Victorian Food Supply Scenarios

Impacts on availability of a nutritious diet

Kirsten Larsen, Victorian Eco-Innovation Lab, University of Melbourne
Dr. Graham Turner, CSIRO Sustainable Ecosystems
Prof. Chris Ryan, Victorian Eco-Innovation Lab, University of Melbourne
Assoc. Prof. Mark Lawrence, Deakin University





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Contacts

Kirsten Larsen
Policy Research Manager, Victorian Eco-Innovation Lab, Faculty of Architecture, Planning and Building, University of Melbourne
Ph: +61 3 8344 9189
Email: klarsen@unimelb.edu.au
www.ecoinnovationlab.com

Prof. Chris Ryan
Director, Victorian Eco-Innovation Lab, Faculty of Architecture, Planning and Building,
University of Melbourne
Ph: +61 3 8344 9175
Email: cryan@unimelb.edu.au
www.ecoinnovationlab.com

Dr. Graham Turner
Senior Research Scientist, CSIRO Ecosystem Sciences
GPO Box 284 Canberra City ACT 2601, Australia
Ph: +61 2 6242 1653
Email: graham.turner@csiro.au

Assoc. Prof. Mark Lawrence
Director, Food Policy Unit
WHO Collaborating Centre for Obesity Prevention, Deakin University
Ph: +61 3 9244 3789
Email: mark.lawrence@deakin.edu.au

This report (and more detailed information from the project) can be downloaded from http://www.ecoinnovationlab.com/research/food-supply-scenarios

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Julian Cribb FTSE

Emma Greenhatch
Food Strategy Manager, Department of Business and Innovation

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Primary Industries and Resources, South Australia

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This well-balanced and expert report is timely. It will help shape our wider thinking in Australia as we tackle the now urgent, and unavoidable, task of reshaping social priorities and our methods of production and consumption in order to achieve a sustainable future - for this country and for the world.

Food systems are crucial to human wellbeing and health, and are a major part of our economy. The sort of innovative thinking and expert modelling evident in this report will help us to bring our food production and food choices, in Australia, back into balance with the long-term needs of the environment - recognising also the now clear prospects of climate change and declines in energy and chemical fertiliser inputs.

Prof. A.J. McMichael, National Centre for Epidemiology & Population Health, ANU College of Medicine, Biology and Environment, The Australian National University

Australia is a relatively food-secure country in an increasingly food-insecure world. As we move to the peak in human demand for food of the mid-century, essential food-producing resources of water, land, oil, nutrients, technology, fish and stable climates will become increasingly scarce and costly – and this will impact on Australian food systems and national security as well as those of the world as a whole. In this study Kirsten Larsen and her colleagues explore these critical issues, encouraging us to take wise forethought and timely action in order to ensure our future health, wellbeing and safety through food.

Julian Cribb, author of 'The Coming Famine' 2010

Climate change will affect food production, and we need to face the fact that what we eat and drink is likely to change with limits to land, water, fuel and fertilisers. This report encourages us to recognise problems, to think laterally and plan our future in such a way so as to achieve the best outcome for as many people as possible. It's not all bad since the diet that is best for the health of the planet just happens to also be best for the health of the people.

Dr Rosemary Stanton OAM, nutritionist

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Executive Summary

There are resource allocation and management decisions being made now in Victoria, and Australia, that will have significant implications for the flexibility and options for our food supply in the next decades and for future generations of Australians. This project sets out a framework for more detailed investigation of some very critical questions, by developing and demonstrating a methodology that can be extended to test various options for 'food security policy'.

This research explores how these decisions will impact on our ability to provide a reliable surplus of the foods required for a nutritious diet, whilst providing for ongoing health of the environment, the economy and ultimately the wellbeing of people and communities (both farming and urban communities).

The Victorian Food Supply Scenarios project has been a 12-month research project funded by the Victorian Health Promotion Foundation (VicHealth) through the Healthy Eating stream of their Research Innovation grants, provided to research a new concept or methodology relevant to the theory, policy and practice of health promotion.

The primary purpose of this project was to develop and demonstrate a new methodology to link land and resource use with availability of a nutritionally adequate food supply for Victoria's population. The research made new use of an existing physical model of the Australian economy developed by CSIRO (one of the project partners) to track the complex interaction of land and resource systems as they affect the availability of food. The research was undertaken within strict time and resource constraints and there was consequently a limit to the analysis of data sets and settings. The assumptions, approximations and generalisations are noted throughout the report.

The tensions identified through this work are significant, in spite of levels of uncertainty resulting from the project constraints. They strongly suggest that a sophisticated and strategic approach to resource allocation is urgently required, if the multiple objectives of food security, energy security, greenhouse emissions reductions, sustainable resource use, a healthy environment and a viable economy are to be achieved. The outcomes do not provide any easy answers, or suggest that one approach to these issues is clearly better than another.

Context

Availability of sufficient foods for a nutritious diet

This project is focused on food availability: "*sufficient quantities of food of appropriate quality*, supplied through domestic production or imports (including food aid)" (FAO 2011); this recognises that the irreducible base of food security is the physical ability to provide for the nutritional needs of the population. We use an indicator of 'net food availability' i.e. how much of each food group under investigation is produced in Victoria / Australia, compared to that required.

Food availability is necessary, but not in itself sufficient, to ensure that a household or population is food secure. This analysis does not discount the critical importance of other aspects of access to food that affect security, e.g. price, consumer preferences, advertising, food safety and so on, but they are outside the scope of the research.

It is assumed that it is possible to import food, and other critical resources, if required; however relative levels of domestic sufficiency are compared under different scenarios. It is also assumed that food produced is physically available to consumers i.e. that the systems function effectively to distribute food (even if those systems operate differently across the scenarios).

Nowhere to hide

There are four overarching drivers that shape this research: climate change; oil; fertilisers and population growth. These drivers contextualise the challenges we face in securing food availability. While these issues may not be fully in our control, it is the divergent strategies for our response that shape future scenarios. In this analysis we have assumed:

- Climate change is already occurring and is a result of human activity through the emission of greenhouse gases into the atmosphere. It will intensify in the study period, as the climate system responds to levels of greenhouse gases that are already in the atmosphere.
- Ambitious action to reduce emissions by 2030 is necessary and will occur.
- Australia's oil production has peaked and increasing imports are required to meet increasing demand. The International Energy Agency suggests that global (conventional) oil production peaked in 2006 (IEA 2010). The increasing cost (energy and financial) of extracting oil resources means that costs will rise significantly. This will drive substantial transformation of the economy, with implications for the food system.
- Increasing global demand, and challenges to the supply, of fertilisers (particularly phosphorus) will reduce availability and increase cost.
- Global population growth will continue, as it will in Australia.

Key Messages

Food availability is complex – it is closely linked with resource and land use, trade, employment and energy and water usage. Assessing or managing food availability requires a coherent assessment of the interactions of all of these factors.

In this project, we have developed and tested three scenarios (described in Section 3.2 and depicted in Figure 3-2) to explore food availability and to investigate its interaction with population, resource use and the economy. One scenario, labelled as "*Adjustment*", assumes free markets and high levels of international trade; "*Control*", as the second scenario, assumes strong policy and regulatory intervention in the market to ensure the domestic supply of core foods; the third, "*DIY*", envisages a more decentralised future with light, mostly local, government intervention.

The scenarios reflect different strategic approaches to the issue of food availability and create divergent sets of variables for modelling: energy demand, efficiency and sources; allocation of land and water resources; levels of waste and losses; levels of water and fertiliser efficiency in agricultural production; and transport patterns and modes. Key findings are outlined below.

All foods are not created equal

By considering the needs for a nutritious diet, rather than the diet as typically consumed, this project has revealed early and immediate tensions in availability of the foods required. An overall surplus of 'food products' is not the same as production of a nutritionally adequate food supply.[1] Results from the analysis show tensions in providing for a nutritious diet, as described in sections 3.3.3.6, 3.3.4.6 and 3.3.5.6 and discussed in section 4.1. These include:

- Australian production of fruit and vegetables already falls short of providing sufficient serves of these foods to meet the recommended food intake patterns.
- Two of the scenarios reallocate land from one type of production (grazing) to another (fruit and vegetables) in an attempt to maintain sufficient production of required foods at a national and

[1] Nutritional health requires both adequate amounts of food to meet human energy requirements and adequate variety of foods to provide the diversity and amounts of nutrients required.

Victorian level respectively. This is successful in providing fruit and vegetables but creates other tensions, resulting in shortages of dairy (by 2030) and lamb (by 2060).

- Some food crops can be used as biofuels. Two of the scenarios see diversion of cereals, sugar and oil crops to 1st generation biofuels, with one producing a serious conflict between food and fuel by 2030.
- In all scenarios, Victoria becomes borderline or a net importer of cereals by 2030. Australia retains a cereal surplus to 2030, but it is in steady decline in all scenarios.

The project shows that under the expected future conditions (climate change, increasing population and diminishing availability of oil), the domestic production of a surplus of required foods – at either Victorian or Australian level – must not be taken for granted.

No such thing as a free lunch

Ultimately the successful provision of food is determined by the bio-physical factors necessary for its production (land, soils, sunlight, nutrients, feed-stocks) and the availability of resources required for organising production, processing and distribution. The scenarios test challenging, but realistic, possibilities for change to availability, allocation and use of resources. These impact on:

- Use of land, water and energy resources;
- Production and distribution infrastructure;
- Targets for reduction in greenhouse gas emissions;
- Levels of import reliance for oil and fertilisers; and
- Settings for key economic indicators (i.e. GDP; unemployment and trade balance) that are considered representative of healthy economic activity.

The rationale and settings for each scenario are described throughout section 3.3. Key settings and findings are outlined below.

Land: Productive land area reduces in all scenarios, due to varying combinations and rates of diversion to forests (for carbon sequestration and bioenergy) and urban land expansion. The change of land use from irrigated to dry-land production also has an impact.

Water: Large reductions in water extraction for irrigation fail to avert 'negative' environmental flows in key river systems, in two out of the three scenarios (sections 3.3.6.1 and 4.2.2).

- The Victorian irrigation districts analysed (*Gippsland* and *Murray*) have negative environmental flows by 2040-50 even with the greatly reduced extractions in *Adjustment* and *Control*. The *DIY* scenario has a 75% reduction, which stabilises and maintains environmental flows throughout the study period, although *Murray* is still declining.
- River systems with 'negative' environmental flows for any period of time are unlikely to support food production in the longer term. It should be noted that the reduced extraction levels, while large, are not at the extreme (high climate change) level that CSIRO (2008) suggested may be required for the Victorian regions of the Murray Darling Basin. This tension clearly cannot be sustained.

Greenhouse Gas Emissions: all scenarios have significantly reduced greenhouse emissions by 2020, with two meeting IPCC requirements for Annex 1 countries at a national level (sections 3.3 and 4.2.3).

- The scenarios have different levels of ambition in reducing greenhouse gas emissions (Table 4-5).
- The settings for the *Adjustment* and *Control* scenarios 'overshoot' their emissions reduction targets and achieve greater reductions on 1990 levels than were sought by 2030, but fail against later targets.
- *DIY* has the most ambitious targets. It is the only scenario that does not achieve its intended 2030 reduction level at a Victorian level, but it exceeds IPCC requirements by 2020 and its own 60% reduction target at a national level in 2030.

- *DIY* is also the only scenario that is able to sustain emissions reductions beyond 2040. This is due to a reduced per capita consumption of good and services (and correspondingly energy use) across the economy, which has negative implications for GDP per capita and unemployment (as currently measured).
- In the other two scenarios, the economic indicators remain 'healthy' but greenhouse gas emissions start rising again from 2040. This is due to increasing energy demand outpacing efficiency gains and the net benefit from carbon sequestration in forests declining as land availability reduces.

Oil: one scenario achieves a high level of energy security and significantly reduces imported oil reliance, although massive and immediate intervention is required (sections 3.3.6.2 and 4.2.4).

- The *Control* scenario achieves the most significant reduction in imported oil dependence, due to an immediate shift to electric vehicles (all new passenger vehicles from 2011) and rapid scale-up of gas for electricity and transport fuel. This leads to electric vehicles using more electricity than buildings by 2030 and sees conventional gas resources under severe strain by 2060.
- The substantial diversion of crops for biofuels in *Adjustment* and *DIY* has an impact on oil demand, but is marginal compared to the decline in Australian oil production. It is a large diversion of food for a minimal energy gain.
- All of the possibilities for fuel substitution that are not quantitatively included in the project would have other costs elsewhere e.g. increased greenhouse gas emissions (coal-to-gas and coal-to-liquids) or environmental damage (and additional loss of agricultural land or water resources) from accessing non-conventional gas resources.

Phosphorous: all scenarios reduce reliance on imported phosphorus, but retain a large requirement (sections 3.3.6.3 and 4.2.5).

The significant reductions in imported phosphorus requirements achieved are largely due to demand-side measures, including:

- Change of diet (the requirement for a nutritional diet modelled in this project has a significantly lower requirement for meat products than the Australian average. The *Control* and *DIY* scenarios reduce the proportion of meat and dairy products being produced);
- Reducing waste / loss levels in some scenarios; and
- Agricultural efficiencies that reduce demand for phosphorus (relative to amount of food produced).

These unresolved tensions in the results point to a need for more detailed investigation. For example, a net zero environmental flow in key river systems is not an acceptable (or viable) outcome. Similarly, constraints on global oil supply or domestic gas could mean that the energy use assumed in this work is either not possible or prohibitively expensive. Testing how and whether these tensions can be resolved becomes a priority for further work.

Methodology

The purpose of this project was to develop and demonstrate a new methodology to link land and resource use with availability of a nutritionally adequate food supply for Victoria's population. To do so, it has built the capacity of the CSIRO stocks and flows model as a platform for on-going 'what-if' investigation of Victorian and Australian food supply security.

The three elements of the methodology developed are:

1. Determining the amount and variety of foods required to meet the recommendations of nutrition reference standards for the population;
2. Constructing qualitative scenarios to frame divergent socio-economic and technical trajectories; and
3. Translating qualitative scenarios to quantitative scenarios and analysing their implications.

Food requirements for a nutritious diet

The Australian Guide to Healthy Eating (AGTHE) defines a nutritious diet as one that meets the key nutrition reference standards. The aim of the AGTHE is to, "encourage the consumption of a variety of foods from each of the five food groups every day in proportions that are consistent with the Dietary Guidelines for Australians" (Commonwealth Department of Health and Ageing 1998).

An estimate of the amount and variety of foods required to meet the recommendations of nutrition reference standards for the population was obtained by:

1. Selecting foods to represent each food group;
2. Selecting the population categories for which the nutrition implications would be assessed;
3. Determining the number of recommended serves for each food group; and
4. Estimating the amounts of foodstuffs required to meet the nutrition reference standards for the population.

Qualitative Scenarios

This project developed and used 'what-if' or 'exploratory' scenarios. These have plausible, internally consistent storylines containing different social, cultural, political and economic regimes. The resulting qualitative scenarios (described in Section 3.2) describe different sets of operating conditions resulting from different responses to identified drivers and dynamics that will impact on food supply. They are then used to explore different policy or strategic approaches to key issues.

The scenario development drew on international precedents as well as a participatory stakeholder process in Victoria.

The scenarios were differentiated along three axes:

- Speed and effectiveness of greenhouse gas emissions reductions;
- Extent to which governments intervene to manage food and energy security concerns; and
- Scale of solutions: global, national or local / regional solutions.

The scenarios describe a 25-year horizon for future thinking, for both practical and strategic reasons (following a process developed in the work of one of the research partners, the Victorian Eco-Innovation Lab). This timeframe is sufficiently removed from the present day that most workshop participants and readers were able to suspend intellectual or business commitments to 'what will happen'. 25 years is also a sufficiently long period that real structural change can take place. While settings have been calculated to 2035, the results of the modelling are shown to 2060 so that longer-term implications of the settings can also be considered.

Quantitative Scenarios

The qualitative scenarios were translated into quantitative scenarios, to enable computational analysis of key settings such as:

- Land moved from food production to urban uses, forests for sequestration and energy;
- Reduced availability and reliability of irrigation water – increased proportion of dry-land agriculture;
- Energy efficiency, changes to energy mix and demand reduction;
- Fuel efficiency, fuel substitution, change of transport mode and demand reduction; and
- Agricultural production efficiencies in water and fertiliser use.

When translated into quantitative scenarios, they are still 'exploratory'. The numbers, proportions and results are set to allow exploration of critical relationships – when we increase X, Y also changes, when we decrease A, we see a significant change in B, C and X. With food we are dealing with a very complex set of interrelated systems – policy or action considering one issue, such as water or energy or land, in isolation from the others will simply displace problems to elsewhere in the system. In practice, none of the scenario parameters are tightly defined and it is possible to adjust the value of some of those parameters so that net food deficits are reduced or inadvertently increased; the results of such adjustments will of course be some change in other system functions.

In this first stage of research, many tensions remain unresolved. These become a priority for further work, for further iterations of scenario settings and modelling, to see whether (and how) they could be.

Market forces allocate resources – they do not make them exist

There is a prevailing argument that constraints on food or energy supply will be partially or largely overcome through 'market forces' as price signals drive innovation, technology development and efficiency improvements. The research has not ignored these issues, they are explored through the scenarios as factors that determine the allocation of resources. Key points relating to prices include:

- The effects of changing prices are implicit in all scenarios – the price signals, market structures and government actions are defined outside the model, but are translated as assumptions about efficiencies or establishment of the new technologies or practices (i.e. assuming that they become economically feasible responses to tensions exposed through the modelling).
- There are both physical and financial constraints to resource extraction, regardless of what level prices for key resources reach. For critical resources like oil, continually increasing prices are unlikely to be economically sustainable, reducing the capital available to access the remaining resource or to develop substitutes.
- By assessing the physical limitations, it is evident that there are real constraints on how much can actually be provided from what is ultimately a finite resource base.

Vulnerabilities and resilience

Tight profit margins on food products, for example, will make some current sources unprofitable as the price of fuel rises and local suppliers become more competitive. Retail industries will need to either re-evaluate the 'just-in-time' business model, which assumes a ready supply of energy throughout the supply chain or increase the resilience of their logistics against supply disruptions and higher prices. [Lloyd's Risk Insight 2010].

The structural differences in the infrastructures of food supply explored in the scenarios would be likely to affect the resilience of each food system – the extent to which food availability can be maintained, or the food system can 'bounce back', in the event of shocks or rapid systemic change. The research was not able to explore these issues in any depth, although it is recognised that this is a critical test of the viability of the food system, one that will become increasingly significant as the impacts of climate change and peak oil impinge on global and local markets.

There are clear signs of vulnerabilities in global trade patterns that raise questions about reliance on imported foods to meet core nutritional requirements. These include: an increasing incidence of governments responding to domestic food security concerns by slowing or banning exports of food (and fertilisers); severity and frequency of extreme weather events disrupting both production and distribution of food; and potential for energy and food constraints to directly impact on distribution systems, and/or trigger social and political unrest.

Further analysis is required to subject the modelled systems to some of the potential shocks that might occur in the future, to test their resilience.

What next?

Research

Research extensions to this project would all involve further development of this physical modelling capability for greater understanding (and improved adaptive management) of complex change in the food system, and to further inform policy and practice. Priorities would be to conduct more detailed analysis of key tension areas, to work to resolve tensions (to test whether and how this could be done) and to evaluate issues of resilience. This project provides a strong foundation for the identification (in collaboration with policy-makers), of policy opportunities, gaps and barriers across the food system and how potential policy interventions might be prioritised. More detail is provided in section 5.1 and Appendix 6.

Opportunities

For Australia's future development, addressing the issues and challenges explored in this project will require substantial reconfiguration of the food system. While no scenario provides an 'easy answer' to how this can or should be done, they all suggest possible responses and solutions that can be further explored. This is not a challenge unique to Australia; in the conduct of this research it became clear that many countries and regions were already grappling with the issues we explored and in many contexts the need for innovation is being given a high priority.

Significant opportunities that are referenced in the qualitative scenarios but have not been accounted for in the quantitative analysis include: use of waste-water; re-cycling of organic waste and other products to produce energy, food and fuel; reduction of emissions in agriculture and sequestration of carbon in soil; next generation biofuels, and so on. It is likely that these could make significant contributions to easing the tensions identified and should be priorities for further research and action.

Policy

A key question arising from the analysis is about how use of limited and contested resources can be optimised to meet critical objectives. This raises fundamental issues about how we frame decisions about land and resource use, particularly in light of concerns about food availability. Are the critical objectives 'profit' or 'productivity', or 'resilience'? Should we plan for short-to-medium term targets (on the assumption that future technological gains will ease the tensions) or should we focus – now – on the long-term public good based on more conservative technological assumptions?

- For policy makers, the challenge is to optimise use of land and resources for the public good, ensuring that appropriate incentive structures stimulate private enterprise and innovation to this end.
- Given the long-term constraints, using price as the only mechanism to determine the flow of land and resources in the short term (i.e. to highest value use) could effectively reduce the resource base and options available to meet population requirements.
- Sensible and strategic decision-making about how resources are used needs to be informed by an evidence base that accounts for physical realities as well as economic drivers. The methodology outlined here could be further developed to this end.
- The assumptions and variables defined in this work point to where more specific policy tools may be applied, and can inform policy frameworks for considering these issues. Key areas for policy consideration are:
    - Reducing waste – closing cycles and increasing resilience of production and distribution systems (reducing extent of losses to extreme events);

- Obtaining multiple outcomes from land and resources, including: 'mosaic' farming for food, energy, biodiversity and carbon sequestration; and urban and peri-urban food production to utilise 'waste' water and nutrients concentrated in population centres;
- Preventing irreversible loss of food production capability, particularly relating to non-substitutable foods (e.g. fruit and vegetables);
- Regenerating soil quality and capability to meet the challenge of reduced fertiliser availability;
- Reducing overall energy and transport demand in both household (passenger) and industrial (freight) sectors;
- Technology and practice change for energy and fuel efficiency, including development of substitute transport fuels and transformation of the transport system;
- Water and nutrient availability and use – developing alternative water and nutrient resources that do not impose additional energy costs; and
- Develop strategic approaches to potentially prolonged challenges to food availability. Could the welfare and emergency food systems cope with extended price impacts of food availability issues?

1. Introduction

The Food and Agriculture Organisation (FAO) has defined food security as being when "all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active life" [FAO 2011]. Lang [2010] has stressed the importance of extending this definition so as to encompass environmental sustainability considerations and it is this extension that is being explored in this research.

Ideally, sufficient food for a nutritious diet should be securely available regardless of population growth, changing land uses, water availability, energy supply and climate, and so on. Given that at least 6% of Victorians are already food insecure (have run out of food and been unable to afford more) [McCaughey Centre 2007], that demand for emergency food relief has increased rapidly (most notably in regional areas) [VicRelief Foodbank 2008], and climate instability is having severe impacts on food supply; it is timely to investigate how exacerbated environmental and resource challenges could impact on future food security for Victorians.

In April 2008, the Victorian Eco-Innovation Lab released *Sustainable and Secure Food Systems for Victoria: What do we know? What do we need to know? (SSFSV)* [Larsen et al. 2008]. That report catalogued the environmental challenges and resource constraints that will impact (and in many cases are already impacting) on the Victorian food system. These include water scarcity, water and soil quality, energy (including oil) and nutrient scarcity, climate change and diminishing biodiversity [Larsen et al. 2008]. These changing circumstances are global as well as local, and are expected to have an impact on the volume and diversity of foods produced and consumed.

The SSFSV report identified many research gaps, including a lack of Victorian research exploring the relationship between environmental and resource constraints and future food security, or how supply challenges might affect secure access to a nutritious diet.

Since the release of the SSFSV report, there has been growing attention to the links between environmental and resource constraints, the decline of natural resources and the sustainable and secure provision of food – in Victoria, Australia and around the world.[2] Awareness of the vulnerabilities of the global food system is rapidly increasing, heightened by the growing contest for limited resources and frequency of events that challenge the highly interconnected global food supply. In Australia, governments at local, state and federal level are beginning to grapple with the complex challenges and opportunities presented by a changing food system, in the context of rapid change in the other systems around it – the economy, climate, energy supply, water, ecosystem and human health and nutrition.

The Victorian Food Supply Scenarios project was a 12-month research project funded by the Victorian Health Promotion Foundation (VicHealth) through the Healthy Eating stream of their research innovation grants, provided to research a new concept or methodology relevant to the theory, policy and practice of health promotion.

The primary purpose of this project was to develop and demonstrate a new methodology to link land and resource use with the availability of a nutritionally adequate food supply for Victoria's population.

1.1 Report Structure

This report outlines and discusses the assumptions, methodology, results and implications of this project.

In the interests of transparency and an open contribution to the debate, the report contains detailed information about the methodology developed, including assumptions and settings within complex quantitative analysis. To fully understand how the results were achieved, it is recommended that the

[2] Examples include Larsen et al. [2008], Campbell [2008], Cribb [2010], Heinberg & Bomford [2009], UNEP [2009] and IAASTD [2008].

report is read in full. However, recognising that for many readers this will not be feasible, the results and discussion can be understood without a full technical understanding of the methodology section.

Key assumptions and areas where further work is required are clearly identified throughout, using the symbols below.

!	*Key assumptions and points*
🕮	*Potential further research or work*

1.2 Aims and Objectives

This project aimed to develop and demonstrate a new methodology to:

- Explore whether potential changes affecting Victoria's food system, within its broader context in Victoria, Australia and internationally, could impact on the secure and sustainable provision of nutritionally adequate diets for Victoria's communities; and
- Consider how the provision of nutritionally adequate diets might impact on the quality of our natural resource base and the ecological and economic health of Victoria.

A detailed exploration of the above is an immensely complex task. This 12-month project was established to test the applicability of scenario and quantitative resource modelling to identify and assess the most critical potential challenges to Victoria's food supply. Most importantly, the project was intended to put in place an appropriately structured model, populated with sufficient data, to lay the groundwork for more detailed 'what if' research to be conducted in the future.

The project's objectives were to:

- Engage a diverse group of stakeholders in thinking about challenges and opportunities for the future of Victoria's food system to inform of a set of qualitative scenarios;
- Investigate the potential applicability of stocks and flows framework models to explore bio-physical questions related to food systems and build modelling capability; and
- Conduct initial explorations of plausible future scenarios and their implications for the:
  - Ability of the food system to provide a sufficient amount and variety of the core foods required for a nutritious diet for all Victorians;
  - Impact on Victoria's environment and use of critical resources from the provision of a nutritious diet; and
  - Impacts on key economic indicators: GDP; unemployment and trade balance.

1.3 Scope

The UN Food and Agriculture Organisation (FAO) has further defined food security as encompassing four components: availability; access; utilisation and stability. This project focuses principally on availability: "*sufficient quantities of food of appropriate quality*, supplied through domestic production or imports (including food aid)" [FAO 2011].

This focus on availability recognises that the irreducible base of food security is the physical ability to provide for the *nutritional needs* of our population. The necessary condition for the modelling of all the scenarios (the common social objective) is that sufficient quantities and variety of food to meet the requirements of a nutritious diet are available for all citizens.

1.3.1 A Nutritious Diet

In this project the phrase 'sufficient quantities of food of appropriate quality' is interpreted as meaning, for Victorians, the recommended number, amount and variety of serves as specified in official recommendations for a nutritionally adequate diet. The project is only concerned with assessing the availability of food required to meet these official recommendations.

Therefore, the food and nutrition analysis is based on an ideal diet profile, not current norms that are characterised by over consumption and dietary imbalances. Recommended intake levels of core foods differ considerably from food consumption patterns of many population groups reported in the 1995 National Nutrition Survey (NNS). For example, over half of males aged 12-44 years nationally had not eaten fruit the day before the NNS survey was conducted [ABS 1995]. For other core foods such as meat and dairy, moving to the dietary recommendations constitutes a reduced 'demand' for these foodstuffs. These changes can be seen as corrections around the 2010 point in the Food Surplus / Deficit graphs in the 'consumed' lines (see Appendix 4).

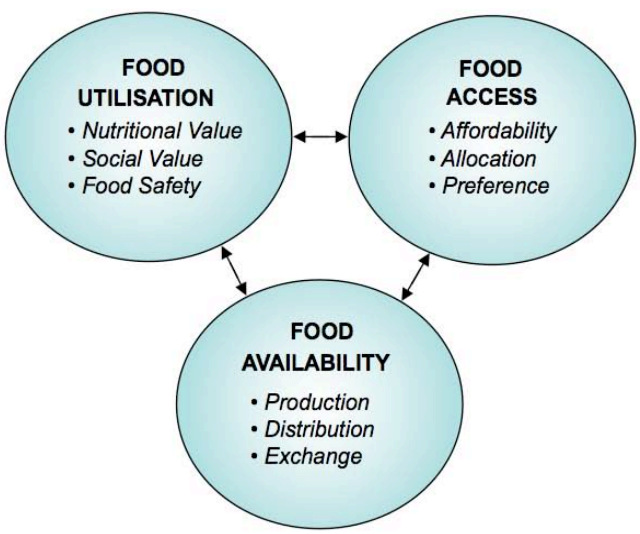
Current fruit and vegetable production in Australia falls short of providing sufficient serves of these foods to meet the recommended food intake patterns [ABS 2000]. However, this shortfall is 'masked' to a certain extent because current food consumption patterns are not consistent with nutrient recommendations and so the gap between production and required level is not 'exposed'.

1.3.2 Food Availability

!	*Food availability is fundamentally a function of the amount of food required and the amount produced.*
!	*Food can be produced in Victoria, Australia or overseas. It is assumed that it is possible to import food if required.*
!	*Food availability also depends on effectively functioning food systems and infrastructure. It is assumed that food produced is physically available to consumers i.e. that the systems function effectively to distribute food.*

Food availability is understood as including how much is produced, as well as the physical infrastructure necessary to ensure that food is physically available to consumers such as processing and packaging, distribution and storage (including the 'last mile' of how people actually get their food). This understanding is reflected in Figure 1-1.

Figure 1-1: Food Availability as a Component of Food Security (Ingram 2008)



The main indicator used to explore this is 'net food availability', that is, how much is produced compared to requirements. This is a function of:

- Food produced in Victoria for Victorian consumption;
- <u>Surplus</u> – food produced in Victoria that is surplus to consumption requirements, generally exported to Australia and rest of world; and
- <u>Deficit</u> – consumption requirements that are not met through Victorian production and are imported from the rest of Australia and the world.

In this project, it is assumed that processing, packaging, distribution and storage systems continue to function effectively, providing food of sufficient quality to meet nutritional requirements, even while substantial changes are applied to their operating structure.

Changes to Victorian or Australian food production are only one part of a complex system (including factors such as production elsewhere, distribution and price impacts), and therefore do not translate directly and immediately into a lack of local food availability. It is important to note that this project is NOT trying to predict or model global food (or other resource) availability – the modelling assumes that imports are available to meet domestic requirements. However, through this work we are able to explore the extent to which resource allocation decisions could affect our surpluses and deficits of core foods. The intent is to establish base data that could underpin further, more detailed, investigations of the vulnerability or resilience of our food supply system in the face of complex change. Vulnerabilities are further discussed in Section 4.4.

The allocation of physical resources to competing uses (e.g. land or energy resources for agriculture versus other areas of production); availability of technological systems for the efficient utilisation of resources (e.g. water or fertiliser); information flows (e.g. to reduce waste); and changes in climatic conditions, are themselves affected by social, political, cultural and economic conditions and systems. In this work those socio-technical landscapes are framed through alternative scenarios that provide 'settings' for the way the essential physical determinants of food production and distribution play out over time. While these landscapes themselves are critical in allocation of resources and how food is produced, this project is focused on the physical and technical limits to the availability of food.

1.3.3 Other Elements of Food Security

!	*Food availability is necessary, but not sufficient, for food security.*

There are many socio-economic or technical aspects beyond availability that are critical to food security overall. This project is in no way suggesting that availability alone provides food security – it is undeniably necessary, but not sufficient. The other three critical elements in food security identified by the FAO are: access, utilisation and stability. While these are not the focus of this project, assumptions have been made about them that frame this investigation. These are outlined below.

Access Not included: • Whether or how individuals have adequate resources (entitlements) for acquiring appropriate foods for a nutritious diet. • Price impacts of the physical changes modelled. • Impacts of price or other factors (e.g. culture, marketing or market control) on demand for and consumption of a nutritious diet.	Assumed: • Availability of the foods for a nutritious diet does not mean that these foods are necessarily accessible. Produce may be exported if a better price can be obtained elsewhere, and some individuals may be unable to acquire and consume it. • Similarly, it would be possible for food produced in Australia to be directly exported to meet the needs of other countries, particularly if they own the land. • A wide range of mechanisms could need to be considered to ensure food access in the case of significant price barriers or prolonged scarcity of core foods e.g. from welfare through to export restrictions or rationing. • Consumer preferences are complex, and significantly shaped by marketing and influence of social norms. By not exploring these critical factors, this project implicitly assumes that people will consume the available diet. Defining the policy and social changes that would enable / cause this to happen is outside the project scope.
Utilisation Not included: • Whether or how individuals have the ability to utilise available food for nutritional well-being, through clean water, sanitation and health care.	Assumed: • That these are in place, that food safety and water quality systems are functioning effectively, food processing is available to spread surplus across the year etc., so that the food that is available can meet nutritional needs. • Available foods are of sufficient nutritional value to provide

	the estimated amount of key nutrients used to determine requirements. This assumes that the changing climate, production systems, and processing, storage and distribution systems, do not reduce the nutritional value of foods that reach the consumer.
Stability Not included: • Acute stability issues i.e. response to sudden disruptions such as pandemics, social actions such as truck strikes, or floods and fires. • Limits to timely or repeated restoration of pre-existing services.	Assumed: • This project focuses attention on dynamics that could undermine existing systems, potentially requiring structural change in current systems of provision. • The modelling allows for the complex interactions between (bio)physical systems (water, energy, climate, soil) that can produce unexpected or rapid changes in food supply. Understanding these relationships is critical to longer-term stability of the population's food supply.

1.4 Context

The Victorian Eco-Innovation Lab (VEIL) is a non-profit, university-based, 'design and research' think-tank established by the Victorian Government through the Environmental Sustainability Action Statement in 2006 (initially funded through the Victorian Sustainability Fund). Its mission is to 'envision' and critically review plausible sustainable futures. This has involved the exploration of scenarios for the future development of Melbourne / Victoria over the next 25 years, considering, in particular, changes in systems of provision of water, energy, food, transport and built infrastructure to meet the requirements of a low carbon economy and to increase resilience in the face of changing patterns of climate. VEIL's scenario, design and innovation projections in relation to food provided the initial background to the scenario formation process.

VEIL and its research partners have embarked on this project with an escalating concern about key drivers of change in the food system that appear to be accelerating faster than policy, research and innovation is responding. A critical aspect of this project is to investigate whether the nutritional requirements can be met considering the challenges of, and response to, climate change; peak oil; population and fertiliser / nutrient availability.

Our understanding has informed how these issues are handled and is summarised below.

1.4.1 Climate Change

!	*High levels of climate change consistent with the A1F1 IPCC scenario are the minimum that can be expected.*
!	*There is scientific consensus on the need for Annex 1 countries (such as Australia) to reduce greenhouse gas emissions – by at least 20-45% on 1990 levels by 2020 – to avoid catastrophic, irreversible climate change. This project attempts to inform efforts to do so.*

1.4.1.1 Climate Impacts

This project is positioned within the context of a high level of climate change. The potential impacts of climate change on availability of food are extremely diverse and complex. As concern about the impacts and responses to climate change is a key driver of the project, little would be gained from inclusion of a low climate change scenario.

The high level of climate change taken as a baseline assumption of this project is based on the 'A1F1' scenario from the Intergovernmental Panel on Climate Change's Special Report on Emissions Scenarios (IPCC SRES), which has the following key assumptions:

- High global economic growth rates;
- Population growth which peaks mid-century (2050) and declines;
- High levels of global co-operation and living standards (convergence);
- Energy requirements principally derived from fossil fuel sources; and
- Increasingly efficient technology [IPCC 2000].

The context of the scenarios should therefore be understood as consistent with the A1F1 climate scenario, as described for South West Victoria, for the period 2010-2030, in a Victorian DPI project:

> *Rainfall in SE Australia is becoming increasingly erratic. Sometimes we get little or no rain for a few years. Then we get a burst in summer followed by nothing. Agriculture becomes opportunistic. The overall reduction in rainfall produces significantly lower crop yields. Extreme storms produce major losses in what is left. Any commodity that survives both the low rainfall and the storms gets a good price, but this is patchy in location and timing. Climate change seems to happening faster than we thought it would. Household stress in farming families increases significantly.*
>
> *Temperature is increasing at or above the upper envelope of the IPCC projections. Historical records for the number of days above 35°C are exceeded almost every year. Intense bushfires are frequent in Victoria. Fuel loads eventually become depleted through burning and limited regrowth. Smoke haze becomes a regular feature of the skyscape. Asthma becomes a real problem. The Greenland ice sheet has decreased to alarming levels. Thawing of frozen tundra produces methane release. The rate of temperature rise is further accelerated. Sea-level rise is causing problems in Bangladesh. Storm surges are exacerbating the plight of Holland and other low-level countries. Scientists are warning of a breakdown in fundamental ecosystem services. Climate refugees appear in increasing numbers* [DPI 2009: 13].

This climate context sets the scene for high (but varying) levels of waste / loss and reduced irrigation reliability in all scenarios.

1.4.1.2 Greenhouse Emission Reductions

!	*There is a scientific and international political consensus on the need for rapid reduction in greenhouse gas emissions.*
!	*Australia will endeavour to reduce emissions in line with international commitments and requirements.*

There is a scientific and international political consensus on the need to limit temperature rise to a maximum of 2°C above pre-industrial levels to avoid catastrophic, irreversible climate change. This is most recently affirmed in the Cancun agreement to which Australia is a signatory [UNFCCC 2011: 2]:

> 3. *Recognizes* that warming of the climate system is unequivocal and that most of the observed increase in global average temperatures since the mid twentieth century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations, as assessed by the Intergovernmental Panel on Climate Change in its Fourth Assessment Report.
>
> 4. *Further recognizes* that deep cuts in global greenhouse gas emissions are required according to science, and as documented in the Fourth Assessment Report of the Inter-governmental Panel on Climate Change, with a view to reducing global greenhouse gas emissions so as to hold the increase in global average temperature below 2°C above pre-industrial levels, and that Parties should take urgent action to meet this long-term goal, consistent with science and on the basis of equity.

For a 50 per cent chance of limiting temperature rise to 2 degrees, atmospheric CO2-e would need to be stabilised at 450ppm (parts per million). This would require Annex 1 countries (such as Australia) to reduce emissions by 25–40% on 1990 levels by 2020 and 80-95% by 2050 [IPCC 2007].

But the Cancun Agreement goes further and "*also* recognizes the need to consider… strengthening the long-term global goal on the basis of the best available scientific knowledge, including in relation to a global average temperature rise of 1.5°C" [UNFCCC 2011:2]. The 'best available scientific knowledge' includes evidence from leading climate scientists that limiting to 2°C is dangerously inadequate. For example, Hansen et al. [2008] suggests that atmospheric levels of CO_2 above 350ppm (parts per million) will destabilise the climate and trigger runaway (i.e. unpredictable and non-linear) effects. They therefore suggest that atmospheric CO_2 levels must be stabilised and reduced from the current level of 391ppm[3] as a matter of urgency. A corresponding aspiration for emissions reductions is in the realm of 60% by 2020, or faster.

With agriculture making up 16% of Australian emissions, and the food system approximately 28% [ACF 2007] it is clear that any significant reduction in greenhouse gas emissions across the economy will require substantial changes to how food is provided and could impact on food availability.

This project investigates the broader physical impacts of substantial and effective action, particularly in relation to food availability, with a view to informing strategies for achieving these emissions reductions. Therefore, the project explores ambitious emissions reduction programs, with all scenarios including programs over the next twenty-five years.

A high climate change scenario has been maintained regardless of the differing emissions reduction trajectories because:

- A1F1 SRES has already been shown to be conservative as both global emissions and the apparent impacts of climate change have exceeded those underpinning or anticipated in this scenario [Allison et. al. 2009; Climate Congress Copenhagen 2009; Hurrell 2010]. There is no agreed 'worse than A1F1' scenario.
- There is a long lag in climate systems, so emissions reductions between 2010 and 2030 will not reduce climate change impacts by 2060 [Solomon et al. 2009].
- There is a strong possibility of hitting climate 'tipping points' and triggering feedback loops – which means that the climate is unlikely to return to a previous state along the same trajectory [Allison et al. 2009]. Reducing our emissions this year to what they were in 1990 will not give us the same climate as 1990, even by 2060 [Solomon et al. 2009].

1.4.2 Oil

!	*Massive changes to how oil is supplied and used are unavoidable and imminent.* There is a possibility that fundamental shifts in economic structure may also be required. The extent to which the peaking of global oil production threatens future food availability in Victoria will depend on the success of a variety of strategies, many of which are explored in this project.

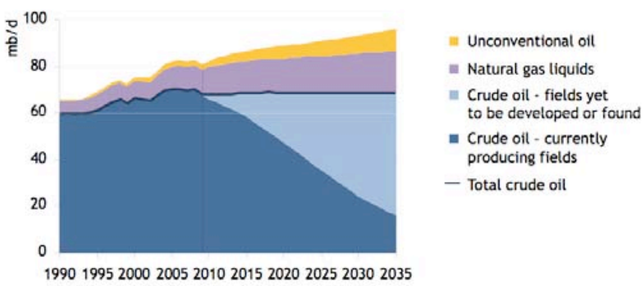
1.4.2.1 Peak Oil

"Peak Oil" refers to the "maximum rate of oil production in any area recognising that it is a finite natural resource, subject to depletion" [Campbell 2011]. When a country's production peaks, it becomes more reliant on imports (unless demand is reduced). When the maximum rate of global oil production is reached, increases in consumption can no longer be sustained - demand will outstrip supply. The ability to access remaining oil reserves becomes increasingly expensive and difficult, requiring substantially (and consistently) higher prices to make investment in this production commercially viable.

Australia's domestic primary oil production (crude oil, condensate and LPG) peaked in 2000-01 and has declined on average 5% per year to 2007-08 [APPEA 2008; ABARE 2008]. This has increased our reliance on imported oil and oil products every year since. This research assumes that Australia's domestic oil production continues to fall over the period 2010 – 2030, requiring increasing imports – or alternative fuel sources – to fulfil demand.

[3] See www.co2now.org

Figure 1-2: IEA Projected World Oil Production by Type (New Policies Scenario) (IEA 2010)



The latest World Energy Outlook 2010 from the International Energy Agency (IEA) [2010] acknowledges a global peak in conventional oil production in 2006 and anticipates substantial decline rates from currently producing fields (Figure 1-2).

The ability to meet global oil demand in this IEA scenario (noting that the estimate demand includes a substantial global climate response and substantial demand reduction in developed nations) is reliant on the unknown viability of fields *"yet to be developed or found"* [IEA 2010: 8].

1.4.2.2 Oil and Food

While peak oil is sometimes seen primarily as a transport issue, liquid fuel availability and cost is critical to the agriculture and food system more widely. For example, fuel costs account for a significant proportion of agricultural expenditure in Australia: 32.4% (cropping), 21.1% (beef) and 15.4% (dairy), but less than 1% of costs for most other industries [Sloan, Sipe and Dodson 2008]. Food production and distribution systems across the world are dependent on access to affordable fossil-fuel based energy.

Oil and gas are also used for production of pesticides and herbicides and other agricultural chemicals, particularly fertilisers (see 1.4.3). Farm machinery and pumps are run with petroleum fuel and other materials and equipment used on farms are often derived from oil products or depend on petroleum fuels for manufacture.

1.4.2.3 EROEI and Economic Expansion

The projected increases in supply from unconventional oil and fields 'yet to be developed or found' in Figure 1-2 above do not take into account declining Energy Return on Energy Invested (EROEI). EROEI is the ratio of how much energy is available for use compared to the amount of energy taken to extract, refine and deliver it – and hence the price that must be sustained to make it worth producing. Extracting energy from unconventional sources requires significantly greater inputs of energy than in the past, therefore it costs more and has lower financial returns.

The relationship between high oil prices and economic contraction, or low oil prices and economic expansion, is attracting renewed attention. Events in recent years have led to suggestions such as that of Murphy and Hall [2010a; 2010b] that "economic growth requires not only energy per se, but inexpensive energy". Further, the International Energy Agency noted in its February 2011 *Oil Market Update* that "the global oil burden[4] in 2010 was the second-highest following a major recession and could rise this year to levels close to those that have coincided in the past with marked economic slowdowns" [IEA 2011 cited in OGJ Editors 2011]. A detailed explanation of how and why high oil prices are closely linked with economic recession can be found in Tverberg [2011]. Recent global modelling of this 'peak oil' dilemma shows just how critical these issues can become [ERC UK 2009; Korowicz 2010].

Given that global production of conventional oil has peaked, as it has in Australia, significant challenges to availability and affordability of imported oil are taken as given. This critical problem for the oil dependency of the Australian food system – and economy more broadly –is a key driver of all scenarios.

[4] "The 'oil burden' concept is defined as nominal oil expenditures (demand multiplied by the crude price) divided by nominal gross domestic product (GDP). A rising oil burden will not necessarily cause an economic recession, but it can greatly compound the effect of other economic and financial shocks" [IEA 2011 cited in OGJ Editors 2011].

1.4.3 Fertilisers

!	*There will be pressure on fertiliser availability and cost*, but the responses to this pressure play out differently across different scenarios.

Availability and use of fertiliser and other agricultural inputs is a critical component to levels of agricultural production. As with oil, global demand for fertiliser products is increasing.

The fertiliser ingredients that agriculture is most reliant on are Phosphorus (P), Nitrogen (N) and Potassium (K). Phosphorus is, for the most part, derived from phosphate rock, a non-renewable resource that is mined. The availability / cost of phosphate fertiliser is dependent on the extent and location of phosphorus reserves, which are subject to the same depletion problem as oil – leading to concern about global 'peak phosphorus' occurring by 2030. All farmers need phosphorus, but just five countries control 85% of the world's remaining phosphate rock reserves [White et al. 2010].

Nitrogen fertilisers (e.g. urea and ammonia) are manufactured through a process that uses natural gas to supply hydrogen. The availability / cost of these fertilisers is therefore closely connected to the availability and cost of fossil fuels e.g. oil.

Potassium is generally applied using potash. All potassium-based fertilisers supplied in Australia are currently imported [Ryan 2010].

1.4.4 Population

!	*Medium growth population scenario – population of Australia is 29 million in 2030 and 36 million in 2050.*

The population assumptions underlying this project are based on the medium growth scenario outlined in the Australian Bureau of Statistics population projections, which suggest 29 million people in Australia in 2030 and 36 million in 2050 [ABS 2008] (Figure 1-3).

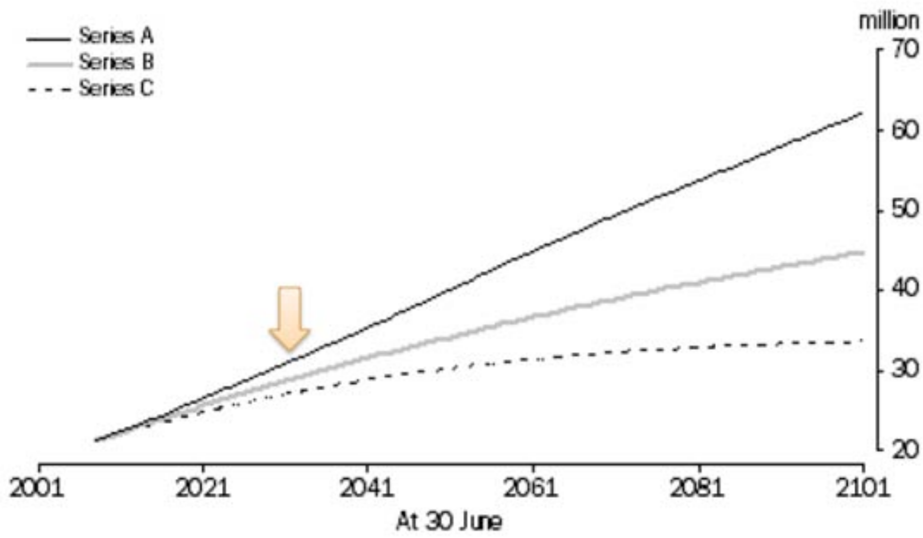
While there are on-going tensions relating to population policy in Australia, a continued increase is assumed because:

- A degree of population growth is inherent in demographic and age structures within the existing population. Population stabilisation is unlikely without significant policy intervention.[5]
- Substantial global population growth is expected to continue. It is likely that Australia's relatively low population densities and high per-capita resource use will continue to attract potential immigrants.
- The resource and climate pressures explored in this project are anticipated globally and may lead to very large population displacement. Pressure to accept refugees, particularly from conflict or climate-affected areas can be expected to increase. A number of participants in this project considered there to be a high likelihood of sharply increasing pressure to accept refugees, particularly from climate-affected countries in the region.
- Undertaking analysis based on assumptions of increasing population can contribute to informed debate as to how Victoria and Australia can sustainably accommodate a greater population.

Therefore it is assumed that the economic pressure to accept a growing population and refugee demand in coming decades will outweigh domestic political pressure to stabilise population. Conducting analysis based on the medium population projection takes a middle line between possible stabilisation and pressure for larger population increases.

[5] ABS Series D produces a stable population, on the basis of zero net immigration and a reduced fertility rate (~1.6) [ABS 2008].

Figure 1-3 - Australian Population Projections



2. Methodology

The primary objective of this project was to develop and demonstrate a new methodology that can be used to explore the links between land and resource use and the provision of a nutritious diet to the population. This section outlines the methodology that has been developed and explains why this combination of tools was used.

The three elements of the methodology developed are:

1. Determining the amount and variety of foods required to meet the recommendations of nutrition reference standards for the population;
2. Constructing qualitative scenarios to frame divergent socio-economic and technical trajectories; and
3. Translating qualitative scenarios to quantitative scenarios and analysing their implications.

2.1 Food requirements for a nutritious diet

!	*Use of fresh foods:* It has been assumed that required food availability could be assessed by estimating availability of certain amounts and types of relatively minimally processed foods, e.g. plain bread and fresh fruit and vegetables.
!	*A nutritious diet is achieved by daily consumption of adequate amounts of a variety of foods from the five food groups, as outlined in the Australian Guide to Healthy Eating.*

To investigate availability of a nutritious diet for the Victorian population, it is first necessary to define what it is. A key challenge when translating nutrition and dietary recommendations into practice is the quantification of the amount and types of foods needed to meet the concepts of balance, variety and moderation for a nutritious diet. Government authorities have developed food selection guides as research, educational, promotional and planning tools to translate scientific knowledge of nutritional requirements and food composition into a practical guide for food selection.

With the exception of breast milk in the first few months of life, no one food can provide a nutritionally adequate diet or achieve the dietary guidelines. Instead, governments – with advice from nutrition experts – recommend that a nutritious diet be achieved by consuming certain amounts of a variety of foods from the five food groups each day, as outlined in the *Australian Guide to Healthy Eating (AGTHE)* (Figure 2-1) [Commonwealth Department of Health and Family Services 1998].

The AGTHE defines a nutritious diet as one that meets the key nutrition reference standards, namely, the Australia Recommended Dietary Intakes [NHMRC 1991] and the Dietary Guidelines for Australians [NHMRC 1992] and the Dietary Guidelines for Children and Adolescents (NHMRC 1995a). The aim of the AGTHE is to, "encourage the consumption of a variety of foods from each of the five food groups every day in proportions that are consistent with the Dietary Guidelines for Australians" [Commonwealth Department of Health and Family Services 1998].

Figure 2-1: The Australian Guide to Healthy Eating

The AGTHE has been constructed by arranging nutritious foods, or 'core' foods, into one of five food groups on the basis of similar nutrient profiles. In particular there is a distinguishing nutrient(s) for each food group. Foods allocated to a particular food group are a rich source of the distinguishing nutrient(s) characteristic of that food group.

A standard serve size is provided for foods in each food group such that different foods within a particular food group can be exchanged to provide approximately equivalent amounts of the distinguishing nutrient(s) for that food group.

A recommended number of serves per day for foods in each food group is provided to support a nutritionally adequate daily food intake for population groups depending on age, gender and life-stage characteristics.

Consumption of this recommended number and variety of food serves will contribute to a diet consistent with the Recommended Dietary Intakes and Dietary Guidelines. However, for those population groups with energy requirements additional to that provided by the recommended food serves, there is some flexibility to include the so-called 'extra' foods while maintaining a healthy diet. Extra foods have a relatively low nutrient content and/or contain a high amount of fat, sugar and/or salt and are not essential to the achievement of a nutritious diet. The combination of core and extra foods is captured in Table 2-1 [AGHE 1998].

From this information, an estimate of the amount and variety of foods required to meet the recommendations of nutrition reference standards for the population can be obtained by:

1. Selecting foods to represent each food group;
2. Selecting the population categories for which the nutrition implications would be assessed;
3. Determining the number of recommended serves for each food group; and
4. Estimating the amounts of foodstuffs required to meet the nutrition reference standards for the population.

The results of this process are explained in Section 3.1.

🕮	*Revision of food estimates based on updated food selection guide and dietary guidelines* The food selection guide on which the assessment of the nutritional adequacy of the food supply under each scenario is based is the AGTHE developed in 1998 as this is the *current* Australian food guide at the time that the research was undertaken. However, the AGTHE is under review and it is anticipated that the guide, including the number and types of foods recommended from each food group, will be updated to capture revised nutrition recommendations contained within the 2006 Nutrient Reference Values (NRVs) for Australians [NHMRC 2006] and the revised Dietary Guideline documents being prepared for Australian Adults, Australian Children and Older Australians – anticipated to be released during 2011.[6]

[6] One practical difference that would emerge from the future use of the 2006 NRVs is that the scope of the modelling to assess the nutrition and health implications would need to be extended to take into account the Acceptable Macronutrient Distribution Ranges (proportion of dietary energy derived from fat, carbohydrate and protein).

Table 2-1: Number of daily sample serves needed to achieve a nutritious diet for children, adolescents and adults

	Energy need (kJ)	Healthy diet example A or B	Bread, cereals, rice, pasta, noodles	Veg, legumes	Fruit	Milk, yoghurt, cheese	Meat, fish, poultry, eggs, nuts, legumes	Extra foods
Children 4-7 yrs	6400–8300	A B	5-7 3-4	2 4	1 2	2 3	0.5 0.5-1	1-2 1-2
Children 8-11 yrs	7700–9800	A B	6-9 4-6	3 4-5	1 1-2	2 3	1 1-1.5	1-2 1-2
Adolescents 12-18 yrs	8100–13500	A B	5-11 4-7	4 5-9	3 3-4	3 3-5	1 1-2	1-3 1-3
Women 19-60 yrs	7200–11300	A B	4-9 4-6	5 4-7	2 2-3	2 2-3	1 1-1.5	0-2.5 0-2.5
Pregnant women [a]	8100–10900		4-6	5-6	4	2	1.5	0-2.5
Breastfeeding women [b]	9200–12300		5-7	7	5	2	2	0-2.5
Women 60+yrs	6500–9300	A B	4-7 3-5	5 4-6	2 2-3	2 2-3	1 1- 1.5	0-2 0-2
Men 19-60 yrs	9000–13700	A B	6-12 5-7	5 6-8	2 3-4	2 2-4	1 1.5-2	0-3 0-3
Men 60+yrs	7400–11000	A B	4-9 4-6	5 4-7	2 2-3	2 2-3	1 1- 1.5	0-2.5 0-2.5

[a] Pregnant women: intake averaged over 40 weeks. Patterns for A and B were very similar so they have been combined.

[b] Breastfeeding women: intake during the first six months of breastfeeding, decreasing thereafter with the increasing establishment of solid food intake. Patterns for A and B were very similar so they have been combined.

2.2 Qualitative Scenario Development

In effect, to engage with scenarios is to hold two or more stories in mind at the same time – and therefore, hold the future not as a belief, but as a fiction [ESF/COST 2008: 18].

Scenarios are used in this project to enable exploration of a complex array of drivers of change, including economic, social, (bio)physical and technological changes, that have the potential to impact on food availability in Victoria. As there are high levels of uncertainty in relation to many (if not all) of the critical dynamics, the use of scenarios allows exploration of different trajectories without needing to determine what is more 'likely' or 'preferable'.

Qualitative 'what-if' or 'exploratory' scenarios are suitable for this purpose. These have plausible, internally consistent storylines built around different social, cultural, political and economic regimes. They represent different dynamics of change, responses and pathways. Exploratory scenarios are not intended to make predictions, foresee the future, or 'get the right answer'.

Divergent exploratory scenarios can also be used to describe different sets of operating conditions resulting from different responses to the identified drivers and dynamics. In this way, they can be used to explore different policy or cultural approaches to key issues.

The scenario timeframe is a 25-year horizon, for both practical and strategic reasons (following a process developed in the work of one of the research partners, the Victorian Eco-Innovation Lab). This timeframe is sufficiently removed from the present day that most workshop participants and readers were able to suspend intellectual or business commitments to 'what will happen'. 25 years is also a sufficiently long period that real structural change can take place. While settings have been calculated to 2035, the results of the modelling are shown to 2060 so that longer-term implications of the settings can also be considered.

The development of the qualitative scenarios involved three steps:

1. Review of international projects on food sustainability and security to consider any scenarios that would have some relevance to Australia and/or provide an international context for framing Australian scenarios;
2. Engagement of a diverse group of stakeholders in discussion about different possible futures and critical dynamics of change for the Victorian food system; and
3. Encapsulate key challenges and unknowns into descriptive 'what-if' scenarios that highlight different possible - and plausible - futures.

2.3 Quantitative Scenario Modelling

Qualitative scenarios are useful in themselves as tools for exploring how the context for Victoria's food system may unfold. However, as this research is focused on the physical availability of a nutritious diet, it is necessary to translate these scenarios to quantitative settings.

Quantitative scenarios can then be used to:

- Explore the relationships between different variables, across different sets of tightly interconnected physical and technological systems with a lot of feedbacks; and
- Reveal 'conflicts' - in this process referred to as 'tensions'– that need to be resolved for the overall system to function. For example, tensions might be the availability of water to meet demand, or the ability to meet greenhouse targets set in the scenario.

The qualitative scenarios were translated into quantitative scenarios through the following process:

- Identification of key settings in variables that are defined by the scenarios and proposing initial values for these. These settings were guided by the qualitative scenarios, research and the project team's existing knowledge of the food system; and use of external sources to confirm plausibility as required;
- A second stakeholder workshop was held to sense-check / investigate the key scenario settings, revealing additional constraints, possibilities, interactions and difficulties; and
- The settings were translated into code for modelling, with additional settings coded as required (process and results are described in section 3.3).

A suitable modelling capacity was identified in CSIRO's Australian Stocks and Flows Framework (ASFF). The rest of Section 2.3 explains what the ASFF is, how it works and why it was chosen for this research. A high level of detail is provided here for transparency and to aid interpretation of the results, however some readers may wish to read the results and discussion first, returning to this explanation afterwards if greater understanding is sought.

2.3.1 The Australian Stocks and Flows Framework

The ASFF is a highly disaggregate simulation of all physically significant stocks and flows in the Australian socio-economic system. Stocks are the quantities of physical items at a point in time, such as land, livestock, people, buildings, etc., and are expressed in numbers or SI units. Flows represent the rates of change resulting from physical processes over a time period, such as the (net) additions of agricultural land, immigration and birth rates, etc. In version 3 of the ASFF, there are over 800 multi-dimensional variables (of which about 300 are exogenous inputs).

The framework provides a means for exploring the implications of different scenario settings within a modelling system that coherently covers all sectors of the economy and environment. Cross-sector impacts, synergies and trade-offs can be properly identified in the ASFF, unlike other models or analysis with less scope. Additionally, the physical feasibility (or otherwise) of a given scenario is highlighted as the relationships in the ASFF are based on irrefutable mass and energy balance. Furthermore, innovative solutions to any identified problems can be explored in the ASFF since past behaviour (such as economic relationships) is not hard-wired into the ASFF. However, past behaviour can be approximated in future scenarios based on projections of historical parameters and use of key feedbacks, as described below.

The open biophysical nature of the ASFF is intended for development of strategy – scenarios analysed are not intended to be normative (ideal) or prescriptive. It is designed to explore the question of where the national economic system could go over the long term within irrefutable biophysical constraints, to inform the development of appropriate policy. No optimisation or ideology is built into the core of the ASFF, though socio-economic feedbacks are incorporated in several ways (see 3.3.1). The ASFF employs mass-balance identities associated with stock and flow dynamics throughout the national economy and its interaction with the environment, but does not model behaviour, instead using many exogenous inputs for parameters of social, economic and technological change. In its operation, the ASFF is very analogous to a flight simulator, where the pilot learns from experimenting in the computer environment, to avoid crashing the aircraft in real-life. As with a flight simulator, there are also many fixed assumptions that govern how the system works.

The key purpose of using the ASFF, then, is to identify strategic environmental or resource issues in advance and explore alternative physically-feasible pathways, rather than attempting to optimise outcomes for futures that are marginal variations on the past. This makes the ASFF an ideal vehicle to explore implications and limitations of food availability.

While the ASFF has not previously been used to explore provision of a nutritious diet to the population, it is particularly suited to investigation of resource allocation issues and provided unique insights for this analysis.

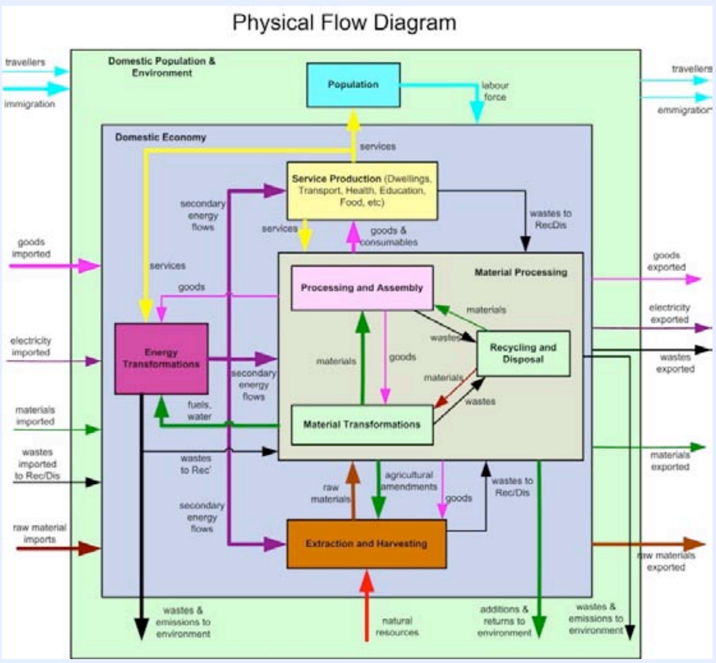
See Box 1 for more information.

Box 1: The Australian Stocks and Flows Framework

The Australian Stocks and Flows Framework (ASFF) has been developed to assess the biophysical longevity of the Australian economy. It treats the biophysical systems as primary – if a physical limit is reached in the biophysical system then, while the value of the declining resource may increase, the needs of the economy may not be able to be met.

It is a process-based simulation that covers the physically significant elements of each sector of the Australian economy, as we currently understand them, including some service aspects (see Figure 2-2). Natural resources (land, water, air, biomass and mineral resources) are also represented explicitly. Part of the framework incorporates a physical input-output model for the transformation of basic materials and energy types [Lennox, Turner et al. 2005]. Elsewhere, there are physical accounting relationships that represent the key processes, such as converting the requirement for transport of goods into the size of the freight transport fleet and the fuel requirement. A detailed explanation of the relationships throughout the ASFF is available [Poldy, Foran et al. 2000]. All variables representing physical stocks and flows obey the thermodynamic constraints of conservation of mass and energy.

Figure 2-2: Schematic Flow Diagram of Modern Economy



Schematic summary of physical flow connections of a modern economy like Australia's. Flows of people, energy and materials may enter and exit the economy, principally as imports and exports on the left and right respectively. Within the domestic economy, natural resources are extracted or harvested from the environment (shown at the centre bottom of the diagram). Materials are transformed progressively (going upward in the diagram), with the use of suitable energy, to eventually provide goods and services for the population. The population provides a labour force (at the top) for all the economic sectors. Wastes and emissions are generated by the economic activity, and may be recycled, exported or returned to the environment. Other flows occur between economic sectors.

Geographically, the ASFF covers continental Australia, including the marine area within Australia's economic exclusion zone (for fishing and fuels). Within specific sectors of the framework different geographic resolutions are used, e.g., agriculture is resolved at the 58 statistical divisions across Australia. The temporal extent of the ASFF is long-term: scenarios over the future are calculated to 2100, and the model is also run over an historical period from 1941. In some sectors such as agriculture it is necessary to provide data substantially prior to 1940 due to the lengthy life-time of important agricultural land stocks, e.g., of different quality [Dunlop, Turner et al. 2002]. The time step used is 5 years, coinciding with Australian Bureau of Statistics census years.

The ASFF applies top-down coverage of the physical economy, based on bottom-up detail. It shares common features with other popular approaches, including MFA, PIOT, and LCA, but is distinctly different from these. We might summarise the ASFF as a dynamic life cycle stock-extended MFA based on IO or activity analysis principles. It spans, and expands on, all of these separate approaches because the biophysical processes throughout the economy (and environment) are represented *explicitly*. It is also necessary and advantageous to structure the sectors of the economy in a logical hierarchical manner, **making use of the concept of "tensions" that require people to resolve them**.

The ASFF has a strong empirical basis—the detailed physical account of the national economy is calibrated with six or more decades of historical data, such that this data is reproduced identically (i.e., not in a statistical sense). Its use enables us to 'truth check' assumptions about what can actually physically occur based on the resources that are available.

2.3.2 History and Previous Use

The CSIRO began development of the ASFF in the mid-1990s under research exploring the nexus between population, technology, lifestyles and the environment. This development was undertaken in collaboration with 'What-If Technologies', the company that provides the software platform for model and scenario development. Early support was provided by the Federal Department of Immigration, to investigate the environmental impacts of alternative immigration levels [Poldy et al. 2000; Foran and Poldy 2002]. In that project a series of 16 workshops were held with sector representatives and policy advisors to review the relevant sub-systems of the ASFF, data and background assumptions.

Following the initial application of the ASFF to immigration, the ASFF has been applied and refined in a number of areas, including:

- Agricultural land [Dunlop et al. 2002] and cropping systems [Dunlop and Turner 2003]—agricultural modules were refined and then calibrated with a substantial number of diverse datasets. An account of land condition was incorporated for four degradation types, linked to agricultural activity, age of the land stock, and ameliorating activities. Scenarios were developed exploring the effects of shifts in location and focus of agricultural development (e.g. between intensive irrigation and wide-spread dry-land cropping).
- Fisheries [Kearney and Foran 2002; Lowe et al. 2003]—disperse data on wild catch fisheries (i.e. about 220 combinations of species and fishing management units) was consolidated and used to calibrate a model of fish stocks for 85% of Australian catch. Scenarios demonstrated that continued trends in fishing would crash many fish stocks, leading to decreased wild catch volumes; alternatively, fishing rates that adjusted dynamically to allow stock recovery could yield slowly increasing catch volumes.
- Rail transport [Turner et al*.* 2002]—potential passenger capture of alternative routes for a Very High Speed Train were calculated using refined population/household modules simulating urban and rural development at local government level (specifically at Statistical Local Area, SLA).
- Settlements [Lennox and Turner 2005]—analysis of energy and water use for an ensemble of settlements across Australia for the national 'State of the Environment Report 2006'. The role of settlement size, affluence, climate and location were examined.
- Environmental impact assessment [Dunlop et al. 2005] and state of the environment reporting – Victorian level data were extracted from the ASFF and augmented with other data were used to identify a wide range of future sustainability issues for Victoria. This informed the creation of the Victorian Government's Environmental Sustainability Framework [DSE 2006]. Environmental and other resource indicators contributed to the 2008 Victorian State of the Environment report [CES 2008].
- Resource use trajectories [Schandl et al*.* 2008]—past and future resource use were modelled for Australia, with an emphasis on the extractive primary industries and the resulting physical trade balance.
- "Green collar" jobs [Hatfield-Dodds et al*.* 2008] and national dematerialisation potential [Schandl and Turner 2009]—the potential to transition Australia to a green economy was assessed in a scenario that incorporated sweeping changes to construction and housing, transport and mobility, primary export industries, electricity generation, and food production. The scenario was partially successful, but also highlighted issues of employment and job creation.
- Immigration [Turner and Baynes 2010; Sobels et al*.* 2010] – the issue of the environmental impacts of alternative immigration levels has been revisited recently for the Department of Immigration and Citizenship. This involved reproducing the economic inputs and results of preceding work that used a Productivity Commission economic model. The ASFF research found that environmental impacts of higher immigration levels considerably outweigh the relatively marginal economic benefits.

Recently a similar framework to the ASFF was developed for the United Nations Environment Program (UNEP) covering the nations of the Asia-Pacific region [Turner and Keen et al. 2010]. This research involved the innovative linking of the ASFF with a non-equilibrium model of the financial economy.

2.3.3 Working with the ASFF: 'Tensions'

To achieve the modelling features described earlier, the actual relationship among data variables and modules within the ASFF is somewhat different to that depicted. In broad terms, relationships represent either 'requirements' or 'provisions' as shown schematically in Figure 2-3.

The high level structure of the ASFF depicts information flows among the major modules of the ASFF (shown as boxes), which may contain other modules (such as household formation, within demography). Arrows indicate data flows from one component to another within the ASFF; solid lines represent information on physical things produced or provided from one component to another; dashed lines represent physical things required by one component from another. This concept of representing requirements as the reverse of a flow of physical items provided, is analogous to the concept of an electrical current being the reverse of the flow of electrons. As a central feature of the Design Approach, these information flows eventually lead to the creation of tensions between requirements and provisions (collected in the components at the bottom and right of Figure 2-3). Further detail on the logic of the links in the ASFF is included at Appendix 1.

In addition to tensions, other indicators report the emissions of greenhouse and other gases to the atmosphere, and waste to landfill, resulting from all economic activity. These indicators could also be interpreted as tensions if they are compared with target emissions and wastes. Other information in the ASFF can be used to form further indicators and tensions, such as the level of education and health of the population.

The ASFF does not ensure that environmental or other physical necessities or environmental objectives are automatically met. For example, it is possible that water resources are over-exploited (beyond that available), or that pollution targets are exceeded. If this happens, it is necessary to identify the factors leading to such tensions by following the physical causations in the ASFF. The scenarios can be subsequently refined by adjusting key factors, to attempt to ameliorate the tensions.

2.3.4 What about Prices?

Although the modelling process described above ensures that key macro-economic objectives are maintained in the ASFF scenarios, some economists are likely to ask "where are the prices?" (i.e. economic behaviour equating supply and demand).

The ASFF generally does not incorporate prices[7] internally, or more specifically, the response of the economy to scarcity in resources (or similar changes).

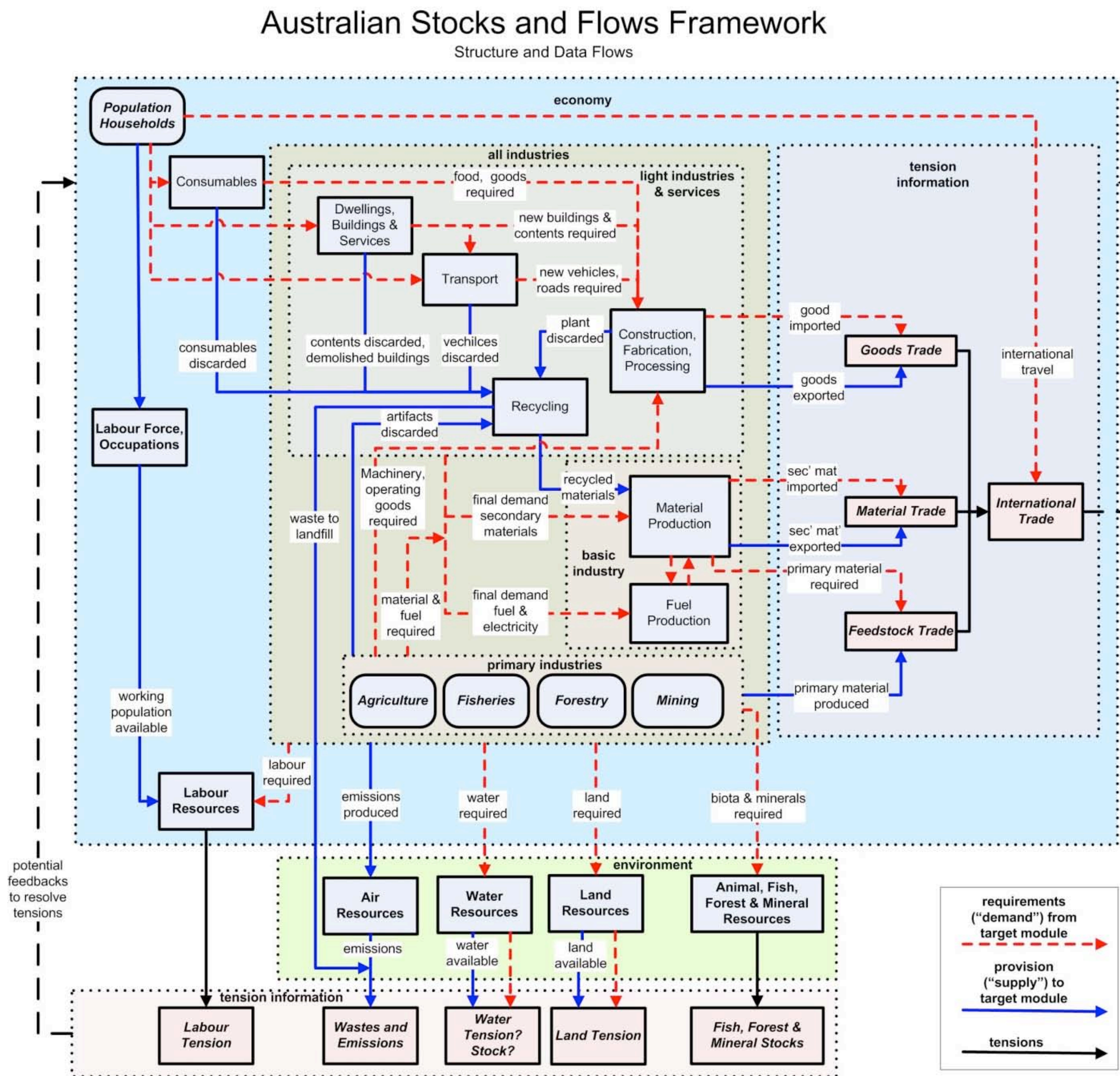
The general approach in the past has been to treat the scenarios as exploratory, so that scarcity or other tensions are highlighted. Subsequently alternative scenarios are created to alleviate the tensions. This approach is common elsewhere, but has often met resistance in Australia; price signals become just one way of resolving tensions between the physical constraints on supply and demand.

While price signals will indeed impact on where and how resources are used, and can drive efficiencies and the development of new technologies, they ultimately cannot make resources exist. In any real world version of our scenarios there would be price points at which alternative resources, technologies or practices become economically feasible responses to the tensions that develop. The price signals, market structures and government actions required to drive the defined allocations occur outside the model – but are translated into the model as assumptions about resource efficiencies, introduction of new technologies etc. (see Section 4.1.3 for further discussion).

[7] In principle, prices and salaries have been included to estimate the trade balance and GDP.

Figure 2-3: Major Components and Information Flows in the ASFF

Components (shown as boxes) and information flows (arrows) between components of the ASFF. Requirements from one component of another are shown as dashed red lines. Flows produced by one component for another are shown as solid blue lines. Two major components, demography and primary industries, are entirely exogenous. Components to the right and bottom of the diagram only receive information flows, and present any tensions (mismatches) between requirements and provisions associated with international trade, natural resources, wastes/emissions, and labour.



On-going research, separate from this study, is investigating the linking of the ASFF with economic modelling (see for example, early results: Turner and Baynes 2010; Turner and Keen et al. 2010).[8] The general concept is that the economic modelling initially prescribes the structure, consumption, growth, etc. of the economy, and these factors determine the input variables of the ASFF. Physical constraints that may arise in the ASFF scenarios should then be inputs fed back to the economic modelling. The process is repeated until the scenarios converge to a solution - assuming they do.

For now, future prices and economic responses are not available to this analysis. However, future research attempting to bring prices to bear on the physical modelling in the ASFF e.g. by coupling the model with different price scenarios is of interest.

It is likely that exploratory scenarios of future price would need to be used in any case, because existing methodologies for anticipating the (relative) price of oil or water, or many other critical resources, into the future are faced with serious uncertainties. Even in recent years, the accuracy (in size or timing) of forecast prices and market responses that could inform further modelling has proved inadequate. Significant examples include a lack of economic predictions of oil price increases (despite physical evidence of a constrained resource) and lack of expectation of the dramatic rise and rapid decline in UK and US housing prices (despite clear evidence of excessive national debt levels).

In the meantime, it is sufficient to use the historical trends in the ASFF (which of course *embody* past price signals) to initially inform possible settings of inputs to the ASFF for creating scenarios. These settings can and are changed by a variety of means. Substantial use has been made of technical information and expert knowledge [Conroy et al. 2000]. Additionally, feedback loops are employed to change inputs on the basis of the ASFF outputs, with the aim of satisfying the assumed set of macro-level economic objectives relating to employment and trade (see explanation of the background scenario in 3.3.1).

[8] Offers or suggestions of access to alternative economic models of suitable scale and coverage are invited to enable us to extend this research.

3. Results

3.1 Estimated food requirements for a nutritionally adequate food supply

The estimated total food requirements for a nutritionally adequate food supply for a healthy population were calculated, based on the recommendations contained in the AGTHE, through the four steps outlined below.

3.1.1 Selecting foods to represent each food group

Many foods share a nutrient composition profile characteristic of one or other of the food groups. It was not feasible to attempt to model every food that could belong to each food group. One food was selected from each of the food groups to represent that food group.

The meat, fish, poultry, eggs, nuts, legumes group was the exception to the approach of selecting a representative food. Given the diversity of different foods within this group, especially the variation in foods depending on whether they were of plant or animal origin, a 'hybrid' food serve was constructed for this particular food group. The hybrid food serve was constructed by calculating the weighted average of foods consumed from this food group. The weighting was based on the proportion of each of the most consumed foods from within this group as reported in the 1995 national nutrition survey, as follows: meat (48%); poultry (27%); all fish and seafood (13%); eggs (7%); and nuts (3%).

There is a diverse range of extra foods that could be considered but, it was not feasible to attempt to model all such extra foods. Sugar and oil were selected to represent these extra foods, as high amounts of these nutrients are characteristic of other foods in this category.

For each food group the representative food, their sample serve size for each representative food and the weighted amount of this sample serve are listed in Table 3-1.

This project is primarily focused on the interaction between land and resources and food availability. To simplify this first analysis, food production that does not require land (i.e. fish) or where land area is less significant than inputs (i.e. intensive pigs, poultry or eggs) have not been included. The production levels of these foods occur in the background scenario (see Section 3.3.1.4). The remaining 'meat' requirement is divided between beef /veal, lamb/mutton, and pigmeat in proportion with recent per capita consumption rates.

3.1.2 Selecting population categories for assessment of nutrition implications

The AGTHE specifies food serve numbers for nine age, gender and life-stage categories. Within this project's resource constraints the nutrition implications were assessed for the following four sub-population categories:

- Children aged 4-11 years, i.e. an aggregate of two separate age groups (4-7 year olds and 8-11 year olds);
- Adolescents aged 12-18 years;
- Adult men aged 18 and above; and
- Adult women aged 18 and above.

There were no estimates included for children less than four years old and estimates do not take into account the differing requirements of pregnant and breastfeeding women, or adults older than 60 years.

3.1.3 Determining the number of recommended serves for each food group

The AGTHE specifies a range of recommended serves for each food group and extra foods category for each age, gender and life-stage population category depending on a number of assumptions. The following assumptions were made to determine a single serve number for each food group:

- The AGTHE specifies two dietary profiles for each age, gender and life-stage category, Diet A (relatively high plant based diet profile) and Diet B (relatively high animal based diet profile). The food serve range specified in the Diet A profile was selected; and
- The specific number of serves selected for each age, gender and life-stage category for Diet A was determined by calculating the approximate midpoint of each serve number range.

3.1.4 Estimating the amounts of foodstuff required

The estimation of the amounts of the representative foods needed to contribute to a diet profile for the population that would be consistent with the nutrition reference standards, i.e. the Recommended Dietary Intakes and the Dietary Guidelines, involved a series of calculations. The first step involved multiplying the weight of a sample serve of the representative food by the number of recommended serves. The results for step one are shown in Table 3-1.

The next steps were implemented directly in the ASFF. The second step involved multiplying the calculated amount of the representative food by the number of people projected to belong to each population category. For the third step, the calculations for each population category were summed to provide an estimate of the total amount required for each representative food.

!	*The representative foods selected for each food group cannot account precisely for relatively minor variation in nutrient composition of certain other foods in the group. In relation to extra foods the potential variation in nutrient composition could be significant as, by definition, there exists no distinguishing nutrient, e.g. sugar was selected as the representative food for this category that might contain foods and drinks as diverse as soft drink, alcohol and chocolate.*
!	*The number of food serves was based on the Diet A profile and this means that a modest meat consumption relative to the current national diet pattern was used in calculations (a relatively modest plant consumption profile would have arisen if Diet B was adopted).*
!	*The weighted portion calculated for the 'Meat, fish, poultry, eggs, nuts, legumes' food group was based on consumption patterns reported in the 1995 National Nutrition Survey (NNS), which although being the most recent national survey of its type, is now more than 15 years old.*
🕮	*Inclusion of more age groups and life-stage categories in the calculations.*
🕮	*Analysis and inclusion of fish, poultry, eggs and pig production systems.*
🕮	*Inclusion of more diverse 'extra' foods.*

Table 3-1: Estimated food requirements for a nutritionally adequate food supply

Food Group Name	Representative Food	Sample serve	Weighted amount of the sample serve	Number of recommended serves				kg / person / day			
				Children (4-11)	Adolescents (12-18)	Adult Males (>18)	Adult Females (>18)	Children (4-11)	Adolescents (12-18)	Adult Males (>18)	Adult Females (>18)
Bread, cereal, rice, pasta, noodles	Bread	2 slices of bread	60g	7	7.5	9	6.5	0.420	0.450	0.540	0.390
Vegetables, Legumes	Aggregate of cooked vegetables[9]	½ cup cooked vegetables	75g	2.5	4	5	5	0.188	0.300	0.375	0.375
Fruit	Aggregate of fruits[9]	1 medium piece	150g	1	3	2	2	0.150	0.450	0.300	0.300
Milk, Yoghurt, Cheese	Milk	1 cup	250ml (~ 250g)	2	3	2	2	0.500	0.750	0.500	0.500
Meat, Fish, Poultry, Eggs, Nuts, Legumes	beef, veal, mutton, lamb, pigmeat	65-100g	Average of 83g per serve x 0.48	0.48	0.48	0.48	0.48	0.040	0.040	0.040	0.040
Meat, Fish, Poultry, Eggs, Nuts, Legumes	Poultry	65-100g	Average of 83g per serve x 0.27	0.27	0.27	0.27	0.27	0.022	0.022	0.022	0.022
Meat, Fish, Poultry, Eggs, Nuts, Legumes	Eggs	2 eggs	120g x 0.07	0.07	0.07	0.07	0.07	0.008	0.008	0.008	0.008
Meat, Fish, Poultry, Eggs, Nuts, Legumes	Fish, crustaceans, molluscs	80-120g	Average of 100g per serve x 0.13	0.13	0.13	0.13	0.13	0.013	0.013	0.013	0.013
Meat, Fish, Poultry, Eggs, Nuts, Legumes	Nuts (peanuts or almonds)	1/3 of a cup	85g x 0.03	0.03	0.03	0.03	0.03	0.002	0.002	0.002	0.002
Extra Foods	Sugar	approx. 600kj/serve	35g	1	1	1	1	35g	35g	35g	35g
Extra Foods	Oil	approx. 600kj/serve	1 tablespoon (20g)	1	1	1	1	20g	20g	20g	20g

[9] Within the constraints of this project it was not possible to analyse the impact of the scenarios on all fruit and vegetables. While recognising that there may be a substantial difference in resource needs between different fruits and vegetables, an 'aggregated' serve for both fruit and vegetables was used as a proxy (for all foods in these categories). In the modeling, production inputs for the aggregate fruit and vegetable categories are based on nationally averaged figures, which prevents the exploration of possibilities to substitute fruits and vegetables within these categories.

3.2 Qualitative Scenarios – Structure and Storylines

Qualitative scenarios were developed to frame divergent socio-economic and technical trajectories i.e. to determine the underlying structures and motivations operating with the scenarios. The development process drew upon a wide range of existing information sources as well as a broad group of participants to identify relevant and important dynamics of change.

3.2.1 Identifying Dynamics of Change

3.2.1.1 Review of Scenario Projects

An array of scenario-based projects related to food and natural resource management were reviewed, internationally, nationally and in Victoria.

Many of the scenario processes reviewed were multi-year, multi-stakeholder projects with very substantial research support. Wherever possible the investment made in those projects has been utilised in this work to extend the scope and capacity of the project.

This review informed further development of the methodology, as well as the results, in the following ways:

- Increased understanding of complementary use of qualitative and quantitative scenarios, informing the type of scenarios developed and key settings; and
- Provided an overview of the drivers of change that appeared prominently throughout those processes, which also validated the selection of key drivers for scenario development in this project.

The scenario processes reviewed are summarised in Appendix 2.

3.2.1.2 Stakeholder Workshop 1

What dynamics, or combinations of dynamics, could affect secure and sustainable provision of a nutritious diet to the Victorian community?

A stakeholder workshop was held to inform the development of the exploratory scenarios for the Victorian context. The workshop was designed to approach the topic of food supply in Victoria from different perspectives, to uncover:

- A breadth of different considerations and factors needed to understand the future of food supply;
- Interconnected factors and relationships involved in the future of food supply;
- Potentially unconsidered “bi-products” or “knock on” effects coming from other areas that may impact food supply;
- Potential risks and opportunities in the periphery of our own “world views”; and
- A systems perspective of how key dynamics may interact.

Prior to Workshop 1, participants were requested to submit their ‘top ten’ dynamics that could impact on food provision for the Victorian community. These suggestions were mind-mapped (Figure 3-1) to identify key drivers and dynamics of change, which were then summarised for use in the workshop (Table 3-2).

Figure 3-1 - Drivers and Dynamics from Participants

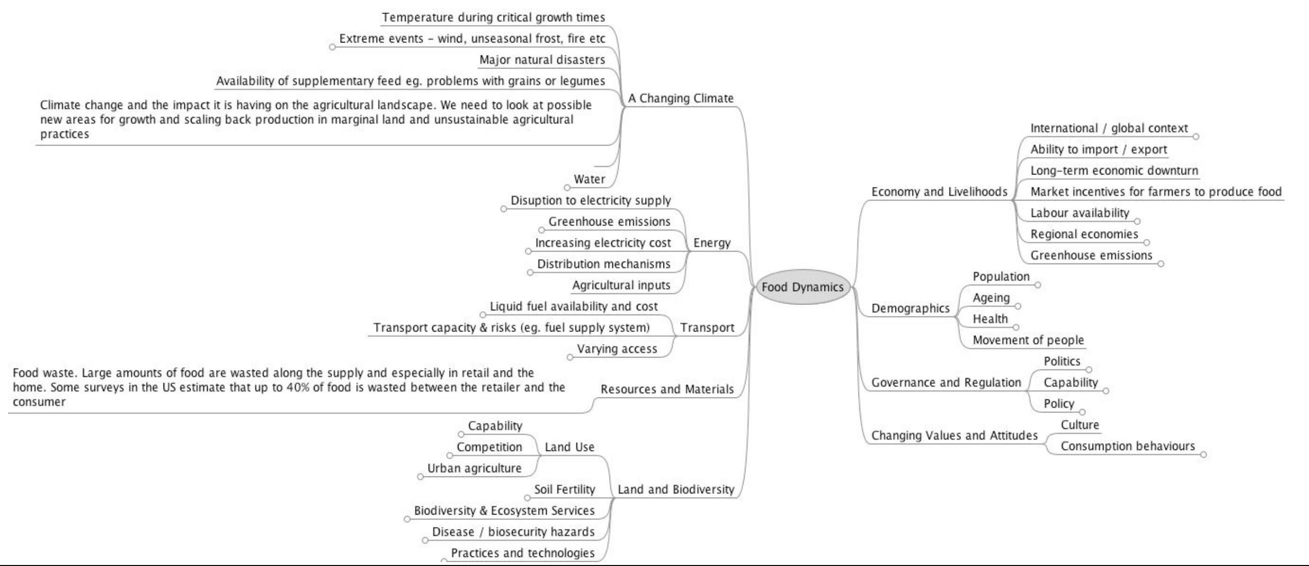


Table 3-2: Pre-Workshop Drivers and Dynamics of Change

Theme	Considerations include	Participant Comment (sample)
Climate Change The climate and environmental conditions are changing and these shifts will cause repercussions through our economy and society.	• Changes to weather patterns including changes to temperature in key growth times and unpredictable seasonal conditions • Reduced and/or less reliable water availability (dryland and irrigation) • Shifting production – impacts for distribution and processing • Extreme weather events – loss of production and impacts on producer / processor viability • Extreme weather events – failure of or damage to key infrastructure e.g. electricity (refrigeration), transport • Climate refugees (*see Demographics*)	Disruption or loss of processing capability Availability of supplementary feed eg. grains or legumes
Energy Energy is at the centre of our society and the way it operates. It drives our economy and underpins our quality of life. It comes with challenges and issues however and is undergoing fundamental change as we strive to overcome associated environmental, economic and resource costs.	• Increasing demand for energy • Increasing, and increasingly unstable prices • Availability and access to traditional energy sources • Emerging energy sources	Electricity distribution upon which refrigeration depends is subject to overload or fire damage
Transport Linking resources, people and places under new constraints and pressures will continue to be a hefty challenge. How might transport solutions and systems evolve with changing requirements?	• Congestion • Cross border/international trade and business • Supply chain management • Evolving personal and freight transport requirements • Transport capacity & risks (e.g. fuel supply system) • Urban design in cities	Rising supply chain costs get pushed back on to farmers

Resources and materials The production or mining, processing, distribution, waste, collection and disposal of the products present in every element of our day-to-day lives has massive impacts on the way society operates. Many of these intersect with food supply – could small changes have big impacts?	• Food waste along the supply chain • Materials for packaging • 'Embodied' water and carbon in food products • Resource availability - competing usage drives up costs • New value and sources of water, materials	Large amounts of food are wasted along the supply, especially in retail and the home.
Land and Biodiversity The historical, current and future use of land both in Victoria and elsewhere will have a major influence on food supply in Victoria. Biodiversity and biological systems offer both opportunities and threats. Choices and issues regarding land planning and ecosystem management are critical considerations when looking at the broad future implications for Victorians.	• Soil health and nutrient availability • Land capability and competing uses • Declining biodiversity and eco-system breakdown • Disease and biohazard • Agricultural systems and management • Reducing greenhouse emissions • Sustainable production systems • Ecosystem services and value of environmental assets	Global dependence for a high percentage of food on just 4 grains. Increasing dependence on GMO single strain varieties all lead to lack of resilience in the food supply chain. This makes food-shocks in supply and cost all the more likely and drastic.
Economic Factors The changing operating conditions regarding the economy, industry and trade will continue to influence all structures including food supply. Increasingly local, national and international considerations need to be addressed.	• Reliance on Australian resource based industries • Regional economies under threat • Interconnected international markets, tightly bound to China • International competition for resources and business – and food • Trade agreements and currency • Economic meltdown – all better now or just beginning? • Cost of capital and credit, impact on trade • How will food welfare be handled for vulnerable communities?	International food security fears and potential import restrictions to protect own interests (here or overseas).
Demographics Changes in the shape, distribution and makeup of local, national and international populations promises to be a key determinant of change. It will influence every aspect of society propelling new outcomes, challenges and opportunities.	• Aging populations • Immigration and planned population increase • Urbanisation and high density living • Coastal development and growth and changing age profiles • Changing family sizes and structures	Clearly it is possible to sustain the current population but if, through major food crises in southern and eastern Asia, Australia were to receive say 25 million refugee immigrants (out of many hundreds of millions displaced) the picture in Victoria would be transformed.
Governance and Regulation Unprecedented challenges and increasing requirements may signal new levels of governance and regulation. Emerging connectivity between various areas of policy is creating the need for increased collaboration and input, while international concerns are requiring local involvement	• Increasing social / public requirements • Access and exposure to information • Adaptive management of complex problems – availability and access • International agreements • Changing role of government in market intervention • Political platforms • Tension between low-cost food, environment and fair price for farmers • Stable states and international trade rules	Government measures to make food more available can result in decreased incentives to farmers

Changing Values and Attitudes Signals of changing values and attitudes are all around us and will facilitate different lifestyles, behaviours and aspirations. These sometimes unnoticed shifts are a huge determinant in the way our society operates and the decisions populations will make in the future.	• Corporate and citizen social responsibility • Increasing requirements for visibility and flexibility • Political involvement • Consumptions patterns and choices • Increased need for welfare assistance – who will pay?	More expensive food could challenge 'feel-good' purchasing decisions

3.2.2 Divergence

From the literature review and the stakeholder workshop, three dynamics clearly emerged to shape divergent trajectories for the scenarios. These are:

3.2.2.1 Speed and effectiveness of greenhouse gas emissions reductions

Our first parameter for scenario definition is based around the extent of emissions reduction that takes place in the study period (2010 to 2030 and then to 2060). Levels of global and national commitment to reducing greenhouse emissions in coming years are unknown. The extent to which emissions reductions are pursued in Australia and Victoria will depend to some degree on global action, but the scenarios are differentiated mainly on the degree to which there is local political will, or perceived advantage, for action. At the time of writing this report, the ***minimum*** emissions reduction to consider would be 5% on 1990 levels by 2020 – the current Australian Government's position presented to international negotiations. The maximum emissions reduction level is considered to be in the order of 60% by 2020 and 90% by 2050, to reflect the scientific consensus on required emissions reductions [UNFCCC 2010; IPCC 2007].

3.2.2.2 Extent to which governments intervene to manage food and energy security concerns

The mechanisms that will manage allocation of scarce resources and drive emissions reductions are unknown. There are currently different competing ideologies and desired approaches, including market-driven, government-driven and community-led. These approaches can be applied to emissions reduction mechanisms, but also to how governments and markets interact in determining the future food system. So, the next parameter of difference is the level of government intervention:

- Market-driven change – structural shift in the economy driven by increasing prices of energy and carbon, as well as other contested resources (land, water etc.). Changes happen in the cheapest ways first, prolonging bigger shifts until new technologies become viable given the prices on resources.
- Government-driven change – Government takes a stronger role in resilience planning for essential services in an uncertain future; intervening to secure resources for critical public good requirements. Interventionist governments drive business and system change through: regulation of minimum standards; investment in infrastructure; intervention in allocation of land and water; high R&D in resource efficiency, energy technology, food, fuels, biodiversity, and so on.

3.2.2.3 Scale of solutions: global, national or local / regional

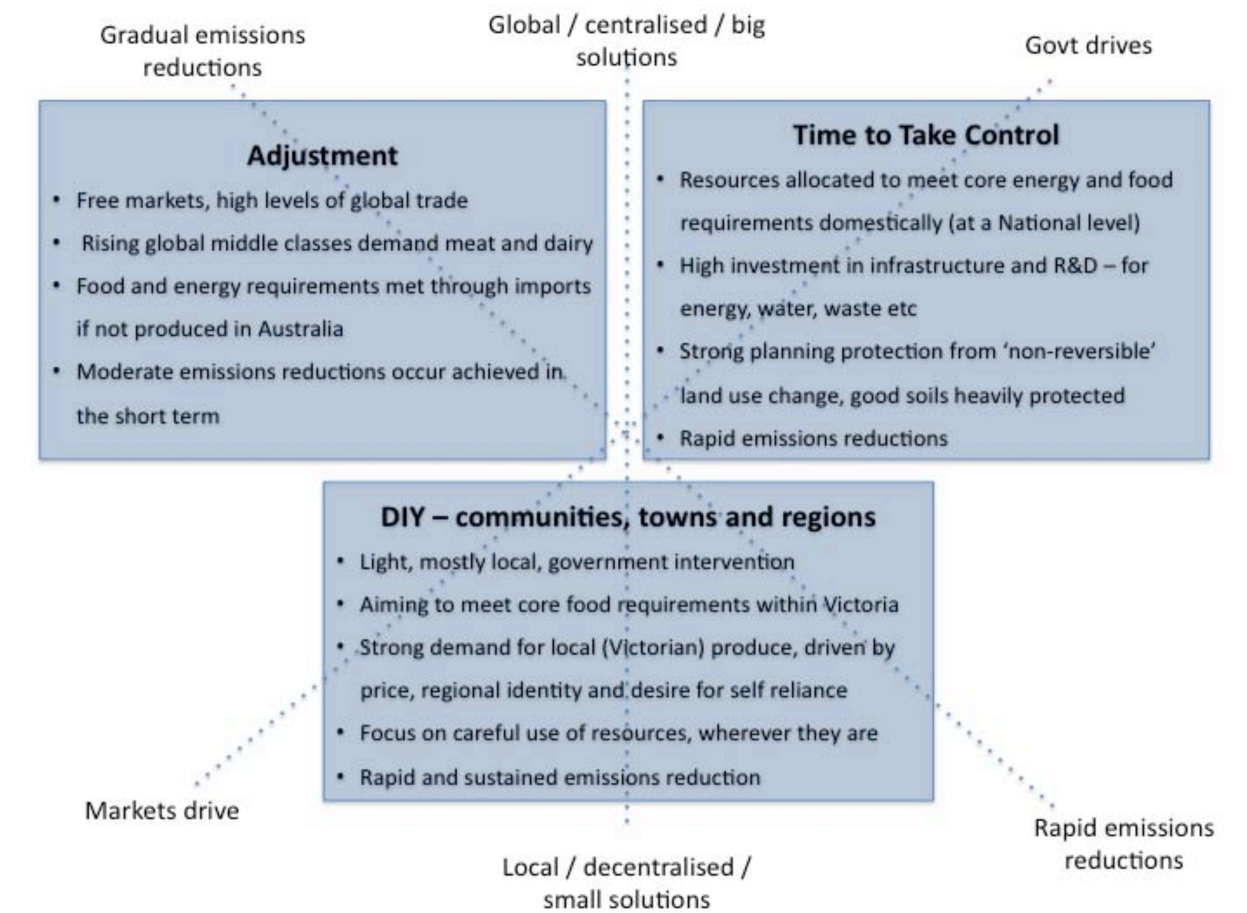
Across global politics at present (as reflected in the review of international scenarios and the workshops) there is a discernable division in policy approaches to innovation, climate mitigation and so on, between 'big' national or centralised programs and the emergence of (many) 'small' decentralised (diverse) actions. This division seems to cross traditional political allegiances, ideologies and parties. We have allowed that axis to play out in these scenarios by having two that are essentially 'top-down' and one that is bottom-up with strongly localised dynamics.

3.2.3 Scenario Descriptions

Through the stakeholder engagement process (and the early exploration of the CSIRO model), it became clear that there was value in moving beyond future conditions recognised as 'possible' by participants to define more challenging, but still plausible, scenarios. The key dynamics and trends were therefore exaggerated, possibly beyond levels that participants expected to occur. This is not an unusual approach and the 'bigger', 'bolder', divergent scenario definition reflected (and was influenced by) similar work undertaken within large projects on food futures within the EU. By exaggerating the different drivers of change in this study we were able to get a better picture of the differences and tensions that arise from them.

The scenarios that emerged from these dynamics (summarised in Figure 3-2) intentionally polarise the way that competing dynamics might unfold. It is unlikely that one of these approaches would prevail over the others, and the future is likely to contain elements of all three (or something else altogether). The purpose of exaggerating the dynamics of change is to clearly distinguish between potential future choices and trajectories, whilst staying within the bounds of plausible futures.

Figure 3-2: Scenario Logic Diagram



The scenarios are framed by these three divergent axes – each scenario is defined by three 'ends' closest to the box.

The three scenarios are described in more detail below.

3.2.3.1 <u>Adjustment: Show me the Market</u>

<u>Snapshot of trajectory (2010)</u>

"Despite ultimately finite quantities of oil, metals, and minerals in the earth's crust, there is little likelihood that the world will run out of natural resources (or food) in coming decades. The existence of ample (and growing) reserves, and a history of significant improvements in the technology with which resources are found and extracted, suggests that supply will continue to rise in pace with demand. True resource exhaustion is unlikely not least because, as resources become scarcer, their prices rise, consumption declines, and alternatives that once may have been uneconomic are substituted for the scarce (and expensive) commodity" [World Bank Group 2009: 74].

<u>What's it like in 2030?</u>

Global support for free trade dominates international relations and there are very few barriers to global trade of agricultural and other produce. The global economy is strong, driving demand for exported energy and mineral resources. The rising middle classes in Asia and around the world demand both commodity and high-quality food products – particularly meat and dairy, some of which Victoria can provide. But use of land and resources is determined by the highest dollar value that can be generated, which is often not related to food production.

Despite ups and downs, the Australian dollar remains strong, largely linked to our ability to export minerals and energy to China [DPI 2009]. A global market for carbon emissions is operating, but the rules are unclear and enforcement is weak. With such varied aspirations between nations and an inability to separate emissions from economic growth, global emissions have not yet peaked. Australia did meet its target of 25% reduction by 2030 – with a significant contribution from international offset purchases.

Those who are able to invest can secure and maximise use of resources wherever they occur. Governments don't interfere with competitive activity, ensuring that there are few barriers to innovation in finding and extracting resources, or developing substitutes for those that have become scarce. Excessive caution in trialling new technologies is often outweighed by the urgency and opportunity of increasing productivity to meet escalating demand for food and energy.

An increasing population coupled with continuing economic strength means that land, along with other resources, moves to those who can pay the highest price. Agriculture rarely occurs in close proximity to settlements or infrastructure because the land is simply too valuable – we can get cheap food elsewhere, from intensive production further out or from new technologies that don't require land at all.

'Brand Victoria' represents high-quality, niche and value-added products, aimed at high-value consumers (often in international markets) who are willing to pay for tightly specified health and environmental attributes. The production of energy and carbon sequestration has added new options for farmers and land managers.

Global trade of commodities and product is high and increasing. Vertical integration enables large companies to maximise efficiency in their value chains, optimising supply of inputs, production, processing and logistics to get product to high value markets anywhere in the world with minimal cost. Concentration occurs across all sectors of the food system, with the vast majority of Australia's food delivered as three TesColeWorths home-brands: *Energising Your Family*– energy needs at the lowest cost, *Especially For You*– tailored functional foods meeting demographic and specific health needs, and *Because You Care*– premium products with broad environmental, animal welfare and social credentials, including 50% Australian produce.

<u>Workshop comments:</u>

- *Rural Australia has to diversify very strongly, and value add – perhaps diversify out of food*

- *Don't want to give up the capacity to switch back to bulk food production again –'swing farming'– perhaps favour technologies that let you change back rather than planting trees that you have to walk away from for quite a long time*

3.2.3.2 *Control*: Time to Take Control

Snapshot of trajectory (2010)

A more coherent and consistent approach is needed for managing the growing demands on land – at different levels of Government, and across the wider community of stakeholders involved in the many land use sectors . . . major challenges and rising tensions will result unless action is taken [Foresight Land Use Futures Project 2010: 9].

What's it like in 2030?

Australian federal and state governments have a strong mandate to do what it takes to make things work, deliver a stable climate, secure essential services and prevent social disruption. The public demands that uncertainties are controlled or reduced – government interventions are regular, strategic and sometimes heavy-handed. High carbon targets regulated and priced to drive strong and rapid change.

Government at all levels in Australia move to act on climate change and secure food and energy supplies – and jobs – *within* domestic economies. There is a strong risk management approach, based on infrastructure investment and management of assets and services. There are variable levels of global cooperation, in the midst of considerable and continuing instability in the financial system, geo-political conditions and a growing level of extreme weather and climate-related events. There is a reduced and more sporadic movement of goods internationally.

Society responds actively to perceived risks, which can be of various kinds (environmental, social and economic). There is particular sensitivity to climate change, large-scale epidemics, obesity, and resource scarcity and access.

The concept of globalisation has shifted with a large focus on longer-term interests. Global cooperation is high between some countries, but variable in that it is turbulent and at times unpredictable, with a shifting attitude to the role of markets and "free trade". There is an aim to facilitate the trade of surpluses and to deal with scarcity; sustainable production in both developed and developing countries is a high priority. However whenever there are shortages of critical resources (particularly energy and food) governments have consistently acted to support the demands of their populace.[10] There is a general consensus worldwide that the safest position to be in is one where you have control over your own food and energy supply – and pursuit of this safety net is a priority action for most nations, although of course some are more easily able to achieve it than others. In Australia this is consistent with other political imperatives to secure livelihoods and jobs, particularly in regional communities.

Strategic planning for long-term goals and social cohesion (and environmental imperatives) underpins intervention in land and resource use, to provide energy, food, fuels, biodiversity etc. for the population, with sufficient redundancy in the system to cover increasingly regular disruptions and shocks.

The government intervenes to ensure that land use necessary for provision of basic needs and public goods (food, energy, sequestration and ecosystem function) is secure. Strong planning protections prevent speculation as there is a high level of confidence that the government won't allow 'non-reversible' land use change in areas identified as critical for essential services, particularly food. These controls are supplemented by heavy investment in infrastructure to make producing food in these areas a viable and profitable proposition.

[10] The possibility of shifts in global policy toward protectionism rather than away from it was considered highly likely (A2) as countries wrestled with globalism ideology and/or restructuring [DPI 2009].

The race to reduce greenhouse gas emissions and secure food supply necessitates high carbon taxes that fund payments for emissions reduction and related research. These, and other resource and financial taxes, are bank-rolling government investment in infrastructure and R&D across agriculture, energy, water and transport systems.

Companies operate within a strong and heavily enforced regulatory framework that allows for predictable profit without expectations of windfalls. Innovation for business survival takes place within a context of high taxes, steadily tightening minimum resource efficiency standards and restrictions on activities that don't comply.

Workshop comments:

- *Will government be more autocratic? Has to see big picture.*
- *What if we actually did something really radical and pushed hard on action against climate change – what impact would that actually have on food? What impact would that have on drivers for alternative land use, sequestration and energy etc.?*

3.2.3.3 *DIY*: Communities, towns and regions (the food internet)

Snapshot of Trajectory (2010)

"We thus move into 2010 with the climate crisis intensifying but climate politics adrift and civil society as disorganized about what to do as our governments, and not only in the U.S. but worldwide, with precious few exceptions . .. we must continue to expand where the situation is the most conducive and where climate leadership emerges, especially at the sub national level where so much dynamism is taking place" Jim Garrison, President – State of the World Forum 2009.

What's it like in 2030?

Characterised by high tech, low-tech mix; reasonable quality of life; highly decentralised. The food supply follows a pattern looking remarkably like the internet. Food production and distribution is best described as a network of networks, with greater interaction between consumers and producers, increasing diversity of products across all food types and a social pride in 'local food'. Innovation and experimentation are very aligned to the open-innovation spirit of the last few decades, with very high and creative use of information and communication technology. Pervasive ICT connectedness is critical to how things work and is a high priority for what limited infrastructure investment is possible.

Environmental awareness and responsibility is strong and action on climate change is led from the bottom-up as a spirit of self-reliance and responsibility drives community action. Retaining a reasonable quality of life is valued more highly than traditional measures of economic growth. Renewable energy, water and food are highly valued resources – culturally and economically. Local/regional self-sufficiency is pursued as a social and environmental goal. A community spirit that celebrates creativity, experimentation and 'open innovation' underpins these social and environmental values.

Governance of all aspects of energy, water and food production, distribution and consumption is regionalised. In some places this is based on functioning local or regional governments, but very often it involves more self-managed local 'communities of interest' (with both formal and informal structures). Overall the situation is one of low government intervention. Political decision-making is strongly decentralised and self-management is an expectation. Old centralised institutions of knowledge support and quality control live on in name only – or they have changed to provide support as a distributed (remote) service. Some groups, areas and regions are better off than others - measured by their resource endowment but also their ability to self-organise and innovate. Where cooperative and resourceful strategies have not been developed, communities are vulnerable to tension from competition for resources. There is resulting social disruption and increasing gap between haves and have-nots.

Regional self-sufficiency and independence drives creative innovation and change, from the bottom-up. With declining jobs and firms in traditional industries, there is significant opportunity for more agile small business and entrepreneurs to fill the gaps for basic products and services. The internet and other information and communication technologies (ICT) facilitate local/regional participatory decision-making and an open-source innovation system that generates endless new ways to make the most of available resources. As soon as something is built once, instructions are online and it's replicated from garages, workshops and farm sheds around the nation (and often the world) within months.

Life is information intensive, with public data, collaboration, information exchange, web-based support services, and real-time monitoring, an accepted part of daily existence. This enables some balance of trade and production of appropriate foodstuffs (with respect to local climate and land availability, soil and so on).

Food production and consumption is a dominant part of culture. Food supply is characterised by great diversity across different landscapes and regions, but also diversity is a characteristic of the changing food-basket over time. Experimentation with diverse crops and local adaptations is crucial to ensuring adequate food supplies in difficult conditions, as well as energy and other industrial needs. Food stocks are generally good with many small service businesses based on preservation and processing.

Food (and water) transport (distance) is a sensitive issue in the community; innovation is focused on improving transport systems to improve movement of surplus as much as new production processes and new food products. Food (and human) waste is reused locally as fertiliser inputs. Because of the high status of the goal of energy and food self-sufficiency, exports and imports of food products is very small. However energy efficiency and reduced consumption means that the demand for biofuels does not displace food production.

Urban development is constrained as land uses for food and energy are highly valued (although conflicts are still frequent). The outer boundaries of larger cities have decreased with migration towards clustered centres but also to smaller regional towns. Cities have increased peri-urban food and energy production; decentralised food production is spread throughout urban areas in larger cities; food markets define the character of neighbourhoods and precincts. Investment in infrastructure (apart from ICT) is, however, low.

3.3 Quantitative Scenarios

!	*The model does not attempt to account for supply or scarcity of particular resources globally, or the political or economic conditions that would make those available to Australia. It assumes that resources are imported if needed where they cannot be supplied from within Australia. Potential vulnerabilities arising from this assumption are discussed in Section 4.4.*
!	*The output of the modelling, like any modelling that deals with future trajectories of national economies, is EXPLORATORY and shouldn't be interpreted as predictive due to the large number of inherent unknowns.*
!	*The scenario settings are adjusted within the model to about 2035. The scenarios are then run to 2060 without further intervention, so that the longer-term implications of short-term changes can be seen.*
!	*Amendments to the ASFF have been made at a national level (i.e. Australia wide), with the implications extracted at a Victorian level for the purposes of this project.*
🕮	*Identifying unresolved conflicts is an important outcome of the project, as it suggests where future research should be focused.*

The intention in this work has been to develop and analyse scenarios to the depth and detail necessary to derive a broad picture of their implications for food availability. The project was intended to identify the significance of different factors, shed some light on how they interact with other areas, and focus further work on those that matter.

The complexity of the food system, and the economy more broadly, means that strategic decisions needed to be made on what could reasonably be included in the quantitative modelling. Table 3-3 clearly summarises what variables have and haven't been included.

The analysis and results outlined in this section are based on the following settings:

- Background settings – providing an equivalent starting point for the three scenarios (Section 1.4 and 3.3.1);
- High-level settings for key variables, differentiated between the scenarios (summarised in Table 3-5 and described throughout this section); and
- Variables and algorithms within the software that work as calculators to make the framework 'balance' i.e. to make sure that all land, water, energy etc. is accounted for.

For this 12-month project, detailed research on appropriate settings for every variable was not possible, or necessary. The assumptions, approximations and generalisations are noted as transparently as they can be without adding unnecessary complexity to the text. These are further discussed in Section 4.

The settings are used to differentiate between *exploratory* scenarios – they are not intended to be 'the truth'. Therefore, the numbers, proportions and results detailed in this section should not be read as numerically exact (in absolute terms). What they reveal are critical relationships – when we increase X, Y also changes, when we decrease A, we see a significant change in B, C and X. It is these *relative* relationships (and their sensitivities) that are important indicators of any future vulnerabilities, or that suggest where closer attention is required.

Table 3-3: Included and Excluded Factors

What's In	What's Out
Climate Change • Reduced rainfall and runoff leads to reduced water availability for irrigation – represented as less land under irrigated production • Irrigation reduction is national, and applied uniformly across existing agricultural / irrigation regions • Land use occurs on a statistical division level, so water requirement is reconciled at regional / catchment area **Waste and Loss** • Loss due to extreme weather events or pest / disease incidents are accounted for through redundancy built into all three of the scenarios in terms of 'wasted' food, along with food 'wasted' along the supply chain and by consumers	• Analysis of which catchments would be likely to see increased or decreased irrigation – taken as an overall decrease, although some areas may increase • As this project is primarily focused on Victoria, we have not gone into analysis of potential irrigation development elsewhere. This would require much more detailed understanding of soil capability and infrastructure, especially in the context of fertiliser constraints. • Affects of climate change on dryland farming – including fertilisation effects of increased atmospheric CO2, timing of rainfall, increased temperatures and extreme weather events • Adaptations in crop / livestock types and management practices. The relative success of adaptation measures is broadly considered within the scenarios, but is reflected in settings for water and fertiliser efficiency and use, rather than as a separate 'climate impact on dryland production'. • Losses to specific extreme weather events / sporadic losses • Spatial distribution of changing production areas
Greenhouse Emissions • Direct agricultural emissions from methane and nitrous oxide • Emissions from energy production and use (including fuel use) • Carbon sequestered and stored in forests and wood products	• Direct emissions reduction from changed agricultural practice e.g. emissions per animal (changed feeding regimes or management) • Soil carbon – either released or sequestered during land use change, vegetation or production methods • Fire and forest decay
Energy • Efficiency – across economy, with same factor applied for electricity, transport and agriculture • Change in energy mix for electricity generation • Allowance for availability of other fuels	• Assessment of viability of potential technologies (CCS, renewables etc.) • Potential conflict between water and fertiliser efficiencies and energy reduction (whether irrigation efficiency etc. is possible while doing energy efficiency) • 2nd or 3rd generation biofuels
Transport • Changes in passenger demand • Use of electric passenger vehicles and first generation biofuels (e.g. cereals and oils) • Fuel efficiency in passenger and freight vehicles • Changed freight demand / distances to reflect changing food production amounts and locations (i.e. intrastate, interstate)	• Overall changes in freight demand / load – changes only made to freight system associated with food distribution • Technology roadmaps / assessments for emerging poss. fuel replacements e.g. coal to liquids, syngas or 2nd generation biofuels • Additional infrastructure and material/energy requirements, e.g., batteries and exchange or re-charging stations; compression for gas and pipelines or pressurised freight • Specific spatial analysis of what would be produced where and freight requirements to move it
Land & Water Use • Changing proportions of land used for crop and livestock production, bioenergy and biofuels, carbon sequestration and urban development • Changing proportion of irrigation / dryland production • Building / construction and demolition of residential areas	• Land and soil capability assessments, overall or at spatial level; the movement of productive land to match water availability under climate change has also not been spatially considered. • Multiple simultaneous uses of land e.g. for agri-forestry or for urban production; Changing distribution of increased population to send more to regional centres
Agricultural Production • Dryland production and irrigation production • Energy efficiency (overall factor) • Water efficiency / use	• Trade-off between water, fertiliser and energy efficiency in agriculture or other economic sectors • Interaction between land management and runoff into river

• Fertiliser efficiency / use	• Type of agricultural production (practices) • Intensive (non-land based) food production (pigs, poultry & eggs) • Alternative water sources (e.g. recycled)
Fish • Deficit in marine catch etc. same across all scenarios	• Potential use of aquaculture and aquaponics systems to increase production of fish because level of detail in V4 is much higher (lots of different fish) and so much more worth doing once we are able to be using that version.
Food Processing • Energy efficiency (across economy)	• Technology or process change beyond energy efficiency. • Change of location for food processing, to follow changing production location

3.3.1 The Background Scenario

A background scenario was created, from which each of the specific food security scenarios were subsequently generated. Key features of the background scenario are settings and feedbacks that aspire to a healthy economy (balance of GDP, unemployment and net foreign debt / surplus) and assumptions around the impacts of climate change.

Subsequently, each food scenario deals with production (primarily of food, but not limited to this), specific sectors of economic activity (e.g. electricity generation) and some aspects of consumption in different ways, as described in detail elsewhere in this report. The effects on economic indicators (unemployment, trade balance and GDP per capita) of the changes in each scenario can then be compared with the background scenario.

3.3.1.1 Maintaining a Balanced Economy

!	*Production (primary and secondary industry output) and final demand consumption are adjusted to in the background scenario to simultaneously maintain a target unemployment rate and a target trade balance (relative to GDP).*
!	*The effects on economic indicators (unemployment, trade balance and GDP per capita) of the changes in each scenario can then be compared with the background scenario.*

Recent development in the ASFF incorporates economic settings within the scenario simulations. This means that economic growth is endogenous to the simulations – it is an outcome rather than an assumption of the simulation. In this approach, to establish a background scenario, both production (primary and secondary industry output) and final demand consumption are adjusted to simultaneously maintain a target unemployment rate and a target trade balance (relative to GDP). The parameters for economic stability in the background scenario are summarised in Table 3-4 and the process for maintaining these is explained in more detail below (and illustrated in Figure 3-3).

Table 3-4: Background Settings

Variable / factor	Settings	Comments
Population	~36m in 2051; (NOM = 230kpa)	Align with ABS and Treasury projections (see 1.4.4)
Diet		Nutritional diet, both in type of food and volume –food consumption is not adjusted to match supply
Labour productivity growth	1% pa	Assume a typical rate of ~1% pa
Unemployment level	5%	Economists talk of an unemployment rate that's more 'stable'– too low and presumably inflation is stimulated
Trade balance w.r.t. GDP	NFD:GDP ~50%	Net foreign surplus or debt should not be too large relative to GDP, or else the economy is considered to be unstable: if debt is too large with respect to GDP, the economy may not be able to pay off the debt

The level of (un)employment is a result of the population size, its age profile, the participation rate, labour productivity, and the various economic activities requiring labour. If no other change is made to the ASFF inputs, then increased productivity (labour input per unit output and other efficiencies) leads to increased unemployment due to the simple fact that the same economic output can be achieved with fewer workers. With typical productivity growth rates of about 1%pa, mass unemployment of the order of 50% would occur after several decades.

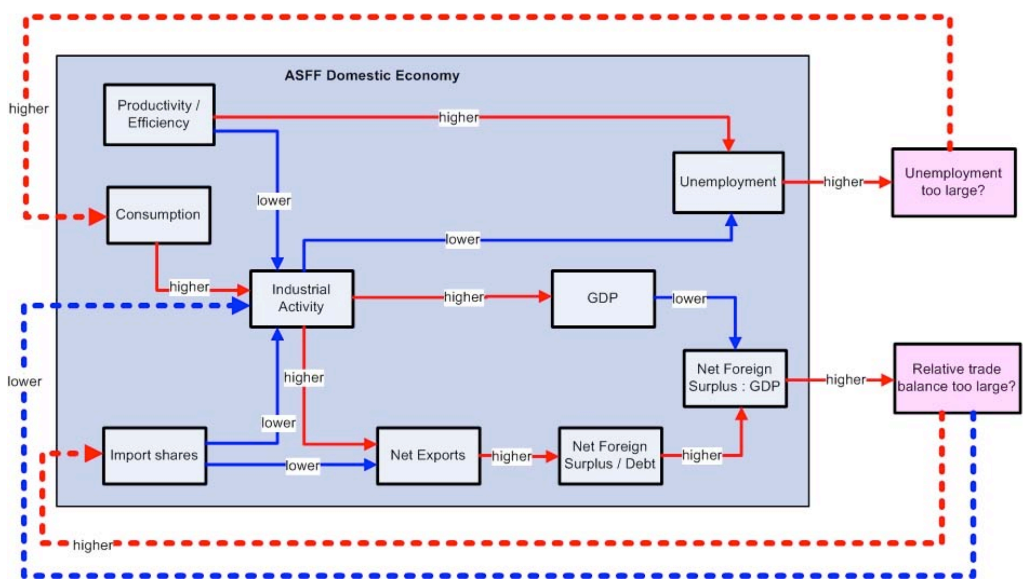
To achieve a stable unemployment level and replicate past economic conditions, the background scenarios incorporate re-employment of displaced labour through increased economic activity. It was assumed that the trends in labour participation rates are not changed from their background settings. Consequently, in the background scenarios, final demand consumption was increased (or decreased) in order to lower (or raise) the unemployment rate. The modelling calculations allow for service workers supporting the physically productive sectors of the economy.

The other key macro-economic indicator simulated is the international trade balance (relative to gross domestic product, GDP). The net foreign debt (NFD) relative to GDP has increased over recent decades, to 52% in 2006 [Kryger 2009]. High rates of debt (and surplus) are considered to be contrary to a stable national economy. In one measure of the economy, the net foreign debt is compared with the nation's GDP in order to judge whether an economy is overstretched to pay its international debt.

The net foreign balance in the ASFF was adjusted by changes to exports and imports, and international travel (inbound visitors, and outbound Australians), and investment. It is possible to achieve the same NFD through different combinations of changes to exports, imports and investment; however, this study (to date) has not explored this sensitivity. Adjustments to exports were made by altering activity in both primary and secondary industry, after allowing for domestic requirements to be met from these industries (where Australian exports are a large fraction of Australian production). International travel and investment are adjusted by the same proportion as exports. Imports were adjusted by changing the fraction of the domestic demand for goods/commodities that is obtained from overseas. These changes also alter GDP, so that an iterative feedback calculation is necessary to achieve the specified NFD to GDP ratio (Figure 3-3).

Figure 3-3: Feedback Processes in the ASFF

Feedback processes used in the ASFF modelling to establish economically healthy unemployment levels and international trade balance (relative to GDP). The arrows indicate the direction of feedback adjustments on aggregate modules of the ASFF to correct poor economic outcomes.



3.3.1.2 Climate Change Impacts

🕮	*Impacts of acute extreme weather events on food availability in the different scenarios*
🕮	*Detailed information and analysis of climate impacts, including spatial information*

The impacts of climate change are set in the background scenario so that they are equivalent across all scenarios.

A high climate change scenario is stimulated through a reduction in rainfall and runoff. An 'envelope' for expected water available for environmental flows is then calculated using two possible reference years – 1998 and 2008 [Raupach et al. 2009]. An assumption of reduced reliability of irrigation water is then reflected in a reduced proportion of productive land irrigated (the extent varies in the three exploratory scenarios).

The specific agricultural impacts of climate change are varied and complex (the subject of significant research processes in themselves), and we have not attempted to account for production variance in particular food types (e.g. sensitivity of grain production to heightened CO_2 levels or impacts of increased temperature on fruit set).

The proportion of the available water used for irrigation and other uses (including environmental flows) varies according to the different scenarios. Increased variability in irrigation water availability would mean that in some years it could be considerably greater or less than this the overall percentage reduction specified in the scenarios.

A future, more detailed, project could allow for other climate impacts in the form of extreme events particularly periods of high rainfall inundation (floods) and extreme temperatures. Given events that have taken place as this report was being prepared, these other ''shocks' in critical weather conditions can have significant impacts on food supply – introducing them into the modelling would be a way to test the resilience of the scenarios (see 4.4).

3.3.1.3 Oil and Fertiliser

The assumption underlying all scenarios is that Australian production of oil continues to decline, based on Geoscience Australia [2009], and global oil prices continue to fluctuate but generally increase. This drives changes in the scenarios to reduce oil reliance.

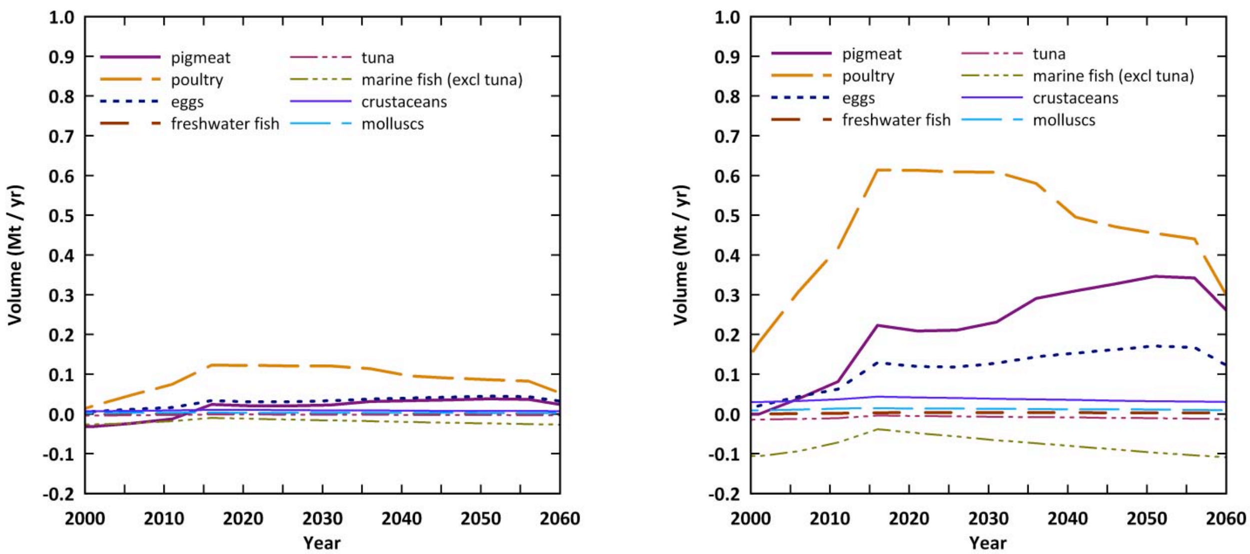
A moderate increase in discovery and extraction of phosphate rock within Australia occurs in all scenarios. This was generated as part of the activity in primary industry of the background scenario, rather than any sector forecasts (due to the apparent lack of these). As can be seen below, this moderate increase is insufficient to seriously impact on import requirements.

3.3.1.4 Non-Land Based Foods

This focus of this project is how the allocation of resources – particularly land and water – affects the availability of core foods. While food production that does not require land (i.e. fish) or where land area is less significant than inputs (i.e. intensive pigs, poultry or eggs) are undoubtedly significant, they have not been analysed in this initial project. The production levels of these foods compared to requirements is determined in the background scenario and they are not affected by the later changes to settings. Figure 3-4 shows a large national surplus of all these foods, except marine fish (excluding tuna) and a smaller Victorian surplus.

Figure 3-4: Other foods (not adjusted in scenarios)

a) Victoria b) Australia



3.3.2 Variables – Translating the Scenarios

The key settings of the three scenarios – the variables that make them operate differently from the background scenario and each other – are shown in Table 3-5.

The greenhouse emission targets in Table 3-5 represent the level of ambition suggested by the qualitative scenarios and were used to guide initial estimates of what other settings should be.

The amount of food 'required' in the scenarios is set as the amount needed to meet nutritional and energy requirements (as defined in 3.1) as well as a 'surplus' needed in the system to provide that requirement. This surplus factor is included to allow for a proportion of waste and losses (some redundancy) whilst still meeting the nutritional requirements of the population. The surplus factor is varied as appropriate in each scenario setting (e.g. 3.3.5.6.1 *Food Required*).

The settings in each scenario determine allocation of natural resources (i.e. land and water) to food production, as well as resource use efficiency, therefore determining how much food is produced. The results then show a production 'surplus' or 'deficit' compared to requirements (for provision of a nutritious diet). When not enough food is produced, the scenarios employ different strategies are to address gaps and make up nutritional requirements:

- *Adjustment*: assumes sufficient food is produced externally and resources are available to buy it, so the domestic food market can import more food; and
- *Control* and *DIY*: Land use patterns are adjusted, reallocating land within agriculture to different food types to increase production.

The rationale, settings and results of each scenario analysis are outlined in the sections below (3.3.3, 3.3.4 and 3.3.5). The modelling has involved making changes within the ASFF at a national level (i.e. settings are applied universally across Australia and not differentiated between states). Therefore, the results can easily be extracted at both a national and Victorian level. The results included within the main document are shown at a Victorian level, with national level also provided where appropriate. With modelling and analysis of this type, it is possible to extract an almost infinite number of variables and relationships.

Table 3-5: Summary of High-Level Scenario Settings

	Adjustment	***Control***	***DIY***
Greenhouse Emissions (target values – reduction on 1990 levels)	15-20% by 2030 45% by 2060	60% by 2030, 80% by 2060	60% by 2030 90% by 2060
Land and Water Use Reduction in productive (food) land by 2035	-20% To forests for bioenergy	-20% To forests for bioenergy and sequestration	-15% To forests for sequestration only
Urban land use (all changes in urban land use are exchanged with land use of 'grazing')	Roll-out of increasing population at current dynamics for household formation, density etc.	Stop conversion of productive land to residential, increasing high-rise density	Contracting urban area, more people per dwelling, larger households, renovation / adaptation
Reduction in proportion of cropland irrigated by 2035	40%	60%	75%
Energy			
Energy Efficiency (across economy)	40%	40%	50%
Energy Production	30% renewable by 2030, increased gas, CCS from 2025	Conversion to gas and renewable	Conversion to renewable
Transport Efficiency / demand reduction	Fuel efficiency	Fuel efficiency	Fuel efficiency, demand and distance reduction
Mode change		90% freight on rail	50% freight on rail
Fuel substitution (where not stated, changes are applied out to 2035)	15% electric vehicles for new passenger vehicles from 2011 10% to compressed gas 1% p.a. increase in crop diversion to biofuel	100% electric for new passenger vehicles from 2011 Switch to gas for remaining road freight	10% p.a. increase in crop diversion for biofuel
Agricultural Production			
Energy efficiency	40% as per overall	40% as per overall	50% as per overall
Water efficiency (% change pa): • intensity of application (reduces) • yield (increases)	 0.5% 0.5%	 0.5% 0%	 1% 0%
Fertiliser efficiency (% change pa): • intensity of application (reduces) • yield (increases)	 0.2% 1%	 1% 1%	 0.5% 0.5%
Labour productivity	As per background	As per background	-2% per annum, agriculture only
Net Food Availability			
Food required (waste & losses)	50% of food produced is wasted / lost	44% of food is wasted / lost	33% of food is wasted / lost
Food available	Any deficits met through imports	Reallocate resources to produce nutritious diet in Australia	Reallocate resource to produce nutritious diet in Victoria

The key variables have been identified and results are explained in the following categories for each of the three scenarios.

- Land and water use;
- Electricity demand and production;
- Transport;
- Agricultural production: water availability and use; and fertiliser;
- Greenhouse gas emissions; and
- Net food availability.[11]

Section 3.3.6 provides results for some key variables for all three scenarios at the same time, enabling comparison of their impacts. These are:

- Net environmental flows in key Victorian irrigation districts;
- Reliance on imported oil;
- Fertiliser (phosphorus) import reliance; and
- Economic indicators – GDP, unemployment and net foreign debt.

Settings were adjusted iteratively as data was explored, until key elements were broadly consistent with the scenario storylines. This was a big advantage of the way the ASFF is constructed, enabling the project team to meet in repeated sessions, interacting with the model, optimising the values for the settings to ensure both consistency (in what was being changed) and divergence (in what it was changed to) across the scenarios. In this process there was also the possibility to 'resolve' tensions as they were revealed. Time and resources in the project limited the number and depth of iterations completed – leaving many tensions unresolved. It is these tensions that are of interest so they are identified and discussed throughout.

> *Resolving tensions in the scenarios*
>
> A much larger project, with a higher number of iterations, would be required to try to 'resolve' tensions, to make each scenario internally consistent and fully explore whether the multiple objectives can physically be simultaneously met.

3.3.3 Adjustment

In the *Adjustment* scenario, markets are considered the main determinant of how resources are allocated and used – both locally and internationally. Increasing competition for resources - and corresponding cost impediments - drive efficiency and innovation, but the structures and systems remain inherently the same as in 2010. The driving forces for this scenario are therefore assumed to be:

- Land and resources allocated according to highest short-term value;
- High levels of efficiency across the economy driven by competitive pressure, including in energy, transport and food production;
- Low levels of public investment in R&D or infrastructure; and
- Moderate emissions reduction – aiming for 15-20% on 1990 levels by 2030.

3.3.3.1 <u>Land Use</u>

<u>Diversion to forests</u>: *Adjustment* sees a 20% loss of land from food production by 2030, most of which is allocated to forestry (for bio-energy). These land uses have added new options for farmers and land managers, but generally only those managing large operations that can capture economies of scale and invest in the capital and infrastructure for competitive systems.

[11] NB. Appendix 4 contains detailed graphs showing the surplus and deficit of foods (by food group) between 2000 and 2060, in Victoria and Australia.

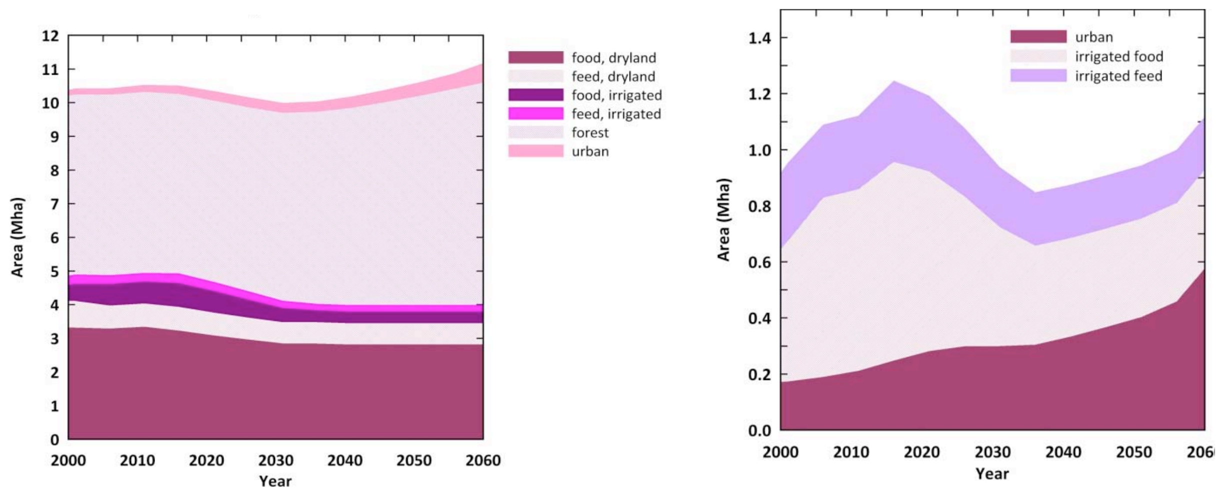
Urban development: agricultural land continues to be converted to residential / urban, as increasing population is translated into household formation, residential development and floor space, without significant constraints on urban growth boundaries (at relatively low land densities), at rates consistent with historical trend. This further loss of agricultural land is taken from grazing land.

Irrigated land area: As irrigation allocations become smaller, less reliable and more expensive, land that has formerly been considered irrigated is increasingly used for dryland production, to take advantage of water when and where it is available. The proportion of cropland assumed to have reliable irrigation is reduced by 40% by 2030.

Figure 3-5: Victorian Land Use (*Adjustment*)

a) Majority land use

b) Urban and irrigated only



Changes in Victorian land use as a result of these settings are shown in Figure 3-5. Increasing forestry and urban expansion reduce land availability for both dryland and irrigation food production. The proportion of food and feed producing land that is irrigated also reduces.

3.3.3.2 Electricity Demand and Production

The increasing cost of energy drives significant innovation and technology improvement for energy efficiency across the economy – 40% reduction in energy used per unit of economic activity by 2040.[12]

Figure 3-6 shows slower rates of electricity demand growth as old, inefficient building and vehicle stock is replaced to 2035, but increasing demand (for new building stock, electric vehicles etc.) outpaces the efficiency increase and total electricity demand continues to rise. Increasing demand for electricity for electric vehicles can also be seen.

Figure 3-7 shows the changing electricity generation sources in *Adjustment*. A renewable energy target of 20% by 2020 is achieved and the trajectory continued, achieving around 40% renewable power by 2030. There is an increase in gas for provision of baseload power, which makes up around 12% of electricity generation by 2030. Carbon Capture and Storage (CCS) becomes viable and reduces the emissions intensity of coal-fired power stations from 2025, enabling them to continue providing a large portion of electricity – around 35% in 2030.

Even with the significant land use change to bioenergy, the relative amount of electricity produced from biomass sources remains relatively small.

[12] This is slightly higher, but consistent with, the energy efficiency assumed in BZE [2010] (33%), which would bring Australia into line with other industrialised economies.

Figure 3-6: Victorian Electricity Demand / Use (*Adjustment*)

a) Major Sectors b) Minor Sectors

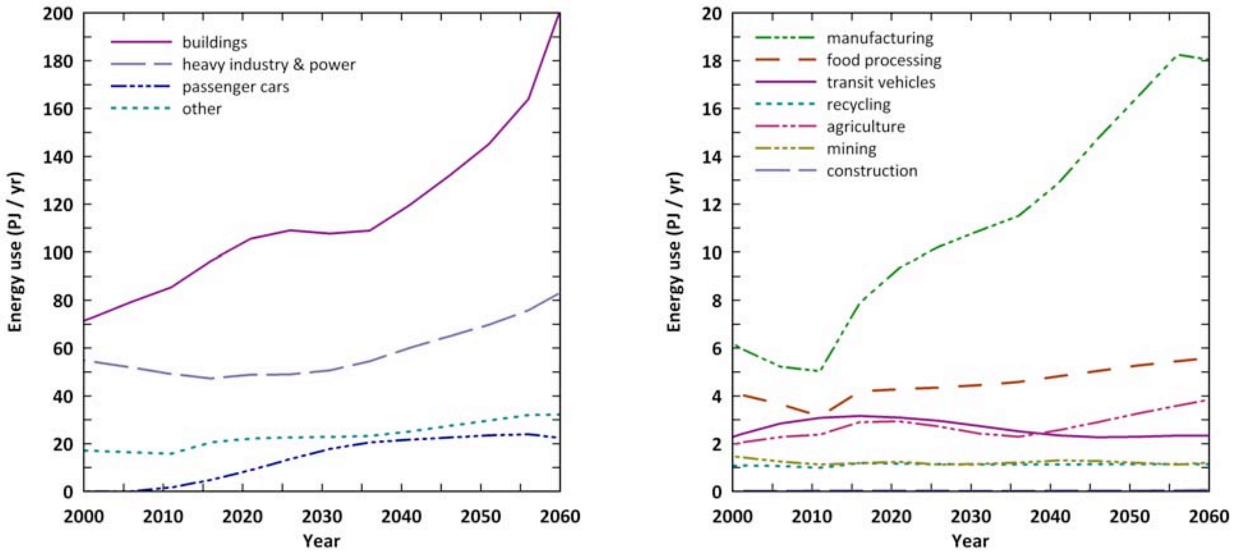
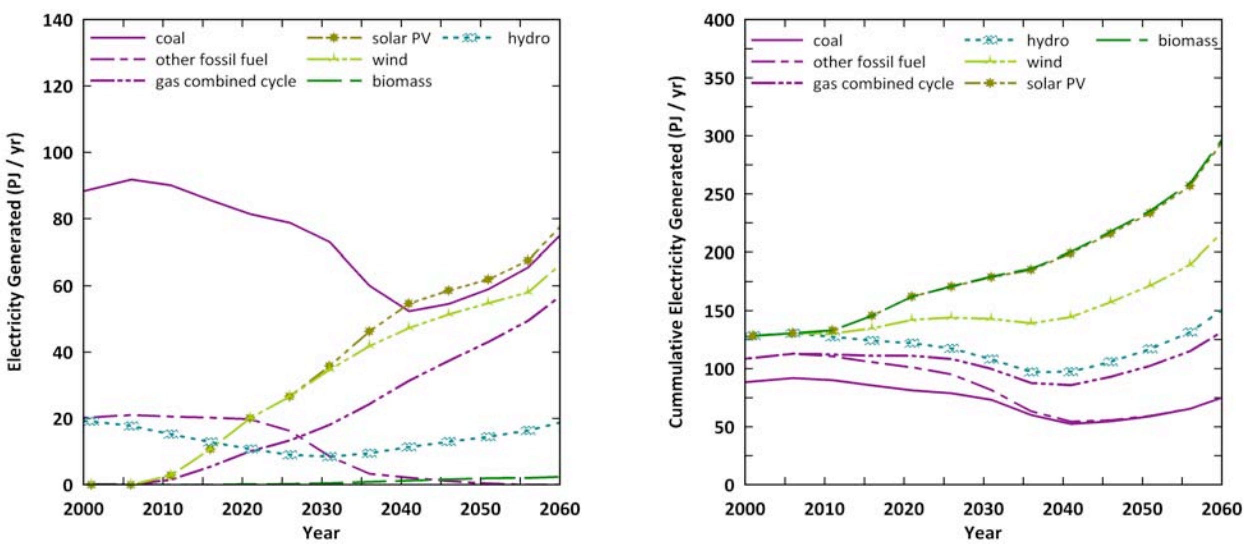


Figure 3-7: Victorian Electricity Production (*Adjustment*)

a) By source b) By source – cumulative



3.3.3.3 Transport

For *Adjustment*, the focus is on efficiency and fuel substitution – getting more transport from less fuel. Passenger and freight demand and distances increase in line with population and GDP growth,[13] reflecting global supply chains and increasing passenger and freight transport distances as urban areas expand.

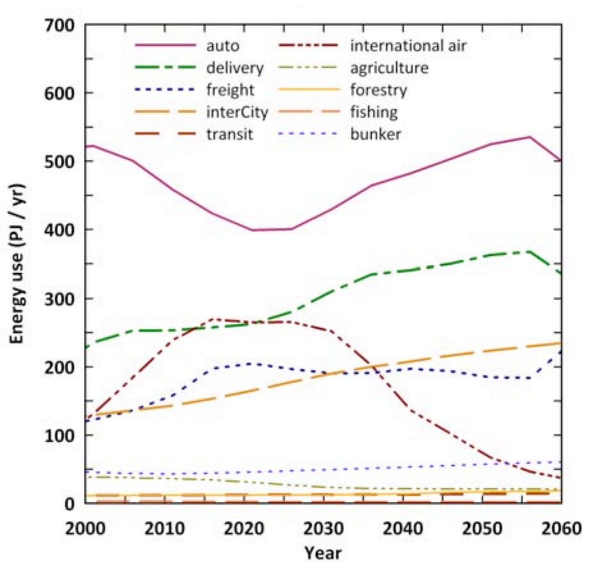
[13] For example: "By 2025, the number of kilometres travelled by road freight vehicles is expected to increase by 70 per cent, with 60 per cent more vehicles on roads" [DOT 2008].

As global demand for oil continues to grow from 2010, investment in new liquid fuel sources followed. Increasing use of biomass and biofuel are supplemented by compressed natural-gas and increasing coal-to-liquids and coal-to-gas.[14]

Infrastructure to support use of changed fuel types is dependent on private investment and therefore only occurs within large vertically-integrated supply chains, or where the value can be fully captured by the investor. This scenario assumes that this leads to diverse but piecemeal changes, with the absence of integrated infrastructure development meaning that the focus is on finding substitute liquid fuels, including 1st generation biofuels from grains and oil crops. Concern that the production of crops for biofuels should not compete with food crops, was outweighed by a strong price signal which drove an increasing use of cereal, oil and sugar crops for biofuels (1% per annum increase in proportion of crop used for fuel).

The food distribution transport task is adjusted in relation to the changing production of food i.e. the total freight tonne and tonne-kilometre tasks are scaled according to how much is produced. There is no change to the relative distances travelled per T of food or other commodity. The activities therefore reflect movement to ports and within Australia, but no major changes to the way food is moved within and around Australia.

Figure 3-8: Transport Fuel Combustion (*Adjustment*)[15]



Key transport variables in *Adjustment* are:

- Significant gains in the fuel efficiency of all vehicles match the energy efficiency achieved across the economy (40% improvement by 2040);
- There is some shift to electric vehicles (15% of new passenger vehicles from 2011);
- Increased use of compressed gas for heavier freight vehicles (especially long freight), as well as within passenger transport (approx. 10% of hydrocarbon fuel use); and
- Some use of cereal, oil and sugar crops for fuel (increase of 1% of production per annum).

Figure 3-8 shows the effect of these changes on Australian transport fuel consumption, with significant reduction in passenger vehicles (auto) to 2025, as a result of efficiencies and mode change. This is outpaced by increasing population and vehicle use beyond 2025. Freight transport fuel use stabilises, again as a result of efficiencies but also as it scales according to production levels (including agricultural production). (*Delivery* relates to freight in urban areas.)

[14] The resolution of oil dependency through increased use of Coal-to-Liquid or Coal-to-Gas technologies has been 'allowed for' in the *Adjustment* scenario, but it has not been quantitatively modelled. Therefore the oil dependency of this scenario would be reduced but the greenhouse emissions are likely to be significantly underestimated. See discussion in Section 4.2.

[15] Includes oil, gas and biofuels.

3.3.3.4 Agricultural Production

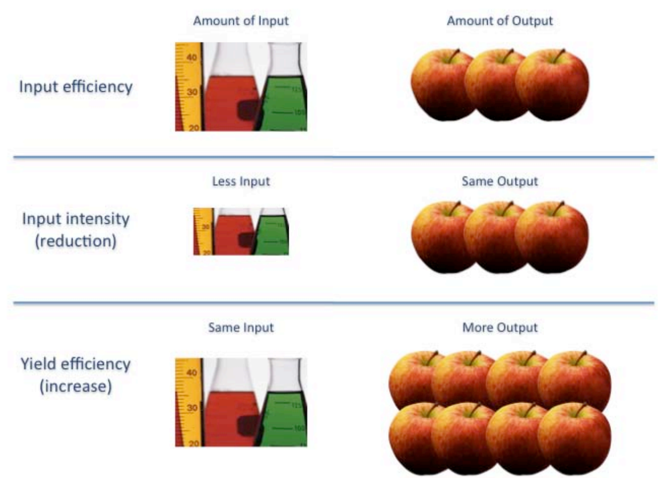
!	*It is assumed that high levels of energy-efficiency improvement can be achieved in parallel with these water and fertiliser efficiencies. This may not be the case (see discussion at 4.1.3).*

Changes in agricultural production are represented through changes to land and water availability / use and assumed increases in input efficiency. In *Adjustment* agriculture decreases in line with availability of traditional water sources.

Farming in the northern irrigation district continues for some, but relies on heavy capital investment and the ability to spread risk – only very big operations can succeed. Adaptation in agriculture is focused on technical efficiency to maximise yield from available resources, primarily within established agricultural activities [Howden et al. 2009]. This approach maximises profit for boom years to sustain operations when little can be produced.

Energy efficiency is considered at the same rate as overall economy (40% improvement). Agricultural efficiency is further enhanced through increasing *yield efficiency* of water and fertiliser (see Figure 3-9). These reflect steady improvements from capital investment, technology improvement, and the removal of uncompetitive operations.

Figure 3-9: Input Efficiency Variables



3.3.3.4.1 Water Availability and Use

Annual variation in water allocations is not reflected in the model, but sporadic and less reliable allocations are assumed to lead to an overall reduction in irrigated production. However, when water is available, it is assumed that high water efficiency and advances in crop yields lead to high production.

Reliable irrigation water availability has reduced significantly, reducing the proportion of productive land irrigated by 40%. At the Victorian level, this is consistent with Murray Darling Basin Authority median climate change projections for water availability from the Victorian proportions of the Murray Darling basin, under a median climate change scenario, by 2030 [CSIRO 2008].

Water, as with land, moves to high value uses such as urban development. Improvements in irrigation efficiency lead to higher yields and more diversion to urban use rather than increased river flows. The following settings reflect water management and use in the Adjustment scenario:

- Increasing irrigation yield efficiency (0.5% per annum) and 0.5% per annum improvement in water use intensity (see Figure 3-9);
- Little water recycling except for where private interests have both a source and a demand (no additional public infrastructure);
- Dryland, assumption of productivity increase in grain yields is balanced with losses to increasing temperature etc., so there is no change [Howden and Crimp 2005].

3.3.3.4.2 Fertiliser

As the driving force of *Adjustment* is maximising yields per input, rather than a reducing in inputs per se, a significant reduction in fertiliser application is assumed to be unlikely – fertiliser application levels remain high to maximise output when conditions are good. So, *Adjustment* sees a small (0.2% per annum) decrease in intensity of fertiliser application (amount used in the field) assuming that increased use of precision agriculture translates to reduced waste and improved use efficiency (more effective application, less run-off etc.). Increasing prices (a result of global demand for fertilisers) also drives this reduction in intensity.

Pressure to maximise yields for competitive terms of trade drives innovation and enables a high (1% per annum) increase in yields per unit of fertiliser applied. This yield increase is applied consistently across all crop production (e.g. horticulture, pasture, grains).

3.3.3.5 Greenhouse Gas Emissions

The settings outlined in previous sections are the main drivers of changing greenhouse gas emissions in the *Adjustment* scenario. The most significant of these are:

- Energy efficiency, energy production and transport fuels; and
- Increased use of forestry for bio-energy and carbon sequestration, with land for forestry taken from previously agricultural land.

Figure 3-10 shows the cumulative greenhouse emissions from all sectors (for national and Victorian emissions), demonstrating that these settings are able to reduce emissions significantly (around 30% nationally and 15% in Victoria on 2000 levels) by 2030.[16] On 1990 levels, this is 42% (national) and 24% (Victoria) by 2030.

Figure 3-10: Greenhouse Gas Emissions (*Adjustment*)
Cumulative Sector Contribution (CO2-e)

a) Victoria b) National

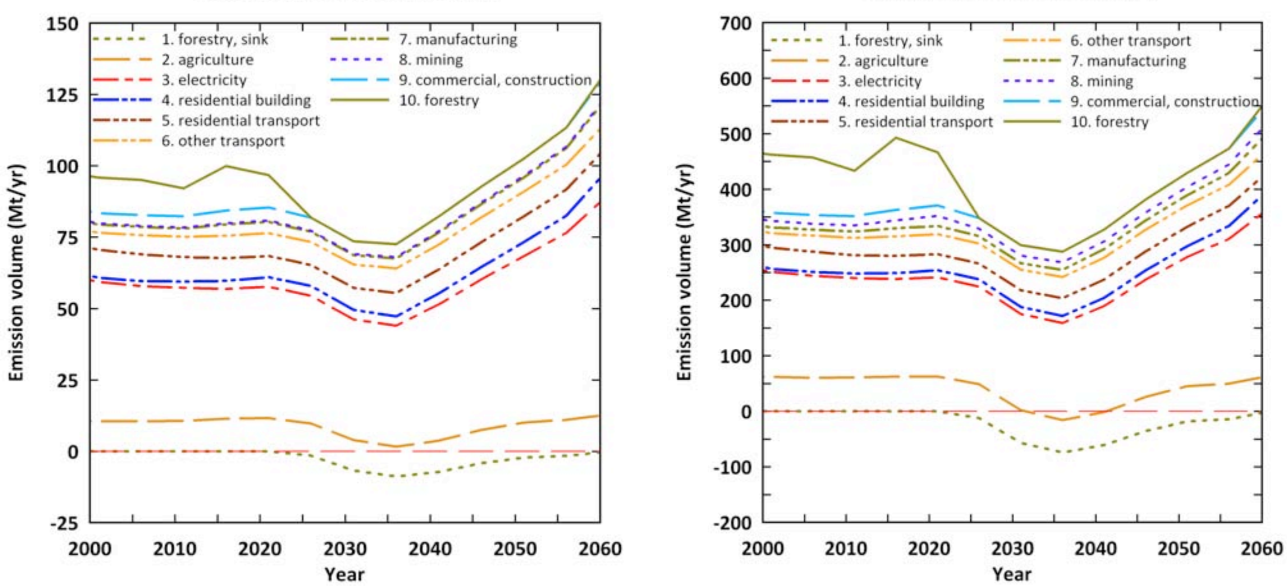


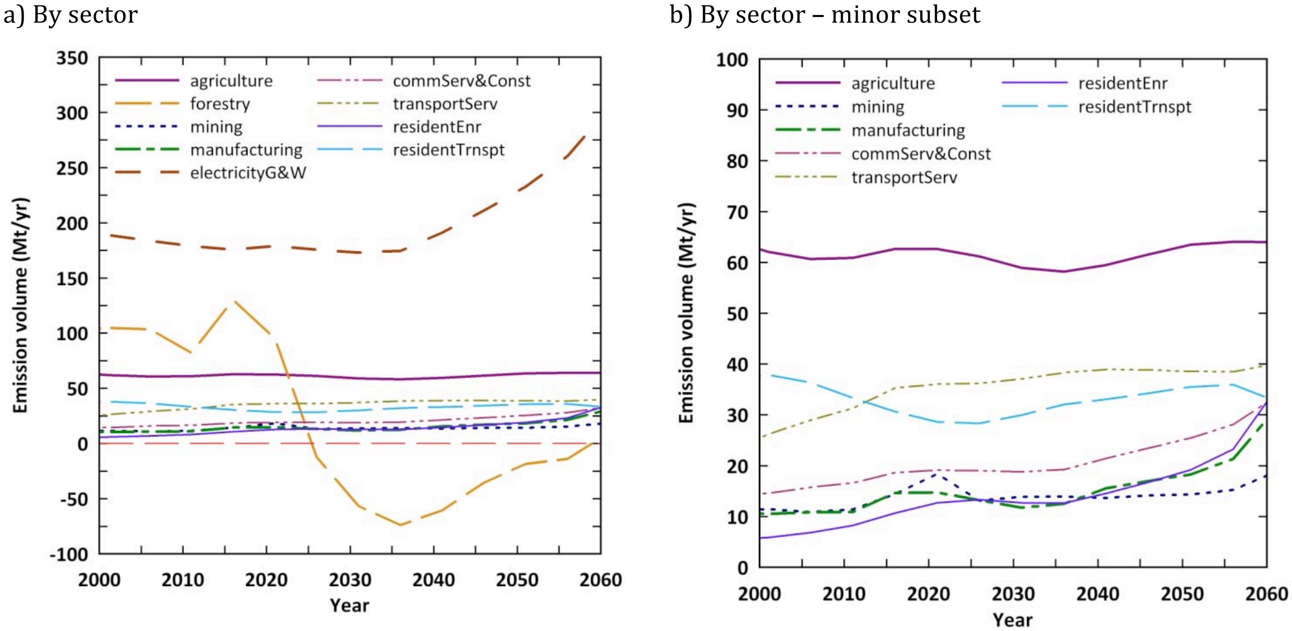
Figure 3-11 shows that most of the change in emissions is due to stabilisation of emissions from electricity, gas and water (to 2035) and increased sequestration of carbon in forests from 2020.

However, Figure 3-10 also shows that these settings are unable to sustain domestic emissions reductions out to 2060. This is primarily because an increasing contribution from carbon sequestration

[16] The differences in Victorian and Australian emissions reductions could be due to a large number of factors e.g. limits to amount of Victorian land able to be transferred to forests; proportion of electricity generated by brown and black coal; proportion of livestock / cropping and therefore relative differences in how settings are applied to these. Time and resource limitations prevented detailed examination of what is driving this difference.

in forests cannot be sustained indefinitely. Similarly, efficiency improvements and reduced emissions intensity from coal-fired power stations from 2025 (simulating the effect of successful carbon capture and storage) are outpaced by growing demand beyond 2035.

Figure 3-11: Australian Greenhouse Gas Emissions (*Adjustment*)



3.3.3.6 <u>Food Availability</u>

3.3.3.6.1 Food Required

Adjustment is allocated the highest levels of waste / redundancy of the three scenarios (50% of what is produced), based on the following assumptions:

- Focus on high-value product (including high aesthetic standards etc.) leads to a tolerance of wasted product – similar or greater to waste levels in 2010;
- Focus on high-yield crops and livestock, often produced in extensive, monoculture production reduces genetic diversity and increases vulnerability to significant pest / disease losses [Zhu et al. 2000];
- Globally integrated supply chains increase the risk of losses along supply chains and the extent of losses through biosecurity or food safety failure; and
- Concentrated areas of intensive production can be highly exposed to losses when extreme events occur.

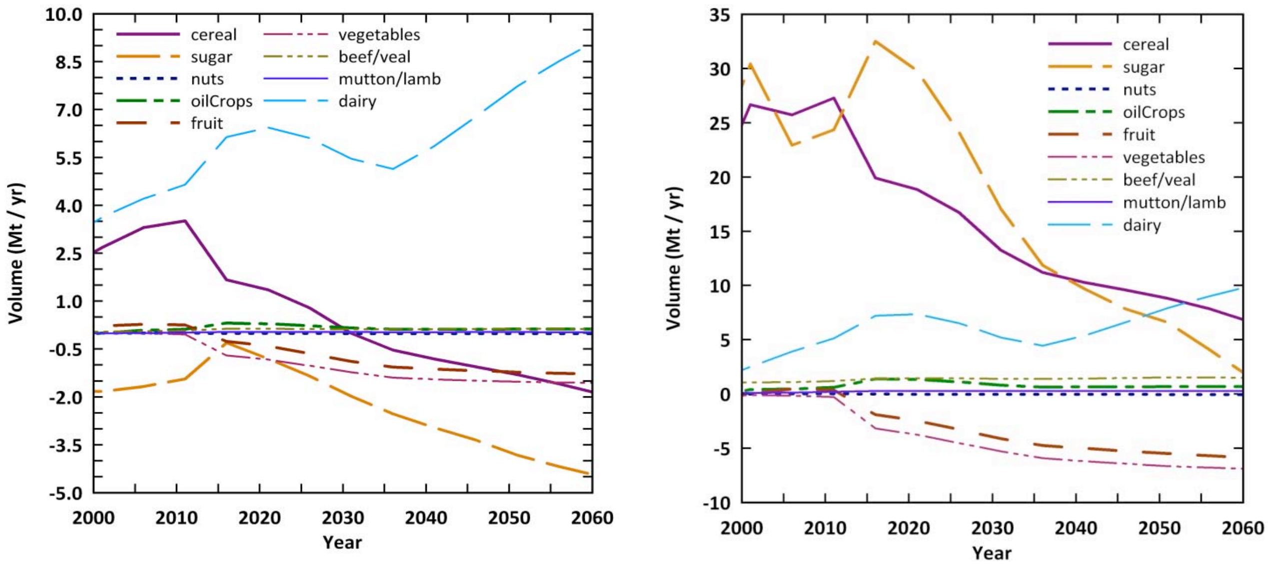
3.3.3.6.2 Food Available

In *Adjustment*, there is no need or attempt to prioritise land or resources for food production per se. Production is focused on the highest rate of return – so even where food is produced it is likely to be exported to high value markets rather than necessarily consumed by the Australian population. Food is imported as required from wherever in the world it can be produced at lowest cost.

Figure 3-12 shows which foods have sufficient production to meet requirements at a Victorian and national level, under these conditions. It also shows which foods would be imported (either from elsewhere in Australia when there is a Victorian deficit, or internationally where there is an Australian deficit).

Figure 3-12: Net Food (*Adjustment*)[17]

a) Victoria b) National



A significant requirement for imported fruit and vegetables is already evident at both a Victorian and National level in 2010. This deficit increases significantly over the time periods to 2030 and 2060.

Dairy, cereals and sugar continue to show significant national surplus to 2030, well above the levels required to feed the population even with substantial allowance for waste and losses to extreme events. However, by 2040 / 2050 these surpluses are rapidly decreasing. Nuts, oils and meat have sufficient (but not large) surpluses to meet requirements.

Victoria moves from a net cereal producer to a net cereal consumer around 2030 (or by 2040 if there is no use of cereals for fuel). By 2030, Victoria is just sufficient in cereals and importing all other foods except dairy products.

3.3.4 Time to Take Control

In the Time to Take Control scenario (*Control*), the National Government takes strong and early action to ensure that basic food and energy security requirements for the country can be met. The driving forces for this scenario are:

- Land and resource allocation is carefully managed through both regulatory and market instruments to ensure provision of core foods, energy, sequestration and ecosystem services;
- Rapid emissions reduction – aiming for 60% on 1990 levels by 2030 and 90% by 2060. This entails a focused effort, commencing in 2010, to transform critical infrastructure systems and enable direct emissions reduction within Australia; and
- Significant public investment in R&D and infrastructure.

3.3.4.1 <u>Land Use</u>

<u>Diversion to forests</u>: *Control* sees a 20% loss of land from food production by 2030, which is allocated to forestry (half for bio-energy and half for plantation forestry for carbon sequestration).

[17] Detailed graphs of surpluses and deficits are included in Appendix 4.

Urban development: Firm planning controls prevent urban expansion over agriculturally productive land – this is effectively frozen from 2011, with particularly strong measures around major population centres (capital cities). The increasing population is accommodated through increased densities within existing urban areas (more high-rise and high density land use and construction). Regional populations also increase, without loss of productive land, also through increased density in regional centres.[18]

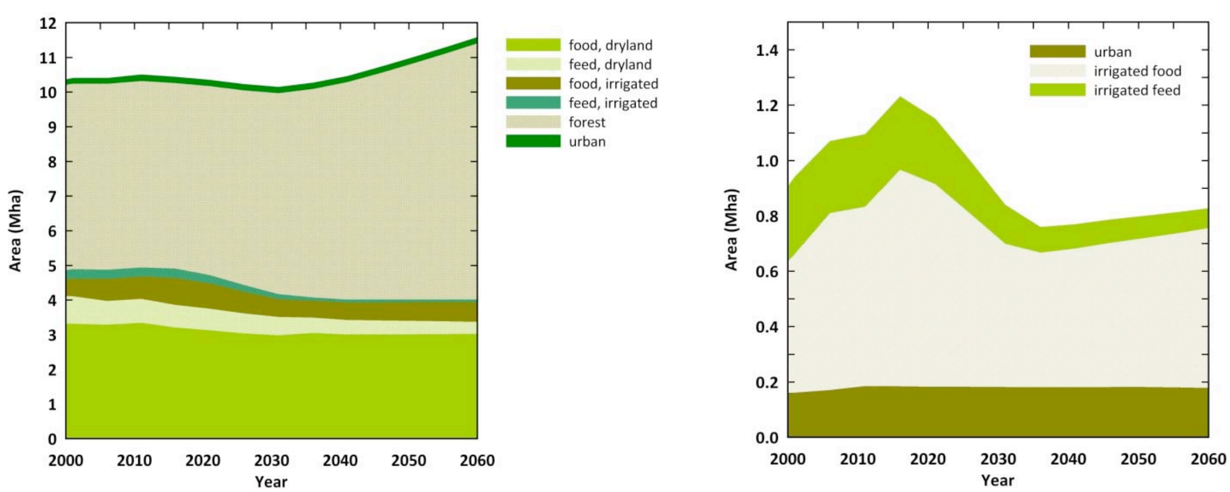
Irrigated land area: As irrigation allocations become smaller and less reliable, land that has formerly been considered irrigated is increasingly used for dry-land production, to take advantage of water when and where it is available. There is a greater and more rapid reduction of irrigated land share in *Control* because the government intervenes to re-establish environmental flows in river systems and secure a margin for river health in advance of expected climate change impacts and reduced water availability. The proportion of agricultural land irrigated is reduced in *Control* by 60% by 2030.

Figure 3-13 shows how these changes affect the proportions of Victorian land use. Total area diverted to forest is the same as in *Adjustment* (but with a larger proportion allocated to sequestration). The reallocations of land by food type also see a reduced requirement for feed production. This, combined with the halt on urban expansion, enables maintenance of a larger total area of irrigated food producing land in 2030, despite the greater loss of irrigated proportion area.

Figure 3-13: Victorian Land Use (*Control*)

a) Majority land use

b) Urban and irrigated only



3.3.4.2 Electricity Demand and Production

While the motivation is different (government regulation and mandatory standards), the energy efficiency achieved across the economy is the same as in *Adjustment* – 40% reduction in energy used per unit of economic activity to 2036. Figure 3-14 shows that this effectively stabilises electricity demand in major sectors (buildings, heavy industry & power, and other) to 2030. However, *Control* has the substantial shift from petrol-powered passenger vehicles to electric vehicles (see also 3.3.4.3), which results in passenger cars using more electricity than buildings by 2030.

In pursuit of ambitious greenhouse emissions reduction goals, *Control* has substantial and rapid change in the electricity production (and transport) systems. These include:

- New power generation from 2011 is gas and renewable generation only. The introduction of existing and available renewable and gas technologies is accelerated by a staged program of closure for coal-fired power, completed by around 2050.

[18] ASFF V3 does not have code to handle regional urban centres, so just sees the population as being in 'capital cities' or 'regional'.

- Government investment in transmission and distribution infrastructure means that this energy transformation is supporting the revitalisation of regional communities, as solar, wind and bioenergy facilities are built around the country.

Figure 3-14: Victorian Electricity Demand / Use (*Control*)

a) Major Sectors

b) Minor Sectors

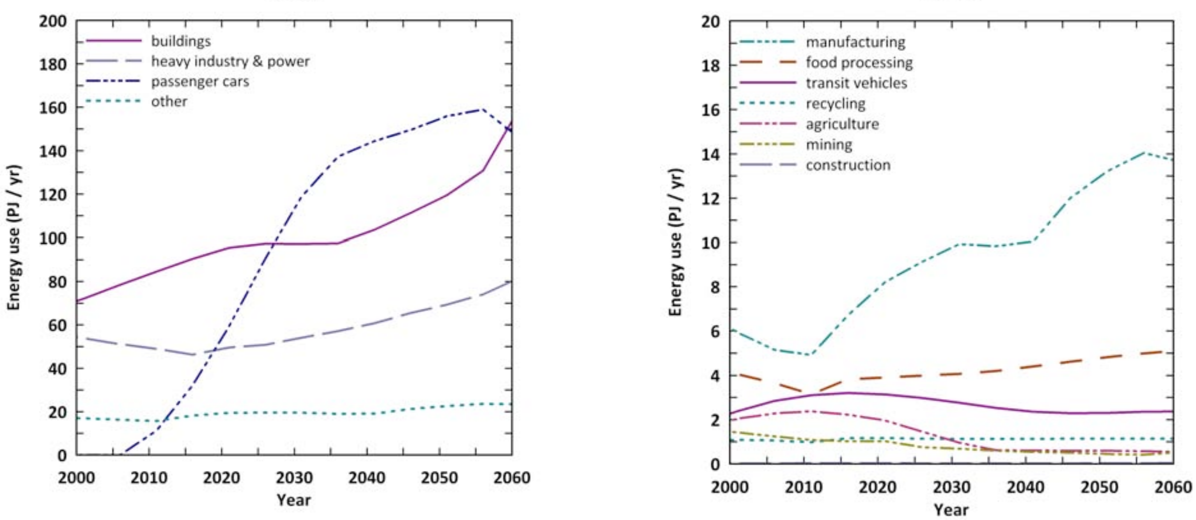


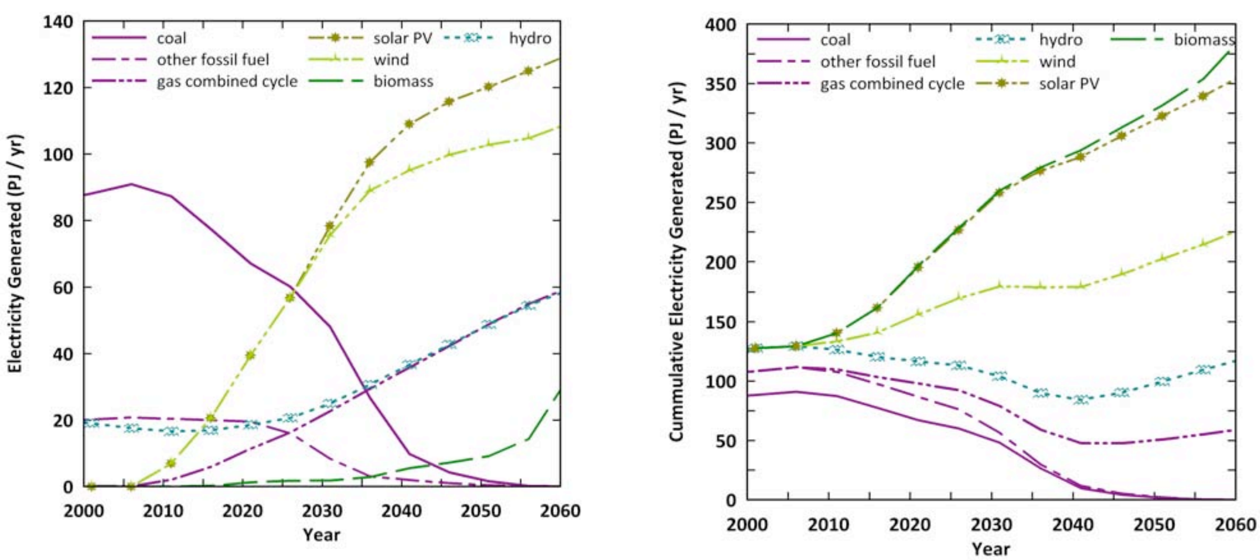
Figure 3-15 shows that by 2030, around 65% of Victoria's energy is produced from renewable power and 8% from gas. By 2060, it is 84% and 16%. These proportions are reflected in Australia's electricity production.[19] Total energy demand is much larger in *Control* than in *Adjustment*, largely due to demand from electric vehicles.

The movement of agricultural land into production of woody biomass for bioenergy (and sequestration) means an increasing contribution to total energy, remaining small in 2030 but becoming noticeable by 2060.

Figure 3-15: Victorian Electricity Production (*Control*)

a) By source

b) By source – cumulative

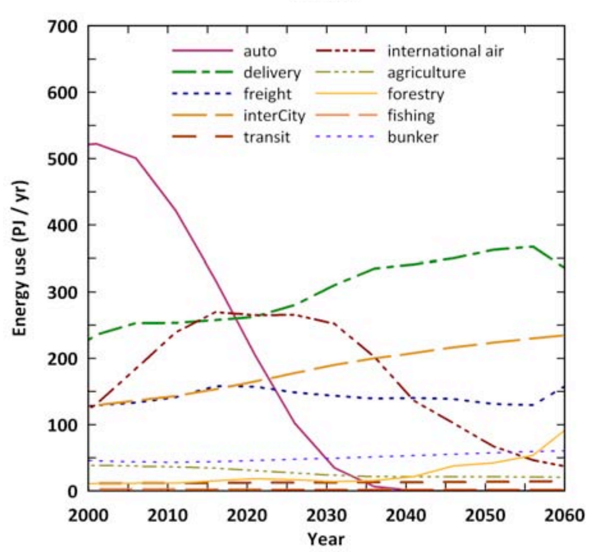


[19] NB. Equivalent Australian graphs in Appendix 3.

3.3.4.3 Transport

Control sees the Government drive fuel and technology substitution to retain high but stabilised levels of domestic mobility while drastically reducing greenhouse gas emissions. High fuel efficiency standards; a rapid, early transition to use of electric vehicles; and a program of infrastructure development; enables reliance on imported oil as a transport fuel to be significantly reduced. The rapid emissions reduction goals (with a high carbon price) mean that use of coal-to-liquids and coal-to-gas technologies to replace oil is not commercially competitive.

Figure 3-16: Transport Fuel Combustion (*Control*)



Key transport variables in *Control* are:

- Replacement of passenger vehicle stock – all new cars are electric from 2011 (electricity demand from these vehicles is shown on Figure 3-16);
- 90% of the freight task is moved to rail;
- Gas is substituted for remaining liquid hydrocarbon in transport fuels (remaining road freight task);
- Negligible use of cereal, oil or sugar for biofuels.

The food distribution transport task is scaled in relation to the changing production of food and other commodities. The main changes to the way food is moved within Australia are the change in fuel mix and mode described above.

For food (as with other commodities), the most significant factor of this shift would be the move of most freight to rail rather than road. However the total fuel used for intercity transport is still increasing, as would be expected for a largely domestic focused food and transport system.

3.3.4.4 Agricultural Production

As in *Adjustment*, irrigated agriculture decreases in line with availability and reliability of traditional water sources. Significant government investment in R&D combines with a concentrated focus on areas with highly productive soils to enable efficiency improvements in both water and fertiliser use. These efficiencies are driven by a desire to produce sufficient amounts of food (and other products), but also with intent to reduce reliance on critical (and unpredictable) resources. Adaptation for resilience in agriculture includes both efficiencies and some diversification of products (varieties), but remains primarily about intensive systems that can produce a reasonable amount of food while reducing water and fertiliser inputs.

Energy efficiency is considered at the same rate as overall economy (40% improvement, as per *Adjustment*). Agricultural efficiency is enhanced through reduced *intensity* in water and fertiliser use (explained in Figure 3-9).

3.3.4.4.1 Water Availability and Use

Water, as with land, is managed to balance the requirements of the population and environment. Reduction in water availability is combined with government interventions to secure environmental flows even in the driest years, leading to a reduction in proportion of land irrigated of 60% by 2035. Even this reduction is less than that projected by the high climate change projections for reduced water availability from the Victorian proportions of the Murray Darling basin, by 2030 [CSIRO 2008].

The following settings reflect water management and use in the *Control* scenario:

- When water is available, it is assumed that high water efficiency and opportunistic dry-land production (including improved soil management to hold and use rainfall) enables high production levels.
- Medium levels of water efficiency in agriculture, supported by public R&D and infrastructure investment and mandated practice change. However, increased government protection of markets also reduces private innovation incentives in this scenario, so this rate is lower than in Adjustment and DIY. There is an increase of 0.5% per annum – achieved through reduced intensity of water application;
- There would be investment in water recycling including public infrastructure for both irrigation and industrial / household use. However, the additional production enabled by this additional water, or the associated energy requirements have not been included at this time (see Section 4.1.3); and
- As with *Adjustment*, there is an assumption that productivity increase in dry-land yields is balanced with losses to increasing temperature etc. However, as there is some move to well-adapted products / crops, these losses are reduced. This is handled through a reduction in waste / losses (Section 3.3.4.6.1) rather than a change in dry-land productivity.

3.3.4.4.2 Fertiliser

In *Control*, the government is operating with a coordinated agenda to plan for reliable domestic food surplus, as well as to improve environmental health (e.g. water quality). To reduce fertiliser runoff into waterways, reduce greenhouse emissions and, in recognition of potential future nutrient scarcity, there are tight (some say draconian) restrictions on how fertiliser may be applied, and heavy penalties for wasteful use. These motivations drive both Government and private investment in R&D and innovation to improve efficiency.

Control sees a 0.5% per annum decrease in the intensity of fertiliser application (amount put on the field) as well as a 0.5% per annum increase in yield efficiency from that which is used. This yield increase is applied consistently across all crop production (e.g. horticulture, pasture, grains).

3.3.4.5 Greenhouse Gas Emissions

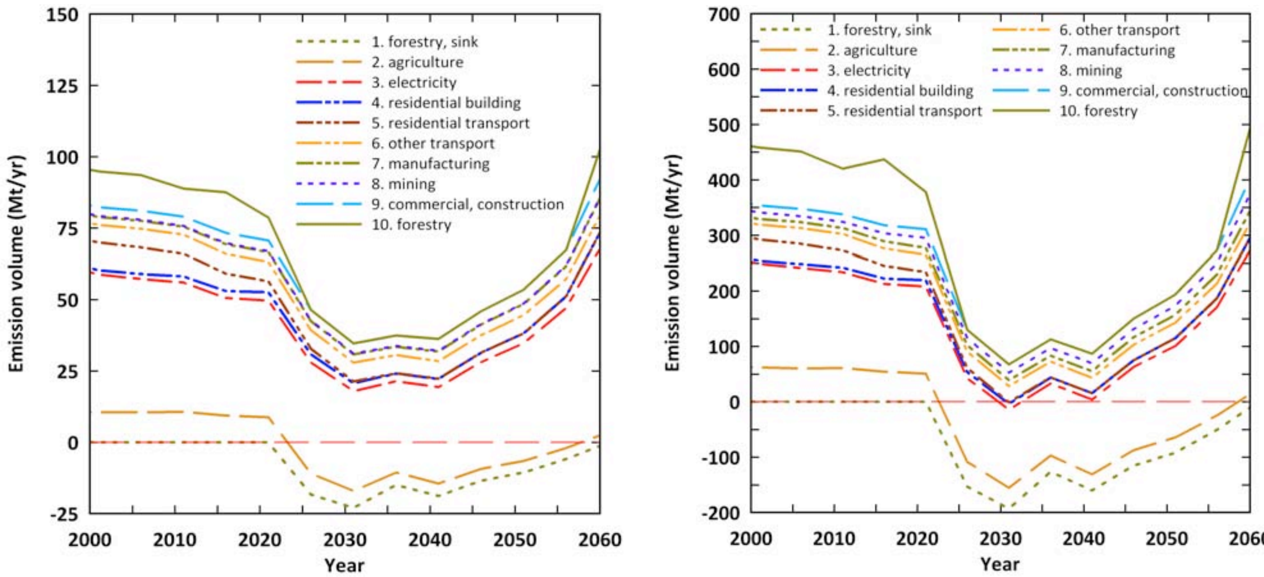
The settings outlined in previous sections are the main drivers of changing greenhouse gas emissions in the *Control* scenario. The most significant of these are:

- Energy efficiency and changes to electricity production;
- Significant changes to transport infrastructure;
- Increased use of forestry for carbon sequestration, taken from previously agricultural land (10% of productive land by 2030);
- Changes to agricultural emissions through changes to fertiliser use and proportion of grazing to other uses.

Figure 3-17 shows the cumulative greenhouse emissions from all sectors (for national and Victorian emissions), demonstrating that these settings are able to reduce emissions from 2000 levels by over 90% (national) and over 60% (Victorian) by 2030. On 1990 levels, these are 86% (national) and 62% (Victoria).

Figure 3-17: Greenhouse Gas Emissions (*Control*)
Cumulative Sector Contribution (CO2-e)

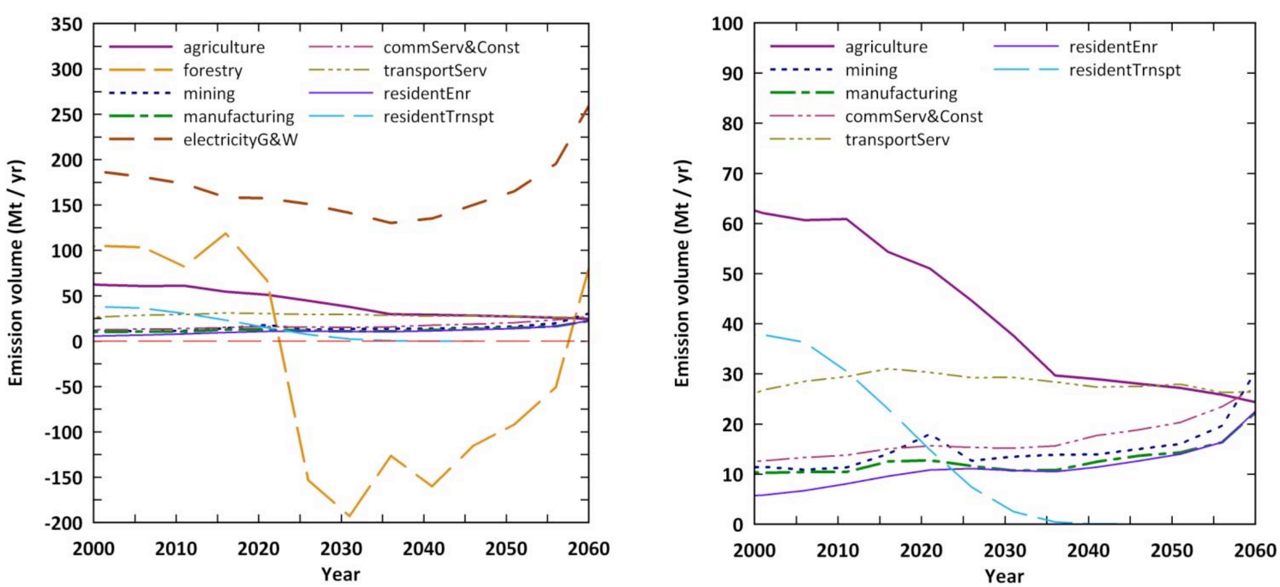
a) Victoria b) National



The reduction in emissions between 2010 and 2030 is achieved through significant reductions in electricity, gas and water; agriculture; passenger transport; and increased sequestration in forests, as initial rapid planting occurs to take up opportunities in this area (Figure 3-18).

Figure 3-18: Australian Greenhouse Gas Emissions (Control)

a) By sector b) By sector – minor subset



However, as shown in both Figures 3-17 and 3-18, the settings in this scenario do not maintain these emissions reductions out to 2060. The extent of offset from forestry slows as land availability reduces and the emissions from forestry then begin to climb, becoming a net emissions source again around 2055.

Emissions from electricity, gas and water also start to increase again from around 2036, as efficiencies and technology change are outpaced by: increasing demand from electric vehicles; and continued use of gas for electricity generation.

By 2060, *Control* has only reduced emissions by 8% nationally and Victorian emissions have increased 2% (on 1990 levels).

3.3.4.6 Food Availability

3.3.4.6.1 Food Required

Control is assumed to have less wasted food than *Adjustment*, as Government intervenes in the market to prevent unnecessary food waste. However, despite public investment in R&D in relation to pest resistance and management and developing new drought / heat / frost resistant varieties, there are still significant losses to the unpredictable climate and changing pest and disease vectors. An additional amount of production, equivalent to 0.8 times the nutritional requirement, is included to account for on-going waste and significant losses.

The main factors assumed to influence waste levels in the *Control* scenario are:

Reduction

- Strictly enforced regulations in relation to waste throughout food supply chain (including purchase specifications etc.);
- Reduced global movement of food product reduces losses along supply chains and biosecurity risks; and
- Maintained peri-urban production of perishables (and increase in protected cropping) reduces both supply chain and production losses.

Increase

- Focus on high-yield crops and livestock, often produced in extensive, monoculture production reduces genetic diversity and significant pest / disease losses;
- Producers are not fully exposed to price signals, reducing private incentives to drive efficiencies and reduce waste;
- Reduced ease of export leads to waste of surplus; and
- Concentrated areas of intensive production increase likelihood of losses to extreme events.

3.3.4.6.2 Food Available

In *Control*, national allocation and use of land and resources is carefully managed to ensure food and energy security from domestic supplies. This results in net food surpluses and deficits as shown in Figure 3-19.

There is minimal diversion of foods to biofuel in *Control* as most vehicles run on electricity or gas. This means that there is no sharp reduction in availability of cereals, oils and sugar but the surpluses are still in steady decline.

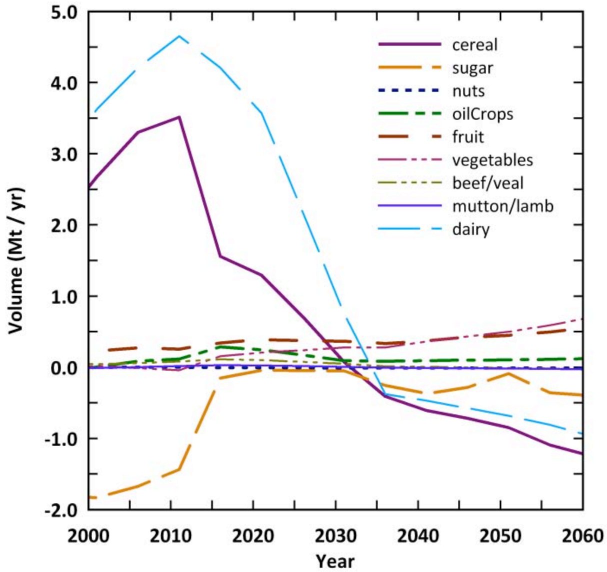
Control sees a sufficient national production of all core food groups, with the exception of milk. This occurs because land was removed from grazing to make up fruit and vegetable production, and with time this overshoots so that there is that not enough dairy production capacity. Further iterations of the modelling would be required to rebalance this land allocation, but for the purposes of this analysis this is left as ‘unresolved’. While there is less lamb / sheep meat produced nationally than required, this is part of the ‘meat group’ which still maintains a surplus.

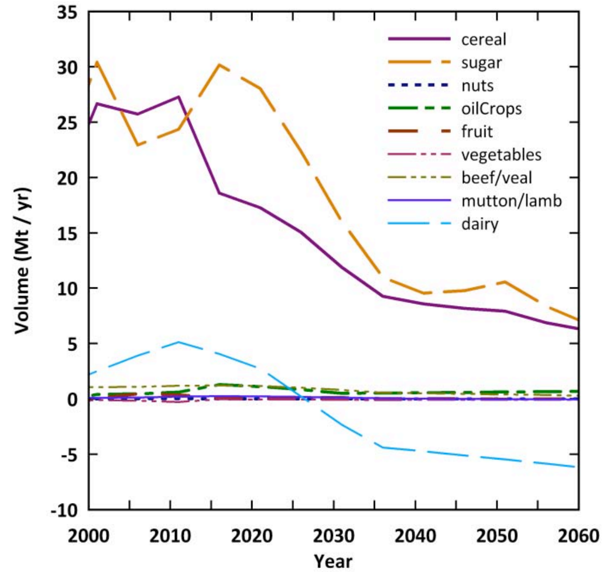
All other food groups show an overall surplus at a National level. These surpluses are not as large as in *Adjustment* as land has been reallocated to produce fruit and vegetables. However, given the still sizeable ‘waste / loss’ factor built into this scenario, availability of the basic nutritional requirements of the population is likely to be maintained.

As in *Adjustment*, Victoria moves from a net cereal producer to a net cereal consumer around 2030. Victoria sees an increasing surplus of fruit and vegetables that would be provided to the rest of Australia. Victoria is also importing dairy from shortly after 2030, due to the reallocation of land for fruit and vegetable production.

Figure 3-19: Net Food (*Control*)

a) Victoria b) National





3.3.5 DIY

In *DIY*, a strong cultural shift has occurred. Communities and regions are leading action on climate change, energy and food security from the bottom-up, with limited intervention or support from government above the local level. The driving forces for this scenario are:

- Pursuit of local / regional self-sufficiency – food and energy requirements met within the state (or more locally) where possible;
- Creativity, experimentation and 'open innovation' developing diverse and locally adapted solutions;
- Limited infrastructure development except for ICT – however there is adaptation and new uses of existing infrastructure; and
- Rapid emissions reduction – aiming for 60% reduction by 2030 and 90% by 2060, through widespread localised action and system change.

3.3.5.1 Land Use

Diversion to forests: *DIY* has a loss of 15% of land from food production, which is allocated to forestry for sequestration (i.e. this changed land use is not allocated to bio-energy). For *DIY*, increase in forestry for sequestration is complemented by a more diverse *climate-greening* movement, which sees dispersed sequestration in smaller patches throughout landscapes rather than in large swathes. This includes re-vegetation of marginal land that has been retired from production. This has a progressively positive result that eventually declines as land availability decreases.

Urban development: The emphasis (and need) to reduce energy and fuel use makes living in outer urban areas with long daily travel distances very difficult. A migration of people to higher density living (reducing transport distances) shrinks urban boundaries and 'clumps' urban development. Peri-urban residential development effectively contracts as people move closer to transport centres – in both capital cities and regional centres. This increased density is enabled by:

- More people in existing building stock and increased renovation and adaptation of urban space for higher densities;
- Increase in co-housing and new models for sharing living and working spaces enable a 25% reduction[20] in 'household formation rate' per population; and
- Increased population share in regional areas (growth of 'rural urbanism' in regional cities) – increase in share of population outside of capital cities at 0.5% per annum.

There is an increase in food production (particularly perishable foods) in urban and peri-urban areas, as more land previously assigned to urban uses shifts to agricultural production. An increase of 1% per annum in agricultural land (taken from urban) reflects increasing food production in urban areas.

The broad engagement in emissions reduction also sees a greatly increased use of timber for building, as this is perceived as a way to sequester carbon in the short-term (80% of clay/ building products – bricks and tiles – are replaced by timber products by 2020 largely for carbon sequestration purposes).

Figure 3-20: Victorian Land Use (*DIY*)

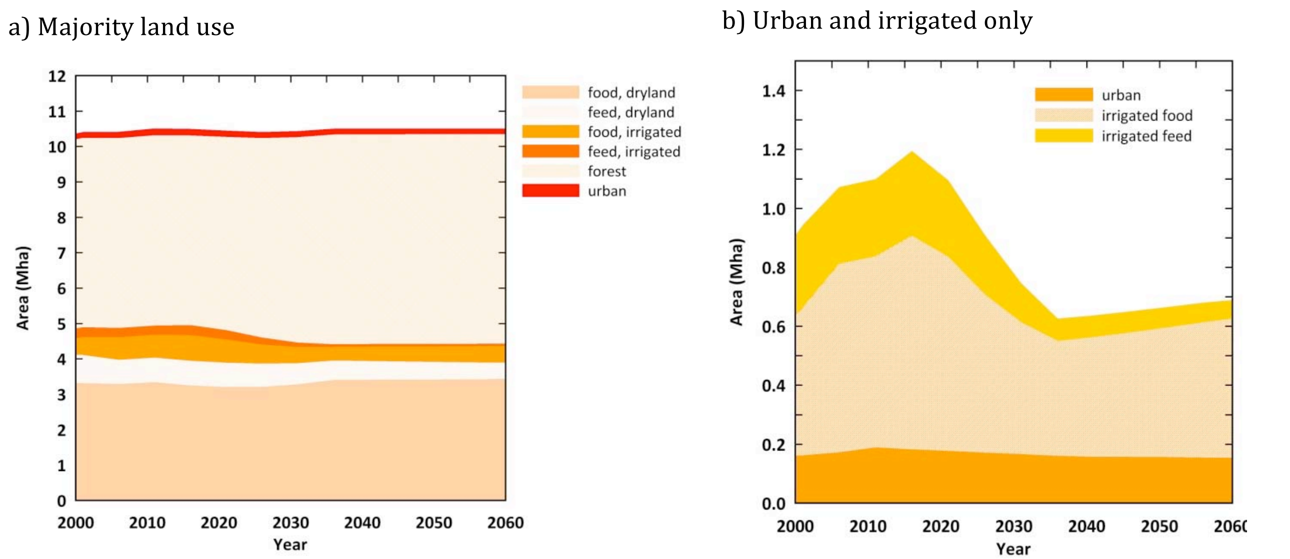


Figure 3-20 shows how these changes affect the proportions of Victorian land use. Compared to the other scenarios, total land-use is more stable over the time period. The halt to urban expansion (a slight retraction) partially counters the loss of irrigated to dry-land production. There is a significant reduction in irrigated feed.

Irrigated land area: As in the other scenarios there is a shift in the proportion of productive land that is irrigated, most marked in *DIY* (75% reduction by 2030), reflecting a significant shift away from reliance on regular irrigation towards dry-land agriculture. Diverse systems and enterprises balance the desire to maximise production when conditions are good, with the necessity of maintaining steady food production in unpredictable conditions. The reduced 'demand' for irrigation from the major systems also allows for greater capture and storage of water throughout landscapes and in soil, enabling land-holders and regions to manage water for 'drought-proofing' and water in river systems to be allocated to the most essential uses.

As it is increasingly difficult to access export markets (the costs and risks of long distance transport far outweigh lower labour or production costs elsewhere) and the cost of energy and fertiliser inputs to manage large monocultures is prohibitively high – the incentives for intensive production of single products are significantly reduced.

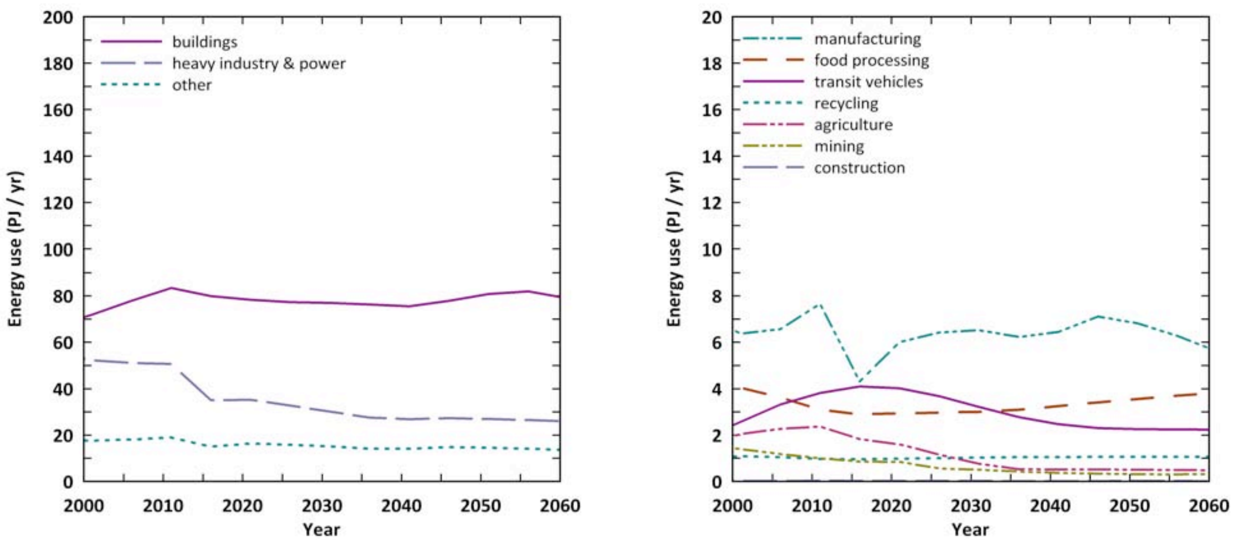
[20] Asymptote is set from 1981 to 2041

3.3.5.2 Electricity Demand and Production

Cost, necessity, system-redesign and social pressure drive energy efficiency across the economy, translating to a 50% reduction in energy intensity (energy use per unit of economic output). This is greater than in *Adjustment* and *Control* and is enabled through a much greater contribution of behaviour change. Reduced material consumption across the economy supports an additional (beyond efficiency) reduction in demand for energy (shown in Figure 3-21). This does not reflect a reduction in quality of life – services and re-generated, or up-cycled goods, reduce demand for newly manufactured consumer goods from virgin materials.

Figure 3-21: Victorian Electricity Demand / Use (*DIY*)

a) Major Sectors b) Minor Sectors



While there are fluctuations and movements within sectors, these levels of efficiency and demand reduction effectively balance population increase and stabilise electricity demand.

Coal-fired power stations close at the end of their working lives and are gone by 2055. There is an increased use of renewable power, particularly that generated at small-to-medium scale. While this is slowed by a lack of strong government support (except in many areas at the local level), the open-source culture and internet systems allow active knowledge transfer of 'alternative' technologies and designs for renewable generation.

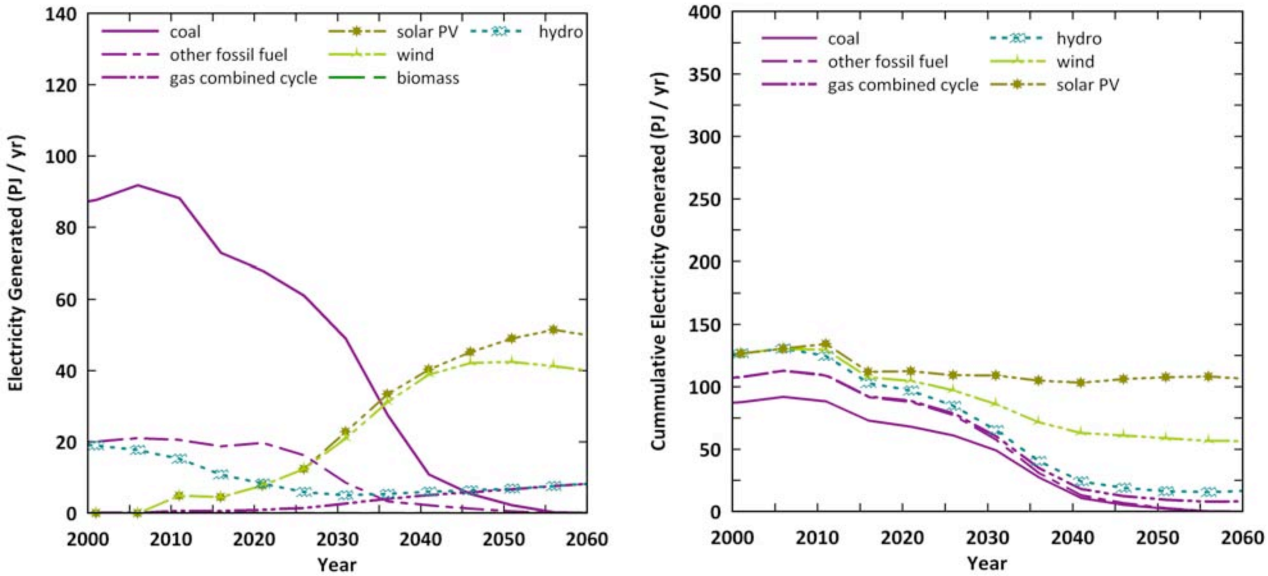
There is growth in businesses producing energy systems that combining local, national and international components (contributing to jobs in the sector). There remains a small but increasing proportion of electricity generation from gas (including biogas).

Figure 3-22 shows that by 2030, around 45% of Victoria's electricity is produced from renewable power and around 55% is still fossil fuels (coal and gas). By 2060, 90% is being generated from renewable sources. It is important to note that the total electricity requirement in *DIY* is much lower than in *Control* or *Adjustment*.

Figure 3-22: Victorian Electricity Production (*DIY*)

a) By source

b) By source – cumulative



3.3.5.3 Transport

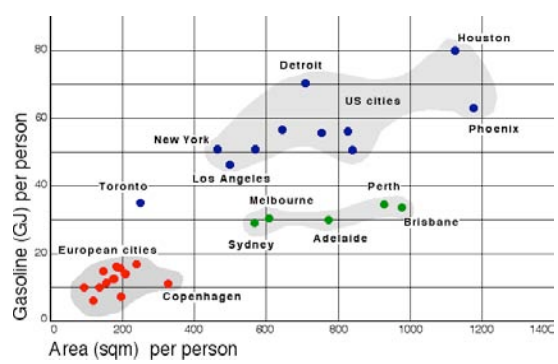
Transport is a sensitive issue in the community – innovation and systems change is focused on improving the efficiency and effectiveness of local (existing) transport systems as much as changing vehicles or fuels. Improvement is aimed firstly at reducing the average distance travelled to meet daily personal and freight needs; and secondly at using more efficient transport modes.

With only limited investment available for new infrastructure there is high utilisation of existing rail for long distance freight; there is some use of electric vehicles and increasing use of low consumption transport (small vehicles and motorised and human-powered bicycle systems). Interstate transport of food and agricultural products is reduced and there is only limited trading of food products on the international market.

Passenger transport demand (in kilometres) is reduced by 50% by 2040, through:

- Shorter transport distances in denser urban environments;
- More effective use of vehicles when used (car pooling and moving goods on passenger trips);
- Increased use of human-powered vehicles – walking, cycling etc.; leading to
- Overall reduction in energy used for private transport with increased population density (as illustrated in Figure 3-23).

Figure 3-23: Private Transport Energy Use Reduces with Density [Newman & Kenworthy 1989]



High levels of fuel efficiency are obtained through vehicle change and mode-shifting, as well as retrofitting and conversion of vehicles, and changes in driver behaviour (including travelling at lower speed limits, etc.).

Figure 3-24: Transport Fuel Combustion (*DIY*)

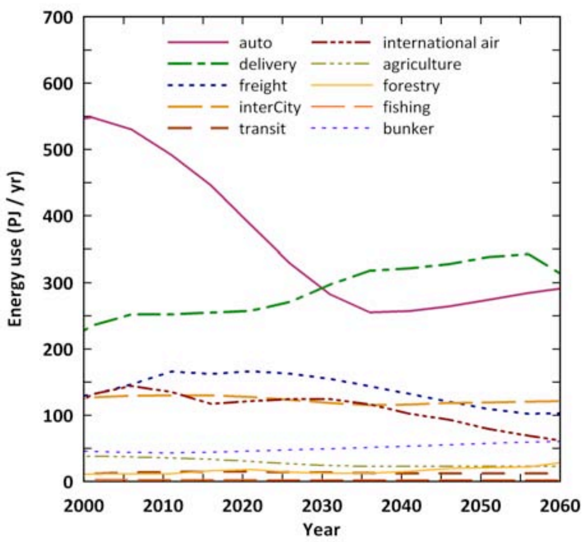


Figure 3-24 shows the effects of the key transport variables in *DIY*:

- High fuel efficiency (50% improvement);
- Reduced transport demand (passenger and freight);
- 50% of the freight task is moved to rail; and
- A large (10% per annum) increase in the proportion of crops (cereal grains, oils and sugar) used as biofuel.

As with the other two scenarios, the food distribution transport task is scaled in relation to the changing production of food and other commodities. However, in *DIY* there is also a significant drop in the level of *all* long distance freight, including food (modelled here by reducing interstate food transport to zero and leaving all other goods at background setting).

3.3.5.4 <u>Agricultural Production</u>

In *DIY*, ICT plays a critical role in linking up food producers around Victoria, Australia and the world to develop resilient farming methods that reliably produce food in the context of unpredictable conditions and vastly reduced access / exposure to export markets. In a much less mobile world, the movement of agricultural techniques and uptake of diverse crops is enabled by online and open-source databases of plants and growing techniques.[21] Productivity is about ecologically sound practices that are knowledge intensive – "They are not chemical intensive. They are not capital intensive. But they are knowledge intensive. You need the right information at the right time" [Swaminathan 2010].

Innovation focuses on maximising effective use of resources – where they are – for critical needs. There has been a shift in perception about what constitutes food security, and it's less about large surpluses and more about reducing waste, increasing diversity and seasonality of foodstuffs and making the best use of available resources. Waste and losses are reduced through greater experimentation with and use of genetically diverse crops, including many from more arid areas that are productive in dry-land conditions. Urban agriculture and the livelihoods of small farmers are the centre-pieces of global food security efforts – and knowledge transfer between farmers, communities and nations is the backbone of it all.

As with the other scenarios, very high levels of energy efficiency are driven by the need to reduce costs of energy use, at the same rate as overall economy (50%). However, in *DIY* there is an assumption that the energy reduction is to some degree replaced by increased labour intensity, causing a decrease in agricultural labour productivity of 2% per annum. In the modelling, this labour productivity reduction was only applied to agriculture, not across the economy (see discussion at 4.3).

3.3.5.4.1 Water Availability, Efficiency and Use

DIY sees the largest reduction in proportion of food producing area irrigated (75%) of the scenarios. The drive to reduce energy intensity in this scenario also sees a reduction in water pumping and irrigation systems, and a greater use of passive and green water management techniques [Zaks and Monfreda 2006]. The leading techniques developed in Australia are rapidly adopted in arid-area food production around the world.

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[21] e.g. http://blogs.worldwatch.org/nourishingtheplanet/; http://www.ruaf.org/

DIY has no significant new infrastructure for water recycling, desalination etc. Water, as with land, is used to meet the requirements of the population and environment – but an attempt is made for this to occur at a Victorian level. The following settings reflect water management and use in the DIY scenario:

- High levels of water efficiency in food production are enabled by dispersed innovation and rapid uptake of successful low-cost techniques, making careful use of every available drop. This amounts to a reduction of 'irrigation' water per yield of 1% per annum (reduced intensity of water application);
- There is a regional focus on meeting basic food requirements, so water (as well as land) is allocated accordingly;
- Tightly connected ICT systems enable self-organisation amongst producers to balance what is being produced across the state, allowing sensible use of resources to meet needs without centralised control; and
- As with *Adjustment* and *Control*, the assumed productivity increase in dry-land yields is balanced with losses to increasing temperature etc. DIY sees a strong shift to better-adapted products / crops, and a much greater diversity in what is produced within properties, regions, states and so on – so that losses from extreme events and changed conditions are reduced. This is handled through a reduction in waste / losses rather than a change in dry-land productivity.

3.3.5.4.2 Fertiliser

In *DIY*, the onus is on producers and regions to manage input costs, which they do by: reducing waste through highly efficient application (0.5% per annum improvement in intensity) and managing soils to maximise plant uptake of nutrients (0.5% per annum improvement in yield efficiency). The use of highly productive soils around the cities (with short transport distances to consumers), as well as widespread use of: crop rotations, mixed farming systems (allowing animals to fertilise fields) and interspersed planting, also reduce reliance on fertilisers, pest controls and other inputs. Continuous innovation in the application of these and many other practices reduce the intensity of application of synthetic fertilisers by 1% per annum – this yield increase is applied consistently across all crop production (e.g. horticulture, pasture, grains).

The use of organic fertiliser sources would be widespread in *DIY* as sources and destinations are closely linked by more integrated production systems, both within mixed farming systems and making use of urban interfaces for the collection of organic wastes. This input to fertilisers is not actually quantified in the model but could be done in further iterations.

3.3.5.5 <u>Greenhouse Gas Emissions</u>

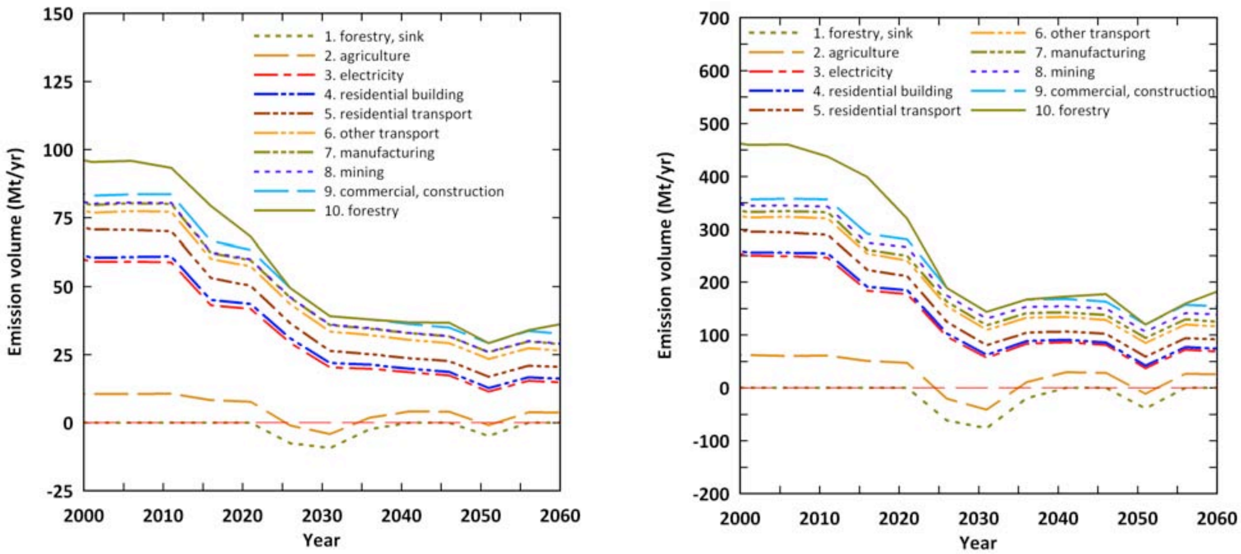
The settings outlined in previous sections are the main drivers of changing greenhouse gas emissions in the *DIY* scenario. The most significant of these are:

- Energy efficiency and changes to electricity production;
- A culture of voluntary austerity in per-capita energy use (significant reductions in consumption);
- Significant changes to transport demand and distances;
- Increased use of forestry for carbon sequestration, taken from previously agricultural land (15% of productive land);
- Changes to agricultural emissions through fertiliser use and livestock numbers; and
- Increased use of timber for building (perceived as a way to sequester carbon in the short-term) – 80% of clay building products (bricks and tiles) are replaced by timber products by 2020.

Figure 3-25 shows the cumulative greenhouse emissions from all sectors (for national and Victorian emissions), demonstrating large emissions reductions between 2000 and 2030 of around 68% (nationally) and 58% for Victoria. The reduction on 1990 levels is 71% and 57% respectively.

Figure 3-25: Greenhouse Gas Emissions (DIY) – Cumulative Sector Contribution (CO2-e)

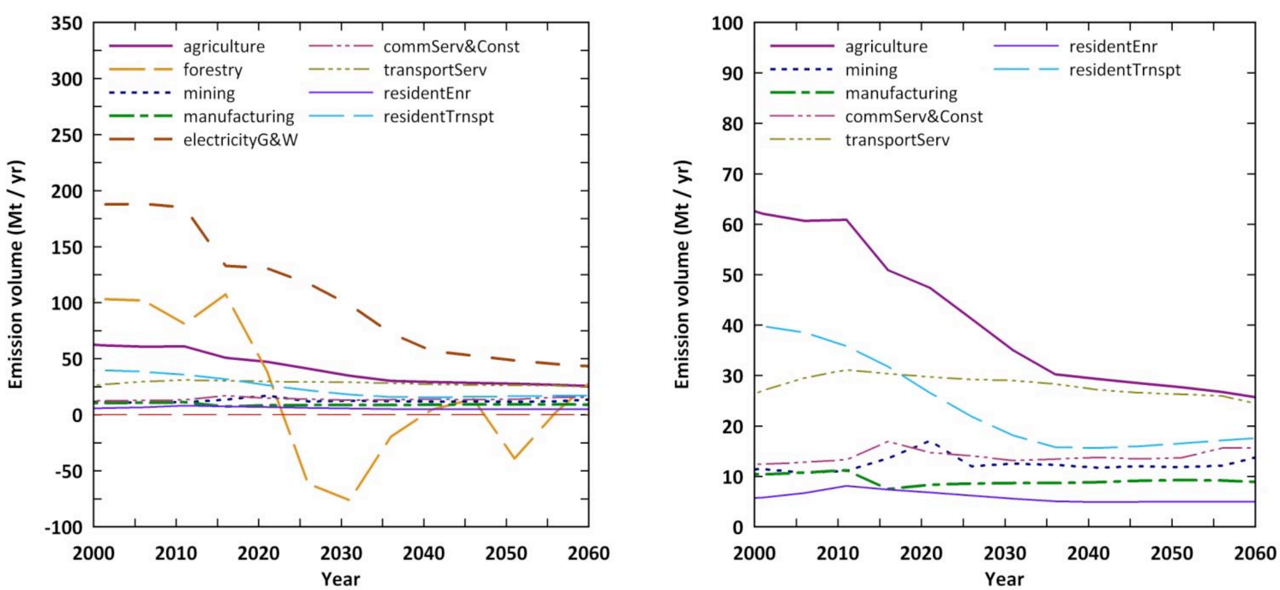
a) Victoria b) National



As with *Control*, emissions reductions between 2010 and 2030 are achieved through significant reductions in electricity, gas and water; agriculture; passenger transport; and increased carbon sequestration in forests (Figure 3-26).

Figure 3-26: Australian Greenhouse Gas Emissions (DIY)

a) By sector b) By sector – minor subset



While further significant reductions are not achieved by 2060, and the scenario is not able to achieve its intended 90% reduction in emissions by 2060, the lower levels of emissions are maintained – rather than increasing again beyond 2030. *DIY* is the only scenario that is able to maintain large emissions reductions out to 2060, and meets IPCC expectations for emissions reductions by 2050.

3.3.5.6 **Food Availability**

3.3.5.6.1 Food Required

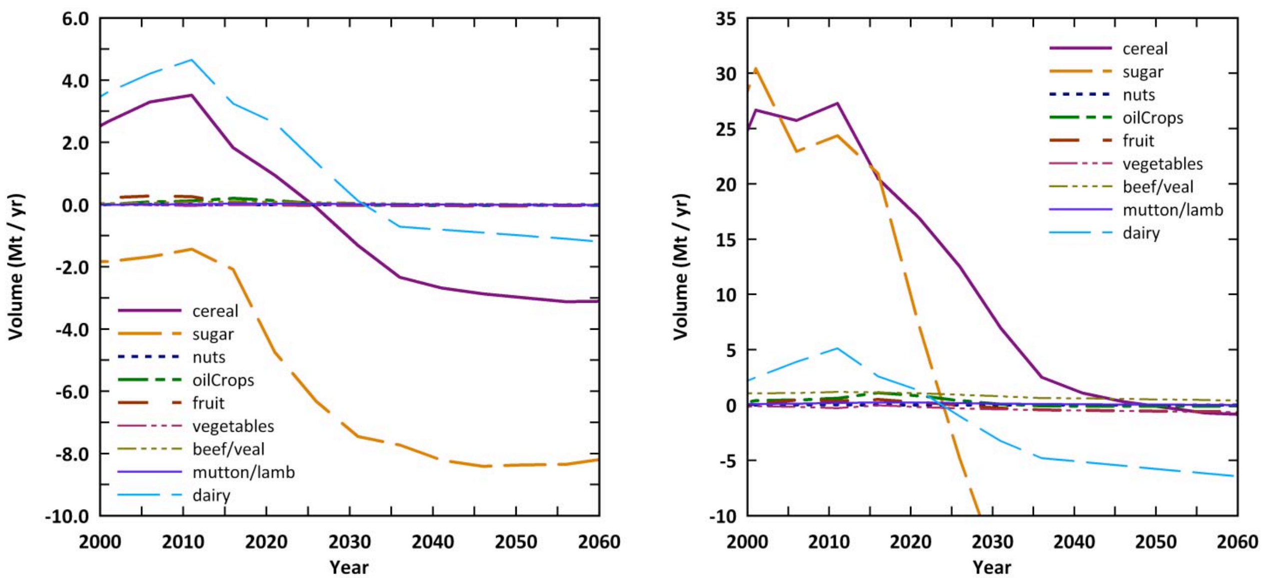
DIY has reduced levels of waste because of a culture with low tolerance to waste, a more direct connection between consumers to producers (reduced requirements for storage) and a greater acceptance of seasonal (and appearance) changes in the composition of food consumed. There is also lower impact from fluctuations in resource availability (particularly pesticides) because of a different approach to production that is less reliant on external inputs. Nevertheless there are still high average losses from weather events and pests. A waste / loss factor of 33% of what is produced applies in *DIY*.

3.3.5.6.2 Food Available

In *DIY*, land and resources are managed at a state (proxy for regional) level for essential food production, with the aim of producing adequate Victorian supplies of all core food groups. This results in availability of core foods as shown in Figure 3-27.[22]

Figure 3-27: Net Food (DIY)

a) Victoria b) National



As with *Control*, the attempt to provide adequate fruit and vegetables drives a reallocation of land from grazing, to the extent that not enough dairy production capacity is maintained and there is a shortfall in lamb by 2060.

DIY is sufficient in all other food groups, if the diversions to biofuel are not considered. However, with these diversions, there is a Victorian deficit of cereals and a heavy reliance on interstate sugar. Although the *DIY* scenario has a smaller 'waste / loss' factor built in, the basic nutritional requirements of the population are still likely to be met.

As well as the deficits in Victoria, *DIY* sees very early *national* deficits of sugar and a greatly reduced surplus of cereals. The diversions for 1st generation biofuels would be a significant factor in food availability and the more detailed graphs are shown in Figure 3-28.

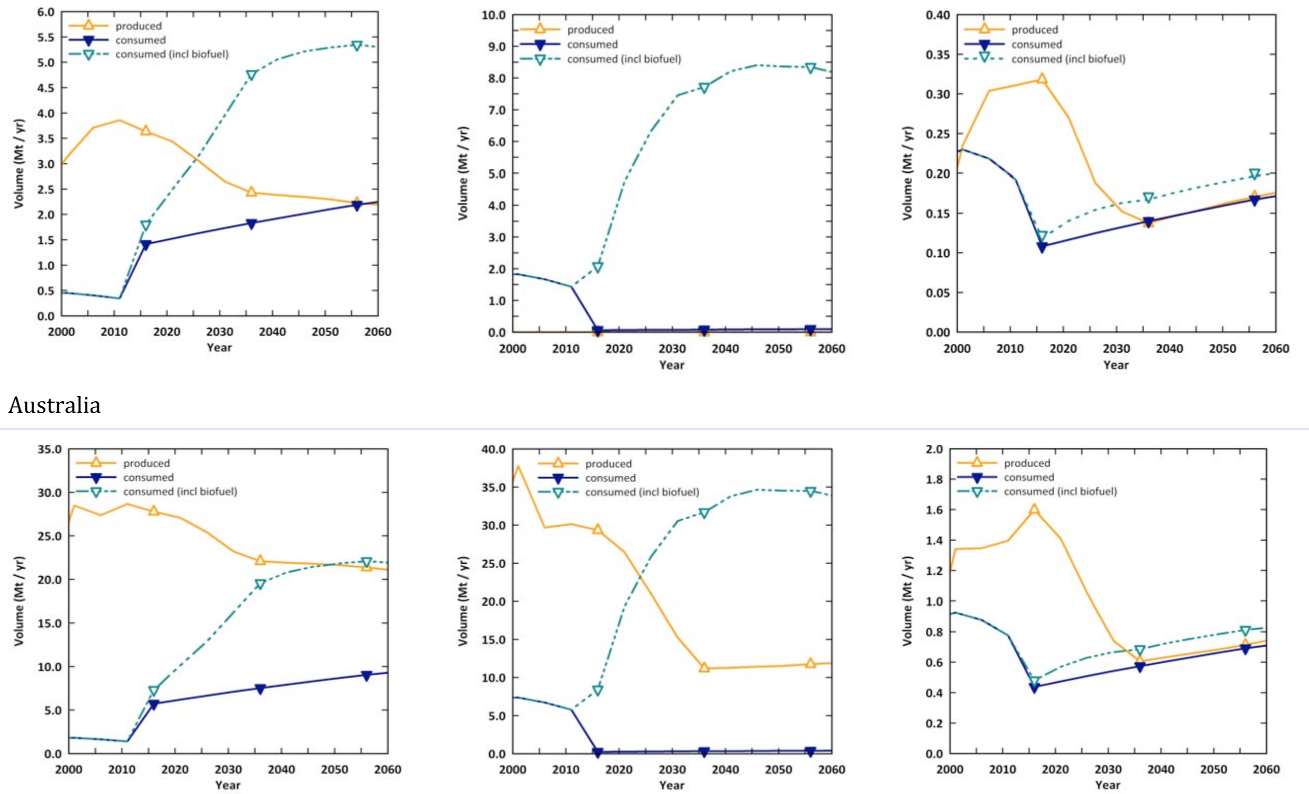
Even with dramatically reduced transport / fuel requirements, attempting to meet fuel needs with renewable (1st generation) biofuels could generate increasing conflict at a state level by 2020.

[22] Detailed food surplus / deficit graphs are provided in Appendix 4.

Figure 3-28: Diversion of Food Crops to Biofuels (DIY)

Cereal Grains | **Sugar Cane** | **Oil Crops**

Victoria



3.3.6 Comparative Results

3.3.6.1 Net Environmental Flows

As outlined in 3.3.1, all scenarios have the same climate change impact of reduced rainfall and runoff i.e. the envelope of 'possible' water available in the system is the same in each scenario.

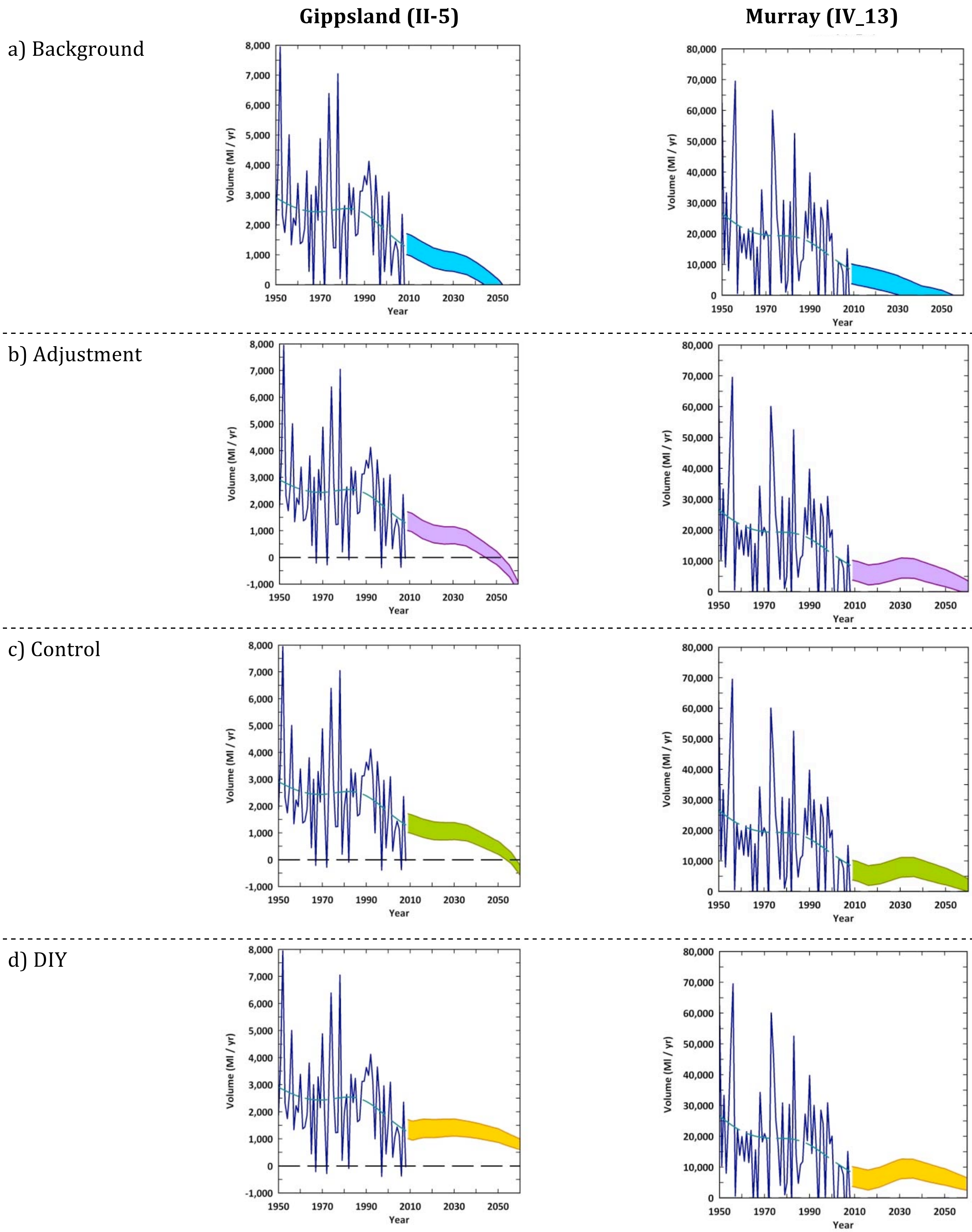
Significant reductions in the proportion of cropland irrigated are assumed in all scenarios: 40% in *Adjustment*; 60% in *Control* and 75% in *DIY*. The water that is no longer used for irrigation is then available for other uses, including environmental flows. All scenarios have the same process for reallocation of water i.e. extracted for irrigation, urban and industrial uses, with what is left shown as environmental flows.

All scenarios also assume the same level of water efficiency improvement across the economy, with the exception of agriculture (as described in the *Agricultural Production* sections). Extractions for urban and industrial use are therefore reflective of population (same in all scenarios) and the level of economic activity (which varies).

Figure 3-29 shows the net environmental flow for two key irrigation areas in Victoria (*Gippsland*, including the Macallister region, and *Murray*, which covers the Victorian 'end' of the Murray Darling Basin) across the background settings and the three scenarios. The boundaries and locations of the selected regions (as defined in the ASFF) are shown in Appendix 5.

Figure 3-29a (the background scenario) indicates that the expected impacts of climate change, a 'business as usual' approach to irrigation extractions and other uses of water such as increasing urban demand, would drive environmental flows to zero in both these regions. In *Gippsland* this would occur between 2040-2050 and in *Murray* between 2030-2050.

Figure 3-29: Net Environmental Flows (All)



Figures 3-29b, c and d show if, or when, the settings in the scenarios are able to overcome the impacts of climate change and retain a net positive environmental flow in these rivers.

Adjustment delays the zero point in *Gippsland* by about 5 years and makes a significant difference to the *Murray* region, maintaining some environmental flows until at least 2055. Control maintains flows until after 2050 in *Gippsland* and marginally longer in *Murray. DIY* is the only scenario that avoids the situation of 'negative' net environmental flows, stabilising both regions out to 2060, although *Murray* still appears to be declining.

Only the *DIY* scenario retains above-zero environmental flows in these river systems out to 2060, with some water to spare. The overall reduced demand on water in *DIY* is due to:

- Largest movement of land from irrigated to dryland production;
- Water efficiency being applied as an input intensity (reduction) rather than yield efficiency (increase) (Figure 3-9). This allows for a progressive use of less water to produce the same amount of food, with the extra water available for other uses (rather than reapplied for increased production); and
- Decreased economic activity reducing demand for industrial water use.

River systems with 'negative' environmental flows for any period of time are unlikely to support food production in the longer term. It should be noted that the reduced extraction levels, while large, are not at the extreme (high climate change) level that CSIRO (2008) suggested may be required for the Victorian regions of the Murray Darling Basin. This is a tension that can clearly not be sustained.

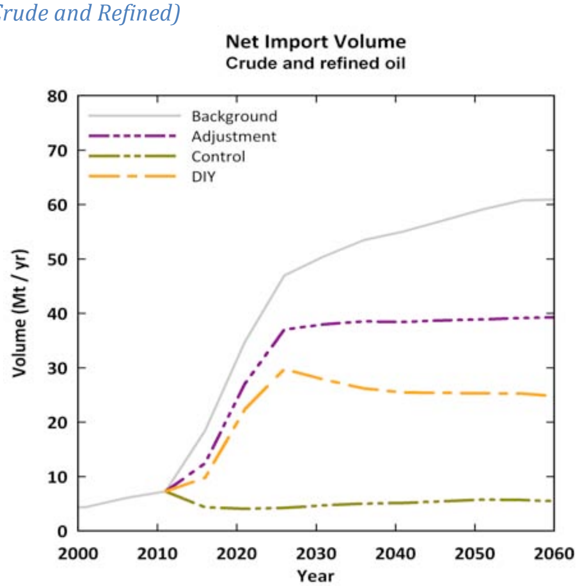
3.3.6.2 <u>Reliance on Imported Oil</u>

All scenarios include a decline in Australian oil production, resulting in an increasing reliance on imported crude and refined oil products. This is a huge challenge to all scenarios, none of which achieve oil self-sufficiency.

While the strategies employed in the scenarios are different, most attention is focused on transport fuel, which includes use of diesel on farm. The different degrees of demand stabilisation or reduction in the scenarios (through fuel efficiency; change in mode and fuel types; reductions in distances etc.) reduce the overall 'requirement' for oil, as do the settings allowing for replacement with biofuels (through diversion of cereal, oil and sugar crops).

This leaves a remaining net oil requirement, as shown in Figure 3-30.

Figure 3-30: Net Oil Import Volume (All)
(Crude and Refined)



All scenarios significantly reduce reliance on imported oil (compared to the background scenario) by 2030, and retain this reduced reliance out to 2060. However, in *Adjustment* and *DIY* the significant changes proposed still leave a large oil import requirement.

Fuel and energy efficiency (40% by 2040) balances increased demand. Small diversion of food crops for biofuel.

Efficiency (50% by 2040); reduced demand and transport distances; and shift of 50% bulk and 33% non-bulk freight to rail. Large diversion of food crops for biofuel.

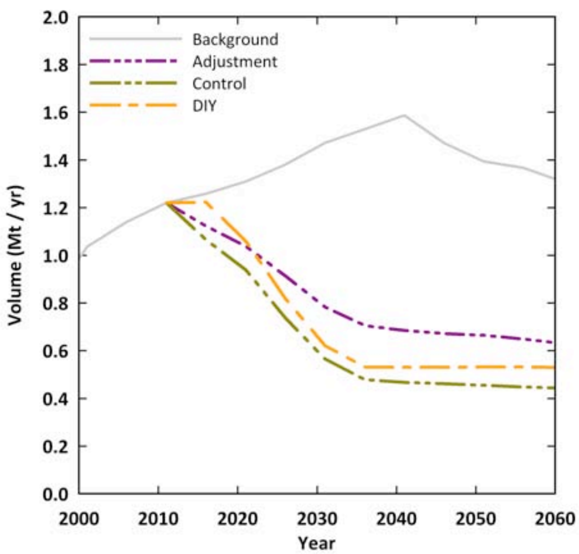
Efficiency (40% by 2040); all new passenger cars from 2011 electric; 90% freight travels by rail and the rest runs on compressed gas.

3.3.6.3 <u>Fertilisers (Phosphorus)</u>

Figure 3-31 shows that all scenarios achieve significant reductions in reliance on imported phosphate fertilisers, largely due to decreased fertiliser requirements resulting from:

- Efficiencies gained through reductions in input intensity – per annum improvements of 0.2% (*Adjustment*), 1% (*Control*) and 0.5% (*DIY*);
- Removal of land from agriculture; and
- An impact from changed production types i.e. reduced irrigated dairy and other grazing land.

Figure 3-31: Net Phosphate Import Volume (All)
Phosphate fertiliser (incl. rock phosphate fertiliser volume)



Adjustment has the greatest removal of land from agriculture, but a smaller reduction in input intensity and a smaller reduction in irrigated production, which therefore leads to a higher fertiliser use over time.

The changed land uses (less irrigation, fewer livestock) in *Control* and *DIY*, lead to lower phosphorus use. *Control* also has higher overall efficiency improvements than *DIY*.

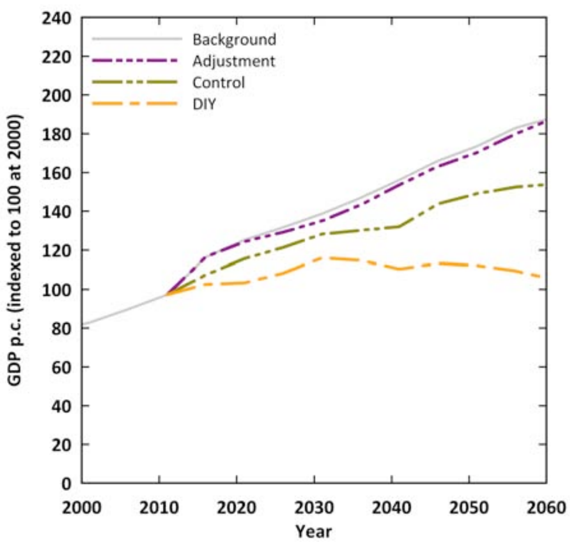
3.3.6.4 <u>Economic Indicators</u>

Section 3.3.1.2 explains how the ASFF has been adapted to allow for some interaction between physical amounts of stocks and flows of material and energy and core economic indicators such as GDP per capita. It outlines how the economic settings are applied in the background scenario, with a view to achieving stable unemployment and trade conditions, with simulated macro-economic processes also resulting in growth of GDP per capita.

As the new settings are applied on top of the background scenarios, the three exploratory scenarios change what is produced and consumed, which then impacts on the economic indicators. The feedback loops are not re-applied after the food scenarios have been run i.e. no effort is made to re-stabilise economic activity.

Figures 3-32, 3-33 and 3-34 show the impacts of the three scenarios on the economic indicators, relative to the background scenario.

Figure 3-32: GDP per capita (All)



Relatively marginal change from the background scenario occurs in *Adjustment*, where stable unemployment and growing per capita wealth are achieved. This is very much in keeping with the general intent of this scenario, where change is gradual – 'adjusted' – rather than transformational.

The economic performance of *Control* is intermediate between *Adjustment* and *DIY*. Per capita wealth grows, but at a slower pace than in *Adjustment*. Similarly, unemployment grows at a lower rate than in *DIY*. In contrast with the other scenarios, the net foreign account diverges toward greater debt, though the level has not exceeded GDP within the scenario timeframe.

The 'economic fundamentals' are most affected in *DIY*. GDP per capita grows steadily but more slowly to 2030, but then starts to gradually decline. The unemployment rate and net trade surplus change dramatically, which would be expected from the significant changes to the structure of the economy (e.g. reduced consumption per capita). When viewed in isolation, the indicator cannot display the associated positive impacts of these changes (e.g. successful and sustained reductions in greenhouse emissions). The implications of these results are further discussed in Section 4.3.

Figure 3-33: Net Trade Surplus (Debt) to GDP (All)

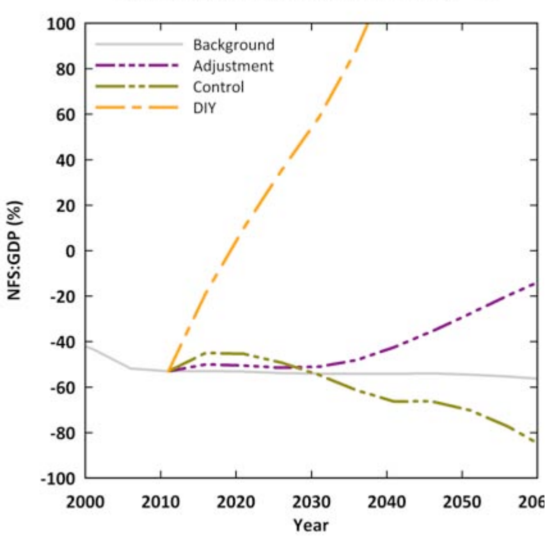
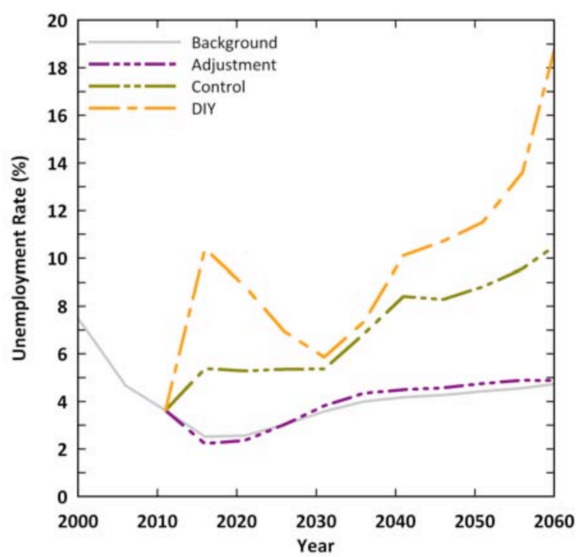


Figure 3-34: Unemployment Rate (All)



4. Discussion

This section draws out the implications, limitations and complex interactions of the scenarios, to explore whether (and how) the multiple objectives of Victoria or Australia's resource use could be simultaneously achieved. It also considers additional factors (outside the scope of the modelling) that could impact on food availability. These vulnerabilities, opportunities and ethical considerations suggest priorities for future analysis and response.

4.1 Challenges to Food Availability

Food availability (sufficient quantities of the foods required for a nutritious diet for the population) requires both production and the necessary physical infrastructure (e.g. processing and packaging, distribution and storage – including the 'last mile' of how people actually access their food) to deliver food from where it is produced.

4.1.1 Production

Comparison of food availability in the scenarios is complex, because the scenarios are themselves based around different approaches to how food availability is secured. *Control* and *DIY* reallocate land within agriculture (between products) in an attempt to retain sufficient levels of production of core foods (at a national and Victorian level respectively), whereas *Adjustment* assumes access to imported foods to make up any production deficits.

The 'success' of the scenarios in meeting their food availability objectives can best be understood by considering the national results of the *Control* scenario (which attempts to manage energy and food security at a national level), with the Victorian results of *Adjustment* and *DIY*. These results are summarised on Table 4-1.

Table 4-1: Net Food Availability[23]

	Adjustment (Vic)		Control (Aus.)		DIY (Vic)	
	2030	2060	2030	2060	2030	2060
Vegetables	Large Deficit	Large Deficit	Borderline	Borderline	Borderline	Borderline
Fruit	Large Deficit	Large Deficit	Borderline	Borderline	Borderline	Borderline
Milk	Large surplus	Large surplus	Borderline	Large Deficit	Small surplus	Small deficit
Meat						
• Beef	Borderline	Borderline	Small surplus	Small surplus	Small surplus	Borderline
• Lamb	Borderline	Borderline	Small surplus	Small deficit	Small surplus	Small deficit
• Nuts	Small deficit	Small deficit	Borderline	Small deficit	Borderline	Borderline
Cereal grains						
• Food and feed	Small surplus	Small deficit	Large surplus	Large surplus	Small surplus	Borderline
• Including fuel	Borderline	Large Deficit	N.A. *	N.A. *	Small deficit	Large Deficit
Oil						
• Food and feed	Borderline	Borderline	Small surplus	Small surplus	Small surplus	Borderline
• Including fuel	Borderline	Borderline	N.A. *	N.A. *	Borderline	Small deficit
Sugar**						
• Food and feed	N.A.	N.A.	Large surplus	Large surplus	N.A.	N.A.
• Including fuel	N.A.	N.A.	N.A. *	N.A. *	N.A.	N.A.

Key:	Large surplus	Small surplus	Borderline	Small deficit	Large Deficit	N.A.

* Minimal use of biofuel in *Control*.

** Victoria's negligible sugar production is not expected to change, so is a state-level deficit in all scenarios.

[23] NB. These are indicative categories, determined by reading off the net food graphs. The ratings refer to the relative size of the surplus or deficit to other foods within that scenario and context. They do not take into account the proportion of total requirement this reflects, or the relative surplus or deficit to the same food category in the other scenarios.

In 2030, *Adjustment* is sufficient or in surplus for all foods except fruit, vegetables and nuts, which have large and increasing reliance on imports. The large surplus in dairy, as well as continued stability in economic indicators, would be assumed to contribute to an ability to buy required fruit and vegetables (or any other food required) from elsewhere. The deficiency in nuts would not be a major nutritional concern as it is part of the meat group, which is sufficient overall. The surplus in cereals is declining rapidly by 2060, exacerbated by increasing diversion to biofuels.

The *Control* and *DIY* scenarios almost achieve their aim of sufficiency at a national and Victorian level respectively. Challenges (or tensions) in achieving this are due to:

- Movement of land from grazing to fruit and vegetables, resulting in shortages of dairy by 2030 in DIY and 2060 in Control;
- The reduction in grazing land also produces insufficiency in lamb by 2060;
- *DIY* having a serious conflict between food and fuel by 2030, with large diversions of cereal crop and heavy reliance on interstate sugar; and
- Even without diversion to biofuels, Victoria surplus declines to just sufficient by 2060 in *DIY*. Victoria is a net importer of cereals by 2036 in *Adjustment* and 2030 in *Control*.

As per Section 3.3.1.3, production of pigs; poultry and eggs and fish were not amended from the background scenario, which produced a large national (and a small Victorian) surplus of these foods. As they form part of the 'meat' group, which also includes beef (remaining in surplus in all scenarios) and lamb, availability of enough meat for a nutritious diet is unlikely to be a concern in any of the scenarios.

In practice, none of the scenario parameters are tightly defined and it is possible to adjust the value of some of those parameters so that food deficits are reduced or inadvertently increased. The results of such adjustments will of course be some change in other system functions (land available for non-agricultural use, water available for natural flows, greenhouse gas production, and so on). Attempting to resolve a 'tension' in one area inevitably creates 'tensions' elsewhere.

Adjustments have been made in an iterative way during the latter part of the project, but the data on food surpluses and deficits within each scenario (from 2010 – 2060) do show some real tensions, which then have to be considered in the light of tensions in other output parameters. These include:

- By considering the needs for a nutritious diet, rather than the diet as typically consumed, this project has revealed early and immediate tensions in relation to some core foods – particularly fruit and vegetables. It also indicates that attempting to resolve those tensions, for example by reallocating land from one type of production (grazing) to another (fruit and vegetables) can lead to a deficit in another required food.
- Use of cereals, oils and sugar for 1st generation biofuels can have significant impacts on food surpluses, while only providing a marginal replacement of demand for oil.
- Even without use of cereals for fuel, Victoria becomes a net cereal importer in all scenarios.
- Therefore, under these conditions (climate change, an increasing population and tensions in availability of oil), the domestic production of a surplus of required foods – at either Victorian or Australian level – must not be taken for granted.

4.1.2 Making Food Available to Consumers

In this project, it is assumed that processing, packaging, distribution and storage systems continue to function effectively, providing food of sufficient quality to meet nutritional requirements, even whilst very substantial changes are applied to their operating structure. Possible impacts and potential further work on these assumptions are discussed below.

4.1.2.1 Processing and packaging

All scenarios assumed major increases in energy efficiency across the economy (40%-50% by 2030). Achieving these levels of energy efficiency would require changes to how food is processed, packaged, refrigerated and stored etc. The technical feasibility and costs of achieving these changes have not been assessed.

The food requirements are calculated based on minimally processed foods. The differential impact of processed versions of these foods is not included. For example, the difference in resource demands between plain bread and highly processed bread with added novel ingredients has not been considered. A move to meeting nutritional requirements through more highly processed versions of foodstuffs (as might be expected in *Adjustment* and possibly *Control*) has potential to undermine energy efficiency improvements within these scenarios.

4.1.2.2 Distribution

Availability of energy (particularly oil) for food distribution is critical to food availability. The scenarios assume different degrees of change to the way food is transported, including high levels of fuel efficiency, changes of freight and passenger mode, and changes to distances travelled for food freight. The technical feasibility and the impact of these changes on system configuration have not been investigated. While it is assumed that they continue to function effectively, it could be expected that this would be challenged in all scenarios.

These changes would all impact on the amount of energy required for food distribution, as well as potentially impacting the resilience of the system overall. Analysis of the significance of the changes to the distribution system for food in particular could be the focus of further work (see also Marquez et al. 2010).

🕮	*Detailed investigation of the challenges and responses of the food distribution system.*

4.1.3 Easing or Increasing Tensions

As outlined throughout the report, the need to simplify a very complex system for analysis has led to exclusion of some relevant parameters and datasets (Table 3-3). The exclusion of this information is likely to impact on whether the scenarios are optimistic or pessimistic i.e. whether the tensions in food availability are under or over-stated.

Some key parameters that would be likely to directly affect food production (but have not been included in the modelling) are summarised in Table 4-2 – many of these are discussed in more detail throughout Section 4.2.

While assessment of the likelihood and extent of technology developments were well outside the scope of the project, the methodology does incorporate assumptions about technical improvement and innovation in response to the tensions that emerge. The scenarios allow some prospective technologies to reduce tension despite significant unknowns about technical or commercial viability. They also include increasing resource efficiencies that reduce the scale of emerging tensions. The high levels allowed for these efficiencies (particularly for simultaneous improvements in energy, water and fertiliser)[24] mean that, if anything, the scenarios are *optimistic* about the level of improvement that could / would be achieved as higher prices drive development and uptake of new technologies and solutions.

Table 4-2: Potential Effects of Excluded Parameters

Easing Tension	Increasing Tension
Multiple uses of same land / resource (i.e. use of forest thinnings for bioenergy; integration of forestry with grazing or other production).[25]	Loss of productive land that is not converted to urban development, energy production or sequestration e.g. fragmentation, mining.
Urban and peri-urban food production – use of urban waste and storm-water and organic waste.	Assessment of land capability and soil quality could reduce the flexibility of land reallocation to the required purpose.
Intensive food production where it reduces reliance on land allocation or energy inputs e.g. some systems of pigs, poultry, hydroponics, vertical farms etc.	It may not be technically possible to simultaneously achieve high efficiencies in energy, water and nutrients (as assumed in all scenarios) as these often undermine each other.
Potential for disruptive development or rapid adoption of new technologies and solutions e.g. 2nd and 3rd generation biofuels	Exclusion of impacts outside Australia – when all or most of the food is being produced here we see all the impact. When we are heavily import reliant we see less, but conversely when we are exporting large amounts of food we bear the environmental costs of that production.
Reduction in biological emissions from agriculture and organic waste, including through carbon sequestration in soils	
Unknown	
Detail on the productivity and ecological impacts of different production systems / land use practices	
Implications of land use change for processing, freight and market access	

There are also known and rapidly developing technology and system changes that are implicit in the qualitative scenarios, but beyond the resources of this project to include in the analysis.[26] Inclusion of these factors would potentially ease tensions and increase food production capability, whilst remaining within the parameters of the scenarios.

Table 4-3 summarises some key areas where assumptions and exclusions impact on the tensions within the scenarios, potentially reducing them (advantaging the scenario), or increasing tensions (disadvantaging the scenario). It suggests that no scenario has been given an 'easier ride' than the others.

Table 4-3: Advantages and Disadvantages

	Advantages to the scenario	Disadvantages to the scenario
Adjustment	Assumed • Successful development and use of Carbon Capture and Storage Technologies (CCS), Coal-to-Gas and Coal-to-Liquids would reduce vulnerability to high oil import requirement – but emissions from these have not been counted. Excluded • Energy use and emissions associated with international transport of food exports and imports are not reflected in Australia's physical accounts (the model). Therefore, these impacts are 'hidden'.	Excluded • Intensive systems for bulk production of high-value produce (incl. for export) e.g. pigs, poultry – or lamb, dairy and beef. • Would expect to find and exploit new sources of phosphorous and nitrogen to a larger degree than the other scenarios.

[24] For example, all scenarios have high rates of energy, water and fertiliser efficiencies in agricultural production. In practice, it may not be possible to achieve these efficiencies in parallel as one often comes at the cost of another. For example, studies show that efforts to increase crop productivity through water efficiency measures often come at the expense of agricultural energy efficiency and even economic efficiency [Mushtaq et al. 2009]. Similarly, where climate change is expected to reduce rainfall, studies in the US have estimated a reduction in agricultural energy efficiency due to increased need for irrigation [Peart et al. 1995].

[25] For example, combining energy and food production, rather than switching from one to the other. See http://www.fao.org/news/story/en/item/51165/icode/

[26] Inclusion was limited by the time and resources of the project, not technical capacity.

Control	Assumed • Ability to transform transport infrastructure at the pace required, including to cope with 90% of freight on rail, electric vehicles and compressed gas. • Functional and effective centralised management, only marginally reducing efficiency gains obtained across the economy.	Excluded • Intensive horticultural production in and around urban centres and where there is good access to rail infrastructure. • Use of recycled water and organic waste streams from urban areas.
DIY	Assumed • Ability to develop significant renewable energy infrastructure without strong government support.	Excluded • Increased use of 'fit for purpose' water for food production, including urban storm-water and wastewater. • Increased use of recaptured nutrients within food production (from waste).

4.2 Emissions, Environment and Resource Constraints

Ultimately the successful provision of food is determined by the bio-physical factors necessary for its production (land, soils, sunlight, nutrients, feed-stocks) and the availability of resources required for organising production, processing and distribution.

Understanding how any limitations on those physical factors will affect the availability of a nutritious diet is inevitably complex and subject to high levels of uncertainty. However, the tensions revealed through this project are considered significant enough to be relevant even with the limitations in scope and setting approximations that were used. The tensions further discussed in this section include:

<u>Land</u>

- Productive land area reduces in all scenarios, due to varying combinations and rates of diversion to forests (for carbon sequestration and bioenergy) and urban land expansion This has a clear and noticeable impact on production levels relative to requirements.

<u>Water Use and Environmental Flows</u>

- Extraction of water for irrigation is reduced in all scenarios, reducing the proportion of food production that is irrigated and therefore yields per hectare. Despite these large reductions in water extraction for irrigation, key river systems see 'negative' environmental flows in both *Adjustment* and *Control*.

<u>Greenhouse Gas Emissions</u>

- All scenarios have significantly reduced greenhouse emissions by 2020, with two meeting IPCC requirements for Annex 1 countries at a national level. However, sustaining significant reductions in greenhouse gas emissions will require changes to usage patterns and demand. Achieving emissions reductions through bio-sequestration exacerbates tensions around land-use.

<u>Oil</u>

- The *Control* scenario achieves a high level of energy security and significantly reduces imported oil reliance, although massive and immediate intervention is required. Efforts to reduce reliance on imported oil through 1st generation bio-fuels causes significant tensions between food and fuel.

<u>Fertiliser</u>

- (Phosphorus): all scenarios achieve significant reductions from the background scenario, largely due to demand-side measures (reduced requirement), but they all retain a large import requirement.

The relative performances of the scenarios against these indicators are summarised in Table 4-4 and further discussed throughout this section.

Table 4-4: Comparison of Scenario Results

Objective	Adjustment		Control		DIY	
	2030	2060	2030	2060	2030	2060
Stabilised or increased environmental flows in selected catchments (Gippsland and MDB)						
Reduction in greenhouse gas emissions						
Reduced demand for imported oil (surplus to Australian production)						
Reduced demand for phosphorus fertiliser (surplus to Australian production)						

NB. Colour coding reflects relative performance of the scenarios

Performance Poorest Middle Best

4.2.1 Land

The differentiating changes in land-use explored in this project are the extent of:

- Movement of cropland to forests for carbon sequestration;
- Movement of cropland to forests for bioenergy or diversion of cropland for biofuel;
- Increase, stabilisation or reduction in use of land for urban development (exchanged with grazing land);
- Decreasing reliability / availability of irrigation water reducing the proportion of cropland that is irrigated; and
- Movement of land from one food type to another to meet nutritional requirements (in *Control* and *DIY*).

These land-use allocations are clearly a fundamental driver of the results in other areas i.e. they determine to a large degree the results in greenhouse gas emissions, oil and fertiliser requirements and food availability.

However, in this research, all land lost to food production moves to uses that have a direct positive impact on other critical focus areas (e.g. energy; greenhouse gas emissions and urban development). This effectively provides a 'bonus' land area for meeting other objectives within the scenarios i.e. a 'loss' in food availability moves to a 'gain' in emissions reduction or oil replacement.

There are other uses of land that could exacerbate the critical tensions being examined in this work rather than re-allocating them i.e. effectively removing land from use for food, energy or sequestration purposes. These could include:

- Abandonment of degraded and/or marginal land;
- Potential loss of access to land or production as a result of foreign ownership or interests (i.e. the land is owned as security by other nations but not actually productive) [Daniel and Mittal 2010]; and
- Irreversible loss to mining [Select Committee 2010] as the export value of energy and minerals outweighs food production.

There are also possibilities for land uses that could ease the tensions, by allowing for more than one 'value' from the same land. For example, this analysis has not accounted for the potential to sequester carbon in trees and soils whilst retaining (or improving) food production levels, or for the use of waste products to provide biofuels (freeing up land used for that purpose). Similarly, the use of land and resources within existing urban areas for food production is qualitatively included in the *DIY* (and to a lesser extent in *Control*) scenarios, but has not yet been included in the quantitative results. *This is a high priority for further research*.

Other priorities for extended analysis in relation to land use include:

- *Land capability and suitability assessment:* in this analysis, land is re-allocated from one use to another in accordance with the scenario settings. Suitability of particular areas for the new land-use; or social, environmental and economic impacts of the major changes suggested; have not been assessed. This assessment would be likely to identify additional constraints and increase tensions; for example it is likely that some of the dairy production areas are less suited to fruit and vegetables and that this transfer would not be viable.
- *More sensitive re-allocation*: to respond to the key settings in the scenarios, there are a number of calculators that automatically shift land from one use to another. For example, to increase the amount of fruit and vegetables produced in *DIY* and *Control*, land is taken only from grazing livestock. This drives dairy (milk production) into deficit, but does not affect use of other land where fruit and vegetables could well be produced. These calculators produce outcomes that would require further refinement in later iterations.
- *Over-allocation:* as explained in 2.3.3, the ASFF does not automatically prevent over-allocation of resources – these are shown as 'tensions' that would need to be resolved in future iterations. An example of where this has occurred in this research is in *Adjustment*, where expanded use of urban land area is exchanged with grazing land, to the point where land is actually in deficit in some areas (including the Melbourne Division). This is shown in the results as slight differences in the 'total' amount of land accounted for (Figures 3-5, 3-13 and 3-20).
- *Land quality / degradation*: is measured in the ASFF as a direct factor of agriculture i.e. based on historical trends, the length of time that land has been cultivated or actively used for agriculture is the best indicator of its level of degradation. Therefore, the ASFF returns information about land quality that effectively suggests that the less land used for agriculture, the less land degradation there is. These results have not been included here as they are unable to take account of the significantly different impacts on land quality that would be expected from agricultural production in the different scenarios. The *DIY* scenario in particular has a move to agro-ecological systems that aim to restore soil quality and biodiversity, potentially allowing for land regeneration within agricultural uses.

All scenarios are challenged by significant reductions in land availability for food production. However, it is inevitable that there will be increasing requirements for output from what it is, ultimately, a finite resource base. As tensions around energy, food, greenhouse gas emissions, population and urban development increase, the difficulty in managing land to meet these multiple objectives will also intensify. While this research has not provided answers for how this can be managed, it has demonstrated a capability that (with further development) could be of great assistance in doing so.

🕮	*Multiple uses of the same land.*
🕮	*Land capability and suitability assessment.*
🕮	*Land quality and degradation or regeneration as a result of different agricultural systems.*

4.2.2 Water and Environmental Flows

In this analysis the water available for net environmental flows is a function of:

- Rainfall and runoff into waterways (blue water), which is reduced as a result of climate change;
- Water that does not runoff catchment areas i.e. is absorbed in plants and soil (green water). This includes that taken up through increasing forestry for sequestration;[27]
- Water that is extracted for irrigation; and
- Water extracted for urban and industrial uses.

Under the climate change assumptions in this work (see 3.3.1.2), the reductions in cropland overall, as well as substantial reductions in proportion of cropland irrigated, are able to maintain environmental flows for longer than in the background scenario. However, under the existing settings, the amount of water extracted for agriculture and other uses (urban and industrial) does not leave enough to maintain environmental flows in either *Control* and *Adjustment* beyond 2030-2050.

Climate change will change historical patterns of rainfall in complex ways, affecting averages and, most probably, the severity of extreme events (including floods), but this analysis has simplified these complex changes into a reduction in 'reliable irrigation allocations'. While this is a significant simplification, it represents a reduced predictability of a constant and affordable supply of irrigation water. The estimated reductions of net environmental flow as a result of climate change require ever-increasing reduction of usage, or a greater use of other sources of water.

There may be less environmental flow in *DIY* than indicated in the results as the changed approach to land management in *Control* and *DIY* (greater use of dry-land agriculture and more water capture in soils and vegetation) could also decrease runoff into river systems. However, this tension would be countered by increased productivity as this water effectively replaces irrigation.

The major area where the water tensions could potentially be reduced is through consideration of use of other water sources (desalination, recycling, reuse and storm-water capture). Various combinations of these would be expected within the scenarios. They would effectively amount to 'additional' water being put back in the system and counter the 'reduced' water available due to climate change.

DIY contains a preliminary attempt to account for increased urban and peri-urban food production, by reducing the water required from traditional irrigation systems for food production and releasing land from urban areas (also returning to food production). However, these changes will significantly underestimate the potential contribution of urban and peri-urban production, because:

- The land released has been returned to 'grazing' land rather than intensive horticulture, which does not allow for the use of alternative water and nutrient sources in peri-urban areas to replace irrigation or fertiliser demands elsewhere; and
- Fruit and vegetable requirements are made up at the expense of dairy, which overlooks the capacity to increase fruit and vegetable production without using 'new' agricultural land.

🕮	*Analysis and 'use' of alternative water resources for food production from reuse, recycling, desalination, stormwater capture etc. – especially in urban and peri-urban areas.*
🕮	*Accounting for effects of regenerative agriculture techniques to store and use 'green water'.*

[27] While it does not entail detailed, sophisticated hydrological modelling, the ASFF does account for different rates of evapo-transpiration under different land uses

4.2.3 Greenhouse Gas Emissions

The ASFF provides an approximated analysis of emissions compared to detailed emissions modelling undertaken in other dedicated emissions models and processes, however the general picture is revealing, and challenging.

As shown in Figure 4-1, all scenarios achieve substantial emissions reductions from the background scenario. However, even with very large assumed energy efficiencies, changes to the energy mix, and land use change to forestry (for carbon sequestration, bio-energy or both), greenhouse emissions reductions are overtaken by increasing population and consumption by 2030-2040 in both the *Adjustment* and *Control* scenarios.

Figure 4-1: Greenhouse Gas Emissions (All)

a) Victoria b) National

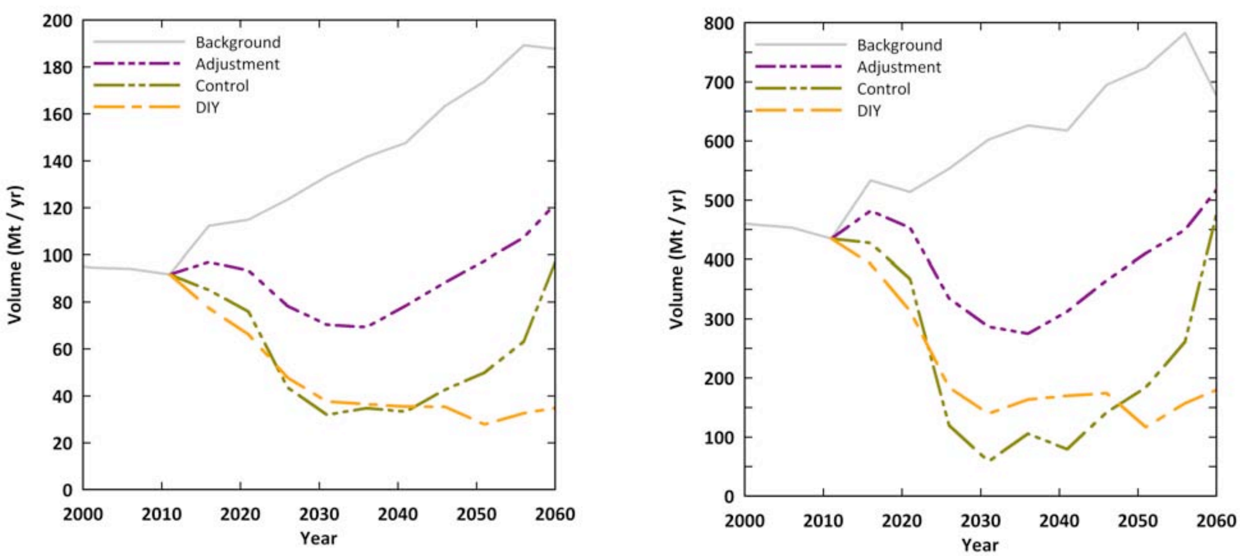


Table 4-5 compares the emissions reductions achieved with the target levels set for each scenario, compared to 1990 levels. It shows that while *Adjustment* and *Control* both overshoot (exceed) the targets set for 2030, only DIY is able to sustain emissions reductions out to 2060, primarily as a result of an overall reduction in energy and resource consumption.

Table 4-5: Achieved Emissions Reduction (On 1990 levels)

		Victoria			Australia		
		2020	**2030**	**2060**	**2020**	**2030**	**2060**
Adjustment	*Target*	*25-40%*[28]	*15-20%*	*45%*	*25-40%*[28]	*15-20%*	*45%*
	Achieved	0%	24%	+29%	12%	42%	+4%
Control	*Target*		*60%*	*80%*		*60%*	*80%*
	Achieved	15%	62%	+2%	27%	86%	+8%
DIY	*Target*		*60%*	*90%*		*60%*	*90%*
	Achieved	27%	57%	62%	35%	71%	63%

Key:	Exceeds target set	Reduction but doesn't reach target	No reduction	Increased emissions from 1990

[28] Included for reference to IPCC expectations for Annex 1 countries.

Each scenario entails assumptions and exclusions that affect the interpretation of greenhouse gas results, particularly where material and energy implications of described changes have not been accounted for in the model. For example, the large and early emissions reductions achieved in *Control* are enabled by rapid development of new infrastructure, but realistically there would be physical and financial constraints to transforming this fast (effectively overnight). For example:

- Shift to rail freight: would require either changes in production regions to match rail access and / or investment in additional rail infrastructure. The spatial implications of this change have not been analysed; and
- The rapid move to electric power for passenger cars and use of compressed gas for heavier vehicles (especially long freight) would require additional infrastructure and material/energy requirements, e.g., batteries and exchange or re-charging stations; compression for gas and pipelines for pressurised movement.

There are also significant sources of emissions that have not been included. Closer examination of these would increase emission estimates, such as:

- *Adjustment* assumes that Coal-to-gas and coal-to-liquid technologies would be able to be developed to 'offset' the large oil import reliance, but the emissions from these would be higher as "synthetic fuels derived from coal will produce a total of 2.5 to 3.5 times the amount of CO produced by burning conventional hydrocarbons" (MIT 2007); and
- Emissions from international travel and shipping are NOT included in the model. Therefore, implications of greater or lesser levels of international trade are not accounted for. These would be likely to reduce the emissions associated with the *Control* and *DIY* scenarios, relative to *Adjustment*.

There are also sources of emissions reduction that have not been taken into account. These could potentially help to ease the tensions, particularly where they are neutral or positive to the productive capacity of land. Examples would include:

- Sequestration of carbon in soil, including potential use of biochar, where it can occur in parallel with productive use (in agriculture and forestry) and/or improve productivity, reduce fertiliser and water requirements etc.;
- Reductions in nitrous oxide and methane emissions from livestock and cropping systems; and
- Use of organic waste for renewable energy production to reduce emissions from methane and provide renewable nutrient (fertiliser) sources.

These results do not provide easy answers to how Victoria or Australia would best achieve the required emissions reductions whilst balancing other nutritional, environmental and economic objectives. However, they do suggest that large reductions can be obtained.

The *Control* scenario suggests that it could be physically possible to achieve 80% reductions on 2000 levels (likely later than 2030 if allowance for infrastructure transformation is made). With application of additional measures from *DIY* (e.g. reductions in energy and transport demand), it could be possible to maintain these reductions out to 2060 and beyond, even with an increasing population. While the emissions reduction targets achieved in *Control* and *DIY* may well be beyond political or financial reach, and there are undoubtedly more complex technical and infrastructure issues than are included in this research, it does suggest that large emissions reductions are physically feasible.

4.2.4 Oil

The modelling has explored a range of strategies to reduce dependence on imported oil, including demand reduction, use efficiency, fuel substitution and mode change (e.g. road to rail). The high levels of fuel efficiency built in to all scenarios, equivalent to the energy efficiency levels seen across the economy, have a significant impact on the rate of increase in fuel oil demand, effectively balancing the increase in population. *DIY* has an additional demand reduction due to changed behaviour and economic structure.

> *Perhaps the first step is for governments to recognise that there is a looming potential problem and to begin to plan for it. Not only will this cushion the impact if it does occur, but many of the solutions to peak oil are also advantageous in the fight against climate change, thereby doubling the benefit of remedial measures* [Ingles & Denniss 2010].

This analysis reveals increased efficiencies and demand reduction are necessary but insufficient for a sustained reduction in demand for imported oil. It has also demonstrated challenges to any significant replacement of oil through fuel substitution, in some cases with direct impacts on food supply. These include:

- *Replacement with 1st generation biofuels:* very large loss of food product for a relatively small displacement of oil demand. The significant amount of land / crop required to reduce oil demand even to this degree is a strong reality check regarding how much 'free' energy has been made easily available through oil;
- *Replacement with electricity:* increasing demand for electricity and challenge in transitioning electricity supply network away from emissions intensive sources;
- *Replacement with gas:* requires substantial transformation of vehicle and refuelling infrastructure, greater use of gas for vehicles and power generation. Furthermore, the energy and material implications of these infrastructure transitions have not been accounted for and they may be significant.[29] The *Control* scenario sees strong signs of conventional natural gas depletion by 2060.[30] Unconventional gas (coal seam and shale) resources are likely to extend the life of gas technologies and infrastructure, but it is becoming evident that this will have direct impacts on land and groundwater availability and quality and thus for food production. Environmental and food production concerns may limit the development of these sources;[31] and
- *Replacement with coal-to-liquid fuels:* 2.5 to 3 times the greenhouse gas emissions of burning oil, therefore undermining emission reduction goals.
- There are some potential sources of oil replacement that are not included (qualitatively or quantitatively) in the scenarios, including the use of waste products (rather than primary crop); biogas and other 2nd / 3rd generation biofuels. These are a priority for further research.

In addition to these physical constraints, there are significant financial limitations to achieving these changes in the short timeframe required, including EROEI implications (with recent modelling raising real doubts about the availability of capital for these substitutions as the energy return on investment of current and future oil sources drops [Korowicz 2010].

As with greenhouse gas emissions, the scenarios reveal no easy answers for how the required reduction in oil dependence can be achieved. The significant structural changes explored leave a large reliance on imported oil in two out of the three scenarios. The assumptions around speed of infrastructure transformation in the *Control* scenario are optimistic (to say the least). The extent and success of diverse

[29] For example, "a Toyota Prius has 7 gallons of oil in every tire and many hundreds of gallons of oil in the plastics, sealants, paints, vinyl, rubber insulation and foam seats" [Ruppert 2009: 151].
[30] See http://peakenergy.blogspot.com/2008/06/no-post-tonight.html
[31] See www.gasland.com.au; http://www.abc.net.au/4corners/

strategies – starting now – will have major implications for the availability of food, both through the viability of production enterprises and the ability to distribute food.

🕮	*Relative resilience of the scenarios to future oil / energy trajectories:* Assessing the imminence or implications of peak oil, ability and cost of substitute other fuels or sources, and the relationship of the oil price to the ability of economies to grow are well beyond the scope of this project. There is increasing global attention to modelling the impacts of peak oil. In future iterations of this research, this information, and hopefully forthcoming Victorian and Australian analyses, would inform testing of the relative resilience of the scenarios to future oil / energy trajectories.
🕮	*Physical and commercial viability of rapid transition to other fuel sources* e.g. biofuel from waste products, 2nd / 3rd generation biofuels

4.2.5 Fertiliser (Phosphorus)

All scenarios retain large gaps between domestic production and demand for phosphorus fertilisers. All scenarios allow for some increase in Australian production of phosphorus, but nowhere near enough to substantially reduce import reliance.[32]

As Cordell [2010] has concluded (Figure 4-2), some of the largest potential for meeting of phosphorus requirements is through 'demand side' measures. Assumptions in the scenarios that constitute 'demand side' reductions include:

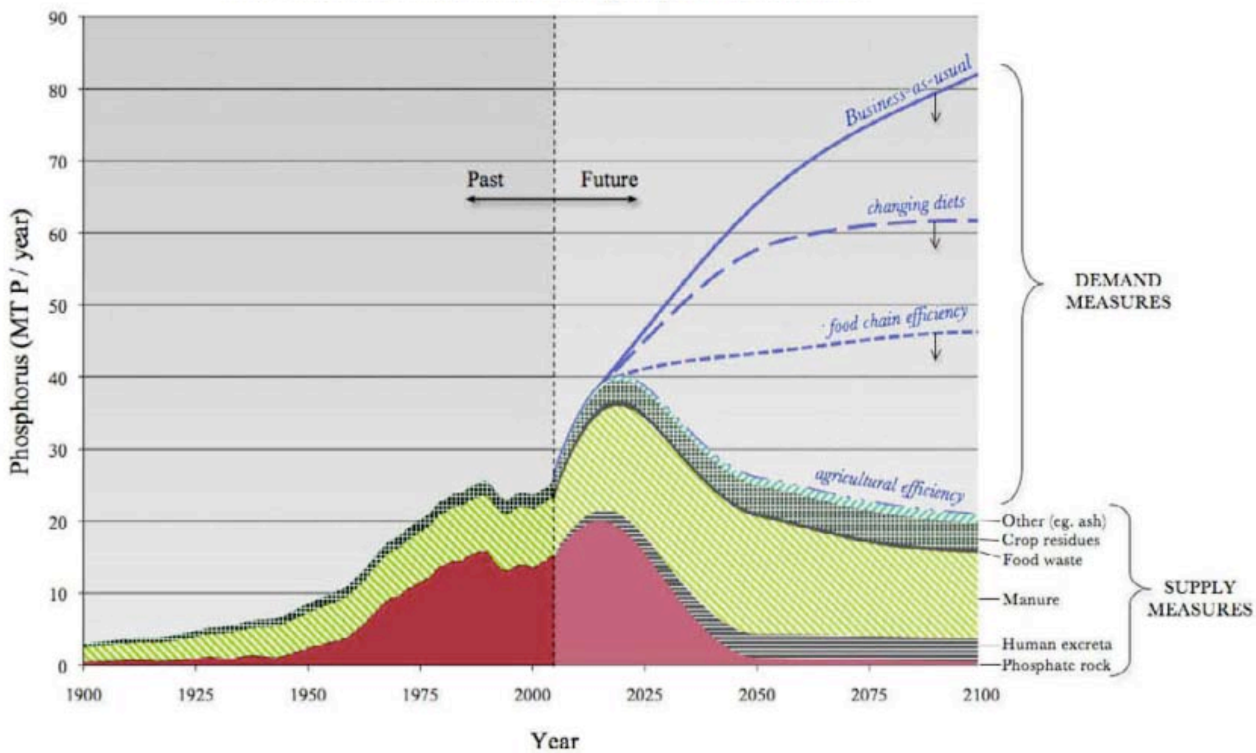
- *Changing diets*: the requirement for a nutritional diet modelled in this project has a significantly lower requirement for meat products than the Australian average. The *Control* and *DIY* scenarios also reduce the proportion of meat and dairy products being produced. This has an impact on phosphorus requirement;
- *Food chain efficiency*: the varying settings for waste and food chain efficiency between the scenarios also affect the amount of phosphorus that is lost or wasted through food chain inefficiencies; and
- *Agricultural efficiency*: all scenarios assume high rates of improvement in fertiliser efficiency, which reduce relative demand for phosphorus (to amount of food produced). As discussed in 4.1.3, the viability of achieving this (in the context of other energy and water efficiencies) could be the focus of future research.

Cordell [2010] also suggests potential contributions from supply-side measures i.e. development and use of alternative phosphorus resources. These have not been quantitatively modelled in this research, but would be likely to impact differently on the different scenarios and would be a priority for future work.

While handling of waste product as a potential input to other processes has not been accounted for in any scenario, this omission is of greatest disadvantage to the *DIY* scenario (and to a lesser extent to *Control*). The feasibility of using distributed nutrient sources such as manure, organic wastes and human excreta is highly dependent on where and how they can be used and the energetics of transport i.e. they are bulky and not necessarily suited to being transported long distances, particularly if there is a constraint on transport. This makes them more suited to diversified or mixed farming systems (where the animals spread manure across soil themselves) and more distributed or localised production where wastes can be returned efficiently (i.e. near urban areas where waste is concentrated). They are therefore likely to be more viable in a scenario (such as *DIY*) where there is a more distributed set of locally-adapted production and consumption systems.

[32] The qualitative *Adjustment* scenario allows for further sources of phosphate rock to be developed and used, potentially within Australia, to meet some of the demand – but this is not included in the quantitative modelling. Therefore, provided that this can occur, the gap between demand and production in *Adjustment* would be likely to reduce. It is also assumed that Australia's strong economic position and continued export of energy and minerals would enable any deficit to be met with imports.

Figure 4-2: Historical and Future Sources of Phosphorus Fertilisers
(Cordell 2010:124)



🕮	*Analysis and 'use' of alternative nutrient resources made available through mixed farming, organic waste reuse, urban waste capture etc.*
🕮	*Accounting for soil management practices to reduce phosphorus requirement and waste / runoff.*

4.3 Economic Structure

This analysis has clearly demonstrated the extent of the challenges in realistically decoupling continued growth in the economy (supported in part by a continued increase in population) from increasing energy use and greenhouse gas emissions.

The use of economic indicators within the ASFF gives an indication of the basic economic fundamentals, as grounded in actual production of goods and services within the economy, how much is surplus (exported) and required (imported), and how many people it takes to produce them. They do not attempt to take account of changing prices over the scenario period, not least because existing knowledge and modelling techniques are unable to reliably predict these. They do allow for an initial investigation into possible economic implications of the physical and structural changes in the scenarios.

The settings and assumptions in *Adjustment* are the least disruptive to the continuing balance of the economic indicators i.e. continuing to attain close to the 'ideal' background settings for economic stability. As well as the highest growth in GDP per capita over the study period, they also allow a reduction in net foreign debt. However, this reduction in net foreign debt does not account for potential but highly uncertain price variations in imports of strategic resources such as oil or food. High reliance on imported oil and food in *Adjustment,* means that fluctuations, instability or increased price for these resources will have the largest impacts on the trade situation. Presumably these would be countered by continuing large exports of energy and food products. While substantial early greenhouse emission reductions are achieved, over the longer term these are not decoupled from economic growth.

The *Control* scenario is the most effective in reducing long-term oil reliance, successfully decoupling growth in the economy from a reliance on imported oil i.e. GDP per capita continues to grow but requirement for oil imports reduces and stays low. However, early success in reducing emissions is not sustained, as the overall growth in demand and activity outpaces the large efficiencies achieved through technology and practice change.

DIY sees significant structural changes across the economy, reflected in the largest divergence from background 'ideal' settings. For example, although growth in GDP per capita is maintained to around 2030, it then stabilises and starts to gradually reduce. Overall per capita wealth is significantly lower than the other scenarios. This is mostly driven by the reduction in consumption per person that is applied across the economy, which relates to a lower throughput of goods and services per person, thereby generating lower demand for production or import of those goods and services. While this stabilised economic activity (reduced per capita) would be very challenging, it is this reduction in consumption that allows the large and sustained reduction in energy use, which in turn enables greenhouse gas emissions to be stabilised at a much lower level than in the other two scenarios.

In contrast with the other scenarios, *DIY* results in a surplus of the net foreign account balance. The substantial growth in the surplus relative to GDP is partly associated with less growth in GDP, but also reflects the reductions in imports due to lower consumption of goods. The high level of the surplus is not likely to be sustainable due to anticipated foreign exchange pressures in such a trading position.

Despite *DIY* being the only scenario that allows for a reduction in labour productivity (-2% per annum) to balance the high requirement for energy efficiency across the economy, there is a significant rise in unemployment as a result of reduced economic activity. However, the reduction in labour productivity is only applied to agriculture – increasing employment in what are assumed to be more labour intensive agricultural systems. A further iteration of this scenario could explore the affect on unemployment of a greater balance of energy efficiency requirements with labour productivity.[33] This would be expected to reduce unemployment. Lastly, there is no need to assume that a higher unemployment rate represents a higher number of people unemployed – the reduced costs to householders of a lower consumption lifestyle may well enable many to voluntarily reduce their paid working week and increase time spent (and value created) in the 'informal' economy. Such strategies could be consistent with higher levels of personal engagement in local activities envisaged in *DIY*.

The modelling allows for imported food, oil and fertilisers to meet demand where it cannot be provided domestically, assuming that the costs of doing so will be offset through production elsewhere in the economy (or reflected in the Net Trade Surplus : GDP indicator). As the constraints on these resources are global, not just in Australia – it is possible that this reliance will have broader economic impacts if food or energy prices rise significantly.

It is also important to note that regardless of what level prices for key resources reach, there are both physical and financial constraints on how much can actually be produced. For critical resources like oil, continually increasing prices are unlikely to be economically sustainable, reducing the capital available to access the remaining resource.

The use of economic indicators within the ASFF is a new development and will be the subject of further study and refinement (beyond the scope of this project). While far from conclusive, this analysis reinforces the common knowledge that the challenges and tensions of managing and allocating land and resources will significantly impact on future economic structure and viability. As stability in the price of

[33] It is estimated that use of one barrel of oil has the amount of joules, or energy, of up to 25,000 hours of human labour (at 40 hours a week, that's 12.5 years of labour for one barrel of oil). See, for example: http://money.usnews.com/money/blogs/beyond-the-barrel/2008/01/07/the-oil-drum-100-a-barrel-quickens-the-beat

key strategic resources (e.g. energy and food) decreases, the management of key domestic resources will become of increased economic significance, as well as being fundamental to achieving emissions reductions and stable food availability.

4.4 Vulnerabilities

This project has explored the extent to which resource allocation decisions can affect surpluses and deficits of core foods, as well as the extent of import reliance for critical energy and fertiliser resources. Whether these surpluses and deficits represent vulnerabilities that could seriously affect food availability would require further analysis.

The structural differences in the infrastructures of food supply explored in the scenarios would be likely to affect the resilience of each food system – the extent to which food availability can be maintained, or the food system can 'bounce back', in the event of shocks or rapid systemic change. The research was not able to explore these issues in any depth, although it is recognised that this is a critical test of the viability of the food system, one that will become increasingly significant as the impacts of climate change, peak oil and cascading impacts of other shocks impinge on global and local markets.

This section provides a brief discussion of how and why tensions revealed could foreseeably become significant vulnerabilities within the timeframe of the scenarios. Sets of interrelated disruptive factors include: prolonged weather events (e.g. droughts); sudden, extreme, weather events (like fires, floods and storms); disruptions to (or increasing costs of) imported resources (principally oil and fertiliser); and availability of specific foods required to cover areas of national deficiency.

4.4.1 Global Trade

Australia's (and Victoria's) current trajectory of increasing contribution from imported food is based on the assumption that it will lessen the cost of foods for the consumer, as well as increase the variety available all year round. Where other states or countries are in a better position to produce food and export it to us, importing food may allow us to reallocate our resources for other more economically productive activities. These assumptions strongly underpin the *Adjustment* scenario. However, there are signs that over-reliance on imported food could increase vulnerability in the future. These include:

- An increasing incidence of governments responding to domestic food security concerns by slowing or banning exports of food (and fertilisers) until basic national requirements have been met (similar to the trajectory of the *Control* scenario). While this response runs counter to the dominant free-market ideology, it is nevertheless one that is likely to increase as global food security concerns intensify.[34]
- Safety, quality and biosecurity concerns about some imported foods.
- The cost of moving products long distances is very likely to increase (with fuel prices), in which case the viability of doing so will decrease. This does not mean that food products will not be traded internationally, simply that transport costs will become a much more significant factor in competitiveness (or access to) domestically produced versus imported produce.
- There is increasing awareness of the potential for challenges to food and energy supplies (and associated price increases) to trigger social and political

> *Tight profit margins on food products, for example, will make some current sources unprofitable as the price of fuel rises and local suppliers become more competitive. Retail industries will need to either re-evaluate the 'just-in-time' business model, which assumes a ready supply of energy throughout the supply chain or increase the resilience of their logistics against supply disruptions and higher prices.* (Lloyd's Risk Insight 2010)

[34] The most recent example is Russia, which banned exports of grain following the loss of est. 26% of its total harvest to drought and wildfires [Seed Daily 2010]. As of February 2011, there are reports of China stockpiling wheat due to concern about the impact of domestic drought on wheat production. Estimates of up to 41% of the world's grain stocks being stockpiled in China suggest significant impacts on availability and costs of global trade. See for example, http://www.canada.com/business/China+grain+hoard+concerns+helps+lift+wheat/4281642/story.html

unrest and/or exacerbate conflict. These events can have immediate and lasting impacts on production and distribution systems within affected nations, as well as severely disrupting supply chains more broadly.

Research, development, knowledge and skills currently tend to be focused on those foodstuffs deemed most economical for local production, or on any anticipated challenge to the profitable production of dominant existing industries. In times of relative stability this knowledge base is important, but its very concentration could become a vulnerability if current patterns of food trade are disrupted. In the event of acute or prolonged disruptions to trade, there would be a lag time until land/resources could be reallocated to domestic production of core foods. Further, the irreversible loss or degradation of high quality productive capacity (e.g. land loss on the urban fringe) significantly reduces future options for ready availability of food.

4.4.2 Extreme Weather Events and Natural Disasters

This project has taken an aggregated view of the impacts of extreme events on the food system, by building in a large 'waste' component, to different degrees in each scenario. This is an extremely crude mechanism for considering the potential impacts of extreme events on food availability. To improve the understanding of food system vulnerabilities to a changing climate – and in particular to extreme events – further analysis would need to consider:

- Impacts of production losses to key food products (rather than uniformly across the system), at different times of year and the impacts on medium-long term viability of producers; and
- The direct impacts of climate change on infrastructure critical to the food system. A review of potential climate impacts on food distribution [Larsen and Estrada-Flores 2011] found many examples of impacts but no coherent analysis of risk and vulnerability. Concerns were expressed through the workshops about: the potential impact of power disruptions on food storage and distribution; long-term and/or acute vulnerabilities in transport infrastructure; and the ability of some people to physically access food during extreme events.

It is likely that the structural differences between the scenarios would have an impact on the extent to which extreme events disrupt food availability and stability. This is an important area for further research.

4.4.3 Biodiversity & Biosecurity

Yields within food production systems are affected from year to year by the extent of losses to (or competition with) pests and weeds. As with extreme weather events, these losses have been broadly included within the large waste buffer built into the analysis. However, they are also more likely to be localised in place, time or food type and therefore have a potentially more significant impact on availability of a nutritious diet than is reflected by the overall average.

The changing climate will impact on the distribution of pests and weeds as changing conditions affect where they can take hold, but also potentially weakening the defences of stressed plants and animals (e.g. during drought periods). Exposure to new and emerging biosecurity threats is also an inherent by-product of global trade of food and other products. Ecosystem services provided to agriculture include pollination, soil restoration, water purification and pest management. The decline of these services, or sudden loss if ecosystems pass 'tipping points', represent significant vulnerabilities to food production.

While this project has not had the scope to analyse it, vulnerability to biosecurity challenges would be expected to be very different within these three scenarios. 'Biodiversity'– diverse biota of both plants and animals – is an important indicator of health and resilience in ecosystems. The extent of biodiversity within both native and agricultural ecosystems, as well as diversity generally in food production systems, are likely to be important defences against changing weather conditions and biosecurity challenges.

4.4.4 Population

Surplus food for export is often interpreted as an ability to easily feed a much higher population, leading to statements such as "Australia produces enough to feed 60 million people" [McKenzie 2010]. However, this project has demonstrated that total food does not mean sufficient food for a nutritious diet – an export surplus in some food products does not mean that Australia could actually feed 60 million people. This work suggests that there will be challenges in domestic provision of adequate foods for a population of 36 million, let alone 60.

The population scenario used as the base for all three scenarios is the median ABS scenario i.e. based on their analysis of birth and death rates, demographics, immigration and emigration etc. In all scenarios, a reduced or stabilised population within Victoria or Australia would potentially make balancing the challenges easier and potentially deliver higher export surpluses. However a global context of continuing population growth, coupled with expectations of potentially significant numbers of climate refugees (including in the Asia-Pacific region), would make stabilising (let alone reducing) Australia's population extremely challenging. The implications of attempting to do so in the continuing context of Australia's relative wealth of resources, raise political and ethical issues of international significance.

While this project has indicated that it is likely to be possible to meet the food availability needs for a much larger population (if significant structural change occurs), the sensitivity of this result to population size – or to sudden increases in population size – has not been explored. A 'shock' that was suggested in the workshops was the need to accommodate a large and sudden influx of climate refugees – potentially leading to an abrupt (rather than gradual) population increase. Within this context, population distribution was discussed as a potentially significant response.

Investigating the impact of 'shocks' and the relative resilience of the different scenarios.

Outlier events / shocks were not incorporated as formative parts of the baseline scenarios. While it would be possible to explicitly design scenarios that show up vulnerabilities in food availability (e.g. 25 million climate refugees; China banning exports of all fertiliser etc.), it was considered more useful to define the scenarios in terms of their structural differences. Further research could focus on the relative resilience of the different scenarios to these events.

4.5 Opportunities – The Sweet Spot

In times of increasing uncertainty the only way to predict the future is to design it[35]

For Australia's future development, addressing the issues and challenges explored in this project will require substantial reconfiguration of the food system. While no scenario provides an 'easy answer' to how this can or should be done, the scenario descriptions, rationale and analyses reference a wide array of opportunities and responses that could be applied in meeting future challenges.

The scenarios are not complete – they do not try to cover every base and consider every possible pathway. They are also not competing – there is no winner which should then guide the direction taken in policy or planning decisions. The differences and similarities between these scenarios are to a significant degree, quite arbitrary. Therefore, translation of lessons from the scenarios does not require boundaries to be maintained or any sense of adherence to type. While use of ICT to enable farmers to learn from old and emerging eco-agricultural practices around the world is a feature of *DIY*, there is no reason why this would not also occur in a world that has high levels of global trade (*Adjustment*) or government intervention (*Control*). Similarly, maintaining the level of internet connectivity and use of ICT that is the hallmark of *DIY*, implies some priorities for investment in infrastructure that presumably

[35] Variously attributed to Alan Kay, Buckminster Fuller, Peter Drucker and Abraham Lincoln

has to come from government or corporations even if there is significant local small-scale innovations (as the scenario implies).

Significant opportunities that are referenced in the qualitative scenarios but have not been accounted for in the quantitative analysis include: use of waste-water; re-cycling of organic waste and other products to produce energy, food and fuel; reduction of emissions in agriculture and sequestration of carbon in soil; next generation biofuels, and so on. It is likely that these could make significant contributions to easing the tensions identified and should be priorities for further research and action.

This is not a challenge unique to Australia; in the conduct of this research it became clear that many countries and regions were already grappling with the issues we explored and in many contexts the need for innovation is being given a high priority.

4.6 A Fine Balance – Ethics

The authors of this report note that the issue of food availability to domestic populations is far from the only consideration in allocation of state, national or international resources, particularly in light of rapidly increasing concern about global food security. As a resource rich country, with a relatively small population, Australia's present decisions about resource allocation will have implications for food availability in populations much larger than our own, and for many years to come.

The greatest challenge we face is to respond to the tensions discussed throughout at both a local and global level, and to ensure that our response is genuinely effective and sustainable, but also *ethical*. The complexity of achieving the physical balance between food production, the condition of natural resources, greenhouse emissions, energy, urban development (etc.), as has been considered in this project, is in reality compounded by a much broader range of policy and ethical issues.

It is far beyond the scope of this project to suggest how these issues should be approached, but it would be remiss to not acknowledge these dimensions as the context in which the physical challenges must be addressed. There are a number of articulations of ethical frameworks, often developed through complex multi-party processes, which can potentially help us to frame and understand the broader implications of our decision-making at this critical juncture point. These include:

> *Even more important, however, is the need for Australia, as a major food exporter, to contribute to meeting the global food task and thereby prevent the potentially disastrous consequences of major food shortages* [Select Committee on Agricultural and Related Industries 2010].

- The United Nations Millennium Declaration: "We recognize that, in addition to our separate responsibilities to our individual societies, we have a collective responsibility to uphold the principles of human dignity, equality and equity at the global level. As leaders we have a duty therefore to all the world's people, especially the most vulnerable and, in particular, the children of the world, to whom the future belongs." [United Nations 2000]
- The Earth Charter: "We must join together to bring forth a sustainable global society founded on respect for nature, universal human rights, economic justice, and a culture of peace. Towards this end, it is imperative that we, the peoples of Earth, declare our responsibility to one another, to the greater community of life, and to future generations." [Earth Charter Initiative 2011]

Issues of global resource allocation will always involve actors with more power than others – use and control of land, labour (and climate) for food is often decided by those with money. Trade operating within a global market framework inevitably includes extreme disparities of wealth and power, therefore there are ethical issues (as well as economic) involved in decisions about what we trade and with whom.

The call to 'feed the world' cannot be used as a justification for maximising production value domestically if that means undermining farming livelihoods elsewhere in the world, or further degrading the resource base that enables food to be produced at all. The decisions made now about allocation of land and resources in Australia will have implications far beyond our borders and far into the future. They therefore need to be made carefully and with due consideration of their wider impacts. Some critical questions worthy of full consideration are briefly listed below.

- Are there ethical implications of securing domestic food availability at the expense of export surplus?
- What are the ethical implications of securing domestic food availability from imported product where this shifts environmental damage or resource depletion from Australia to less wealthy nations?
- How do we recognise the needs of the vulnerable (those who cannot pay) when balancing competing interests for food products and the resources to produce them – feed for animals vs. feed for cars vs. feed for domestic pets vs. feed for people?
- Do Australian food commodity exports necessarily improve food availability or security in receiving nations?
- Can the export of high-value food products that may be highly processed, energy dense and nutrient poor be said to be making a contribution to food security? Or should they be considered separately as increasing choices for those who are already food secure?
- How can issues of cost and access for consumers best be reconciled with fair and viable livelihoods for producers and land managers?
- To what extent, or in what circumstances, should foreign ownership of critical resources be restricted? When does foreign investment become a resource or land-grab that undermines long-term national interests?
- How can global efforts to improve food security also support the rights of people to local food sovereignty – determination over what, how and who provides their food?
- Where does the responsibility for the maintenance of genetic diversity in foods lie? Where does the responsibility for unintended side-effects or externalised costs of agricultural technologies lie?
- In a world facing significant challenges to the availability of healthy food how should we balance – ethically – the priorities of our economic development?

5. Conclusion and Next Steps

There are resource allocation and management decisions being made now in Victoria, and Australia, that will have significant implications for the flexibility and options for our food supply in the next decades and for future generations of Australians.

This research has explored how these decisions could impact on our ability to provide a reliable surplus of the foods required for a nutritious diet, whilst providing for ongoing health of the environment, the economy and ultimately the wellbeing of people and communities (both farming and urban communities).

In this project, we have developed and tested scenarios to explore food availability and investigate its interaction with population, balance of trade and employment. We have varied: energy demand, efficiency and sources; allocation of land and water resources; levels of waste and losses; levels of water and fertiliser efficiency in agricultural production; and the strategic approach taken to securing food availability.

The research made new use of an existing physical model of the Australian economy developed by CSIRO (one of the project partners) to track the complex interaction of land and resource systems as they affect the availability of food. The research was undertaken within strict time and resource constraints and there was consequently a limit to the analysis of data sets and settings. The assumptions, approximations and generalisations are noted throughout the report.

The tensions identified through this work are significant, in spite of levels of uncertainty resulting from the project constraints. They strongly suggest that a sophisticated and strategic approach to resource allocation is urgently required, if the multiple objectives of food security, energy security, greenhouse emissions reductions, sustainable resource use, a healthy environment and a viable economy are to be achieved. The outcomes do not provide any easy answers, or suggest that one approach to these issues is clearly better than another. It sets out a framework for more detailed investigation of some very critical questions, by developing and demonstrating a methodology that can be extended to test various options for 'food security policy'.

Key findings include:

<u>All foods are not created equal</u>

The project shows that under the expected future conditions (climate change, increasing population and diminishing availability of oil), the domestic production of a surplus of required foods – at either Victorian or Australian level – must not be taken for granted.

By considering the needs for a nutritious diet, rather than the diet as typically consumed, this project has revealed early and immediate tensions in availability of the foods required. An overall surplus of 'food products' is not the same as production of a nutritionally adequate food supply.[36] Net food availability in the different scenarios (as summarised on Table 4-1) reveals tensions in providing for a nutritious diet, including:

- Australian production of fruit and vegetables already falls short of providing sufficient serves of these foods to meet the recommended food intake patterns;
- The *Control* and *DIY* scenarios reallocate land from one type of production (grazing) to another (fruit and vegetables) in an attempt to maintain sufficient production of required foods at a national and Victorian level respectively. This is successful in providing fruit and vegetables but creates other tensions, resulting in shortages of dairy (by 2030) and lamb (by 2060);

[36] Nutritional health requires both adequate amounts of food to meet human energy requirements and adequate variety of foods to provide the diversity and amounts of nutrients required.

- Some food crops can be used as biofuels. Two of the scenarios see diversion of cereals, sugar and oil crops to 1st generation biofuels, with *DIY* producing a serious conflict between food and fuel by 2030;
- In all scenarios, Victoria becomes a net importer of cereals by 2030. Australia retains a cereal surplus to 2030, but it is in steady decline in all scenarios.

<u>No such thing as a free lunch</u> – ultimately the successful provision of food is determined by the bio-physical factors necessary for its production (land, soils, sunlight, nutrients, feed-stocks) and the availability of resources required for organising production, processing and distribution. The scenarios test challenging, but realistic, possibilities for change to availability, allocation and use of resources. These changes result in critical and unresolved 'tensions' between:

- Availability of a nutritious diet (net surpluses and deficits of the required foods);
- Use of land and water resources;
- Targets for reduction in greenhouse gas emissions;
- Levels of import reliance for oil and fertilisers; and
- Settings for key economic indicators (i.e. GDP; unemployment and trade balance) that are considered representative of healthy economic activity.

These unresolved tensions in the results point to a need to investigate the above issues in greater detail. For example, a net zero environmental flow in key river systems is not an acceptable (or viable) outcome. Similarly, constraints on global oil supply or domestic gas could mean that the energy use assumed in this work is either not possible or prohibitively expensive. Testing how and whether these tensions can be resolved becomes a priority for further work.

5.1 Research

5.1.1 Development of Methodology

This project has been supported through the Healthy Eating stream of VicHealth's research innovation grants, which provide 12-month's funding to trial an innovative idea or research a new concept or methodology relevant to the theory, policy and practice of health promotion.

The primary purpose of this project was to develop and demonstrate a new methodology to link land and resource use with availability of a nutritionally adequate food supply for Victoria's population. This has been achieved.

The more specific objectives of this project were:

a) Engage a diverse group of stakeholders in thinking about challenges and opportunities for the future of Victoria's food system and in the development of a set of qualitative scenarios for the future;
b) Investigate potential applicability of stocks and flows framework models to explore questions related to food systems and build modelling capability; and
c) Find and include data sets in the model (build capability) and identify gaps; and
d) Conduct initial explorations of some plausible future scenarios and their implications for availability of a nutritious diet; emissions, environment and resource use; and key economic indicators.

Within the limits discussed throughout the report, these objectives have also been achieved. While doing so, the project has built the capacity of the ASFF as a platform for on-going 'what-if' investigation of the security of the food supply for Australia/Victoria by:

- Updating data related to agricultural production and calibrating for changes over the last decade;
- Developing modules for transition of land from agriculture to carbon sequestration (through forestry) and bioenergy;

- Identifying freight requirements associated with food, enabling these to be independently adjusted;
- Updating the 'food required' calculators to match calculated nutrition requirements (plus waste) rather than adapting to match production; and
- Assessing implications for environment and resource management of those scenarios.

5.1.2 Research Extension – What Next?

Use of the ASFF is similar to how a pilot learns from experimenting in the computer environment, to avoid crashing the aircraft in real-life [Dr Graham Turner, CSIRO]

The large investment that has already been made in developing and populating the Australian Stocks and Flows Framework has established a significant and valuable capability that can help us to navigate the many uncertainties we face – including the implications of these for food availability. While this project has demonstrated the potential of this capability, it is far from delivering a fully functional tool for analysis of Victoria's (or Australia's) food system or food availability.

Research extensions to this project would all involve further development of this physical modelling capability for greater understanding (and improved adaptive management) of complex change in the food system, and to further inform policy and practice. Priorities would be to conduct more detailed analysis of key tension areas, to work to resolve tensions (to test whether and how this could be done) and to evaluate issues of resilience. This project provides a strong foundation for the identification (in collaboration with policy-makers), of policy opportunities, gaps and barriers across the food system and how potential policy interventions might be prioritised.

There are essentially five directions that research extension could take (ideally concurrently):

1. The Scenarios – Undertake further iterations of work to refine the analysis of these three scenarios, with deeper analysis of appropriate settings for the key drivers and a closer investigation on whether and how key tensions could be resolved.
2. Monitoring and Policy Assessment – Focus on refining spatial and technical detail in the ASFF to build state, national or regional capabilities for monitoring challenges to food availability, and to inform resource allocation policy where sustainable provision of nutritious diets needs to be a consideration.
3. Design New Systems – Further refine spatial and technical capacity in the ASFF, but with an applied focus on the design of more resilient and sustainable food production and distribution systems i.e. attempt to build 'normative' scenarios in the model to inform development of those systems in practice.
4. Identify cost-effective policy priorities for food security in the face of population and environmental change – Food policy research is essential to provide information to help translate the present project's preliminary findings into policy actions to reform the food system and promote food security.
5. Linking Physical, Economic and Social Modelling

Within a project of this size it has not been possible (nor would it have been productive) to thoroughly research all settings and assumptions at the outset, as a great deal of effort could be spent refining variables that turn out to be of little significance. In all cases, building the capability to consider the factors included in Table 3-3 provide strong starting points for more refined analysis. Other outstanding questions and areas for further refinement have been touched on throughout this report. Prioritisation of these research areas would depend on the purpose and audience of the extended research, described in more detail in Appendix 6.

5.2 Policy Implications

5.2.1 Informing Decision Making

A key question arising from the analysis is about how use of limited and contested resources can be optimised to meet critical objectives. This raises fundamental issues about how we frame decisions about land and resource use, particularly in light of concerns about food availability. Are the critical objectives 'profit' or 'productivity', or 'resilience' and should we plan for short-to-medium term targets (on the assumption of future technological gains) or do we focus, now on the long-term public good based on conservative technological assumptions?

The committee is therefore of the view that governments around the world, including Australia's, must plan for the food needs of the population into the long term future. Such planning should begin in earnest as of now. (Select Committee on Agricultural and Related Industries 2010).

For policy makers, the challenge is to optimise use of land and resources for the public good, ensuring that appropriate incentive structures stimulate private enterprise and innovation to this end. Given the long-term constraints, using price as the only mechanism to determine the flow of land and resources in the short term (i.e. to highest value use) could effectively reduce the resource base and options available to meet critical public needs in the longer term, particularly where this movement is irreversible.

Sensible and strategic decision-making about how resources are used needs to be informed by an evidence base that accounts for physical realities as well as economic drivers. This project has revealed five areas of physical constraint that require immediate policy attention:

- The on-going provision of a nutritious diet, to a potentially much larger population, needs to be a fundamental consideration in resource allocation policy and decisions. If domestic provision of basic nutritional requirements for the population is a priority, then this needs to be planned and accounted for in policy concerning land and water allocation. This project has provided a framework for development of a capability to do so at either State or National level, and could also be refined for use at a regional or catchment level.
- The need to rapidly reduce greenhouse gas emissions will stimulate changes in land use that will have implications for food availability, particularly through incentives for carbon sequestration in soils and vegetation and the development of renewable energy. The development of these policies needs to understand and adequately value food provision, incentivising 'win-win' land uses with multiple benefits (sustainable food production as well as sequestration and energy production).
- Global oil production has peaked leading to an increasing degree of vulnerability from with import reliance for critical population requirements. Peak oil has significant and potentially imminent implications for the food system (and broader economy) in Australia. Reducing reliance on imported oil and oil products will require major structural change. While the implications of this change extend well beyond the food system, the fundamental importance of food availability to population health suggests that an action plan to reduce reliance on oil within the food system should be prepared as a matter of priority.
- Similarly, the critical dependence on phosphorus for food production coupled with inevitable scarcity of fertiliser products from conventional sources, requires an immediate evaluation of how to reduce waste and value and re-capture nutrients – particularly phosphorus – from all sources.
- The tensions revealed by this project, as well as the global context of increasing food security concerns, suggest a need to value the actual nutritional contribution of food and agricultural products in the allocation of resources for their production.

5.2.2 Specific Policy Tools

The way the assumptions and variables are defined in this work point to where more specific policy tools may be applied, and can inform policy frameworks for considering these issues. Key areas for policy consideration are:

- Reducing and more effectively utilising waste – closing cycles and increasing resilience of production and distribution systems (reducing extent of losses to extreme events);
- Obtaining multiple outcomes from land and resources, including: 'mosaic' farming for food, energy, biodiversity and carbon sequestration; and urban and peri-urban food production to utilise 'waste' water and nutrients concentrated in population centres;
- Preventing irreversible loss of food production capability and food producers, particularly relating to critical and non-substitutable foods (e.g. fruit and vegetables);
- Regenerating soil quality and capability to meet the challenge of reduced fertiliser availability;
- Reducing overall energy and transport demand in both household (passenger) and industrial (freight) sectors;
- Technology and practice change for energy and fuel efficiency, including development of substitute transport fuels and transformation of the transport system;
- Developing alternative water and nutrient resources that do not impose additional energy costs; and
- Develop strategic approaches to deal with potentially prolonged challenges to food availability or security be handled? Could the welfare and emergency food systems cope with extended price impacts of food availability issues?

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Appendix 1: ASFF Internal Logic

Two of the major modules in Figure 2-3 (the boxes with round corners), representing demography and the primary industries, are driven exogenously and have only data flows exiting them. For example, the Australian population provides a labour force (blue solid line), which is subsequently compared with the requirement for labour created by activity in all industries (red dashed line exiting the box around all industries). A population consumes food and other non-durables, and needs dwellings and other buildings (for offices, education, health services, etc.), and personal and public transport. Consequently, the requirements of the Demography component drive the Consumables, Buildings and Transport components. The latter is also driven by requirements for transport services that are related to the building stock, such as urban freight.

The requirement for manufactured goods and infrastructure drives the modules in the Secondary Light Industry component. Additionally, discards of goods, durables and decommissioned infrastructure are potentially recycled in Secondary Light Industry. Manufactured goods can be sourced from overseas, so the Secondary Light Industry generates a requirement for imported goods (dealt with in the International Trade component). Likewise, manufactured goods may also be exported from Australia (also informing International Trade calculations).

The functioning of Buildings, Transport and Secondary Light Industry collectively creates (with the Primary Industries) a requirement for materials, fuel and electricity from Secondary Heavy Industry ('Basic Materials and Energy'). Allowance is also made for secondary materials/energy that are imported (to satisfy domestic demand of the other industry sectors), or exported from Australia after domestic production. This module employs a physical Input-Output process (that also incorporates evolution of productive capacity) to calculate the primary materials required.

Separately, the exogenous Primary Industry component produces primary materials from agriculture, forestry, fisheries and mining. This information is compared in International Trade with the requirement from Secondary Heavy Industry for primary materials. Conservation of mass implies that if there is insufficient domestic production of primary materials in a scenario, then primary materials are imported to satisfy the domestic demand as calculated from above; alternatively if there is excess domestic production of primary materials, they are exported. Along with the imports and exports of secondary materials and goods, and international travel (driven from the Demography component) and invisibles, the International Trade component consolidates the trade balance (in financial units, using prices in combination with the physical flows). The trade balance is one of a collection of "tensions"; an excessively large positive or negative trade balance flags an unlikely international trade situation (which can be solved in a feedback, as described in the following section).

Other tensions may occur, located in the Natural Resources and Labour components, where requirements are compared with provisions (the comparison is represented by opposing left and right arrow heads). The requirement for land, water and labour is gathered from the individual requirements in each of the economic activities represented in the prior components. Unemployment is an obvious tension between higher labour availability and lower requirements, while the opposite i.e., more workers required in the economy than is available in the labour force is also a tension, though one that is not physically feasible. Similarly, it is possible to produce a preliminary scenario where water required is greater than available resources, or more land required than land-mass.

Appendix 2: Scenario Influences

Overview of Scenario Review

Scenario-Based Projects Considered

GLOBAL	
UNEP Global Environmental Outlook 3	Four scenarios to explore what the future could be, depending on principally different approaches to policy making: • Markets First • Policy First • Security First • Sustainability First Narrative descriptions of possible futures, which are supported by quantitative scenario analysis.
EU	
ESF/COST Forward Look Scenarios	The four scenarios that have been defined in the ESF/COST Forward Look were named after the buttons of a tape recorder: what could happen to European food systems if we press the button “fast forward”, “pause”, “rewind” or “play”. The four scenarios are related to the identified driving forces, in particular to the drivers on economic growth and global markets and policy development. The two axes defining the scenarios are: • Low Crisis Impact / Incentive to Act VS High Crisis Impact / Incentive to Act • Globalised Markets VS Regional Markets European Science Foundation (ESF) & European Cooperation in Science and Technology (COST) ‘Forward Look on European Food Systems in a Changing World’, (2008) available at http://www.esf.org/
EEA Prelude	Land-use scenarios for Europe: qualitative and quantitative analysis on a European scale. Five scenarios developed: • Great Escape; (Europe of contrast); • Evolved Society (Europe of harmony); • Clustered Networks (Europe of structure); • Lettuce Surprise You (Europe of innovation); • Big Crisis (Europe of cohesion). European Environment Agency (2007), *Creation of scenarios focused on land use issues in the EU*
Ground for Choices (1992)	Four scenarios examine a range of possible futures for Europe’s rural areas, related primarily to different societal priorities regarding free market and free trade, regional development, and the protection of nature and environment. • Free Market & Free Trade • Regional Development • Nature and Landscape • Environmental Protection
EUruralis – European Land Use Scenarios	Examines current policy issues in EU rural areas depicting land use changes as a result of driving forces shaping land use and agriculture in Europe. Four contrasting scenarios, based on the IPCC-SRES scenarios. • Global Economy • Global Co-operation • Continental Markets • Regional Communities
Standing Committee on Agricultural Research (SCAR)	Europe’s Foresight expert group formulate scenarios based on a 20 year perspective to identify long term research priorities. The primary focus is on food production systems, however under the ‘food crisis’ scenario, food consumption, packaging and health systems are highlighted.

Foresight Project	Four disruption scenarios are compared to a baseline scenario; • Climate Shock • Energy Crisis • Food Crisis • Cooperation with Nature
UK	
Thinking about the Future of Food (Chatham House)	• Just a Blip (food prices trend down, system structure unchanged) • Food Inflation (food prices up, structure unchanged) • Into a New Era (food prices down, new system structure – agroecology) • Food in Crisis (food prices skyrocket, system change)
Future Scenarios for the UK Food System (Food Ethics Council UK)	• A Lot of Allotments • Pass the VatBeef QuickNoodle • Cash Rich, Time Poor, Experience Hungry • Carry on Consuming
Australia	
Paddock to Plate: Possible Agricultural Futures (Andrew Campbell for the Australian Conservation Foundation)	Snapshots of four potential trajectories for Victorian agriculture and food production. Each snapshot contains a mix of: type and application of new technologies; the prevailing policy and institutional framework at local and national levels; the extent of engagement with world markets; the regional social and economic context; and finally prevailing community attitudes and norms. • Corporate HiTech • Landscape Stewardship • Back to Earth • Farming like an Australian
Future Scenarios for Energy Descent (David Holmgren)	Scenarios developed to explore how the simultaneous onset of climate change and the peaking of global oil supply may impact globally and on Australia, noting that climate change and peak oil both limit potential responses to the other. Axes of the scenarios are speed of oil decline (slow vs. fast) and severity of climate change (benign vs. destructive) • BrownTech (slow oil decline with destructive climate) • GreenTech (slow oil decline with benign climate) • Lifeboats (rapid oil decline and destructive climate) • Earth Steward (rapid oil decline and benign climate)
Victoria	
Scenarios for Agriculture in the South West (DPI Victoria)	Aimed to develop different, challenging, contextual scenarios to provide insights into the current global trends and future uncertainties that are likely to impact on Victorian agriculture in the coming decades. The DPI VCCAP scenarios are centred around 3 of the series of climate projections developed by the Intergovernmental Panel on Climate Change (IPCC). • A1FI: A 'worst case' climate projection based on high global economic growth and fossil fuel use • A2: A divided world rather than a co-operative world, where the focus is on implications for trade as well as a gradually worsening climate • B1: A 'best case' climate projection based on a major global shift to renewable energy, and the opportunity which this creates for multi-purpose use of agricultural land
Irrigation Futures of the Goulburn Broken Catchment (2006-07)	Irrigation Futures was a collaboration between a range of regional, state and national organisations, managed by DPI Victoria and the CRC for Irrigation Futures, which explored the future of irrigated agriculture in the Goulburn Broken region. • Moving On • New Frontiers • Pendulum • Drying Up

Adjustment

Project	Scenario	Description
UNE Global Environment Outlook 3	Markets First	Market-driven development converge on the values and expectations that prevail in industrialised countries
EU Ground for Choices	Free Market and Free Trade	Agriculture is primarily an economic activity: economic criteria determine where agricultural production takes place
Eururalis	Global Economy	Highly globally integrated, low regulation
PRELUDE	Great Escape	International trade (globalisation), decreasing solidarity, reduced policy intervention
ESF Forward Look	Fast Forward	More global markets with a low incentive to act: A future shaped by the combination of continued economic globalisation, the expansion of global food markets and decreasing pubic concerns about climate change, energy scarcity and food safety scares
	Pause	Still global markets but a higher incentive to act, focus on food safety
Chatham House	Food Inflation	Demand for food grows with population and slightly outpaces supply, as Asian meat consumption grows and weather losses mount. High energy prices support the push for biofuels and raise fertiliser prices. The push for increased supply encourages investment in new production technology. Productivity improves but input costs and food prices remain high.
Paddock to Plate	Corporate HiTech	Large scale, vertically integrated operations, generic commodities, functional foods and nutriceuticals targeting world markets

Time to Take Control

Project	Scenario	Description
EU Ground for Choices	Regional Development and Nature & Landscape	Maintaining agricultural employment is a key driver. Market forces, including import and export are heavily regulated
UNEP Global Environment Outlook 3	Policy First	Strong actions are undertaken by governments in an attempt to reach specific social and environmental goals
Eururalis	Global Co-operation	Highly globally integrated, high regulation
PRELUDE	Big Crisis	Growing environmental awareness (after crisis), growing solidarity and policy intervention (centralisation)
	Evolved Society	Energy scarcity and shift to renewable resources, growing environmental awareness, policy intervention (regional development)
ESF Forward Look	Pause	Globalising markets and higher perception of risk
	Rewind	Higher awareness of impact and incentive to act with regionalised focus
Chatham House	Into a New Era	Oil supply tightens as peak oil arrives. Climate change is stark and weather-related crop losses mount. International carbon pricing is agreed and environmental regulations get tougher, restricting energy use and inputs. Under these conditions, fundamental long-term supply constraints become apparent. The problems of the existing agricultural paradigm are accepted and production gradually shifts to an eco-technical approach
Paddock to Plate	Landscape Stewardship	Trend towards diversification and extensification, where rural landscapes are valued as arenas of consumption as well as engines of food, fibre and clean energy production

DIY

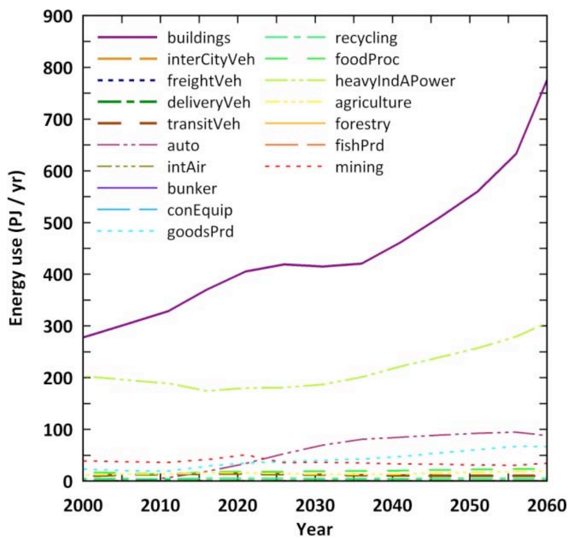
Project	Scenario	Description
Millennium Ecosystem Assessment	Adapting Mosaic	Regionalised approach that emphasises proactive management of ecosystems, local adaptation, and flexible governance
Eururalis	Continental Markets	Regional focus, low regulation
	Regional Communities	Regional focus, high regulation
PRELUDE	Lettuce Surprise U	Technological innovation (including surprises), growing environmental awareness and reduced policy intervention (decentralisation)
ESF Forward Look	Rewind	Higher awareness of impact and incentive to act with regionalised focus
	Play	Regionalised markets and low perception of risk
Chatham House	Food in Crisis	New diseases and water shortages bite etc. . . .
Paddock to Plate	Back to Earth	Many communities on the eastern seaboard of Australia approach self-sufficiency with a wide range of locally produced foods.

Appendix 3: Additional National Results

Adjustment

Figure A-1: National Electricity Demand / Use (Adjustment)

a) All sectors



b) Minor sectors
('heavy power and industry' and 'buildings' removed)

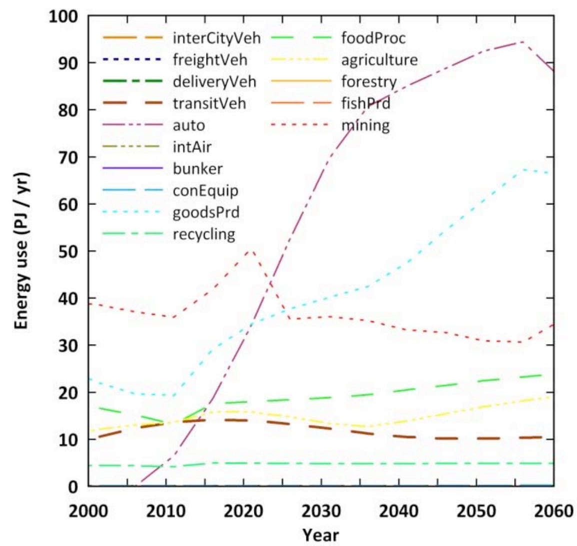
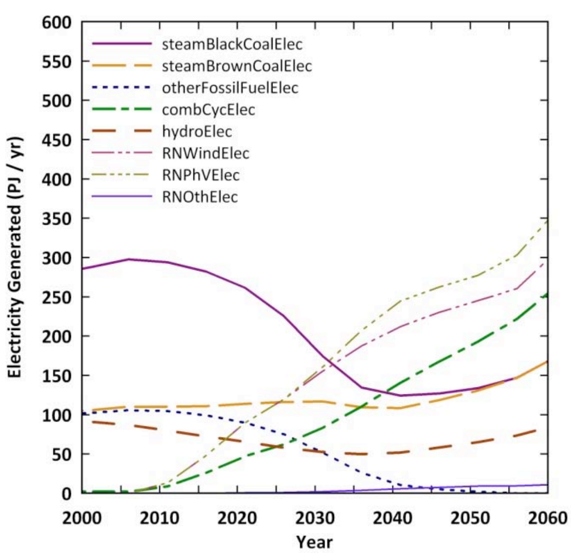
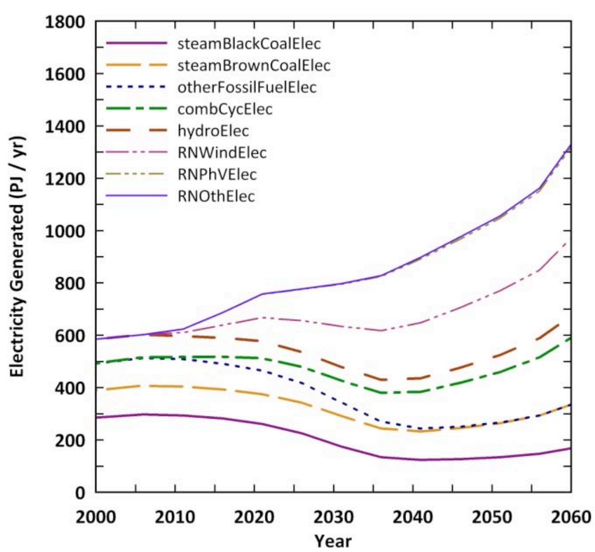


Figure A-2: National Electricity Generation (Adjustment)

a) By sector



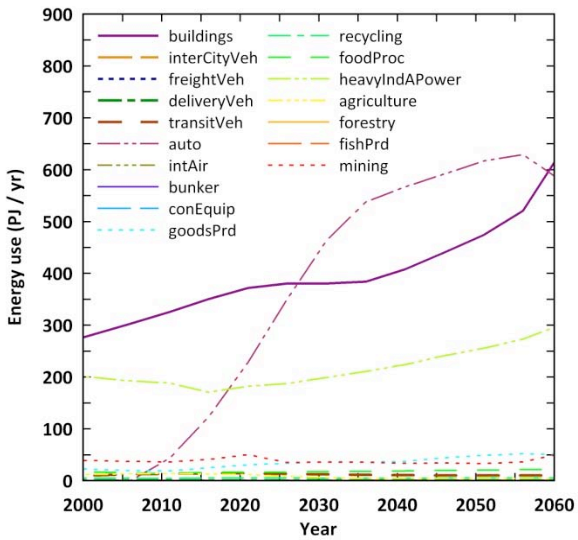
b) Cumulative



Control

Figure A-3: National Electricity Demand / Use (Control)

a) All sectors



b) Minor sectors
('heavy power and industry' and 'buildings' removed)

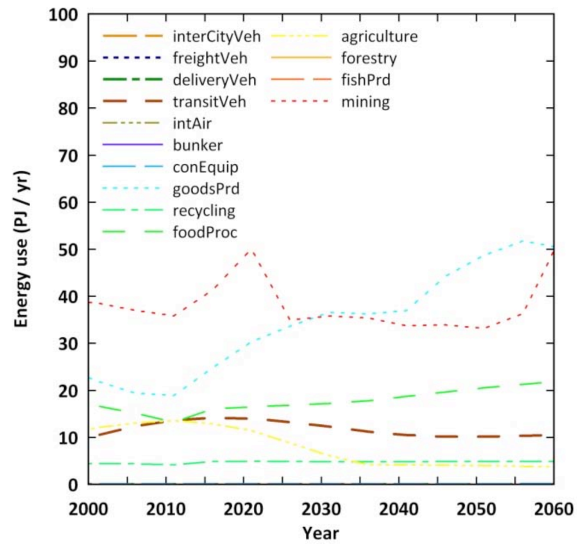
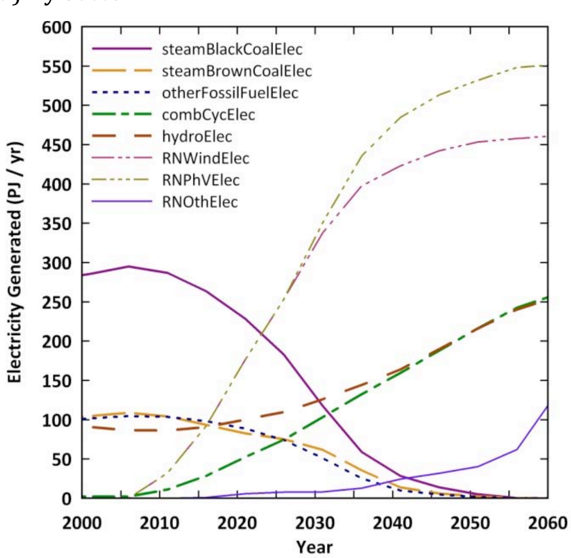
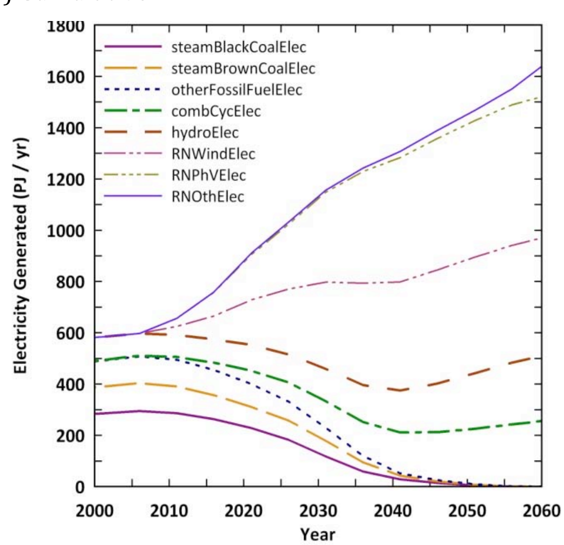


Figure A-4: National Electricity Generation (Control)

a) By sector



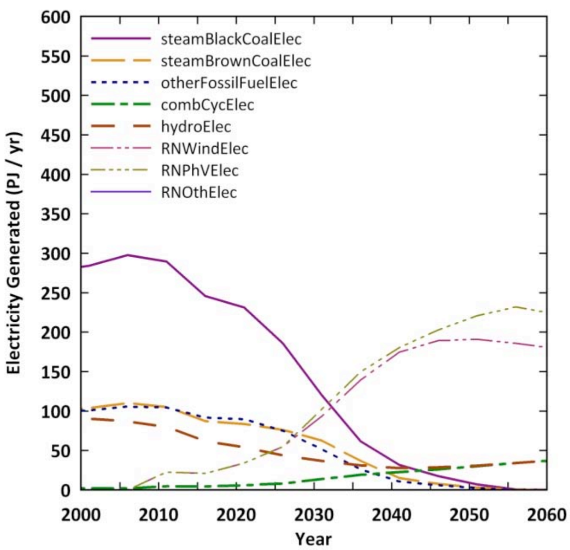
b) Cumulative



DIY

Figure A-5: National Electricity Demand / Use (DIY)

a) All sectors



b) Minor sectors
('heavy power and industry' and 'buildings' removed)

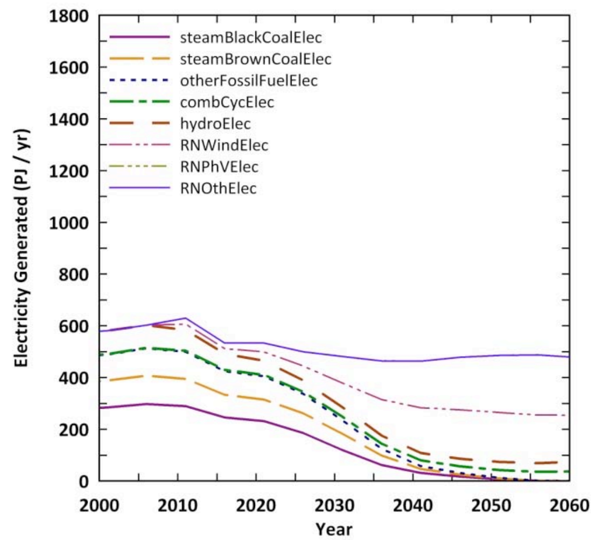
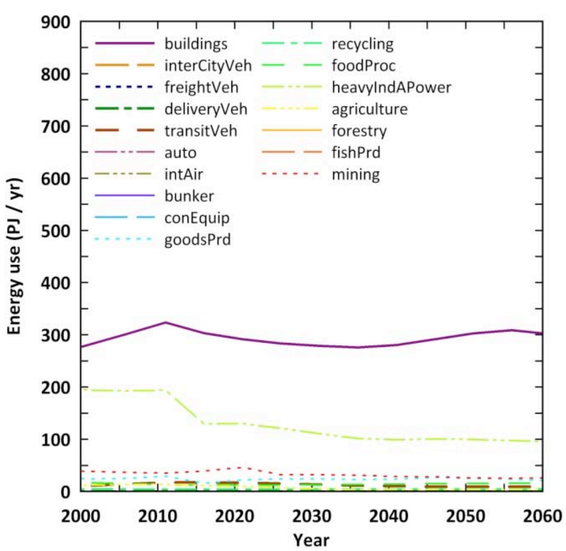
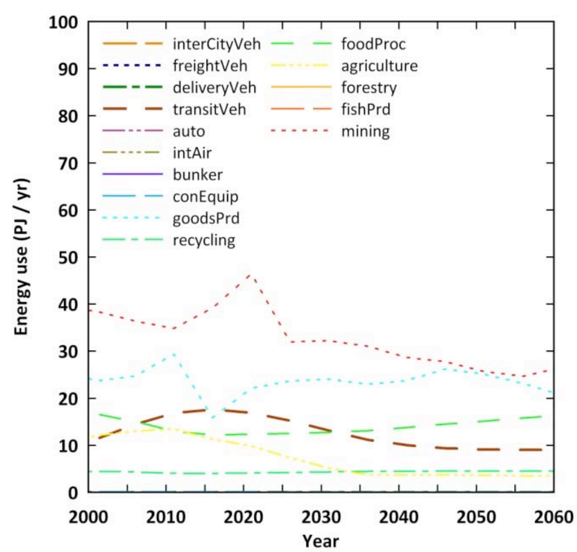


Figure A-6: National Electricity Generation (DIY)

a) By sector



b) Cumulative



Appendix 4: Food Surplus and Deficit Graphs

Adjustment

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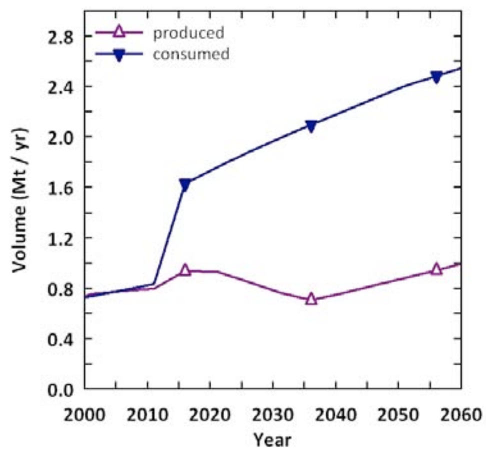
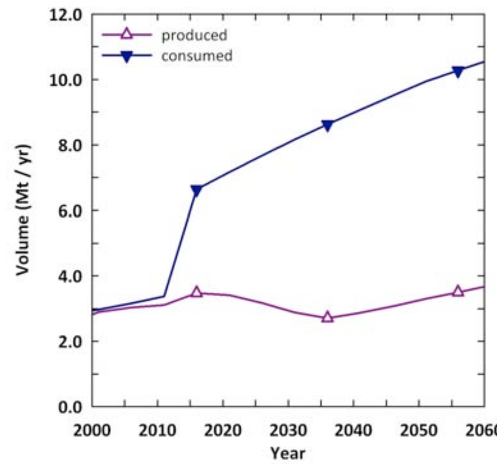
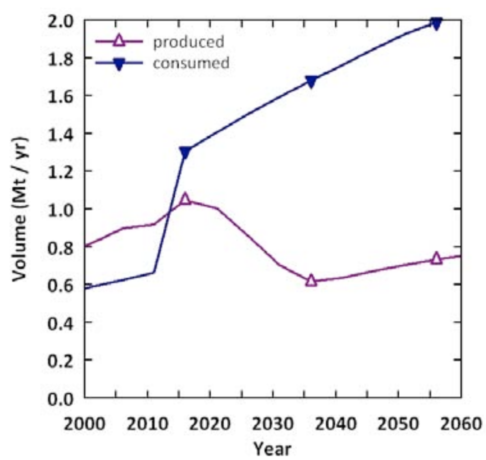
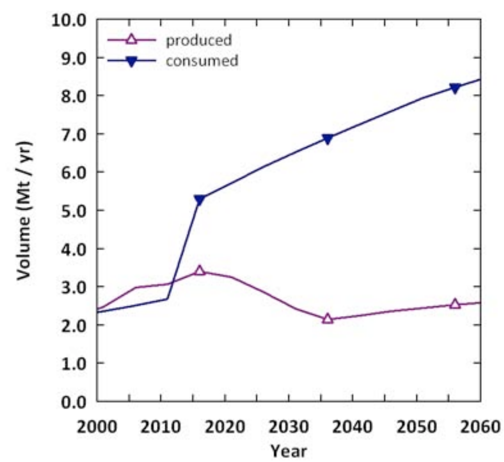
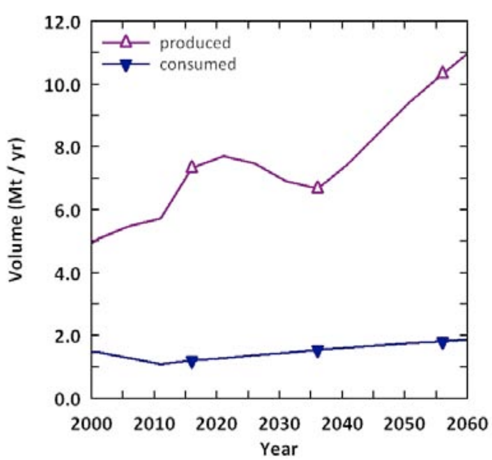
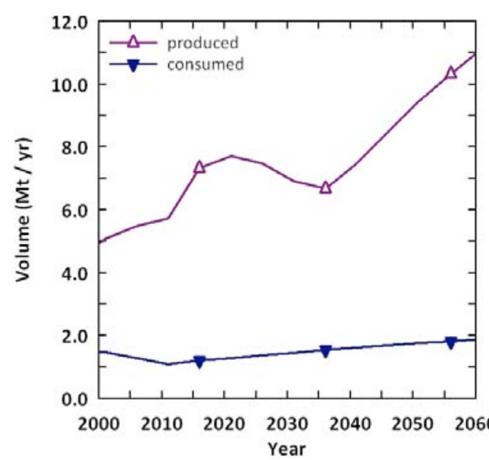
Vegetables		
Fruit		
Milk (dairy)		

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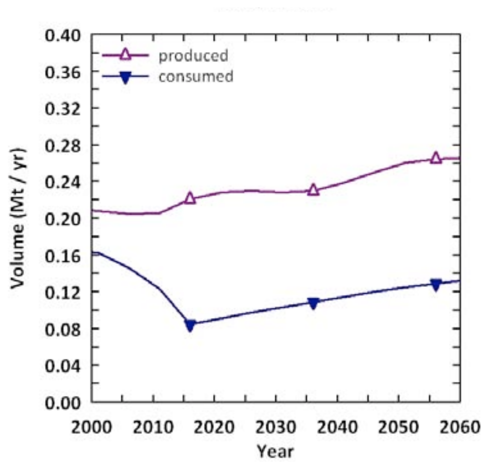
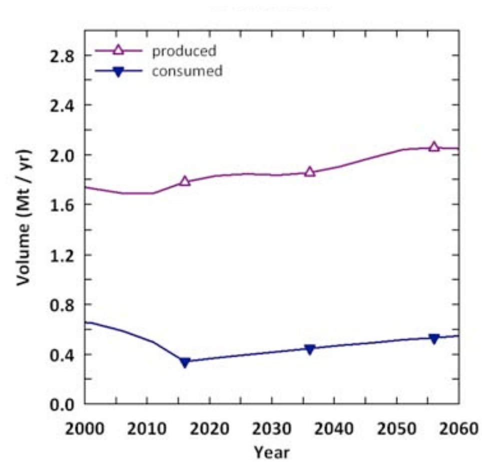
<tr><td>Beef</td><td>
</td><td>
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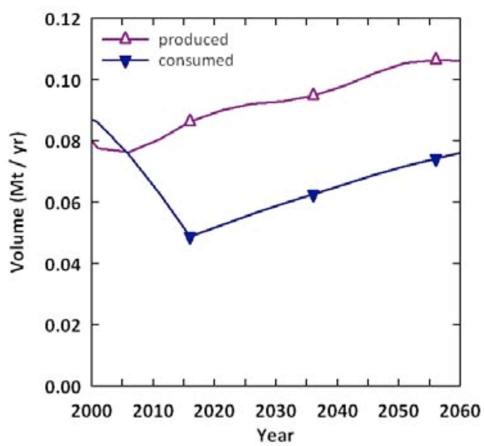
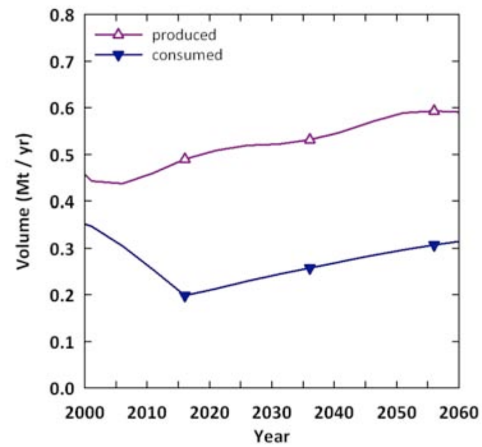
<tr><td>Lamb</td><td>
</td><td>
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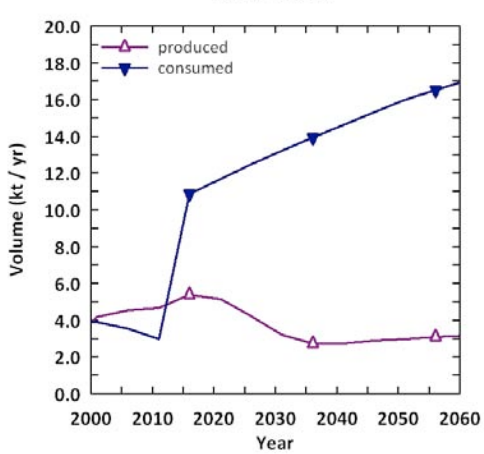
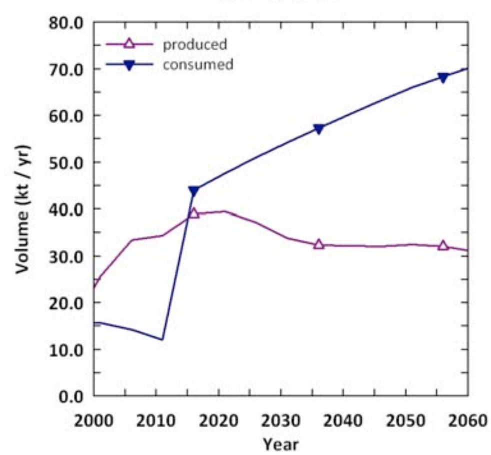
<tr><td>Nuts</td><td>
</td><td>
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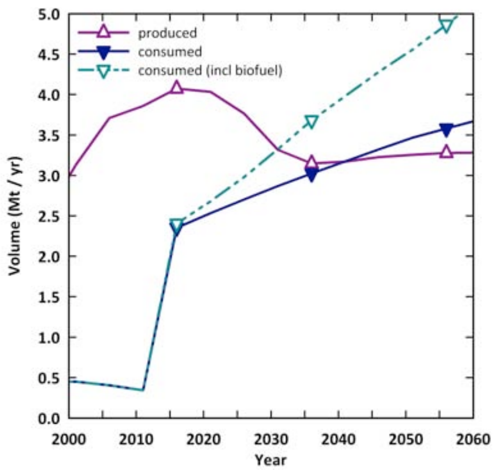
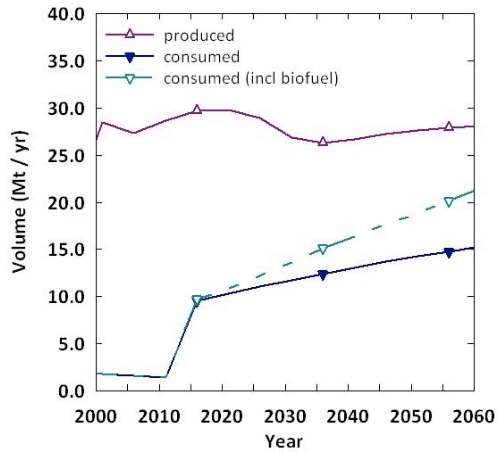
<tr><td>Cereals</td><td>
</td><td>
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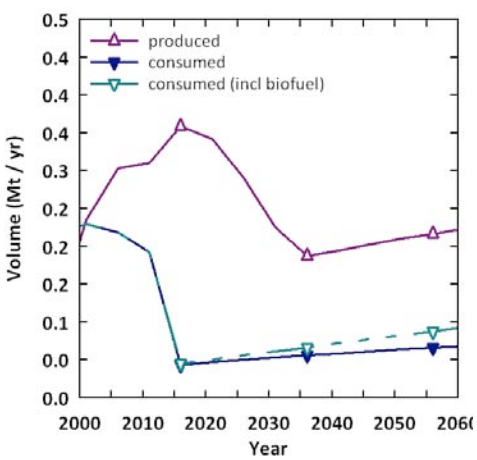
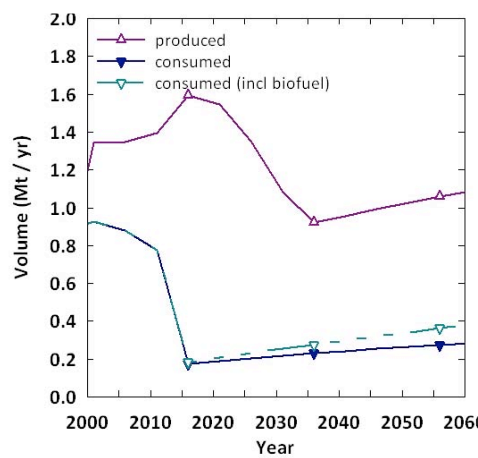
<tr><td>Oil crops</td><td>
</td><td>
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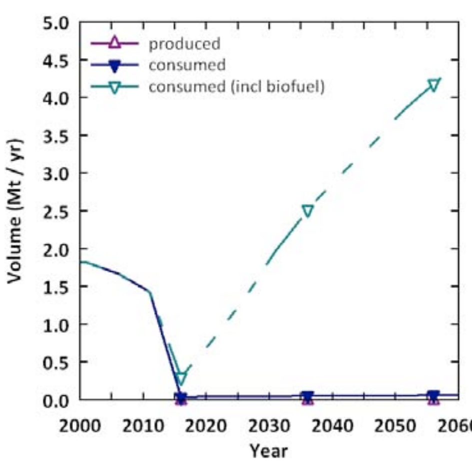
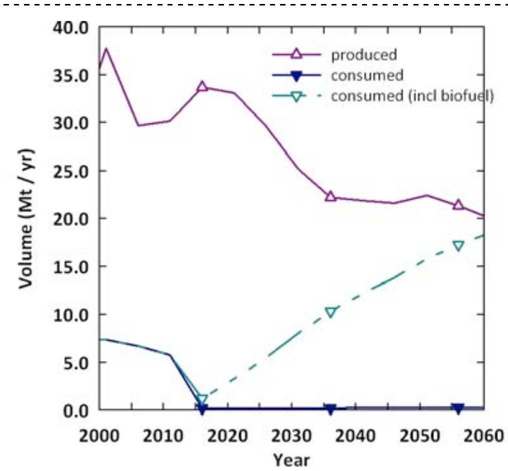
<tr><td>Sugar</td><td>
</td><td>
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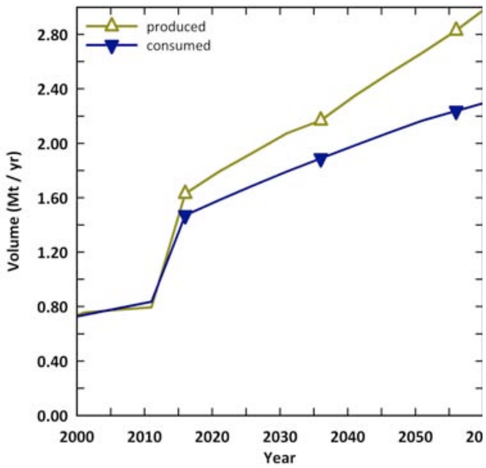
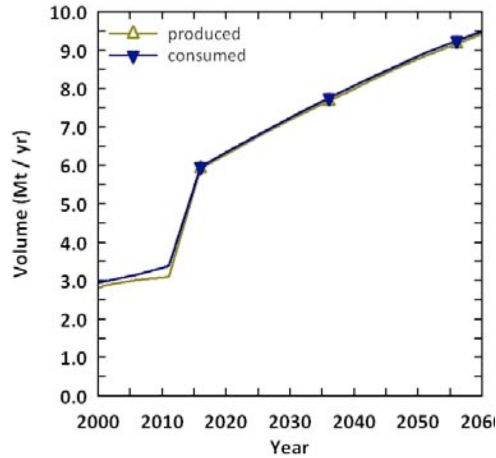
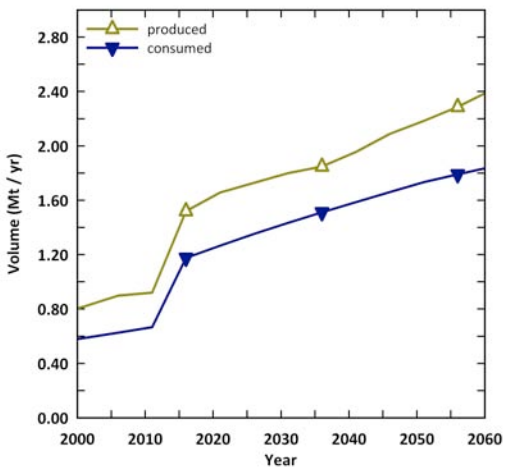
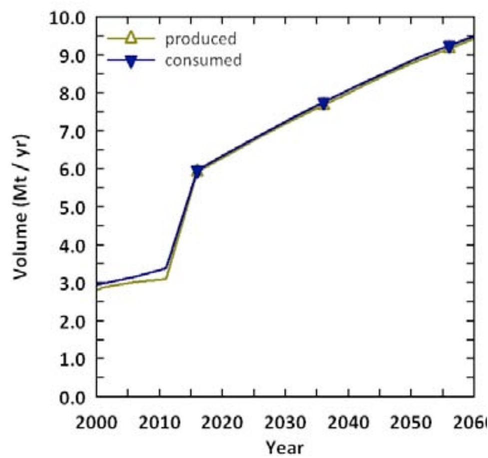
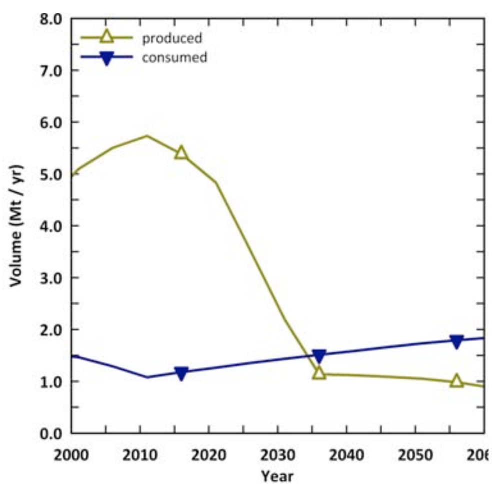
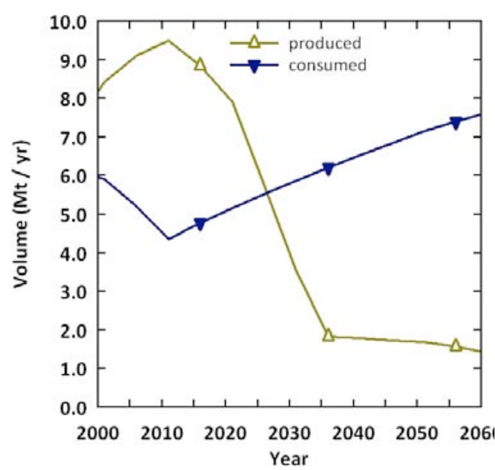
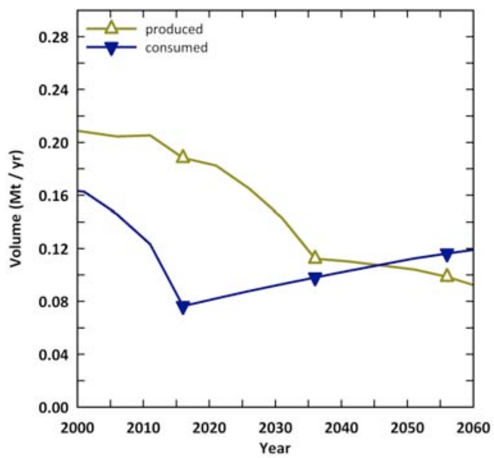
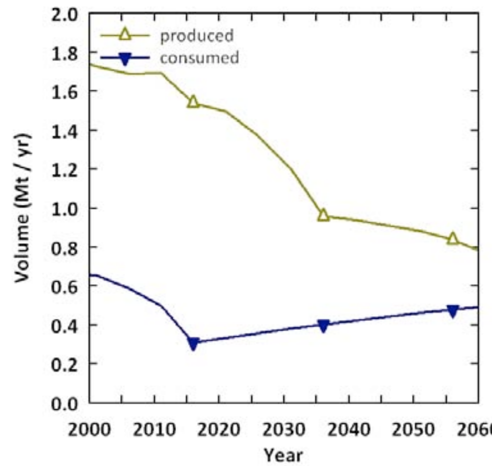
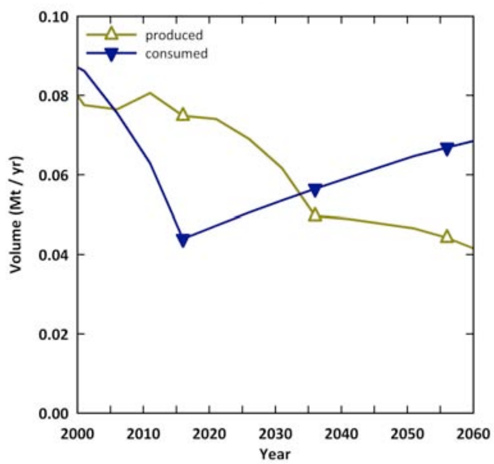
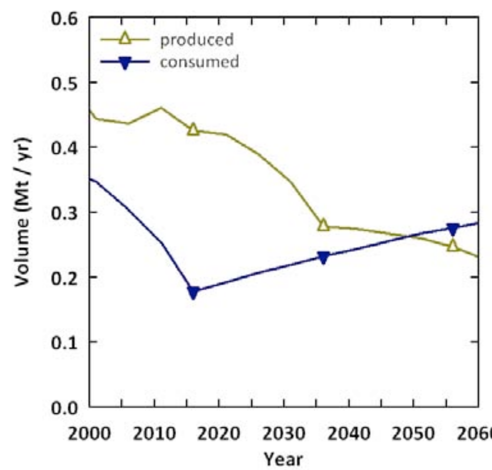
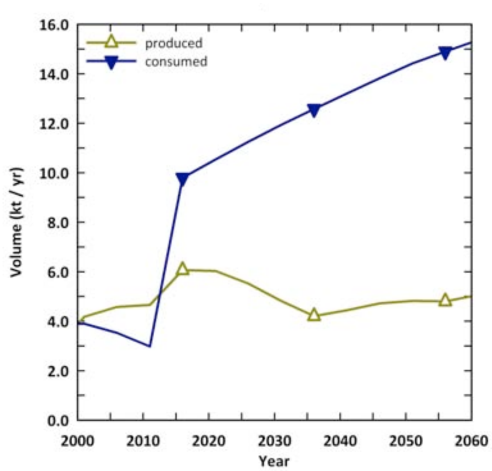
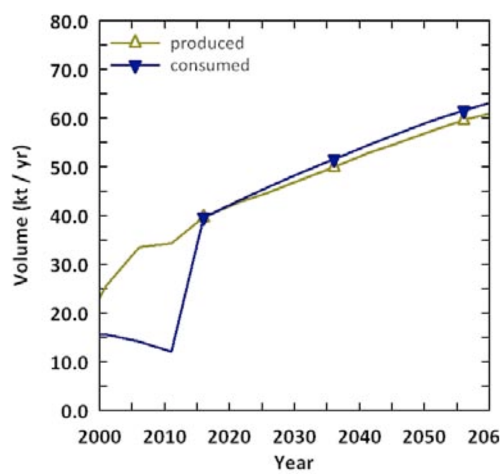
Control

	Victoria	Australia
Vegetables		
Fruit		
Milk (dairy)		

	Victoria	Australia
Beef		
Lamb		
Nuts		

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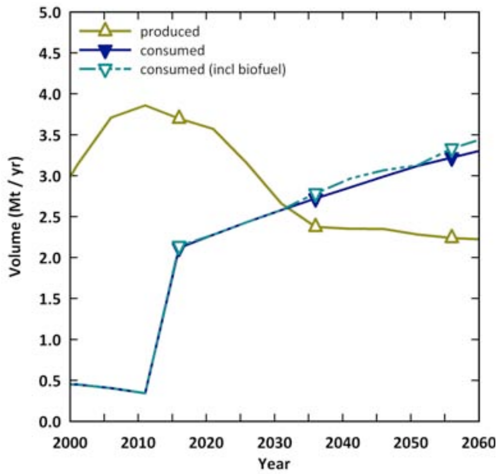
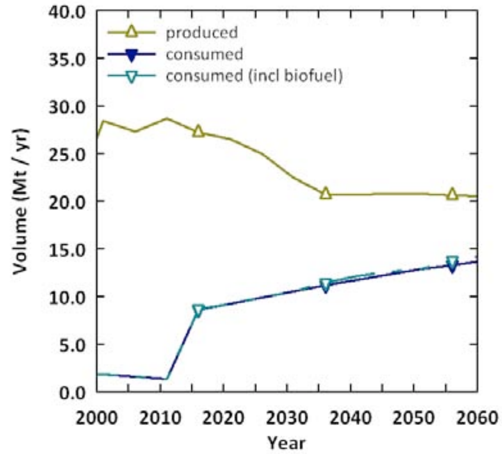
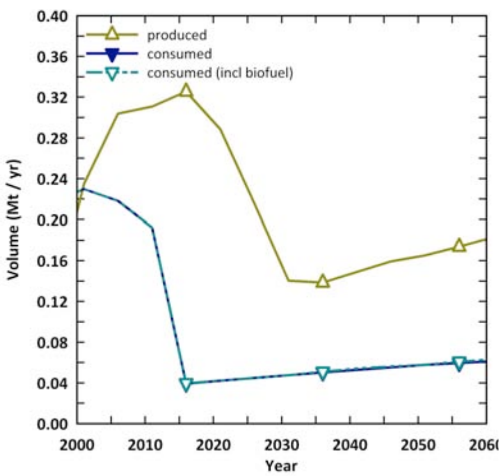
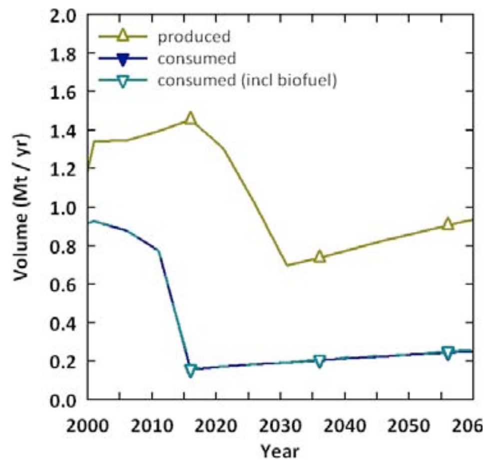
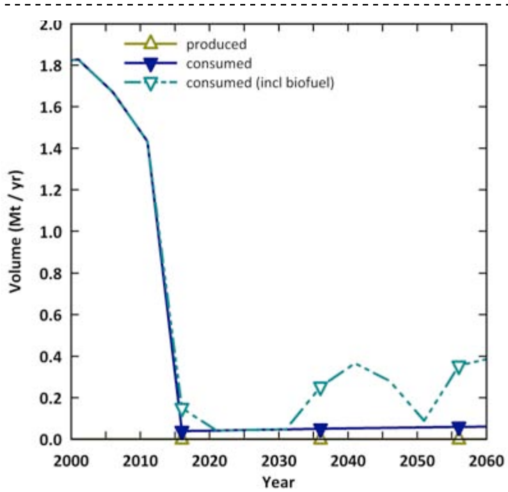
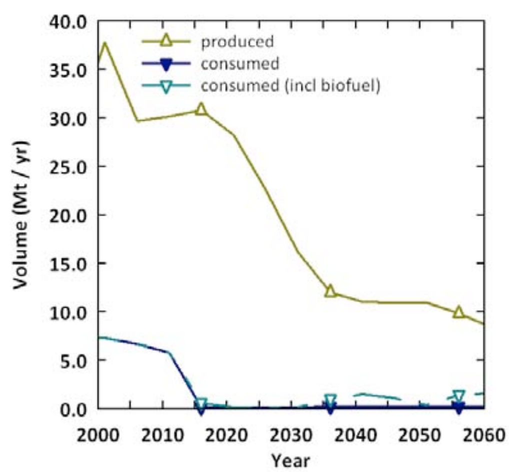
Cereals		
Oil crops		
Sugar		

DIY

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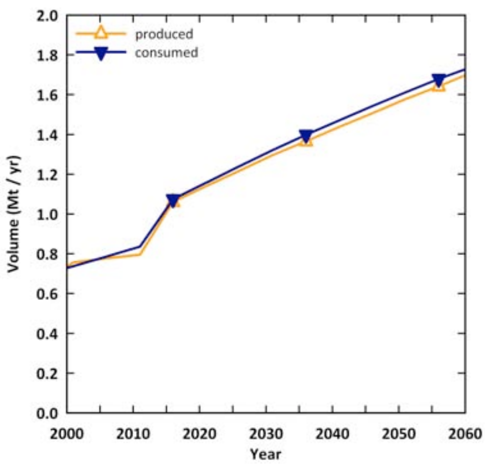
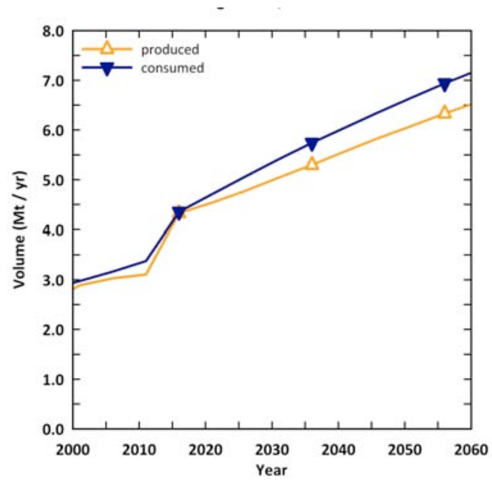
<tr><td>Vegetables</td><td>
</td><td>
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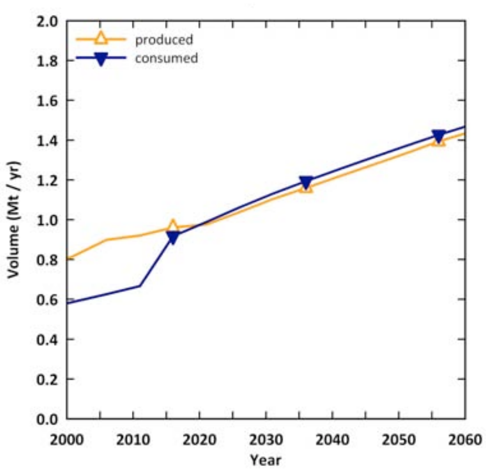
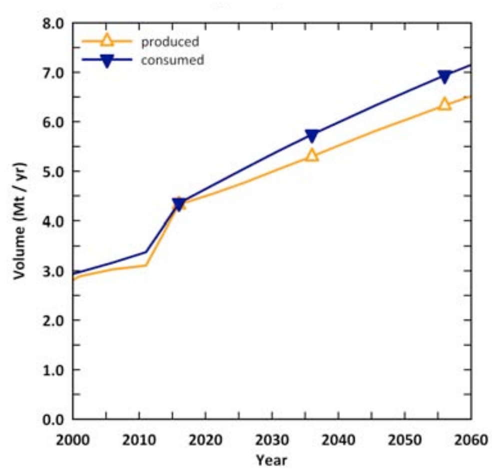
<tr><td>Fruit</td><td>
</td><td>
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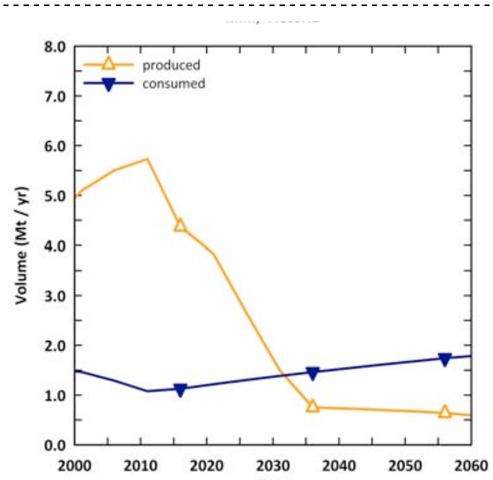
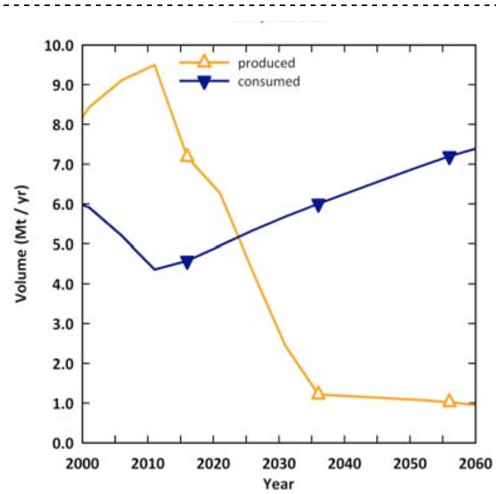
<tr><td>Milk (dairy)</td><td>
</td><td>
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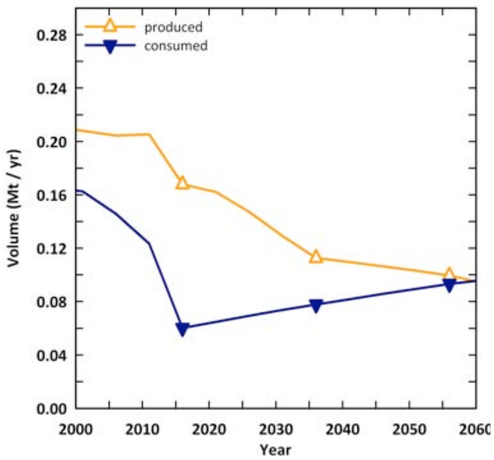
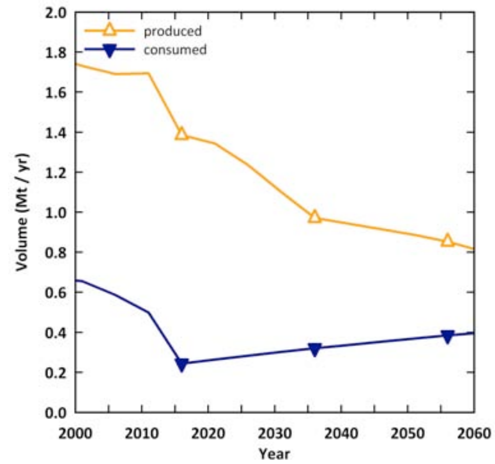
<tr><td>Beef</td><td>
</td><td>
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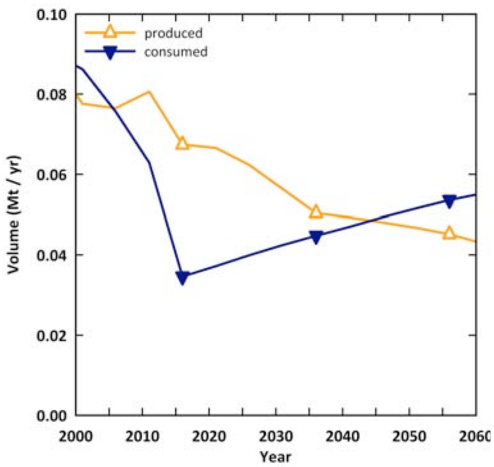
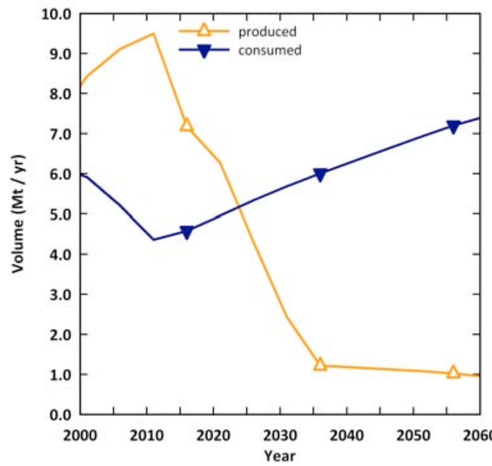
<tr><td>Lamb</td><td>
</td><td>
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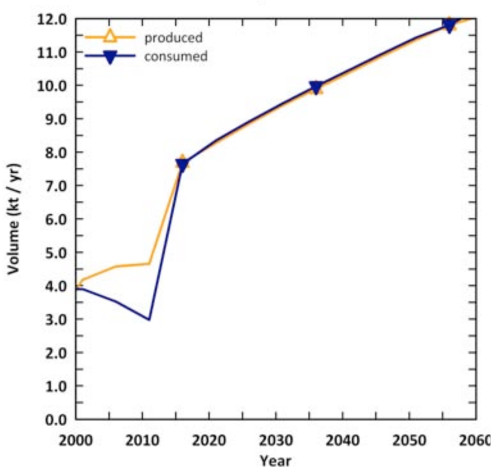
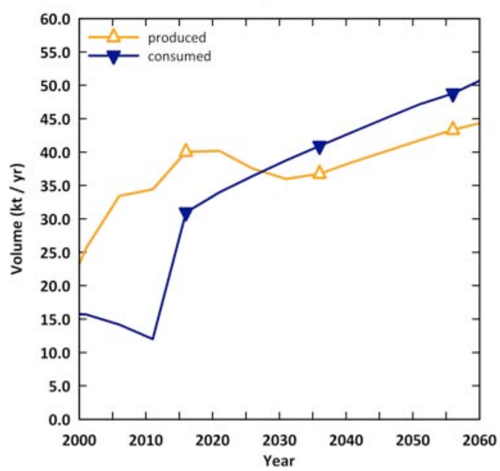
<tr><td>Nuts</td><td>
</td><td>
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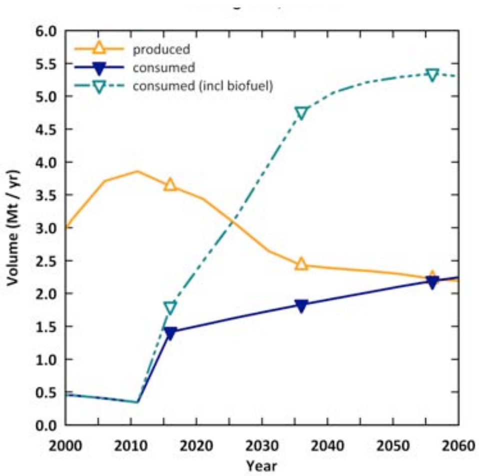
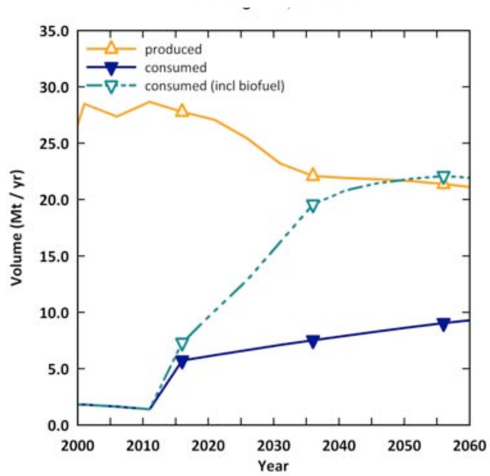
<tr><td>Cereals</td><td>
</td><td>
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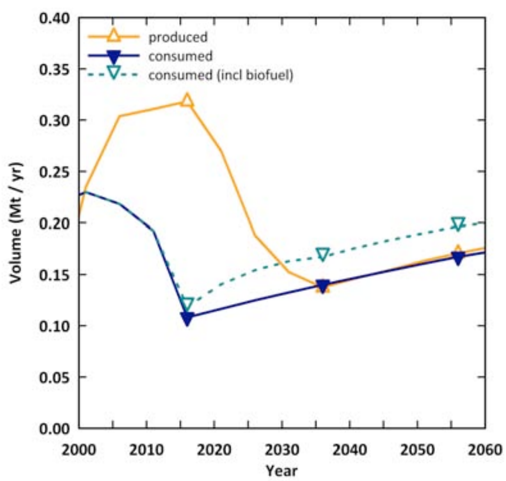
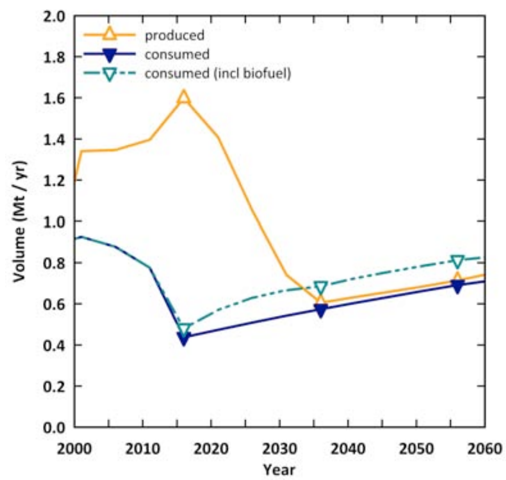
<tr><td>Oil crops</td><td>
</td><td>
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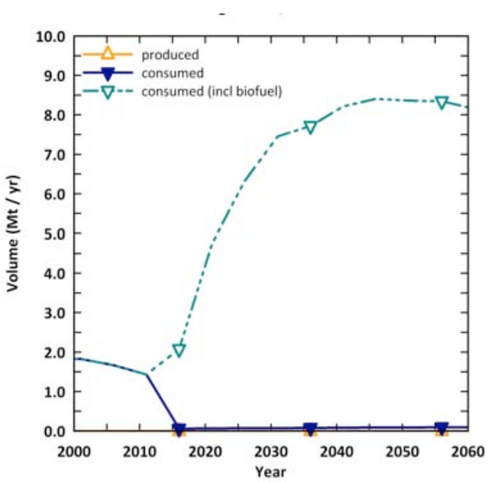
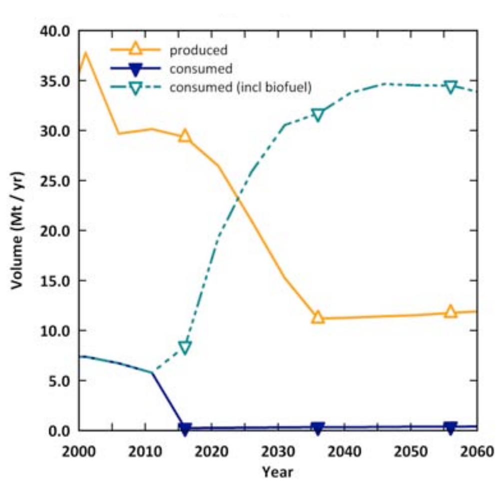
<tr><td>Sugar</td><td>
</td><td>
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Net balance (comparative)

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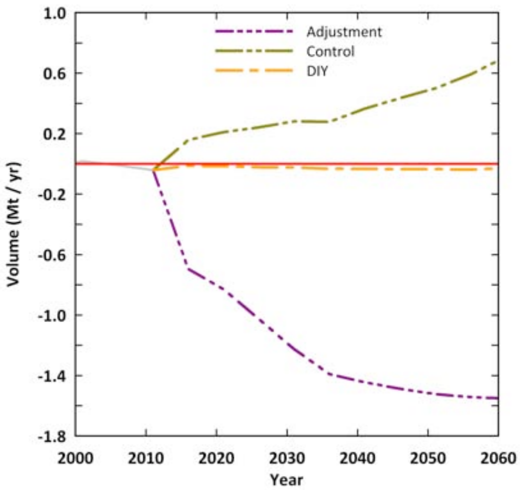
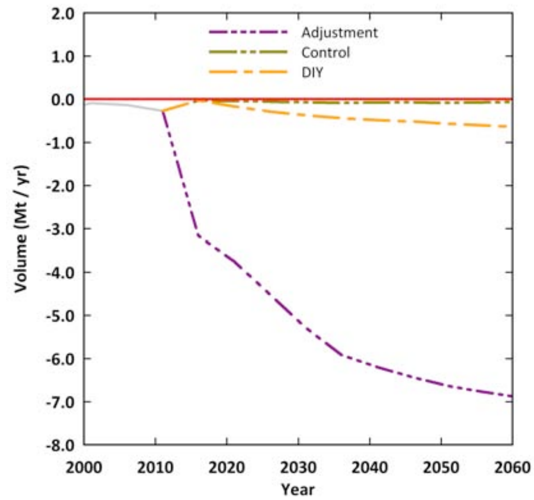
<tr><td>Vegetables</td><td>
</td><td>
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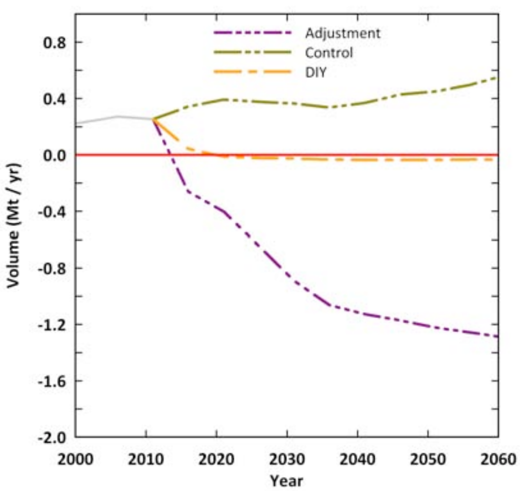
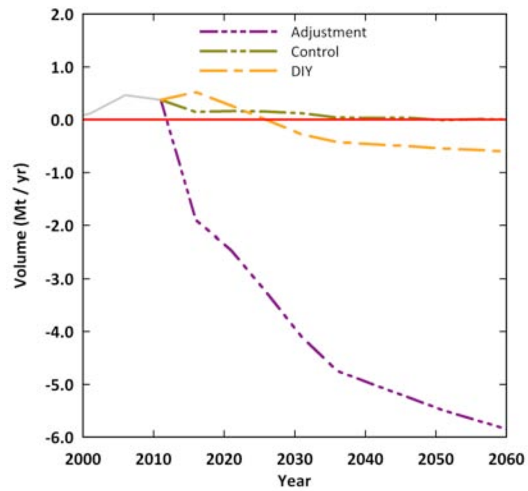
<tr><td>Fruit</td><td>
</td><td>
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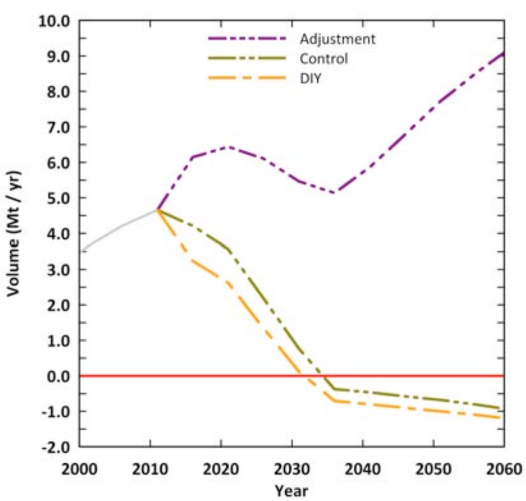
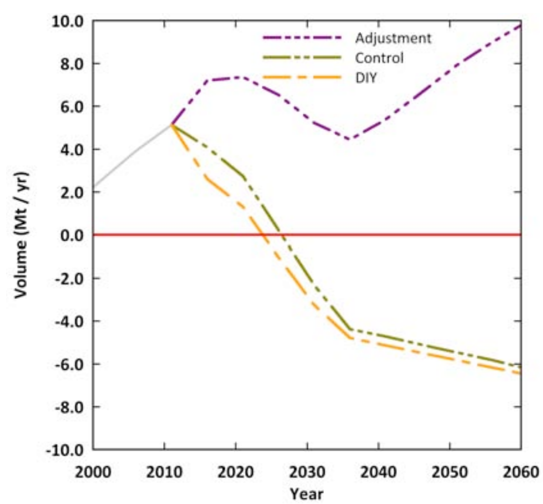
<tr><td>Milk (dairy)</td><td>
</td><td>
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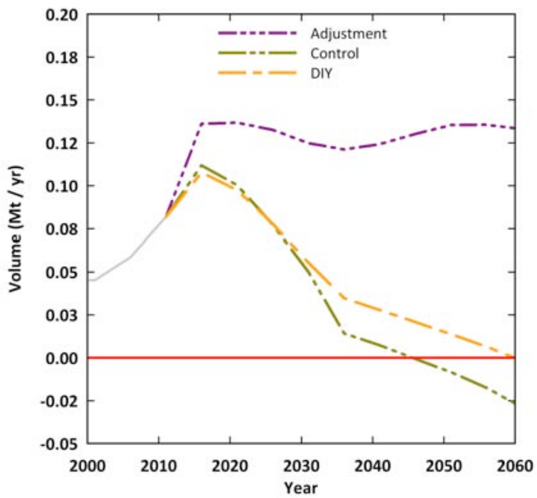
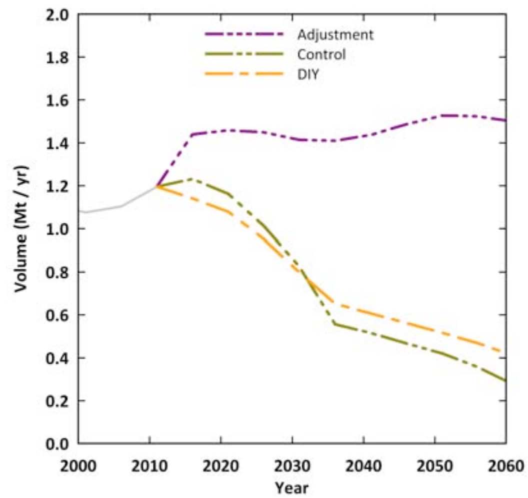
<tr><td>Beef</td><td>
</td><td>
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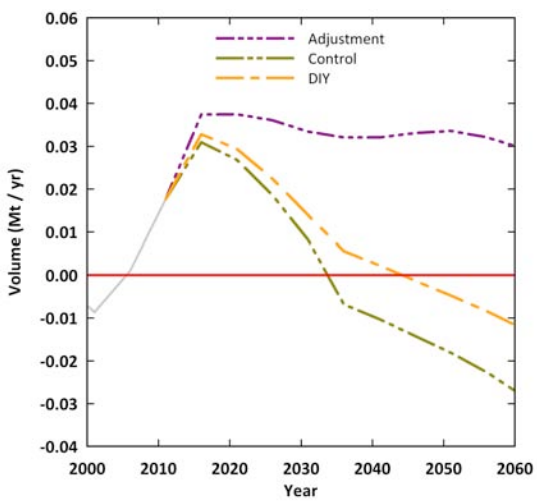
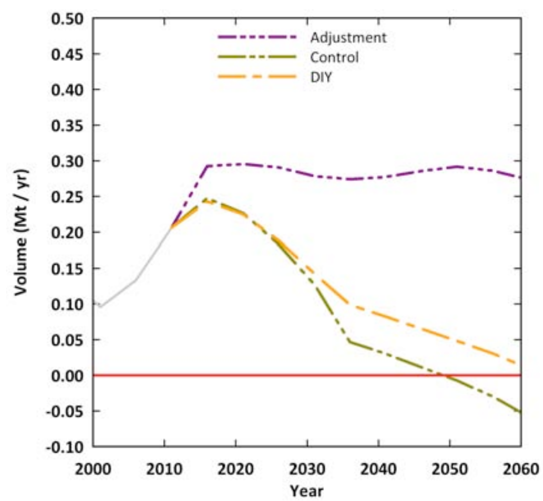
<tr><td>Lamb</td><td>
</td><td>
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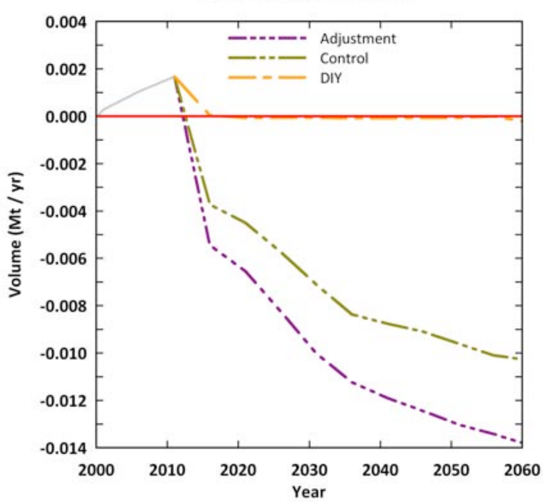
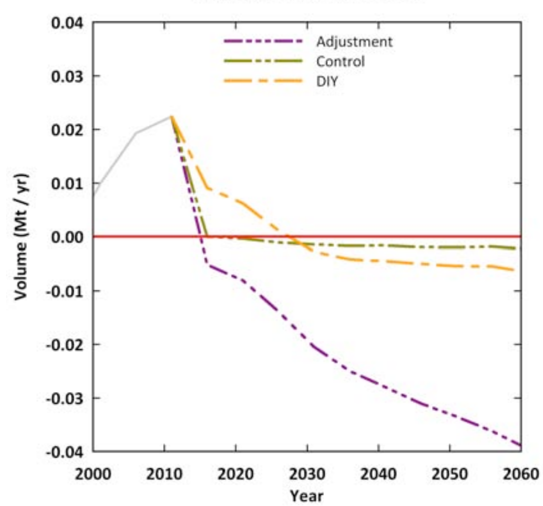
<tr><td>Nuts</td><td>
</td><td>
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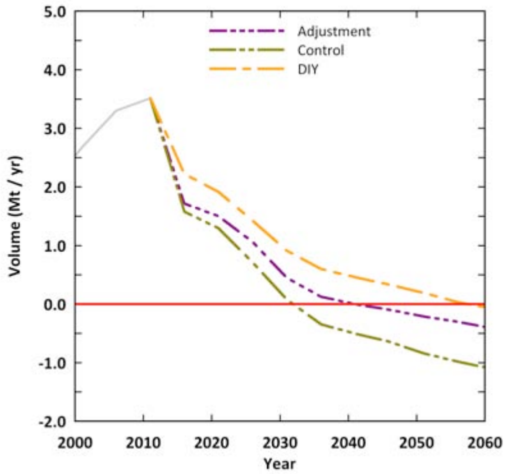
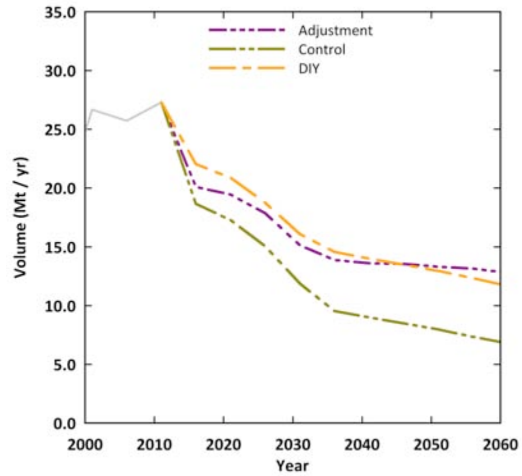
(ex. fuel)</td><td>
</td><td>
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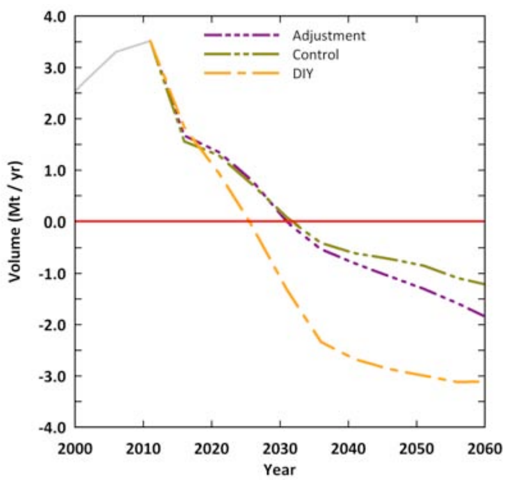
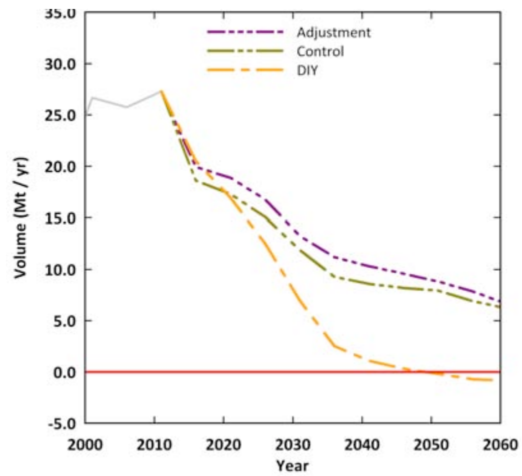
(inc. fuel)</td><td>
</td><td>
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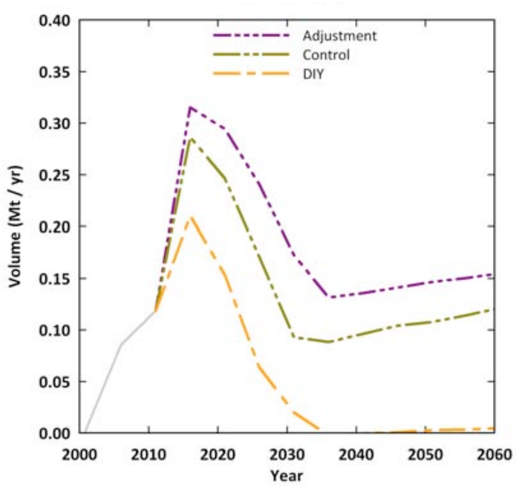
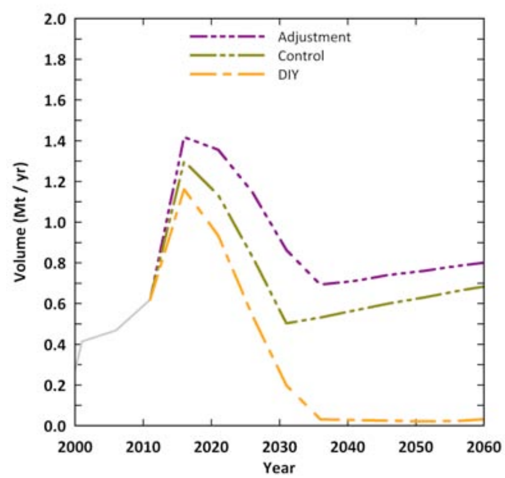
(ex. fuel)</td><td>
</td><td>
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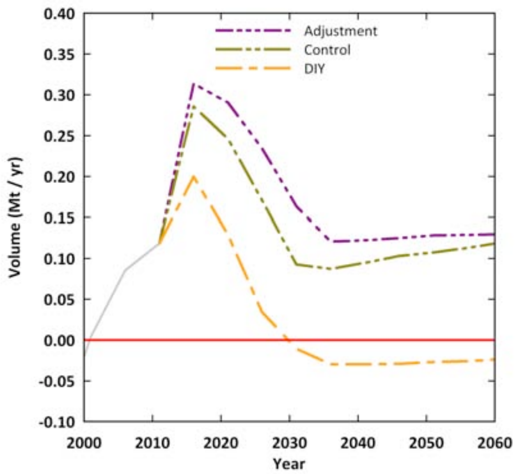
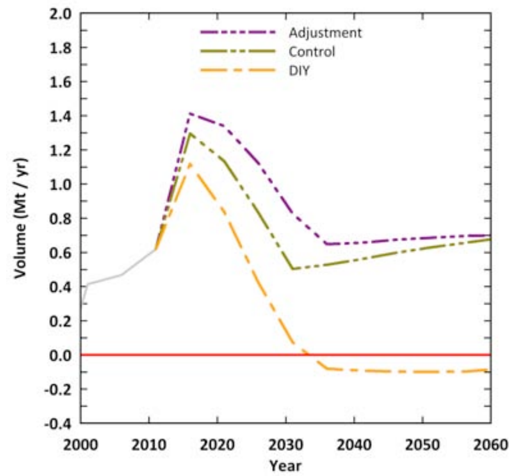
(inc. fuel)</td><td>
</td><td>
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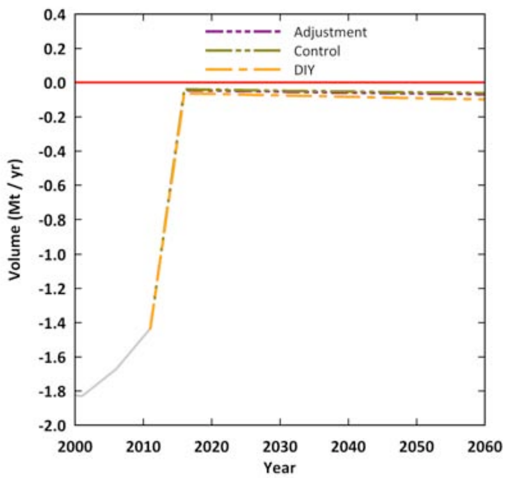
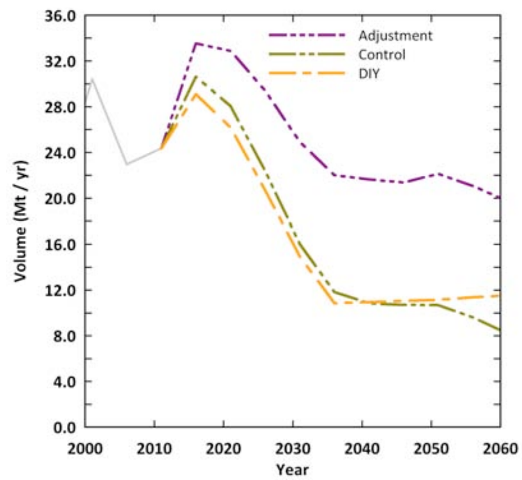
(ex. fuel)</td><td>
</td><td>
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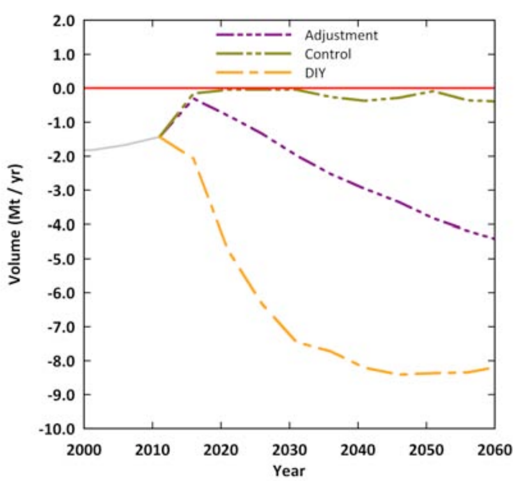
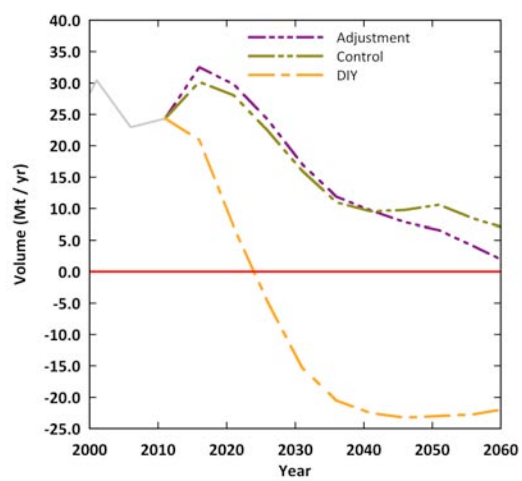
(inc. fuel)</td><td>
</td><td>
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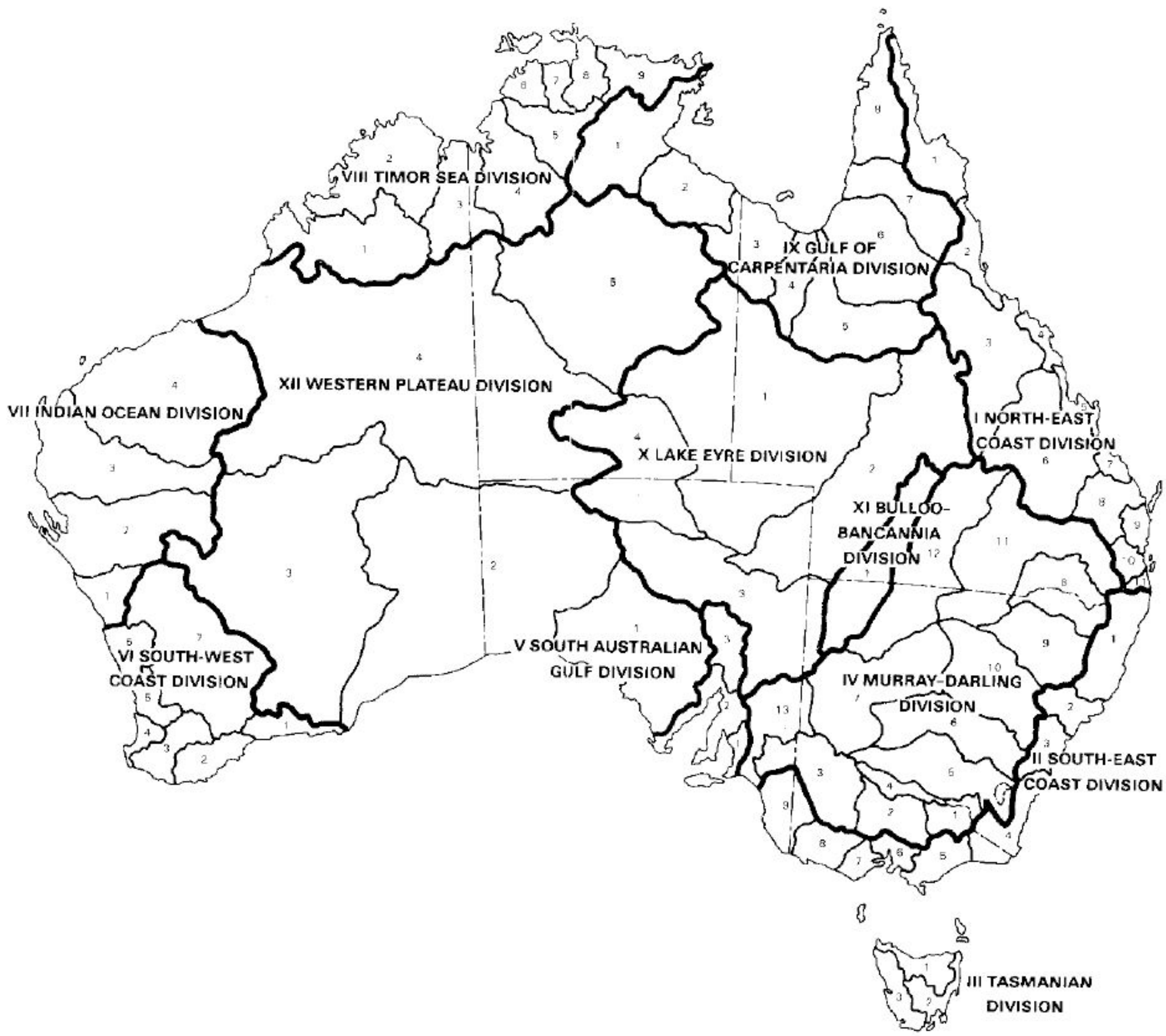
Appendix 5: Water Regions in the ASFF



Appendix 6: Priorities for Further Methodology Development

5.2.3 The Scenarios

The primary purpose of further analysis of the three scenarios developed in this project would be to explore the relative costs and benefits of the structural changes they entail. This further analysis would include:

- Refining data sets, assumptions, settings and analysis in priority areas;
- Further iterations to explore and resolve outstanding tensions (where possible); and
- Comparative analysis of costs and benefits of the different scenario structures, particularly through exploration of relative resilience (of food availability) to shocks and change.

Section 4 described priority areas that would need to be investigated for comparative analysis to take place, including assessment of assumed system efficiencies and inclusion of urban and wasted resources as inputs for food production. The key tensions also point to priority areas for improved understanding and further analysis, such as: greenhouse gas emissions (including potential for reduction within the food system); energy, oil and fertiliser use; and land and soil capability for the use that is suggested in the scenarios.

Following research and refinement of the inputs, further iterations could be undertaken in an attempt to resolve or reduce the tensions that have been identified in this project.

This further refinement would support comparative analysis of the costs and benefits of the structural differences inherent in the different scenarios. As outlined in Section 4.4, a priority for this comparative analysis would be the robustness or resilience of food availability in light of the significant vulnerabilities identified.

5.2.4 Monitoring and Policy Assessment

This project has demonstrated the potential of the ASFF to analyse implications for food availability of changes to resource allocation, emissions reduction, energy supply etc. at a national or state level. This potential could be further developed to build a capability for on-going assessment / monitoring of tensions, management and policy development that is able to consider these complex interactions. However, it is not currently refined to the level of detail or accuracy would be required for use as an on-going policy and management tool.

Much of the early part of this project (identifying data requirements, integrating them and building capability of the ASFF) was completed in a later version of the ASFF (v4) that is currently under development at CSIRO. However, as the later version was not fully functional within the timeframe for this project, the scenario analysis was conducted in the earlier version (v3 as described throughout). ASFF (v4) will have a much greater level of spatial detail available for analysis, as well as improved capabilities to operate as a more responsive tool for 'real-time' policy analysis and exploration of different scenarios. These include routines for updating data more readily, and refined and more transparent relationships between components.

Once the model can satisfactorily account for key variables, it could be regularly updated and used to:

- Assess progress towards meeting multiple goals and resolving foreseeable future tensions;
- Test the implications of policy in one area on other areas i.e. implications of changing water allocations on food availability for Australian population and/or export surplus;
- Explore possibilities for achieving energy independence / surplus while achieving scientifically demanded emissions reductions, and consider the implications of this for land use change and food availability; and
- Test the implications of different land use changes at both micro and macro levels.

NB. The settings and analysis in this project has focused on issues that are particularly pertinent in Victoria. It has therefore assumed reductions in irrigation water availability consistent with projections for the Victorian regions of the Murray Darling Basin, and assumed the main drivers of land loss to be forestry and urban development. If the analysis were to be expanded to a National level, more consideration would need to be given to both the potential expansion of other irrigation systems, but also loss of productive land to mining.

5.2.5 Design New Systems

The real value of this form of 'what-if' modelling is the ability to test innovations to reduce unwanted impacts and increase the certainty that the provision of healthy food for our population is secure and sustainable. This work has emphasised the critical importance of looking at land-use, agricultural production, food processing and distribution, as a *system*. The complexity of this system (and of sub-system interactions) is challenge for existing processes of innovation that focus on sub-system changes. However the approach in this research provides a mechanism for exploring complex system innovation.

The different scenarios used for this work do focus attention on the potential for the redesign of the food system and suggest that modelling different systems of food provision (production, distribution and access) would be of considerable value. In the face of significant future uncertainties (climate, oil supply, patterns of global population growth, and so on) there is a discernible shift in thinking about systems design and modelling, recognising the value of accepting increasing uncertainty and designing robust or resilient systems that to cope with 'the unexpected'.

The model could be further developed with a particular focus on creating and testing food system configurations that can provide healthy and sustainable food supplies within expected resource limits.

5.2.6 Identifying cost-effective policy priorities for food security

The research extension projects 1-3 build upon and develop the present project's preliminary findings into more sophisticated analyses to further strengthen the evidence base. An essential complement to this work is research that will help translate the evidence base into practical food policy actions. This food policy research would aim to identify the priority policy and regulatory interventions to reform the food system and promote food security. This component of the research extension agenda would involve three main stages.

- Further refinement and extension of the ASFF to increase the rigour of the technical assumptions as they relate to nutrition and to enable to inclusion of the imminent revised nutrition reference standards (Australian food selection guide and dietary guidelines);
- Exploring policy interventions through stakeholder engagement and consultation that maps the food system to identify the policy gaps, barriers and opportunities to respond to identified food supply vulnerabilities; and
- Prioritising the identified policy interventions using cost-effectiveness analysis modelling.

5.2.7 Linking Physical, Economic and Social Modelling

While not the core objective of this project, it has nevertheless touched on the interface of a domain that our past / existing economic systems and models are not equipped to deal with. The assumption that supply of critical resources (i.e. energy) will increase to meet demand as higher prices make new sources feasible, is being shown to be limited by the ability of current economic structures to tolerate consistently high energy prices. There are currently few (if any) models that can assist in testing these relationships or informing economic policy that can take account of physical resource or energy limits. While far from being able to achieve this, integration of the ASFF with economic modelling tools would be a potentially valuable avenue for further research.

VEIL | victorian eco innovation lab

Victorian Eco-Innovation Lab [VEIL]
Faculty of Architecture, Building and Planning
Old Commerce Building
University of Melbourne
Victoria, Australia 3010
T: +61 3 8344 9175
www.ecoinnovationlab.com
www.sustainablemelbourne.com
www.sustainablecitiesnet.com

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