34] Terms of trade have been steadily declining for many Australian farmers since the 1960s,[35] and only farms already returning high incomes are able to continue producing.

The economic pressure on farmers to enlarge for their survival has seen a continual decline in the number of farms – particularly family and small-scale farms – in Victoria from 69,000 in 1950-51 to 35,000 in 2001 and 32,000 in 2005.[36] Between 1986 and 2001, the number of Victorian grains producing farms smaller than 500 hectares dropped by roughly a third, while the number of farms of 2500 hectares or more, more than doubled.[37] In the Wimmera and Mallee, grain-producing areas in western Victoria, the number of farms almost halved between 1961 and 2001, while the average farm size nearly doubled, from 480 hectares to 920 hectares.[38]

This move towards larger farms has been accelerated by the expansion of corporate agribusiness in Victoria ('corporate agribusiness' refers to large farms that are owned and managed by bodies other than family enterprises). This has been particularly driven by Managed Investment Schemes (MIS), which provide significant tax incentives for co-investment in agribusiness. Since 2000-01, over $300 million has been invested in large-scale agribusiness production of almonds, olives and grapes.[39] In Victoria, $152 million was invested just in 2005-06 (non-timber). From this money investment, it is estimated that 84,000 hectares of timber plantations and 19,400 hectares of agricultural operations would be established.[40] As they are able to raise large amounts of investment capital, these enterprises are characterised by large scale, modern equipment, low unit production costs and high water efficiency.

Larger farms are more able to continue the pursuit of production efficiencies and continued yield increases through investment in technological solutions and capital investment for new crop varieties etc. High values can be obtained through this approach – the10% of Australian farms earning the highest gross farm income produce over 50% of the value of Australian agricultural production, while the 50% earning the least produce only 10% of the value.[41] Small (sub-commercial) farms owners / residents typically make most of their income off the farm but are managing an increasing amount of land.[42]

Australia's increase in agricultural commodity production can largely be attributed to "significantly higher crop production, based on increased areas and a widespread improvement in broad-acre crop yields around Australia compared with 2004-05."[43] Broad-acre farm productivity has averaged a 3.26% growth per year in output per unit (1989-2004), while productivity in the grains sector has grown at 4.86% a year.[44]

Intensification of food production has meant an increase in monocultures and high specialisation

[33] Barr, N. (2005), *Understanding Rural Victoria*, Department of Primary Industries, State of Victoria, p5
[34] Ibid.
[35] ABARE (2004a), cited in Ibid, p4
[36] Taylor, M. (2008), *Victorian Agriculture, Forestry and Fishing Industries: At a Glance 2007 (Version 3.3)*, Victorian Department of Primary Industries, State of Victoria, p23
[37] ABS (2003b), cited in Barr, N. (2005), *Understanding Rural Victoria*, Department of Primary Industries, State of Victoria, p4
[38] Barr, N. (2005), *Understanding Rural Victoria*, Department of Primary Industries, State of Victoria, p5
[39] Australian Agribusiness Group (2006), *Agri and Hort Managed Investment Schemes: Snapshot of the Economic Development Outcomes in Regional Victoria*, Regional Development Victoria, p4
[40] Ibid, p1
[41] Barr, N. (2005), *Understanding Rural Victoria*, Department of Primary Industries, State of Victoria
[42] Hooper, S. et al. (2002), cited in Francis, J. (2002), *Recognising the Value and Potential of Small Farms: Learning from the USA*, Department of Primary Industries, State of Victoria, p1
[43] DAFF (2007), *Australian Food Statistics 2006*, Department of Agriculture Fisheries and Forestry, p1
[44] Taylor, M. (2008), *Victorian Agriculture, Forestry and Fishing Industries: At a Glance 2007 (Version 3.3)*, Department of Primary Industries, State of Victoria, p23

for commercial farming. This has made use of higher levels of irrigation, chemical inputs and heavy machinery use. Between 1990 and 2000, farm chemicals and fertiliser use increased substantially, with sales of farm herbicides, insecticides and fertilisers more than doubling,[45] (for longer range trend see *2.2.3 Land and Soil*). This has played a significant role in increasing costs and farm viability.[46]

There is also a trend towards agribusiness patents of plant and animal genetic resources,[47] and a reduction in seed saving of crops.

Employment and aging populations

According to the ABS Australian labour market statistics,[48] 73,600 people left the agriculture, fisheries and forestry sector in the last five years. There has also been a significant growth in off-farm income earned by farming families. For high rainfall beef farms in south-eastern Australia, off-farm income has more than doubled since 1980.[49]

Since 1976, the number of Australian farmers aged in their 20s has declined by over 60%.[50] This lack of succession capability facilitates the take-over of small-scale or family farms by larger commercial farms. This decline in small farmers and decrease in the number of younger farmers signifies a loss of agricultural skills & knowledge specific to local bioregions.

Changing demand and land-use in formerly agricultural regions is seeing an increase in lifestyle farming (no financial reliance on the land productivity due to off-farm income), or semi-reliance and changing crops and environmental management – see *3.2.2 Diversification.*

Global competition

Australia's primary producers are exposed to international market conditions (eg. deregulated commodity and input markets) and, unlike many other industrialised economies, Victoria provides no routine assistance to agricultural producers through tariff protection or production subsidies.[51] This, according to the Department of Primary Industries, "creates strong incentives for primary producers to improve efficiency, remain flexible and responsive to commodity price changes, and to fundamentally change their participation in primary production."[52]

This also increases producer vulnerability to fluctuating market prices of their particular produce, while agricultural tariffs and export subsidies of other countries, create artificially low prices that do not reflect actual production, labour and resource costs. Imported products can often be sold at the same price, if not cheaper, than local products.[53] This is currently exacerbated by the strength of Australian dollar, which places economic pressure on Victorian farmers exposed to import competition.[54]

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[45] ABS (2003a), *Australia's Environment: Issues and Trends, Cat. No. 4613.0*, Australian Bureau of Statistics, Canberra, p31
[46] Australian Agribusiness Services (1997), cited in Barr, N. (2005), *Understanding Rural Victoria*, Department of Primary Industries, State of Victoria
[47] Heller, M.C. and Keoleian, G.A. (2000), *Life Cycle-Based Sustainability Indicators for Assessment of the US Food System* (No. CSS00-04), Centre for Sustainable Systems, University of Michigan, p10
[48] ABS (2007b), *Australian Labour Market Statistics*, Cat. No. 6105.0, Australian Bureau of Statistics, Canberra
[49] ABARE (2004b), cited in Barr, N. (2005), *Understanding Rural Victoria*, Department of Primary Industries, State of Victoria, p31
[50] Cork, S. and Delaney, K. (2005), *Thinking About the Future of Australia's Landscapes*, Land and Water Australia, p10
[51] Taylor, M. (2008), *Victorian Agriculture, Forestry and Fishing Industries: At a Glance 2007 (Version 3.3)*, Victorian Department of Primary Industries, State of Victoria, p23
[52] Ibid, p23
[53] Mamen, K. et al. (2004), *Ripe for Change: Rethinking California's Food Economy*, International Society for Ecology and Culture, Berkeley.
[54] State of Victoria (2005), *Budget Strategy and Outlook 2005-2006*, Victorian Government Melbourne.

As reported in *The Weekly Times* in February 2008, current drought-driven shortages and the strength of the dollar have led to a sharp rise in food imports, "eroding farmers' returns and forcing processors to sack staff."[55] ABS data quoted in this article states that between 2002-03 to 2006-07: meat imports more than doubled; dairy imports climbed 25 per cent; fruit and vegetable imports surged more than a third; and wine imports more than doubled.

Globalisation and the freer movement of food products around the world are also contributing to pressure on Australian producers in international horticulture, grains and meat markets. "Increasing production from South America, China, South Africa, Russia, and Eastern Europe is tending to lower prices and market share for Australia in export markets and is already displacing Australian production from domestic markets."[56] These pressures present major challenges to Victorian producers.

However, the food safety and environmental standards of international producers may be much lower than those of Australian producers:

> The list of Chinese food exports rejected at American ports reads like a chef's nightmare: pesticide-laden pea pods, drug-laced catfish, filthy plums and crawfish contaminated with salmonella. Pesticides and chemical fertilizers are used in excess to boost yields while harmful antibiotics are widely administered to control disease in seafood and livestock. Rampant industrial pollution risks introducing heavy metals into the food chain.[57]

This leads to the possibility of market advantage for 'clean' produce from Victoria and Australia to compete internationally, as well as have a higher value for some domestic consumers. Increasing liberalisation, particularly in the EU, may present new opportunities for Australian producers with good environmental credentials.

1.6.2. Processing

Victoria's agricultural sector is also a crucial base for other significant sectors of the economy such as food manufacturing industries (which take 51% of the primary produce)[58] – more than 90% of Victorian milk is used for manufacturing cheese, butter and milk powders.[59]

There are almost 2500 food manufacturing businesses in Victoria, most of them are small (employ less than 20 people) but there are 52 that employ more than 200 people.[60] In 2003, the largest 50 Australian food and beverage firms held more than 75% of the revenue in manufacture / processing of fruit and vegetables, poultry, wine, spirits, bread, milk and cream etc.[61] This consolidation in the food processing sector is also reflected in suppliers – in many cases, one or two of the largest suppliers for particular products share more than 50% of the domestic market.[62]

In 2006-07, the total value of Victoria's food exports was $5.58 billion (decrease of $181 million or 3% from the previous year), which accounted for 25% of Australia's total food exports.[63]

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[55] Hunt, P. (2008), "Cheap Shot", *The Weekly Times*, 6 February 2008, http://theweeklytimes.com.au/

[56] Dickson, A., Hirad, S., and Buetre, B. (2005), "Emerging Markets: The Role and Changing Environment of Agricultural Trade Reform", *Australian Commodities* 12, no. 1: 219-26.

[57] Associated Press (12 April 2007), *China's Food Safety Woes Now a Global Concern*, http://www.msnbc.msn.com/id/18078824

[58] Taylor, M. (2008), *Victorian Agriculture, Forestry and Fishing Industries: At a Glance 2007 (Version 3.3)*, Department of Primary Industries, State of Victoria, p2&3

[59] DPI (2006a), *Victorian Food Industry Fact Sheets,* Department of Primary Industries, accessed 15 December 2007, http://www.dpi.vic.gov.au/dpi/nrenti.nsf/LinkView/2969C33369DFA832CA256BC20016E3933EAE47A0DB5D4984CA25727A00781A83.

[60] VCEC (2007), *Simplifying the Menu: Food Regulation in Victoria*, Victorian Competition and Efficiency Commission, p78

[61] Short, C., Chester, C., and Berry, P. (2006), cited in Ibid., p78

[62] AFFA (2002), p9, cited in VCEC (2007), p78

[63] Taylor, M. (2008), *Victorian Agriculture, Forestry and Fishing Industries: At a Glance 2007 (Version 3.3)*, Department of Primary Industries, State of Victoria, p15

1.6.3. Distribution

Increasing food chain distances

The distance travelled by food travelling between production and consumption is increasing as supply chains continue to globalise further. Food produced domestically is often sent to other countries to be processed and then imported for consumption, while in other cases food products are being produced for export as identical food products are imported. This increased transportation of food involves greater energy use, while emitting higher levels of greenhouse gases, not only in relation to the transport itself, but also the refrigerated storage over longer periods. The relative importance of transport distances in reducing environmental (particularly greenhouse) impacts is the subject of considerable debate worldwide. Further discussion can be found in *2.1.2 (Transport - Food Miles)* and *3.3.1 Localisation*.

Retail

There are almost 17,000 food retailers in Victoria however over half of all the sales for food, grocery and liquor sales occurring through the two major retailers: Coles and Woolworths.[64] The supermarket sector in Australia experienced a growth of 5.6% in total sales value in 2005-06 – comparable to a growth of 3.6% in the previous year – with individual business growth achieved through an expansion of store networks.[65] However, as increasing numbers of meals are eaten out of the home, the supermarkets' share of total retail food sales is declining.[66]

Having such a large market share enables the two major retailers substantial control of varieties, specifications and prices for food. This then controls what is produced and how much of a margin producers can make. Victoria is less dominated by the two main retailers than the Australian average. Australia wide the two major retailers held 78% of the total grocery trade in 2005-06,[67] reflecting Victoria's higher proportion of fresh food markets and Independent Grocers Association stores (IGAs). This higher proportion of independent grocers associations may allow for more flexibility and variety.

The extent to which this consolidated control is allowing major retailers to influence food prices is the subject of an Australian Competition and Consumer Commission review (underway in early 2008).

1.6.4. Consumption

Today's globalised food system means that consumers' have access to foods from all around the world, presented in many different formats.

Some of the factors that have most significantly affected the way Australians eat are developments in: food production and distribution arrangements, food and kitchen technologies, marketing, immigration sources (British, Chinese, Mediterranean, Asian etc) and the role and status of women.[68]

There is a trend towards eating out, take-away food, home deliveries, pre-processed and packaged food.[69] There has been an ongoing shift from consumption of unprocessed wholefood meals to processed wholefoods, and again to "processed reconstituted" foods (products

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[64] AFRG (2006), p68, cited in VCEC (2007), *Simplifying the Menu: Food Regulation in Victoria*, Victorian Competition and Efficiency Commission, p79

[65] DAFF (2007), *Australian Food Statistics 2006*, Department of Agriculture Fisheries and Forestry, p16

[66] AFFA (2005), cited in VCEC (2007), *Simplifying the Menu: Food Regulation in Victoria*, Victorian Competition and Efficiency Commission, p79

[67] DAFF (2007), *Australian Food Statistics 2006*, Department of Agriculture Fisheries and Forestry, p16

[68] Bannerman, C. (1998), *Acquired Tastes - Celebrating Australia's Culinary History*, National Library of Australia, Canberra, , p78

[69] DAFF (2007), *Australian Food Statistics 2006*, Department of Agriculture Fisheries and Forestry, p27

constructed from deconstituted components of wholefoods, chemical additives, artificial fats and sugars).[70] According to the Department of Agriculture, Fisheries and Forestry, non-grocery sectors of the food retail market have experienced faster growth than the grocery sector, with cafes and restaurants accounting for 12-13% of total food sales and 9.5% for takeaway food outlets in 2005-06.[71] Growth in the takeaway food sector can be largely attributed to major fast food chains expanding their networks and diversifying their menus to cater for increasing health concerns around consumers.[72]

Dietary composition is also changing, perhaps partially in response to health concerns and increasing proportions of 'high value' foods such as seafood, poultry and fresh fruit and vegetables. Consumption trends appear to be moving away from meat, eggs, grains and sugar, although dairy products have remained quite stable.[73]

Australian meat consumption patterns may be changing (eg. less red meat and more poultry), but Australian overall meat consumption (approximately 304g per day)[74] is still very high compared to global averages – only the USA average is higher (342g per day), compared to the developed country average of 224g per day and the developing country average of 47g per day.[75]

Consumer behaviour is further discussed in *3.4 Consumer Choices.*

1.6.5. Prices

Since September 2005, grocery prices have increased by 12 per cent, or twice the rate of the Consumer Price Index. Households are struggling with a 33 per cent increase in the price of vegies, while the price of fruit has skyrocketed by 43 per cent because of the drought.[76]

Domestic food prices increased with the food component of the consumer price index increasing by 4.5% in 2005-06. This price increase was particularly visible for meat and dairy products, where 2005-06 prices increased by 7% for fresh milk, close to 16% for butter, 4% for cheese, 6% for beef and 4% for lamb.[77] This has been a longer-term trend, for example, between 1998 to 2005 the average retail price of lamb increased by 71% and beef by 53%.[78]

The most recent data shows that over the twelve months to December quarter 2007 average food prices rose 1.2% - a much smaller rise than some other sectors of the economy. However, this average hides a complex picture with the price of some foodstuffs increasing significantly while others fell. Some results are shown on Table 1.1 below.

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[70] Scrinis, G. (2007), "From Techno-Corporate Food to Alternative Agri-Food Movements", *Local-Global* 4, p119
[71] DAFF (2007), *Australian Food Statistics 2006*, Department of Agriculture Fisheries and Forestry, p4
[72] Ibid., p18
[73] Short, C., Chester, C., and Berry, P. (2006), p11, cited in VCEC (2007), *Simplifying the Menu: Food Regulation in Victoria*, Victorian Competition and Efficiency Commission. p70
[74] Includes beef, lamb, pork, bacon and poultry but excludes canned meat – figures drawn from *ABS (2000), Apparent Consumption of Foodstuffs 1998-99,* Cat. No. 4306.0, Australian Bureau of Statistics, Canberra,
[75] McMichael, A.J. et al. (2007), "Food, Livestock Production, Energy, Climate Change and Health", *The Lancet* 370, no. 5: 1253-63, and MacMillan, T. (2007), "Consumers", *Food Ethics magazine*.
[76] ACF (2007b), *Climate Change Shock to Grocery Prices. . . Unless We Act Now*, accessed November 2007, http://www.acfonline.org.au/articles/news.asp?news_id=1543.
[77] DAFF (2007), *Australian Food Statistics 2006*, Department of Agriculture Fisheries and Forestry, p4
[78] MLA (2007), *Retail and Food Service, Meat and Livestock Australia - Domestic Market Information Online*, Meat and Livestock Australia, accessed 10 January 2008, http://www.mla.com.au/TopicHierarchy/MarketInformation/DomesticMarkets/Consumption/default.htm

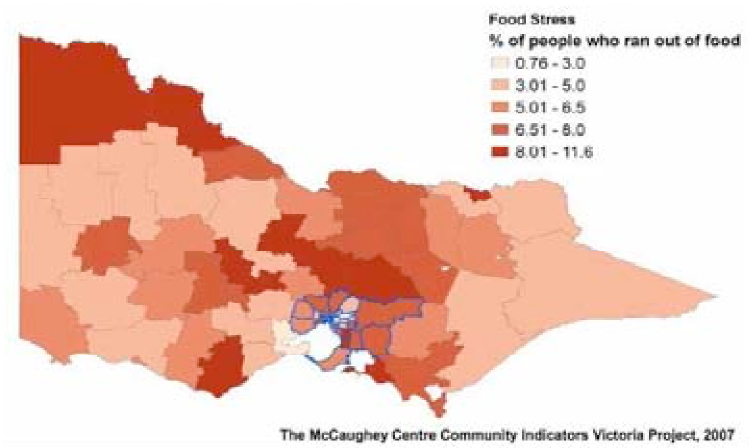
Table 1-2: Food price changes to December 2007[79]

Category	Quart to Dec 07	Year to Dec 07	Comment
Food overall	-0.1%	1.2%	
Fruit	-13.5%	-32%	• Fruit provided the only offsetting annual fall and this was driven mainly by the drop in banana prices (following their extreme rise the previous year) • Offset by rises in apples, pears, oranges and mandarines
Vegetables	-6.9%	+8.6%	• Quarterly fall due to good growing conditions in some areas • Some vegetables have gone up, eg. potatoes, pumpkins and onions)
Milk	5.6%	10.1%	• Strong world demand for dairy and reduced availability of feed
Cheese	4.9%		
Bread	2.7%	8.8%	• Increase in price of flour and production costs
Poultry	4.1%		
Take away and fast foods		4.9%	• These overall price increases are reflected in the increased cost of meals from take away and restaurants, as proprietors pass costs on to customers
Restaurant meals		3.8%	

NB. The increase in imports to replace local production declines may have prevented more extreme price increases.

Food scarcity, particularly access to fresh fruit and vegetables, is already a problem in disadvantaged sections of the community (see *2.5 Health and Nutrition*), with 12% of Victorians already in food stress (Figure 1.4).

Figure 1.4 – Food Stress (in the last 12 months, were there any times that you ran out of food and couldn't afford to buy more?)[80]



Victorian adults: 6.1% plus dependent children (1:1), approximately 12% Victorians (550,000 individuals)

Rising food prices, along with rising transport and housing costs, are likely to expand the proportion of the population in food stress.

Environmental factors such as drought have affected these food prices, as have other impacts of climate change such as extreme weather events. The retail price of bananas increased 70% following the destruction of banana crops in northern Queensland by tropical cycle Larry.[81,82] The existing impacts of environmental factors on food prices are discussed in more detail in *2.1.1 Direct impacts of Climate Change*, *2.2.1 Water* and *2.2.2 Oil, Biofuels and Agricultural Inputs*. The introduction of emissions trading will also affect food prices, further discussed in *2.1.2 Energy, Greenhouse Emissions and Responses to Climate Change*.

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[79] ABS (2007c), *Consumer Price Index, Australia, Dec 2007 - Online Summary*, Cat. No. 6401.0 Australian Bureau of Statistics, Canberra

[80] McCaughey Centre (2007), reproduced in Davidson, B. (2007), "Local Government: Maitre De or Kitchen Hand of Food Security? " paper presented at *Future Foods for Future Health Conference,* 25 July 2007, Victorian Local Governance Association, Melbourne.

[81] Taylor, M. (2008), *Victorian Agriculture, Forestry and Fishing Industries: At a Glance 2007 (Version 3.3)*, Department of Primary Industries, State of Victoria, p4

[82] The correction of this increase stabilised overall food price increases in 2007, despite increases in other products.

2. Environmental Risks and Impacts

The food system is vulnerable to environmental change and has a significant impact on the environment – these issues are elaborated throughout Section 2. A US study has calculated externalised costs (in natural resources, wildlife, ecosystem biodiversity and human health) of agricultural production at $5.7 to $16.9 billion (£3.3 to £9.7 billion) annually. This amounts to approximately $29.44 to $95.68 (£16.87 to £54.82) per cropland hectare – without including greenhouse gas emissions.[83] While acknowledging that this was a first attempt, and calling for further research, this study may indicate some of the unseen costs of Victorian production.

2.1. Climate Change

Climate change will impact on the food system in two ways. Firstly, the changing climate will impact (and is already being seen to impact) on food systems – discussed in *2.1.1 Direct Impacts of Climate Change*. Secondly, the need to reduce emissions from production and supply chains will affect processes and viability of different systems, as will policy responses to climate change – discussed in *2.1.2 Energy, Greenhouse Emissions and Responses to Climate Change*.

2.1.1. Direct Impacts of Climate Change

Summary and Recommendations:

The impacts of climate change include: higher temperatures, increased drought, extreme weather events, fires, and movement and outbreaks of disease, pests and weeds. Although there will be localised advantages and disadvantages, these impacts will present an overall challenge to food security.

Climate change is already affecting worldwide food availability and prices. Further impacts (such as higher degrees of warming) will exacerbate these effects and reverberate through the system (eg. reduced grain yields are likely to affect availability of bread, cereals, meats, eggs and dairy products).

These impacts cannot be ‘predicted’ with any great certainty – fluctuations and unpredictability in weather conditions will be the new operating conditions. Farmers are adapting now by changing what they produce, when and where they produce it, or moving off the land. Ongoing adaptation will be required.

Climate change impacts, particularly extreme weather conditions, will also have impacts on food distribution and storage. For example, damage to transport infrastructure could prevent supplies reaching consumers. Heat waves could increase food spoilage directly or require more refrigeration – in turn adding pressure to stressed electricity systems (and greenhouse emissions). During the 2003 heat wave in France, 25-30% of food businesses were found to have inadequate cold storage capability.[84]

Food processing and storage industries will also need to adapt and be flexible to changing inputs from continually adjusting producers. Increasing energy costs will also already affecting these industries.

Increasing resilience of the food system to climate impacts will require flexibility, diverse solutions and continuous adaptation.

Social response to climate change generally – adaptation in other areas of the economy and mitigation efforts - will also cause problems for the food system. This is discussed in the following section.

! *Climate change will interact with other challenges to drive up food prices*

! *There is a need to develop improved data and information while building local capacity for ongoing adaptation*

[83] Tegtmeier, E. and Duffy, M. (2004), "External Costs of Agricultural Production in the United States", *International Journal of Agricultural Sustainability*. vol. 2, no. 1: 1-20.

[84] Létard, V. et al. (2004) cited in IPCC (2007a), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by Parry, M. et al, Cambridge University Press, Cambridge, UK.

!	*The loss of small / medium sized producers with diverse and local knowledge could reduce overall capacity for adaptation and the resilience of the food system overall.*
!	*Future food security may require balanced access to both locally grown and distant food supplies to reduce exposure to supply and storage system disruption, as well as to local production losses*
🕮	*The IPCC has identified a number of research gaps regarding climate change impacts in Australia. These include:* ➢ *Impacts on agricultural pests, disease and weeds in Australia* ➢ *Interrelations of increased temperatures, carbon dioxide AND changing rainfall patterns on disease, weed and pest ranges (have mainly been studied separately – little is known about combined impacts)*
🕮	*The IPCC has also noted that global modelling of projected food security under climate change has tended to rely on assumptions about economics, trade and technology that are poorly tested against observed data. Further work is needed in this area.*[85]
🕮	*Expanded analysis of climate change adaptation in the food system beyond agricultural production*
⚡	*Increase diversity of food production to increase the likelihood of harvest even in unpredictable conditions*
⚡	*Changes to planting dates and varieties, more resilient crops and systems*
⚡	*Opportunities for low-input agricultural techniques (including organic systems), as they have been found to be particularly "resilient and productive" in climate adaptation strategies.*[86]
⚡	*Redundancy and flexibility in processing, logistics and distribution systems*
⚡	*Reduce the vulnerability of food distribution systems*

Both our global and local food systems are highly dependent on the stability of climatic cycles. Climate change will see a progressive shift in conditions critical for agricultural production – average temperatures and rainfall will alter over time. But this shift in the average weather conditions will not be simply progressive and incremental; modelling shows an increased likelihood of significant fluctuations in conditions about the mean, increased incidence of extreme temperatures (high and low), extreme rainfall conditions (high and low) and winds and severe storms. Such fluctuations and unpredictability, in combination with other anticipated impacts such as rising temperatures, variations in water supply, fires and severe weather events are already disrupting food production and dissemination and are likely to have major impacts on food production and distribution. Some of the expected impacts of climate change and possible implications for Victoria's food system are described below.

Many of the projections below are drawn from the Intergovernmental Panel on Climate Change's 2007 Fourth Assessment Report. It should be noted that while the IPCC is a well respected international authority on climate change, the nature of the climate system and climate modelling means that it is hard to predict changes with a high level of certainty, particularly at a regional level. It should also be noted that emissions are currently growing at a faster rate than predicted by most of the scenarios used in IPCC modelling, meaning that impacts currently look likely to be more severe and less predictable than many of those described here.[87]

This suggests a need to focus on solutions that increase resilience to unexpected, convergent and potentially severe combinations of climate change impacts, along with other environmental risks and constraints. Some of these are discussed in Section 3 *Response Strategies*.

Average Temperatures

By 2030, average daily maximum temperatures may rise by 0.5-1.5°C over most of Victoria,

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[85] IPCC (2007a), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by Parry, M et al, Cambridge University Press, Cambridge, UK, chapter 5, p285

[86] International Trade Centre (2008), *Organic Farming and Climate Change*, International Trade Centre, Switzerland, http://www.intracen.org/Organics/publications.htm (NB: The ITC is the joint technical cooperation agency of the UN Conference on Trade and Development (UNCTAD) and WTO for business aspects of trade development)

[87] Climate Adaptation Science and Policy Initiative (2007), *Evidence of Accelerated Climate Change*, The Climate Institute, Sydney

with slightly more warming in spring and less warming in winter and in southern areas. By 2070, average daily maximum temperatures may rise by 0.7 to 5.0°C over most of Victoria with spatial variation similar to those for 2030.[88]

Predicted temperature rises are likely to have major implications for our food systems. Rising temperatures can affect the productivity of agriculture and shift which agricultural products and systems are suited to which region. There are likely to be regional challenges and opportunities, for example:

- Grapes are likely to ripen sooner and to be of lower quality. For the Yarra Valley, the price per tonne is predicted to drop 4-10% by 2030.[89] However alternative grape varieties could be grown,[90] and some analysis of potential new varieties has been carried out.[91]
- Rising temperatures increase the risk of heat stress for livestock, which can reduce productivity. This may be partially counteracted by other factors such as reduced lamb deaths from cold stress.[92,93]
- The risk of heat-shock proteins in wheat grains will increase if the temperature increases by more than 4°C.[94]
- Fewer cold days[95] may impact on fruit setting (as most require cold winter conditions to bloom and produce fruit in spring and summer).[96]

Warmer temperatures are also likely to affect the distribution of pests, weeds and diseases. For example:

- In North America, earlier spring activity of insects has already been observed, while the populations of some pests are increasing rapidly.[97]
- The impact of cattle tick on the Australian beef industry is predicted to increase and to be felt further south.[98]
- Warming of 0.5-2.0°C could see the range of the Queensland fruit fly expand across most of the non-arid areas of Australia, including areas which are currently quarantined as fruit-fly free zones.[99]

In general, climate change is likely to encourage the southwards movement of a number of weeds and pests that are currently restricted to warmer northern conditions.

The 2003 heatwave in Europe illustrates how events such as this can affect agricultural production. It caused maize yields in the Po Valley in Italy to drop by 36%, while maize yields in France were 30% lower, fruit harvests 25% lower, wheat yields 21% lower and forage production 30% lower than

[88] CSIRO (2007), *Infrastructure and Climate Change Risk Assessment for Victoria*, Australian Commonwealth Scientific and Industrial Research Organisation
[89] Webb, L. et al. (2006), cited in IPCC (2007a), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK, chapter 11, p519
[90] IPCC (2007a), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK, chapter 11, p519
[91] Alan, M. (2007), "Grapes of Wrath", *Cosmos*, 2 May 2007, and talk by president Winemakers Federation of Australia 18 Dec 2007, from http://www.abc.net.au/rn/perspective/stories/2007/2120925.htm
[92] IPCC (2007a), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK, chapter 11, p520
[93] Ibid, chapter 5, p287
[94] Howden, S.M., Reyenga, P.J., and Meinke, H. (1999), citied in Ibid., chapter 11, p518
[95] Australian Bureau of Meterology (2003), *Climate Activities in Australia 2003, Chapter 4 - Climate Impacts and Responses*, accessed 4 February 2008, http://www.bom.gov.au/inside/eiab/reports/caa03/.
[96] Wolfe, D. (2007), cited in CNN (2007), *Climate Change Challenging Gardeners to Plant Smarter*, accessed 8 August 2007, http://www.cnn.com/2007/LIVING/homestyle/08/08/climate.gardening.ap/index.html
[97] IPCC (2007a), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK, chapter 5, p283
[98] White, N. et al. (2003), cited in Ibid., chapter 11, p520
[99] Sutherst, R.W., Collyer, B.S., and Yonow, T. (2000), cited in IPCC (2007a), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK, chapter 11, p519

the previous year. Some of the hay and silage stocks for winter were used in the summer and wine production was the lowest it had been in 10 years. This heatwave cost the European Union's agricultural sector €13 billion in (uninsured) economic losses. [100]

Average rainfall and drought

One of the most important climate change predictions for Australian agriculture is lower average rainfall and increased drought in much of the (previously) productive agricultural areas of Australia. Annual streamflow in the Murray-Darling Basin, which supplies around 70% of Australia's irrigated farmland, is likely to fall 10-25% by 2050.[101] While increased carbon dioxide in the atmosphere could aid plant growth, researchers have found that a 10% reduction in rainfall is likely to be enough to offset any benefit to Australian pasture growth.[102] *(*The impact of rainfall changes and drought on food systems are discussed in detail in *Resource Constraints – Water).*

Drought is also likely to worsen land erosion as increased carbon dioxide in the atmosphere will reduce crop evapotranspiration. According to the IPCC:

> This increases the risk of water moving below the root zone of crops (deep drainage), potentially exacerbating three of Australia's most severe land degradation problems across agricultural zones: waterlogging, soil acidification and dryland salinity.[103]

(For more information on how these issues affect the food system see *2.2.1 Water* and *2.2.3 Land and Soil*).

Unusual and extreme fluctuations in weather

More extreme weather events are likely to occur, such as heat waves, floods storms, extreme cold days, drought and fires. Whilst Victoria's rainfall is predicted to become less frequent, it is also predicted to become more intense.[104]

The risk of bushfire is likely to increase, with the IPCC projecting 4 - 25% more very-high and extreme fire danger days in south-eastern Australia by 2020. In addition, it predicts more intense fires, faster fire spread and a longer fire season.[105] This, combined with drought, is likely to reduce agricultural production over large areas of southern and eastern Australia.[106]

Globally, it is predicted that:

> More frequent extreme events may lower long-term yields by directly damaging crops at specific developmental stages, such as temperature thresholds during flowering, or by making the timing of field applications more difficult, thus reducing the efficiency of farm inputs.[107]

Unusual or extreme weather events can also increase plant disease and pest outbreaks, further damaging food production.[108] Economic dependence on single crop varieties (monocultures) may heighten farmers' vulnerability to crop loss from extreme weather events or pest pressure.[109]

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[100] IPCC (2007a), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK, chapter 5, p277

[101] Ibid, chapter 11, p516

[102] Howden, S.M. et al. (1999), and Crimp, S.J. et al. (2002), cited in Ibid, chapter 11, p519

[103] IPCC (2007a), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK, chapter 11, p518

[104] IPCC (2007b), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by Solomon, S et al., Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, chapter 10, p750

[105] Hennessy, K. et al. (2006), citied in IPCC (2007a), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK, chapter 11, p515

[106] IPCC (2007a), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK, chapter 11, p509

[107] Antle, J.M. et al. (2004), and Porter, J.R. and Semenov, M.A. (2005), cited as examples in Ibid., chapter 5, p284

[108] Alig, R.J. et al. (2004), and Gan, J. (2004), cited in IPCC (2007a), *Climate Change 2007: Impacts, Adaptation and*

The increased number and severity of tropical cyclones is unlikely to directly affect Victoria, but will affect the supply to the state of food grown in northern Australia (e.g. Cyclone Larry's impact on banana availability in Victoria).

Impacts on fishing

Climate change is expected to change sea surface temperatures and ocean currents, and this is expected to change both fish numbers and which fish are available where. For example, reduced upwelling of nutrients combined with warmer water along the east coast of Australia is likely to reduce krill and jack mackerel numbers, which will then affect other species dependent on them, such as tuna, seals and seabirds. Climate change is likely to compound overfishing problems, while the IPCC states that changed distributions will mean that "fishers will be faced with relocation or face reduced catches in situ"[110] (see also *2.2.4 Depleted Stocks (Fish)*).

Impacts beyond the farm gate

Climate change is also likely to impact on the food system beyond the farm gate. Infrastructure and the food industry are less susceptible to gradual temperature rise, but are vulnerable to extreme weather events as well as to other factors which themselves are affected by climate change.[111] Extreme weather events risk affecting transport infrastructure (for example flood damage to roads, buckling of rail lines in heat waves), as well as electricity transmission lines (storms or fires).[112]

The 2003 heatwave in France caused an increased demand for electricity, while decreased river flows and warmer water reduced the cooling efficiency of thermal power stations, undermining their ability to supply power.[113] Under these circumstances 25-30% of food-related establishments were found to have inadequate cold storage systems under the circumstances.[114]

A carbon tax could also affect the food industry's access to transport and electricity - making extensive refrigeration less affordable just as rising temperatures are increasing the demand for it. Food industries will need to be flexible and adaptable to minimise damage from this and respond to changing input supplies.

Effects on food prices

Locally, nationally and worldwide, climate change is already impacting on food costs. In 2007, the price of bread was on the rise in certain parts of the world due to poor wheat harvests caused by drought around Ukraine and a heatwave in Greece, while storms in France and Britain caused significant crop damage.[115] Drought in Australia has driven up the cost of wheat and dairy around the world.

At the Australian domestic level the prices of bananas remained high well into 2007 as a result of

Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, chapter 5, p283

[109] Zierhl, A. (2004), *Organics and Sustainability: Substantiating the Claim of 'Clean and Green'*, Department of Primary Industries, State of Victoria, p15

[110] IPCC (2007a), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK, chapter 11, p521

[111] Ibid, chapter 7, p359

[112] Ibid, chapter 7, p371

[113] Victoria suffered a similar sequence of events in the summer of 2006-7 including the loss of interstate electricity because of fires between Victoria and NSW

[114] Létard, V., Flandre, H., and Lepeltier, S. (2004), cited in IPCC (2007a), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK, chapter 7, p362

[115] Hunt, M. (2007), *Rain Hits W. Europe Wheat, Drought Devastates East*, http://www.planetark.com/dailynewsstory.cfm/newsid/42816/story.htm

Cyclone Larry in March 2006. Banana crop recovery was particularly slow in some areas due to a cold snap during late May to early June in Queensland and Northern New South Wales. This unusually cold period also destroyed vegetable crops and disrupted maturation of fruit which form Melbourne's usual winter supply of vegetables. The main products affected were beans, zucchinis, corn and tomatoes. This, along with the flood damage further north which also affected fruit and vegetable supplies, reduced supplies to Melbourne and therefore increased prices for the affected lines[116] (see also *1.5 - Prices*).

Professor John Quiggin, an economist at the University of Queensland, argues that prices will continue to be affected by both temperature increases and drought:

> Above three degrees of warming, we would see reduced grain crop yields right around the world, not just in Australia. Grain is an essential element in producing bread, cereals, many meats, eggs and dairy products, so climate change-related increases in global grain prices could permanently elevate the prices of a large range of foods.[117]
>
> Dangerous climate change would mean more droughts – as much as 40 per cent more in eastern Australia by 2070 if we don't act – and for Australian consumers would mean price spikes more often, particularly for foods like fresh fruit and vegetables that are supplied mainly by local producers.[118]

In Victoria, floods in Gippsland in 2007 affected the local supply of some vegetables and herbs (primarily broccoli, cauliflower, carrots, some lettuce and herbs).[119] It is likely that climactic events such as these, and the following volatility of food prices, will be increasingly regular occurrences. Globally, the IPCC predicts that fish production for food will increase between now and 2020, but not as fast as demand, resulting in rising fish prices.[120]

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[116] Stewart, M. (2007), "Impact of Climate on Current Price Volatility of Fruit and Vegetables", *Herald Sun,* Melbourne Market Authority, 13 July 2007.

[117] Quiggin, J. (2007), cited in ACF (2007b), *Climate Change Shock to Grocery Prices. . . Unless We Act Now*, accessed November 2007, http://www.acfonline.org.au/articles/news.asp?news_id=1543.

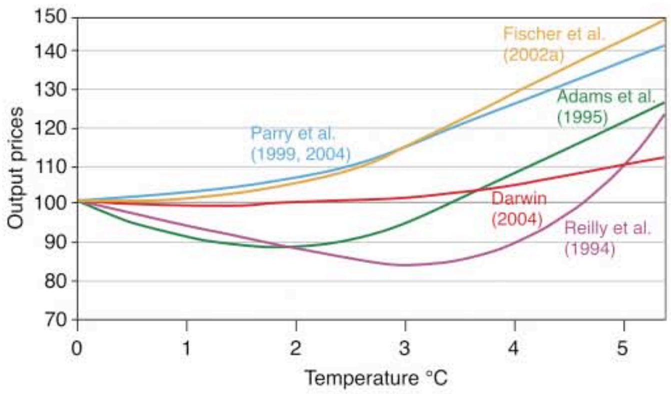
[118] Quiggin, J. (2007), *Drought, Climate Change and Food Prices in Australia*, School of Economics and School of Political Science and International Studies, University of Queensland.

[119] Stewart, M. (2007), "Impact of Climate on Current Price Volatility of Fruit and Vegetables", *Herald Sun,* Melbourne Market Authority, 13 July 2007.

[120] IPCC (2007a), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK, chapter 5, p281

Figure 2.1 – Cereal prices as a percentage of the baseline price versus global mean temperature change[121]

(According to a number of modelling studies)



NB: Prices for food in general are expected to decrease around the world for small temperature increases and increase significantly for large temperature increases. The global grain price has already increased sharply, as climate change interacts with other factors it is likely that food prices will increase more than shown on this graph.

Adaptation and Opportunities

While climate change poses significant risks to the food system, there are significant opportunities to both to reduce greenhouse gas emissions and to adapt food systems to the changes.

Adaptation opportunities include changing planting dates and varieties and the IPCC predicts that strategies such as these could turn a likely drop in Australia's national gross value of wheat to a likely increase in value in 2070.[122]

Many individual farmers are already making changes to produce and practices in response to current and anticipated weather conditions, such as:[123]

- Some dairy farmers in the northern irrigation region have started to use limited water only on high value crops (rather than irrigating perennial pastures) and explore deeper rooted (more resilient) crops like Lucerne;
- Increasing temperatures and decreasing rainfall in Gippsland may increase the focus on growing grass during winter, to harvest as silage and hay to get through the summer; and
- Many farmers are already starting silage harvesting much earlier.

Agricultural production that has lower emissions intensity is likely to have privileged access to (and higher value) in international markets – as the emissions intensity of many Australian products is likely to be already lower than international competitors there are export opportunities. Additionally, knowledge, methodologies and technologies that reduce emissions (including sequestration in soils) will have extensive global applications.

[121] Ibid, figure 5.3, chapter 5, p297

[122] IPCC (2007a), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK, chapter 5, p297

[123] Eckhart, R. (2007), *The Abatement Challenge for Australian Agriculture*, Discussion Paper for Garnaut Review Forum, The University of Melbourne and Department of Primary Industries, Victoria.

2.1.2. Energy, Greenhouse Emissions and Responses to Climate Change

Summary and Recommendations:

Food production is a significant contributor to greenhouse gas emissions. Biological emissions from agriculture were directly responsible for 16.8% of Australia's greenhouse gas emissions in 2005, and 12.9% of Victoria's.[124] When emissions from energy, transport and waste are included, it has been estimated that at least 23% of Australian emissions come from the food system.[125]

Energy inputs to food production have increased with technological development. Chemical inputs, processing and storage facilities have greatly increased agricultural productivity and the economic value of our food resources, enabling us to exceed our domestic food requirements and export to global markets. While labour productivity has improved (the amount of food produced per person-hour), the energy intensity of the system has not. *Direct energy use in Australian agriculture* (on-farm, not including manufacture of inputs) has been estimated to represent only 25-30% of the energy consumed in the whole food supply chain.[126] The increasing energy intensity of agriculture and the rest of the food system increases risk as the cost of key energy inputs (eg. fertilisers) increase (due to oil scarcity and carbon pricing).

The full energy or greenhouse gas picture for food supply in Victoria is not well understood. Victoria has a substantial food-processing sector, but the emissions from this sector are generally attributed (in data sources such as ABS) to 'industry' rather than 'food', as is agricultural chemical production. Food related transport emissions are also accounted for elsewhere (under transport). The greenhouse emissions generated through raw material consumption for food packaging are also a potentially significant contribution – in Europe it is estimated that 25% of raw material production in 2001 was used as food packaging.[127]

Introduction of a *carbon price* will affect foodstuffs very differently – meat from ruminants and dairy, highly processed foods and foods that travel longer distances would be expected to rise in cost significantly. However, the survey of international studies undertaken for this report tells us that there are no generalisable answers, it depends on the specifics of the food system; some meat products are less energy-intensive than some vegetables (although overall greenhouse emissions are probably still higher); in some circumstances cooking of food has the most impact; emissions from processing and storage can be very significant for some foodstuffs; transport of food to retailers is significant in some circumstances, travel by consumers to retailers is more significant in others. How much these different aspects of the system will impact on food prices in a carbon constrained economy cannot be understood until there is detailed (life-cycle) data for different food products / plates.

International efforts to understand and manage the environmental impacts of the food system have produced significant analytical work, but findings are not directly applicable to Australia or Victoria. Australian analysis has identified the broad sectors within the food system that have the highest greenhouse intensity, but this analysis has not been refined to reflect Victorian conditions or to consider specific products in those sectors. Life-cycle data for different food products or plates does not currently exist in Victoria.

Carbon sequestration in agricultural soils (along with other changed techniques) has the potential to change the emissions profile of agriculture, as well as having other potential productivity benefits (such as improved water retention and fertility in soils).[128] There are difficulties in measuring soil carbon levels, but this should not prevent an accelerated roll-out of known techniques and investment in their improvement and further development.

Transport and long production chains have been shown to contribute significant energy (and greenhouse emissions) for some foods, but this is only one factor in the full lifecycle impacts of food. Distance does not directly indicate the level of total greenhouse or total environmental impact (as it doesn't take into account different transport modes or transport utilisation factors). Furthermore, it has been found (in the UK), that the

[124] Victorian Greenhouse Gas Inventory (2007), *Victorian Greenhouse Gas Inventory: Information Sheet 2005*
[125] Hatfield-Dodds et al. (2007), cited in Garnaut Climate Change Review (2007), *Issues Paper 1 – Climate change: Land Use – Agriculture and Forestry*, Garnaut Climate Change Review, Melbourne
[126] Watt, M. (1979) and Organisation for Economic Co-operation and Development (1982), cited in Wood, R. et al. (2006), "A Comparative Study of Some Environmental Impacts of Conventional and Organic Farming in Australia." *Agricultural Systems*, vol. 89, no. 2-3: 324-48, p326. NB: These figures are from 1979 and 1982 – updated analysis would be very useful!
[127] Jancovici, J. (2004), *How Much Greenhouse Gases in Our Plate?*, accessed 12 July 2007, from www.manicore.com/anglais/documentation_a/greenhouse/plate.htm
[128] Bellarby, J. et al. (2008), *Cool Farming*, Greenpeace International.

'car miles' (car-based shopping emissions) can be ***greater*** than transport emissions from the production and distribution phases,[129] and for some foods it could even be the most significant emissions contribution.[130] The impact of 'car miles' in Melbourne (and probably the rest of Victoria) would be likely to be higher again – a recent study has found that Melbourne's transport produces approximately 2.5 times as many greenhouse emissions (per person) as London's (road freight removed).[131]

Unless there are major changes in the mix of transport modes (towards very low carbon transport systems) and better life-cycle energy data for different foods then 'food miles' is likely to continue being accepted by consumers (and probably retailers) as a 'proxy' system indicator for environmental impact. Interest in food miles also reflects community concern about oil shortages (see 2.2.2. *Oil, Biofuels and Agricultural Inputs*) and a desire for reconnection with the producers of their food (*2.3 Distribution Strategies*).

!	*The potential for emissions reductions within the agriculture sector and throughout the food supply chain is very significant and must be pursued – making use of current knowledge and technology and despite limitations to tracking and measurement*
!	*Significant reductions in on-farm emissions will require changes to the way we farm livestock and use synthetic fertilizers*
!	*Other developed countries (eg. UK) are reducing their emissions by moving greenhouse intensive production offshore. This may create export opportunities in other markets, but it also shifts the pressure to actually reduce emissions to the exporter*
!	*Other emissions in the food chain, including energy to produce agricultural chemicals, processing, packaging, storage and transport, mean that food prices could rise with the introduction of emissions trading, even if agriculture is initially excluded*
!	*Demand for local foods is driven by a range of factors and is likely to continue increasing, even though the concept of 'food miles' does not convey full (or accurate) information about lifecycle energy or greenhouse impacts, unless detailed life cycle data becomes available for Australia/Victoria*
!	*Soil carbon sequestration could transform agriculture's emissions profile – with wide ranging ramifications for land use and production techniques.*
!	*Low-input agricultural techniques (including organic production) can make a significant contribution to emissions reduction and could be 'quick-win' policy options*[132]
🕮	*Update analysis of the energy and emissions of the full food chain (most recent Australian analysis is from 1982)*
🕮	*Conduct full lifecycle analysis (particularly on greenhouse emissions) on a range of essential foods in Victoria, to better understand how they will be affected by policy changes and how emissions can most effectively be reduced. Victorian information on direct agricultural emissions (from conventional systems) is good. However, beyond the direct on-farm emissions very little information exists.*
🕮 !	*Measure and investigate the potential greenhouse benefits of non-conventional production and distribution systems (including techniques that reduce reliance on inputs)*
⚡	*Shift to food production, processing and distribution systems that minimise greenhouse emissions will have competitive advantage under carbon pricing*
⚡	*Market advantages where Victorian agricultural production is less emissions-intensive than international competitors*
⚡	*Track and label emissions profiles to strengthen this advantage eg. inclusion of emissions data in new commodity tracking systems*
⚡	*Drive development and extension (many are already known) of locally appropriate techniques for soil carbon sequestration*

[129] Foster, C. et al. (2006), *Environmental Impacts of Food Production and Consumption: A Report to the Department for Environment, Food and Rural Affairs*, Manchester Business School, DEFRA, London, accessed December 2007, from www.defra.gov.uk/science/project_data/DocumentLibrary/EV02007/EV02007_4601_FRP.pdf.
[130] Morgan, D. et al. (2006), *Seattle Food System Enhancement Project: Greenhouse Gas Emissions Study*, University of Washington, Program on the Environment, accessed 14 January 2008, from http://courses.washington.edu/emksp06/SeattleFoodSystem/Final_GHG_Report.pdf.
[131] BusVic (2008), *Transport Emissions 2006: Melbourne Vs London*, Bus Association of Victoria.
[132] International Trade Centre (2008), *Organic Farming and Climate Change*, International Trade Centre, Switzerland, http://www.intracen.org/Organics/publications.htm (NB: The ITC is the joint technical cooperation agency of the UN Conference on Trade and Development (UNCTAD) and WTO for business aspects of trade development)

Food-related greenhouse emissions are substantial

The full lifecycle of food and beverages in Europe has been found to account for 31.1% of greenhouse emissions.[133]

Agriculture was directly responsible for 16.8% of Australia's greenhouse gas emissions in 2005 and 23% when emissions from energy, transport and waste are included,[134] so as a sector it provides a significant opportunity to reduce Australia's total emissions. Recalculations of the greenhouse warming potential of methane in the short term suggest that direct emissions from agriculture could actually account for 30% of Australia's greenhouse gas emissions.[135] Agriculture is the primary emitter of methane and nitrous oxide, the two principle non-CO2 greenhouse gases.[136] Although not yet accounted for, some common agricultural techniques also lead to on-farm topsoil depletion, whereby organic materials in the soil breakdown and release carbon dioxide into the atmosphere.[137]

Direct emissions from agriculture are only one stage in the supply chain that actually provides us with food; the emissions from energy in other stages of this supply chain (processing, distribution, packaging, storage, cooking, waste) are also considerable. It is estimated that direct energy use in Australian agriculture only represents between 25-30% of the energy consumed in the whole food supply chain.[138] Significant sources of emissions in other parts of the food system are often accounted for through other sectors, for example production of synthetic fertilisers and other chemicals are often counted as 'industry' (usually chemical), and emissions from transport or other stationary energy use are accounted for in those sectors.

The increase in embodied energy in food is to a large extent related to increased consumption of more processed food. In broad terms, the more food is processed, the higher the resource input and the more total 'food miles' involved as ingredients/components may be taken from whole-foods grown in a number of different regions.[139] Victoria has a substantial food-processing sector, but the emissions from this sector are generally attributed to industry rather than food specifically, in a similar way to fertilisers. Similarly, packaging consumes a significant proportion of raw materials such as aluminium, steel and plastics (fossil fuels), releasing greenhouse gases in processing and production (and through transport of the packaging product to food processing).

The impacts of climate change and the pressure to reduce emissions are becoming more significant, and national and global action to significantly reduce CO_2 emissions through the use of a variety of policy approaches is inevitable. Targets for reduction have been adopted in many countries and a broad scientific consensus currently points to global reductions in $CO_{2\text{-}e}$ production of around 60-90% by 2050 (compared to 2000 emissions). A major reorganisation of the food production and consumption system will be required if anything approaching this scale of emissions reductions is to be achieved.

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[133] European Science and Technology Observatory and Institute for Prospective Technological Studies (May 2006), *Environmental Impact of Products (EIPRO): Analysis of the Life Cycle Environmental Impacts Related to the Total Final Consumption of the EU25, Full Report*, http://ec.europa.eu/environment/ipp/identifying.htm, p106

[134] Hatfield-Dodds, S. et al. (2007), cited in Garnaut Climate Change Review (2007), *Issues Paper 1 - Climate Change: Land Use - Agriculture and Forestry*, Garnaut Climate Change Review, Melbourne.

[135] Calculations based on IPCC (2007b), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by Solomon, S et al., Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, Chapter 2, p212, and AGO's National Greenhouse Inventory (2005), Table 3, http://www.zeroemissionnetwork.org.au/facts-and-figures-agriculture

[136] Jancovici, J. (2004), *How Much Greenhouse Gases in Our Plate?*, accessed 12 July 2007, from www.manicore.com/anglais/documentation_a/greenhouse/plate.htm

[137] Yeomans, A.J. (2005), *Priority One: Together We Can Beat Global Warming*, Keyline Publishing, Arundel, p107

[138] Wood, R. et al. (2006), "A Comparative Study of Some Environmental Impacts of Conventional and Organic Farming in Australia", *Agricultural Systems,* vol. 89, no. 2-3: 324-48, p326. NB: These estimates are from 1978 and 1982.

[139] Scrinis, G. (2007), "From Techno-Corporate Food to Alternative Agri-Food Movements", *Local-Global,* Vol. 4, p119

Reducing emissions will affect the price of food

An emissions trading scheme will be introduced in Australia by 2010. This will effectively put a price on greenhouse gas emissions, making 'greenhouse-intensive' products and services more expensive. As this system is currently under development the price on emissions is unknown and the form and nature of the system (what will be included and what won't) have not been determined. However, it is clear that the price of goods and services will come to reflect the greenhouse emissions released throughout the production lifecycle. Shorthand terms being used to describe this are 'embodied carbon', the 'carbon footprint' or 'carbon intensity' (where carbon refers to CO_2 equivalent).

Many food products are carbon intensive, but there will be significant policy issues associated with increased costs to consumers of essential commodities. There may be pressure to exclude 'food' from carbon pricing systems out of concern for regressive effects or political backlash. The exclusion of agriculture from emissions trading is unlikely to really buffer increasing food prices, as they will still be impacted by price changes throughout the long and complex supply chains characterising current food systems. Rebating these costs is technically feasible, but complex to administer and audit. As a significant contribution to life-cycle emissions in the food system is from energy inputs to agricultural chemicals, machinery, processing, packaging and so on, which are often accounted for in another industry category, the idea of isolating food from carbon taxes poses significant challenges and the potential for real economic distortions.

It is likely that rising energy costs, and carbon costs throughout our own economy and those of our trading partners, will have greater impacts on some foods than others eg. food that travels long distances, has more nitrogen inputs and energy usage in production, or is more highly processed. Securing affordable food supplies in a carbon-constrained economy will require both careful policy design and major reductions in the emissions produced throughout the food chain. As food itself is vital to our existence, there is no avoiding the need over coming years to ultimately design a greenhouse-neutral, if not greenhouse-positive, food supply system.

Seeking innovation and redesign of the food system (as for energy and transport systems) requires careful analysis of priorities for investment, an understanding of the 'low-hanging fruit' and need for structural adjustment, and a multi-pronged approach. To prioritise and direct research and innovation towards the most greenhouse-intensive parts of the supply chain, we first need to understand where and how the emissions are produced, where they are unavoidable, and where they can (and must) be reduced.

Direct Agricultural Emissions

Worldwide, greenhouse emissions from agriculture (crop production and animal husbandry) and associated changes in land use, are estimated to exceed those from power generation and transport.[140]

Agriculture was directly responsible for 15.9Mt (12.9%) of Victoria's greenhouse gas emissions in 2005, up from 15Mt in 1990.[141] As greenhouse emissions from agriculture are a substantial contributor to Victoria's emissions profile, they will be an important area for potential reduction. The largest contributors to Victoria's (and Australia's) direct agricultural emissions in 2005 were:

- 71% methane from enteric fermentation (livestock 'burps'), which constitutes 9.1% of Victoria's total greenhouse gas emissions.[142] This source has been relatively stable (decreasing 0.07 Mt between 1990 and 2005), however this slight reduction most likely reflects the national fall in sheep numbers (42%) offset by a slight rise in beef cattle numbers (9.9%), which is due to

[140] McMichael, A.J. et al. (2007), "Food, Livestock Production, Energy, Climate Change and Health", *The Lancet*, vol. 370, no. 5: 1253-63, p61
[141] Victorian Greenhouse Gas Inventory (2007), *Victorian Greenhouse Gas Inventory: Information Sheet 2005*
[142] AGO (2007b), *Australia's National Greenhouse Accounts: State and Territory Greenhouse Gas Inventories 2005*, Australian Greenhouse Office, Commonwealth of Australia, Canberra, p23

external market conditions (and drought induced stock reductions) rather than the effects of mitigation actions.[143]

- 24% nitrous oxide from agricultural soils – mainly associated with increasing use of nitrogen fertilizers (see *2.2.3 (Chemical Inputs)*) and other activities that disturb the soil.[144,145] This source of emissions increased 22% between 1990 and 2005 and is responsible for most of the net increase in agricultural emissions.[146]
- About 5% of direct agricultural emissions were from manure management – the decomposition of animal wastes held in manure management systems.[147]

Australia has well developed on-farm emissions calculators for dairy, beef, sheep, grains and cotton industries, which include fuel and energy use as well as methane and nitrous oxides.[148] These tools are based on standard National Greenhouse Gas Inventory calculations and enable identification and management of current emissions sources. While they do include carbon sequestration through tree plantings, they do not allow consideration of soil carbon or non-conventional production methods.

Reducing direct agricultural emissions is difficult, but there is significant potential

A substantial mitigation of direct agricultural emissions may be achieved through changes to management practices and some research and investment is devoted to this (albeit minor compared to investment in emissions reduction in energy). McMichael et al (2007) have suggested that available mitigation technologies could reduce global emissions per unit of animal product by up to 20% at fairly low costs, making use of the following options:

- Carbon sequestration – reversing current trend of deforestation for agricultural intensification (less relevant in Victoria) and restoring organic carbon to cultivated soils and degraded pastures;
- Improved animal efficiency – changes to diets to reduce enteric fermentation, especially in ruminants (cattle, sheep and goats);[149]
- Changed type of animals – move towards less emissions intensive meat sources in human diets – chickens, monogastric mammals and vegetarian fish;
- Improved management of manure and biogas to reduce methane emissions; and
- Improved use of nitrogenous fertilisers to reduce nitrous oxide emissions. More efficient and targeted application has both greenhouse and productivity benefits (reduced cost to farmer)

See also *2.1.2 (Soil Carbon)*, *3.2 New Production Strategies* and *3.4.4 Choosing a Sustainable Diet*.

Energy and lifecycle emissions of food provision

Australia has experienced a long-term trend towards using more energy for food provision across the whole food supply chain.[150] This increase in the embodied energy of food can be attributed to the increased use of fossil fuel-based inputs such as fertilisers, pesticides and herbicides,

[143] AGO (2007a), *Australia's National Greenhouse Accounts: National Greenhouse Gas Inventory 2005*, Australian Greenhouse Office, Commonwealth of Australia, Canberra, p11

[144] AGO (2007b), *Australia's National Greenhouse Accounts: State and Territory Greenhouse Gas Inventories 2005*, Australian Greenhouse Office, Commonwealth of Australia, Canberra, and ibid. p11

[145] The conversion of nitrogen fertilizer to nitrous oxide varies according to conditions. Emission factor estimates range from 1.25% of nitrogen applied (IPCC) to a range of figures for different types of production in Australian / Victorian conditions are cited in Eckhart, R. (2007), *The Abatement Challenge for Australian Agriculture*, Discussion Paper for Garnaut Review Forum, The University of Melbourne and Department of Primary Industries, Victoria, p4

[146] Victorian Greenhouse Gas Inventory (2007), *Victorian Greenhouse Gas Inventory: Information Sheet 2005*

[147] AGO (2007b), *Australia's National Greenhouse Accounts: State and Territory Greenhouse Gas Inventories 2005*, Australian Greenhouse Office, Commonwealth of Australia, Canberra, and AGO (2007a), *Australia's National Greenhouse Accounts: National Greenhouse Gas Inventory 2005*, Australian Greenhouse Office, Commonwealth of Australia, Canberra.

[148] See http://www.greenhouse.unimelb.edu.au/gia.htm

[149] The full lifecycle emissions of grains and alternative feedstocks would also need to be considered when calculating benefits.

[150] Wood, R. et al. (2006), "A Comparative Study of Some Environmental Impacts of Conventional and Organic Farming in Australia", *Agricultural Systems,* vol. 89, no. 2-3: 324-48, p326

increased use of heavy agro-machinery, an increase in food processing and the transport of food across long food supply chains.

The energy efficiency of the food system (measured as energy in vs energy out – calories for human consumption) has been a significant concern for many years. As early as 1994, the energy (in)efficiency of the US food production was noted, with each calorie of food consumed requiring ten calories for its production (including packaging and delivery, but not household cooking).[151] While this refers to the US food system (and energy inputs are likely to have increased over the last 13 years), it can be assumed that Australian figures would be similar.

Recent studies on household ecological impacts have revealed that food is one of the most significant energy uses and that in most developed countries the food sector accounts for 15-20% of total energy use.[152]

In Australia, environmental pressures like the need to use water more efficiently have led to the development and introduction of new technologies (such as micro-sprays) that require more energy use in production. Year-round provision of high quality fruit and vegetables has also led to an increase in crops grown in greenhouses or under shade cloth; while extending the seasonal availability of produce with imports from interstate and overseas also increases energy consumption in the supply chain.[153]

To effectively reduce energy use, and consequently emissions, across the food chain requires a good understanding of where (aside from on-farm methane and nitrous oxides) the emissions actually occur.

There is increasing data on food emissions from research projects in many other countries (eg. Sweden, Denmark, the UK and the USA), but little in Australia. Some of the leading activities in lifecycle analysis and carbon footprinting (where a lifecycle analysis is conducted only on the greenhouse emissions) are summarised below.

European countries, in particular **Sweden** and **Denmark** and the **UK** have led efforts to understand greenhouse emissions (and other sustainability impacts) of food production and consumption. In October 2007, the European Platform on LCA published guidelines for carbon footprinting (which is basically LCA but only considering greenhouse emissions).[154] The European Commission also has significant resources available to enable European governments and businesses to conduct lifecycle analyses of all products and services (including foods).[155] These resources may well include methodologies, databases and information pertinent to Australian lifecycle analyses of food products.

Denmark

In Denmark a full LCA database has been established with calculated information on the lifecycle impacts of basic food products produced and consumed in Denmark. The information is accessible via a website – www.lcafood.dk - and the site covers processes from primary sectors such as agriculture and fishery through industrial food processing to retail and cooking.[156] This database could provide a useful model for development of an Australian equivalent. This site also

[151] Giampietro, M. and Pimentel, D. (1994), *The Tightening Conflict: Population, Energy Use and the Ecology of Agriculture*, accessed 15 August 2006, http://www.dieoff.com/page69.htm
[152] Carlsson-Kanyama, A et al. (2003), "Food and Life Cycle Energy Inputs: Consequences of Diet and Ways to Increase Efficiency", *Ecological Economics*, vol. 44: 293-307, p294
[153] Foran, B., Lenzen, M., and Dey, C. (2005), *Balancing Act - A Triple Bottom Line Analysis of the Australian Economy*, CSIRO Sustainable Ecosystems, http://www.cse.csiro.au/research/balancingact/, p54
[154] JRC European Commission (2007), *Carbon Footprint - What It Is and How to Measure It*, European Platform on Life Cycle Analysis, http://lca.jrc.ec.europa.eu/Carbon_footprint.pdf
[155] See http://lca.jrc.ec.europa.eu/lcainfohub//directory.vm
[156] Nielsen, P. et al. (2003), *LCA Food Data Base*, www.lcafood.dk

contains information on the 5th International Conference on LCA in Food, held in Gothenburg, Sweden, in April 2007 however information is restricted to participants at this time.

Sweden

Between 1997 and 2004 a Swedish research program, Food 21, involved about a hundred researchers working together to find ways to achieve sustainable food production systems. The research program included systems and lifecycle analysis, with particular focus on cheese, milk and pigs.[157]

One particular Swedish researcher (Annika Carlsson-Kanyama) has been involved in a range of projects concerning greenhouse gas emissions from food production and consumption.

In a 2003 study, Carlsson-Kanyama et al[158] presented, compared and discussed the estimated life cycle energy inputs for typical foods consumed in Sweden (listing energy inputs for 150 food items). This study compared foods at an average portion size and accounted for their final 'ready to eat' embodied energy ie. including cooking energy where required.[159] Key findings were:

- Energy inputs in food life cycles vary from 2 to 220 MJ per kg due to factors related to animal or vegetable origin, degree of processing, choice of processing and preparation technology and transportation distance.
- Daily total life cycle energy inputs for diets with a similar dietary energy consumed by one person can vary by a factor of four, from 13 to 51 MJ.
- Current Swedish food consumption patterns result in life cycle energy inputs ranging from 6900 to 21,000 MJ per person and year. Choice of ingredients and gender differences in food consumption patterns explain the differences.
- Up to a third of the total energy inputs is related to snacks, sweets and drinks, items with little nutritional value.
- It is possible to compose a diet compatible with goals for energy efficiency and equal global partition of energy resources. However, such a diet is far from the Swedish average and not in line with current trends. (Findings concerning nutritional value are discussed at *Choosing a Sustainable Diet*).

This work included a discussion of how energy efficient meals and diets can be composed, considers menu planning for energy efficient consumption and proposes an idea of "Climate Watching" – promoting environmentally conscious food consumption based on the Weight Watchers model. Further discussion can be found in *3.4.4 Choosing a Sustainable Diet*.

The extent to which these figures could be translated to Australia is unknown, but would be worthy of further exploration. Studies that combine the emissions from agricultural production and from the energy inputs (the second study) do not appear to have yet been done in Sweden.

France

Analysis of the French food system suggests that 30.5% of France's greenhouse emissions in 2001 were related to food production and consumption.[160] The majority of emissions were (as for other countries) related to food production (methane and nitrous oxides), however Jancovici also estimates emissions from processing and transport. According to this analysis, in 2004, only 20% of France's food expenditure went towards raw or whole food products (fresh fruit, vegetables,

[157] See http://www-mat21.slu.se/eng/index.htm

[158] Carlsson-Kanyama, A. et al. (2003), "Food and Life Cycle Energy Inputs: Consequences of Diet and Ways to Increase Efficiency", *Ecological Economics*, vol. 44: 293-307.

[159] A model for accounting for the energy required for cooking and cold storage in households can be found in the work of Sonesson, U. et al. (2003), *Energy for Preparation and Storing of Food - Models for Calculation of Energy Use for Cooking and Cold Storage in Households,* Sik-Rapport Nr 709, www.sik.se

[160] Jancovici, J. (2004), *How Much Greenhouse Gases in Our Plate?*, accessed 12 July 2007, www.manicore.com/anglais/documentation_a/greenhouse/plate.htm

meat or fish).[161] The energy consumed and greenhouse gases emitted during food processing (for the processed foods that make up the other 80%) are accounted for within France's 'industry' sector and consume 15% of the total energy used by that sector. Jancovici also calculates that 25% of raw materials production in Europe in 2001 (steel, aluminium, cement, plastics, glass and cardboard) was used as food packaging – this is almost as much as was used for construction (30%).

United Kingdom

In the UK, the Department of Environment Food and Rural Affairs commissioned the Manchester Business School to conduct research to "inform government policy development to reduce the environmental impacts of food consumed in the UK."[162] The project also aimed to develop information for more sustainable food choices to assist the food industry. A report was provided to DEFRA in October 2006. This work took a sample of food types that were considered representative of the 150 highest selling food products.

The overall finding of this study was that detailed studies of full lifecycle environmental impacts have not been conducted for many basic foods in the UK and even fewer processed foods. Most research is focused on the production stage, occasionally extended to processing, and very few take account of specific UK circumstances. They note inconsistencies in the data and indicators included (and again note the bias towards on-farm analysis only), but do state that almost all existing studies include energy use (and therefore CO_2 emissions) and most include methane and nitrous oxides as well. Acknowledging that European studies (particularly the Scandinavian ones outlined above) could be reasonably applicable to the UK, the authors suggest caution as "systems of food production and consumption have strong national specificities."[163]

Although this caution applies when comparing findings of European and UK studies with Australian conditions, the general conclusion on the need for more information and detailed lifecycle analysis for particular foods within the national context is readily transferable!

An example of the complexities identified by this study relates to increasing refrigeration as a 'default' method of food preservation and storage (more than 50% of UK supermarket lorries are now temperature controlled for movement of chilled or frozen goods),[164] which will lead to higher emissions from electricity generation. However, while the energy consumption (hence emissions) involved in refrigerated foods is greater than for fresh foods, it is difficult to quantify how this may be offset by reduced wastage. There is currently insufficient information to draw strong overall conclusions about the value of refrigerated, preserved (canned, bottled or dried) and fresh food. Other findings from this study are included in other sections of this report, see *3.2.3 Reducing Reliance on Inputs* and *3.3 Distribution Strategies.*

In the UK several of the primary supermarkets have committed to a significant program of analysis that will allow the 'carbon intensity' of all foodstuff to be displayed as a guide for consumers. DEFRA, the Carbon Trust and BSI British Standards are currently developing a 'carbon footprint' measurement for products and services. This is aimed towards a single standard labelling system across the supply chain to measure embodied greenhouse gases. A draft standard will be rolled out across 30 individual products (a range of tomatoes, potatoes, orange juice, light bulbs and washing detergent) sold through Tesco to provide detailed feedback for the development of a single common standard.[165] At the time of publication of this report, a draft standard was being circulated for comment.

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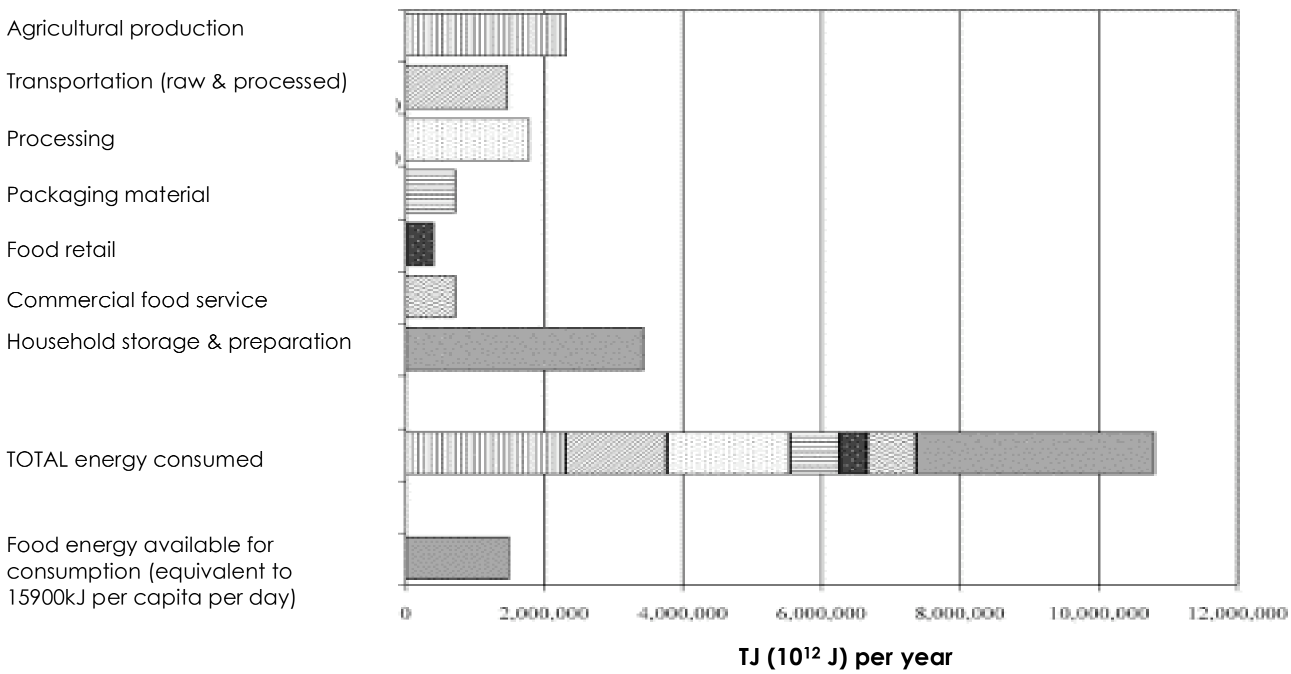
[161] Jancovici, J. (2004), *How Much Greenhouse Gases in Our Plate?*, accessed 12 July 2007, www.manicore.com/anglais/documentation_a/greenhouse/plate.htm
[162] Foster, C. et al. (2006), *Environmental Impacts of Food Production and Consumption: A Report to the Department for Environment, Food and Rural Affairs*, Manchester Business School, DEFRA, London.
[163] Ibid, p12
[164] Ibid, p12
[165] Environmental Management News (2007), *Carbon Footprinting Hits UK Supermarket*, accessed 15 October 2007, www.enviromentalmanagementnews.net/storyview.asp?storyid=120110

USA

In the US, a 2000 study conducted by the University of Michigan,[166] presented key economic, social and environmental indicators across the life cycle stages of the food system - origin of (genetic) resource, agricultural growing and production, food processing, packaging and distribution, preparation and consumption, and end of life. A later study (conducted in 2003) took these indicators and methodology and conducted a lifecycle analysis of the food system in general – although not broken down into specific sectors or products. The energy balance of the US food system, according to this study, is shown in Figure 2.2.

Figure 2.2 – Life cycle energy use in supplying US food

(Sources and methodology detailed in Heller and Keoleian 2000).[167]



Australia

The two most extensive analyses of the direct energy requirements of the Australian food supply chain were last conducted in 1979 and 1982.[168] Their results are summarised in Figure 2.3. These analyses considered the primary energy consumed directly during the various activities and found that for Australia agriculture accounted for 25-30% of the energy in the food supply system.

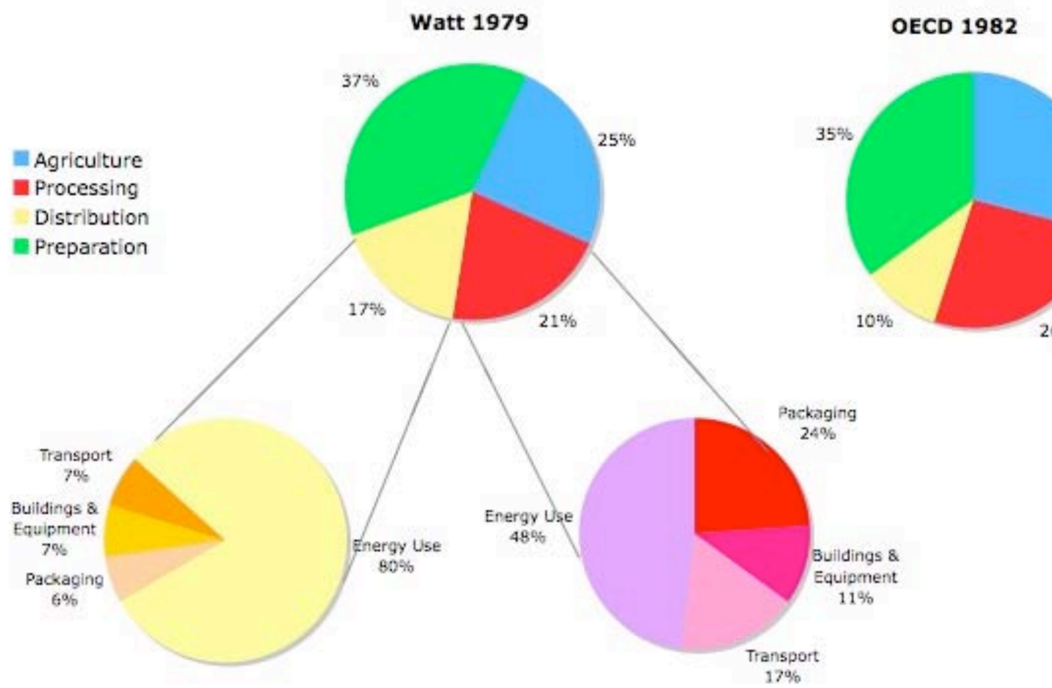
It is important to note that these analyses did not include the 'upstream' energy use – that needed to produce agricultural chemicals and machinery etc. Wood et. al's analysis concluded that it was very important to consider both upstream and downstream environmental impacts of

[166] Heller, M.C. and Keoleian, G.A. (2000), *Life Cycle-Based Sustainability Indicators for Assessment of the Us Food System* (No. CSS00-04), Centre for Sustainable Systems, University of Michigan.
[167] Heller, M. and Keoleian, G. (2002), "Assessing the Sustainability of the Us Food System: A Life Cycle Perspective", *Agricultural Systems*, vol. 76, no. 3: 1007-41.
[168] Watt, M. (1979), and Organisation for Economic Co-operation and Development (1982), cited in Wood, R. et al. (2006), "A Comparative Study of Some Environmental Impacts of Conventional and Organic Farming in Australia", *Agricultural Systems,* vol. 89, no. 2-3: 324-48, p326

agriculture, particularly for energy and related emissions, as most of these impacts occur off farm[169] (see also *3.2.3 Reducing Reliance on Inputs*).

It is most likely that changes to the food system in the last 25 years would significantly affect these figures, but updated analysis does not seem to have occurred.

Figure 2.3 - Direct Energy Requirements of the Australian Food Supply Chain[170]



CSIRO's 2005 Balancing Act Report[171] is a triple bottom line assessment of the Australian economy. Environmental factors such as energy intensity, greenhouse gas emissions, water requirement and land disturbance are described as impact per dollar of final demand for each industry sector. The results of this study indicate which sectors have high greenhouse impacts per dollar, along with other environmental and social impacts. The high level of consolidation (many different types of activities within each industry sector) means that this type of analysis can only be used to give a broad overview.

The method described in this report accounts for impacts of the full upstream supply chain of an economic entity such as a company or sector. Downstream impacts, for example those associated with the use of the products sold by a company (e.g. the transport and storage of food), were beyond the scope of this work, but may be included in enhanced analytical methods that are currently under development at the University of Sydney.

Results are given in direct effect (effect is due to the sector itself) and indirect effect (due to its chain of suppliers) e.g. direct greenhouse gas emission effects in the dairy industry of 78% include methane and nitrous oxides as well as carbon dioxide. Indirect effects are from electricity generation (4%), land development (3%), animal feeds (4%) and basic chemicals (1%).

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[169] Wood, R. et al. (2006), "A Comparative Study of Some Environmental Impacts of Conventional and Organic Farming in Australia", *Agricultural Systems* 89, no. 2-3: 324-48, p325

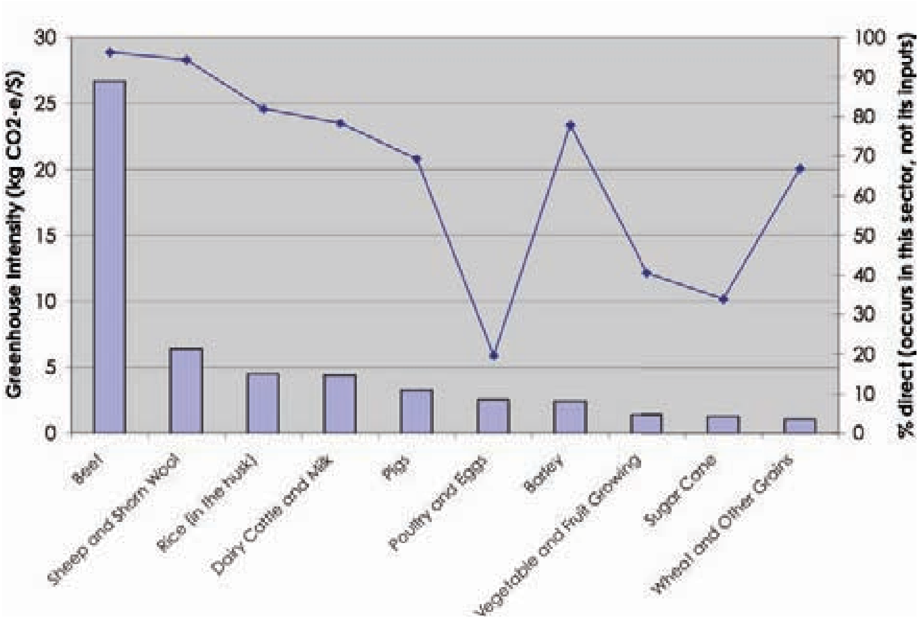
[170] Watt, M. (1979), and Organisation for Economic Co-operation and Development (1982), cited in Wood, R. et al. (2006), "A Comparative Study of Some Environmental Impacts of Conventional and Organic Farming in Australia", *Agricultural Systems* 89, no. 2-3: 324-48, p326

[171] Foran, B., Lenzen, M., and Dey, C. (2005), *Balancing Act - A Triple Bottom Line Analysis of the Australian Economy*, CSIRO Sustainable Ecosystems

The figures in this analysis are based on conventional mainstream agricultural practices and do not account for soil carbon sequestration.

Direct emissions from beef, sheep, rice and dairy make these by far the most greenhouse intensive food production sectors (see Figure 2.4) as discussed in the previous section. Although the emissions from beef dwarf those from other sectors, most food sectors are still very greenhouse intensive compared to the economy average. For example the greenhouse intensity from Wheat and Other Grains is equal to the economic average. Although Figure 2.4 makes it look small in reality this graph shows the extent to which food sectors have higher than average greenhouse intensities per $ of final demand.

Figure 2.4 – Greenhouse Intensity in Primary Production



The lower percentage attributed to direct emissions indicates that sectors such as Poultry& eggs, Vegetable & fruit growing and Sugarcane have significant emissions from their inputs. These are:

- Poultry and Eggs: beef cattle → meat products (40%) plus via other food products (2.4%), other food products (non-beef origin) (7.9%) and electricity supply (6.7%);
- Vegetable & fruit growing: forestry (24%), electricity (5.2%) and basic chemicals (2.5%); and
- Sugarcane: forestry (27%), electricity (5.7%) and basic chemicals (2.7%).

No secondary sector is directly responsible for more than 15% of its associated emissions ie. for all sectors more than 85% of emissions are in production and inputs to production. This indicates that the most significant emissions reductions come before the product reaches the farm gate.

As discussed above, most agricultural emissions are due to methane and nitrous oxides in production. However there are also significant energy emissions in the food system. Figures 2.5 and 2.6 show the energy intensity of primary and secondary production for key food sectors.

Figure 2.5 – Energy Intensity in Primary Production

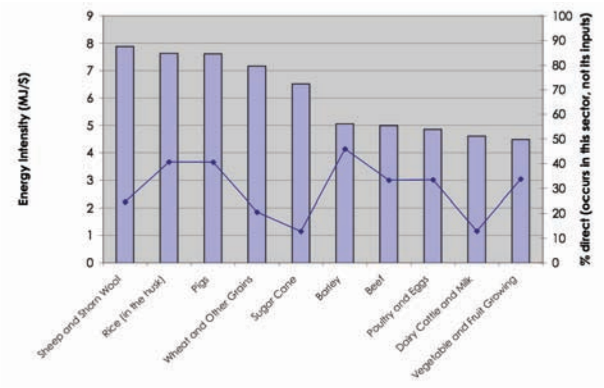


Figure 2.6 – Energy Intensity in Secondary Production

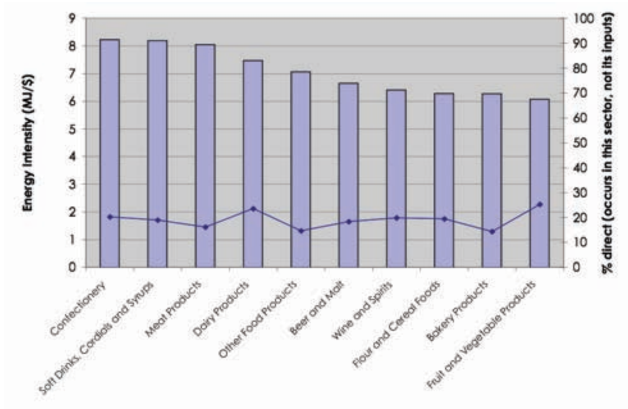


Figure 2.5 shows that for many sectors (most notably barley, rice and pigs) a significant proportion of the energy is used in inputs to primary production (upstream energy use). Figure 2.6 suggests that for all sectors, the value-adding processing phase (eg. dairy cattle to dairy products) accounts for about 15-25% of the energy use per dollar of final demand.

As this analysis does not include transport, storage, or waste after the processing stage, it does not provide comparative information on where energy is getting used in the full system. As the figures are based on a per dollar turnover, they would vary according to economic conditions of demand and supply and the value of the Australian dollar. They do not reflect the emissions per kg of product, making these figures are therefore difficult to compare with international studies. The high level of aggregation (ie. commodity categories rather than specific foods) also makes it difficult to draw meaningful conclusions regarding specific changes in supply chains or consumer choices. However, as a starting point, this study gives some indications on where attention could be focused.

A detailed study of the full lifecycle greenhouse gas emissions of one product – a packet of corn chips from Australian maize – was conducted by CSIRO and RMIT in 2006.[172] According to this report, of the total emissions of carbon dioxide equivalents (CO_2-e) emitted, the post-farm processes (transport, corn-chip processing and packaging) release the highest proportion of around 58%, while emissions from on-farm processes (pesticide & herbicide degradation, irrigation, machinery use, crop drying, N_20 from applied fertiliser and land disturbance) comprised 36% and pre-farm processes (fertiliser, pesticide & herbicide production, fuel production) released only 6% of emissions.

Similar LCA research has been conducted at Curtin University on wheat-to-bread, barley-to-beer and canola-to-cooking oil. "The application of LCAs in broad acre agriculture or for food products in general is novel in Australia", according to the research team at Curtin, "However, to maintain, and possibly even improve, the image of Australia as a 'clean and safe' producer of grains, it will become necessary to provide detailed evidence, in a format that allows domestic and overseas food producers to assess the environmental impacts of their products with appropriate environmental life cycle information for the grain ingredients produced in Australia." [173]

NIEIR has done a study on embodied carbon of a number of products commonly consumed by Victorian households using aggregated data for broad industry sector impacts, in an attempt to analyse impacts of carbon pricing on food prices.[174] They acknowledge that this use of

[172] Grant, T., and Beer, T. (2006), "Life Cycle Assessment of Greenhouse Gas Emissions from Irrigated Maize: The Life- Cycle and Value Chain Analysis", paper presented at the *5th Australian Conference on Life Cycle Assessment*, 22-24 November 2006, Australian Life Cycle Assessment Society, Melbourne.

[173] Narayanaswamy, V. et al. (2005), "Application of Life Cycle Assessment to Enhance Eco-Efficiency of Grains Supply Chains", paper presented at the *4th Australian Life Cycle Assessment Conference*, Sydney.

[174] NIEIR (2007), *The Impact of Carbon Prices on Victorian Selected Household Types: A Preliminary Analysis*, Report for the Brotherhood of St Laurence, National Institute of Economic and Industry Research.

aggregated data only provides a 'preliminary analysis' and although it demonstrates that food represents a significant proportion of total Victorian CO_{2-e} generation,[175] this information is not sufficient to analyse the relative affects on different products.

Transport – Food Miles

Part of the energy intensity of the food system comes from the organisation of food production, processing storage and delivery, which often involves increasing distances for the total transport from farm to consumption. In another shorthand these distances have been labelled as total 'food miles'. Following research from the Wuppertal Institute in Germany in 1993,[176] in which the ingredients of a typical tub of yoghurt was found to have travelled a total of around eight thousand kilometres before it is consumed, this 'measure' of systems organisation has grown in popularity as a indicator of energy/CO_2 efficiency. In practice this is not considered a usable measure as it ignores modes of transport and transport load factors, which affect the energy/CO_2 outcomes.[177] Nevertheless food miles is an indicator of system organisation and, for a number of products, the Wuppertal Institute has been able to show that reorganisation of production-consumption systems can lead to large 'factor' reductions in total transport distances, with 'factor 4' to 'factor 10' reductions in life-cycle environmental impacts, including CO_2.[178]

In the UK, DEFRA commissioned a study in 2005 to explore whether a practical and reliable indicator could be developed for food miles. This study found that a single indicator based on kilometres travelled is not an adequate sustainability indicator and recommended a suite of indicators based on the major adverse impacts of food transport. The study quantified the contribution of food transport to adverse environmental, social and economic effects (including finding that food transport accounts for 25% of all heavy goods vehicle kilometres in the UK), but also found that the most significant adverse impact is congestion rather than greenhouse gas emissions.[179] This type of overarching analysis has not yet been conducted in Australia or Victoria, but some of the findings may be similar.

It has also been found in the UK that the car-based shopping emissions are **greater** than transport emissions from the production and distribution phases,[180] and for some foods it could even be the most significant emissions contribution.[181] The impact of 'car miles' in Melbourne (and probably the rest of Victoria) would be likely to be a much higher proportion even than this – a recent study has found that Melbourne's transport produces approximately 2.5 times as many greenhouse emissions (per person) as London's (road freight removed).[182] Foster et al. also noted that increasing air-freighting of food items was a trend that may need to be discouraged – although the current proportion of air-freighted food in the UK is very small, the emissions associated with aviation are relatively significant.

A 2006 New Zealand study received widespread attention when it revealed that the total emissions associated with lamb, dairy, apples and onions produced in New Zealand and shipped to the UK were still lower (sometimes significantly lower) than for those goods produced in the UK.[183] This study demonstrated that just looking at 'food miles' was not a sufficient measure of

[175] Ibid.
[176] Boge, S. (1993), citied in Weizsäcker, E. et al. (1998), *Factor Four: Doubling Wealth, Halving Resource Use*, Earthscan.
[177] DEFRA (2005), *The Validity of Food Miles as an Indicator of Sustainable Development: Final Report*, AEA Technology Environment, http://statistics.defra.gov.uk/esg/reports/foodmiles/default.asp
[178] Weizsäcker, E. et al. (1998), *Factor Four: Doubling Wealth, Halving Resource Use*, Earthscan, Chapter 10: Examples of Revolutionising Transport Productivity.
[179] DEFRA (2005), *The Validity of Food Miles as an Indicator of Sustainable Development: Final Report*, AEA Technology Environment
[180] Foster, C. et al. (2006), *Environmental Impacts of Food Production and Consumption: A Report to the Department for Environment, Food and Rural Affairs*, Manchester Business School, DEFRA, London.
[181] Morgan, D. et al. (2006), *Seattle Food System Enhancement Project: Greenhouse Gas Emissions Study*, University of Washington, Program on the Environment, accessed 14 January 2008, http://courses.washington.edu/emksp06/SeattleFoodSystem/Final_GHG_Report.pdf.
[182] BusVic (2008), *Transport Emissions 2006: Melbourne Vs London*, Bus Association of Victoria.
[183] Saunders, C. et al. (2006), *Food Miles - Comparative Energy/Emissions Performance of New Zealand's Agriculture Industry*, AERU - Lincoln University.

carbon intensity, and emphasised that 'local' food is not always best (see *3.3.1. Localisation* for further discussion).

In 2007 a study was conducted in Melbourne to explore the food miles and associated emissions from road transport of a typical 'food basket' to point of purchase.[184] This study was limited to emissions from transport, based on (probably conservative) information from food organisations and companies. It only considered one or two of the most significant ingredients in processed foods and its results are indicative at best. However, this first attempt to quantify local food miles provides some useful indicative information, such as:[185]

- The total distance of the road transportation in the food basket was 21,073 kilometres (km), almost the same distance to travel around Australia's coastline (25,760 km) – this figure represents the food miles associated with domestically produced food.
- The total distance for all transportation of the food basket is 70,803 km – this figure includes shipping and air transport from imported produce.
- The five lowest food miles emissions estimate were from lettuce, apples, chicken, potatoes and beef – reflecting both local production and that these items are sold in their original form (eg. no other ingredients added).
- The five highest food miles emissions estimates were for bananas, white sugar, unsaturated margarine, potato chips/crisps and orange juice. This can be associated with the location of raw produce (bananas), sourcing produce from multiple locations and the level of processing (white sugar, unsaturated margarine, potato chips/crisps and orange juice).
- In general food requiring less processing has fewer transport related emissions.
- This study only calculated greenhouse emissions from road transport within Australia, however noted the substantial differences in kilometres travelled by Australian produce compared to imported produce (eg. Australian oranges travelled an average 567km and Californian oranges an average 12,878km).
- If miles travelled by packaging materials were included the total 'food miles' would be significantly greater. Averages for two materials were calculated – the travel distances of tin cans (17,108km) and milk cartons (8,035km) highlight the significance of packaging in any full assessment.

These studies all clearly indicate that emissions from transport are only one factor to be considered in full lifecycle assessments, and products with the lowest food miles may not have the lowest greenhouse or total environmental impact. However, unless there are major changes in the mix of transport modes (towards very low carbon transport systems) 'food miles' is likely to continue acting as a 'proxy' system indicator for consumers wishing to reduce their environmental impact. Interest in food miles also reflects community concern about oil shortages (see *2.2.2 Oil, Biofuels and Agricultural Inputs*) and in some cases a desire to support local producers. For further information on innovations and community movements responding to these issues, see *3.3 Distribution Strategies*.

Soil Carbon

Soil can hold significant amounts of carbon

The amount of carbon stored in a soil is referred to Soil Organic Carbon (SOC) and is expressed as a percentage by weight (g C/kg soil). The amount of carbon stored in a soil is related the amount of organic matter in the soil. The amount of soil organic matter (SOM), and hence SOC, in Australian soils varies greatly depending on soil type, land use and conditions. SOM in Victorian soils ranges from 1.3 to 10.5 per cent.[186]

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[184] The food basket is based on the items included in Queensland Health (2000), *The Healthy Food Access Basket Survey 2000*, Queensland Government, Australia, p12
[185] Gaballa, S. and Abraham, A. (2007), *Food Miles in Australia: A Preliminary Study of Melbourne, Victoria*, Centre for Education and Research in Environmental Strategies (CERES) Community Environment Park.
[186] Leeper, G. and Uren, N. (1993), cited in Catchment Knowledge Exchange (2007), *Question 4 - If You Increase Soil Carbon What Is the Impact?*,

There are various estimates as to how much carbon the world's soils currently hold and how much they could potentially. One estimate is that they currently hold between 1200 and 1800 GT of carbon – twice as much as that stored by all terrestrial plants.[187] Bolder advocates suggest that they hold four times as much carbon as vegetation does and three times as much as is in the atmosphere.[188] It has been suggested that "it would only require a 1% increase in soil carbon on 15 million hectares of land to sequester 8GT of carbon dioxide in the soil, which is equivalent to the greenhouse emissions for the entire planet."[189] Even if this estimate is too large, there is no question that potential carbon sequestration in soils has significant potential benefits.

The balance of carbon between the soil and the atmosphere is constantly shifting through processes including photosynthesis, transfer of carbon to the soil via roots and decomposing plant residues, activities of soil biology and then oxidation of the carbon back into the atmosphere (usually when the soil is disturbed or burnt). The main inputs to soil carbon are the decaying roots of crops and the bodies of living biological matter in the soil – "thriving biological life in the soil, thriving biological life above the soil."[190] This living balance tends to be enhanced by "intermittent disturbance"[191] ie. reducing disturbance of the soil structure through ploughing / tillage. Some soil carbon stores are relatively transient, while some are much more stable and can hold carbon firmly in the soil for long periods of time.[192] It is difficult to measure and guarantee the amount of carbon stored in any particular soil, but the extent of potential significance in carbon sequestration means that increasing attention is inevitable, and vital.

Higher levels of soil carbon also contribute to healthier and more productive soils.

SOC helps "increase the cation exchange capacity (CEC) and water-holding capacity of sandy soil and contributes to the structural stability of clay soils."[193] Increasing soil carbon is good for productivity because higher levels of organic matter in soil hold more nutrients, cations and trace elements, decrease nutrient leaching and increase mineral availability to plants.

It has been estimated that historic levels of organic matter in Australian agricultural soils may have been twice what they are now.[194] Agricultural methods leading to overstocking, overly simplistic and excessive fertiliser regimes, and inappropriate cropping systems have exacerbated the loss of soil carbon. As revegetation of all agricultural land with perennial species and forests is probably not viable, the development and application of agricultural methods and systems that help to increase soil carbon will become increasingly valuable.

As seen in Figure 2.7, intensively cropped soils have a particularly low carbon content and therefore high potential for improvement through improved land management. However, modified cropping practices (such as direct drilling and stubble retention) have been found to have a limited impact on soil carbon increase,[195] conversion from crop to pasture would have more benefits (Victorian trend is conversion from pasture to crop, see also *2.3.1 Native Biodiversity*).

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http://www.catchmentknowledgeexchange.net.au/mambo/index.php?option=com_content&task=view&id=108&Itemid=129

[187] Smil, V. (1997), cited in Catchment Knowledge Exchange (2007), *Question 4 - If You Increase Soil Carbon What Is the Impact?*

[188] Jones, C. (2007), "Building Soil Carbon with Yearlong Green Farming", *Evergreen Farming Newsletter*, September 2007.

[189] Farm Online (2007), *$90/Tonne for Carbon*, sourced from Farm Weekly WA, accessed 29 March 2007, http://www.farmonline.com.au/news_daily.asp?ag_id=41436

[190] Jones, C.E. (2002), "Creating Topsoil- Stipa Native Grasses", paper presented at the *Changing Landscapes Forum*, 3 May 2002, Armidale, http://www.amazingcarbon.com/JONES-BuildingNewTopsoil.pdf.

[191] Ibid.

[192] Catchment Knowledge Exchange (2007), *Question 4 - If You Increase Soil Carbon What Is the Impact?*

[193] Leeper, G. and Uren, N. (1993), *Soil Science, an Introduction*. 5th ed, Melbourne University Pres, Melbourne and ibid.

[194] Charman, P. and Murphy, B. (2000), cited in Catchment Knowledge Exchange (2007), *Question 4 - If You Increase Soil Carbon What Is the Impact?,*

[195] Cowie, A. (2007), "Carbon Sequestration in Agricultural Soils: A Potential Carbon Trading Opportunity?" paper presented at the *Greenhouse 2007 Conference*, NSW Department of Primary Industries, Sydney, http://www.greenhouse2007.com/downloads/papers/071004_CowieAbstract.pdf

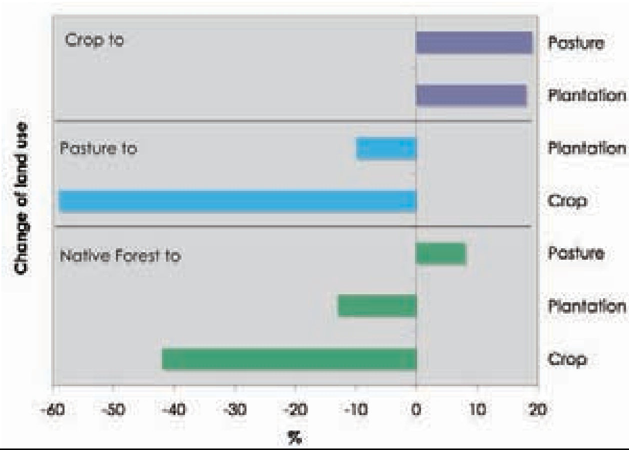
Figure 2.7 - Land use changes have led to the loss of carbon stored in soils[196]

Figure 2.7 shows the estimated soil carbon emissions and sequestration from changing land uses as estimated in a 2002 meta-analysis by scientists from CSIRO Plant Industries division.[197]

It shows that a land use change from pasture to crop leads to the most significant loss of soil carbon, followed closely by conversion of native forest to crop.

Including soil carbon within carbon pricing / trading schemes could have significant impacts on land use decisions affecting both agriculture and forestry – including native forest clearing.

Soil Carbon Loss and Sequestration from Land Use Change



Soil carbon can be actively increased

Leading Australian work in this area by Dr Christine Jones in WA has led to the launch of *The Australian Soil Carbon Accreditation Scheme (ASCAS)* in 2007 (in partnership with Rio Tinto Coal). This scheme will pay farmers for activities that sequester atmospheric carbon in the soil on their farms, by taking annual samples of designated areas for an initial 3-year period. The scheme will pay $90 per tonne of carbon - a 0.15% increase in soil carbon in the Defined Sequestration Areas would be equivalent to adding 23.1t/ha of carbon, earning $21.19/ha per year.[198]

Some early results from this trial are suggesting very significant environmental and economic gains, with one site achieving more than three times the amount of carbon in soil used for broad acre cropping than under the surrounding native vegetation (149tC/ha under native veg vs 516tC/ha under the crop).[199] The soil carbon increase described in the above test site has also yielded substantial productivity benefits – the wheat crop yielded 4t/ha grain with 13.5% protein (which is well above the district average).[200]

The difficulty with soil carbon is that it is highly variable across soil types, management practices and weather patterns. This is causing difficulties for its inclusion in climate policy – how can we tax / reward soil carbon changes if we can't measure where and when they are occurring? This difficulty is compounded by the widespread implications of accounting for soil carbon losses and gains.

The potential of soil carbon sequestration is very significant and the need to reduce emissions and sequester carbon is urgent. Technical and political difficulties should not delay the development and encouragement of practices that are already known to increase soil carbon.

Pilot schemes such as the WA ASCAS will improve information about specific techniques and soil types. As techniques that improve soil carbon have other productivity benefits as well, the development of new soil carbon building practices provide opportunities for 'win-wins' for

[196] Cowie, A. (2007), "Carbon Sequestration in Agricultural Soils: A Potential Carbon Trading Opportunity?" paper presented at the *Greenhouse 2007 Conference*, NSW Department of Primary Industries, Sydney.
[197] Guo, L. and Gifford, R. (2002), "Soil Carbon Stocks and Land Use Change: A Meta Analysis", *Global Change Biology*, vol. 8: 345-60.
[198] Farm Online (2007), *$90/Tonne for Carbon*, sourced from Farm Weekly WA, accessed 29 March 2007, http://www.farmonline.com.au/news_daily.asp?ag_id=41436
[199] Interview and e-mailed information from Dr. Christine Jones, provided by the Biological Farmers Association of Australia
[200] Ibid

farmers. More information on techniques that contribute to soil carbon sequestration (along with other benefits) can be found at *3.2.1 Environmental Management*.

Further research is required to quantify and specify soil management practices that maintain or restore soil carbon in Victoria.

2.2. Resource Constraints

Summary and Recommendations:

Resource constraints present foreseeable threats to the agricultural sector and the maintenance of affordable and accessible food supplies, as producers adapt to increasing scarcity of water, land, oil and agricultural inputs (N-P-K fertilisers).

Resource constraints will also impact on Victoria's ability to continually increase production despite growing international demand. As resources become more expensive, producers may struggle to compete.

Increasing understanding of these threats can help us prepare for and reduce risks to producers and vulnerable consumer groups. Some resource constraints are already impacting on food production, supply chains and therefore prices.

Some general recommendations for dealing with constrained resources are outlined below.

!	*Impending resource shortages may be masked by economic fluctuations and other factors. Provision of information and analysis of trends and alternatives can ease transition and avoid resource 'shocks'*
!	*Some inputs are finite and will become unaffordable – food systems will need to adapt to significant input reductions and changes e.g. systems relying on oil and conventional agricultural inputs will continue to be vulnerable*
🕮	*Analysis of social and economic vulnerabilities to food price changes (linked to resource constraint) – possibly the development of scenarios*
⚡	*Increase efficiency of input use*
⚡	*Proactive investment in and development of renewable / sustainable resource alternatives*
⚡	*Restore degraded land, soil and water resources so that production systems require fewer inputs*
⚡	*Develop production and distribution systems that do not rely on scarce or contested non-renewable inputs (make use of what is available)*
⚡	*Reuse 'waste' water and organic materials for food production – including in urban areas*

The existing food system has developed within a mindset of abundance. It is now becoming understood that this mindset is no longer viable – we can no longer simply expand into new land, extract more water, or access cheap fertiliser and fuel without consequences.

This section outlines some of the major resource constraints that will affect Victorian food systems in coming years – most of which are already being seen now. Competition for, and constraints on, resources will all directly affect food availability and affordability.

How we respond to these now will vastly shape our options in the future. To develop a sustainable food system in the context of severe resource constraints, we need to act at three levels:

- Restore ecosystems – move towards food systems that restore and maintain the health of the ecosystems on which they depend;
- Reduce vulnerability to resource constraints (reduce reliance on scarce inputs and identify renewable / sustainable alternatives); and
- Develop innovative and resilient food systems that underpin both local food security and export potential

Four areas where constrained resources will affect the production and distribution of food explored below are:

- Water – declining supply and increasing competition
- Land – limited quantity (competing land uses) and quality (deterioration of soil quality in many agricultural systems)
- Oil, Biofuels and Agricultural inputs – increasing competition for non-renewable supplies and the effects on food of substitutes like biofuels
- Depleted Stocks (eg. Fish) – the focus of this report is mainly on agriculture, however the pressure on wild food resources (in particular fish) and the implications of increasing aquaculture are also briefly outlined.

2.2.1. Water

Summary and Recommendations:

Approximately 30% of Australia's water is used to grow food for domestic consumption.[201] Almost 50% of an Australian urban household's water use is through their food consumption, compared to 11% directly in showers, gardens and cleaning.[202] Water prices will grow significantly as demand grows and new supply systems are introduced (such as desalination). Food prices will rise correspondingly.

International demand for food (particularly meat and dairy) is continuing to increase, but water scarcity may restrict Victoria's ability to grow in response to this need. Approximately 40% of Victoria's harvested water is exported in food products – this constitutes about 25% of historic average streamflows (which are no longer being attained). Growth in exports will require a changed export mix, or would require all of our water by 2050.[203]

Some foods require much more water to produce than others. Victorian and Australian water production efficiencies are better than the international average, however we also have less water. Trade in water-intensive products between water rich and water scarce nations could improve global water efficiency, but would be complicated by oil and carbon constraints and the need to develop resilient systems.

Rain-fed agriculture is becoming increasingly difficult to manage and there is little scope to increase irrigation – many irrigation areas have now reached the limit of their supply and are not receiving their full water allocations. There are still significant gains to be made through improvements to irrigation systems (reducing losses) though some gains will lead to associated energy / emission costs.

Competition for water means that it will be increasingly used for 'high value' products (eg. wine, almonds and dairy) often for export. As Australian and Victorian producers struggle with water scarcity and increasing costs, cheaper imports from international markets are filling market niches for basic food products such as fruit and vegetables. Under current conditions and excessive debt many producers are ceasing production, but reduced domestic production capability could undermine future food security.

!	*Water scarcity will continue to place pressure on Victorian producers and drive up the cost of food. Some foods will become more expensive than others and this could affect access to a healthy diet.*[204]
!	*Structural adjustment in response to water pricing (eg. replacement of local essential food production with high-value export crops) could increase vulnerability to other risks such as transport disruptions or carbon pricing*
!	*Importing water-intensive products ('virtual water' trade) has some advantages, but so does retaining local food production (eg. security)*
!	*Improving water access or efficiency through irrigation or technological investment often has an*

201 Lenzen, M. and Foran, B. (2001), "An Input–Output Analysis of Australian Water Usage " *Water Policy*, no. 3: 321–40.
202 Lenzen, M. (2002), cited in Watermark Australia (2007), *Our Water Mark: Australian's Making a Difference in Water Reform*, The Victorian Women's Trust, Melbourne.
203 Muntisov, M. (2007), "Thinking About Virtual Water," *Water: Journal of the Australian Water Association*, Sept 2007, p5
204 Reidpath, D. et al. (2002) and Block, J.P., Scribner, R.A., and DeSalvo, K.B. (2004), cited in VicHealth (2005a), *Healthy Eating - Food Security: Investment Plan 2005 - 2010*, Victorian Health Promotion Foundation, p6

	energy / greenhouse (or other) implication. Carbon pricing will then affect the ongoing viability of these systems
!	*Strategies to improve efficiency of large irrigation systems (eg. maximise run-off and minimize evaporation and leakage) may conflict with strategies to prevent evaporation at the outset (eg. storage in soils and vegetation) and maximise production where this water is available*
	Explore the relationship between water pricing and nutritional value per litre - how can nutritional value from water and other scarce resources be maximised? Potential for analysis of L/$ to be extended to L per kj or other nutritional measure
	Improve understanding of the affects of water scarcity on food production, prices and security. Investigate the changing volumes of Victorian production, how much of this is exported and how this is impacting on changes in local prices
	Develop consumer information around embodied water in food choices through detailed lifecycle analysis of key food products (correct market failure and reduce reliance on cruder measures)
	Investigate the water efficiency potential of active soil management in Victorian soils, in conjunction with soil carbon sequestration and other productivity benefits
	Use of alternative water sources for food production – recycled water, greywater (research also required to ensure human and environmental safety). Increase production where these resources are most accessible
	Transition to less water intensive foods or production systems – focus on making use of water where it is available (including storage where it falls and water in and around cities)
	Accounting systems that can record water information for supply chain and consumer decision making – through global supply chains

Reduced water availability

Agricultural production and food availability are inextricably reliant on water supply. Increasing demand for water from urban and industrial users, combined with a likely decrease in supply will temper Victoria's ability to continually increase food production, regardless of high global demand.

In some sectors there is still debate about whether the current drought is just a continuation of an Australian weather pattern, or whether it is the beginning of a new set of, hotter and drier, conditions linked to climate change. To build a resilient agricultural sector and secure food supplies for the future, this debate is largely irrelevant. Our water availability is decreasing and local and global populations are increasing – unpredictable and increasingly contested water supply is now part of our operating conditions.

In 2004-05, Victorian agricultural industries made up 65.7% of the total Victorian Water consumption. Losses from irrigation and rural distribution make up another 13.3%.[205] Australian and Victorian agriculture has become increasingly reliant on irrigation, between 1990 and 2000 the Australian land area under irrigation increased by 30%.[206] Unpredictable weather conditions and changing rainfall patterns will make rain-fed systems increasingly difficult to manage, but there is limited scope to expand irrigation – many irrigation areas have now reached the limit of their supply sources and are operating well below their design allocation.

Significant investment is underway to improve Victoria's irrigation systems and infrastructure – these elements are well documented and discussed elsewhere. Gains can be made by improving the irrigation system as it is estimated that only 77% of diverted water actually reaches the customer – the rest is lost in seepage, evaporation or just not used.[207] The Government is investing in upgrading and improving irrigation systems to reduce this waste and some of the saved water will be available for agriculture (and some will be diverted to Melbourne).

[205] Taylor, M. (2008), *Victorian Agriculture, Forestry and Fishing Industries: At a Glance 2007 (Version 3.3)*, Department of Primary Industries, State of Victoria, p14
[206] Dunlop, M et al (2004), Environmental Sustainability Issues Analysis for Victoria: A Report Prepared for the Department of Sustainability and Environment, Victoria, CSIRO Sustainable Ecosystems, Canberra.p19
[207] Taylor, M. (2008), *Victorian Agriculture, Forestry and Fishing Industries: At a Glance 2007 (Version 3.3)*, Department of Primary Industries, State of Victoria, p14

Some Australian landholders have also developed innovative strategies and techniques to prevent of water evaporation at the outset (eg. storage in soils and vegetation) and maximise production where and when water is available. In many cases these activities can reduce reliance on external irrigation and help to 'drought-proof' farms. Some of these strategies are outlined in *3.2.1 Environmental Management*.

The broader implications of water shortages for food consumption and export (including food security and lifecycle impacts) and possible links to a wider range of opportunities are outlined below.

Reduced water supply means less, and more expensive, food

Our lack of rain has wiped out between 40 and 60 per cent of this season's wheat crop, irrigation channels lie empty and farmers are beginning to walk off the land.[208]

Australian agriculture has always been prone to drought, particularly due to the El Nino southern oscillation cycle and the 2006 drought, referred to as the worst drought in a century,[209] caused global wheat prices to soar to a ten-year high,[210] as Australia is the world's third highest wheat exporter.

The current reduction in water availability is directly affecting agricultural production. In 2005-06, Australian livestock production was negatively affected by dry conditions and the volume of beef cattle slaughtered was reduced by 5%.[211] Although all food prices have increased, water scarcity has (and will continue to) effect some sectors more than others because of the different amount of water used to produce different kinds of food. For example, over 50% of Victoria's agricultural water consumption is for dairy farming[212] and the price increase of dairy products (milk and cheese) has been the most significant (see *1.6.5 Prices*).[213] Global dairy prices and food-processing industries have both been affected[214] as the volume of milk produced across the country declined by 10%.[215]

In the Goulburn and Murray Valley regions in particular, water shortage combined with unseasonal frosts has affected fruit tree health and resilience.[216] The Murray-Darling basin typically accounts for 60 per cent of Australian-grown fruit, but in late 2007 the system did not have enough water available to keep the fruit trees alive (and certainly not producing) – some of the 150,000ha of citrus, apples, pears, apricots, plums, cherries, table grapes and winegrapes had to be allowed to die.[217,218] Some citrus growers were forced to put trees 'to sleep' or let less profitable trees die.[219]

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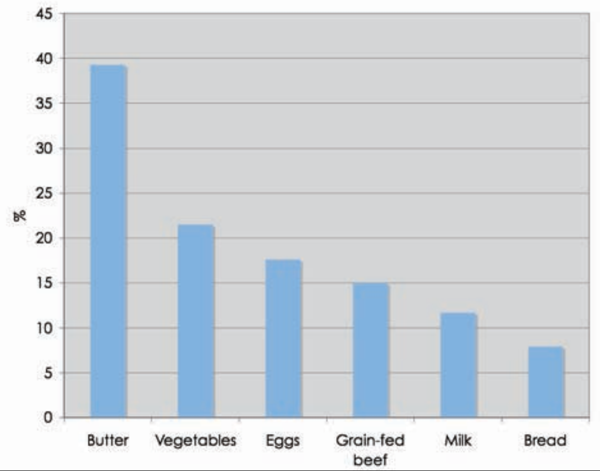
[208] Cornish, R. (2007), "Price Check", *The Age*, 20 November 2007, http://www.theage.com.au/news/epicure/bepicureb-the-only-way-is-up-why-our-food-is-getting-dearer/2007/11/19/1195321658883.html
[209] Patton, D. (2006), *Australian Drought Could Impact Dairy Prices*, Asia Pacific Food Technology, accessed 16 July 2007, http://www.ap-foodtechnology.com/news/ng.asp?n=71475-dairy-australian-grain
[210] Wilson, J. and Dreibus, T.C. (2006), *Commodities: Australia Drought Lifts Price of Wheat to 10-Year High*, International Herald Tribune, http://www.iht.com/articles/2006/10/11/bloomberg/bxcom.php.
[211] DAFF (2007), *Australian Food Statistics 2006*, Department of Agriculture Fisheries and Forestry, p19
[212] Taylor, M. (2008), *Victorian Agriculture, Forestry and Fishing Industries: At a Glance 2007 (Version 3.3)*, Department of Primary Industries, State of Victoria.
[213] This is also partially due to strong international demand for dairy – supply is lagging demand.
[214] Mortished, C. (2007), "Milk Price Soars as Drought Hits Dairy Industry", *The Times Online*, accessed 16 July 2007, http://business.timesonline.co.uk/tol/business/industry_sectors/consumer_goods/article1913132.ece
[215] Harley, M. (2007), "Responding to Market Challenges: Consumer, Customer, Regulation & Supply", paper presented at the *Future Foods for Future Health Conference*, July 2007, Melbourne.
[216] Stewart, M. (2007), "Impact of Climate on Current Price Volatility of Fruit and Vegetables", *Herald Sun*, Melbourne Market Authority, 13 July 2007.
[217] Wahlquist, A. (2007), "Drought, Oil Send Food Prices Souring", *The Australian*, 15 September 2007, http://www.theaustralian.news.com.au/story/0,25197,22419980-643,00.html
[218] Cornish, R. (2007), "Price Check", *The Age*, 20 November 2007, http://www.theage.com.au/news/epicure/bepicureb-the-only-way-is-up-why-our-food-is-getting-dearer/2007/11/19/1195321658883.html
[219] Ibid.

Figure 2.8 – Estimated Change in Food Prices[220]

(over 6-12 months to November 2007)



The effect of the drought on food prices received widespread media attention throughout 2007 and early 2008. The reported increases in food prices (attributed to the drought) are considerably higher than those measured by the ABS[221] (and discussed at *1.6.5 Prices*).

Grain prices have hit record levels (the cost of wheat for chicken feed has doubled from $280 a tonne to around $500 in six months),[222] and these prices are travelling through the feed chain – affecting prices of beef, dairy, pork, eggs and chicken -- and reaching consumers.[223] Price changes as reported in November 2007 are shown in Figure 2.8.

Drought is constraining production, while international demand (particularly for meat and dairy) is increasing. Victorian consumers are increasingly in competition with international markets for scarcer food and our local production capability is less reliable than it has been in the past.

Thinking about the system

There are systemic problems related to water use and food that cannot be solved simply by improving the performance of existing agricultural and irrigation systems. For example intense irrigation has contributed to general decline in soil structure through water-logging, along with salinity and reduced natural water flows (see *2.2.3 Land and Soil* and *2.3 Biodiversity*). Irrigation also affects the levels of greenhouse gas emissions and energy required to produce food. According to an RMIT/CSIRO study, the greenhouse gas emissions associated with irrigation are three times that for tractor use on typical farms and those produced by pumping irrigation water from deep bores is three times that of surface water irrigation.[224] CSIRO has also noted that current supply constraints are driving investment in more efficient and complex water delivery systems (such as micro-sprays), but that these also increase energy use and therefore emissions from fruit and vegetable production.[225] A resilient system cannot be developed though the optimisation of one resource without consideration of systemic impacts.[226]

It will also be important to consider the balance between water efficiency and resilience to unpredictable weather patterns under climate change. There are risks to an exclusive focus on resource efficiency at the expense of diverse or more 'shock-proof' systems – as has been seen under current drought conditions in Victoria's fruit-growing regions. As supply of irrigation water ceased in late 2007, it was noted that "many of the best operators, and the most innovative, will be the hardest hit. The most water efficient, computer-controlled method of growing fruit trees results in a dense root ball . . the intention is to reduce the amount of water it needs, but it means it has no deep tap roots so the moment irrigation goes off and there is no rain they will die in

220 Anecdotal reports from food industry interviews, Cornish, R. (2007), "Price Check", *The Age*, 20 November 2007,
221 (2007c), *Consumer Price Index, Australia, Dec 2007- Online Summary*, Cat. No. 6401.0, Australian Bureau of Statistics, Canberra
222 Cornish, R. (2007), "Price Check", *The Age*, 20 November 2007
223 Wahlquist, A. (2007), "Drought, Oil Send Food Prices Souring", *The Australian*, 15 September 2007
224 Grant, T., and Beer, T. (2006), "Life Cycle Assessment of Greenhouse Gas Emissions from Irrigated Maize: The Life- Cycle and Value Chain Analysis", paper presented at the *5th Australian Conference on Life Cycle Assessment*, 22-24 November 2006, Australian Life Cycle Assessment Society, Melbourne.
225 Foran, B., Lenzen, M., and Dey, C. (2005), *Balancing Act - A Triple Bottom Line Analysis of the Australian Economy*, CSIRO Sustainable Ecosystems, http://www.cse.csiro.au/research/balancingact/, p54
226 Walker, B., and Salt, D. (2006), *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*, CSIRO Sustainable Ecosystems, Island Press, USA.

about two weeks."[227]

We are already seeing local horticulture shortfalls being compensated for by increased imports from international markets (*1.6.1 Production*). As local producers struggle with drought conditions, even perishable food from overseas becomes competitive. In one way this increases the security of food supplies – enabling fresh produce to be available even when local conditions are difficult – but it also increases the energy intensity and greenhouse gas emissions ('food miles', packaging and storage) as discussed in *2.1.2 Energy, Greenhouse Emissions*. It may not be feasible to rely on imported food replacements permanently, particularly as both oil shortages and carbon pricing will affect transport and storage costs.

Biofuel production is also emerging as a competitor for water currently used to produce food – see *2.2.2 Oil, Biofuels and Agricultural Inputs*.

Embodied (Virtual) Water

The production of 1kg of beef requires an estimated 20,000 litres of water; 1 kg of wheat needs 1100 litres of water; and 1 litre of milk needs 800 litres of water.[228]

In debates around water use, behaviour change and the need to use water more efficiently, the fact that the vast majority of our water is used for agriculture (65.7% of Victoria's water)[229] is sometimes used to suggest that consumers and city dwellers are less responsible for high water consumption than farmers / irrigators. This overlooks the fact that this water is used to produce food – 30% of Australia's water use is devoted to food production for domestic consumption.[230] The largest impact that households have on water use is through the food they consume – almost 50% (1.5ML a year) – compared to only 11% directly consumed in showers, watering gardens and cleaning.[231] This finding was reinforced through an international water footprint study, which found that 56% of Australia's water footprint was due to 'agricultural goods'.[232] A recent Victorian analysis has found that Victorian's virtual water consumption in the form of dairy products exceeds total direct household consumption.[233]

Although it is difficult, and therefore contentious, to compare the embodied water of different products, as calculation methods and definition of system boundaries can vary (eg. whether natural rainfall is included as well as other managed water), reasonably robust analyses have been conducted to explore water intensity and embodied water in food products and sectors.

[227] Wahlquist, A. (2007), "Drought, Oil Send Food Prices Souring", *The Australian*, 15 September 2007, http://www.theaustralian.news.com.au/story/0,25197,22419980-643,00.html
[228] Jay, M. and Morad, M. (2006), "Ecological Modernisation and Global Trade in Virtual Water: The Geopolitics of the Water Footprint", paper presented at the *2006 Annual Meeting of the Agri-Food Research Network AGRI-FOOD XIII*, University of Otago, Dunedin.
[229] Taylor, M. (2008), *Victorian Agriculture, Forestry and Fishing Industries: At a Glance 2007 (Version 3.3)*, Department of Primary Industries, State of Victoria, p14
[230] Lenzen, M. and Foran, B. (2001), "An Input–Output Analysis of Australian Water Usage ", *Water Policy*, No. 3: 321–40.
[231] Lenzen, M. (2002), cited in Watermark Australia (2007), *Our Water Mark: Australian's Making a Difference in Water Reform*, The Victorian Women's Trust, Melbourne.
[232] Hoekstra, A. and Chapain, A. (2007), "Water Footprints of Nations: Water Use by People as a Function of Their Consumption Pattern", *Water Resource Management*, No. 21: 35-48, p42
[233] Muntisov, M. (2007), "Thinking About Virtual Water", *Water: Journal of the Australian Water Association*, Sept 2007, p5

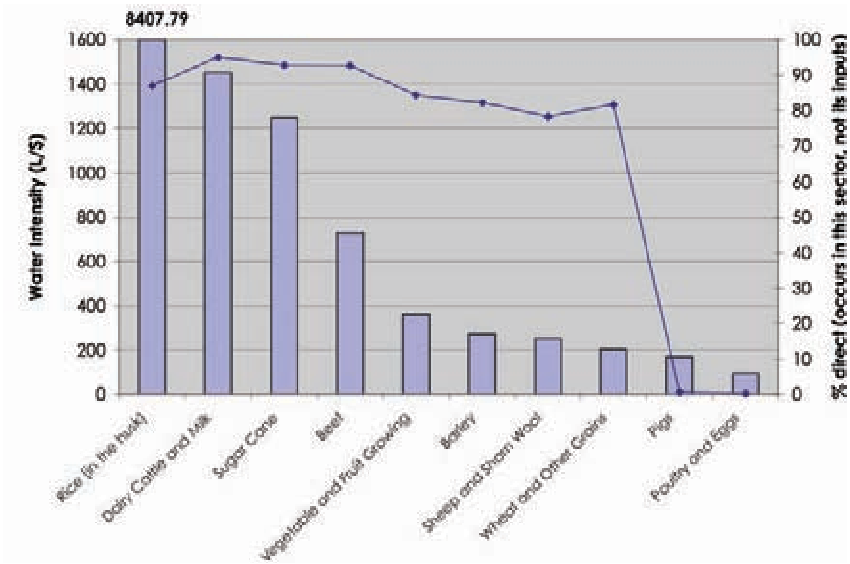
Table 2-1 – Global average virtual water content of selected products, per unit of product[234]

Product	Virtual water content (litres)
1 glass of beer (250 ml)	75
1 glass of milk (200 ml)	200
1 cup of coffee (125 ml)	140
1 cup of tea (250 ml)	35
1 slice of bread (30 g)	40
1 slice of bread (30 g) with cheese(10 g)	90
1 potato (100 g)	25
1 apple (100 g)	70
1 cotton T-shirt (250 g)	2000
1 sheet of A4-paper (80 g/m^2)	10
1 glass of wine (125 ml)	120
1 glass of apple juice (200 ml)	190
1 glass of orange juice (200 ml)	170
1 bag of potato crisps (200 g)	185
1 egg (40 g)	135
1 hamburger (150 g)	2400
1 tomato (70 g)	13
1 orange (100 g)	50
1 pair of shoes (bovine leather)	8000
1 microchip (2 g)	32

Global average virtual water content, per unit of product, of selected products evaluated by Hoekstra & Chapain. However, their research also reveals that, for most products (except wheat, soybeans, beef, pork and sheep), Australian production is more water efficient than the global average.[235] Therefore the figures for food produced in Australia would be expected to differ significantly.

In Australia, analyses of the value generated by water use have been conducted by the CSIRO and were published in the 2005 Balancing Act report. The water intensities (L of water used per dollar generated in the economy) of a number of different food sectors are shown in Figures 2.9 and 2.10.

Figure 2.9 – Water Intensity in Primary Food Production Sectors[236]



Pigs and Poultry/Eggs have a low percentage of the water intensity directly attributed because most of the water impact is through their inputs.

For pigs, the water use occurs through inputs of: dairy products, rice → flour and cereal foods, fruit & vegetable production, and sugar → other food products.

For poultry and eggs, the most signficant water inputs are beef cattle → meat products (28%) and sugar → other food products (25%).

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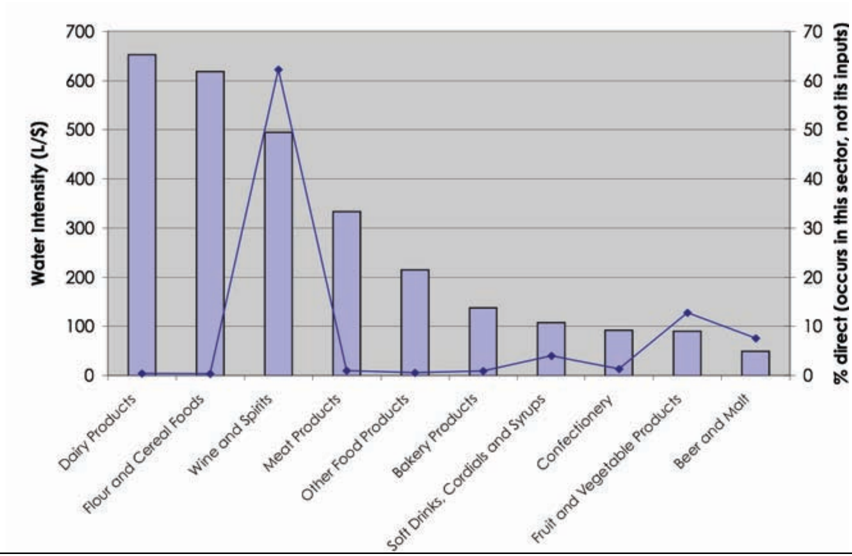
[234] Hoekstra, A. and Chapain, A. (2007), "Water Footprints of Nations: Water Use by People as a Function of Their Consumption Pattern", *Water Resource Management* 21: 35-48.
[235] Ibid, p40-41
[236] Foran, B., Lenzen, M., and Dey, C. (2005), *Balancing Act - A Triple Bottom Line Analysis of the Australian Economy*, CSIRO Sustainable Ecosystems, http://www.cse.csiro.au/research/balancingact/, p38&43

Figure 2.10 – Water Intensity in Secondary Food Production Sectors[237]



For value-adding food sectors, the water intensity is generally lower and most of the water intensity is at the production stage (rather than in processing).

Wine & spirits, beer & malt and fruit & vegetable processing are exceptions, indicating that a significant portion of the water is used in the processing stage for these products.

This data suggests that the embodied water of water-intensive food products is mostly in primary production itself. With some exceptions (fruit & vegetable processing and alcoholic beverages), water efficiency gains post-production will be minimal. Any limit to production water efficiency effectively sets the embodied water of the final food product.

It also shows the extent to which some foods are reliant on large amounts of water. As water scarcity becomes more clearly expressed in the cost of food increasing cost is likely to impact on what is eaten and when – this may already be affecting disadvantaged groups.

Caution is required in interpreting and using this data, particularly if extrapolating to Victorian circumstances, as some Victorian operations are more (or less) efficient than the National average.

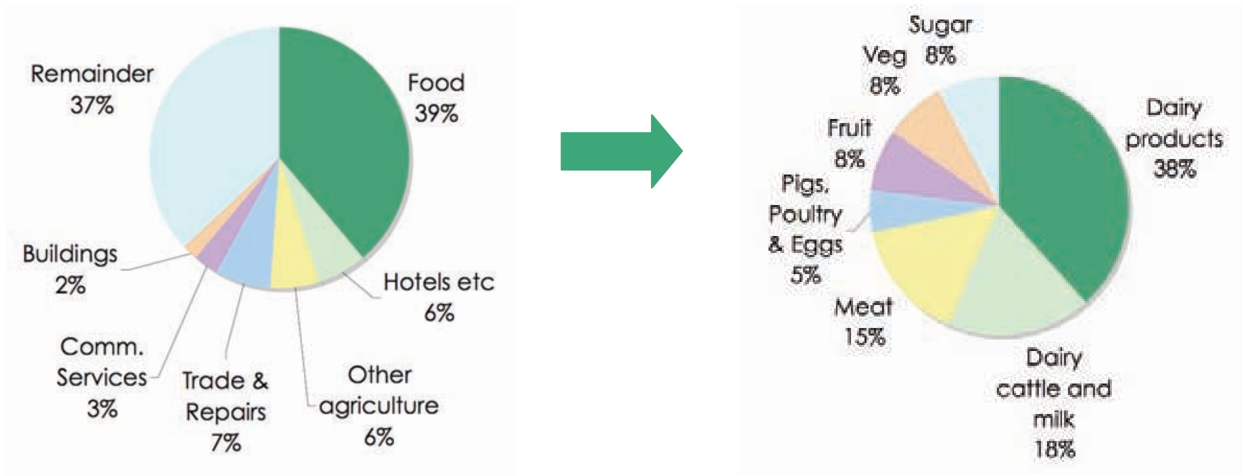
A Victorian analysis of virtual water (all the water embodied in good and services) has been carried out, which will provide more specific information for Victoria once it is released.[238] Preliminary findings include that the embodied water in red meat and dairy products consumed in Victoria makes up more than a quarter of total virtual water consumption – as shown in Figure 2.11.

Behavioural changes to dietary composition are already emerging as concerned individuals and communities attempt to reduce their environmental footprint. This is further discussed in *3.4.4 Choosing a Sustainable Diet*. Policy driven dietary changes (as have been attempted for health reasons) are difficult, but could be called for as environmental concern heightens.

[237] Foran, B., Lenzen, M., and Dey, C. (2005), *Balancing Act - A Triple Bottom Line Analysis of the Australian Economy*, CSIRO Sustainable Ecosystems, p38 & 43

[238] By GHD, funded by the Victorian Water Trust – due to be published in 2008

Figure 2.11 – Virtual Water in Victorian Final Demand[239]



Trading Virtual Water - what is a 'High-Value' water use?

Trade of real water between water-rich and water-poor regions is generally impossible due to the large distances and associated costs, but trade in water-intensive products (virtual water trade) is realistic. Virtual water trade could thus ideally be used to improve global water efficiency[240]

Input-output analysis of Australia's water use suggests that 30% is used for export-oriented food production.[241] When Australia exports agricultural products, we are said to also be exporting the amount of 'virtual water' required for the production of that product. As a water-scarce country, some would argue that Australia could actually be looking to save water by importing high water intense products rather than exporting them.[242]

Primarily through the export of food products, Victoria exports around 40% (2000 L) of our harvested water (which is currently around 25% of historical average streamflows). Under a business-as-usual scenario, with an unchanged export mix and approximate 3% pa growth, we would have to harvest 100% of streamflows by 2050.[243] Historic average streamflows are not the streamflows we are getting now, so this would actually happen earlier.

The trends outlined in Section 1 indicate a continuing increase in water-intensive food consumption worldwide, particularly increasing demand for meat and dairy in Asia. This, and demand for other high value crops such as grapes, olives, almonds, is likely to increase pressure on diminishing water resources in Victoria.

Although food production is intrinsically more water intensive than many other sectors of the economy, it is also essential for people to eat. Some current 'high-value' crops (those that return the best export dividend) are very water intensive (almonds are estimated to require an 6L per almond.)[244] Perhaps increasingly importantly, these products may not represent significant nutritional value per litre of water. As worldwide water and food pressures coincide with other resource constraints, we may need to reconsider what a 'high-value' crop is and challenge existing uses of scarce water resources. This may require "reviewing our export product mix,

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[239] Muntisov, M. (2007), "Thinking About Virtual Water", *Water: Journal of the Australian Water Association*, Sept 2007, p5
[240] Zimmer, D. and Renault, D. (2003), cited in Jay, M. and Morad, M. (2006), "Ecological Modernisation and Global Trade in Virtual Water: The Geopolitics of the Water Footprint", paper presented at the *2006 Annual Meeting of the Agri-Food Research Network AGRI-FOOD XIII*, University of Otago, Dunedin.
[241] Lenzen, M. and Foran, B. (2001), "An Input–Output Analysis of Australian Water Usage ", *Water Policy*, no. 3: 321–40.
[242] Jay, M. and Morad, M. (2006), "Ecological Modernisation and Global Trade in Virtual Water: The Geopolitics of the Water Footprint", paper presented at the *2006 Annual Meeting of the Agri-Food Research Network AGRI-FOOD XIII*, University of Otago, Dunedin
[243] Muntisov, M. (2007), "Thinking About Virtual Water", *Water: Journal of the Australian Water Association*, Sept 2007, p5
[244] Watermark Australia (2007), *Our Water Mark: Australian's Making a Difference in Water Reform*, The Victorian Women's Trust, Melbourne, p58

importing virtual water-rich products from water rich nations such as New Zealand, or moving water intensive industries to water-rich parts of Australia."[245] Simultaneously, the impacts of climate change, possible oil shortages and the need to reduce emissions could require an increased reliance on locally produced food. If local production of staple foods has become unviable because of competition for water, the lack of diverse products and production systems could significantly undermine future food security (see *3.2.2 Diversification*).

An emerging issue over coming years may be how to maximise nutritional value (and food security) from local water and energy inputs, while maintaining vital food supplies to the rest of the world.

A description of virtual water and water footprinting methods can be found in VIWA 2006.[246] The value and flaws of 'virtual water' analysis will be under increasing debate between different interest groups as consumer awareness of embodied water in food increases. Virtual water is not a flawless measure, but as with food miles, consumers and policy makers are likely to increasingly use it as a proxy measure until more detailed analyses are available. As discussed in *2.1.2* regarding greenhouse emissions, detailed lifecycle analysis of water use in food products is necessary to enable effective comparison and improvement.

Alternative Water Sources

To ease pressure on rivers and potable water supplies recycled water and greywater could potentially be used for food production. Water treatment facilities in some rural areas (eg. Gippsland and the Grampians) are already recycling 100% of their effluent for local agriculture.[247] Melbourne currently recycles 22.5% of its wastewater (for agricultural as well as other uses),[248] and Victoria's 448 GL/year of effluent[249] is potentially a very valuable resource for food production, although there are risks.

In 2005 the Department of Primary Industries launched a field-based research project to investigate the food safety and environmental impacts of vegetable crops irrigated with Class A reclaimed effluent water. They found that the recycled water was actually microbiologically cleaner than the river water, there was no heavy metal contamination in either the plants or soils irrigated with recycled water and pesticide contamination was below recommended levels. Although there was no increased development of disease or tendency towards post-harvest rots, the salt content of the recycled water was a significant problem – it dramatically reduced the yield of salt-sensitive crops such as lettuce (up to 60%) and increased soil salinity, unless irrigation and other management practices are optimal. In summary, salt (sodium) was the major problem (requiring specific research into management) and more extensive field trials were recommended, as two years was considered insufficient for full evaluation.[250]

Research is also underway into the impacts of greywater reuse for irrigation. Under current Victorian water restrictions, there has been a significant increase in the use of household greywater for irrigation in urban environments, including use on fruit trees and on vegetables (see also *3.4.4 Urban Agriculture*). Most of the concern regarding greywater reuse has been due to possible health risks from biological contaminants, and systems and advice have been configured to minimise these risks. However, research conducted in Victoria is now suggesting that there are also significant environmental risks and that cumulative damage may start becoming evident in coming years. The most significant concern is again salt (sodium) in wastewater. When saline

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[245] Muntisov, M. (2007), "Thinking About Virtual Water", *Water: Journal of the Australian Water Association*, September 2007
[246] Victorian Water Industry Association (2006), *Virtual Water: A Project of the Water Efficiency Task Group*, www.vicwater.org.au/uploads/Water%20Restrictions/Virtual%20Water%20Final.pdf.
[247] Melbourne Water (2008), *Recycling Water for a Greener Future*, accessed 15 March 2008, http://www.melbournewater.com.au/content/water_recycling/recycling_water_for_a_greener_future/recycling_water_for_a_greener_future.asp
[248] Rood, D. (2008), "Melbourne Hits Water Recycling Targets", *The Age*, 28 February 2008
[249] Radcliffe, J. (2004), "Water Recycling in Australia", *Australian Academy of Technological Sciences and Engineering*.
[250] Faggian, R., Barker-Reid, F., and Engleitner, S. (2007), *Recycled Water for Horticultural Irrigation: Final Report for Project 05197*, Department of Primary Industries, State of Victoria.

water is put on plants it can actually reduce their ability to take up water, exacerbate 'droughting' effects and eventually cause damage to the plant structures and death. The accumulation of salt, phosphorus and other contaminants can eventually damage or collapse the soil structure. Even low sodium and phosphorus laundry detergents typically have a very high pH (9-10), which can actually activate all the phosphorus in the soil causing toxicity in plants and possible run-off problems. Further research is required to understand these impacts and design greywater systems that deal with environmental as well as human health.[251,252]

2.2.2. Oil, Biofuels & Agricultural Inputs

Summary and Recommendations:

The implications of oil scarcity and price increases on Victorian food security are poorly understood. Oil underpins food security most obviously through transport through long supply chains, but also through agrochemical production and on-farm machinery in industrialised systems.

The international oil price increased by almost 400% between September 2003 and January 2008.[253] In Australia, this increase was moderated by a strong dollar but local prices are also increasing - petrol prices rose by 14.3% in 2007.[254] There are a number of contributing drivers to these price increases, but a slow-down in the growth of oil supply and concerns about 'peak oil' are part of increasing concern. Oil price increases have had repercussions throughout the food chain and, in combination with other costs (like water) and climate change impacts (like drought), are contributing to increased food prices (sometimes referred to as 'agflation'). If the gap between supply and demand for oil outpaces mobilisation of new fuel sources, fuel scarcity could severely jeopardise food security.

Concern about oil shortages is driving development of possible substitutes, including biofuels. Biofuel production presents another risk to food supply. In many countries, the growth of the market for biofuels is driving deforestation Biofuels are also directly competing with food production for land, water and agricultural inputs – and therefore contributing to increasing prices.

Increasing global demand for food, and the rapid move from food to biofuel crops in the US, has led to surging demand for agricultural inputs such as fertilisers and pesticides. This demand is outpacing supply (some of which is dependent on oil) and prices are increasing fast – key fertiliser products in Australia increased by about $200/tonne or 30% between 2006 and 2007.

Melbourne's layout (with car-dependent outer suburbs) will compound the impacts of oil price increases for those that have to drive to collect it, on top of the upstream costs (which will be embedded in the price).

!	*On-going access to oil or affordable substitutes cannot be assumed and it is likely that declining oil availability will continue to increase the costs of food, particularly foods which travel long distances. This complicates responses to the risks of climate change and water shortages*
!	*Increasing biofuel production can directly affect food production (and prices) through competition for land, water and agricultural inputs*
!	*Loss of peri-urban agricultural land to residential development is increasing transport distances and therefore reliance on oil for urban food supplies, affecting vulnerability and cost*
!	*The cost of driving to get food will increase food security concerns for vulnerable areas of Melbourne and regional / rural Victoria*
	Assessment of the Victorian food system's vulnerability to oil and input scarcity – how reliant is it? Where is substitution viable and where it is unlikely? Could significant production decreases or supply disruptions occur? Need to model possible price / adaptation scenarios
	Production methods and systems that are less reliant on oil, oil-based products (eg. chemical

[251] Lanfax (2007), *Laundry Products Research - Domestic Greywater*, accessed 10 December 2007, http://www.lanfaxlabs.com.au/

[252] Recommendations for greywater use include using shower water before laundry water, liquid rather than powdered laundry products.

[253] BBC (2007), *Oil Reaches New Record above $99*, accessed 15 January 2008, from http://news.bbc.co.uk/2/hi/business/7105044.stm

[254] Colebatch, T. (2008), "Inflation Shock Puts Pressure on Rates", *The Age*, accessed 23 January 2008, from http://www.theage.com.au/news/national/rates-tipped-to-rise/2008/01/23/1201024993875.html

	fertilisers and pesticides) and contested agricultural inputs
〃	*Alternative biofuel production that is not reliant on conventional inputs or large amounts of productive land (possibility of genetically modified crops or algae systems)*
〃	*Developing markets / making use of potential biofuel feedstocks that are currently going to waste (eg. lignocellulosic (wood))*[255]
〃	*Renewable / sustainable substitutes for petroleum-based agricultural inputs, including organic wastes*
〃	*Supply chains and distribution systems within cities – increasing production closer to consumption and/or innovations in food distribution and access*

The current food system is enabled by a reliable flow of cheap oil, both for production and for the transport of food back and forth across the world. Industrialised agriculture is reliant on agro-machinery and a number of oil-based chemical inputs such as fertilisers, pesticides and herbicides.

The standard crude oil price rose from less than US$25/barrel in September 2003, to over US$60 by August 2005, to above $75 in 2006. The price dropped in early 2007 but then escalated to $92/barrel by October 2007 and $99.29/barrel in New York on November 21, 2007.[256] On 3 January 2008, oil prices had an all-time peak at $100.05 per barrel.[257] At the time of going to print (April 2008) the international oil price had reached approx $110 per barrel[258] – there is no indication that this trend will turn around.

Fluctuating oil prices present major risks to global food security, especially in the most industrialised cities.[259]As the rising oil prices will raise costs across the food chain, it can be anticipated that this will, in turn, cause further increases in food prices – referred to as "agflation".

Australian oil prices may be somewhat insulated by the currently high value of the Australian dollar, but they are increasing – petrol prices rose by 14.3% in 2007.[260] There are a number of contributing drivers to these price increases, but it is possible (likely) that the slow-down in growth of oil supply is contributing.

Oil may be reaching – or have already reached – the peak of its production, known as "peak oil".[261] 'Peak oil' refers to the theory that global oil production will peak and then decline as extraction exceeds new discoveries. Global demand for oil is increasing rapidly, largely driven by growth in large developing countries like China and India. If / when production peaks, inability to meet demand would increase competition for the declining resource and drive up prices for remaining stocks. This could be contributing to the current escalation of oil prices.

It is important to consider the wide-ranging impacts of oil and other fossil fuel shortages to the food system, in conjunction with the other challenges. Solutions that assume continued access to oil for tractors, transportation, fertiliser and other chemicals will be increasingly challenged by decreased affordability and constrained access to the scarce oil.

The systemic impacts of oil shortages are often underestimated. Oil is the basis of (or closely linked to) a number of agricultural inputs as discussed below. Oil is also the basis of plastics used for much food packaging and many synthetic fabrics – oil shortages could drive a return to natural fibres with corresponding impacts for land and resource competition.

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255 Francis, P. (2008), personal communication from editor of the *Australian Farm Journal*, 13 March 2008.
256 BBC (2007), *Oil Reaches New Record above $99*, accessed 15 January 2008, http://news.bbc.co.uk/2/hi/business/7105044.stm
257 BBC (2008), *Single Trader Behind Oil Record*, accessed 15 January 2008, http://news.bbc.co.uk/1/hi/business/7169543.stm
258 Bloomberg (2008), *Bloomberg – Energy Prices*, accessed 11 April 2008, http://www.bloomberg.com/energy/
259 Heinberg, R. (2005), "Threats of Peak Oil to the Global Food Supply", paper presented at *What Will We Eat as the Oil Runs Out?* 23-25 June 2005, Feasta, Dublin, http://www.energybulletin.net/7088.html.
260 Colebatch, T. (2008), "Inflation Shock Puts Pressure on Rates", *The Age*, 23 January 2008, http://www.theage.com.au/news/national/rates-tipped-to-rise/2008/01/23/1201024993875.html
261 Campbell, C.J. *What Is Peak Oil*, Association for the Study of Peak Oil & Gas, accessed 16 July, 2007, http://www.peakoil.net

The extent to which the Victorian / Australian food system is reliant on oil does not seem to have been comprehensively analysed.

Efforts to reduce reliance on oil throughout the economy (particularly for transport systems) are creating pressure for an increased production of biofuels. Substitution of biofuels may alleviate pressure from the rate of oil depletion, but is having other impacts on the food system.

Biofuels

The working conditions in the plantations for cane sugar in Brazil and palm oil in Malaysia come close to slavery. The environmental side of things is not sparing either, with pollution of soil and water created by the production of biofuels, and a dramatic deforestation under way in Indonesia and Brazil.[262]

Growing concern about the convergence of climate change and peak oil has driven the search for new, more environmentally friendly, fuel sources. One of the early responders has been the ethanol / biofuel industry. The high demand for ethanol has doubled corn prices in places such as Mexico, and farmers are converting fields of food crops (Mexican beans, potatoes, rice, barley or agave (for tequila)) to more lucrative corn for fuel.[263] In other regions the same trend is occurring with soy crops and prices both increasing due to smaller supplies.[264] This is having severe implications for the price and availability of food worldwide.

The use of corn crops for producing biofuels may be seen as a threat to food production globally. In 2006, according to The Age, "ethanol consumed about a fifth of the US corn crop. By next year, ethanol could consume up to half of the crop, sparking a debate about food versus fuel."[265] Not only is biofuel production threatening food security by drawing directly from food crops, but with less grain available to meet the stockfeed demand it is also causing a rise in the price of meat, dairy and egg products.[266]

While there is no doubt that use of biofuels will play some role in the transition to a low-carbon transport system, biofuels are far from environmentally benign and do not represent a simple solution to either fuel shortages or greenhouse gas reductions. Their development and use must be managed carefully with consideration to full lifecycle environmental impacts. A 2007 OECD Report concluded "the potential of the current technologies of choice – ethanol and biodiesel – to deliver a major contribution to the energy demands of the transport sector without compromising food prices and the environment is very limited."[267] Current areas of concern environmentally include:[268]

- Tropical regions are the most efficient places to grow biomass feedstocks. This is currently driving massive land clearances (including large areas of forest and wetlands), removing habitat refuges for endangered species (such as orangutans) and releasing large amounts of carbon;
- Only three of the existing biofuel technologies[269] can substantially reduce greenhouse gas emissions compared with gasoline or mineral diesel – even without considering the emissions from forest clearing and other land use change;

[262] Emilie Pons, a researcher at Paris-based University Sciences Po, cited in Cronin, D (2007), *Report Challenges EU Subsidies for Biofuels*, InterPressNews, accessed 9 November 2007, http://ipsnews.net/news.asp?idnews=39515
[263] Llana, S.M. (2007), "Mexican Farmers Replace Tequila Plant with Corn", *Christian Science Monitor*, accessed 22 June 2007, http://www.csmonitor.com/2007/0621/p04s02-woam.html
[264] Coultan, M. (2007), "Bumper Corn Crop Fuels Us Energy Dilemma", *The Age*, 9 June 2007, p16
[265] Ibid.
[266] Ibid.
[267] Doornbosch, R. and Steenblik, R. (2007), "Biofuels: Is the Cure Worse Than the Disease?" paper presented at the *Round Table on Sustainable Development*, 11-12 September 2007, Organisation for Economic Co-operation and Development, Paris , p3
[268] Ibid, p4-5
[269] Sugarcane-to-ethanol in Brazil, ethanol produced as a by-product of cellulose production (as in Sweden and Switzerland), and manufacture of biodiesel from animal fats and used cooking oil.

- The overall environmental impacts can actually be greater than petrol or diesel when impacts such as soil acidification, greenhouse emissions (nitrous oxide) from fertilizer use, biodiversity loss and toxicity of agricultural pesticides are taken into account; and
- Many of the plants being explored as potential biofuels in Australia have the potential to be serious weeds and present significant risks if introduced.[270]

Biofuel production is also emerging as a competitor for water currently used to produce food. According to the International Water-Management Institute, at a global average, 1,000 - 4,000 litres of water are consumed in the production of one litre of biofuel.[271] Following release of their report *Biofuel Market Worldwide*, research group RNCOS asserts that "biofuel is not going to be environmentally sustainable until alternatives that require less use of water for feedstock are considered. Its time to question the biofuel production taking water concerns in the forefront."[272] As a water scarce country, it is crucial that both water and land issues are taken into account as well as the overall energy/greenhouse balance of biofuel production in Australia.

All of these issues are relevant to food, particularly where biofuels are proposed to replace oil based fuels to keep the current system operating. The agricultural inputs required to produce the biofuels are already competing with their use on food crops (as described above), and globally food production is being displaced as land is turned over to fuel crops.

Biofuel production in Victoria has the potential to provide new markets for farmers, however there are also new risks. The ability to use previously marginal land for some biofuel production could place it in competition with remnant native vegetation and have biodiversity consequences. Biofuel production will also be subject to the same environmental challenges as other agricultural activities, as outlined in this document – questions about agricultural inputs (fertilisers and chemicals), production methods, distribution, crop diversity etc will be as pertinent for biofuels as they are for other products.

Agricultural Inputs

Many agricultural inputs are sourced from non-renewable (and in some cases increasingly scarce) resources. For example, the most significant raw materials for fertilizer manufacture are hydrocarbon sources (mainly natural gas), sulfur, phosphate rock, potassium salts, micro-nutrients, water and air.[273] Oil is also an important input to the production of fertilisers and pesticides.[274]

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[270] Low, T. (2007), *The Weedy Truth About Biofuels*, Invasive Species Council, http://www.invasives.org.au/issues/biofuels.html
[271] De Fraiture, C. (2007), *Biofuel Crops Could Drain Developing World Dry*, Science and Development Network, accessed 19 July 2007, http://www.scidev.net/content/opinions/eng/biofuel-crops-could-drain-developing-world-dry.cfm
[272] RNCOS (2007), *Expanding Biofuels May Shrink Water Supplies in Developing Nations*, RNCOS, http://www.rncos.com/Press_Releases/Expanding-Biofuels-may-shrink-Water-Supplies-in-Developing-Nations.htm
[273] FIFA (2007a), *Fertilizer Production*, Fertilizer Industry Federation of Australia, http://www.fifa.asn.au/default.asp?V_DOC_ID=837
[274] The Paleontological Research Institution (2007), *Petroleum Education - Everyday Uses of Oil: Plant Fertilizer*, accessed 10 November 2007, http://www.priweb.org/ed/pgws/uses/fertilizer.html

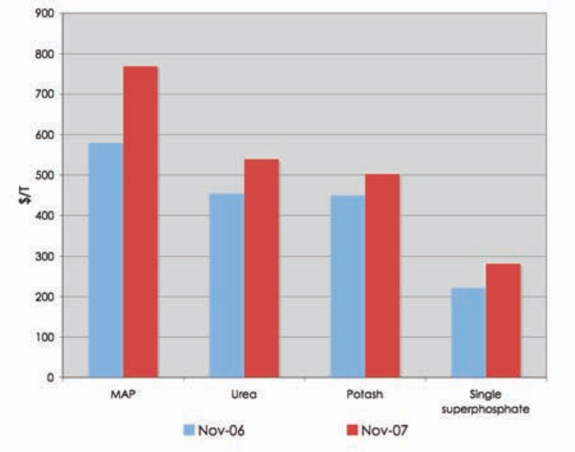
Figure 2.12 – Increasing Fertiliser Costs[275]

Global fertiliser prices increased 150% in 2007[276] and this is flowing in rapid increased in local prices – most key fertiliser products increased by about $200/tonne, or 30% between 2006 and 2007.[277]

This shift is the product of:

- Global demand for food supplies is increasing
- Demand for agricultural inputs is outstripping supply
- A rapid move from food to fuel crops (particularly in the USA) is requiring large amounts of fertiliser
- Shipping shortages.

Scarcity and increasing cost of oil supplies will further affect agricultural inputs, unless they can be supplied from sources other than oil.



Super-phosphate is an industrially processed form of phosphate rock, which is a mined resource. The global production of phosphate rock has already peaked and is falling – in 1988 166 million tonnes of phosphate rock was produced, but by February 2008 it was approximately 125 million tonnes per year.[278]

2.2.3. *Land and Soil*

Summary and Recommendations:

Land resources for food production are limited by the amount available (competing uses) and soil capability (how much it can produce). The amount of Victorian land used for agriculture is increasing, but this will be limited by changing water availability and competition with other uses – especially residential development and biofuels.

Housing availability and cost is currently an issue of great community concern and this is likely to maintain pressure for conversion of peri-urban agricultural land; about 3% of Melbourne's new housing is on previously agricultural land on the urban fringe.[279] Since 1945, the expansion of Australian cities has removed more than one million hectares of rural land. If current trends continue, by 2021 Melbourne will have lost another 25,000 hectares of rural land to urban development.[280] In the context of oil and other resource constraints, and global pressures on food supply, protection of peri-urban land explicitly for food production (particularly horticulture) will be required.

The productive capacity of existing agricultural land depends on the distribution, nature and condition of the soil; continuing decline in soil condition globally and in Victoria presents a major risk to food security.

The need to protect remnant native vegetation makes further land clearing untenable – continued food production will require active restoration of existing land.

Some land quality issues (eg. salinity, erosion and acidification) have been widely recognised. Others; such as structural decline (soil compaction), contamination (from chemical fertilisers, pesticides etc) and loss of biological life in soils, are emerging concerns about which less is known and even less is being done.

[275] Farm Online (2007), *Fertiliser Price Rise on Way*, sourced from Farm Weekly WA, accessed 14 November 2007, http://www.farmonline.com.au/news_daily.asp?ag_id=46887
[276] Business Spectator (2008), *Fertiliser Pain Grows*, sourced from the Weekly Times, 13 March 2008, http://www.businessspectator.com.au/bs.nsf/Article/Fertiliser-pain-grows-CNVW3?OpenDocument
[277] Farm Online (2007), *Fertiliser Price Rise on Way*, sourced from Farm Weekly WA
[278] NSW Farmers Association (2008), *Fertiliser Prices Factsheet*, accessed 10 April 2008, www.nswfarmers.org.au/__data/assets/pdf_file/0003/45732/Fertiliser_Prices_Factsheet_0208b.pdf
[279] DSE (2002), *Melbourne 2030 - Planning for Sustainable Growth*, Department of Infrastructure, State of Victoria,
[280]Buxton, M. and Goodman, R. (2002), *Maintaining Melbourne's Green Wedges: Planning Policy and the Future of Melbourne's Green Belt*, School of Social Science and Planning, RMIT University, p76

There are known techniques that can reduce agricultural impacts on land and soil (eg. minimum tillage, grazing management, perennial pastures) but the take up of these techniques varies widely. Increased consumer interest (locally and in export markets), and the potential to reduce input costs, are increasingly making these practices beneficial to producers (rather than a cost) – see *3.2.1 Environmental Management*.

The long-term impacts of agricultural chemicals on soil quality are only starting to be understood. For example, some studies have demonstrated that reducing / removing synthetic fertilisers and pesticides can improve soil organic matter (and carbon retention) at least as much (or more) than reduced tillage.[281,282]

Soil quality is affected by physical, chemical and biological factors, and different soil types and management practices dispose soils to different problems. Management requires integrated consideration of all three elements, in the context of particular soil conditions.

!	*Land area is finite and competition between food production and residential development on the urban fringe will intensify – there is a need to balance immediate development demands with longer-term food security (possible protection of horticultural zones)*
!	*Depleted soils that are heavily reliant on inputs for productivity will be less resilient to a changing climate and input shortages. Building healthy and resilient soils now can increase our ability to produce food in unpredictable conditions*
!	*The quality of land / soils is as important to food production as water supplies – attention to the root causes of land degradation, which includes some ongoing agricultural practices, will be necessary to reduce vulnerability to climate change and resource constraints*
!	*Many farmers recognise these issues and are improving / adapting where they can; communicating the outcomes of this experimentation will be critical to stimulating ongoing innovation*
!	*Innovations that overcome some land use problems can lead to other environmental impacts eg. raised-bed cropping making more land suitable has led to loss of some remnant grasslands*
!	*Improved land and soil management can have benefits for water use (greater retention in soils) and greenhouse emissions (carbon sequestration). Research specific to the Victorian context would help to fully capture the emerging opportunities.*
	There is a lack of statewide data on the actual state of soil health – little is known about the extent and spatial distribution of soil problems
	Long-term monitoring of soil health, including impacts of physical, chemical and biological management in specific types of Victorian condition, network of sites to enable controlled comparison of management practices
	Active soil management techniques designed to reduce input costs and increase productivity while improving land and soil quality
	Create supportive conditions for diverse innovation and experimentation across many landscapes eg. different farming systems, crops, scales of production
	Design of residential developments that make use of productive capability of the land on which they are being built (urban agriculture built in from the start)

Land Availability

The use of land resources for food production is limited by both the amount of land available (competing uses) and its condition (how much it can actually produce). Worldwide, the declining condition of agricultural land has often meant the need to expand into new territory with environmental affects such as the loss of biodiversity and release of sequestered carbon. In Australia there is now limited scope for expansion and agricultural land that is still potentially productive is being converted from agricultural use into other uses that are currently considered higher value (such as housing).

Urban sprawl can be considered a threat to food security in modern cities as it eats into valuable agricultural land

281 United States Department of Agriculture (2007), "Organic Farming Beats No-Till?" *ScienceDaily*, 24 July 2007, from http://www.sciencedaily.com/releases/2007/07/070722162434.htm

282 Khan, S. et al. (2007), cited in Science Daily (2007), "Nitrogen Fertilizers Deplete Soil Organic Carbon", *Science Daily*, accessed 30 October 2007, from http://www.sciencedaily.com/releases/2007/10/071029172809.htm

Melbourne was originally settled on a fertile plain and flourished from the productivity of the surrounding land. As Melbourne's suburbs expanded after the turn of the century, providing many families with a 'quarter acre' home and garden, this low-density urban sprawl began to eat into productive agricultural land. Buxton and Goodman (2002) state that "Australian cities have spread across more than one million hectares of rural land since 1945. On current trends, another 25,000 hectares of rural land will be lost to urban development in Melbourne by 2021."[283]

Since the 1960s, a policy has been in place to protect the 'Green Wedges' throughout peri-urban Melbourne,[284] not least to protect valuable agricultural land on the urban fringe – after the Goulburn-Broken region, the Port Phillip region is Victoria's most valuable agricultural area (the value per hectare is three times greater in Port Phillip).[285]

A 2005 study found that 25% of the $value of Australia's food – most of it for human consumption in Australia, is grown in the 'peri-urban' areas of our major cities and that parts of our metropolitan edges are generally our most intensively farmed land.[286] For Victoria, peri-urban agricultural land makes up 13% area but 25% of value. According to M2030, about 3% of new housing in the metropolitan area is on previously agricultural land on the urban fringes – this represents a significant loss of productive capacity.

There is little doubt that the competition between land for food production and new land for residential use will become a significant policy issue, particularly as housing costs and availability are currently issues of great community concern.

The urban development of land around the edges of cities, displacing food production, increases food transport distances to city markets. While the economic value of the land may currently be higher for housing development than agricultural production, the policy challenges identified in this report may change this value proposition as transport distances and emissions profiles affect food prices and availability. ***Developing good agricultural land for housing development now may present significant challenges to future urban food supplies.***

In 2006, the Australian Government conducted an inquiry into Australia's future oil supply and alternative transport fuels. A number of submissions highlighted the potential impacts on agriculture and urban food supplies, and recommended that:

> *The Australian Government needs to bring to the attention of state and local governments the importance of preserving horticultural land close to urban centres, so that transport costs of horticultural produce are reduced*[287]
>
> *One of the ways we can do this in Australian cities is to establish **Horticultural Precincts** immediately adjacent to our cities. These areas need to set aside the good soils and ensure they are retained in perpetuity for horticulture*[288]

Land Quality - Soil

Despite our best management efforts, land degradation persists and, in many places, is worsening. In environmental and economic terms, the impact is profound.[289]

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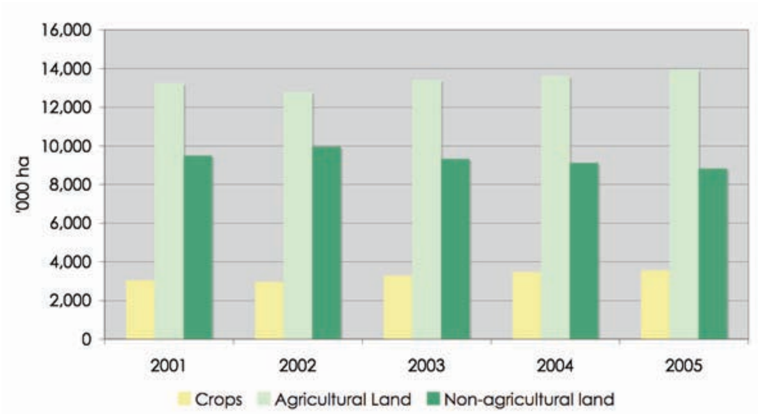
[283] Buxton, M. and Goodman, R. (2002), *Maintaining Melbourne's Green Wedges: Planning Policy and the Future of Melbourne's Green Belt*, School of Social Science and Planning, RMIT University, p76
[284] Ibid.
[285] Ibid, p76
[286] Budge, T. (2007), "Securing Our Future Food - Integrating Metropolitan, Economic and Land Use Strategies", paper presented at *Future Foods for Future Health Conference*, 25-26 July 2007, Planning Institute of Australia, Melbourne.
[287] Bennett, D. (2006), *Submission 49 - to the Inquiry into Australia's Future Oil Supply and Alternative Transport Fuels*, Australian Association for the Study of Peak Oil & Gas, accessed 20 November 2007, http://www.aph.gov.au/senate/committee/rrat_ctte/oil_supply/submissions/sub49.pdf
[288] Newman, P. (2006), *Submission 11 - after Peak Oil: Will Our Cities and Regions Collapse? Inquiry into Australia's Future Oil Supply and Alternative Transport Fuels, Agriculture, Fisheries and Food Working Group*, Murdoch University, accessed 15 November 2007, http://www.aph.gov.au/senate/committee/rrat_ctte/oil_supply/submissions/sub11.pdf.
[289] VCMC (2007), *Catchment Condition Report 2007*, Victorian Catchment Management Council, State of Victoria, p44

Land degradation diminishes productive capacity all over the world. According to Wood et al., one third of the world's cropland has been abandoned because of soil erosion and degradation within the last 40 years.[290] As most nations have already undergone major agricultural development, there is less and less 'undegraded' land to move to as existing land is used up and becomes less and less productive. Further land clearing for agriculture cannot be sustained – uncleared land must be maintained for other environmental reasons ie. to protect remnant biodiversity and prevent greenhouse emissions (see *2.3 Biodiversity* and *2.1.2 Energy, Greenhouse Emissions etc*).

Figure 2.13 – Victorian Land Use to 2005[291]

The ABS estimates that 13.9 million hectares or 61% of Victoria's land area was used for agricultural activity in 2004-05, with just over one quarter of this used for cropping.[292] In the years between 2000 and 2005 the amount of land used for agriculture, and the proportion of this used for cropping, have both increased (Figure 2.13).



The productivity of land is primarily affected by the soil – its distribution, type (suitability to purpose) and condition (level of degradation). Unhealthy and degraded soils are affected by physical, chemical and biological imbalances, which can cause a range of conditions. The most common types and impacts of land degradation, and their estimated scale in Victoria / Australia, are outlined in Table 2.2.

Table 2-2: Land & Soil Quality Conditions

	Impact	Extent	Cause
Salinity	Excessive water drainage from the root system, ground water level rises and mobilises salts stored in the landscape affecting plant growth. In current drought conditions the lack of water has meant that salinity is not as apparent.	Up to 3.1 million hectares of Victoria could be at risk of dryland salinity by 2050.[293] Estimated that some catchments affected by dryland salinity will require over 60% of the land to be revegetated.[294] Irrigation salinity can be ameliorated through changes to irrigation practice and land use	Clearing of deep-rooted native vegetation (replaced with shallow-rooted vegetation, excessive irrigation.
Sodicity	Sodium attached to clay particles in the soil affects the soil structure. Causes waterlogging, increased runoff and poor water storage, crusting, poor crop emergence, problems with	About 30% of Australia's agricultural soils are sodic (five times as much as is saline)[295]	Leaching of salt down through the soil, may be exacerbated by irrigation with saline water (eg. bore water), gradual affect from sea winds and rainfall

[290] Wood, R. et al. (2006), "A Comparative Study of Some Environmental Impacts of Conventional and Organic Farming in Australia", *Agricultural Systems,* vol. 89, no. 2-3: 324-48, p325
[291] Ibid.
[292] ABS (2006a), *Agricultural State Profile, Victoria, 2004-05,* Cat. No. 7123.2.55.001, Australian Bureau of Statistics, Canberra.
[293] VCMC (2007), *Catchment Condition Report 2007*, Victorian Catchment Management Council, State of Victoria, p136
[294] DSE (2005), *Victorian Landscapes: Condition and Emerging Directions for Natural Resource Management*, Land and Catchments Division, Department of Sustainability and Environment, State of Victoria.
[295] Rengasamy, P. and Walters, L. (1994), *Introduction to Soil Sodicity - Technical Note 1*, Cooperative Research Centre for Soil and Land Management, Adelaide, http://www.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/sodic_soils.

	cultivation and erosion.		
Acidification	As acidity increases, some soils release manganese and aluminium in quantities toxic to plants, and may restrict the availability of trace elements vital to plant growth. NB. Some elements such as Boron become toxic when the soil is alkaline – soil pH is important to nutrition	For Victoria, 4-5 million hectares of agricultural topsoil is strongly acidic and a further 2-3 million hectares are moderately acidic. Estimated loss of agricultural production valued at $470 million annually.[296]	Naturally occurs in rainfall areas >500mm/year. Increasing acidification is occurring in <500mm rainfall zones due to the use of fertilisers and some pastures. Exacerbated by agricultural practices such as consistent biomass removal and poor biomass cycling (resulting from annual cropping).[297]
Erosion	Loss or removal of top-soil (which contains the organic matter that plants need for growth and those soil organisms that decompose waste).		Clearing of native vegetation, inappropriate ploughing, fallowing and cropping and overgrazing – all of which lead to increased surface water run-off and/or wind exposure.
Soil structure decline (compaction)	Poor water infiltration, water logging, soil biodiversity loss, poor nutrient holding and uptake	UNKNOWN (?)	Sodicity (as above), heavy machinery use, hoofed animals, over stocking
Contamination	Little is understood about the long-term soil viability impacts of fertiliser, pesticide and herbicide use	UNKNOWN (?) The use of farm chemicals and fertilisers increased between 1990 and 2000. Sales of farm chemicals such as herbicides and insecticides more than doubled. The amount of phosphorus use more than doubled, while nitrogen use more than tripled.[298]	Use of chemicals and fertilisers that either cannot be taken up by the plant (excessive amounts remain in soil or runoff) or remain in the soil
Nutrient depletion	Depletion of trace nutrients in soils such as sulphur, iron, boron, manganese, molybdenum, copper and zinc. Shortages of any plant nutrient leads to reduced yield, increased susceptibility to pests and disease, and eventually lower nutrient content in the food produced.[299]	UNKNOWN (?)	Intensive agricultural monocultures that grow the same crops in the same soil thus depleting the minerals that crop requires. Use of fertilisers that only include N, P & K mean that trace elements are never replaced.

These conditions generally become evident through degradation of the topsoil. However, there is also an emerging understanding of the need to consider subsoil type and condition in assessing soil health and agricultural suitability.[300]

Agricultural Techniques and Land / Soil Degradation

In the 2007 Catchment Condition Report, the VCMC noted the continued validity of their 2002 observation "from the indicators we can ascertain a weakness in the area of soil and soil

[296] Environment and Natural Resources Committee (ENRC) (2004), cited in VCMC (2007), *Catchment Condition Report 2007*, Victorian Catchment Management Council, State of Victoria, p44
[297] DSE (2005), *Victorian Landscapes: Condition and Emerging Directions for Natural Resource Management*, Land and Catchments Division, Department of Sustainability and Environment, State of Victoria, p18
[298] ABS (2003a), *Australia's Environment: Issues and Trends,* Cat. No. 4613.0, Australian Bureau of Statistics, Canberra, p31
[299] Bender, A.E. and Bender, D.A. (1995), "Food and the Environment", *Environmental Management and Health,* Vol. 6, no. 3: 4-6, p4
[300] DPI (2006b), *Subsoil Constraints to Cropping in the High Rainfall Zone of South East Australia: A Scoping Study,* Final Report for Grains Research and Development Corporation Project - Dav00056, Department of Primary Industries, State of Victoria.

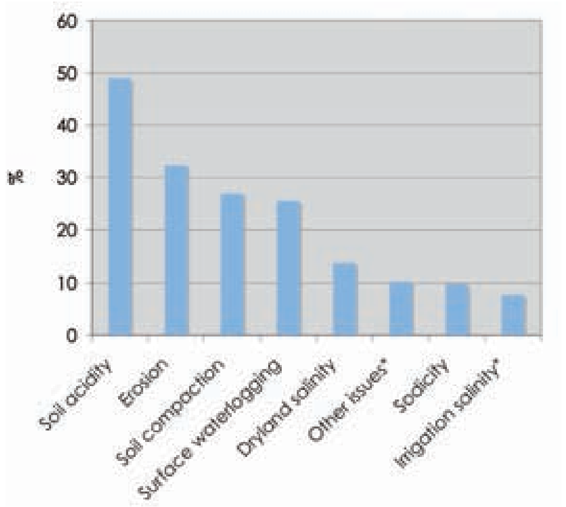
management. The future for our soils does not look optimistic and this needs to be addressed at a statewide level. Over half of the world's biomass is found underground. From a biodiversity and agricultural production perspective soil health is fundamental".[301]

Replacement of native vegetation with shallow rooted pastures and crops since European settlement of Victoria was the initial trigger of the most problematic forms of land degradation. However, these initial impacts have been exacerbated through intensified production – many of the techniques that enabled past productivity increases have degraded land and soil and therefore created the conditions now threatening resilience and productivity.

Agricultural techniques that have increased productivity but also exacerbated land degradation include monoculture farming, intensive chemical use and use of heavy machinery. Cropping practices that have contributed to land degradation include: intensive cultivation of soil before sowing, fallowing (leaving fields bare between crops) and stubble burning (to remove crop remnant).[302]

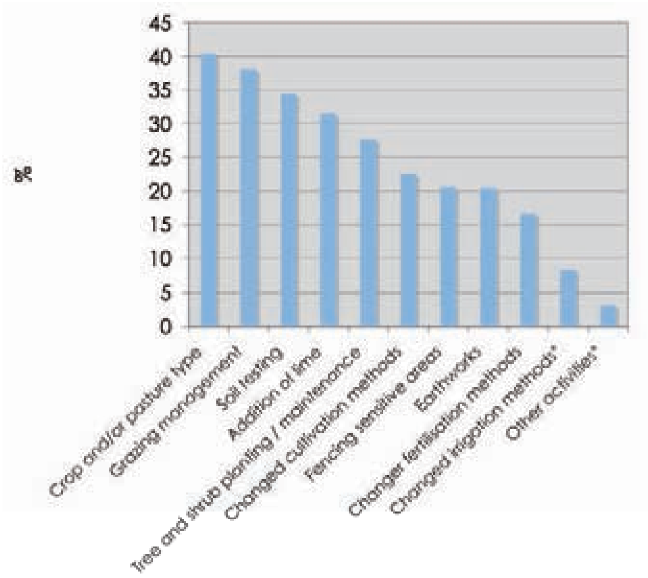
Some of these effects are well understood and attempts are being made to actively manage their impacts while maintaining production levels. The ABS estimates that main activities undertaken in relation to preventing and/or managing land and soil issues were management of crop and/or pasture type and grazing management (Figures 2.14 and 2.15).

Figure 2.14 – Proportion of Victorian Establishments Reporting Land and Soil Issues[303]



* Estimate has a relative standard error up to 25% and should be used with caution.

Figure 2.15 – Proportion of Victorian Establishments Reporting Land and Soil Activities[304]
(of those reporting issues)



In Victoria, land degradation issues on cropland are primarily managed through improved tillage methods (reduce compaction and soil structural breakdown), reducing the level of fallow between crops (to prevent erosion) and improved stubble management (to increase the amount of organic material put back into the soil) – the use of these techniques is known as 'conservation cropping'. Despite improvements in take-up of these techniques, it is estimated that conventional

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301 VCMC (2002), cited in VCMC (2007), *Catchment Condition Report 2007*, Victorian Catchment Management Council, State of Victoria, p22

302 Victorian Resources Online (2008), *Adoption of Best Management Practices*, Department of Primary Industries, http://www.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/landuse-best_management

303 ABS (2006a), *Agricultural State Profile, Victoria 2004-05*, Cat. No. 7123.2.55.001, Australian Bureau of Statistics, Canberra, p24

304 ABS (2006b), *Natural Resource Management on Australian Farms 2004-05*, Cat. No 4620.0, Australian Bureau of Statistics, Canberra, p24

tillage is still the dominant method in Victoria (50% in 1996/97) and levels of stubble retention and fallow fluctuate.[305]

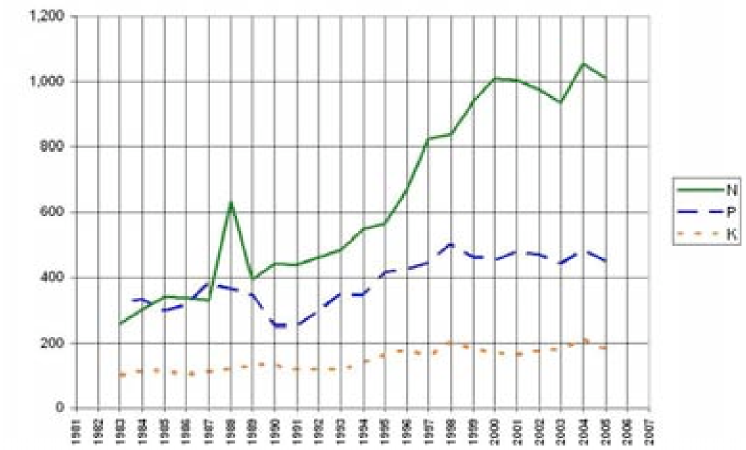
Re-introduction of deep-rooted perennial pastures (including some natives) on agricultural land can help to control land degradation (including salinity, acidification and erosion) as it is closer to the original vegetation of woodlands and native perennial grasslands. The Victorian Department of Primary Industries reports that the adoption of improved pasture management has generally been lower than desirable, although there was an increase in 2005/06 of 2.4% perennial pasture and 0.6% lucerne resowing rates and there was a large drop in fertiliser use on pasture between 1990 and 1995.[306] The existing data suggests that resowing rates are tightly linked to the wool price – if the wool price is good farmers can afford to invest in 'environmental' management.

These problems are widespread and as well as affecting the environment and productivity, they are also costing farmers large amounts of money and time for management.[307] As seen with wool prices and pasture resowing, time and money limit the extent to which farmers can manage their land and soil problems – the maximum proportion of farmers using any of the management techniques listed above is 40%, which suggests a large gap between identification of problems and active management. It is likely that under current stress levels, farmers are less able to prioritise land and soil protection, unless methods can be found that actually increase productivity, viability and/or reduce input costs.

Chemical Use

In the 1940s it was discovered that soluble acidic-based N-P-K fertilisers could stimulate plant growth. This discovery led to the widespread development and marketing of industrially processed fertilisers from mineral deposits. These and other chemicals (pesticides etc) were the basis of the 'green revolution' and chemical fertiliser use has continued increasing rapidly (see *2.2.2 Oil, Biofuels and Agricultural Inputs* for a discussion of the constraints to further increases).

Figure 2.16 – Nutrient Inputs to Australian Agriculture (kT per element)[308]



The full impacts of chemical fertiliser (and other chemical use) on land and soil are poorly understood and are not yet identified by the ABS as land / soil problems. Excessive use of agricultural chemicals may cause / contribute to soil contamination, nutrient depletion, loss of

[305] Victorian Resources Online (2008), *Adoption of Best Management Practices,* Department of Primary Industries, http://www.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/landuse-best_management
[306] Ibid.
[307] ABS (2006b), *Natural Resource Management on Australian Farms 2004-05*, Cat. No. 4620.0, Australian Bureau of Statistics, Canberra
[308] FIFA (2007a), *Industry Statistics*, Fertilizer Industry Federation of Australia, http://www.fifa.asn.au/default.asp?V_DOC_ID=876.

organic matter (and therefore soil carbon) and loss of soil biodiversity. Continued use of fertilisers in the absence of adequate humic substance in the soil is now also believed to contribute to soil acidity, weed invasion and rising saline water tables.[309]

Changing the use of agricultural chemicals may have more affect on some soil conditions than changing tillage methods.

A long-term field trial in the USA (1994 – 2002) found that the improvement in soil organic matter was greater under light-tillage organic corn, soybean and wheat than the same crops grown with no-till plus pesticides and synthetic fertilizers.[310] In a follow-up study, in which corn was grown with no-till practices on all plots, the organic plots were found to have more carbon and nitrogen and yield 18 percent more corn than the other plots.

Soil carbon sequestration is receiving increasing attention as the need to reverse carbon dioxide in the atmosphere intensifies (see *2.1.2 Energy, Greenhouse Emissions etc*). A recent study at the University of Illinois, which reviewed soil sample analyses from over 100 years and a wide variety of cropping and tillage practices, found consistent evidence of organic carbon decline in soils which have received nitrogen fertiliser. This finding was consistent throughout the world and including much of the USA corn-belt.[311]

Different methods will change the balance between improvement of soil structure and of soil organic matter – these both need to be considered.

Opportunities

Significant research has taken place into new approaches to deal with and minimise impacts of chemical use and soil-carbon loss, including extensive research in Victoria. An example of a successful innovation has been the development of raised bed cropping practices to reduce the risks of water logging and soil compaction, particularly in those areas with high rainfall. This has enabled cropping of paddocks that were previously unviable. However, caution must be taken with innovations that actually open up new land (rather than repairing existing degraded land) as this can impact on native biodiversity (*2.3.1*).[312]

Active soil management attempts to build living soils (ie. build up living and organic matter in the soil) as the basis for more resilient crops and reduced input requirements. Taking a strongly empirical approach to understanding the local make-up and condition of the soil, these techniques then balance physical, chemical and biological elements to balance the soil for maximum health and productivity. Once the soil is balanced, including strong thriving biological matter, it becomes resistant to change and, being resilient, is able to recover from disturbances caused by extremes in weather or management. Such soils will remain more productive with climate change as living soil organisms can adapt. Victorian producers are beginning to experiment with more active soil management in lieu of or in combination with reduced chemical inputs in an attempt to reduce input costs, and increase the resilience and adaptability of their farms. It should be noted that these techniques can often be used alongside and within existing agricultural systems, enabled a staged / gradual reduction in dependence on expensive and scarce inputs. Further information on active soil management, including drivers and some of the techniques being used are outlined in *3.2.1 New Production Strategies*. Carbon-rich organic matter in healthy, productive soils can sequester carbon and has benefits for productivity – see also *2.1.2 (Soil Carbon)*.

[309] Petit, R. (2007), *Organic Matter, Humus, Humate, Humic Acid, Fulvic Acid, and Humin: Their Importance in Soil Fertility and Plant Health*, CTI Research, Texas A&M University, http://www.humate.info/.
[310] United States Department of Agriculture (2007), "Organic Farming Beats No-Till?" *ScienceDaily*, accessed 24 July 2007, http://www.sciencedaily.com/releases/2007/07/070722162434.htm
[311] Khan, S. et al. (2007), cited on Science Daily (2007), "Nitrogen Fertilizers Deplete Soil Organic Carbon", *Science Daily*, accessed 30 October 2007, from http://www.sciencedaily.com/releases/2007/10/071029172809.htm
[312] Crosthwaite, J. et al. (2004), *Mega-Drivers of Broadacre Cropping - Background Report No. 1*, Drivers of Land Use Change project (Driver Research Phase), Department of Sustainability and Environment, State of Victoria.

2.2.4. Depleted Stocks (eg. Fish)

Summary and Recommendations:

Fish are a renewable resource but when the rate of fishing exceeds the rate at which they reproduce, populations decline and can eventually collapse. 76% of the world's fisheries are fully or overexploited,[313] and catch records from 1950 to 2000 show that 366 out of 1,519 fisheries worldwide (approx. 25%) have collapsed.[314]

No Australian managed fisheries are currently classed as 'overfished', however at least 20% of the species that are fished in Australia are. It is also likely that fish imported to Australia is from depleted stocks.[315]

Fishing has other environmental impacts (such as damage to marine ecosystems) and is affected by other issues outlined above (eg. oil constraints).

Aquaculture (fish farming) is increasingly providing an alternative source of fish and could potentially alleviate pressure on wild stocks. However, it also has environmental impacts and some systems are much more sustainable than others.

Integration of aquaculture with horiculture (aquaponics) makes use of the nutrients fish excrete to grow food and can be a very efficient mixed production system

Traditionally fish for food supplies have been sourced from wild fish stocks. When fish are removed at a greater rate than they can breed the overall fish stocks decline – called 'overfishing'. When overfishing continues for long periods of time it can lead to population collapse. This has already occurred in approximately 25% of the world's fisheries and 76% are considered fully or overexploited.[316]

Overview of production and consumption of fish and seafood in Victoria

Victorian fisheries production totalled an estimated 8,194 tonnes and $97,607 in 2005-06, with over half of this by price being abalone. Victoria is also a major producer of rock lobster and farmed trout. The value of Victorian fisheries production dropped 11% between 2005-2005 and 2005-2006, due to a decrease in the amount of abalone caught in the wild. The value of aquaculture production (which makes up about 20% of the industry by price) also fell.[317] Nationally, the fishing industry has been negatively impacted by a range of factors:

> *"Fishing effort and catches have been influenced by cost increases, particularly fuel prices, which have reduced profit margins for operators. Many fisheries have also been affected by reductions in total allowable catches, changes to access arrangements and more restrictive input controls. The appreciation of the Australian dollar since 2002-03 has simultaneously made exports less competitive and imports more attractive to consumers. In real terms (2005-06 dollars) the value of Australian fisheries production has been declining since 1999-2000."*[318]

Environmental impacts and constraints of the fish and seafood industry

Overfishing

In 2006, significant catches were made for 97 different stocks, species or groups of species, in

[313] Worldwatch Institute (2008), *Oceans in Peril: Protecting Marine Biodiversity,* prepared by the Greenpeace Science Team, Exeter University, UK
[314] Greenpeace International (2007), *Worldwatch Report: Oceans in Peril*, from http://www.greenpeace.org/international/news/world-watch-report-190907
[315] Larcombe, J. and McLoughlin, K., eds, (2007), *Fishery Status Reports 2006: Status of Fish Stocks Managed by the Australian Government*, Bureau of Rural Sciences, Canberra, pp195–203
[316] Worldwatch Institute (2008), *Oceans in Peril: Protecting Marine Biodiversity,* prepared by the Greenpeace Science Team, Exeter University, UK.
[317] ABARE (2007), *Australian Fisheries Statistics 2006*, Australian Bureau of Agriculture and Resource Economics, Canberra,
[318] Ibid.

fisheries managed by the Australian Government. Of these, 27 were not overfished, 51 were classified as uncertain, while 19 were classified as either already overfished or becoming overfished in 2006. While Australia itself is not currently overfishing – no stocks managed solely by the Australian Government were considered subject to overfishing,[319] Australia potentially consumes fish fished from depleted stocks elsewhere.

Damage to other species

Fishing tends to involve "bycatch" – the catching of other species of fish and animals besides the target species. Some is kept but "often a large portion" is dumped at sea, when it is already dead or dying.[320] Globally, it is estimated that at least 10 million metric tons per year of animals are discarded, and this figure underestimates the number of marine mammals, turtles and seabirds.[321]

Damage to habitat

Some fishing practices damage habitat, most notably bottom trawling, and conservationists have called for it to be banned.[322] Prawn trawling in the Great Barrier Reef Marine Park can remove 5-25% of the bottom-dwelling organisms in a single trawl, and causes cumulative damage.[323]

Environmental constraints

The fishing industry (in both river and ocean habitats) is also affected by environmental problems with other causes. Pollution from households and industry, including runoff and dumping, affects habitats and fish stocks. For example, reduced numbers of shark pups off eastern Tasmania and central Victoria in the early '90s relative to the '50s is believed to be partly due to pollution and environmental degradation from urbanisation of these areas.[324] While overfishing is an issue for marine fish, habitat loss and environmental degradation are the main threats to fresh water fish.[325]

Aquaculture

Aquaculture is a rapidly growing source of the fish consumed and may alleviate pressure on wild fish stocks. There were 110 licensed aquaculture farmers in Victoria in 2004 producing 20 different species – primarily rainbow trout and mussels.[326] However, it can also have significant environmental impacts.

Aquaculture can cause water pollution from fish urine and faeces, chemicals, antibiotics and vaccines. In addition, the Australian Marine Conservation Society claims that "less than 30 per cent of the protein in aquaculture feed is retained by the species farmed; the rest is either excreted or not eaten."[327] Management of fish numbers, reduction of excess feeding, use of quality fish food, well designed culture systems, biofiltration systems and the collection of solids (for example through settlement ponds) can significantly reduce release of nutrients and suspended solids. Combinations of these techniques have reduced suspended solids by 60 percent in some

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319 Larcombe, J. and McLoughlin, K., eds, (2007), *Fishery Status Reports 2006: Status of Fish Stocks Managed by the Australian Government*, Bureau of Rural Sciences, Canberra, pp195–203

320 Kura, Y. et al. (2004), *Fishing for Answers: Making Sense of the Global Fish Crisis*, World Resources Institute, Washington DC.

321 Ibid.

322 Halweil, B. (2006), *Catch of the Day: Choosing Seafood for Healthier Oceans*, Worldwatch Institute, World Watch Paper 172, Washington DC, p53

323 Poiner, I. et al. (1998), cited in Kura, Y. et al. (2004), *Fishing for Answers: Making Sense of the Global Fish Crisis*, World Resources Institute, Washington DC.

324 Larcombe, J. and McLoughlin, K., eds, (2007), *Fishery Status Reports 2006: Status of Fish Stocks Managed by the Australian Government*, Bureau of Rural Sciences, Canberra, pp195–203

325 Kura, Y. et al. (2004), *Fishing for Answers: Making Sense of the Global Fish Crisis*, World Resources Institute, Washington DC.

326 DPI (2006a), *Victorian Food Industry Fact Sheets*, Department of Primary Industries, accessed 15 December 2007, http://www.dpi.vic.gov.au/dpi/nrenti.nsf/LinkView/2969C33369DFA832CA256BC20016E3933EAE47A0DB5D4984CA25727A00781A83.

327 Australian Marine Conservation Society (2008), *Farming Australia's Seas – It's No Solution!* accessed 31 January 2008, http://www.amcs.org.au/default2.asp?active_page_id=159

cases and nutrient discharge by 50 percent in others.[328] While some freshwater aquaculture occurs in streams, it often uses ponds and dams and so avoids most water pollution problems.[329]

Aquaculture impacts on wild fish stocks when the farmed species are fed fishmeal made from wild caught fish. According to the Australian Marine Conservation Society, between two and 12 kilograms of fishmeal are used in the production of one kilogram of farmed fish or prawns.[330] Besides being better adapted to living in high densities in small areas, farmed freshwater species tend to be vegetarian or omnivorous, so require none or less fishmeal.[331] Impacts on wild stocks can also occur when fish are taken from the wild for use in aquaculture, for example egg-bearing female prawns and juvenile tuna (which are often taken to be "fattened up" before they have had a chance to reproduce).[332] Juvenile fish introduced into aquaculture are often not counted in catch statistics, giving the impression that there is less pressure on wild stocks than is in fact occurring.[333]

Other sustainability problems include the transfer of disease from crowded cages to wild species, damage to ecosystems when caged fish not native to the area escape, and deaths of other species (including turtles and birds) when these are caught in aquaculture nets.[334]

Opportunities

Innovations in aquaculture systems are integrating them with horticultural production to use the nutrients from fish excrement as an agricultural input. See *Diversification* and *Urban Agriculture* (referred to as Aquaponics).

2.3. Biodiversity

'Biodiversity' – diversity of biological life within a system – increases resilience. Biodiversity is important in both the ecological systems that underpin food production and in the agricultural systems themselves. Agriculture systems impact on the land and water on and around the farm - these impacts have repercussions for ecosystem function (native biodiversity) and eventually undermine productivity. Furthermore reduction of diversity within agricultural crops and livestock can increase their vulnerability to pests, changes in climate etc (agricultural biodiversity).

2.3.1. Native Biodiversity

Summary and Recommendations:

For Victoria, clearing of woody vegetation has slowed and ongoing native biodiversity loss is mainly due to changing use and poor soil management of existing agricultural land. This includes land being converted from pasture to crops, increase in irrigated crops (including vines) and intensive dryland pasture farming. Increasing intensification of land use has led to removal of remnant trees and patches of vegetation.[335]

The farming practices that have the greatest impacts on terrestrial (on-land) biodiversity include grazing,

[328] Miller, D. and Semmens, K. (2002), and World Bank et al. (2002), cited in Kura, Y. et al. (2004), *Fishing for Answers: Making Sense of the Global Fish Crisis*, World Resources Institute, Washington DC.
[329] Australian Marine Conservation Society (2008), *Farming Australia's Seas – It's No Solution!* accessed 31 January 2008, http://www.amcs.org.au/default2.asp?active_page_id=159
[330] Ibid.
[331] Ibid.
[332] Ibid, and Kura, Y. et al. (2004), *Fishing for Answers: Making Sense of the Global Fish Crisis*, World Resources Institute, Washington DC.
[333] Ibid.
[334] Ibid.
[335] VCEC (2007), *Simplifying the Menu: Food Regulation in Victoria*, Victorian Competition and Efficiency Commission, p17

monoculture cropping, inadequate buffers between cropping and waterways and native habitats and incremental loss of paddock trees.[336] Agricultural practices also impact on aquatic and marine biodiversity, primarily through competition for water (removal from rivers and streams), loss of streamside vegetation and contamination of waterways with agricultural chemical and nutrient run-off.[337] There are known strategies to improve biodiversity outcomes and increase productivity, such as rotational grazing, more cautious chemical use (with benefits to the soil and reduced run-off), protection of remnant trees, use of native vegetation for shelterbelt and, preventing grazing in riparian zones (by streams).[338] Specific interventions are occurring in these areas. There are also existing and emerging farming innovations that incorporate biodiversity improvement, such as integrated pest management, pasture cropping, phase cropping etc (see *3.2.1 Environmental Management*). Comparatively little is known about soil biodiversity, either the causes or impacts of its loss, the management techniques for improvement or the potential productivity benefits.[339] This lack of knowledge is reflected in the lack of intervention.	
!	*Current agricultural impacts on biodiversity are well known, as are some actions to reduce them. However, the costs of protecting biodiversity could increase with competition for land and changing land uses.*
!	*Techniques and systems that have been developed as 'alternatives' (such as polyculture systems and reduced chemical use) have been shown to have significant native biodiversity benefits – these may also have productivity and broader environmental benefits.*
!	*New challenges will be presented by genetically modified crops, the possibility of bee colony collapses, increasing competition for land and climate change.*
🕮	*Improve information about soil biodiversity – what's there, what's disappearing, what impact does that have on productivity and environmental services?*
⚡	*Use of native species for food – may encourage preservation and improved knowledge while reducing impact on the environment*
⚡	*Identifying and applying (in new contexts) techniques and systems that improve biodiversity and productivity (win-wins)*
⚡	*Food products that incorporate and value native biodiversity eg. 'premium' for saltbush lamb*
⚡	*Soil carbon sequestration potential of some native species or ecosystems may facilitate habitat preservation*

The overall condition of Victoria's biodiversity appears to be declining.[340]

44% of Victoria's native plants and 30% of native vertebrate species are thought to be extinct, threatened or vulnerable to extinction. This does not include the status of invertebrates and species living in the soil (which are crucial for soil formation, nutrient cycling etc) about which very little is known.[341] In the 2007 Catchment Condition Report, the VCMC reported that in the period between 2002 and 2005 the number of plant taxa (species, subspecies and varieties) and vertebrate animals considered to be extinct, endangered and vulnerable increased, and they concluded that the overall condition of biodiversity is still declining, and 'of great concern.'

As more land becomes unviable and demand for food increases, increasing amounts of land worldwide are cleared for agriculture. According to Wood et al., agriculture accounts for 80% of global deforestation.[342]

[336] Wilson, J. et al. (2004), *Land Use Impacts on Native Biodiversity - Background Report No. 1*, Drivers of Land Use Change Project (Driver Research Phase), Department of Sustainability and Environment, State of Victoria.
[337] Ibid.
[338] Ibid.
[339] State of the Environment Advisory Committee (SoEAC) (1996), cited in Yencken, D. and Wilkinson, D. (2000), *Resetting the Compass- Australia's Journey Towards Sustainability*, CSIRO Publishing, Collingwood, p230
[340] VCMC (2007), *Catchment Condition Report 2007*, Victorian Catchment Management Council, State of Victoria, p23
[341] State of the Environment Advisory Committee (SoEAC) (1996), cited in Yencken, D. and Wilkinson, D. (2000), *Resetting the Compass- Australia's Journey Towards Sustainability*, CSIRO Publishing, Collingwood, p230
[342] Wood, R. et al. (2006), "A Comparative Study of Some Environmental Impacts of Conventional and Organic Farming in Australia", *Agricultural Systems,* vol. 89, no. 2-3: 324-48, p325

This removal, decline in quality and fragmentation of habitat leads to biodiversity loss. Victoria has experienced extensive land clearance (approximately 70% of all Victoria's native vegetation has been cleared – more than any other state) and habitat modification through soil disturbance, grazing and altered fire regimes.[343] In Victoria, as elsewhere, much of this clearing is related to agriculture (as well as other changing land use such as urban expansion). Victoria has experienced a significant increase in the amount of land under crops and sown pastures, requiring land clearing and causing habitat destruction/loss. This includes a growth in irrigated pasture, irrigated crops (especially vines), cropping of higher rainfall areas and intensive dryland pasture faming in the south.[344]

Agriculture and Biodiversity

As of 2007, the VCMC suggests that clearing rates of woody native vegetation have slowed, but changing agricultural land uses are diminishing different vegetation types, such as the native grasslands threatened by the shift from grazing to cropping in some regions.[345] Native vegetation in 'fragmented' landscapes is still in decline generally, except where specific government and/or landowner interventions are being made.

DSE's 2004 Report *Land Use Impacts on Native Biodiversity*[346] identified where agriculture has the most significant impacts on biodiversity and highlighted the farming practices that required priority attention. Their findings are outlined below.

- The 'where' and 'when' of grazing tends to have the greatest effect on native biodiversity
- Monoculture cropping provides little habitat for the majority of native species
- When land use changes to cropping, remnant native biodiversity areas are often removed eg. native pasture and remnant paddock trees
- Inadequate buffers between cropping, waterways and remnant native habitat allow fertilisers and biocides to cause adverse effects
- Incremental loss of trees is a major factor in habitat loss in the agricultural regions (e.g. tree dieback, felling paddock trees for pivot irrigation). Mature trees can take up to 200 years to grow – there are few of sufficient maturity to replace remnant trees as they die.

The report specifically highlighted farming practices which should be discouraged because of their damage to biodiversity, including:

- Cropping that replaces, or is too close to, existing native biodiversity assets, including scattered trees, treed remnants and native pasture, wetland areas, fallen timber, rocks and understorey.
- Grazing in riparian zones – revegetation and restriction to stock access are essential.
- Grazing without rest periods – rest periods allow for the regeneration of native species.
- Anything more than minimal grazing once or a few times a year of areas of high native biodiversity value. Fencing of treed remnants and the re-establishment of understorey are critical.
- Inadequate weed and feral animal control programs, and allowing introduced grasses and other species to invade areas of high native biodiversity value.
- Chemical seepage associated with cropping into riparian zones and remnants.

Amongst the recommended actions for protecting native biodiversity in agricultural landscapes, this report included strategies that may also increase productivity, such as rotational grazing, integration of native biodiversity principles into shelterbelts and plantations, and reduced (more cautious) application of herbicide and pesticide use. Protection of remnant trees can have

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[343] DSE (2005), *Victorian Landscapes: Condition and Emerging Directions for Natural Resource Management*, Land and Catchments Division, Department of Sustainability and Environment, State of Victoria.

[344] Dunlop, M., Poldy, F., and Turner, G.M. (2004), *Environmental Sustainability Issues Analysis for Victoria: A Report Prepared for the Department of Sustainability and Environment, Victoria*, CSIRO Sustainable Ecosystems, Canberra.

[345] VCMC (2007), *Catchment Condition Report 2007*, Victorian Catchment Management Council, State of Victoria, p17

[346] Wilson, J., Ford, J., and Lavis, T. (2004), *Land Use Impacts on Native Biodiversity - Background Report No. 1*, Drivers of Land Use Change project (Driver Research Phase), Department of Sustainability and Environment, State of Victoria

productivity benefits through reduced heat stress in livestock, and native shelterbelts have been shown to reduce lamb deaths through protected birthing areas.[347]

The report also discusses the need to make decisions across landscapes about where biodiversity protection is paramount, to divide land into intensive use areas and conservation areas and restrict the total area within a region that is cropped. It also suggests that no native pastures or wetland areas be converted to crops – however this is still occurring.

Freshwater and Marine Biodiversity

The condition of rivers and streams affects the biodiversity in and around them, and appears to be closely related to the level of change in the catchment landscape – the poorest rivers tend to be found where there the catchment landscape has had the most significant modification.[348] The health of Victoria's rivers and streams appears to have stopped deteriorating over the last five years, however still only one catchment area (East Gippsland) that has good to excellent ratings for its waterways – largely due to the extent of its unmodified forests.

The main impacts of agriculture on aquatic biodiversity are:

- Use of water for irrigation (see *2.2.1 Water*), removal of water from river and stream systems for irrigation, and modification of flow regimes affects aquatic ecosystems. In 2007, 32% of rivers and tributaries were in poor or very poor, 47% moderate, and only 21% in good or excellent condition.[349] Stream condition was found to be particularly poor downstream of irrigation systems and dams, where water is removed for agricultural or town use.[350]
- When streamside zones are healthy they provide organic matter (food), logs (habitat), shade and bank stability to a river and are therefore crucial components of a healthy ecosystem. They are the buffer between land and streams, and can assist in protecting the waterway from impacts of adjoining land use. Streamside zones are in moderate to poor condition across most of Victoria, mainly due to clearing of native riparian vegetation for agriculture.[351] As discussed above, protection of remnant riparian vegetation from grazing or clearing for cropping is essential.[352]
- Water quality reflects the land use in the surrounding environment (including issues discussed in *2.2.3 Land and Soil*). Chemical intensive agricultural practices have caused a decline in water quality and 61% of river basins assessed by the National Land & Water Resources Audit had nutrient levels in excess of water quality guidelines.[353] This increases algal blooms and consequent suffocation of aquatic animal life & production of toxins.[354] Although Victorian water quality indicators such as phosphorus run-off and turbidity appear to have improved since 1999, this is most likely due to low run-off in drought conditions rather than actual improvement.

  The 2007 VCMC report predicted that if / when wetter conditions return, phosphorus levels and turbidity were expected to increase again.[355] In January 2008 (following a combination of some high rainfall and warm, calm weather conditions) the extent of the run-off caused severe blue-green algae blooms in the Gippsland Lakes, and the Victorian Department of Human Services recommended that people avoid contact with the water.[356]

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[347] Wilson, J., Ford, J., and Lavis, T. (2004), *Land Use Impacts on Native Biodiversity - Background Report No. 1*, Drivers of Land Use Change project (Driver Research Phase), Department of Sustainability and Environment, State of Victoria
[348] VCMC (2007), *Catchment Condition Report 2007*, Victorian Catchment Management Council, State of Victoria, p29
[349] Ibid, p82
[350] Ibid, p28
[351] Ibid, p88
[352] Wilson, J., Ford, J., and Lavis, T. (2004), *Land Use Impacts on Native Biodiversity - Background Report No. 1*, Drivers of Land Use Change project (Driver Research Phase), Department of Sustainability and Environment, State of Victoria
[353] National Land and Water Resources Audit (2002), cited in ABS (2003a), *Australia's Environment: Issues and Trends,* Cat. No. 4613.0, Australian Bureau of Statistics, Canberra.
[354] Nielsen, R. (2005), *The Little Green Handbook: A Guide to Critical Global Trends*, Scribe Publications, Melbourne, p55
[355] VCMC (2007), *Catchment Condition Report 2007*, Victorian Catchment Management Council, State of Victoria, p86
[356] AAP (2007), "Gippsland Lakes Health Warning Issued", *The Age*, 4 January 2007, http://news.theage.com.au/gippsland-lakes-health-warning-issued/20080104-1k5a.html

Actual levels of aquatic life are believed to be stable, although poor across much of the west and north of the state. Full analysis of the condition of fish in Victoria's steams will be available at the end of 2008. Aquatic life cannot however survive without water. The challenges around water and food supply are outlined above (*2.2.1 Water*) and these challenges directly affect biodiversity through competition for environmental flows in rivers. Despite policy commitments to preserve / increase environmental flows, immediate urban and agricultural water demands are politically difficult to resist.

Agriculture related nitrogen and sediment run-off also threatening the health of estuaries and bays. Further issues of marine biodiversity related to food production are outlined in *2.2.4 Depleted Stocks (Fish).*

Soil Biodiversity

Soil organisms create a living, dynamic system that needs to be understood and managed properly for best plant growth. Understanding soil health requires knowing what organisms occur, which ones are working, how many are present and whether they are the right kinds for the desired plants.[357]

As mentioned in *2.2.3 Land and Soil*, the VCMC has noted that "we can ascertain a weakness in the area of soil and soil management. The future for our soils does not look optimistic and this needs to be addressed at a statewide level. Over half of the world's biomass is found underground. From a biodiversity and agricultural production perspective soil health is fundamental".[358]

Healthy biological life in the soil is increasingly recognised for its importance in nutrient cycling and the creation of organic matter that sequesters carbon (see *2.1.2 (Soil Carbon)*). High levels of organic matter and carbon in soil have multiple benefits, and are critically linked with thriving and diverse biological activity in soils. Restoring and building new topsoil is reliant on "thriving biological life in the soil, thriving biological life above the soil."[359]

However, comparatively little is known about soil biodiversity. The Australian Soil Foodweb Institute in NSW has been working with growers since 2001 to build knowledge about soil organisms and use this knowledge to improve soil health and productivity. Some soil biodiversity management is starting to occur as part of efforts to improve soil quality, however there is very little information about what species exist (including any that may be endemic to Victorian soils), their functions, and which are being / have been lost.

'New' Biodiversity Challenges

Loss of native vegetation and vertebrate species have been familiar environmental issues for many years and are well known and understood even if far from resolved. More recently, a number of issues have arisen that could be considered 'new' biodiversity issues, as they have not been detected or examined in the past. For example, pests and weeds threaten biodiversity directly (eg. foxes preying on native animals) and indirectly by competing for habitat or food sources; however a new biosecurity issue threatens both biodiversity and food production directly.

Bee populations in the USA appear to be threatened / vulnerable to a range of conditions which have been loosely described as 'Colony Collapse Disorder'. There are many opinions as to what is causing the disappearance of bees, from agricultural chemical use (particularly pesticides which

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[357] Ingham, E. (2007), *Soil Foodweb Institute Australia*, accessed 14 January 2008, www.soilfoodweb.com.au
[358] VCMC (2002), cited in VCMC (2007), *Catchment Condition Report 2007*, Victorian Catchment Management Council, State of Victoria, p22
[359] Jones, C.E. (2002), "Creating Topsoil- Stipa Native Grasses", paper presented at the *Changing Landscapes Forum*, 3 May 2002, Armidale, http://www.amazingcarbon.com/JONES-BuildingNewTopsoil.pdf.

can affect bees and other pollinating insects),[360,361] to mobile phones, the varroa mite, overwork and lack of nutrition through lack of access to anything other than monoculture crops.[362] As most of our food crops are dependent on bees and other pollinating insects, any decline in bee populations has the potential "to decimate most facets of agriculture, and in turn threaten our very existence through a diminishing food supply." [363]

Australia has thus far avoided the introduction of the varroa mite and our bee colonies are very well-managed by international standards. However, the need for massive movement of colonies to pollinate large plantations (see *1.6.1 Production*) could lead to intensified USA style bee management and increase the risk of less resilient bee populations. Although the bees that do most of the pollination of food crops here are introduced European bees (native bees are not very good at pollinating European crops), introduction of the varroa mite tends to first wipe out native bee colonies. This would represent a significant threat to both food production and the pollination of native plant species.[364]

Emerging technologies may present different threats to biodiversity – see discussion in *3.1 Emerging Technologies*.

Increasing competition for land may also represent new biodiversity threats. For example, economic motivations to produce biofuels may increase viability of land that has been considered too marginal for agriculture. Anecdotal evidence suggests that this is already happening in the UK where land that was previously partitioned off voluntarily for biodiversity purposes is now being converted to oilseed and biofuel production areas. The monetary incentives offered by government for biodiversity protection may be surpassed by money to be made from biofuels.

Climate change also presents significant new challenges to biodiversity, as fragmented habitats make it difficult or impossible for vulnerable populations to move to more suitable locations as temperatures and water availability change. The establishment of biolinks within and across agricultural landscapes will be essential if native vegetation and animals are to adapt to changing weather conditions.

Opportunities

Market interest in 'clean and green' produce may increasingly return value to producers with good biodiversity outcomes on their farms.

There is increasing recognition of important role that biodiversity plays in healthy agro-ecosystems. Services to agriculture include "recycling of nutrients, regulation of microclimate and local hydrological processes, suppression of undesirable organisms and detoxification of noxious chemicals."[365] Opportunities to increase native biodiversity in Victoria, while also increasing agricultural health include:

- Native biodiversity increases productivity – biodiversity 'win-wins' – native vegetation integrated into agricultural landscapes, not just fenced off at the edges (see *3.2.1*

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360 Monson, T. (2007), *The Future Development of the Honey Bee Industry*, Submission to the House of Representatives Agriculture, Fisheries and Forestry Committee, May 2007, accessed 12 December 2007, www.aph.gov.au/house/committee/primind/honeybee/subs/sub006.pdf

361 Mapes, L.V. (2007), "Growers Fear the Sting of Bee Die Off", *The Seattle Times*, 10 June 2007, http://seattletimes.nwsource.com/html/localnews/2003742020_bees10m.html

362 Range of sources, cited in Radio National (2007), "Trouble with Bees - Background Briefing", 29 July 2007, http://www.abc.net.au/rn/backgroundbriefing/stories/2007/2104818.htm#transcript

363 Monson, T. (2007), *The Future Development of the Honey Bee Industry*, Submission to the House of Representatives Agriculture, Fisheries and Forestry Committee, May 2007, accessed 12 December 2007, www.aph.gov.au/house/committee/primind/honeybee/subs/sub006.pdf

364 Radio National (2007), "Trouble with Bees - Background Briefing", 29 July 2007, http://www.abc.net.au/rn/backgroundbriefing/stories/2007/2104818.htm#transcript

365 Altieri, M.A. (1999), cited in Heller, M. and Keoleian, G. (2002), "Assessing the Sustainability of the US Food System: A Life Cycle Perspective", *Agricultural Systems*, vol. 76, no. 3: 1007-41.

Environmental Management).
- Development of distinctive food products using native vegetation – the native foods industry is being increasing recognised as having significant export potential, as well as domestic interest
- Use of native species for food may have lower environmental impacts and actually encourage biodiversity
- New ownership models – while some new ownership models are leding to vast monocultures of high export value crops (which have limited biodiversity potential), there are also other possibilities emerging from land use change. VicSuper's recently announced project to manage a large tract of land, including landscape assessments for production suitability and biodiversity priorities across a landscape, holds significant promise for improved environmental sustainability outcomes
- Carbon sequestration market opportunities – many native species have very deep root systems (ie. mallee scrub) that can be used to sequester carbon, provide biodiversity corridors through paddocks, and in some cases also provide harvestable products.

2.3.2. Agricultural Biodiversity

An elaborate dance between predator and prey is played out everywhere in the natural world, a struggle in which the delicate balance of power depends on the ability of a species to constantly shift through a vast genetic reservoir and find new characteristics that some distant cousin has used successfully to fight off the threat. When we intervene in the process of evolution by directing the selection of those genetic characteristics that will be passed on from one generation to the next, the choices are usually based on the maximum yield and current market value of the varieties in question rather than their overall genetic resilience. The vitality of the germplasm is therefore diminished while the rate of evolution among pests and blights continues unabated. Moreover, because the pests and blights are no longer aiming at a rapidly moving target, they can systematically search their own genetic arsenals for an offensive strategy that works. And when they find one, it works not only against the individual plant that is first attacked, but, because so many of our new plants are genetically identical, against billions of other suddenly vulnerable plants as well.[366]

Summary and Recommendations:	
Declining diversity of crop and livestock varieties used for agricultural production (both fewer species and less genetic diversity within species) will increase vulnerability to environmental change and resource constraints.[367]	
!	*Declining diversity in agricultural products (and genetic variation) increases risk and vulnerabilty*
!	*The pace and extent of challenges to the food system will make 'keeping up' with emerging problems through problem-specific technical solutions increasingly difficult*
⌁	*Diversification of species, products, mixed-farming systems etc – see 3.2.2 Diversification*

The term 'agricultural biodiversity' can be used to refer to both the diversity of plant and animal species cultivated for human consumption and the genetic diversity of the species themselves. In the 12,000 years that humans have been involved in agriculture, about 7,000 plant species have been cultivated and collected for food.[368] It is now estimated that 12 of these provide 75 percent of our food and only four provide over half of the food we eat.[369] Within each species there is a continuing reduction in genetic variety – one of the ways this can be seen is the reduced number of varieties produced and available. For example, species variety in apples has reduced significantly – in 1871 a Melbourne supplier was selling 131 varieties of apple tree and a recently

[366] Gore, A. (1992), *Earth in the Balance: Forging a New Common Purpose*, Earthscan Publications Ltd, London, p129
[367] UN FAO (2007), *Biological Diversity in Food and Agriculture - Crop Genetic Diversity*, United Nations Food and Agriculture Organisation, accessed 10 December 2007, from http://www.fao.org/biodiversity/crops_en.asp
[368] Convention on Biological Diversity (2007), *Biodiversity for Food and Nutrition*, accessed 3 March 2008, http://www.cbd.int/agro/food-nutrition/
[369] UN FAO (2007), *Biological Diversity in Food and Agriculture - Crop Genetic Diversity*, United Nations Food and Agriculture Organisation, accessed 10 December 2007, from http://www.fao.org/biodiversity/crops_en.asp

closed London nursery stocked more than a thousand.[370] As well as having cultural implications, this reduction in species diversity has very significant implications for the security of food supplies generally. The UN Food and Agriculture Organisation (FAO) notes that erosion of food and agriculture's genetic resources has increased the vulnerability of agriculture, impoverished the human diet and "poses a severe threat to the world's food security in the long term."[371]

In part this reduction in diversity has been driven by the benefits of uniform produce for processing, packaging and supermarket sale. [372] This model of food distribution standardises consumer expectations for any specific produce and offers variety in the way the food is processed and packaged rather than the food source itself. Uniformity increases vulnerability as uniform crops are vulnerable to a single mutation in a pest, which can quickly affect or wipe out vast amounts of food. The vulnerability of this uniform system was identified many years ago by the National Academy of Sciences, who described America's principle crops as "impressively uniform . . and impressively vulnerable."[373]

Intensified agricultural practices have focused on plant breeding and development of varieties with characteristics for short-term returns, primarily maximising yield. This focus has enabled yields to be dramatically increased, but has reduced the resilience of the developed crop varieties, making monoculture crops increasingly vulnerable to emerging pests and diseases (and climate change).[374] To develop new, more resistant crop varieties, scientists can make use of biotechnology and plant breeding techniques to introduce more resistant genes. This may help to respond to specific pests and crop threats as they arise and to develop crop varieties with traits that suit new conditions, such as drought resistance (see *3.1.1 Emerging Technologies*). However, the continued reduction in genetic diversity within these crops makes it easier for pests to adapt and overcome the new traits. In addition, "genetic engineering may actually exacerbate genetic uniformity because the high research and development cost in creating a new genetically engineered organism favours using the same variety over a large area rather than applying the technology to many regionally adapted varieties."[375]

Some reports have suggested that even with the increased use of pesticides, crop losses due to insect attack have continued to increase.[376] Keeping up with the evolution of pests and weeds through specific technology interventions will continue to be very challenging and expensive, however failure to do so in a system reliant on monocultures exposes us to substantial food security threats.

As resistant pests continue to emerge, the domesticated genetic stores sometimes cannot counter the new threat. At this point, we are reliant on the genetic stores of wild 'cousins' of the domesticated plants, which have continued to evolve and develop new gene pools of resistance. Finding and accessing these wild strains is difficult, as fewer wild places remain – "plant geneticists must literally return to the place on earth where the endangered crop makes its genetic 'home' and search through the countryside – sometimes on hands and knees – for a wild relative".[377] Gore describes a number of historical occasions when pests have exploited traits bred into the vast majority of specific crops (ie. rice or corn) and solutions have not been able to be found within gene storages causing (fortunately successful) searches for wild samples with

[370] Timms, P. (2006), *Australia's Quarter Acre - the Story of the Ordinary Suburban Garden*, The Miegunyah Press, Melbourne University Publishing Ltd, Melbourne, pp131&139
[371] UN FAO (2007), *Biological Diversity in Food and Agriculture - Crop Genetic Diversity*, United Nations Food and Agriculture Organisation, accessed 10 December 2007, from http://www.fao.org/biodiversity/crops_en.asp
[372] UK Agricultural Biodiversity Coalition, *Sustaining Agricultural Biodiversity: Genetic, Species, Ecosystems, Cultural and Temporal Dimensions*, UK Food Group, accessed 27 July 2007, http://www.ukabc.org/ukabc3.htm#f.
[373] Horsfall, T.G. (1972), *Genetic Vulnerability of Major Crops*, National Academy of Sciences, 1972, Washington D.C.
[374] Thrupp, L.A. (2003), "The Central Role of Agricultural Biodiversity: Trends and Challenges", *Conservation and Sustainable Use of Agricultural Biodiversity* Paper 3, p24
[375] Rissler, J. and Mellon, M. (1996), cited Heller, M.C. and Keoleian, G.A. (2000), *Life Cycle-Based Sustainability Indicators for Assessment of the US Food System* (No. CSS00-04), Centre for Sustainable Systems, University of Michigan, p10
[376] Zierhl, A. (2004), *Organics and Sustainability: Substantiating the Claim of 'Clean and Green'*, Department of Primary Industries, State of Victoria p15
[377] Gore, A. (1992), *Earth in the Balance: Forging a New Common Purpose*, Earthscan Publications Ltd, London, p132

resistant genes. He also notes that the places where those wild samples were found in the past have, in a number of instances, now been developed, flooded or deforested.[378]

The decrease in biodiversity within agricultural species has coincided with a decline in regional seed saving and plant breeding of varieties that are specifically suited to local conditions and / or adaptable to a variety of conditions. This reduces the availability of previously existing varieties that might be more suited to local conditions under climate change or in response to other environmental and resource challenges.

Innovations emerging from concern about the continuing loss of agricultural biodiversity are outlined in Section 3.

2.4. *Waste*

If we stopped wasting food which could have been eaten, it would have the same impact on carbon emissions as taking 1 in 5 cars off UK roads.[379]

Summary and Recommendations:

Large amounts of food are generated throughout the food system. This wasted (ie. not eaten) food represents significant wastage of water, energy, land, oil, chemicals, packaging and so on. The risk of spoiled and wasted food may increase along with other risks eg. extreme weather events, increasing energy prices or pest infestations.

Increased processing and improvements in packaging reduce food spoilage and waste in long supply chains, but they also have environmental impacts.

In Victoria, 47% of municipal waste sent to landfill is food and green waste.[380] This has immediate environmental impacts (release of methane as it decomposes). It is also a wasted resource. There has been little innovation or intervention in management of household food waste. There would appear to be many opportunities in this area.

!	*A lot of food waste is embedded in the system – long distances, storage times, aesthetic standards etc. The relationships between food waste and other system elements will need careful consideration*
!	*Food waste and food safety concerns may sometimes conflict. For example, consumer food waste could decrease as prices increase, with potential health impacts if information is not available*
	Analysis of waste throughout the food system in Victoria: ➢ *Where does it occur (pre-harvest due to pests, through gluts, retailer logistics, spoilage, household, etc)* ➢ *Where can it be avoided, reused (as inputs to another process or redistributed), or recycled (potential resource?)*
	Analysis of the balance between the environmental impacts of food processing, storage & packaging, and the saved impacts of wasted food
	Analysis of the productive potential of Melbourne / Victoria's food waste – including consideration of travel distances and available processing technologies
	Food preservation technologies and systems eg. reduced reliance on refrigeration
	Nutrients in food 'waste' as alternative fertiliser sources – organic waste recycling providing inputs to food production ➢ *urban* ➢ *rural – innovation potential in logistics / distribution?*

378 Gore, A. (1992), *Earth in the Balance: Forging a New Common Purpose*, Earthscan Publications Ltd, London, p136
379 Waste and Resources Action Program UK (2007), www.lovefoodhatewaste.com
380 EcoRecycle Victoria (2005), *Information Sheet 2 - Waste Facts*, last modified March 2005, from http://www.sustainability.vic.gov.au/www/html/2039-waste-and-recycling-information-sheets.asp

⚡	*Effective, self-managing home composting systems or services*
⚡	*Biodegradable and recyclable food packaging*
⚡	*Adaptive food processing systems – able to adjust products and systems in response to scarcity and seasonal gluts*

The environmental impacts at each stage of the food system (as outlined above) are all in vain if the food is not eaten, and a lot of it is not.

Large amounts of food waste occur at every stage of the food chain. A 2004 US Study found that in total almost half of the food produced in the country (to a point where it is ready for harvest) goes to waste.[381] Although some of this is unavoidable (due to weather etc), a large amount of it is due to speculation on commodity markets and other profit driven motivations in the food system. The concentration of the food chain in two major retailers (see *1.6.3 Distribution*) means that retailers can control the specifications and acceptability of produce. They can make decisions about what will sell based on size and appearance. Slightly small or blemished produce is often not accepted for sale and, in the absence of other markets (see *3.3.2 Farmers' Markets*) disposed of.

Increasing lengths of food chains, transport, storage, processing, and the increase of convenience foods have all contributed to increasing need for food packaging. The energy and materials involved in food packaging are extensive and much of this packaging ends up as waste.[382] However, in Australia a large, and increasing, proportion of this packaging is recycled. Development and uptake of recyclable and bio-degradable packaging methods could further reduce this impact.

The Australian Food and Grocery Council comment that processing and packaging of food helps to reduce the amount of food wasted,[383] by reducing spoilage and damage during transport. However – it is not known whether the environmental costs of the processing and packaging (including materials, energy etc) are greater or less than the environmental costs of wasted food.

Large amounts of uneaten food are also being discarded at the household level. Recent international studies have found that US households dispose of 14% of their food purchases (15% of which is unopened produce still within its use-by date)[384] and for UK households it's almost 33% of all the food purchased.[385] In 2004, Australians threw away an estimated $5.3 billion worth of food - $2.9 billion of fresh food, $630 million of uneaten take-away food, $876 million of leftovers, $596 million of unfinished drinks and $241 million of frozen food,[386] nearly 3.3 million tonnes a year.[387] In Victoria, food and green waste made up over 47% of the municipal waste sent to landfill.[388]

As organic waste such as food decomposes in landfills it produces methane gas, which is 20 times more powerful as a greenhouse gas than carbon dioxide. This is because decomposition in landfills typically occurs under anaerobic conditions (the absence of oxygen), therefore causes the production of methane rather than carbon dioxide. To manage these emissions, some landfills

[381] Dr. Timothy Jones (research associate with the Contemporary Archaeology Project at the University of Arizona) (2004), cited Food Production Daily, *Half of All Us Food Goes to Waste*, accessed November 2007, http://www.foodproductiondaily.com/news/ng.asp?n=56340-half-of-us
[382] Heller, M. and Keoleian, G. (2002), "Assessing the Sustainability of the US Food System: A Life Cycle Perspective", *Agricultural Systems*, vol. 76, no. 3: 1007-41.
[383] Australian Food and Grocery Council (2005), *Packaging – April 2005 Update*, accessed 23 January 2007, http://www.afgc.org.au/index.cfm?id=136
[384] Jones (2004), cited in Food Production Daily (2007), *Half of All Us Food Goes to Waste*, accessed November 2007, http://www.foodproductiondaily.com/news/ng.asp?n=56340-half-of-us
[385] Waste and Resources Action Program (2007), cited in Edwards, F. and Mercer, D. (2007), "Gleaning from Gluttony: An Australian Youth Subculture Confronts the Ethics of Waste", *Australian Geographer*, vol. 38, no. 3: 279-96, p280
[386] Hamilton, C., Denniss, R., and Baker, D. (2005), *Wasteful Consumption in Australia, Discussion Paper Number 77*, The Australia Institute, http://www.tai.org.au/
[387] Smith, B. (2005), cited in Edwards, F. and Mercer, D. (2007), "Gleaning from Gluttony: An Australian Youth Subculture Confronts the Ethics of Waste", *Australian Geographer*, vol. 38, no. 3: 279-96, p280
[388] EcoRecycle Victoria (2005), *Information Sheet 2 - Waste Facts*, last modified March 2005, http://www.sustainability.vic.gov.au/www/html/2039-waste-and-recycling-information-sheets.asp

capture the methane and use it as an energy source, burn it to produce CO_2 instead (a less potent greenhouse gas), or cover with a thick soil layer to reduce the methane emitted.[389]

Most of the household food waste that enters our landfills is suitable for composting or mulching.[390] Effective composting ensures that oxygen is available during decomposition, therefore CO_2 rather than methane is produced and the greenhouse impact of the food decomposition is reduced.[391] Home composting also enables recycling of the nutrients back into the home garden (potentially for food production, see *3.3.4 Urban Agriculture*).

Between March 2005 and 2006, just under half of Australian households (48%) reported that they did recycle or reuse kitchen or food waste. Those that didn't expressed their reasons as: not producing any or enough to warrant recycling or reusing (38%); not interested or too much effort (21%); recycling service or facility was either unavailable, inadequate or unknown (approx. 20%); and no room to compost organic matter (ie. no backyard) (10%).[392] As these are self-reported survey results they are indicative at best, but do they suggest that a significant increase in reuse / recycling of food waste could be achieved through development of simple and accessible systems that are also available to those in flats and units.

A 2005 Australian study compared the environmental impacts of four types of household food waste disposal: home composting, in-sink food waste processors (FWP), codisposal (landfilling with other waste) and centralised composting. It found that home composting was clearly the most 'environmentally friendly' option, provided that the composting occurred aerobically (in the presence of sufficient oxygen).[393] If home compost systems turn anaerobic they too can produce methane (which cannot realistically be captured). The main drawbacks to the other systems were:

- FWP – impact of materials to produce the units, high water use, high eutrophication (nutrient impacts on waterways) and toxicity;
- Codisposal – high greenhouse emissions and eutrophication potential as nutrients leak into groundwater;
- Centralised composting – high transport emissions involved in a separate waste collection system. This was particularly pronounced in this study (compared to similar European studies) due to the lower density of Australian cities.

For higher density areas, larger scale waste to energy systems for processing organic waste could be viable, particularly in areas where household composting is less so (ie. high rise dwellings).

The success of household recycling systems in Victoria suggests that messages and actions around waste disposal do resonate with Victorians, provided that systems are provided that make it easy. Innovative systems or services to simplify management of household food waste could make a significant difference.

[389] GHG (2007), *Sources of Methane - Landfill,* Greenhouse Gas Online, accessed 11 December 2007, http://www.ghgonline.org/methanelandfill.htm
[390] EcoRecycle Victoria (2005), *Information Sheet 2 - Waste Facts*, last modified March 2005, http://www.sustainability.vic.gov.au/www/html/2039-waste-and-recycling-information-sheets.asp
[391] GHG (2007), *Sources of Methane - Landfill,* Greenhouse Gas Online, accessed 11 December 2007, http://www.ghgonline.org/methanelandfill.htm
[392] ABS (2007a), *Australian Social Trends 2007 - Article: Household Waste*, Cat. No. 4102.0, Australian Bureau of Statistics, Canberra.
[393] Lundie, S. and Peters, G. (2005), "Environmental Assessments and Waste Management Life Cycle Assessment of Food Waste Management Options", *Journal of Cleaner Production*, vol. 13, no. 3: 275-86.

2.5. Health and Nutrition

Annual analysis carried out over 50 years by DEFRA's predecessor, MAFF, revealed a 12 - 76% decline in the trace mineral content of UK grown fruit and vegetables between 1940 and 1991.[394]

Summary and Recommendations:

Disease related to nutrition is significant in Victoria; this includes obesity (8%), high cholesterol (6.1%) and inadequate fruit and vegetable intake (3.3%). Together, these conditions have a greater health impact than tobacco smoking (8.2% burden of disease); physical inactivity (4.1%) and alcohol (1.5%).[395]

The 2003 Joint Expert Panel of the World Health Organization and the Food and Agriculture Organization outlined basic recommendations for a dietary consumption pattern that "is not only healthier but more favourable to the environment and sustainable development."[396] A number of international studies have also suggested a strong correlation between recommendations for a healthy diet and lower-environmental impact diets.[397,398,399]

There is evidence that long storage periods can reduce the nutritional value of foods.[400] High 'energy-dense' foods (such as junk foods) with little nutritional value are more affordable than fresh fruit and vegetables[401] and therefore likely to make up a large part of the diet when money is scarce.

Attention is being given to increasing the concentrations of specific nutrients in foods via functional foods (to create high-value food products), although knowledge about how individual food constituents behave when isolated from whole foods remains limited. There is increasing evidence of the nutritional benefits of foods produced with reduced chemical inputs (eg. organic).[402]

!	*Some disadvantaged groups already have difficulty accessing healthy and nutritious food, including fresh fruit and vegetables. Increasing food prices will increase the vulnerability of these groups.*
	Analysis of recommended 'healthy eating' in Victoria / Australia and the environmental implications of recommended changes to dietary composition (such as reduced sugar, increased fruit and vegetables, level of processing); are there areas where these conflict?
	Analysis of the impacts of carbon pricing on access to healthy and nutritious foods (which foods will become more expensive and how will this affect food access?)
	Analysis of potential improvement to nutritional densities of Victorian fruit and vegetable products through changed production methods – do methods that improve health outcomes have positive or negative environmental impacts? Which methods make a difference and for which foods?
	Analysis of the potential for health and nutritional aspects of food to be improved through changes in processing, distribution and supply chains
	Analysis of the potential to meet food needs through local, seasonal production in Melbourne / Victoria – what would diet include? Would it be nutritionally adequate?
	Identification of input / production factors that affect nutrition in food holds marketing / export potential

[394] McCance & Widdowson (1940-91) and Mayer, A.M. (1997), cited in Prism Web Cast (2007), *EU-Funded Quality Low Input Food Project Indicates Significant Nutritional Benefits from Organic Food*, http://www.prismwebcastnews.com/pwn/?p=1550
[395] DHS (2005), *Victorian Burden of Disease Study: Mortality and Morbidity in 2001*, Department of Human Services, State of Victoria
[396] WHO/FAO (2003), *Diet, Nutrition and the Prevention of Chronic Diseases: Report of the Joint WHO/FAO Expert Consultation* (No. 916), accessed 31 January 2008, from http://www.who.int/dietphysicalactivity/publications/trs916/summary/en/index.html.
[397] Gussow, J. and Clancy, K. (1986), "Dietary Guidelines for Sustainability." *Journal of Nutrition Education*, vol. 18, no. 1: 1-5.
[398] Collins, A. and Fairchild, R. (2007), "Sustainable Food Consumption at a Sub-National Level: An Ecological Footprint, Nutritional and Economic Analysis." *Journal of Environmental Policy and Planning*, vol. 9, no. 1: 5-30, p16
[399] Duchin, F. (2005), cited in Carlsson-Kanyama, A. et al. (2003), "Food and Life Cycle Energy Inputs: Consequences of Diet and Ways to Increase Efficiency." *Ecological Economics*, vol. 44: 293-307.
[400] Choice (2006), *Fresh Fruit and Veg?*, from www.choice.com.au
[401] Drewnowski, A. and Monsivais, P. (2007), "The Rising Cost of Low-Energy-Density Foods." *Journal of the American Dietetic Association* 107, no. 12: 2071-76., as discussed in Parker-Pope, T. (2007), *A High Price for Healthy Food*
[402] Benbrook, C. et al. (2008), *New Evidence Confirms the Nutritional Superiority of Plant-Based Organic Foods*, State of Science Review, March 2008

⚡	*Involvement in food production can increase knowledge of and access to healthy food, physical activity and/or community interaction*
⚡	*Supply and distribution systems that minimise nutritional loss*

Disease related to nutrition is that largest category of disease in Victoria. It includes obesity (8%), high cholesterol (6.1%) and inadequate fruit and vegetable intake (3.3%). Together, these conditions have a greater health impact than tobacco smoking (8.2% burden of disease); physical inactivity (4.1%) and alcohol (1.5%).[403]

Health and nutrition challenges in the food system are closely integrated with environmental and resource challenges. These issues are touched on briefly below.

Correlation between environmental and nutritional impacts

VicHealth's 2005 *Position Statement on Healthy Eating* suggests that nutritious foods can help prevent chronic disease and that diets high in fat and sugar, or low in fruit, vegetables and dietary fibre can contribute to chronic disease and obesity.[404] As seen above (in *2.1.2 Energy, Greenhouse Emissions* and *2.2.1 Water)* different foodstuffs can also have vastly different environmental impacts. Gussow and Clancy's 1986 paper articulates a set of 'dietary guidelines for sustainability', which explore the environmental benefits of common nutritional recommendations, including:[405]

- Eat a variety of foods – nutritional diversity is supported by biological diversity (although this should be balanced with other environmental issues like seasonality);
- Maintain ideal weight – excess calorie consumption could be considered wasted food;
- Avoid too much fat, saturated fat and cholesterol – major dietary sources are meat and dairy;
- Eat foods with adequate starch and fibre – wholegrains, fruit and vegetables (with consideration to other environmental impacts); and
- Avoid too much sugar and salt – this paper notes the potential health implications of breeding 'salt-tolerant' plants to deal with salinity.

Two international studies that explore in detail some possible correlations between healthier and more environmentally friendly diets are outlined in *3.4.4 Choosing a Sustainable Diet*.

Storing foods for long periods (eg. up to 18 months in some supply chains) can lead to a significant nutrient reduction.[406] Examples include significant decline in antioxidant properties[407] and reduction in vitamin levels, eg. up to 60% loss of Vitamin C in some vegetables stored in cold storage.[408] Public health recommendations of '2 fruit and 5 vegetables' a day are based on an understanding of nutrient levels that may not be correct for those that have been stored.

Disadvantage and nutrition

Environmental factors and resource constraints that make fruit and vegetables more expensive could exacerbate nutritional problems for disadvantaged groups, and extend food access difficulties to a larger group of people. VicHealth has commented that, "when money is scarce, food choices are discretionary but not utilities or rents. Vulnerable groups are more likely to consume higher amounts of "energy dense" foods (high in fat and sugar), and lower amounts of plant-based foods. Energy dense foods (such as take-away and delivered foods) are often perceived as being more affordable, more filling, more acceptable by family members and readily available in disadvantaged areas."[409]

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403 DHS (2005), *Victorian Burden of Disease Study: Mortality and Morbidity in 2001*, Department of Human Services, State of Victoria.
404 VicHealth (2005b), *Position Statement on Healthy Eating*, Victorian Health Promotion Foundation
405 Gussow, J. and Clancy, K. (1986), "Dietary Guidelines for Sustainability", *Journal of Nutrition Education,* vol. 18, no. 1: 1-5.
406 Choice (2006), *Fresh Fruit and Veg?*, www.choice.com.au
407 Tarozzi, A., Marchesi, A., Cantelli-Forti, G. and Hrelia, P. (2004), "Cold-Storage Affects Antioxidant Properties of Apples in Caco-2 Cells", *The Journal of Nutrition*, vol. 134, no. 5: 1105-09.
408 Keijbets, M. and Ebbenhorst-Seller, G. (1990), "Loss of Vitamin C (L-Ascorbic Acid) During Long-Term Cold Storage of Dutch Table Potatoes", *Potato Research*, vol. 33, no. 1.
409 Reidpath, D. et al. (2002), and Block, J.P et al. (2004), cited in VicHealth (2005a), *Healthy Eating - Food Security:*

A 2007 US study found that "higher-calorie, energy-dense foods are the better bargain for cash strapped shoppers" and calculated that meeting daily energy requirements (2,000 calories) would only cost for $3.52 a day if made up of junk food, whereas low energy-dense foods would cost $36.32. Noting that low-income people in the US spend about $4 a day on food, they are more able to meet daily energy requirements from energy-dense junk foods than a diet including fresh fruit and vegetables, and therefore are unlikely to meet their nutritional needs. This study also noted that, as well as costing less than fresh fruit and vegetables, junk foods are also less likely to rise with inflation.[410]

Opportunities

Value-added foods with increased concentrations of specific nutrients (known as 'functional foods') are receiving considerable interest, although knowledge about how individual food constituents behave when isolated from whole foods remains scarce. There is also increasing interest in changed production methods which increase the nutritional value of foods – this is further explored in *3.2.3 Reducing Reliance on Inputs* (*Health)*.

VicHealth also note that there are documented health and social benefits from the joint growing, preparation, sharing and eating of food, and from increasing physical activity.[411] The potential health benefits of involvement in urban food production are touched on in *3.3.4 Urban Agriculture*.

Investment Plan 2005 - 2010, Victorian Health Promotion Foundation, p6

[410] Drewnowski, A. & Monsivais, P. (2007), as discussed in Parker-Pope, T. (2007), *A High Price for Healthy Food*, http://well.blogs.nytimes.com/2007/12/05/a-high-price-for-healthy-food/?em&ex=1197262800&en=f2ea34be5e998c32&ei=5087%0A

[411] VicHealth (2005b), *Position Statement on Healthy Eating*, Victorian Health Promotion Foundation

3. Response Strategies

We cannot know exactly how, where and when the impacts of climate change, international or local emission control policies, resource constraints or ecological system breakdowns will affect food production and consumption capability. The environmental and resource challenges outlined above will impact on food systems in different ways and at different times, perhaps with unexpected systemic impacts. Planning for and managing a secure food supply, and viable food industries, under these circumstances will require attention to the resilience of the entire food system to complex and unpredictable change.

The resilience of a system refers to how effectively it can respond to shock and change while still delivering its critical functions (in this case providing food).

The resilience approach is useful to agribusiness and in thinking about supply chains, as enterprises that wish to stay viable will need to "maintain the security of business inputs that are exposed to uncertainty of supply and cost, and to manage production in an environment of unreliable climate, including managing the supply and cost of water."[412] The emerging study of 'agricultural supply chain resilience' starts from an understanding that "increasing efficiency is often not the primary goal in agriculture value chains. Resilience, or the ability to return to a desirable state in the event of a value chain disturbance, is often a greater need for participants in agriculture chains when striving for sustainability."[413]

Considering resilience requires an examination of the balance between 'efficiency' and 'redundancy'.

Many existing responses to environmental and sustainability challenges are focusing exclusively on resource efficiency – finding ways to reduce energy, water and land required per kilogram or dollar generated. Optimising the use of one resource without considering the systemic impacts of the changes can reduce overall resilience.

In his 2006 book *Resilience Thinking*, CSIRO's Dr Brian Walker suggests that "the key to sustainability lies in enhancing the resilience of communities, not in optimising isolated parts of the system."[414] His book argues that "local communities are better able to withstand various cycles of change if they know more about the ecological drivers of their region, embrace rather than control the processes of natural change, and are empowered to make their own decisions about appropriate local developments."[415]

Resilient food systems will need to make the best use of available resources, respond to changing local conditions and adapt to ongoing change. This will require:

- Diversity: in strategies and innovations, and in supplies, production practices and distribution pathways, *see 3.2.2 Diversification*
- Redundancy: participants should build networks of suppliers and customers and ensure inputs (and food) can be obtained from a range of sources (networked distributed systems); and
- An ability to learn: participants in the system need to be able to learn from each other's successes and failures, and have access to information.

[412] DAFF (2007), *Australian Food Statistics 2006*, Department of Agriculture Fisheries and Forestry, p 30
[413] Archer, A. (2006), "Agricultural Chain Resilience under Urbanizing Pressures", workshop abstract from "Simulation and Modelling of Sustainability Transitions & Applications in Policy", paper presented at the *Planning and Management Workshop*, Melbourne, http://www.complexsystems.net.au/wiki/SMURT
[414] Walker, B. and Salt, D. (2006), *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*, Island Press, USA.
[415] CSIRO (2006), *Long Term Prosperity Needs 'Resilience' Not Just Efficiency* (No. 06/183), 18 September 2006, CSIRO Media Release, http://www.csiro.au/news/ps2a3.html

Which Strategies?

There are varying perspectives about preferred future food systems, and debate around what will be both productive and resilient enough to deal with changing climates and environmental conditions. Boundaries are very difficult to draw, but a useful classification of different 'types' of food systems has been developed by the UK Economic and Social Research Council's Technological Transformations in Food Consumption and Production Systems Project, outlined in Table 3-1.

Table 3-1: Food System 'Paradigms'[416]

Conventional industrial	Traditional sustainable	Organic	New industrial
Advanced breeding techniques, major inputs of chemical fertilisers and pesticides. Transport intensive, requires high-energy processing, relies on modern retailing systems and demands high-tech kitchens.	Few synthetic inputs, labour-intensive. Uses localised distribution systems.	Avoids synthetic chemicals and draws on natural systems and cycles. Food processing aims to reduce environmental impacts. Focus on 'natural' products and production methods to ensure human health, animal welfare and high quality environments	Crop management using genomics and improved resource use with techniques such as precision farming. Improving conventional industrialised agriculture through high tech solutions. Aims to incorporate nutrition and health care through functional foods and nutraceuticals

It is most likely that each of these will contribute knowledge and innovations to improved future food systems.

Victoria has considerable research investment in the development of technologies and systems that enable increased productivity and international competitiveness though 'new industrial' techniques – including the creation of new, value-added food products and significant improvements in resource efficiency. A brief overview of some technological possibilities is outlined in the following section, *3.1 Emerging Technologies*.

Individuals and communities are also adapting, reducing their own risks and their impacts on the environment. Some of these innovations they are developing could be classed as 'organic' or 'traditional sustainable.' Innovations being developed and applied by producers and consumers are considered in: *3.2 New Production Strategies*, *3.3 New Distribution Strategies* and *3.4 Consumer Choices* are considered, along with discussion of their potential environmental costs and benefits.

It can be difficult to distinguish between the production and consumption elements of particular drivers. For example, the rapidly increasing consumer demand for organic food seems to be mostly driven by individual health concerns, whereas producers may be more concerned about environmental impacts, longer term sustainability of their farming practice, and reduced input costs. These intersect and drive a change in the market. The strategies discussed in this paper have been categorised as shown in Table 3-2.

Table 3-2: Response Strategies

Technology	Production	Distribution	Consumption
ICT	Environmental management	Localisation	Waste Reduction
Biotechnology	Diversification	Farmers' markets	Fair Trade
Nanotechnology	Reducing reliance on inputs	Community Supported Agriculture (CSA)	Eating in Season
		Urban agriculture	Choosing a sustainable diet

[416] Technical Transformations in Food Consumption and Production Systems Project (2004), *Project Brief 3 - How Green are My Fries?*, Economic and Social Research Council, accessed 12 November 2008, http://www.sustainabletechnologies.ac.uk/Projects/food.htm

3.1. Emerging Technologies

Summary and Recommendations:

Rapid advance in information and communications technologies (ICT); biotechnology; nanotechnology; and the convergence of these technologies have the potential to increase the efficiency of existing technologies and systems, and could reduce the environmental impacts of food production and consumption. Change will also come from the continuing diffusion of technologies that already exist as they are used in new ways, particularly information technology and mobile communications. Development, convergence and widespread uptake of these technologies may also pose risks to the environment, and (particularly in food) to human health.

Information and Communications Technology (ICT) includes all technologies that enable communication and information processing.

Biotechnologies are technologies that use and manipulate living organisms such as cells, bacteria and yeast, or parts of these ie. genes and enzymes.

Nanotechnology is the manipulation of atoms and molecules to create new materials, new structural characteristics and new products.

The **convergence** of ICT, biotechnology and nanotechnology could revolutionise science and technology. It is it has been claimed that "over the next two decades, the impacts of this convergence on farmers and will exceed that of farm mechanisation or of the Green Revolution."[417]

The urgent need to reduce the vulnerability of the food system to environmental challenges means that all possible solutions and areas of investigation should be explored. However, the precautionary principle should apply and a careful and measured scrutiny of the science must be maintained to avoid increasing environmental (or health) risks to the food system. This is a critical issue for future policy as the unintended side-effects of a premature technology release could lead consumers to reject other possible contributions from science and technology. Careful handling and governance is required.

For technological developments to become useful 'innovations', their social and cultural contexts need to be understood as well as their commercial applicability. The relationship between emerging technologies and their social acceptance (rejection or endorsement) is particularly important in relation to food, where people are immediately and physically impacted if wrong judgements are made.

!	*Urgent need for major change means that all possible solutions and areas of investigation should be explored. These must encompass technological change, system change and behaviour / life-style change*
!	*The food system is very vulnerable and already exposed to many risks – increasing risk to the environment or human health should be avoided*
!	*Insufficient caution in early release of emerging technologies could lead to consumer backlash against later technologies*
!	*Potential for conflict between producers wishing to use GM crops and those who don't*
!	*The need for change is now – priority is uptake and transfer of existing, proven and safe, technologies and techniques that are already available*
	Governance of emerging technologies – particularly how to manage entry into the food system
	Environmental impacts of genetically modified crops, including on soils and surrounding biodiversity
	Potential environmental impacts of nanotechnology
	New applications and reconfiguration of existing technologies

At this time, it seems that the key technology groups influencing change in all systems of production and consumption are likely to be: advanced information and communications technologies (ICT); biotechnology; and nanotechnology Rapid advance in these areas has the

[417] ETC Group (2004), *Down on the Farm: The Impact of Nano-Scale Technologies on Food and Agriculture*, ETC Group, Ottawa from http://www.etcgroup.org/en/materials/publications.html?pub_id=80, p1

potential to increase the efficiency of existing technologies and systems, and could reduce the environmental impacts of food production and consumption. Change will also come from the continuing diffusion of technologies that already exist as they are used in new ways, particularly information technology and mobile communications.

3.1.1. Technological Possibilities

Information and Communications Technology (ICT) includes all technologies that enable communication and information processing. For the food system, increasing use of ICT will include technologies and techniques for gathering data (eg. using sensors and database systems to improve water efficiency), modelling eco-systems (and other systems such as consumption / production systems), and improving stock management and logistics.

Biotechnologies are technologies that use and/or manipulate living organisms such as cells, bacteria and yeast, or parts of these ie. genes and enzymes. 'White biotechnology' refers to the use of biotechnologies in industrial processes (eg. enzymes and yeasts) and may have benefits for food processing. Agricultural biotechnology (adaptation or engineering of agricultural crops and livestock) is sometimes known as 'green biotechnology'. Genetic modification is a specific category of biotechnologies in which the genes of an organism are engineered to give desired characteristics – genetic modification of food crops and livestock is not the only type of biotechnology relevant to food systems.

Nanotechnology is the manipulation of atoms and molecules to create new materials, characteristics and products. Internationally research funding for nanotechnologies is increasing rapidly, and nanotechnologies have potential to vastly change many technologies and systems. The convergence of ICT, biotechnology and nanotechnology could revolutionise science and technology. It is anticipated that "over the next two decades, the impacts of nano-scale convergence on farmers and food will exceed that of farm mechanisation or of the Green Revolution."[418]

There is potential for emerging technologies to contribute to a lower impact food system. A 1999 study examined ten national foresight studies, to identify social, economic and environmental trends in the agro-food sector, and the development needed to respond to those trends.[419] This study concluded that the main drivers of technological change in the agri-food system would be environmentally-friendly food production, higher yields for higher populations, and competition for new food technologies and niche markets.[420] Table 3-3 summarises some of the projected / possible benefits of these technology developments to reducing the environmental impacts of the food system, as identified by Zappacosta and Paloma's study and a range of other sources.

Table 3-3: Existing and Emerging Agro-Food Technologies[421,422]

	ICT	Biotechnology	Nanotechnology
Environmentally friendly	• Manufacturing control (increased resource efficiency) • Field conditions monitoring • Improved understanding of demand – less waste • RFid tags to track food products and allow	• Reduction in use of fertilisers and pesticides • Crops genetically resistant to water scarcity • Pathogen and microbe detection • White biotech – packaging, industrial processes	• Could assemble food from carbon, hydrogen and oxygen atoms present in the air as water and carbon dioxide • Reduce pesticide and antibiotic use

[418] ETC Group (2004), *Down on the Farm: The Impact of Nano-Scale Technologies on Food and Agriculture*, ETC Group, Ottawa, accessed July 2007, http://www.etcgroup.org/en/materials/publications.html?pub_id=80, p1
[419] Zappacosta, M. and Paloma, S. (1999), "Agro-Food: Food for the Future", *Foresight*, vol. 1, no. 6, p576
[420] Ibid, p581
[421] Zappacosta, M., and Paloma, S. (1999), "Agro-Food: Food for the Future", *Foresight*, vol. 1, no. 6
[422] Horizon Scanning Centre (2006), cited in UK Cabinet Office (2008), *Food: An Analysis of the Issues*, The Strategy Unit, London, p61
[423] ETC Group (2004), *Down on the Farm: The Impact of Nano-Scale Technologies on Food and Agriculture*, ETC Group, Ottawa, accessed July 2007, http://www.etcgroup.org/en/materials/publications.html?pub_id=80, p44

	transmission of info – could include emissions, water use etc.[423]	• Enhanced biofuel crops and possibilities	• Improve supply chain efficiency
Increased yield	• Improved food preservation	• Enhanced crop production • Increased digestibility • Control ripening for reduced spoilage	• Reduce food waste – packaging that stops food sticking to the sides of containers
New products for industrialised markets	• Functional food • Remote / internet shopping	• Enhanced nutrition • Reduce fat absorption (eg. in potatoes) while frying • Reduce allergic responses eg. to wheat	• 'Smart' foods that interact with consumers • 'Smart packaging' that detects when food is spoiled • Reduce food-borne disease

3.1.2. Consumer concerns

Public trust in the new technologies is a key issue . . continued challenge can be expected[424]

Technological developments cannot be understood in isolation. To become useful 'innovations' their social and cultural context and commercial applicability need to also be understood – there is no independent 'technical system' that can be analysed for its impact *on* society. The interaction between emerging technologies and social acceptance / endorsement is particularly important in relation to food, where people are immediately and physically impacted if insufficiently safe technologies affect what they eat.

People may come to accept genetically modified (GM) crops as an essential part of future sustainable agriculture, although there is still strong consumer resistance. The CSIRO acknowledged in 2004 that although there was no evidence of GM food causing adverse health effects in humans, they were relatively new to the diet (eaten in the US since 1993 and Australia in processed foods since 1996) and effects may become evident in time.[425] By 2007 emerging evidence of health impacts in the United States and Canada was emerging and fuelling community resistance.[426]

There are also on-going debates about the possibility of GM crops exacerbating environmental risks to the food system. For example cases of modified genes transferring to wild populations or unmodified crops (genetic pollution) have already occurred – herbicide resistant weeds are now a severe problem in the United States,[427] and super-weeds have also been detected in the UK.[428] Resistant insects may also evolve due to constant resistance pressure.[429] Claims that genetically modified crops will reduce pesticide and fertilizer use may not be supported by early developments which have focused on 'round-up ready' products, which enable more spraying.

The risks of nanotechnology are potentially even greater as they are less understood and 'societal concern' is increasing sharply. Nanotechnology is already being used in some food products, with very little governance or safety testing, and raising significant alarm, as examples of how material properties can change dramatically just through changes in size become evident.[430] A 2004 study

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[424] UK Cabinet Office (2008), *Food: An Analysis of the Issues*, The Strategy Unit, London, p61, http://www.cabinetoffice.gov.uk/strategy/work_areas/food_policy.aspx
[425] CSIRO (2004), *Gene Technology in Australia - GM Food Safety Q&A*, Australian Commonwealth Scientific and Industrial Research Organisation, http://www.csiro.au/pubgenesite/foodsafe_faqs.htm
[426] Smith, J. (2007), *Genetic Roulette: The Documented Health Risks of Genetically Engineered Foods*, Chelsea Green.
[427] Friends of the Earth International (2007), *Agriculture and Food: Who Benefits from GM Crops? - An Analysis of the Global Performance of GM Crops (1996 - 2006)*, Friends of the Earth International Secretariat, Amsterdam, p86
[428] Ibid.
[429] Rissler, J. and Mellon, M. (1996), cited Heller, M.C. and Keoleian, G.A. (2000), *Life Cycle-Based Sustainability Indicators for Assessment of the US Food System* (No. CSS00-04), Centre for Sustainable Systems, University of Michigan, p10
[430] ETC Group (2004), *Down on the Farm: The Impact of Nano-Scale Technologies on Food and Agriculture*, ETC Group, Ottawa, accessed July 2007, http://www.etcgroup.org/en/materials/publications.html?pub_id=80.

by the ETC group cites many other studies concerning toxicity affects of nano-particles, both to humans and the environment, for example: [431]

- Nanoparticles as a class appear to be more toxic as a result of their smaller size. They can also move more easily into the body, across protective membranes such as skin, the blood brain barrier or perhaps the placenta;
- One study showed that fish exposed to small amounts of manufactured carbon nanoparticles suffered "rapid onset of damage in the brain" and half the water fleas living in the water also died; and
- Nanoparticles have also been shown to move through soil in unexpected ways, sometimes carrying other substances with them. Increasing recognition of the cumulative affects of other substances in the food chain (including agricultural chemicals), would suggest that extreme caution should be taken in the release of nanoparticles into the environment.

Environmental groups are also raising concerns about the introduction of nanotechnologies into the food system. A Friends of the Earth report released in March 2008 found 104 food and food-related products (such as packaging) containing nanotechnologies available on international markets. However as there are no requirements for nanomaterials to be labeled, they suggest that there are probably many more. They also state that "still no nanotechnology-specific regulation or safety testing required before manufactured nanomaterials can be used in food, food packaging, or agricultural products."[432] The report refers to a significant body of scientific work demonstrating that nanomaterials in food and agricultural products introduce new environmental and health risks into the food system, and calls for a "moratorium on the further commercial release of food products, food packaging, food contact materials and agrochemicals that contain manufactured nanomaterials until nanotechnology-specific safety laws are established and the public is involved in decision making."[433]

The need to reduce the vulnerability of the food system to environmental challenges means that all possible solutions and areas of investigation should be explored. However, the precautionary principle should be considered and a careful and measured scrutiny of the science must be maintained to avoid increasing environmental (or health) risks to the food system. Furthermore, side-effects of premature technology release could lead consumers to reject many other possible future contributions – careful handling and governance is required.

There will undoubtedly be promising advances in the fields outlined above that make significant contributions to sustainable and healthy food systems.

3.2. New Production Strategies

Producers are responding to challenges and risks, finding ways to increase the resilience of their farming and food production while improving terms of trade and/or opening up new opportunities.

Some of the strategies outlined in this section have also been described within Section 2, as techniques that are being used for environmental remediation or possible responses to particular environmental impacts / risks. Their further inclusion within this section signifies ongoing and active innovation by producers seeking to develop new solutions, often in conjunction with direct consumer interest.

The strategies included in *3.2.1 Environmental Management* include specific practices aimed at reducing overall environmental impact of production and increasing sustainability of the

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[431] Ibid, p7

[432] Friends of the Earth (Aus, EU, and US) (2008), *Out of the Laboratory and onto Our Plates: Nanotechnology in Food and Agriculture*, edited by Miller, G. and Senjen, R., Friends of the Earth Australia.

[433] Ibid, p3

enterprise. In some cases this can enable certification and retail premiums as consumer interest increase.

3.2.2 Diversification explores the possible contributions to innovation, resilience and food security of diverse scales of farming, production systems and products.

3.2.3 Reducing Reliance on Inputs summarises trends, arguments and available evidence related to organic and biological farming systems. Strong consumer interest in organics is driving rapid growth in this sector, and producers wishing to reduce reliance on increasingly expensive inputs are also looking for new methods (some of which are developing through biological farming).

The boundaries between these three sections are unclear – many of the strategies mentioned may be being explored across all three.

3.2.1. Environmental Management

The purpose of agriculture is to feed and clothe people. Two things will guarantee this happens with maximum efficiency. Firstly, farming must be prosperous and secondly, soil fertility must constantly improve.[434]

We can learn to use the power of nature rather than fighting it.[435]

Summary and Recommendations:

Improved environmental practices are now being applied more broadly within existing production systems. Farmers are working independently and in small groups to explore more sustainable, resilient and profitable farming methods that do not rely on great capital investment or increasing farm size.[436]

Increasing consumer interest and concern about how food is produced (from both an environmental and ethical perspective) have created opportunities to reward producers for doing things that were previously considered a cost (eg. fencing off creeks and remnant vegetation, reducing stock numbers, decreasing or eliminating synthetic fertilisers and pesticides, and so on). Gippsland beef producers who implement an (independently audited) Environmental Management System (EMS) and supply *Enviromeat*[437] can receive a 25% premium for their meat.[438] Some Australian farmers are also working with polycultures, perennial species (including native grasses), cover crops, reduced tillage, rotational / cell grazing, keyline techniques and mineral and trace element balancing to develop innovative systems suitable to their conditions. One example of such an innovation is pasture cropping,[439] which is claimed to be 27% more profitable than conventional agriculture, whilst also improving soil and regenerating landscapes.[440]

!	*Important innovations are emerging that do not require large capital investments, and depend more on knowledge and understanding of particular landscapes; these need to be systematically captured, evaluated and communicated*
!	*There are no simple answers – there is a need to encourage and support producers to experiment and share both successes and failures*
	Evaluate benefits of specific methods in Victorian conditions – which ones work best where and why? Measurement and evaluation through controlled trials
	Further development and application of existing methods above, underpinned by research
	Certifications / branding that can take new issues into account – improved soil health, water use, emissions generation, potentially carbon sequestration

[434] P.A. Yeomans, cited www.permaculture.biz
[435] Stapper, M. (2006), *Soil Fertility Management: Towards Sustainable Farming Systems and Landscapes*, CSIRO Sustainability Network Newletter - 61E, http://www.bml.csiro.au/susnetnl/netwl61E.pdf
[436] For an example, see Birchip Cropping Group – Agricultural Community Innovators, www.bcg.org.au
[437] Enviromeat is a premium beef brand that requires producers to implement an EMS covering: protection of biodiversity and water quality, management and protection of soil health and organic matter, and control of weeds and vermin.
[438] *Future Farming in Gippsland*, available via www.enviromeat.com.au
[439] Sowing crops directly into perennial pastures (usually native) – benefits of polycultures, cover crops, perennial plants etc
[440] Seis, C. (2006), "Pasture Cropping as a Means to Managing Land", *Australian Organic Journal*, Winter 2006.

Some of the techniques being used to improve existing production systems were mentioned in Section 2, but it was noted that they are often considered as costs or added burdens on already stressed farmers and production. Some producers are now actively pursuing the development of new techniques and strategies specific to their conditions, which can increase the viability and sustainability of their farming as well as profitability. Innovation driven by producers and producer groups is leading to new possibilities for agriculture,[441] and consumer interest in the environmental impacts of food is now adding value to some of these practices.

Enviromeat – South Gippsland Beef

GippsBeef is a meat producers' alliance that produces two premium brands, Gippsland Natural and Enviromeat. These brands are capitalising on consumer demand for grass-fed beef with no artificial hormones, produced in an environmentally responsible way. The Enviromeat brand requires producers to implement an EMS which covers:

- Protection of biodiversity and water quality
- Management and protection of soil health and organic matter
- Control of weeds and vermin

To be an accredited supplier to Enviromeat, producers must have their EMS certified by external auditor to ensure meat quality and the integrity of the environmental management system.

Enviromeat farmers Ross and Sue Svenson have paid particular attention to protecting remnant vegetation and revegetating significant areas – particularly along creeks and riparian zones. These activities have improved capital gains on the property, reduced the amount of fertiliser lost as run-off, and helped to keep water clean for stock. They have also found that using legumes (such as snow peas and clovers) is a much quicker and cheaper way to renovate pastures than many other conventional methods.

In Gippsland, farmers who implement an EMS and supply Enviromeat are rewarded with a 25% increase in the price paid for their meat ($4.00 per kg vs $3.00 per kg for conventional meat).

Source: *Future Farming in Gippsland*, available via www.enviromeat.com.au

As discussed in *2.1.2 (Soil Carbon)*, techniques that improve living and organic matter in the soil contribute to carbon sequestration, as well as having other benefits. Most of the practices outlined below reduce soil disturbance and contribute to carbon sequestration, and are likely to further increase in value (especially if soil carbon sequestration is accounted for in emissions trading or offset schemes).

Polyculture cropping is where crops are grown in mixtures of species rather than single species stands (monocultures). This can increase yields as more than one harvest / product can be obtained from the same amount of land, and the diversity of species (different heights and different root patterns) can mean that they get more light and more efficient use of the soil. They also tend to limit the need for fertilisers and chemicals and have been shown to significantly reduce vulnerability to pests, pathogens and weeds.[442]

Perennial crops and pastures are those that grow for several seasons before they die (as opposed to annual crops such as cereals, wheat and rice whose lifecycle is completed in one growing season). Productive perennial crops include fruit trees, berries, perennial grasses (most native grasses are perennial) and some forage crops like alfalfa.[443] The use of perennial crops has benefits for soil structure as they: do not require tillage, build more extensive root systems and do not expose the soil. The use of trees within crops or pasture (agroforestry) or perennial grasses and forage crops is being increasingly explored to gain these benefits.

The use of new perennial crops is also being explored, most notably by the Land Institute in Kansas

[441] See the Birchip Cropping Group – Agricultural Community Innovators (www.bcg.org.au) for an example of a community-led initiative, striving for (and achieving) the development of innovative solutions. All findings, technologies and practices developed by BCG are freely available and actively promoted to producers. Beyond improving productivity, BCG also seeks to strengthen rural communities and improve long-term sustainability of agriculture.
[442] Raman, A. (2007), *Managing Agro-Ecosystems, Course Notes - Module 3*, Charles Sturt University, Faculty of Science, p10
[443] Petersen, R. (1994), *Agricultural Field Experiments: Design and Analysis*, CRC Press, Google Books http://books.google.com/books?id=gKCJFk2E01UC

US,[444] which is aiming to transform major grain crops into perennials to develop ecologically stable cropping systems that maintain high yields based on the stable ecology of prairie ecosystems.[445] The use of perennial systems would also reduce fossil fuel use as fewer passes over the land are required (no need to plough and sow every year) and the deep root systems would increase resilience to fluctuating weather.

Cover cropping is where annual or perennial herbaceous plants are grown under crops to keep the soil covered. Annual plants can be mulched into the soil to become organic matter and perennial plants can be maintained (with benefits as above). The additional roots and organic matter improve air and water flow through the soil, improving soil structure, and reducing erosion and water run-off. Cover crops can increase soil fertility where nitrogen-fixing crops are used, and provide support for beneficial insects (those which compete or prey on pests).[446]

Crop rotation involves different crops being grown in succession, in carefully designed sequence, on the same land. Crop rotations influence soil fertility and survival of plant pathogens, soil erosion and microbiology and biodiversity. When used in organic systems they are designed to build resilience to pests and diseases ie. crops of the same species or with similar pest / disease problems are never grown in succession.[447] Crop rotation is increasingly being applied in conventional systems.

Phase cropping is an example of a crop rotation being developed and used in Australia, where summer active lucerne is rotated with a grain crop. This method has a number of benefits, including: improved soil structure and reduced water infiltration to groundwater (salinity impact).[448] Rotations can range from a number of years to a seasonal rotation, interspersing summer-active lucerne with winter-active crops.

Reduced / minimum tillage includes a number of methods designed to reduce disruption to the soil. As discussed throughout Section 2, soil disruption breaks down structure and releases carbon. Minimum tillage reduces the number of times the paddock is ploughed and techniques such as direct drilling (where the seed is directly drilled into the soil without the soil being disturbed) can mean that the soil is never ploughed at all.

Integrated pest management can reduce the amount of chemical pesticide applied by making use of biological control as well as or instead of chemicals. It includes developing knowledge about the pest and therefore understanding when in lifecycles chemicals may be most effective. It also includes learning about particular pests and encouraging natural predators and disagreeable conditions.[449]

Rotational grazing / Pasture rotation means that grazing animals are limited to small area for small periods of time and then repeatedly moved. Intensively grazing one area at a time (rather than having animals on all areas) enables areas to be 'rested' in between grazing rotations. This allows the plants to recover and grow (including developing better root systems which contribute to soil health) and reduces soil compaction of particular areas.

Seed saving is the practice of capturing and storing seed from crops for use the following year. Some sources suggest that this practice has become less common as producers have moved towards highly bred hybrid crops from seed companies rather than making use of locally adapted

[444] See http://www.landinstitute.org
[445] Glover, D., et al. (2007), "Future Farming: A Return to Roots?", *Scientific American*, accessed 29 January 2008 http://www.landinstitute.org/pages/Glover-et-al-2007-Sci-Am.pdf
[446] Raman, A. (2007), *Managing Agro-Ecosystems, Course Notes - Module 3*, Charles Sturt University, Faculty of Science, p11
[447] Ibid, p13
[448] Robertson, M. (2006), *Lucerne Prospects: Drivers for widespread adoption of lucerne for profit and salinity management*, CRC for Plant-Based Management of Dryland Salinity, Perth, p12
[449] NOVA (2001), *Integrated pest management – the good, the bad and the genetically modified*, Australian Academy of Science, http://www.science.org.au/nova/041/041key.htm

varieties, which could be contributing to the loss of valuable genetic material.[450] However, it is also believed that many Victorian wheat farmers do keep seed from year to year and only buy seed in when a new variety comes out that they want. Different farmers might upgrade more or less regularly.[451] Community seed saving is also increasingly popular (*3.3.4 Urban Agriculture)*.

Mineral & Trace Element Balancing is based on optimising nutrition and energy flows within the soil to maximise soil life, plant/crop, animal and ultimately human health – mainly based on the work of William Albrecht and Carey Reams.

Landscape hydrology – there are a number of management systems that aim to improve management of water in Australian landscapes. They aim to increase resilience to drought by improving water storage in soils and vegetation (reducing evaporation) and designing systems that maximise productivity of the available water within farming landscapes. The two most well known of these are keyline and natural sequence farming.

Keyline farming is based on the work of P.A. Yeomans, who first developed and promoted this holistic farm design method through the publication of *Water for Every Farm* in 1954. It is a farming method enabling control and redirection of run-off water to maximise its use as it travels through the farm and to enhance the development of topsoil. Its key features are: identification of how to site dams high in the landscape to enable gravity fed irrigation, and how to increase the water holding capacity of the land (by building healthy topsoil and ensuring subsoil infiltration of water).[452]

From its initial inception in the 1950's, keyline has undergone significant development and ongoing innovation. Leading Australian keyline practitioners are now making use of GIS, CAD and GPS to apply keyline principles to broadacre systems and their expertise is increasingly sought internationally.

Natural sequence farming is promoted as a "rural landscape management technique aimed at restoring natural water cycles that allow the land to flourish despite drought conditions. The technique is based on ecological principles, low input requirements and natural cycling of water and nutrients to make the land more resilient."[453] It requires observation of how water used to move through Australian landscapes compared to how it does now. It then attempts to rebuild / simulate native water systems such as floodplains, to capture water in soils and replenish nutrients in agricultural landscapes. Its proponents claim that it helps to manage salinity, reduces the need for weed management (by valuing the ecological functions performed by weeds) and captures organic matter to rebuild soil – rather than having it all washed away down eroded waterways in flood periods.[454]

Natural Sequence Farming was developed by a NSW farmer called Peter Andrews, has received a large amount of attention since his work was promoted on the ABC's Australian Story and is now the subject of further research. Elements of Natural Sequence Farming are conceptually similar to riparian land management – management of "the area of land that adjoins, regularly influences or is influenced by a river."[455]

Pasture cropping is an Australian innovation that makes use of a number of these principles – by sowing crops directly into (usually) native perennial pastures the producers obtain crop and pasture for grazing from the same land at the same time. This system demonstrates the benefits of polycultures as it gives the producer more than one use of the same land, whilst also: keeping

[450] ABC (2007), Gardening Australia, Seed Collecting Factsheet, accessed 26 July 2007, http://www.abc.net.au/gardening/stories/s241173.htm
[451] Reid, W. (2008), personal communication from employee of the Australian Wheat Board, 4 February 2008.
[452] Yeomans, K (2007), *Yeomans Keyline Design*, accessed 8 April 2008, http://www.keyline.com.au/ad1ans.htm
[453] Natural Sequence Farming (2007), accessed February 2008, http://www.nsfarming.com/
[454] Andrews, P. (2006), *Back from the Brink: How Australia's Landscape Can Be Saved*, ABC Books, Sydney.
[455] DNRE (2002), cited in West Gippsland Catchment Management Authority (2008), *Riparian Land Management*, www.wgcma.vic.gov.au

cover under the crops, making use of perennial plants to improve soils, contributing to reduced inputs and improving pest management. It can be used in conventional or organic systems (or anything in between) and it has been suggested that "pasture cropping is 27% more profitable than conventional agriculture, coupled with great environment benefits that will improve the soil and regenerate landscapes"[456] – see case study below.

NB. Pasture cropping may not be as feasible to farmers in Victoria as it is further north, as fewer grasses that grow during summer are available. However, phase cropping (outlined above) is based on a similar concept and used in Victoria, replacing summer active grasses with summer active lucerne.

Colin Seis – 'Winona', Gulong, New South Wales

Colin Seis runs a mixed farming operation (sheep and cereal crops) on 840 hectares in the Central Tablelands of NSW. In response to difficult conditions in the late 1970's and an inability to afford high inputs, his family decided to stop using superphosphate. Realising that the original vegetation of the land was native grassland with scattered trees, they decided to allow the native pasture species (adapted to the area) to return. At the time they suspected that these native species must have played a role in controlling ground water and salinity.

From this first step in 1979, Colin has now experimented with and implemented the following techniques:
- Stopped fertilising and allowed native pasture species to regenerate
- Aggregated sheep into two large mobs
- Introduced 'pulse grazing' where sheep spend only a few days on a pasture
- Pasture allowed to rest for three months afterwards
- Zero tillage
- Ground cover maintained at all times
- Winter crops sown directly into summer-growing native pastures
- Over 12,000 trees planted

The results of these changes are:
- Computer modelling showed '**Winona' 25% more profitable than a traditional farm**
- Profitability increases come from reduced inputs
- Now run the same number of sheep as when using high inputs
- Zero costs in pasture seed and maintenance
- Reduced costs in labour, fertiliser and weed control
- Huge increases in biodiversity
- Reduction in water tables measured by piezometers.

Colin's advice to other farmers wanting to move to more sustainable practices is
Don't spend a cent. Put your animals into large mobs and start moving them around the infrastructure you already have. Focus on native perennial pastures – they've evolved here and obviously they are the best plants for Australia.

Source: LandCare Farming Case Study, *Pasture cropping brings up profit by an incredible 25%*, https://wic004tv.server-secure.com/vs154616_secure/resources/seis.pdf

3.2.2. Diversification

Summary and Recommendations:

One important aspect of environmental management and food security is diversification. Maintaining diverse crops and ground cover is a way to increase resilience in the face of unpredicted weather conditions and pests, with producers avoiding situations in which they lose their entire crop/ income because of extreme weather or pest infestation.

Large farming systems and agribusiness has provided a path to continual productivity increases and the associated capital investments required to retain viable and internationally competitive operations. This has meant the consolidation of many small, family farms and the consequent movement of farmers off the land.

Changing conditions, including increasing environmental risks and vulnerabilities, may see another (complementary?) trend with a viable new role for smaller farms with diverse production systems. These farms may be more able to survive in a market that emphasises security and resilience in the total food supply, with

[456] Seis, C. (2006), "Pasture Cropping as a Means to Managing Land", *Australian Organic Journal*, Winter 2006, www.bfa.com.au/_files/x06aoj_042-43.pdf

different organisational systems linking producers and consumers. A network of smaller independent farms may be more likely to develop innovations that respond to local conditions, using information systems to communicate knowledge about management of intensive agricultural systems and new methods of sustainable food production. Diversification is also important in development and application of technologies; a concentrated focus on particular technology trajectories can reduce openness to imaginative innovation.[457]

The variety of products and methods being experimented on by small / medium farms could potentially support the security of food supplies in changing conditions. Diversification within single enterprises (including the productivity and environmental benefits of polycultures and mixed farms – integrated livestock / cropping systems) is likely to provide different types of solutions that can increase the overall resilience of Victorian food. Gippsland Natural (*EnviroMeat*) has demonstrated how effectively groups of smaller farmers can produce quality food with high market value.

There is a strong movement in the USA for smaller farms, partially for the social and environmental, as well as local economic benefits of keeping more people active in landscapes.[458] The potential importance to food security of maintaining diverse production systems and products (and increasing the contribution from small farms) is still to be systematically explored in Victoria. The support services needed for farmers with diverse smaller scale systems, or different types of farming enterprise may well differ from those developed for larger, export-oriented farmers.[459]

!	*Diverse small / medium sized farms could increase the resilience of the food system*
!	*The knowledge of local bio-regions and ecosystems that is held by small / medium farmers could be important in adaptation to climate change*
!	*Diversification in systems, products and technologies enables more widespread innovation and increases resilience*
🕮	*How important are diverse farms to Victorian food production / security? Key questions include:* ➢ *What types of products? How is it being distributed? How viable are these businesses?* ➢ *What production systems / methods are they using?* ➢ *What are their relative efficiencies and environmental impacts?* ➢ *What is the potential contribution to food security?*
🕮	*Analysis of the contribution of smaller farms and more farmers in the landscape to health and social objectives and adaptation to climate change*
⚡	*Extension services for entrepreneurial small farmers to develop new products and reach new markets*
⚡	*Production and distribution systems more suited to smaller land areas and farming enterprises*
⚡	*Adaptation of agricultural knowledge and services to smaller-scale, diverse production systems*

As discussed in Section 1, the dominant Victorian trajectory is a move towards large agribusiness style farming systems. This is considered necessary to achieve the continual productivity increases and associated capital investments required to retain a viable and internationally competitive operation. It has meant the movement of many small / family farmers off the land, and/or the transition of a large number of small farms to a small number of large farms.

In parallel with the movement towards larger agribusiness enterprises, there is also an increase in 'lifestyle' farming. This can involve breaking up previous farming enterprises into smaller blocks in amenity landscapes on which agricultural activities characteristically supply only a small proportion (if any) of the income. This type of 'small farmer' is now managing a growing amount of land in Victoria and while the importance of this is beginning to be recognised in terms of land management (risks and opportunities for biodiversity and weed/pest management), their potential contribution to Victoria's food system has not been considered.[460]

[457] Reeve, I. (1992), "Sustainable Agriculture: Problems, Prospects and Policies," *Agriculture, Environment and Society: Contemporary Issues for Australia*, edited by G. Lawrence, Vanclay, F. and Furze, B., MacMillan, Melbourne, Australia, p211
[458] Francis, J. (2002), *Recognising the Value and Potential of Small Farms: Learning from the USA*, Department of Primary Industries, State of Victoria, pviii
[459] HAWCAEP 2001, cited in Ibid., pix
[460] Francis, J. (2002), *Recognising the Value and Potential of Small Farms: Learning from the USA*, Department of Primary Industries, State of Victoria.

While large-scale farms are believed to be the most effective systems for providing produce for export, some of the challenges outlined above (in Section 2) may mean that diverse small and medium sized enterprises have a changing role. They could be increasingly important in providing diverse and resilient food supplies.

Diverse scales of farming

How a society feeds itself and utilizes its natural resources determines how long it will last . . the quality of rural life and the existence of many rural communities depend on a mix of different-sized farms.[461]

Farms with an estimated value of agricultural operations (EVAO) greater than $22,500 are defined as commercial (by the ABS), and there were just over 100,000 of them in 2001. Sub-commercial farms as those with EVAO of between $5,000 and $22,499, and there were 33,674 of these in Australia in 2000. These sub-commercial farms are estimated to operate almost 16.6 million hectares of land, but the owners / residents typically make most of their income off the farm.[462] Victoria has many of these establishments and although they are loosely referred to as 'small farms', this encompasses a broad range of enterprises and a more specific description would be desirable.[463]

There is a strong movement in the USA to retain small and medium sized farms, based on an understanding that small farms mean more people in landscapes; providing support for community services and increasing social capital. They can enhance cultures, aesthetics and environmental values in their communities, and contribute wealth, employment and tourism opportunities to their local economies.[464] Although the definition of a small farm in the USA is much larger than a small farm in Australia,[465] it is likely that some of the documented advantages of small farms in the USA are translatable to small / medium sized enterprises in Victoria.

Farmers such as those on lifestyle blocks are developing food production enterprises that can supplement their external income, or potentially be grown into primary businesses. These are less likely to be intensive systems, but may make up a sizable proportion of organic fruit and vegetables, olives and olive oil, wine, cheese and beef. These enterprises may be significant contributors to farmers' markets particularly in their establishment phase (see *3.3.2 Farmers' Markets*).

Having a diverse range of farming styles and systems can increase the resilience of food supplies as they will be resistant to different kinds of risk. For example, the highly technical water efficient systems being developed and used in corporate agribusiness are very different from landscape hydrology methods. Large corporate enterprises are likely to profit from systems that rely on technical investment, whereas smaller / medium enterprises can make use of intimate knowledge of landscapes and observation of microclimates. Diverse approaches will develop different knowledge and skills, increasing overall resilience.

Research has been conducted in the USA that suggests that the efficiencies of small and medium sized farms might be as much as those of very large farms.[466] Similar research does not seem to

[461] Duffy, M. (1997), '"Are Big Farms More Efficient?"' *Leopold Letter - Newsletter of the Leopold Centre for Sustainable Agriculture*, partial transcript of testimony to US Secretary of Agriculture Commission on Small Farms 1997, http://www.leopold.iastate.edu/pubs/nwl/1997/1997-4-leoletter/duffystructure.htm

[462] Hooper, S. et al. (2002), cited in Francis, J. (2002), *Recognising the Value and Potential of Small Farms: Learning from the USA*, Department of Primary Industries, State of Victoria

[463] Francis, J. (2002), *Recognising the Value and Potential of Small Farms: Learning from the USA*, Department of Primary Industries, State of Victoria, p1

[464] Ibid, pviii

[465] In the USA, a small farm is defined as one in which "annual gross receipts under US$250,000, on which day-to-day management and labour are provided by the farmer and/or the farm family who owns the production or owns, or leases, the productive assets," which encompasses 91 per cent of all US farms – Hooper, S et al. (2002), cited in Ibid, p5

[466] Duffy, M. (1997), '"Are Big Farms More Efficient?"' *Leopold Letter - Newsletter of the Leopold Centre for Sustainable Agriculture*, partial transcript of testimony to US Secretary of Agriculture Commission on Small Farms 1997

have been done in Victoria or Australia – there is no information on the relative food production capability, relative water and energy use, or environmental quality of different scales or types of farming in Victorian landscapes.

Diverse products

A number of the techniques outlined in *3.2.1* make use of diversity to increase resilience and/or yield (eg. polycultures, cover cropping, crop rotation). Diversity within a farm can maximise synergies and increase efficiency ie. making use of different levels of soil moisture, changing light access to crops, providing biodiversity that supports native biodiversity and pest predators. Diversification can be made more productive / profitable by active design of how the systems interact – this kind of design may be more suited to smaller enterprises.

The general principle of maintaining diverse plant species and ground cover also increases resilience to adverse weather conditions and pests, as producers are less likely to lose their entire income. It may also increase resilience to fluctuating international markets and mean that outputs from one production stream can be used as valuable inputs to another (eg. animal manure).

The term 'mixed farming' is generally used to describe farming which makes use of relationships between animals and crops, in particular the exchange of resources between them. Mixed farming can also reduce risk to an individual farmer because all their output is not concentrated in one product. Pasture cropping (as described above) is an example of an Australian mixed farming technique. Other mixed farming systems currently being explored include aquaponics – where nutrients from aquaculture systems are recycled into horticultural production or other use.

Diverse systems

Unpredictability in resource availability and climate change impacts will mean that different types and systems of production will enable continued production in changing circumstances. For example, indoor production of some foods may increase resilience to extreme weather events (see also *3.3.4 Urban Agriculture*).

For some food types intensification and ICT have combined to make diverse systems such as hydroponics, aquaponics and aeroponics viable and competitive. Thse systems may also make an increasingly important contribution to secure food supplies.

3.2.3. Reducing Reliance on Inputs

Summary and Recommendations:

Production systems that seek to minimise or eliminate the use of synthetic chemical inputs are experiencing rapid growth around the world. The major systems considered in this discussion paper are 'organic' and 'biological'. Organic systems have an absolute ban on synthetic fertilisers, pesticides and herbicides. Biological farming (similarly to 'natural farming' and 'regenerative farming') seeks to actively improve soil fertility and reduce use of synthetic chemicals, but allows use of microbe-friendly fertilisers and herbicides. Biological systems aim to actively regenerate soil biology and fertility, and are being used in conjunction with conventional farming. Biodynamic farming is a subset of organic farming, which additionally focuses on the farm as a closed, self-nourishing system[467,468] where (ideally) everything needed for production should be provided from the farm (in current practice this is often not be the case as pre-prepared biodynamic formulations are now available).

In Australian retail sales, organic lines are growing fast. So is export market potential; the Asia-Pacific region's

[467] Lorand, A. (1996), *Biodynamic Agriculture — a Paradigmatic Analysis*, Ph.D. Thesis, Pennsylvania State University.
[468] Diver, S. (1999), *Biodynamic Farming & Compost Preparation*, ATTRA - National Sustainable Agriculture Information Service, Publication #IP137

demand for organics is growing faster than any other market in the world, posting a 28% annual growth rate.[469] The Australian organics industry is currently on a 'recruitment drive' for farmers to help it keep up with its growth rate of 25 per cent a year.[470] Despite industry growth, both domestic and export market demand for certified organic produce still exceeds the Australian supply of organic produce.[471]

Adoption of biological, natural and regenerative farming methods is linked to the increasing costs of agricultural inputs. The techniques that have been developed through these systems over the last 20 years can be used to increase soil and plant resilience and therefore reduce dependence on fertilisers, pesticides and other inputs. Biodynamic, organic and biological practices are also being adopted in some industries (eg. viticulture) because they are believed to produce a higher quality product.[472]

There is ongoing vigorous debate about the environmental benefits of low or no synthetic input food production (including organics and biological farming). There are many international studies exploring the relative benefits of different systems, and results vary according to food type, production system and location. While insufficient evidence exists to say that all organic production is better for the environment than all conventional production, there are substantiated benefits (biodiversity, land and soil health, water efficiency) for many food types.[473,474] The extent to which these translate into overall lifecycle benefits is not clear. It is most likely that for many foods the overall environmental impacts of organic produce are lower than those conventionally farmed, particularly when water use and off-site energy impacts are accounted for. [475] However, the relative benefits of different systems need to be assessed for particular products rather than in general, and a full system analysis is required which considers possible trade-offs eg: productivity per acre and the impacts of different tillage methods and fertilizers on the sequestration of soil carbon and soil structure.

The potential contribution of organic systems to greenhouse gas mitigation and to climate change adaptation is receiving increased attention. A 2008 study that conducted a comprehensive review of the relevant peer-reviewed scientific literature, found that organic farming could serve as a 'quick-win' policy option in carbon offsetting markets. The study concluded that:[476]

> *organic agriculture has much to offer in both mitigation of climate change through its emphasis on closed nutrient cycles and is a particularly resilient and productive system for adaptation strategies.*

There is substantial international evidence that low/no input agricultural production systems can sustain yields at or close to conventional agricultural levels for many products, and considerably more in some circumstances (up to 80% more in developing countries).[477] Long-term field trials in the USA and Europe have had varying conclusions for a range of products; systematic trials in Victorian / Australian conditions would be required for better understanding.

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[469] Prance, L. (2007), *Increased Health Awareness Drives Organic Food and Beverage Market*, accessed 15 November 2007, from http://www.foodnavigator.com/news/ng.asp?n=78397&m=1FNE723&c=opcaiaxodmazqrp
[470] Farm Online (2007), *Farmers Wanted to Meet Organic Boom*, accessed 1 May 2007, from http://theland.farmonline.com.au/news/nationalrural/agribusiness-and-general/general/farmers-wanted-to-meet-organic-boom/54910.aspx
[471] Kinnear, S. (2000), cited in Ashley, R. et al. (2007), *Intensive Organic Vegetable Production: Integrated Development,* Report Produced for the Australian Government Rural Industries, Research and Development Corporation, RIRDC Publication No 04/121
[472] de Bortoli now has some organic lines - http://debortoli.com.au/our-wines/press-reviews.html, a list (and discussion) of wineries moving to biodynamic can be found at http://redwhiteandgreen.com.au/
[473] Alfoeldi, T. et al. (2002), "Organic Agriculture and the Environment," *Organic Agriculture, Environment and Food Security, Environment and Natural Resources - Series 4*, edited by N. El-Hage Scialabba and H. Caroline, Food and Agriculture Organisation of the United Nations (UN FAO), Rome.
[474] Zierhl, A. (2004), *Organics and Sustainability: Substantiating the Claim of 'Clean and Green'*, Department of Primary Industries, State of Victoria, p41
[475] Foster, C. et al. (2006), *Environmental Impacts of Food Production and Consumption: A Report to the Department for Environment, Food and Rural Affairs*, Manchester Business School, DEFRA, London, p14
[476] International Trade Centre (2008), *Organic Farming and Climate Change*, International Trade Centre, Switzerland, http://www.intracen.org/Organics/publications.htm (NB: The ITC is the joint technical cooperation agency of the UN Conference on Trade and Development (UNCTAD) and WTO for business aspects of trade development)
[477] Badgley, C. et al. (2007), "Organic Agriculture and the Global Food Supply." *Renewable Agriculture and Food Systems*, vol. 22: 86-108.
[478] Cordis RTD-News (2007), "EU Research Finds Organic Food Healthier and Better", *Food Quality and Safety - Cordis EU*, 30 October 2007, from http://cordis.europa.eu/
[479] Benbrook, C et al. (2008), *New Evidence Confirms the Nutritional Superiority of Plant-Based Organic Foods*, State of Science Review.

Many developments and discoveries in the fields of organic and biological farming also have benefits for conventional farming, particularly with the increasing need to reduce agricultural inputs and environmental impact. Many of these are already being picked up, developed and used (eg. crop rotation and cover cropping – see *3.2.1 Environmental Management*).

High tech (precision techniques) and agro-ecological or biological farming systems are not mutually exclusive; future farming systems can make use of nets of sensors to monitor soil condition, information technology systems to mange minimum input, and GIS/GPS to design landscape scale applications of low-input techniques – 'the best of both worlds.'

Controlled field trials are suggesting nutritional advantages to some foods produced with low-input methods, eg. organic fruit and vegetables containing up to 40% more antioxidants and organic milk up to 60% higher levels of beneficial minerals such as iron and zinc.[478] Possible health concerns (and how to reduce them) are also being investigated through this research program. Furthermore, an extensive review of controlled comparison studies (released in March 2008) found that "yes, organic plant-based foods are, on average, more nutritious."[479]

!	*Increasing consumer demand for organics (domestically and in international markets) creates opportunities for Victorian producers – inability to meet increasing demand in Victoria requires more imports*
!	*Reducing reliance on costly and potentially scarce inputs can increase the resilience and reduce the environmental impact of all agricultural systems – not just those labelled 'organic'*
!	*Low-input farming (including organics) has significant potential to affect emissions profiles through soil carbon sequestration and is likely to increase resilience in the context of climate change*[480]
!	*In Victoria, the innovation potential of low input agricultural methods and innovations are being largely overlooked in institutional or research investment*
!	*Recognising and developing innovations that reduce input reliance may be resisted by some commercial interests*
!	*Conflicts between biological farming methods and potential for organic certification. For example, best-practice low-input grazing management requires flexible stocking rates (which means buying in cattle seasonally), but high demand for organics means that young 'organic' animals are likely to be sold straight to market rather than to other farmers. Therefore it is very difficult for many small farmers following biological or organic methods to certify their meat as organic, because they cannot source organic animals to bring onto their properties.*
	Long-term field trials of organic, biological and conventional methods, including: ➢ *yield comparisons for different products* ➢ *overall efficiencies of inputs and yields*
	Further investigation of the environmental benefits of low/no-input farming methods in a Victorian / Australian context, with particular attention to: ➢ *The most significant changes – which techniques / processes make the most difference to environmental impact (including soil, water and emissions) and what is the potential for their adaptation more broadly; and* ➢ *For which food types or production systems are the benefits greatest – focus attention on development of methods and systems with most potential impact*
	Investigate whether low-input production in Victoria is resulting in higher nutrient levels in fruit and vegetables – pursue opportunities for health ***and*** *environmental gains*
	Improving low/no-input systems and techniques – significant domestic and export potential for knowledge and innovation in this area
	Improvements to sustainability and resilience across all agricultural systems using knowledge / techniques developed in low/no input production systems
	Product quality improvements through organic / biodynamic / biological methods eg. viticulture
	Build consumer awareness of biological / low-input farming systems other than organic – possibly branding / labels – enabling purchase of products from low-impact farming methods
	Integration of other technology development eg. use of ICT for precision farming, soil testing, GIS/GPS for low-input methods etc[481]

480 International Trade Centre (2008), *Organic Farming and Climate Change*, International Trade Centre, Switzerland, http://www.intracen.org/Organics/publications.htm (NB: The ITC is the joint technical cooperation agency of the UN Conference on Trade and Development (UNCTAD) and WTO for business aspects of trade development)

481 As with all agriculture, energy / emissions and resource implications may need to be considered

Production systems that seek to minimise or eliminate the use of synthetic chemical inputs are experiencing rapid increases around the world. The terminology used to describe these systems varies and can have slightly different meanings. Systems which aim to reduce synthetic inputs include biodynamic, organic, biological, natural and regenerative farming.

Organic production systems have an absolute ban on the use of "synthetic fertilizers, pesticides and herbicides. That means adopting other techniques to nourish crops and protect the soil, such as growing 'cover' crops between seasons to prevent erosion and to restore organic matter."[482] For produce to be sold as organic in Australia it must be certified as a guarantee that:[483]

- Produce is grown and processed without **any** synthetic chemicals, fertilisers, or GMOs; and
- Standards to achieve this are internationally recognised, and are assured through annual audits of all certified operators by an independent third party auditor.

Biodynamic farming is a subset of organic farming (ie. no chemical inputs are used), which explicitly focuses on reintroducing and improving soil biology and humus. Biodynamic farming also focuses on the farm as a closed, self-nourishing system[484,485] – ideally everything needed for production should be provided from the farm. In modern practice this may not be the case as pre-prepared biodynamic formulations are now available.

Consumers that purchase organic and biodynamic produce are willing to pay a premium for this assurance and it is this premium that has tended to make the conversion to organic production viable for some producers. Producers and businesses that certify their produce as organic rely on the credibility of that label as a 'value-add' in their produce.

Biological farming also reduces the addition of chemical synthetics, but allows for judicious use of microbe-friendly fertilisers and herbicides with humic additives and molasses or sugar.[486] Biological farming is similar in intent to 'natural farming' and 'regenerative farming' in that they all seek to restore (and increase) soil fertility and build balanced systems that rely on the soil structure and health. They make use of knowledge, techniques and expertise from organic farming, but don't necessarily fully adopt organic principles (or seek certification). Biologically farmed produce is currently not certifiable and while valued by producers themselves is not yet understood or demanded by consumers. It has been suggested that biological agriculture can support the transition from conventional[487] by allowing recovery of the environmental support systems before any attempt to become fully 'organic'. The amount of input required gradually decreases as balance is restored to the soil and the system, until no inputs are needed.

Organic systems are effectively a stricter subset of biological systems. Both are based on similar principles, aim to build healthy soils and both benefit from reintroduction and enhancement of humic and soil biological activity.[488] Hereafter and throughout this document, the term organic is used to include but not be limited to organically certified methods and produce. As 'organics' is more established and understood at the consumer interface, most research comparing systems is branded as 'organic' but this often includes 'low-input' or biological practices. Additionally any findings based on strictly organic systems (techniques, benefits etc) can be considered to carry through to biological systems to some extent, as they incorporate similar practices.

A more active approach to soil management (adopting the best of biological systems and emerging knowledge) could potentially improve the quality and sustainability of some certified

482 Nelson, L. et al. (2004), "Organic FAQs", *Nature*, vol. 428: 796-98.
483 Biological Farmers of Australia - http://www.bfa.com.au/index.asp?Sec_ID=133
484 Lorand, A (1996), *Biodynamic Agriculture — a Paradigmatic Analysis*, Ph.D. Thesis, Pennsylvania State University.
485 Diver, S. (1999), *Biodynamic Farming & Compost Preparation*, ATTRA - National Sustainable Agriculture Information Service, Publication #IP137, http://attra.ncat.org/attra-pub/PDF/biodynam.pdf
486 Stapper, M. (2006), *Soil Fertility Management: Towards Sustainable Farming Systems and Landscapes*, CSIRO Sustainability Network Newletter - 61E, p5
487 Ibid.
488 Ibid, p5

organic farming enterprises by ensuring that healthy and productive soil is the ultimate goal, not just the reduction of chemical inputs.

The principles and methods of permaculture can inform all farming systems, as they are also focused on avoiding agricultural inputs through methods such as crop rotation, companion planting, reusing on-site resource inputs such as compost and manure, and simply growing produce suitable to the land, soil, climate, available resources.[489] Permaculture was developed in Australia in the 1970s, and also places a high priority on designing for greater efficiency and minimising the need for energy inputs through use of existing energy sources, such as the sun, animal energy (e.g. chook tractors), or human energy. As such, permaculture techniques also have potential to contribute to new farming systems that are less reliant on oil and other constrained resources.

What is happening?

The number of certified organic farms is increasing globally by 30% each year.[490] In the US, a growth of 20% p.a.is visible and organic farming is considered one of the fastest growing segments of US agriculture by the Department of Agriculture. Certified organic cropland has nearly doubled from 500,000 hectares in 1997 to 970,000 hectares in 2001.[491]

Australia is following a similar trend where a 2003 study estimated 1,511 certified organic farms in Australia, about 1.7% of Australia's agricultural area, with predictions of a 20-30% growth within one to three years including only those farms in the process of conversion to organic.[492] According to the Biological Farmers of Australia, the certified organics market is growing at rates in keeping with trends in the United States, the United Kingdom, Europe and Asia, making the organics industry one of the fastest growing farm sectors in Australia. The Australian organics industry is on a 'recruitment drive' for farmers to help it keep up with its growth rate of 25 per cent a year.[493]

Australian retail sales of organic produce have also increased – from around $28m in 1990 to around $250m in 2003.[494] Mainstream retailers have also increased their organics lines, for example Coles had 150 lines in 2005 compared to 12 in 2003.[495]

The Asia-Pacific region's demand for organics is growing faster than any in the world, posting a 28 per cent annual growth rate.[496] Despite industry growth, both domestic and export market demand for certified organic produce still exceeds the Australian supply of organic produce.[497]

A range of organic products are produced across Victoria, including nuts, grains, meat (beef, lamb and pork), wine, olives and olive oil, fruit juices, flours, fruit and vegetables. Victoria is also Australia's leading producer of organic milk and the centre for organic food processing.[498]

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[489] Holmgren, D. (2002), *Permaculture: Principles and Pathways Beyond Sustainability*, Holmgren Design Services, Melbourne.
[490] Troeth, J. (2001), cited in Ashley, R et al. (2007), *Intensive Organic Vegetable Production: Integrated Development,* Australian Government Rural Industries, Research and Development Corporation, RIRDC Publication No 04/121.
[491] Ryciak, R. (2007), "Sexy and Sustainable", *Seattle Conscious Choice*, accessed 27 June 2007, http://seattle.consciouschoice.com/2005/11/farm0511.html
[492] DAFF (2004), *The Australian Organic Industry: A Summary*, Department of Agriculture Fisheries and Forestry, http://www.daff.gov.au/agriculture-food/food/organic-biodynamic/industry.
[493] Farm Online (2007), *Farmers Wanted to Meet Organic Boom*, accessed 1 May 2007, from http://theland.farmonline.com.au/news/nationalrural/agribusiness-and-general/general/farmers-wanted-to-meet-organic-boom/54910.aspx
[494] Lea, E. (2005), cited in Cuthbertson, B. and Marks, N. (2007), *Beyond Credence? Emerging Consumer Trends in International Markets*, Department of Primary Industries, State of Victoria, p13
[495] Ibid, p14
[496] Prance, L. (2007), *Increased Health Awareness Drives Organic Food and Beverage Market*, accessed 15 November 2007, http://www.foodnavigator.com/news/ng.asp?n=78397&m=1FNE723&c=opcaiaxodmazqrp
[497] Kinnear, S. (2000), cited in Ashley, R. et al. (2007), *Intensive Organic Vegetable Production: Integrated Development,* Australian Government Rural Industries, Research and Development Corporation, RIRDC Publication No 04/121.
[498] Business Victoria (2007), *Victorian Organic Food Products Directory*, http://www.business.vic.gov.au/BUSVIC/STANDARD//pc=PC_62045

If existing demand trends continue, there is value in increasing investment in Victorian organic innovation and capacity purely from an industry development perspective.

Use of biological methods is also increasing, however as the change has happened recently and the resulting products are not certified there has been little formal data collection. A suggestion of how these methods are evolving and spreading can be found in case studies (as below), but is not yet quantified.

Why is it happening?

Various studies have sought to identify the main drivers of both the transition to organic production and consumer demand. While the driver main driver is believed to be food safety in Japan, for the UK and Australia it is the environment, health and quality. The motivation for producers is primarily improved environmental management, but for consumers the main driver is individual health.[499]

Adoption of biological farming methods is linked to the increasing costs of agricultural inputs. The techniques that have been developed by biological farmers over the last 20 years can be used to increase soil and plant resilience and therefore reduce dependence on fertilisers, pesticides and other inputs. These are receiving increasing attention amongst farmers as input prices rise.

Charlie Hilton – Bordertown, SA

Instead of fighting against 'bloody soil, bloody weeds' and just adding more chemicals . . I thought 'there's got to be a better way' and that's when I really started looking at root growth, soil health and soil testing, which led me down the path of biological farming,

It's about having those enterprises supplement each other instead of fighting each other. The biological system incorporates the attributes of an organic system and chemical farming system with minimal till. It brings them into the one, balanced system.

Instead of just throwing a heap of urea on the soil, and applying a chemical that's just a one-hit wonder, you're looking to get your soil nutrition levels, your aeration levels, and microbiology increased. Then you use crop rotations to create a better environment for plants to grow. It's looking at the whole picture.

Source: Marino, M. (2007), "Biological farming - Soil health the focus of a balanced system", *Ground Cover*, Issue 67: March-April 2007, Grains and Research Development Corporation

Biological farming is being used as a way to improve the environmental performance of conventional farming systems, increase production resilience and break the cycle of ever increasing pest and weed problems and chemical inputs.

Some Victorian wine producers are adopting biodynamic and organic practices purely to improve the quality of their produce. These producers do not explicitly label their produce as organic or biodynamic as they are not seeking a value-add for environmental or health reasons – their main interest is in the quality of the wine.[500]

A 2004 discussion paper published by the Victorian Department of Primary Industries found that even without price premiums or subsidies an organic system may in fact economically outperform a conventional system, as a result of comparative and higher yields, reduced inputs and reduced negative external impacts.[501]

What do we know, what do we need to know?

There is ongoing vigorous debate about the relative benefits and costs of organic production systems and whether there is evidence to support the various arguments for and against.

The most vigorously contested questions are:

[499] Cuthbertson, B. and Marks, N. (2007), *Beyond Credence? Emerging Consumer Trends in International Markets*, Department of Primary Industries, State of Victoria, p13
[500] de Bortoli now has some organic lines - http://debortoli.com.au/our-wines/press-reviews.html, a list (and discussion) of wineries moving to biodynamic can be found at http://redwhiteandgreen.com.au/
[501] Zierhl, A. (2004), *Organics and Sustainability: Substantiating the Claim of 'Clean and Green'*, Department of Primary Industries, State of Victoria, p22

a) Is it actually more sustainable?
b) Are yields sufficient for effective contribution to the world's growing food needs without further environmental degradation? and
c) Is it actually healthier?

A brief overview of the arguments and research is presented below.

a) Is it actually more sustainable?

The main findings of the Food and Agriculture Organisation of the United Nations' assessment of organic agriculture's impacts on the environment included:[502]

- Organic matter content is usually higher in organically managed soils indicating a higher fertility and stability of organic soils, thus reducing the risk of erosion
- Organically farmed soils have significantly higher biological activity and a higher total mass of micro-organisms. As a consequence of the higher activity of micro-organisms, in organically managed soils nutrients are recycled faster and soil structure is improved
- Organic farming poses no risk of ground and surface water pollution through synthetic pesticides. Nitrate leaching rates per hectare are significantly lower in organic farming compared to conventional farming systems
- The diversity of cultivated species and of agricultural genetic resources is higher in organic farming
- Floral and faunal biodiversity on organic land is higher than on conventional land. Furthermore a higher number of endangered and rare species are present
- Organic farming offers vast food resources for beneficial arthropods and birds, thus contributing to natural pest control
- Organic farming enables ecosystems to better adjust to the effects of climate change and offers a major potential to reduce the emissions of agricultural greenhouse gases
- Organic agricultural strategies comprises recycling of organic matter and tightening internal nutrient cycles, thus contributing to carbon sequestration

This assessment noted the lack of research on the environmental impacts of organic agriculture in the Southern hemisphere, but pointed to practical examples that suggest the findings hold.

Consistent with these findings a 2004 Victorian discussion paper *Organics and Sustainability: Substantiating the Claim of 'Clean and Green'* concluded that, although it is complex to compare organic, integrated and conventional agricultural systems, organic agriculture and horticulture systems generally have:[503]

- long term yields that can be comparative or higher and have a lower long-term variability;
- increased soil health;
- increased ecological, biodiversity and landscape benefits;
- reduced off-farm impacts;
- potential increased rural and social benefits; and
- increased food nutrition benefits.

The main underlying reason for these environmental benefits is that the impacts of organic farming, unlike conventional farming, are largely contained within the farm bounds.[504] Advantages tend to include elimination of chemical run-off to land and waterways, improved soil biology and health (which contribute to soil carbon sequestration),[505] and reduced impacts on ecological health (such as bee colonies, neighbouring wildlife, etc).

[502] Alfoeldi, T. et al. (2002), "Organic Agriculture and the Environment", *Organic Agriculture, Environment and Food Security, Environment and Natural Resources - Series 4*, edited by N. El-Hage Scialabba and H. Caroline, Food and Agriculture Organisation of the United Nation (UN FAO), Rome.
[503] Zierhl, A. (2004), *Organics and Sustainability: Substantiating the Claim of 'Clean and Green'*, Department of Primary Industries, State of Victoria, p41
[504] Wood, R. et al. (2006), "A Comparative Study of Some Environmental Impacts of Conventional and Organic Farming in Australia", *Agricultural Systems,* vol. 89, no. 2-3: 324-48, p344
[505] Ingham, E. (2000), *Soil Biology Primer*, Natural Resources Conservation Service, United States Department of Agriculture, accessed 25 July 2007, http://soils.usda.gov/sqi/concepts/soil_biology/biology.html

A review of international studies comparing organic and conventional agriculture has found that the biodiversity impacts actually extend up through every level of the food chain from bacteria to mammals, not just on and around farms.[506] It was found that this was largely due to a number of key practices such as: reduction of chemical pesticides and fertilisers, management of land where there are no crops, and mixed farming (particularly beneficial to some bird species). However, the study also suggested that organic systems themselves may not be necessary – the use of specifically beneficial practices within conventional systems may achieve the same benefits.

These benefits have already been recognised by some governments, leading to active support for organic systems to protect natural resources. For example, the Iowa Natural Resources Conservation Services (NRCS) offers organic farmers $50/acre during their transition to organic farming through the Environmental Quality Indicators Program (EQIP).[507]

Lifecycle impacts are complicated, but suggest overall advantages . .

The wider (ie. lifecycle) impacts of organic farming in comparison to conventional farming are particularly difficult to conclusively determine and findings of different studies vary. Livestock impacts are quite different from cropping or horticulture and therefore the difference that can be made by changing to low/no input systems are also different.

The German Federal Ministry for Food, Agriculture and Forestry commissioned research in 2000 into the relative primary energy inputs and greenhouse emissions of organic and conventional production. This research found that reducing mineral nitrogen fertiliser in any system is the most effective way to reduce primary energy inputs and greenhouse gas emissions from production. The report suggests that this can be done by integration of crop and animal production combined with the use of local concentrate feed-stuffs production – and that the resulting system could be either conventional or organic. It should be noted that this research did not include 'biogenic' emissions, therefore eliminating enteric fermentation – the most significant source of emissions.[508]

A 2006 report for DEFRA in the UK found that while many organic products had lower ecological impacts than conventional methods using fertilisers and pesticides, this is counterbalanced by other organic foods - such as milk, tomatoes and chicken - which are significantly less energy efficient and can be more polluting in the UK context than intensively-farmed conventional equivalents. They concluded that, "while there is no doubt that, for many foods, the environmental impacts of organic agriculture are lower than for the equivalent conventionally-grown food . . especially if biodiversity and landscape aesthetics were to be taken into consideration,"[509] there is insufficient evidence to state that overall organic agriculture would have a lower environmental impact than conventional.

An Australian study was undertaken in 2003 to compare the environmental impacts associated with conventional and organic farming, taking into account on-farm and indirect energy consumption, land disturbance, water use, employment, and emissions of greenhouse gases, NO_X and SO_2.[510] In summary, the conclusions of this study were:[511]

- Direct (on-farm) *energy use, energy related emissions and greenhouse gas emissions were*

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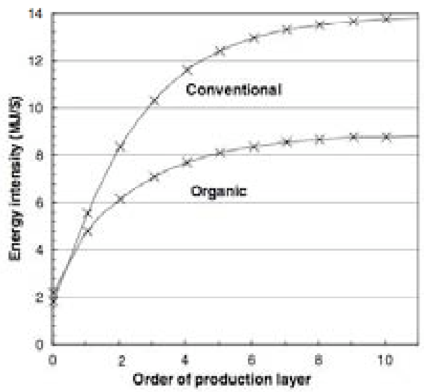
[506] Randerson, J. (2004), "Organic Farming Boosts Biodiversity", *New Scientist,* 11 October 2004.
[507] Delate, K. (2007), *Fundamentals of Organic Agriculture*, Organic Agriculture Series, Leopold Centre for Sustainable Agriculture, Iowa State University, http://extension.agron.iastate.edu/organicag/pubs.html
[508] Murphy, D. et al. (2000), *Evaluation of Conventional and Organic Agricultural Production in Relation to Primary Energy Inputs and Certain Pollution Gas Emissions*, Federal Ministry for Food, Agriculture and Forestry (BML), Bonn, accessed via Food Climate Research Network, 12 December 2007, http://www.fcrn.org.uk/researchLib/PDFs/dmb_summary.pdf
[509] Foster, C. et al. (2006), *Environmental Impacts of Food Production and Consumption: A Report to the Department for Environment, Food and Rural Affairs*, Manchester Business School, DEFRA, London, p14
[510] Wood, R. et al. (2006), "A Comparative Study of Some Environmental Impacts of Conventional and Organic Farming in Australia", *Agricultural Systems,* vol. 89, no. 2-3: 324-48.
[511] Ibid.

slightly higher for the organic farming sample (2.2MJ/A$) than for a comparable conventional farm sample (1.8MJ/A$), largely due to on-farm use of diesel and petrol for weed control and manure spreading;
- As higher orders of input are accounted for, *the conventional farm requires significantly greater indirect energy (13.8 MJ/A$) than the organic farm (8.8 MJ/A$),* mainly due to dependence on products with high indirect energy requirements, such as machinery, fertilisers, chemicals and pesticides (see Figure Y); and
- The organic farming sample had *much lower water intensity than conventional sample - 46.8L/A$ compared to 220.9L/A$ (only 20% of the water per A$). This* study noted insufficient information to explain this difference, observing that it could be due to lower grazing and cropping concentration of organic farming and/or a philosophy apparent amongst organic farmers of the importance of self-sufficiency of water use, but there was insufficient research to form any conclusions about contribution of increased mulch use or higher organic matter in soil.

The over-riding conclusion of this study was the importance of considering off-site impacts when evaluating agricultural and food systems, particularly for energy and greenhouse emissions (see also 2.2.2), where more than five times the on-site impact occurs off-site (shown in Figure 3.1).[512]

Figure 3.1: Energy intensity by production layer[513]



These findings also strongly suggest that existing organic farming philosophies and methods can make significant contributions to energy, greenhouse emissions and water use improvements in food systems. Traditional proponents of organic production have focused on improved local environmental conditions – a lifecycle approach reveals possible advantages to more systemic environmental problems such as climate change and water shortages.

More recently the potential contribution of organic systems to greenhouse gas mitigation and to climate change adaptation is receiving increased attention. A 2008 study that conducted a comprehensive review of the relevant peer-reviewed scientific literature concluded that:[514]

> *organic agriculture has much to offer in both mitigation of climate change through its emphasis on closed nutrient cycles and is a particularly resilient and productive system for adaptation strategies.*

The study also found that through its ability to store carbon in soils and reduce emissions, organic agriculture could serve as ‘quick-win’ policy option in carbon offsetting markets and through the Clean Development Mechanism.

It is very likely that for some food products, the expansion of low/no-input techniques (as developed via organic and biological agriculture) have significant potential for reducing greenhouse emissions and other lifecycle impacts (such as water use). Expansion of these techniques does not necessarily mean full-scale conversion to ‘organic’ systems – application of the most effective techniques within conventional systems could achieve significant gains. There is a marked absence of high-level lifecycle analysis, empirical data and/or field trials in an Australian context. Our urgent need to reduce greenhouse emissions, water use and land/soil degradation from food production means that research on the actual costs and benefits of readily available techniques should be a priority.

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[512] Wood, R. et al. (2006), "A Comparative Study of Some Environmental Impacts of Conventional and Organic Farming in Australia", *Agricultural Systems,* vol. 89, no. 2-3: 324-48, p343
[513] Ibid.
[514] International Trade Centre (2008), *Organic Farming and Climate Change*, International Trade Centre, Switzerland, http://www.intracen.org/Organics/publications.htm (NB: The ITC is the joint technical cooperation agency of the UN Conference on Trade and Development (UNCTAD) and WTO for business aspects of trade development)

b) Are yields sufficient for effective contribution to the world's growing food needs without further environmental degradation?

A major point of contention in system comparison is yield uncertainty – can alternative systems sustain sufficient outputs to meet the needs of a hungry world without requiring even more land to be converted to agriculture? Results from different studies vary, some recently released results are summarised in Table 3-4.

Table 3-4: Yield Capability of Organic Systems

Name of Study	Publication / Institution	Methodology	Findings
Organic Agriculture and Global Food Supply	Renewable Agriculture and Food Systems[515]	Examined a global dataset of 293 examples	• Developed countries – organic systems produce 92% of the yield of conventional • Developing countries – organic systems produce 80% more • Leguminous cover crops could fix enough nitrogen to replace the amount of synthetic fertiliser currently in use
Long-Term Agro-ecological Research (LTAR) initiative (believed to be the largest randomised, replicated comparison of organic and conventional crops in the USA)	Leopold Center for Sustainable Agriculture, Iowa State University[516]	10 years of work with experimental plots - replicated conventional and organic systems, using identical crop varieties	• Organic crop yields were equal to conventional in the three years of transition • In the fourth year, organic corn yields in the longest rotation outpaced those of conventional corn • Organic and conventional soybean yields have been similar every year of the trial • Organic plots infiltrate more water, which reduces soil runoff and more effectively recharges groundwater supplies • Organic soils cycle nutrients more efficiently, making them available when and where the plants need them • Soil structural stability remained good, despite increased tillage involved with the organic rotations
Soil Fertility and Biodiversity in Organic Farming	• Research Institute of Organic Agriculture, Frick, Switzerland[517]	Results from a 21-year study of biodynamic, bioorganic, and conventional farming systems in Central Europe	• Crop yields on organic plots were on average 20 per cent lower than those on conventional plots • Potato yields on organic plots were only 60 per cent of those on conventional plots • Organic winter wheat achieved 90 per cent, and grasses fed on manure did just as well as those fed on fertiliser • The overall system was more efficient - soils nourished with manure produced more crops for a given input of nitrogen or other fertiliser. Nitrogen inputs were as much as 50 per cent lower in the organic system • Organic soils had more earthworms and insects (indicators of healthy soil) and 40 per cent more mycorrhizal fungi colonising plant roots

There are differences in these findings and there may be greater benefit in organic production of some crops than others (eg. probably not potatoes). However, these studies were conducted mostly in the northern hemisphere and there do not appear to be any comparable studies for Victorian or Australian conditions – these findings are unlikely to be directly applicable.

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515 Badgley, C. et al. (2007), "Organic Agriculture and the Global Food Supply", *Renewable Agriculture and Food Systems*, vol. 22: 86-108.
516 Leopold Centre (2007), *Leopold Centre News Release*, 13 November 2007, http://www.leopold.iastate.edu/news/newsreleases/2007/organic_111307.htm
517 Mäder, P. et al. (2002), "Soil Fertility and Biodiversity in Organic Farming", *Science and Development Network*, vol. 296, no. 5573.

c) Is it actually healthier?

Recent outbreaks of food scares and heightened awareness of the health benefits of organically produced ingredients are thought to be behind the dramatic turn from unhealthy ingredients such as carbohydrates, fat, calories and hydrogenated oils, and the use of genetically modified organisms (GMOs) in food products.[518]

The possibility of human health being affected by agricultural inputs has been debated over a long period of time, and has led to the development of standards and strict controls on safe levels of chemical residues in food. Some proponents of organic food claim that it is better for you because it contains no pesticide or herbicide residues, hormones or the large doses of antibiotics used in conventional systems, however a vast number of studies in this area have contradictory findings.

International food safety bodies have maintained an insistence that there is no evidence of increased health benefits of organically produced food, based on studies such as a 2002 meta-analysis, which concluded that there was insufficient proof to either support or refute claims that organic food offers greater nutritional values, more consumer safety or any distinguishable difference in taste.[519] Williams did note "reasonably consistent findings for higher nitrate and lower vitamin C contents of conventionally-produced vegetables, particularly leafy vegetables."[520]

However, there has more recently been an increased research focus on this topic in the UK and Europe and emerging results based on controlled field trials are now suggesting nutritional advantages. The European Commission has established a major integrated research program called *Quality Low Input Food (QLIF),*[521] to provide an empirical scientific response to the many questions around low input food production. As part of this program, it has a number of work programs focused on 'Quantifying the effect of organic and "low input" production methods on food quality and safety and human health.' Early results from this research stream have found that:

- Organic fruit and vegetables contain up to 40% (and milk up to 60%) more antioxidants (believed to cut the risk of heart disease and cancer) than non-organic foodstuffs, and organic milk also had higher levels of healthy fatty acids[522]
- Organic tomatoes "contained more dry matter, total and reducing sugars, vitamin C, B-carotene and flavonoids in comparison to the conventional ones", while conventional tomatoes in this study were richer in lycopene and organic acids. The organic tomatoes also contained less nitrates and nitrites[523]
- Organic peaches 'have a higher polyphenol content at harvest' – this led to the conclusion that organic production has 'positive effects … on nutritional quality and taste'[524]
- Organic apple puree was found to contain 'more total phenols, vitamin C, total flavones and

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[518] Global Industry Analysts (2007), cited in Prance, L. (2007), *Increased Health Awareness Drives Organic Food and Beverage Market*, accessed 15 November 2007, http://www.foodnavigator.com/news/ng.asp?n=78397&m=1FNE723&c=opcaiaxodmazqrp

[519] Bourn, D. and Prescott, J. (2002), "A Comparison of the Nutritional Value, Sensory Qualities, and Food Safety of Organically and Conventionally Produced Foods", *Critical Reviews in Food Science Nutrition*, vol. 42, no. 1: 1-34., and Williams, C. (2002), "Nutritional Quality of Organic Food: Shades of Grey or Shades of Green?" paper presented at the *Nutrition Society Conference*, Cambridge University Press.

[520] Williams, C. (2002), "Nutritional Quality of Organic Food: Shades of Grey or Shades of Green?" paper presented at the *Nutrition Society Conference*, Cambridge University Press.

[521] For more information, see http://www.qlif.org/research/index.html

[522] Cordis RTD-News (2007), *EU Research Finds Organic Food Healthier and Better*, Food Quality and Safety - Cordis EU, http://cordis.europa.eu/

[523] Hallmann, E. and Rembialkowska, E. (2007), "Comparison of the Nutritive Quality of Tomato Fruits from Organic and Conventional Production in Poland", poster presented at the *3rd QLIF Congress: Improving Sustainability in Organic and Low Input Food Production Systems*, 20-23 March 2007, University of Hohenheim, Germany.

[524] Fauriel, J. et al. (2007), "On-Farm Influence of Production Patterns on Total Polyphenol Content in Peach", paper presented at *3rd QLIF Congress: Improving Sustainability in Organic and Low Input Food Production Systems*, 20-23 March 2007, University of Hohenheim, Germany.

showed a higher antioxidant capacity' than the puree from conventional apples.[525] This study also demonstrated that processing had a negative effect on both antioxidant capacity and bioactive substances from both organic and conventional systems.

An extensive 2008 review of controlled comparison studies found that "yes, organic plant-based foods are, on average, more nutritious."[526]

There are also studies exploring health benefits of organic dairy and livestock production. For example, one three-year UK study conducted by the Universities of Liverpool and Glasgow, found a direct link between the whole organic farming system and higher levels of Omega 3 fatty acids in organic milk. After considering a cross-section of UK farms over a 12-month production cycle, this study found that a pint of organic milk contains on average 68.2% more total Omega 3 fatty acids than non-organic milk.[527]

There are a number of areas in which organic / low-input production may present different health risks to consumers. For example, the use of raw animal manure as a fertiliser can result in transfer of pathogens (such as Salmonella, E. coli and Chryptosporidium) onto crops and therefore into the food chain. The threat of this is greatest for vegetables that may not be cooked and are likely to have contact with the soil, such as lettuce, spinach or carrots. The European QLIF Program is also researching the extent of this problem and techniques to manage it (eg. proper composting of the manure before application).

3.3. Distribution Strategies

Distribution can be taken to include all activities which involve movement and value-adding of food – from farm to processor, processor to wholesaler / retailer etc. Technological developments are likely to enable improved logistics and transport efficiencies, improved packaging materials and more efficient storage and therefore help reduce the environmental impacts of food distribution. Attention to increasing efficiencies in food processing and retail will have benefits. Continual improvement throughout mainstream agri-business and food supply chains will be necessary and the need to reduce risk and impact is increasingly understood (see case study below).

Supermarkets are adapting their practices in response to consumer demands. In the UK, a number of larger supermarket chains are beginning food miles labelling, while others are beginning to source products locally and/or sell a variety of organic produce. High profile attempts to calculate carbon footprints (eg. by Tesco in the UK) are proving difficult, but still signal potential changes in future food distribution systems. Because supermarkets hold such power in the food retail sector, any such shifts in supermarket practices are likely to drive changes through their supply chains.

Case Study: Sustainable Food Lab

We must be able to guarantee sustainable production if we wish to continue to satisfy the wishes of the consumer and thus survive as an enterprise. In other words: conviction coupled with enlightened self-interest. No fish, no fish fingers. No water, no tea. It's as simple as that.
Antony Burgmans, Chairman, Unilever

We, business leaders of global food and agriculture, recognize that we influence the way one quarter of the

[525] Rembialkowska, E. et al. (2007), "Influence of Processing on Bioactive Substances Content and Antioxidant Properties of Apple Purée from Organic and Conventional Production in Poland", poster presented at *3rd QLIF Congress: Improving Sustainability in Organic and Low Input Food Production Systems*, 31 May-3 June 2005, University of Hohenheim, Germany.
[526] Benbrook, C., Zhao, X., Yáñez, J., Davies, N., and Andrews, P. (2008), *New Evidence Confirms the Nutritional Superiority of Plant-Based Organic Foods*, State of Science Review.
[527] Ellis, K. et al. (2006), "Comparing the Fatty Acid Composition of Organic and Conventional Milk", *Journal of Dairy Science*, vol. 89: 1938-50.

world's population earns a living, half the world's habitable land is cared for, and two-thirds of the world's fresh water is used. With such influence comes opportunity and responsibility. We commit ourselves to establish standards of excellence in social, economic and environmental responsibility.

Each member agrees that they will:
- Undertake periodic assessments of supply chains and sourcing practices, and identify high-priority issues for action;
- Put in place management systems that integrate social and environmental considerations into business and decision-making processes. Management systems include establishing indicators of social, economic and environmental performance, appropriate objectives and targets, and practicing continual improvement; and
- Work with suppliers to source those goods and services which are more socially, economically and environmentally responsible in the way they are grown, manufactured, used, transported, stored, packaged and disposed of. Indicators, targets and improvement will be transparently shared.

Partners in this project include: COSTCO, RaboBank, Heinz North America, Unilever, Starbucks and General Mills

Source: www.sustainablefoodlab.org/business-coalition

In addition to the efforts of food industries to increase efficiencies and reduce impacts in the existing processing / distribution chains, there is a significant community interest in more sustainable (and resilient) distribution. Community-led strategies are focusing on localisation – reducing the distance that food travels between the producer and consumer. This 'distance' can be conceived both directly in kilometres (as reflected in the discussion on food miles in *2.1.2*) and in stages of the food chain ie. reduced processing, packaging, storage. Localisation movements have led to innovations such as Community Supported Agriculture (CSA) and Farmers' Markets, discussed further below.

3.3.1. Localisation

Summary and Recommendations:

Food localisation aims to shorten the supply chain by producing food close to where it is consumed,[528] reducing the energy used and greenhouse gases released through food-related transportation[529] and the associated processing, packaging and storage. Food localisation movements are also being driven by concern about resilience of local food supplies, particularly in preparation for the dual challenges of climate change and peak oil.

International analyses have suggested that while there are general environmental advantages to local food production, this depends on the type of foods, how they are produced, processed, packaged and stored. For example, the lower embedded energy of lamb produced in NZ makes it a lower impact choice for UK consumers than lamb produced locally in the UK.[530]

It is most likely that for Victoria, which has relatively good production conditions for many food groups and substantial food production and processing capability, local foods will present environmental benefits.[531] But analysis appropriate to local conditions (taking into account water efficiency & scarcity, relative emissions in production etc) is advised before specific conclusions could be drawn.

As discussed in *2.1.2*, in the section on *Transport-Food Miles*, the greenhouse emissions from car based shopping may exceed the transport emissions from production and distribution, and if purchase of some

[528] Cowell, S.J. and Parkinson, S. (2002), "Localisation of UK Food Production: An Analysis Using Land Area and Energy as Indicators." *Agriculture, Ecosystems and Environment,* vol. 94, p222
[529] Van Hauwermeiren, A. et al. (2007), "Energy Lifecycle Inputs in Food Systems: A Comparison of Local Versus Mainstream Cases." *Journal of Environmental Policy and Planning*, vol. 9, no. 1: 31-51.
[530] Saunders, C. et al. (2006), *Food Miles - Comparative Energy/Emissions Performance of New Zealand's Agriculture Industry*, AERU - Lincoln University
[531] Short transport distances and favourable local conditions led to this finding in a US study, Victoria's strengths in food production suggest that it might also be the case here - Morgan, D. et al. (2006), *Seattle Food System Enhancement Project: Greenhouse Gas Emissions Study*, University of Washington, Program on the Environment, accessed 14 January 2008, from http://courses.washington.edu/emksp06/SeattleFoodSystem/Final_GHG_Report.pdf.

local foods (from different outlets than the rest of the food) means extra car trips, this could outweigh benefits.

Climate change, emissions pricing and oil constraints will present new challenges to long food supply chains, and ensuring access to locally produced basic foods could help increase resilience and food security under these conditions. Local production of food is also likely to have health and regional development benefits.

!	*Ongoing access to food from interstate and overseas will continue to reduce vulnerability to disruption of local food production (such as extreme weather events)*
!	*Consumption of some locally produced some foods will have clear environmental benefits, but others may need careful balancing across water, emissions, land impact etc*
!	*In many cases, local food systems have nutritional and food security benefits, improved understanding and regulation of production practices, and benefits for local communities and economies.*
	Analysis of benefits of local food consumption in Victoria, with consideration given to: ➢ *How much environmental impact is related to transport & storage vs production;* ➢ *Different production conditions for different foods; and* ➢ *Relative environmental impacts of production / processing in Victoria vs elsewhere*
	Analysis of the potential to meet food needs through local, seasonal production in Melbourne / Victoria – what would it include? Would it be nutritionally adequate?
	Reducing environmental impacts and vulnerability of supply chains – logistics, packaging innovations, storage systems etc
	Collaboration with transport / retailer / health sectors to encourage change in how people access food ie. increase walking / cycling and ensure that increased local food purchase does not require extra car trips

What is happening?

Interest in local food initiatives is growing steadily around the world. Educational campaigns such as *Buy Local*[532] are educating consumers about the economic, social and environmental costs of long food supply chains, while personal initiatives such as *The Hundred Mile Diet*[533] have emerged as individual and community impact reduction strategies. The Hundred Mile Diet began in Vancouver with two people deciding to only consume food produced within 100 miles of their homes. The idea has now spread throughout North America and beyond, with people taking on the diet in the UK, Sweden and Melbourne, Australia.[534] Another local food initiative is Café 150, based at Google's Mountain View campus in California. Serving up to 600 meals a day, Café 150 sources all its ingredients within 150 miles of the campus.[535] In July this year, a similar, though relatively up-market, 100 Mile Café has now opened in Melbourne's CBD.[536]

Some communities are in the process of actively localising their food production and consumption on a broad scale and in a systematic manner (or have already done so). These include: the town of Kinsale, Ireland, which has developed an Energy Descent Action Plan; Canada's largest city, Toronto, which has integrated food production into its urban planning; and the nation of Cuba, which has survived and adapted to its own peak oil experience.

Why is it happening?

Localisation seeks to bring people and their basic necessities closer together,[537] primarily to increase community energy security, strengthen local economies and to achieve large

[532] Local Harvest (2007), *Why Buy Local?* accessed 25 July 2007, http://www.localharvest.org/buylocal.jsp
[533] Smith, A., and MacKinnon, J. (2007), *The Hundred Mile Diet*, accessed 25 July 2007, http://100milediet.org/
[534] Scruby, M. (2007), "Close to Home", *The Age*, 25 July 2007, http://www.theage.com.au/news/epicure/close-to-home/2007/01/22/1169330797668.html
[535] Wu, O. (2006), "Now Google's Cooking", San Francisco Chronicle, accessed 25 July 2007, http://sfgate.com/cgi-bin/article.cgi?f=/chronicle/archive/2006/03/01/FDG32H9OF61.DTL
[536] See 100 Mile Café - http://www.100milecafe.com.au/
[537] Shuman, M. (2000), *Going Local: Creating Self-Reliant Communities in a Global Age*, Routledge, New York.

improvements in environmental conditions and social equity.[538] Food localisation in particular aims to shorten the food supply chain by producing food close to where it is consumed,[539] reducing the energy used and greenhouse gases released through food-related transportation.[540]

Food localisation strategies are driven by a desire to increase the resilience and self-reliance of local food supplies, particularly in preparation for the dual challenges of climate change and peak oil. The communities mentioned above (Kinsale, Toronto and Cuba) demonstrate different scales of localisation, all of which increase the resilience of the communities to fluctuating outside forces beyond their control (such as affordability and access to oil, and disruption to global food supply chains).

Food localisation may strengthen the relationships between food producers and consumers.[541] Because the shorter food supply chains generally mean that food producers are more accountable for their production methods and impacts of this, consumers are also driven to localised food systems by concern for environmental issues, animal welfare, food quality and taste, food safety, regional development.[542]

What do we know? What don't we know?

While the food localisation movement claims that localising food systems will reduce the amount of transport related greenhouse gas emissions, and therefore decrease food-related contributions to climate change, the environmental implications of localisation are not so clear-cut. As with alternative production systems, the complexity of the food system makes simple answers hard to come by.

A major movement towards localised food systems may actually reduce food security in a future with unpredictable climactic events. Access to global trade of food supplies currently enhances food security to wealthier nations when local production is hit by events (hurricanes, frosts, drought etc), which have the potential to wipe out a region's local food supply. The challenges currently being faced by Victorian agriculture are being reflected in food prices, but actual food shortages are being avoided through increased imports from other markets.

Additionally, locally produced food may sometimes have more environmental impacts than imported food. New Zealand was one of the first to explore this issue, with a view to how it might affect their export markets (primarily the UK). They examined the full lifecycle carbon impacts of key products to assess the relative contribution of transport to overall emissions, and found that lamb raised in New Zealand and shipped 11,000 miles by boat to Britain produced fewer greenhouse emissions per tonne than locally produced (British) lamb. This difference was primarily due to different feeding requirements (NZ lamb can graze whereas British farmers are more likely to use feed). This study also found that dairy, apples and onions produced in NZ and shipped to the UK still had lower total emissions.[543] This finding was reinforced by UK research, which suggested "if you are concerned about the 'carbon footprint' of foods, there can be good case for importing some of them (eg tomatoes or lamb) even if they can be grown in the UK. The evidence available so far shows that 'local' is not always the best option for the

[538] Post Carbon Institute (2007), *What Is Relocalization?* , The Relocalization Network, accessed 25 July 2007, http://relocalize.net/about/relocalization.
[539] Cowell, S.J. and Parkinson, S. (2002), "Localisation of UK Food Production: An Analysis Using Land Area and Energy as Indicators", *Agriculture, Ecosystems and Environment*, vol. 94, p222
[540] Van Hauwermeiren, A., Hannelore, C., Engelen, G. and Mathijs, E. (2007), "Energy Lifecycle Inputs in Food Systems: A Comparison of Local Versus Mainstream Cases", *Journal of Environmental Policy and Planning*, vol. 9, no. 1: 31-51.
[541] Hinrichs, C.C. (2003), "The Practice and Politics of Food System Localization", *Journal of Rural Studies*, vol. 19, p39
[542] Van Hauwermeiren, A. et al. (2007), "Energy Lifecycle Inputs in Food Systems: A Comparison of Local Versus Mainstream Cases", *Journal of Environmental Policy and Planning*, vol. 9, no. 1: 31-51.
[543] Saunders, C. et al. (2006), *Food Miles - Comparative Energy/Emissions Performance of New Zealand's Agriculture Industry*, AERU - Lincoln University

environment."[544,545] These studies emphasise the need to consider full lifecycle environmental impacts and not assume localisation is a simple solution.

The University of Washington used Life Cycle Assessment to compare the greenhouse gas emissions of two similar plates of food in Seattle.[546] They considered locally produced vs imported (from inter-state or international) and production methods. They found that, for Seattle, locally produced food should be recommended (partially because of transport distances but also because they are in a highly productive region and able to produce some foods with relatively low emissions), but that transport distances are not the only factor. They too concluded that each food should be considered separately as harvest yields and production practices make a big difference. They also identified that individual car trips to get the food might be the most significant greenhouse contribution for fruit and vegetables and recommended further detailed studies.

For Victoria, which has relatively good production conditions for many food groups, it is likely that local production presents significant environmental benefits. But we don't know. For some food products Victorian or Australian production may be more water efficient than in other locations and this could contribute to a lower overall impact of local produce – although it would also need to be balanced with how much water is actually available. There is a need for analysis of how much of our food footprint is due to transport and the relative environmental impacts of food products produced in Victoria / Australia vs imported products, before confident recommendations around the benefits of local foods could be made.

As discussed in *2.1.2 (Transport-Food Miles)*, the greenhouse emissions from car based shopping may exceed the transport emissions from production and distribution and if purchase of some local foods (from different outlets than the rest of the food) means extra car trips, this could outweigh the benefits.

3.2.2 & 3.2.3 Farmers' Markets and Community Supported Agriculture (CSA)

Summary and Recommendations:

The emergence of farmers' markets and community supported agriculture (CSA) schemes has been driven by desire to: reconnect producers and consumers, provide new distribution avenues that give producers a higher proportion of the return, and improve consumer access to fresh and diverse produce.

Farmers' markets are increasingly popular in Australia – there are now over 40 regularly operating in Victoria and the economic and social advantages have been documented.[547] Likely environmental benefits include: reduced waste and packaging (as produce and packaging do not need to meet strict supermarket conformity standards); reduced travel distances for food; and opportunities to access more sustainably produced food. However it is possible that farmers travelling to more distant farmers' markets (ie. not just their local one) with small amounts of produce could cause an increase in transport emissions.

CSA's are very popular in the USA but less so in Australia and as of 2001 only one was operating in Victoria.[548] It is unclear why this innovation is so popular internationally but has not found a market niche in Australia. It may be due to a lower rural to urban proportion of population, the different distribution of people in the landscape (Australians are concentrated in a few big cities whereas Americans have more smaller cities surrounded by rural areas), or higher levels of awareness / concern in US communities.

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544 Green, K. (2003), cited in Manchester Business School (2007), *Research Case Study*, University of Manchester, http://www.mbs.ac.uk/research/casestudies/defra.aspx.

545 DEFRA (2006), *British Government's 2006 Food Industry Sustainability Strategy*, Department for Environment, Food and Rural Affairs

546 Morgan, D. et al. (2006), *Seattle Food System Enhancement Project: Greenhouse Gas Emissions Study*, University of Washington, Program on the Environment, accessed 14 January 2008, http://courses.washington.edu/emksp06/SeattleFoodSystem/Final_GHG_Report.pdf.

547 Coster, M. and Kennon, N. (2005), *'New Generation' Farmers' Markets in Rural Communities* (No. 05/109), Rural Industries Research and Development Corporation (RIRDC).

548 Parker, A. (2001), *Feasibility of Community Supported Agriculture in Australia*, Department of Natural Resources and Environment, State of Victoria.

Victoria / Australia's population densities may affect the overall environmental benefits, and vulnerability to oil prices, of farmers' markets and CSAs (if they require more car / small truck trips).	
!	*Urban farmers' markets may be more concentrated in higher income areas (where producers can get good returns) limiting access to disadvantaged groups*
🕮	*An understanding of the full transport patterns of Victorian farmers' markets, and comparison with full transport cycles of conventional distribution systems*
⚡	*Increased efficiencies and accessibility of food distribution – reducing reliance on separate car / small truck trips*

3.3.2. Farmers' markets

A Farmers' Market is a predominantly fresh food market that operates regularly within a community, at a focal public location that provides a suitable environment for farmers and food producers to sell farm-origin and associated value-added processed food products directly to customers.[549]

What & Why?

Farmers' markets started reappearing in 1983, firstly in North America and in Europe. There are now over 3,500 in the USA and more than 450 in the UK alone. In recent years farmer's markets have been appearing around Victoria and there are now over 40.[550]

The primary aims of farmers' markets (as stated by the Australian Farmers' Markets Association)[551] are:
1. To preserve farmland and sustainable agriculture
2. To support and stimulate the profitable trading, viability and business growth of independent primary producers, hobby farmers, community and home gardeners, and associated produce value-adders
3. To provide customers with regular supplies of fresh food and access to improved nutrition
4. To contribute to the economic, social and health capital of the host community

Farmers' markets can do this by 'cutting out the middle man' and reconnecting producers and consumers. Consumers can benefit from access to fresh fruit and vegetables, diversity of produce and the opportunity to talk to producers - customers in regional and rural markets are also concerned about supporting local industry.[552] For farmers the benefits include new product development and testing, increased sales (and capture of all the sale value), and changes to their overall production systems.[553] The markets also provide an opportunity to increase consumer knowledge about production practices, seasonality and how to identify quality food.

What do we know?

Coster & Kennon (2005) reported the following possible environmental benefits of farmers' markets:[554]
- Food travels shorter distances – from producer to consumer (not via processors, supermarkets etc);

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549 Australian Farmers' Market Association (2007), *AFMA Charter*, accessed 18 March 2008, http://www.farmersmarkets.org.au/about.jsp
550 For a list of farmers' markets in Victoria http://www.farmersmarkets.org.au/finder/vic.jsp
551 Australian Farmers' Market Association (2007), *AFMA Charter*, accessed 18 March 2008, http://www.farmersmarkets.org.au/about.jsp
552 Coster, M. and Kennon, N. (2005), *'New Generation' Farmers' Markets in Rural Communities* (No. 05/109), Rural Industries Research and Development Corporation, pviii&15
553 Ibid, pviii
554 Coster, M. and Kennon, N. (2005), *'New Generation' Farmers' Markets in Rural Communities* (No. 05/109), Rural Industries Research and Development Corporation, pviii&15

- Less waste – some of the food sold at farmers' markets is outside the very strict conformity standards required by supermarkets. In the absence of alternative, more direct, sales methods this produce is thrown out (American farmers have reported that 22% of their crop could not be marketed);[555]
- Less waste – there may also be significant reductions in packaging when not needing to travel so far or meet supermarket requirements;
- Opportunities for consumers to talk to producers and learn about production practices; and
- Opportunities to access less processed and more sustainable food.

This report found that food miles for particular products were considerably lower for foods at the farmers' markets as they only need to include the distance from the producer to the actual market. It found that the greatest average distance to market was for the urban example (Collingwood Children's Farm Market) at 114km. The regional and rural markets had average travel distances of 44km and 22km respectively. This is compared to a rough Victorian average of 500km for supermarket produce.[556]

A major component of food miles is that associated with transport from outlet to home (see *2.1.2*). The report found that while most customers arrived at the markets by car, in the urban markets many did walk and use public transport – it is likely that this would be similar for access to other food outlets. The report also found that a large proportion of customers at Victorian farmers' markets are local (suggesting that the distance travelled to access food may not be vastly different than from other outlets). 50% of the customers at the Collingwood market travelled for less than 5kms and more than 50% of the customers at the regional market (Hume/Murray) were from the two adjoining local government areas.[557]

What don't we know?

While farmers' markets provide opportunities for consumers to learn about seasonality, quality and sustainable production methods it is not clear whether this affects larger consumer behaviour. It is also not known whether the interactions between producers and consumers are driving more sustainable practices in response to consumer concern.

There is evidence to suggest that farmers' markets do reduce the environmental impact of food supply chains, in particular the associated emissions, through reductions in processing, packaging and transport. However, where producers have identified farmers' markets as a high value business practice, they may be inclined to travel long distances to reach these markets, for relatively small amounts of food. For example, farmers involved in development of the draft charter for the Victorian Farmers' Markets Association were keen to ensure the right to travel to non-local markets, in particular suburban markets, because of the high returns and business development opportunities.[558]

The increased number of trips associated with small orders of food may have unintended 'food miles' side effects and these enterprises could be vulnerable to oil price fluctuations.

3.3.3. Community supported agriculture

Producers and consumers in some areas have come together to develop community supported agriculture (CSA) schemes. These originated in the 1960s in Switzerland and Japan, where "consumers interested in safe food and farmers seeking stable markets for their crops joined together in economic partnerships."[559] People in urban areas pay a relatively local farmer a bulk

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555 Coster, M. and Kennon, N. (2005), *'New Generation' Farmers' Markets in Rural Communities* (No. 05/109), Rural Industries Research and Development Corporation, p3
556 Ibid, p23
557 Ibid.
558 Regional Development Company (2006), *Victorian Farmers' Market Association - Draft Charter*, Statewide Meetings - Feedback and Recommendations.
559 Food Connect (2005), *Community Supported Agriculture (CSA)*, www.foodconnect.com.au

amount at the start of the year and receive a weekly supply of fresh, seasonal produce from that farm. In this manner, the consumers of the food share the risks and successes of the farmer, have an increased connection with where their food is coming from (many of these farms encourage their urban partners to make up some of their payment through hours worked on the farm) and ease the financial strain on the producer by ensuring that there is money at the start of the season (when it is needed), not at the end.[560] These systems can reconnect farmers and consumers, increase the farmers' income, and offer fresher produce and lower prices to urban consumers.[561]

What is happening?

CSA schemes are very popular in the United States, where there are over 1000 enterprises with the number of customers varying between 10 and 700.[562] In Australia the concept is not well known and only a few CSAs exist – in 2001 only four could be found (one in Harcourt, Victoria).[563]

The Victorian CSA was the only one documented that appeared to have significant competition; from health food shops, a boxed delivery services and organic roadside stalls.[564] It is not clear why this approach has not become more popular in Australia. It may be due to a lower rural to urban proportion of population, or the different distribution of people in the landscape (Australians are concentrated in a few big cities whereas Americans have more smaller cities surrounded by rural areas).

Other consumer / producer interactions (such as *Slow Food* in case study below) are increasing in popularity.

Case Study: Slow Food

We must allow enough time to enjoy our food; we should share the act of eating with others; we ought to think of where the food came from and how it ended up on our plate
(Pignatelli, cited in *Slow Food Revolution*, documentary screened on SBS, 30 July 2007, http://www.sbs.com.au/whatson/index.php3?id=756)

The Slow Food movement started in Italy as a response to the increasing prevalence of the fast food culture (particularly galvanised by an attempt to open a MacDonald's in a historic building in Rome). The idea of Slow Food is that food should taste good and be enjoyed, in the company of family and friends, and should also be good for the environment and producers. One of the major drivers of Slow Food in Europe is to preserve cultural and bio-diversity in the food chain – the movement makes a specific effort to identify and preserve varieties that the mainstream food system no longer supports, but are tasty, unique and/or have strong local and cultural value.

Slow food participants are described as co-producers rather than just consumers, because their choice to make informed choices about which production systems they support, they become part of the production process.

The Slow Food movement now has over 80,000 members in over 850 local chapters worldwide, Australia has 35 local chapters and of these 10 are in Victoria.[1] Melbourne has a permanent Slow Food cafe (Piadina Slowfood in the CBD), there is a Taste of Slow festival every year as part of the Melbourne Food and Wine Festival and a Slow Food farmer's market once a month. Many more activities are coordinated through the other Victorian chapters.

Source: Slow Food Website, see http://www.slowfood.com/about_us/eng/

[560] Genauer, E. (2006), "Peak Oil and Community Food Security", *Communities: Journal of Cooperative Living*, Spring 2006, Issue 130, p37, http://www.energybulletin.net/18521.html
[561] Norberg-Hodge, H. (2002), *Bringing the Food Economy Home*, Zed Books, London, p107
[562] DPI (2007), *Small Farms: Community Supported Agriculture (CSA)*, Department of Primary Industries, State of Victoria http://www.dpi.vic.gov.au/
[563] Parker, A. (2001), *Feasibility of Community Supported Agriculture in Australia*, Department of Natural Resources and Environment, State of Australia.
[564] Ibid, p25

3.3.4. Urban Agriculture

Eco-cities must be farming cities... [as] urban farming creates green space, recycles wastes, cuts down on freight transport, prevents soil erosion and is good for the micro climate.[565]

Demand for chook food is greater than at any time in the (Thornbury) shop's 40 year history . . the younger generation want free range eggs and chooks. [566]

Oakland California is debating a food policy initiative that would mandate by 2015 the growing within a fifty-mile radius of city center of 40 percent of the vegetables consumed in the city.[567]

Summary and Recommendations:

Over 50% of the world's population now live in cities, and there is increasing attention to the benefits of producing food close to these consumers in the cities themselves – urban food production now accounts for 15% of the world's food production.[568]

Large amounts of food can be grown in cities and by citizens when it is required – Cuban cities produce an average of 60% of their vegetables (a response to oil shortages), [569] and US Victory Gardens in World War II produced up to 40% of the national food supply.[570] Australians have a strong history of urban food supply and, from the most recent records (1992), Victoria already has the largest number of households growing fruit and vegetables.[571]

Urban agriculture can reduce environmental impacts and increase the resilience of urban food supplies by: reducing vulnerability to oil prices; reducing food miles (and greenhouse emissions); making use of alternative 'agricultural inputs' ie. stormwater, wastewater and food waste; and reducing land conflict between food production, biodiversity and biofuels.

Consumer transport emissions from cars to actually collect food may be the most significant transport component of food footprint,[572] and for some foods it could even be the most significant emissions contribution.[573] Producing some food in backyards and local neighbourhoods has potential to remove (or significantly reduce) this impact.

International efforts to increase urban food production are making use of both traditional as well as innovative technological developments.

!	*Access to affordable food may be greatly improved through urban production – at home, community or commercial levels. Flexible urban water policy should allow for (or even encourage) this*
!	*Increased interest in home food production without adequate consideration of water provision may lead to environmental and public health risks (particularly greywater use on vegetables)*
!	*The ability to produce food is particularly important for low-income families and other disadvantaged groups*

565 Pearce, F. (2006), "Ecopolis Now: Forget the Rural Idyll. Urban Living May Be the Best Way to Save the Planet", *New Scientist*, Issue 190, no. 2556, p39
566 Gallagher, H. (2007), "Backyard Boom in Chooks", *Northcote Leader, Edition 1*, Wednesday 14 November 2007
567 Randy Hayes, Sustainability Director of the City of Oakland, June 2005, cited in Heinberg, R. (2005), "Threats of Peak Oil to the Global Food Supply", paper presented at *What Will We Eat as the Oil Runs Out?*, 23-25 June 2005, Feasta, Dublin, http://www.energybulletin.net/7088.html.
568 Pearce, F. (2006), "Ecopolis Now: Forget the Rural Idyll. Urban Living May Be the Best Way to Save the Planet." *New Scientist* 190, no. 2556, p39
569 Institute of Science in Society (2008), *Organic Cuba without Fossil Fuels*, accessed 23 January 2008, from http://www.cityfarmer.info/organic-cuba-without-fossil-fuels-the-urban-agricultural-miracle/#more-87
570 Hopkins, R. (2006), "Designing Energy Descent Pathways: Unleashing Abundance as a Community Response to Peak Oil," *Transition Culture*, accessed 26 July 2007, from http://transitionculture.org/?p=266
571 ABS (1992), *Home Production of Selected Foodstuffs, Australia*, Cat. No. 7110.0, Australian Bureau of Statistics, Canberra
572 Foster, C. et al. (2006), *Environmental Impacts of Food Production and Consumption: A Report to the Department for Environment, Food and Rural Affairs*, Manchester Business School, DEFRA, London.
573 Morgan, D. et al. (2006), *Seattle Food System Enhancement Project: Greenhouse Gas Emissions Study*, University of Washington, Program on the Environment, accessed 14 January 2008, from http://courses.washington.edu/emksp06/SeattleFoodSystem/Final_GHG_Report.pdf

- *Explore the economic and social implications of increased urban agriculture – how much could it affect access to and affordability of food (particularly fruit and vegetables)*
- *Investigate how much food is currently, and could potentially be, produced within Melbourne[574] - how much land could be available and what technologies / systems could contribute?*
- *Analyse the resource / environmental costs and benefits of urban food production (specific to Melbourne and regional urban centres)*
  - *Relative contributions of transport, energy, water use (including potential use of wastewater)*
  - *Comparison of water / emissions / inputs of home vegetable garden & fruit trees to food from other sources[575]*
- *Cheap, simple and safe household greywater systems enabling use for food*
- *Small scale green / organic waste composting systems (and larger scale energy from waste facilities)*
- *Integrated urban water treatment / food production systems*
- *Improved production practices in urban systems – applying useful agricultural knowledge to small-scale (household and community) systems*
- *Knowledge and systems for urban food production have very significant export potential*

What is happening?

In 2007 a major milestone has been reached, now, for the first time, over 50% of the world's population live in cities. The ecological footprint of most cities is much greater than the land area they take up – for the most part cities exist by taking in resources from the surrounding area and then sending their waste back out. Moves towards sustainability suggest a need to change this model to reduce the footprint of cities. Increasing awareness of threats and vulnerabilities of the city system also suggests a need to bolster their self-reliance. The importance of maintaining agricultural land in peri-urban areas for supply to cities is discussed in 2.2.3 *Land and Soils*. In recent years, there has also been an increasing interest in actually bringing food production back into the cities – this urban food production now accounts for 15% of the world's food production.[576]

There is little recent data on Australian urban food production (for historical information see *What do we know?* in this section). However, the *Australian Garden Market Monitor* stated that, for the year ending June 2007, "awareness and concern for environment is stronger and some consumers are drawn to gardening activity as a means of connecting. Indicator products such as vegetable seedlings are enjoying growth as consumers warm to the option of home grown vegetables."[577]

In addition to backyard food production, current urban food production in Melbourne includes other activities:

- Public spaces – food being grown in public spaces such as parks, available to all;
- Supported community gardens – community gardens that have been established primarily for social and health reasons, run for education and social interaction of particular vulnerable groups;
- Independent community gardens – community gardens that primarily consist of private allotments for people who don't have space to grow food at home, and/or prefer the interaction and support of doing so with others;
- Private gardens – the production of food in gardens for private consumption and/or small amounts of surplus for swapping or sale;

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[574] VEIL is investigating how much food is already being produced within urban Melbourne.

[575] Rough calculations suggest that between $5.7 and $29.4 million of fruit and vegetables could be produced in the City of Melbourne, using 10% of the mains water currently used for open space irrigation and 25% of that used for private gardens – see full report for calculation (3.3.4 *Urban Agriculture*),

[576] Pearce, F. (2006), "Ecopolis Now: Forget the Rural Idyll. Urban Living May Be the Best Way to Save the Planet", *New Scientist*, Issue 190, no. 2556, p39

[577] Garden Market Monitor (2007), *Australian Garden Market Monitor - Year Ending 30 June 2007*, Horticulture Australia Limited (HAL) & the Nursery & Garden Industry Association http://www.ngia.com.au/industry_structure/industry_structure.asp

- Commercial activities (small / medium scale) – food production for marketing and sale, including market gardens and value-adding operations; and
- Hubs and networks including extensive online resources and information exchange and emerging 'social networking' models.

These types of activities have been receiving increasing attention in the context of possible energy shortages and the need to reduce environmental footprint of food. Some grassroots urban food movements arising from concern about actual food supplies to cities are shown in Table 3-5.

Table 3-5: Grassroots Urban Food Production Movements

Name	Where	What	Intent
Permablitz[578,579,580, 581]	Originated in Melbourne, spread through Australia and North America	Groups of volunteers conduct 'backyard blitz' type makeovers to convert urban land to food production, uses permaculture inspired techniques.	Knowledge and skill sharing Production of affordable organic food Food security
Garden Sharing	USA	People who have no garden space share gardens with people who are unable to tend their gardens[582]	Make use of available land Skill sharing
Urban Orchard	CERES, Melbourne	Over 170 households from Melbourne's inner Northern suburbs come together fortnightly to swap and share the products of their backyard gardens. Initially established to reduce waste fruit, the project has expanded to vegetables, herbs and seedlings[583]	Reduce waste
Local Seed Networks[584]	Originated in Byron Bay, now over 60 networks across Australia (12 in Victoria)	Collecting seeds from open-pollinated heirloom crops for sharing and planting the following season. Provides a means for sharing seeds and sharing knowledge about seed saving techniques and the value of genetic diversity	To retain knowledge and access to 'non-corporate' seed varieties, including local adaptations
Local Councils	Throughout Victoria incl. Darebin, Moreland, Port Philip	Providing information and support to constituents wishing to grow food at home, as part of sustainable gardening and sustainable living programs	To support increased home food production and reduce organic waste

Exploration of urban food production opportunities has also started to expand from 'traditional' methods towards more 'high-tech' integration of food production into cityscapes. This ranges from pioneering projects exploring the integration of food production into green roofs (with potential to reduce urban heat island effects, insulate buildings, filter stormwater etc), to the early development stages of sophisticated, highly productive, urban systems. Some examples are outlined in Table 3-6.

Table 3-6: Innovative Urban Food Production Systems

Name	Location	Description	Advantages
Aquaponics	Melbourne	Building a highly productive aquaponics system that will produce fish and organic vegetables from farm, cafe and market waste as nutrient inputs http://stephenmushin.com/photo_library.php?library_id=16	• Ready made market • Uses waste as a resource

[578] See http://www.permablitz.net
[579] Abraham A.B. (2006), "Permablitzing the Suburbs", *Energy Bulletin,* accessed 26 July 2007, http://energybulletin.net/20945.html
[580] Kizilos, K. (2007), "Blitzing the Burbs", *The Age*, 16 July 2007, http://www.theage.com.au/news/in-depth/blitzing-the-burbs/2007/07/16/1184559700758.html
[581] Curnow, T. (2006), *Eat the Suburbs: Gardening for the End of the Oil Age*, Cross Stitch Films.
[582] Hayes, P. (2007), "The 'Sharing Backyards' Idea", *Urban Agriculture Note,* City Farmer - Canadian Office of Urban Agriculture, accessed 26 July 2007, http://www.cityfarmer.org/sharingBackyards.html
[583] CERES (2007), *Urban Orchard Project*, Centre for Education and Research in Environmental Strategies, accessed 26 July 2007, http://www.ceres.org.au/farm/organicfarm.htm#urban
[584] See http://www.seedsavers.net

ecoCity Farm	NSW	Commercial aquaponic system packaged into an IT supported retail franchise. Integrated fish and vegetable production Vertically stacked components give production capacity up to 12 times that of existing systems of the same footprint. Feasible in urban areas where land is expensive, grower can sell produce directly to consumers. http://rivendellorganics.com/ecocity.html	• Minimal or no transport costs • No refrigeration or storage costs • No extra labour costs on top of what the farmers are paid to grow and tend the food
Vertical farming	USA (concept)	"The majority of humans, living in cities, are protected against the elements, yet we subject our food-bearing plants to the rigors of the "great outdoors". However, with a rapidly changing climate floods, droughts, hurricanes, and severe monsoons take their toll each year, destroying millions of tons of valuable crops. It is time to learn how to safely grow our food inside environmentally controlled multistory buildings within urban centers." http://verticalfarm.com/index.php	• Year-round crop production; 1 indoor acre is equivalent to 4-6 outdoor acres or more) • No weather-related crop failures • Recycles black water • Reduces need for marginal farmland • Converts black and gray water into potable water by collecting the water of evapotranspiration • Generates energy via methane • Reduces fossil fuel use (no tractors, ploughs, shipping, transport)

Why is it happening?

In developing nations the main incentive for urban agriculture is malnutrition and food insecurity among the cities' poor. Malnutrition and access to fresh produce for some segments of the population has also been considered a driver in many cities in the developed world (Chicago, Toronto) and to some degree in Melbourne over the last 5-10 years. Food production activities involving vulnerable sectors of the community[585] have documented social and health benefits, including increased access to fresh produce, more diverse nutrition, community interaction and psychological well-being.[586] Some Australian / Victorian initiatives that have been established with primarily health / community benefits in mind include:

- Community gardens: CERES Community Environment Park, Collingwood Children's Farm, Cultivating Community, and the Australian City Farms and Community Gardens Network
- School kitchen-gardens: Cultivating Community, Stephanie Alexander Kitchen Garden Foundation

These benefits may also be more broadly available for people who wish to take a more active role in urban food production.

Urban agriculture is also being increasingly posited as a tool for both reducing the footprint and increasing the resilience of city dwellers. This has driven the more recent surge of interest in urban food production, including calls for more structured and coordinated approaches. The opportunity presented by urban food production is to:

- Increase resilience to oil scarcity by maintaining and enhancing productive capacity as close as possible to where the food will be consumed (ie. in urban and peri-urban areas);
- Localise food production and reduce 'food miles' and therefore greenhouse gas emissions;
- Make use of alternative sources of 'agricultural inputs' ie. grey-water and organic waste – it is efficient to convert these back into food close to where they are generated;
- Reduce land use conflict between food production, biodiversity and biofuels;
- Over 50% of the world's population now live in cities – significant opportunity to export technically supported and highly productive urban food systems.

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[585] Such as people who are: single parents with young dependent children; unemployed or have limited formal education; have a disability, including mental illnesses; non-English speaking backgrounds (refugee and asylum seekers); affected by alcohol and/or substance abuse, homeless and/or from Aboriginal and Torres Strait Islander backgrounds

[586] Nugent, R.A. (1999), "Measuring the Sustainability of Urban Agriculture", In *For Hunger-Proof Cities: Sustainable Urban Food Systems*, edited by Koc et al, International Development Research Centre, Toronto.

As described in Sections 1 and 2, fresh fruit and vegetables are likely to become significantly less affordable in coming years. This will impact on disadvantaged sectors of the community first, as is already being seen (*2.5 Health and Nutrition*). Home and community food production may be able to provide a significant food security buffer as costs of transport, carbon, global competition and water combine.

For citizens themselves, the drive to increase home food production is related to desires for increased self-sufficiency, affordable fresh fruit, vegetables and eggs, reduced environmental footprint and knowledge that their food is safe and ethically produced.[587]

Figure 3.2: Affordable Food[588]

What do we know?

So far, home gardening has been largely ignored as irrelevant to the sustainability debate - by redesigning the food production and supply chain around garden agriculture and urban agriculture it may be possible to achieve huge gains in resource use efficiency.[589]

We know that urban agriculture, particularly horticulture, can produce significant amounts of food. When oil supplies to Cuba were cut in the early 1990s they faced a food crisis. Part of their response was the development of urban agriculture – "production levels of vegetables have double or tipled every year since 1994, and urban gardens now produce about 60 percent of all vegetables consumed in Cuba, but only 50 percent of all vegetables consumed in Havana."[590]

During the Second World War 'Victory Gardens' in the UK, Canada and US saw private gardens, car parks, empty allotments and rooftops turned to food production to reduce pressure on the national food supply.[591] In the US, 20 million people were involved in victory gardening, producing up to 40 percent of the food consumed nationally. Although the Victory Garden concept was promoted by the US Department of Agriculture, they were originally initiated by individuals who needed to augment their rations.[592]

Victoria (and Australia) also has a successful history of urban food production as the climate and relatively high amounts of space make the production of many vegetables, fruits, vinecrops and berries available at a modest cost.[593] The most recent statistical information on Australian home food production was collected in 1992,[594] and although it does not separate food production in rural and regional from urban areas it does suggest the potential significance of home food production (Figure 3.3).

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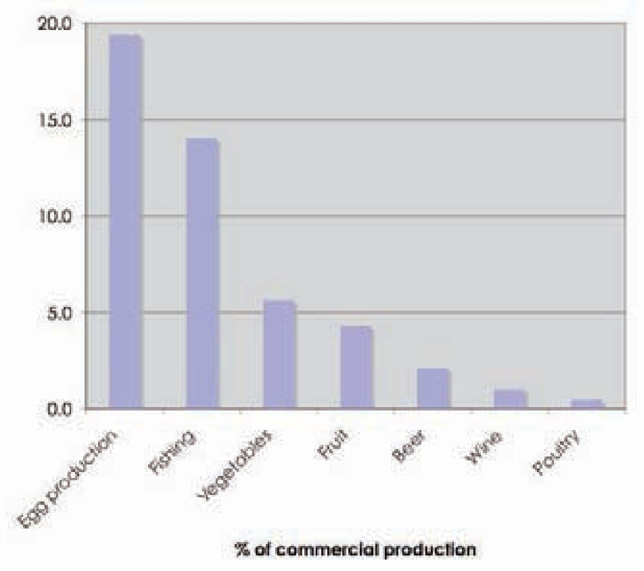
587 Gallagher, H. (2007), "Backyard Boom in Chooks", *Northcote Leader, Edition 1*, Wednesday, 14 November 2007
588 The Digger's Club (2007), www.diggers.com.au
589 Lenzen, M. and Foran, B. (2001), "An Input–Output Analysis of Australian Water Usage ", *Water Policy*, No. 3: 321–40.
590 Institute of Science in Society (2008), *Organic Cuba without Fossil Fuels*, accessed 23 January 2008, http://www.cityfarmer.info/organic-cuba-without-fossil-fuels-the-urban-agricultural-miracle/#more-87
591 Hopkins, R. (2006), "Designing Energy Descent Pathways: Unleashing Abundance as a Community Response to Peak Oil", *Transition Culture*, accessed 26 July 2007, http://transitionculture.org/?p=266
592 Ibid.
593 Timms, P. (2006), *Australia's Quarter Acre - the Story of the Ordinary Suburban Garden*, The Miegunyah Press, Melbourne University Publishing Ltd, Melbourne, p131
594 ABS (1992), *Home Production of Selected Foodstuffs, Australia*, Cat. No. 7110.0, Australian Bureau of Statistics, Canberra,

Figure 3.3: Contribution of Home Food Production[595]



- Households with reference person aged 55-69 produced the most fruit, vegetables, nuts and wine
- Households with reference person aged 35-44 produced the most eggs, beer and poultry slaughtered
- Victoria had the largest number of households growing fruit, and vegetables
- Most significant fruit crops were lemon/limes, apples, oranges, bananas and plums – average home fruit crop was 48.9kg
- Most significant vegetable crops were tomatoes, pumpkins, cabbages and brussel sprouts, lettuces and potatoes – average home vegetable crop was 70.4kg
- Victorian domestic hens laid 5.49 million dozen eggs

In the past, access to a variety of food was mostly dependent on home food production as many products were only available if produced at home.[596] Increased home food production in the future could serve the same purpose by increasing availability and affordability of basic foods.

Urban production could reduce environmental impacts of food consumption . .

A significant contributor to the energy requirements of many food products is the distances that it travels and the energy required for the associated storage and packaging (*2.1.2*). Urban food production can reduce these impacts as "food grown in urban spaces is rarely transported long distances – perhaps to a farmer's market or even given to family and friends. This reduces both the environmental costs of transport and the need for packaging and storage (and associated energy costs)."[597]

Urban food production also offers opportunities to reorganise food systems to close the loop on resources. Cities have usually been conceived as users of resources and producers of waste, but urban food systems could "reduce both the importation of natural resources and goods, and the exportation of waste and pollution."[598] This can be done because food grown in urban areas could make use of wastewater (of which there is plenty), as well as rainwater and stormwater that currently runs off impervious surfaces and is wasted. It can also provide localised recycling of nutrients from food and green waste (which made up over 47% of municipal waste sent to landfill in 2002/03).[599] Food waste from urban areas is a valuable resource and will become more so as fossil fuel based fertilisers become more expensive (see *2.2.2 Oil, Biofuels & Agricultural Inputs* and *2.4 Waste)*.

A 2007 Canadian study of the city of Kingston, which included interviews, modelling and calculations, found that urban agriculture could:[600]

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[595] Ibid.
[596] Timms, P. (2006), *Australia's Quarter Acre - the Story of the Ordinary Suburban Garden*, The Miegunyah Press, Melbourne University Publishing Ltd, Melbourne, p131
[597] Nugent, R.A. (1999), "Measuring the Sustainability of Urban Agriculture", *For Hunger-Proof Cities: Sustainable Urban Food Systems*, edited by Koc et al, International Development Research Centre, Toronto, p97
[598] Ibid, p97
[599] EcoRecycle Victoria (2005), *Information Sheet 2 - Waste Facts*, last modified March 2005, http://www.sustainability.vic.gov.au/www/html/2039-waste-and-recycling-information-sheets.asp
[600] Lam, S.O. (2007), *Urban Agriculture in Kingston: Present and Future Potential for Re-Localization and Sustainability*, Queen's University, www.cityfarmer.org/SunnyLamThesis2007.pdf

- Contribute at least $190 to $860 million per year (Canadian dollar) in positive environmental, health and economic benefits;
- Reduce annual greenhouse gas emissions by at least 1,300 to 14,000 tonnes for 39 common fresh fruits and vegetables;
- Meet the fresh fruits and vegetables needs of up to 76% or more of the Kingston CMA population; and
- Make use of the 5,600 ha of area in the inner-city that was suitable for food production.

The low population density of many Australian suburbs is equivalent (or less) than some of the world's densely populated agricultural regions, and the irrigation that already occurs in home gardens and urban landscapes (currently for amenity reasons) offers significant potential for irrigated food production.[601] A recent study of water availability and use in the City of Melbourne has found that over 80% of Melbourne's current water use could be met with the rain that falls on the city (if it was captured), and that almost 3GL (approx. 12% of total) water is used to irrigate open spaces (≈ 1GL) and private gardens (≈ 2GL).[602] A conservative redistribution of some of this water to food production[603] could produce between $5.7 million and $29.4 million dollars worth of fruit and vegetables.[604]

The use of wastewater for food production in and around cities is receiving increasing attention internationally, with a growing research interest in the related science, social and public health aspects.[605] DPI has commenced research into the use of Melbourne's recycled water for horticulture (see *2.2.1 Water*). The use of greywater (ie. waste water without urine or faeces) for vegetable production is currently not recommended, although use on fruit trees is encouraged.[606] However, under current water restrictions there is significant community and grassroots experimentation underway with greywater systems to support existing food production. The emergence of this behavior has both policy challenges and innovation opportunities, particularly in light of the environmental and health concerns about greywater reuse.

The high-tech urban food proposals outlined above offer opportunities to integrate wastewater treatment with food production, potentially even providing a source of potable water (through collection of vapour from evapo-transpiration).[607]

[601] Holmgren, D. (2005), "Garden Agriculture: A Revolution in Efficient Water Use", *Journal of the Australian Water Association*, vol. 32, no. 8.
[602] City of Melbourne (2008), *The City as Catchment*: *A Strategy for Adaptation*, prepared by EDAW - Ecological Engineering Practice Area, (preliminary draft for comment February 2008, due for release 2008)
[603] 10% of open space irrigation water, and 25% of private garden water
[604] These estimates are based on figures for average water efficiency of Australian fruit and vegetable production (103L / $ - from Lenzen & Foran (2001)) and best-practice small-scale permaculture production (20L / $ - from Holmgren (2005)). Figures that represent volumes of produce would be more useful, but are not readily available.
[605] Buechler, S et al. (2006), "Wastewater Use for Urban and Peri-Urban Agriculture", *Cities Farming for the Future - Urban Agriculture for Green and Productive Cities*, edited by Veenhuizen, R, RUAF Foundation, IDRC and IIRR.
[606] Byrne, J. (2005), *Fact Sheet: Grey Water, 28 May 2005*, Gardening Australia, Australian Broadcasting Corporation, http://www.abc.net.au/gardening/stories/s1366316.htm.
[607] Vertical Farm Project (2007), *Advantages of Vertical Farming*, www.verticalfarm.com

3.4. Consumer Choices

Consumers are willing to reduce their environmental footprint by cutting food waste and eating local food in season. They are less willing to make significant changes to the overall balance of their diet on sustainability grounds, though may consider doing so for health reasons.[608]

Consumer concerns and demand for different types of food, produced and distributed in different ways, can become expressed as new consumption preferences which change the marketplace. Even though they may be relatively small (compared to the mainstream market) they can have real economic impacts, either because of their purchasing power or because there are marketing companies or producers focused on 'trend-spotting', looking to find new niche markets to expand.

Although influenced by what is available, patterns of *consumption* are not completely bound by systems of production or distribution – consumer demand can emerge and influence the production system. This is evident, for example, in the case of clothing and 'fashion'. Food has similar cultural dimensions to clothing but has the added significance, in terms of consumption, that it is even more intimately associated with individual survival and bodily health.

There is increasing consumer concern about health, climate change and other environmental issues[609] and a growing interest amongst consumers in the origin of their food and how (and by whom) it is produced.[610] DPI studies of Victorians' attitudes to food indicate that although they express strong support for individual farmers, they are concerned about aspects of the increasingly industrialised system of food production, particularly GM organisms and agricultural chemicals. As a result, many express a preference for food from 'alternative' systems, although remain unsure of who to believe about what the benefits may be.[611] Consumers are choosing to pay more for food that has perceived health and environmental benefits (eg. organics), while co-operative associations and networks between consumers and small-scale local farmers are being formed to close the gap between producers and consumers – as described above.

The production and distribution strategies already covered have been driven and supported by consumer demand and participation. Participation in these movements has generally not yet been driven by price or convenience – these movements are driven by value drivers relating to personal and environmental health, fairness and ethics, and a view of food as a statement and reflection of personal and cultural values, not just a biological input. As described throughout this report, internalised environmental costs could mean that price and access also become drivers for expansion of these strategies.

Consumer concerns and interests are also being expressed through preferences and behaviours that do not directly influence the type of production or distribution system. These can be choices about: what brand to eat (Fair Trade); how to eat and how to obtain food (efforts to reduce food waste); and what types of food to eat (attempting to reduce the overall environmental impacts of diets by eliminating or reducing some foods).

Consumer strategies for choosing more ethical and sustainable food from the offerings available are further explored below.

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[608] Food Ethics Council (2007), "Sustainable Behaviour - If We Really Cared, Wouldn't We Pay More?", paper presented at the *Business Forum Meeting* on 13th September 2007.
[609] Carlsson-Kanyama, A. et al. (2003), "Food and Life Cycle Energy Inputs: Consequences of Diet and Ways to Increase Efficiency", *Ecological Economics*, vol. 44: 293-307.
[610] Hendrickson, M.K. and Heffernan, W.D. (2002), "Opening Spaces through Relocalization: Locating Potential Resistance in the Weaknesses of the Global Food System", *Sociologia Ruralis*, vol. 42, no. 4: 347-69.
[611] Klugman, M. (2006), *Victorians' Attitudes to Farming: A Review of Literature*, Department of Primary Industries, State of Victoria, p4

3.4.1. Fair Trade

Summary and Recommendations:

Fair Trade aims to improve conditions for producers in the developing world by providing a fair price for produce – consumers in the developed world pay a premium for Fair Trade products on the basis of social benefits (ie. no claim to or guarantee of quality or environmental benefits).

Markets for Fair Trade produce are increasing: worldwide sales increased 42% in 2006,[612] and Australian and New Zealand sales were $12 million in 2006/07 (making up almost half of the total sales of $25 million since September 2003).[613]

!	*Some consumers are willing to pay more for fair prices and conditions in developing countries. It is not yet clear whether consumers are / would be willing to pay more to ensure more sustainable operating margins for local producers*
🕮	*Are Victorian producers receiving 'fair' prices for their produce?*

Fair Trade is a global movement that aims to improve the conditions of producers in the developing world by providing a fair price and in doing so enable improved social and environmental practices. This movement relies on consumers in developed nations being willing to pay a price premium for an ethical reason.

In 2006, worldwide sales of certified Fairtrade products increased 42% on 2005, to approximately 1.6 billion Euros.[614] Although this is a very small component of total world physical trade, fair trade products are now accounting for 0.5-5% of all sales in their product categories in Europe and North America.[615] By October 2006, over 1.5 million disadvantaged producers worldwide were directly benefiting from fair trade while an additional 5 million were indirectly benefiting through access to infrastructure and community development projects established through fair trade.[616]

In Australia and New Zealand, 2006/07 annual retail sales of Fairtrade products were over AU$12 million, bringing total retail sales in Australia and New Zealand (since the first certified and labelled product was released in September 2003) to over AU$25 million.[617] The types of products being produced and sold as Fair Trade is expanding from the traditional areas of coffee, tea and chocolate products – over the last 18 months sportsballs, rice, sugar, quinoa and cotton have reached the Australian market.

The growth in Fairtrade sales reflects increasing consumer desire to think about the origins and impacts of their products, and their choice to "have a direct and positive impact on the lives of farmers, workers and their families in developing countries."[618]

[612] Fairtrade Labelling Organizations International. (2007), *Figures*, accessed 18 March 2008, www.fairtrade.net/figures.html
[613] Fair Trade Association of Australia and New Zealand (2007), *Fairtrade Retail Sales Set to Top AU$12 Million in Australia and New Zealand*, accessed 12 November 2007, from http://www.fta.org.au/node/1761/view
[614] Fairtrade Labelling Organizations International (2007), *Figures*, accessed 18 March 2008, www.fairtrade.net/figures.html.
[615] Krier, J.M. (2005), *Fair Trade in Europe 2005: Facts and Figures on Fair Trade in 25 European Countries*, the FINE Platform, a partnership of: FLO - Fair Trade Labelling Organizations, IFAT - International Fair Trade Association, NEWS! - Network of European World Shops, and EFTA - European Fair Trade Association.
[616] Fairtrade Labelling Organizations International (2006), *Fairtrade FAQs*, accessed 12 November 2007, http://www.fairtrade.net/faq_links.html?&no_cache=1.
[617] Fair Trade Association of Australia and New Zealand (2007), *Fairtrade Retail Sales Set to Top AU$12 Million in Australia and New Zealand*, accessed 12 November 2007, http://www.fta.org.au/node/1761/view.
[618] Steve Knapp, Director, Fairtrade Labelling Australia and New Zealand, cited in Ibid.

3.4.2. *Waste Reduction*

Summary and Recommendations:

Reducing food waste at the household level can save money and reduce environmental impacts of food.

Food waste can be reduced through changed eating habits, improved storage and revival of food, and more information about how to cook and make use of ageing food.[619] The environmental impacts of food waste can be ameliorated by reusing / recycling (ie. composting) the food waste – ABS data has suggested that an increasing number of households are composting food / kitchen waste,[620] perhaps almost 50%.[621]

Food that is discarded by retailers and wholesalers is sometimes salvaged by 'urban gleaners' or 'freegans', who aim to live off the waste generated by the mainstream food system.[622,623] Salvaged food waste is either consumed personally or redistributed to the homeless or other groups.[624,625]

!	*Understanding and reducing food waste at the household level may be an effective way to both build resilience to rising food prices and reduce environmental impacts*
	How much food is wasted, and where in the system could it be reduced, salvaged, redistributed or recycled (see 2.4 Waste)
	Reducing, reusing and recycling food that is currently wasted at the consumer end of the system (ie. retailer and household)
	Potential for processing innovations to reduce waste from seasonal 'gluts'

A reduction in food waste has been identified as a sustainable food behaviour change that consumers are most likely to be willing to make (along with consumption of local, seasonal produce).[626]

Almost half of Australian households report that they do reuse or recycle kitchen and food waste[627] (see 2.4 – *Waste*). ABS surveys suggest that this is increasing, from 35.6% in 1992 to 44.9% in 1996,[628] and 48% in 2005/06.

Since the UK identified that a third of the food purchased by households is wasted, they have initiated a campaign called "Love Food Hate Waste" – www.lovefoodhatewaste.com. This website provides advice and tools for estimating portions, recipes for food that might be past its prime (ie. bananas into banana bread) and leftovers, and tips for storage and revival of food. This approach aims to reduce the amount of food actually being thrown out at a household level.

Urban gleaning is one way of describing a range of practices in wealthy nations in which people voluntarily (politically) pursue and eat food that has been disposed of by others – particularly large retail outlets. The practice has been described as dumpster diving, skip dipping, freeganism and urban scavenging or foraging.[629] These practices involve sorting through the discarded goods of retailers, residences, offices and other facilities to salvage still useful (and edible) goods.

[619] See "Love Food Hate Waste" – www.lovefoodhatewaste.com
[620] ABS (1998), *Australian Social Trends 1998 - Waste Management: Household Waste Management*, Cat. No. 4102.0, Australian Bureau of Statistics
[621] ABS (2007a), *Australian Social Trends 2007 - Article: Household Waste*, Cat. No. 4102.0, Australian Bureau of Statistics, Canberra, p3
[622] see Freegan Info at http://freegan.info/
[623] Singer, P. and Mason, J. (2007), *The Ethics of What We Eat: Why Our Food Choices Matter*, Text Publishing, Melbourne
[624] See http://www.foodnotbombs.net/story.html
[625] Port Philip Leader (2007), cited in Edwards, F. and Mercer, D. (2007), "Gleaning from Gluttony: An Australian Youth Subculture Confronts the Ethics of Waste." *Australian Geographer*, vol. 38, no. 3: 279-96, p281
[626] Food Ethics Council (2007), "Sustainable Behaviour - If We Really Cared, Wouldn't We Pay More?", paper presented at the *Business Forum Meeting* on 13th September 2007.
[627] ABS (2007a), *Australian Social Trends 2007 - Article: Household Waste*, Cat. No. 4102.0, Australian Bureau of Statistics, Canberra, p3
[628] ABS (1998), *Australian Social Trends 1998 - Waste Management: Household Waste Management*, Cat. No. 4102.0, Australian Bureau of Statistics.
[629] Rush, M. (2006), "Skip Dipping in Australia", *The Australia Institute Webpaper*, February 2006, http://www.tai.org.au/index.php?option=com_remository&Itemid=36&func=fileinfo&id=201

An Australian study, specifically focused on gleaning practices related to food, found that participants are predominantly male, in their mid-20s and from well-educated middle class backgrounds with strongly ideological motivations.[630] By living off the waste generated by the mainstream, gleaning is considered by these participants to be a form of lifestyle/diet related resistance to the over-consumption and wasteful nature of the current food systems.[631,632] This type of gleaning is sometimes known as 'freeganism' – defined as "minimising impact on the environment by consuming food that has literally been thrown away."[633]

Beyond gleaning for personal consumption, movements have also arisen which aim to distribute wasted food to poorer people in urban areas. Food Not Bombs originated in the USA in 1980 as a volunteer network to recover waste food (that has been or would be thrown out), cook fresh hot vegetarian meals, and serve them in public places to anyone that wants or needs them. Food Not Bombs has been able to mobilise quick responses through volunteer networks and be among the first providing hot, fresh meals on the ground following September 11 attacks in New York, the Asian Tsunami and Hurricane Katrina.[634] There are five Food Not Bombs groups operating in Australia, including at least one in Melbourne. Another Melbourne based group is SecondBite, a volunteer organisation that coordinates the weekly sorting and distribution of approximately 500kg of unsold produce from the South Melbourne Markets.[635]

3.4.3. Eating in Season

The three main barriers to local seasonal food consumption were consumers' reluctance to deny themselves out-of-season produce, their lack of knowledge about what is seasonal and local, and poor access to shops selling such foods . . the message to eat local food in season appeals to consumers but they want guidance on how to do it.[636]

Summary and Recommendations:

Seasonality may simplify analysis of distribution systems and enable more general statements to be made about the sustainability of local foods. If foods are grown locally and in season, this is more likely to mean that they have not required greenhouses or other climate control for production, and may have also undergone less processing, packaging and storage. Production conditions in some areas may still be more sustainable than others, but seasonality removes one layer of complexity!

!	*A changing climate is likely to change the concept of 'seasonality' – knowledge about what is seasonal in particular locations will probably need to continually adapt*
	Explore seasonality in Victoria (and/or different regions in Victoria) – is it changing?
(R)	*Analysis of the potential to meet food needs through local, seasonal production in Melbourne / Victoria – what would diet include? Would it be nutritionally adequate?*
	Information and access to seasonal produce[637,638]
(R)	*Processing and marketing of seasonal gluts*

630 Edwards, F. and Mercer, D. (2007), "Gleaning from Gluttony: An Australian Youth Subculture Confronts the Ethics of Waste", *Australian Geographer*, vol. 38, no. 3: 279-96.
631 See Freegan Info at http://freegan.info/
632 Singer, P. and Mason, J. (2007), *The Ethics of What We Eat: Why Our Food Choices Matter*, Text Publishing, Melbourne.
633 Macmillan English Dictionary Online (2002), cited in Edwards, F. and Mercer, D. (2007), "Gleaning from Gluttony: An Australian Youth Subculture Confronts the Ethics of Waste", *Australian Geographer*, vol. 38, no. 3: 279-96, p281
634 See http://www.foodnotbombs.net/story.html
635 Port Philip Leader (2007), cited in Edwards, F. and Mercer, D. (2007), "Gleaning from Gluttony: An Australian Youth Subculture Confronts the Ethics of Waste", *Australian Geographer*, vol. 38, no. 3: 279-96, p281
636 Food Ethics Council (2007), "Sustainable Behaviour - If We Really Cared, Wouldn't We Pay More?", paper presented at the *Business Forum Meeting* on 13th September 2007
637 A US example can be found at http://www.nrdc.org/health/foodmiles/, search by State and time of year for a list of locally seasonal products.
638 Seasonal fruit and vegetable guides for Victoria were published by the Melbourne Market Authority in 2002 and are available from: www.marketfresh.com.au/images/download/fruitguide.pdf and www.marketfresh.com.au/images/download/vegetableguide.pdf

Some of the ambiguities of local food consumption may be reduced if seasonality is also considered. Consumption of foods that are in season locally means that their production is likely to be in accordance with the climate. For example, part of the reason that some foods in the UK and Europe have higher impacts than their imported counterparts is because cooler climates require them to be grown in greenhouses or with more inputs. If seasonality is considered (ie. only foods which are growing locally with 'ease' are included) then a smaller footprint is much more likely.

For Victorian, where the climate enables many foods to be produced, eating local seasonal foods is likely to mean reduced processing and storage. However, it could also mean reducing consumption of foods that can't be produced in Victoria.

Seasonal fruit and vegetable guides for Victoria were published by the Melbourne Market Authority in 2002 and are available from:
www.marketfresh.com.au/images/download/fruitguide.pdf and
www.marketfresh.com.au/images/download/vegetableguide.pdf

3.4.4. Choosing a Sustainable Diet

Summary and Recommendations:

Some people are attempting to reduce the environmental impacts of their food by making personal choices about the types of food they will actually eat. Concern about health has and will continue to shift eating habits, and concern about the environment may well shape the average Australian diet into the future. As some people attempt to adjust their diets to reduce their environmental impact, it is important that they do not jeopardise their health and nutrition in the process, or make decisions based on misguided information.

Swedish researcher Anika Carlsson-Kanyama has found that "food products with similar functions and nutritional qualities can differ widely in terms of life cycle energy inputs, so meals and diets can be more or less energy efficient while providing households with adequate nutrition,"[639] and that meals similar in calorie content can vary by 2-9 times in greenhouse gas emissions.[640] She found that, in Sweden, some meat products are much more energy intensive than others, as are some vegetable products – product specific analysis is necessary for recommendations.

A number of international studies, including the 2003 Joint Expert Panel of the World Health Organisation and the Food and Agriculture Organisation, have suggested that healthier diets (lower in salt, sugar and saturated fats, with more fruit, vegetables and legumes, and a higher proportion of foods of plant or marine origin), are also better for the environment.[641,642] Carlsson-Kanyama's work also highlighted the potential to reduce both environmental impacts and health concerns through a reduction in snacks, sweets and drinks.[643]

A Welsh study analysed the economic, environmental and nutritional impacts of a number of dietary changes. They found that substantial reductions in the ecological footprint of diets can be achieved through food substitution (with equivalent nutritional value), and can often represent a financial saving to the consumer.[644]

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639 Carlsson-Kanyama, A., Pipping Ekstrom, M., and Shanahan, H. (2003), "Food and Life Cycle Energy Inputs: Consequences of Diet and Ways to Increase Efficiency." *Ecological Economics*, vol. 44: 293-307, p300

640 Carlsson-Kanayma, A. (1998), "Climate Change and Dietary Choices: How Can Emissions of Greenhouse Gases from Food Consumption Be Reduced." *Food Policy*, vol. 23, no. 3-4: 277-93.

641 WHO/FAO (2003), *Diet, Nutrition and the Prevention of Chronic Diseases: Report of the Joint WHO/FAO Expert Consultation* (No. 916), accessed 31 January 2008, from http://www.who.int/dietphysicalactivity/publications/trs916/summary/en/index.html.

642 Duchin, F. (2005), cited in Carlsson-Kanyama, A. et al. (2003), "Food and Life Cycle Energy Inputs: Consequences of Diet and Ways to Increase Efficiency." *Ecological Economics*, vol. 44: 293-307.

643 Carlsson-Kanyama, A. et al. (2003), "Food and Life Cycle Energy Inputs: Consequences of Diet and Ways to Increase Efficiency." *Ecological Economics*, vol. 44: 293-307, p306

644 Collins, A. and Fairchild, R. (2007), "Sustainable Food Consumption at a Sub-National Level: An Ecological Footprint, Nutritional and Economic Analysis." *Journal of Environmental Policy and Planning*, vol. 9, no. 1: 5-30.

The high environmental impacts of meat (particularly from ruminants) and dairy consumption are under increasing international and domestic scrutiny.[645,646,647]	
!	*There is a strong correlation between the dietary changes recommended for improved health, particularly reduction in non-communicable diseases, and reduced environmental impact.*
!	*The personal choice to reduce red meat consumption (particularly from ruminants) and dairy consumption is very likely to reduce the environmental impact of an individual's diet.*
!	*Livestock play an important part in mixed farming systems and provide essential inputs (manure) that will increase in importance as conventional agricultural input costs increase. Efforts to reduce the environmental impacts, particularly methane emissions, from livestock are vitally important as worldwide demand for meat and dairy continues to increase.*
!	*Ultimately though, a continuing global expansion of meat (from ruminants) and dairy consumption is likely to be undermined by the need to reduce greenhouse gas emissions and constrained land and water supplies[648]*
🕮 (R)	*Analysis of recommended 'healthy eating' in Victoria / Australia and the environmental implications of recommended changes to dietary composition (such as reduced sugar, increased fruit and vegetables, level of processing); are there areas where these conflict?*
🕮	*Analysis of the most effective ways to reduce the environmental impact of diets through food substitution in a Victorian context – which foods to reduce, avoid, replace etc*
🕮	*Adaptation of knowledge about behaviour change in other fields (health, water, drink-driving etc) – how can food programs be developed, or integrated into existing programs*
⚡	*Alternative sources of meat protein and other foods – native species?*
⚡	***Systems and information enabling informed consumer choices***

As outlined in Section 2 and in some of the strategies above, the type of production and distribution system can have a significant impact on the footprint of particular products. Some food types have an intrinsically higher environmental impact than others and current dominant trends in food choices point towards increased environmental impacts.[649,650] There is potential for individual consumers to reduce the environmental impacts of food intake by making personal choices about what *types of food* they will actually eat. To prevent distortions and move through existing consumer confusion there is a need to identify, analyse and advise on what actually constitutes a more environmentally friendly diet.

How much impact could this have?

Voluntary dietary changes may have an increasing impact in years to come as better information about environmental impacts becomes widely accessible, understood and urgent. The likelihood of a large number of people making dietary choices based on environmental factors seems small now, but individual and collective changes to diets do occur as societal norms and aspirations change.

> Early cooking suggestions include parrot pie (made from rosellas), roasted carpet snakes, bandicoot, wallaby, kangaroo, witchetty grubs (similar to oysters apparently), young pigweed and native figs as substitutes for lettuce and spinach respectively.
>
> *Source: Mina Rawson 1895, cited in Bannerman 1998.*

Historical change of the average Australian diet reveals the transitory and fleeting nature of our dietary norms. Australia's native food resources were an important source for pioneer settlers and

[645] FAO (2006), *Building Resilience for an Unpredictable Future: How Organic Agriculture Can Help Farmers Adapt to Climate Change*, Food and Agriculture Organisation of the United Nations
[646] Diesendorf, M. (2007), *Paths to a Low Carbon Future: Reducing Australia's Greenhouse Gas Emissions by 30 Per Cent by 2020*, Sustainability Centre, Epping, Australia, p16
[647] McMichael, A.J., Powles, J.W., Butler, C.D., and Uauy, R. (2007), "Food, Livestock Production, Energy, Climate Change and Health." *The Lancet*, vol. 370, no. 5: 1253-63.
[648] Ibid.
[649] Carlsson-Kanyama, A. and Lindén, A. (2001), "Trends in Food Production and Consumption - Swedish Experiences from Environmental and Cultural Impacts", *International Journal of Sustainable Development (IJSD)*, vol. 4, no. 4: 392-406.
[650] Carlsson-Kanyama, A. et al. (2003), "Food and Life Cycle Energy Inputs: Consequences of Diet and Ways to Increase Efficiency", *Ecological Economics*, vol. 44: 293-307.

bushmen. However, later emigrants wished to retain their British food traditions and these efforts died out by 1900.[651]

Most of Australia's early white population were convicts and working class people, and the idealisation of the itinerant male bush-worker as the 'Australian legend' meant that meat, flour and tea became the main food staples or choice and habit, long after their original purposes – military convenience, shortage of supply and the need for portability – were irrelevant.[652] As Australian culture has continued to develop, the food we desire and eat has been influenced by waves of migration – Chinese, Italian, Greek, Lebanese, Vietnamese, Indian, Thai, Turkish, and some regions of Melbourne are now experiencing increases in Ethiopian, Somalian and Sudanese food outlets.

Concern about health has and will continue to shift eating habits, and concern about the environment may well shape Australian diets into the future. As some people attempt to adjust their diets to reduce their environmental impact, it is important that they do not jeopardise their health and nutrition in the process, or make decisions based on misguided information.

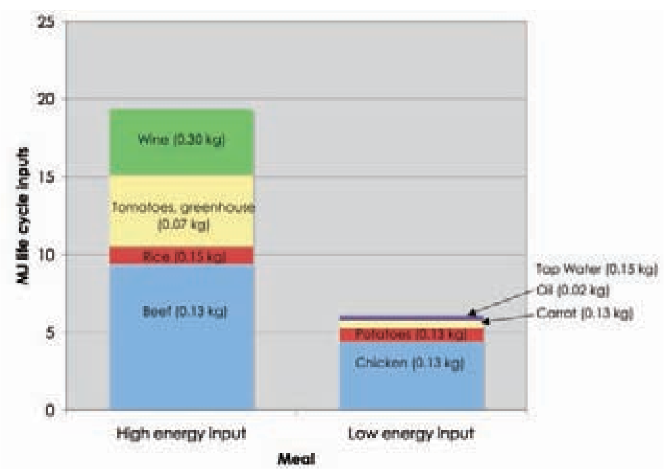
Energy Balance

A number of international studies have examined what might constitute both a 'sustainable' and healthy diet. Carlsson-Kanyama has found that "food products with similar functions and nutritional qualities can differ widely in terms of life cycle energy inputs, so meals and diets can be more or less energy efficient while providing households with adequate nutrition,"[653] and that meals similar in calorie content can vary by 2-9 times in greenhouse gas emissions.[654]

By comparing the differing energy inputs of meal compositions with the same nutritional value (for breakfast, lunch, snack and dinner), Carlsson-Kanyama was able to identify some significant determinants in a meal's embodied energy. Some findings confirmed those of previous studies, but others revealed new information. The comparison of a high energy input dinner and a low energy input dinner are shown on Figure 3.4.

Carlsson-Kanyama also noted that although vegetables grown in greenhouses (rather than in the open) and meat are generally more energy intensive, there are occasional cases where meat can be less energy intensive than vegetables. Meat type matters, as does the level of processing and transport – in Sweden chicken sausages require less energy than frozen broccoli from overseas.[655] The study suggests that recommendations must differentiate between meat and vegetable products depending on local conditions – ie. growing conditions, processing, storage and transport.[656]

Figure 3.4: Energy Input Differences in Meals



[651] Bannerman, C. (1998), *Acquired Tastes - Celebrating Australia's Culinary History*, National Library of Australia, Canberra
[652] Ibid.
[653] Carlsson-Kanyama, A. et al. (2003), "Food and Life Cycle Energy Inputs: Consequences of Diet and Ways to Increase Efficiency", *Ecological Economics*, vol. 44: 293-307, p300
[654] Carlsson-Kanayma, A. (1998), "Climate Change and Dietary Choices: How Can Emissions of Greenhouse Gases from Food Consumption Be Reduced", *Food Policy*, vol. 23, no. 3-4: 277-93.
[655] It should be noted that this study is only looking at energy balance, and not taking direct agricultural emissions into account.
[656] Carlsson-Kanyama, A. et al. (2003), "Food and Life Cycle Energy Inputs: Consequences of Diet and Ways to Increase Efficiency", *Ecological Economics*, vol. 44: 293-307, p304

This study found that it is possible to compose a diet compatible with goals for energy efficiency and equal global partition of energy resources, but that current trends are not heading in that direction, and it was certainly far from the Swedish average.

Health and Sustainability

According to the 2003 Joint Expert Panel of the World Health Organization and the Food and Agriculture Organization, 40% of non-communicable chronic diseases might be prevented by healthier food choices. In its summary statement, the Panel suggests that "people should eat less high-calorie foods, especially foods high in saturated or trans fats and sugar, be physically active, prefer unsaturated fat and use less salt; enjoy fruits, vegetables and legumes; and select foods of plant and marine origin. This consumption pattern is not only healthier but more favourable to the environment and sustainable development."[657]

A 2005 study of possible alternative future diets, that considered both land and energy required for production and obesity and nutrition related health concerns, found that the Mediterranean diet, consisting mainly of plant-origin foods but not excluding a small proportion of meat and other animal products, is be able to fulfil these needs than the current average US diet.[658]

Carlsson-Kanyama also suggests that a reduction in snacks, sweets and drinks (which have very little nutritional value and often have significant negative health impacts) could substantially reduce environmental impact – in Sweden they account for almost a third of the energy inputs to the food system. She suggests that "increased attention should be given to the environmental consequences of such items in a diet."[659]

A Welsh study has used ecological footprint analysis to examine the environmental impacts of food consumption, how they might be reduced through dietary changes, and the potential economic and nutritional impacts of doing so. For the city of Cardiff in Wales, food and beverage consumption is estimated to account for approximately 25% of the ecological footprint.[660] As in Australia, the biggest contributors to the Cardiff food and beverage footprint were 'meat and meat products' and 'milk and dairy products' – accounting for almost two thirds of the total footprint.[661]

The study then examined a number of scenarios for dietary changes to reduce impact (based on the food consumed at home). These scenarios and a summary of the results are shown on Table 3-7.

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[657] WHO/FAO (2003), *Diet, Nutrition and the Prevention of Chronic Diseases: Report of the Joint WHO/FAO Expert Consultation* (No. 916), accessed 31 January 2008, from http://www.who.int/dietphysicalactivity/publications/trs916/summary/en/index.html.
[658] Duchin, F. (2005), cited in Carlsson-Kanyama, A. et al. (2003), "Food and Life Cycle Energy Inputs: Consequences of Diet and Ways to Increase Efficiency", *Ecological Economics*, vol. 44: 293-307.
[659] Carlsson-Kanyama, A. et al. (2003), "Food and Life Cycle Energy Inputs: Consequences of Diet and Ways to Increase Efficiency", *Ecological Economics*, vol. 44: 293-307, p306
[660] Collins, A. and Fairchild, R. (2007), "Sustainable Food Consumption at a Sub-National Level: An Ecological Footprint, Nutritional and Economic Analysis", *Journal of Environmental Policy and Planning*, vol. 9, no. 1: 5-30, p12
[661] Ibid, p16

Table 3-7: Ecological footprint reductions from dietary change scenarios[662]

	% foods replaced	% EF reduction	% cost change	Energy and Nutrients below Recommended Nutritional Intake*
1. Increasing consumption of organic products	86.8	33.9	23.8	UK nutritional analysis not available
Replacing food and drink items with a high ecological impact per kilogram with low impact alternatives				
2. EF ≥ 0.006 gha/kg eg. cream, cheese, beef, veal, mutton and lamb	5.8	26.4	-7.7	4 nutrients and energy
3. EF ≥ 0.004 gha/kg	9.1	33.7	-15.6	3 nutrients and energy
4. EF ≥ 0.002 gha/kg	15.5	38.7	-38.0	5 nutrients and energy
5. Typical Vegetarian diet (includes eggs and dairy produce)	10.9	8.7	-18.0	8 nutrients and energy

* The average Cardiff diet used for comparison in this study had four nutrients and energy below recommended levels, therefore only the last two scenarios show a reduction in nutritional value.
NB. Gha = global hectares, EF = ecological footprint

Replacement or substitute foods were chosen to have similar nutritional value, eg. beef was replaced with pork and eggs with cheese. This study shows that substantial reductions in the ecological footprint of diets can be achieved, often representing a financial saving to the consumer. The most significant reduction was scenario 4, in both cost and environmental impact, however the authors note that this scenario requires the most substantial changes to diet and therefore could be difficult to achieve. The surprisingly low environmental benefit of the vegetarian diet is attributed to the substitution of meat products with cheese, which is highly processed and in some cases actually has a higher footprint than primary meat products such as pork. The authors acknowledge that substitution of legumes and soy rather than just cheese would improve both the nutritional and environmental elements of this diet, but attribute this limitation to insufficient data.[663]

The study includes more detailed information regarding the nutritional impacts than is discussed here. The authors also state that, while the study suggests ecological footprint can be reduced through dietary changes, demographic differences and complexity across the system (possible rebound and problem displacement effects) make policy design in this area very difficult.[664]

As discussed in *2.1.2* and elsewhere in this report, the quantitative results of these studies cannot be applied in an Australian context as the conditions are very different. For example, Australian beef and lamb animals are primarily grass-fed, leading to lower total and saturated fatty acids than the grain-fed animals of the US and Europe.[665] Therefore the nutritional changes (and relative environmental impacts) would possibly be quite different. Similarly however, fewer Australian vegetables are grown in glasshouses than in Europe so lower impact vegetable production is also likely.

There appears to be a strong correlation between the dietary changes recommended for improved health and reduced environmental impact. Applicability to Australia could be further explored.

[662] Collins, A. and Fairchild, R. (2007), "Sustainable Food Consumption at a Sub-National Level: An Ecological Footprint, Nutritional and Economic Analysis", *Journal of Environmental Policy and Planning*, vol. 9, no. 1: 5-30, p22
[663] Ibid, p27
[664] Ibid, p28
[665] MLA (2002), *Submission to the Joint WHO/FAO Expert Consultation on Diet, Nutrition and the Prevention of Chronic Diseases, Meat and Livestock Australia*, accessed 9 January 2008, www.who.int/entity/dietphysicalactivity/media/en/gsfao_cmo_070.pdf.

Meat in the middle

"A kilogram of meat is responsible for more greenhouse gas emissions than driving for three hours whilst leaving all the lights on back home…. A kilogram of beef leads to the emission of greenhouse gases with a warming potential equivalent to 36.4 kilograms of carbon dioxide…"[666]

Some people are choosing to reduce or eliminate meat,[667] dairy and fish from their diets – to become vegan, vegetarian or just remove meat from a couple of meals a week. People are also making choices around seafood consumption, perhaps not giving up fish altogether but consciously choosing varieties from more robust stocks or sustainable operations. Public debate of this issue has (and is likely to continue) caused conflict in a state and country with strong cultural attachments to the production and consumption of meat and valuable meat and livestock industries.

Figures 2.3, 2.9 and 2.11 and Table 3-7 strongly suggest that a diet with more plant foods and less of some meats and dairy will have lower environmental impacts. Victorian analysis has suggested that a vegetarian diet has half the virtual water content of a standard meat-rich diet.[668] The FAO also undertook a major investigation in 2003 and revealed the full impact of livestock production on the environment.[669] The personal choice to reduce meat consumption is very likely to reduce an individual's ecological footprint and an overall reduction in meat consumption would significantly reduce environmental impacts and increase capacity of the food system. The increasing sense of urgency around climate change throughout 2007 saw a number of Australian studies breaking the cultural 'taboo' and recommending changes to the way meat is consumed. For example:

- Diesendorf (2007) proposes that Australia should reduce beef consumption by 20 per cent, which he suggests could be accomplished by shifting to kangaroo meat and/or lower-meat diets;[670]
- McMichael et al. (2007) suggest an international contraction and convergence system to enable developing countries to increase intake of meat while requiring those in industrialised countries to reduce theirs. Noting that the current global average meat intake is 100g per person per day (with approximately a 10-fold difference between high-consuming and low-consuming nations), they recommend a target of 90g per person per day with less than 50% able to come from ruminants (e.g. cattle, sheep and goats). This would signal a significant reduction in Australian meat consumption levels (around 304g per person per day, of which at least 126g is from beef and lamb), to enable corresponding increases in developing countries.[671] They also note that this would only *stabilise* emissions from meat production and further decreases would be required if they were actually to be reduced. (McMichael's analysis of global potential to reduce emissions within meat production – up to 20% at fairly low cost – are outlined within *2.1.2*).

It should be noted that the previous sections have highlighted some of the ambiguities and risks of sweeping generalisations about any dietary change, eg:

- Under some conditions vegetables could have higher energy use than meat (although it would be very difficult for them to have higher greenhouse emissions unless someone drove to the supermarket just to collect that vegetable); and
- Substitution of meat products with other highly processed products of the same nutritional value could mean that the benefit is reduced.

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666 Ogino, A. et al. (2007), "Evaluating Environmental Impacts of the Japanese Beef Cow-Calf System by the Life Cycle Assessment Method", *Animal Science*, vol. 78, no. 4: 424-32.
667 Meat from ruminants (cows, sheep and goats) is the main concern due to high greenhouse (methane) emissions. White meats such as pork and chicken have lower greenhouse impacts – full analysis in Australian conditions has not been done.
668 Muntisov, M. (2007), "Thinking About Virtual Water", *Water: Journal of the Australian Water Association*, September 2007
669 Steinfeld, H. et al. (2006), *Livestock's Long Shadow: Environmental Issues and Options*, Food and Agriculture Organisation of the United Nations, Rome.
670 Diesendorf, M. (2007), *Paths to a Low Carbon Future: Reducing Australia's Greenhouse Gas Emissions by 30 Per Cent by 2020*, Sustainability Centre, Epping, Australia, p16
671 McMichael, A.J. et al. (2007), "Food, Livestock Production, Energy, Climate Change and Health", *The Lancet*, vol. 370, no. 5: 1253-63.

There are a number of additional reasons why meat (including red meat) will continue to play a part in diets even as environmental costs and constraints are felt, for example:

- Livestock play an important part in mixed farming systems and manure is likely to become an increasingly important input to production of other foods;
- Some land on which meat is produced is not suitable for other agricultural production; and
- There is some debate as to whether existing food systems could actually support a major (and rapid) change to more plant-based diets (ie. could we produce enough fruit and vegetables?).

While there may be small consumer movements encouraging the reduction of meat, global demand for meat and dairy continues to grow unabated (and increased consumption of meat and dairy in developing nations can have significant nutritional benefits).[672] Efforts to reduce the environmental impact of meat and dairy production (as mentioned in Section 2 and above) will continue to be vitally important.

Ultimately though, a continuing global expansion of meat consumption is likely to be undermined by the need to reduce greenhouse gas emissions and deal with increasingly constrained land and water supplies. Furthermore, any genuine carbon or water pricing system will further reduce the affordability of meat and dairy products and thus contribute to a changing role for meat and dairy in the Australian diet.

[672] WHO/FAO (2003), *Diet, Nutrition and the Prevention of Chronic Diseases: Report of the Joint WHO/FAO Expert Consultation* (No. 916), accessed 31 January 2008, http://www.who.int/dietphysicalactivity/publications/trs916/summary/en/index.html.

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