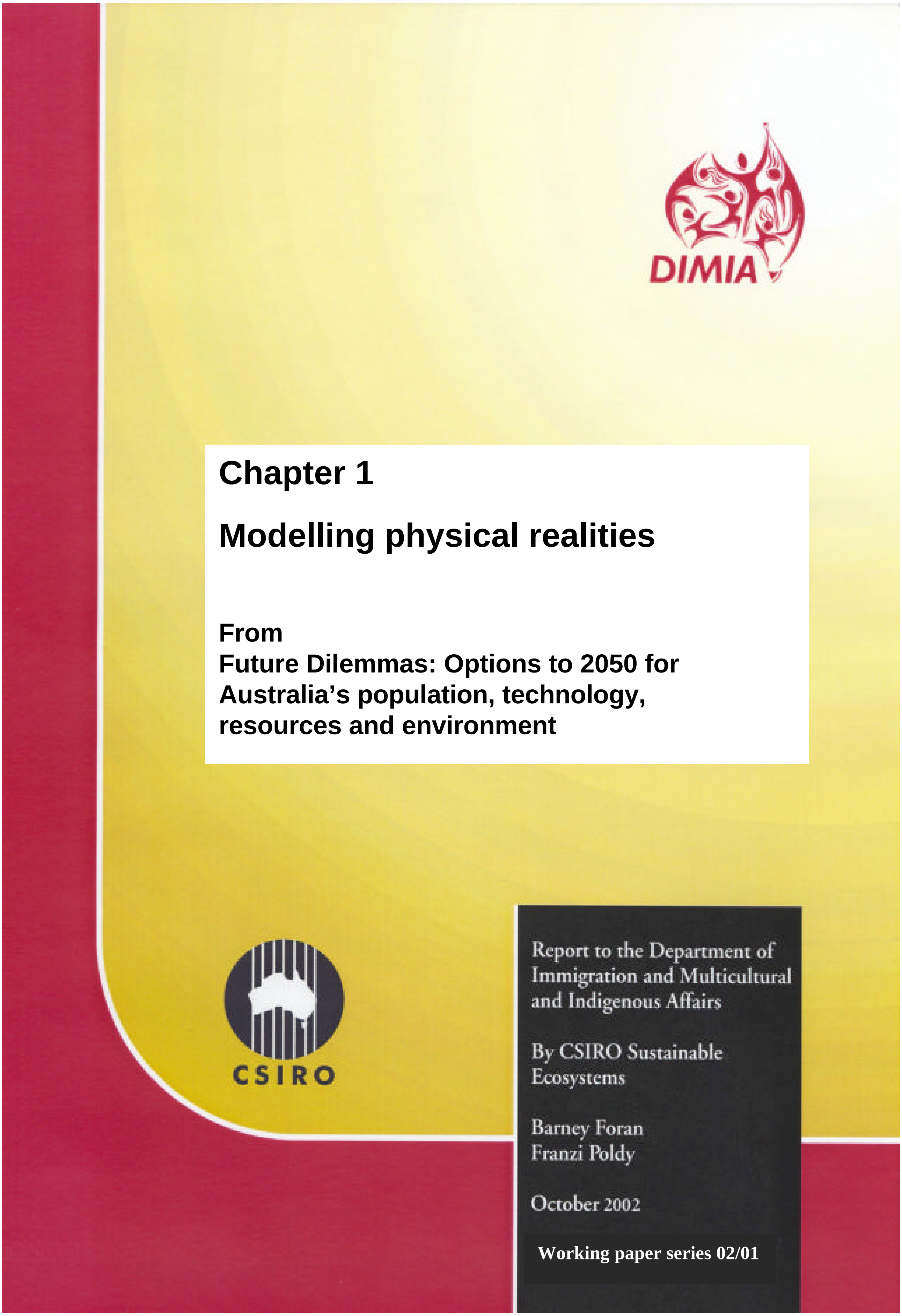

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Chapter 1

Modelling physical realities

From
Future Dilemmas: Options to 2050 for Australia's population, technology, resources and environment

CSIRO

Report to the Department of Immigration and Multicultural and Indigenous Affairs

By CSIRO Sustainable Ecosystems

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Disclaimer

The results presented in this report are a product of the model used and the assumptions stipulated.

Chapter 1
Modelling physical realities

ABSTRACT

The concept of sustainability, fossil energy use and greenhouse negotiations, population policy and lifestyle options are all linked to environmental quality in the long term. This does not mean that larger populations live less sustainably than smaller ones. Nor does it assume that technology will find a way to overcome all environmental challenges or constraints to resource use. This opening methodological chapter makes three key points. Firstly, sustainability must deal with the long term. Secondly, long-term issues must be explored with long-term methods which quantify slow moving variables such as population momentum and infrastructure inertia. Thirdly, decision makers must be comfortable with long-term 'beyond the horizon' analyses and accept that such analyses are a valid and necessary part of the national policy process.

In order to examine the long-term consequences of many policy interactions, analytical frameworks are required to design and test different functions and structures for the physical economy. The term 'physical economy' is coined to describe the vast array of physical transactions which underpin the monetary economy. For every dollar exchanged in Australia's gross domestic product, there is a chain of physical transactions that bring that final good or service to the shopkeeper's counter and the consumer's basket. In Australia, more than 200 tonnes per person per year must be moved to supply our essentials, our lifestyle and the exports needed to pay for our imports. By contrast, Japan moves around 40 tonnes, while the USA moves 80 tonnes per person.

The ability to analyse these transactions is described within two analytical frameworks, the Australian Stocks and Flows Framework and the *OzEcco* embodied energy flows model. The first (ASFF) is a set of 32 linked calculators which follow, and account for, the important physical actions that underpin our everyday life. The second (*OzEcco*) is based on the concept of embodied energy, the chain of energy flows from oil well and coal mine which eventually are included or embodied in every good and service in both the domestic and export part of our economy. Both analytical frameworks are based on systems theory and implemented in a dynamic rather than an equilibrium approach. This allows transition pathways towards new states of the physical economy to be designed and tested for physical feasibility using concepts of age and inertia. These concepts are critical to the process of infrastructure renewal and market penetration by new technologies. The concept of physical feasibility is important, but does not reflect feasibility in a political, social or economic sense.

While these approaches are relatively novel in Australian and international policy terms, the underlying concepts are slowly gaining acceptance in parallel to a range of policy debates that are underpinned by physical realities. Energy and greenhouse, land degradation and river salinity, population growth and air emissions, oil depletion and transportation systems all represent physical realities with slow moving response times to policy interventions. Current use of the modelling frameworks is focussed on long-term population policy, land and water futures, fisheries management and the de-carbonisation of the transport fuels cycle. Importantly, the frameworks are used with clients and stakeholders. Understanding the physical issues involved is a vital precursor to accepting the radical redesigns of Australia's physical economy that may be required if the concepts behind sustainability are to be eventually implemented.

INTRODUCTION

Public policy, world views and analytical approaches

The capacity for public policy analysis and decision making implies that people have a choice: the future is not pre-determined but can be influenced by what we decide to do. There are many alternatives from which we might choose and the choice to do nothing, is a wilful one (Robbert

Associates, 2000). Within this context, some of the more difficult issues of public policy involve balancing longer-term societal interests and shorter-term individual or private interests. This is particularly so in the case of public policy concerned with the environment, natural resource management and public health. Many of these problems involve externalities — situations where the activities undertaken by one individual or group in pursuit of its objectives, have adverse unintended consequences for other individuals, groups or society at large. Some externalities are characterised as 'problems of the commons' where the lack of a clear and just system of property rights, decouples the link between shorter-term opportunities, from a longer-term possibility of a run down in system function or productivity. The issues of global climate change and marine fisheries are typical examples where short-term expediency can lead society to overload the waste assimilation capacity of the atmosphere, or to over-harvest particular fish resources in wild fisheries.

Science can help to identify and resolve environmental and resource management issues. Where common resources (atmosphere, marine fisheries, rangelands) are at stake, science is able to quantify their state, as well as possible pathways along which they might evolve. Science might estimate concepts such as sustainable yield as well as providing the basis for technologies which might reduce externalities, or increase productivity. However science as a discipline is limited in its ability to comprehend policy analysis, since this process requires a fuller understanding of how institutional and political systems might change in response to a particular policy innovation or new technology. Various processes such as expert panels, computer modelling and community workshops can help bridge the gap between science and policy development with different levels of success. Systems simulators offer another scientific approach which combines observations of past states of the system with an understanding of the drivers of the system. This can provide the foundation for active learning on how the simulated system responds to policy intervention and technological innovation.

Over the last 40 years, system simulators have been used to aid integrated policy advice with mixed success. The scenarios developed and tested by The Club of Rome *World* models in the early 1970s (Meadows et al., 1972, 1992) were widely interpreted as predictions. Today those predictions are judged by many to have been incorrect, particularly in regard to resource depletion issues. However, The Club of Rome scenarios ran until 2070, and many issues (fisheries collapse, environmental pollution and social equity) examined in their scenarios are supported by an increasing weight of evidence (Ehrlich and Ehrlich, 2002). Many large systems simulators of global climate systems have gained wide acceptance in global science and policy circles. These simulators link issues such as population growth, energy use, agriculture, forestry, water use and so on to climate dynamics at a global level. A new era appears to be emerging where policy deliberations are again open to simulation approaches of this type.

This fledgling era of policy analysis has strong links to core debates of nearly two centuries ago. In an effort to tease apart some of the foundations of current and future policy debating platforms, four quadrants of world view and analytical paradigm are proposed (Figure 1.1). These are derived from analytical views that are either 'technologically guarded' or 'technologically optimistic', and whether those world views are guided by an understanding of the 'momentum' embodied in population growth and economic growth, or the 'inertia' embodied in national infrastructure and societal institutions. Being 'guarded or optimistic' about the prospects of technological innovation is neither right nor wrong. Rather it helps classify a philosophical foundation and the analytical procedures used to promulgate those views (the glass 'half empty' versus the glass 'half full' analogy).

The understanding of momentum (quantity of motion) in an economic and demographic sense is based on an understanding of the structure of human populations and monetary economies, the potential for growth, and the time required before a different structure of population or economy can be reached. The understanding of inertia (sluggishness) in an infrastructural and institutional sense is derived from the observation that infrastructure (houses, roads, bridges, power plants) and institutions (courts, laws, parliaments, schools, business affiliations) have a wide range of characteristics that enforce their current structure and limit the rate of change. This inertia restricts the capacity of new technologies and new modes of organisation to replace the status quo. The mapping of a particular policy approach or method of analysis in the four quadrants helps us describe the methods used, the disciplinary base of the analysts and ways in which the results might be extended into policy relevant discussions.

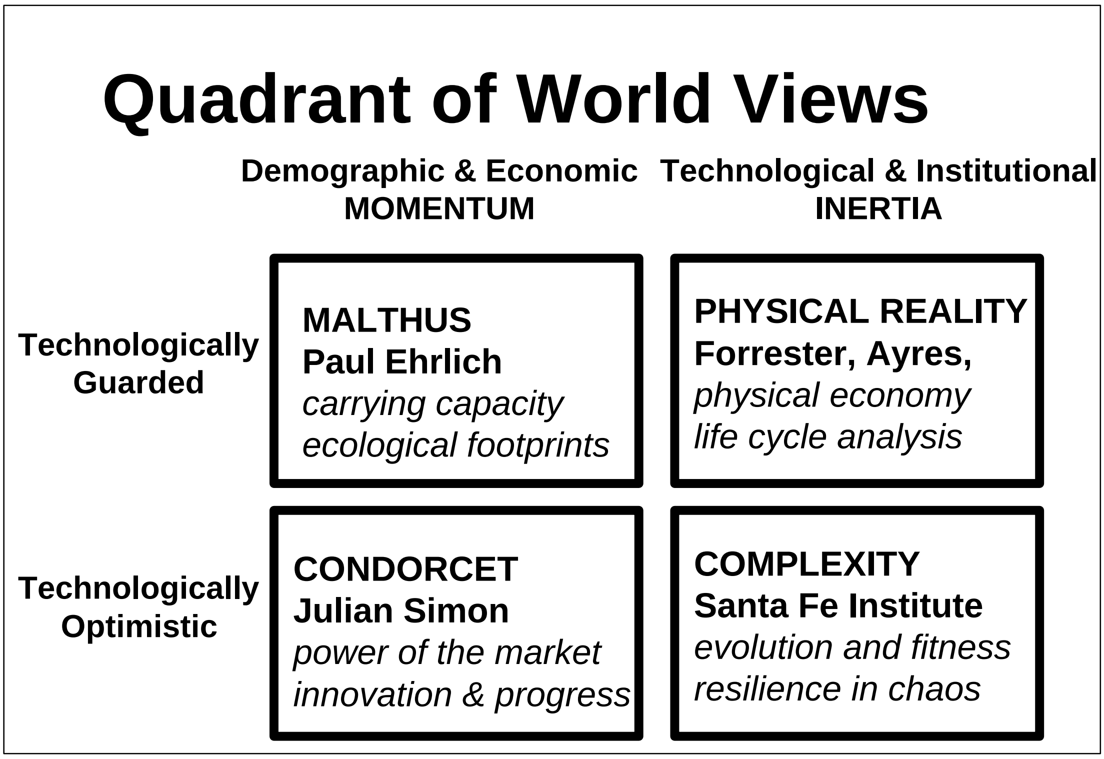

Figure 1.1. An organising framework of four world views within scientific disciplines. Different world views determine how people understand, analyse and act on the realities within the physical economy.

When the Reverend Thomas R. Malthus first wrote his essay, *A Summary View of the Principle of Population* as a supplement to the 1824 version of the *Encyclopaedia Britannica* (Mentor Books, 1960), he would not have expected the debate to still be raging at the start of the second millennium. Scientists such as Paul Ehrlich (1968) and Lester Brown (1998) still propose that continuing population growth and linked lifestyle and resource consumption pose a serious threat to the ecological integrity of world ecosystems. The analytical philosophies used in this quadrant (technologically guarded, demographic and economic momentum) are well versed in demography, ecology, pollution generation and use of natural resources. The concepts of human carrying capacity (Cohen, 1995) and ecological footprints (Wackernagel and Rees, 1996) are good examples of concepts developed in this quadrant. These analyses are based on comprehensive data and are relatively straight forward. As such they often attract criticism because they are seen as static (rather than dynamic), present problems (rather than solutions) and they ignore much of humankind's history of innovation and progress.

In the same era when Malthus was promoting the world view of the first quadrant, Marquis de Condorcet was promoting the views of the technologically optimistic group (University of Berkeley, 2000). He espoused that the richness of the human spirit had the potential to overcome all odds, and that there was no limit to humankind's capacity to invent and solve. These views are still being repeated and many of Condorcet's disciples, most notably Julian Simon (1990) and Boserup (1999), have won a number of important debating points over the their technologically guarded colleagues.

The analytical methods of this group generally include many economic approaches most notably the computable generalised equilibrium (CGE) models at the heart of national decision making in macro-economic areas for most developed economies. In Australia these include the MONASH model (formerly the ORANI Model) developed at Monash University, the TRYM model used by Commonwealth Treasury, the Murphy Model used by the private firm EconTech and the Salter Model used by the Federal Department of Foreign Affairs and Trade (EPAC, 1994). Some criticisms directed at this analytical approach include the 'absence of equilibrium' in most functional economic and natural systems and the limited long-term validity of the behavioural assumptions that describe the concept of elasticity. Nevertheless, such approaches are underpinned by an extensive body of theory and data and represent a comprehensive understanding of how economic structures react to policy innovation and shocks, particularly in the short term.

Adherents to the third quadrant are technologically guarded and attuned to the inertia in most infrastructure and institutional systems. This approach is typified by the work of Ayres (1998), Slesser et al. (1997) and Forrester (1961) and has two key components not found in the left hand quadrants of Figure 1.1. These proponents argue that the economic and social world views are within the physical world, and must therefore eventually conform to physical laws. These laws include the laws of thermodynamics and mass balance which impose constraints on the optimism of the world views residing in the second quadrant. The physical realists use dynamic systems modelling techniques to enhance the analysis and understanding of dynamics. They avoid assumptions of notional equilibrium structures or resting points, where all forces are in balance. They also seek to ensure that important forces such as population growth and economic growth are linked to the biophysical realities of resource requirements, and the production of waste and pollution. Critics of this approach question the degree to which improvements in human management, substitution between materials, and innovation are excluded from modelling considerations. The modelling approaches used in this study (ASFF and *OzEcco*) lie predominantly within this third quadrant, but use theory and data from other quadrants.

The fourth quadrant includes those who are both technologically optimistic and also aware of inertias in infrastructure and institutions. Their work is typified by the complex systems research underway in the Santa Fe Institute USA (Santa Fe Institute, 2000) and made popular by concepts such as emergent properties (Ruitenbeek and Cartier, 2001) and books such as *Complexity* (Waldrop, 1994). The complexity quadrant brings together seemingly disparate groups such as evolutionists, economists, ecologists and pure mathematicians to help foster order and understanding on complexity and chaos from the level of genes to money markets to climate systems and the intricacies of the future human mind. The overall methodological approach employed by this quadrant is difficult to typify beyond being based on complex mathematics, agent based modelling and advanced analytical approaches. A criticism of the approach might be that it is difficult for a policy analyst to understand and apply, outside its immediate research environment.

Population-development-environment studies in Australia

The development of economy-wide modelling in environmental issues was stimulated in Australia by the continuing population debate. The concepts of population targets and carrying capacity were introduced into Australia starting in the 1920s when a Sydney university geographer Thomas Griffith Taylor set Australia's estimated carrying capacity at 65 million people and later reduced this estimate to 20 million people (Cocks, 1996). The 1980s and 1990s have seen several national inquiries on population, the most recent of which, the Jones Inquiry (Long Term Strategies Committee, 1994), stopped short of recommending a national population policy (Cocks, 1996). By default, Australia's population seems to be moving towards a more or less stable number of around 23-25 million people within one or two human generations. During the 1990s, the national population debate evolved to cover a wide range of issues such as resilience of ecological systems, material consumption levels, sustainability issues and population size as a determinant of domestic market efficiencies and Australia's place in world affairs.

It was against this background that CSIRO initiated a strategic project to underpin the population debate, and its linkages to resource use and environmental quality, with scientific analysis. The project's initial aim was to focus on the environmental aspects of population impact with particular emphasis on the quality and quantity aspects of water, soils, biodiversity, atmosphere and natural amenity. Initially the work followed a conventional scientific route to examine the effect of population on water resources, land resources and so on. However because of the complex linkages between all sectors of society and the economy, this approach would have been difficult to implement. In addition, the project was challenged with a future focused and long-term topic which required integrated advice and a range of possible solutions. At this time the project became aware of two important methodological approaches. The first was the work of Godet (1991) on *strategic prospectives* and thence the use of foresighting and scenario development by multinational companies such as Royal Dutch Shell. The second was the implementation of population-development-environment simulators, particularly the work by IIASA in Mauritius (Lutz, 1994), the physical analysis paradigm using the design approach (Gault et al., 1987) and the embodied energy approach of Slesser (1992) and Slesser et al. (1997).

The project design then evolved to "influencing national policy agenda in regard to population policy and the impact of humans on the environment". Two linked themes of work emerged; first scenario development, proposed a number of robust and well documented national scenarios to lead and inform debate on national development and sustainability issues. Three scenarios, *Economic Growth*, *Conservative Development* and *Post Materialism* have been published in book form (Cocks, 1999). The second theme of work developed in order to underpin the scenario work with quantitative analyses. Two system simulators were developed based on different paradigms of physical analysis. One of these, *OzEcco* (Foran and Crane, 1998), used the embodied energy approach of Slesser (1992, 1997) to construct a top-down and aggregated simulator of Australia's physical economy. This analytical approach assumes that the delivery of goods and services to a domestic economy, and its human population, is a function of the extraction, delivery and efficiency of use of energy resources, most of which are derived from fossil sources.

The second simulator, the *Australian Stocks and Flows Framework* (ASFF), was a disaggregated set of linked models which access a database describing the last 50 years of Australia's physical function or physical metabolism. The 'design approach' used by ASFF is philosophically attractive for two reasons: firstly it treats the complete range of physical functions as separate entities (crops, animals, people, cars, steel production, chemical production) and allows a detailed treatment of 'vintaging' or age for most big-ticket items of physical infrastructure. Secondly, physical functioning is retained within the modelling code and termed 'machine space'. The management and policy decisions that guide this physical functioning are retained as part of a scenario under development and testing by the user or policy analyst and are termed 'control space'. Gault et al. (1987) describe the design approach in the quotation which follows:

> The design approach is a philosophy for building computer based simulation frameworks, which represent socio-economic systems, and for using the simulation framework to design alternative futures through repeated simulation. It is the exploration of alternative futures by the user, who forms part of the system, which distinguishes this approach from that of macro-economics with its emphasis on prediction. The exploration and the involvement of the user result from the absence of optimisation or equilibrating mechanisms in the physical representation of the socio-economic system. This ensures that the user, working alone or with the aid of a model of decision processes, controls the system. The policy decisions necessary to exercising this control are required to be explicitly stated,

and they form a record of how the future, resulting from the simulation, was arrived at.

The following sections describe the system simulators in more detail. For reference purposes, an example of a global approach to physical modelling — the IMAGE global change model (Alcamo et al., 1994; 1998) — is also included. This model has been used in a wide range of international policy studies. Some examples of model use within policy and science processes are also described in this chapter as well as some challenges for these analytical approaches in achieving a goal of 'influencing national policy'. The chapter concludes with some insights into the many conundrums which researchers face when they use integrative modelling of the physical economy to implement approaches of this type.

MODEL DESCRIPTIONS

Models of global climate change

The issue of global climate change has stimulated the development and use of a large variety of modelling frameworks. Some of them deal comprehensively with one issue, such as carbon metabolism at a global level, and others attempt to integrate all important issues in an approach termed 'integrative assessment' (Goudriaan et al., 1999). An example of the latter is IMAGE (Alcamo et al., 1994; 1998) developed by the National Institute for Public Health and the Environment in The Netherlands. It combines three distinct areas: the energy-industry system, the terrestrial-environment system and the atmosphere-ocean system (Figure 1.2). The nationally scaled models described next in this chapter use the first two of these systems but lack the ocean-atmosphere system. The key difference between this approach and the latter ones is one of scale. IMAGE models the physical metabolism of the entire globe in 13 different regions, whereas the national models deal with one nation described by many sub-divisions.

The IMAGE model links the effects of human management through the full chain of physical processes that run the globe. Thus, population growth and increased per capita affluence cause land use change and increasing energy use, all of which increase the emissions of carbon dioxide and other greenhouse gases such as methane. These emissions cause changes in function of the earth-ocean system, leading to changes in rainfall and temperature which, over the duration of the model simulations, can feed back to affect sectors such as agricultural productivity and water yield from catchments. While models such as IMAGE are generally used to test scenarios, they can also be used for prediction and back(hind)-casting. In prediction mode, model analysts make assumptions covering the full range of possibilities for the driving forces.

The simulation outputs include issues such as atmospheric concentrations of greenhouse gases, temperature changes, rises in sea levels and changes in agricultural productivity. Since the future is relatively unknown, such assumptions usually include a full range of sensitivity testing so that ranges of error, or probabilities of outcomes, can be measured. After making predictions, the model can then be used for back-casting. In this case, key assumptions that drive global climate change (population growth, fossil energy use, land use change) are altered in an attempt to reduce or change the nature or the severity of the initially simulated outcome. Using the model in this way, can give new insights or understanding leading to improved policy design and targets for technological innovation. At some stage in the global simulation process, these broader insights must be applied on a national scale, where more detailed investigations are required to substantiate the social and political changes required. This is where the more detailed national modelling is required.

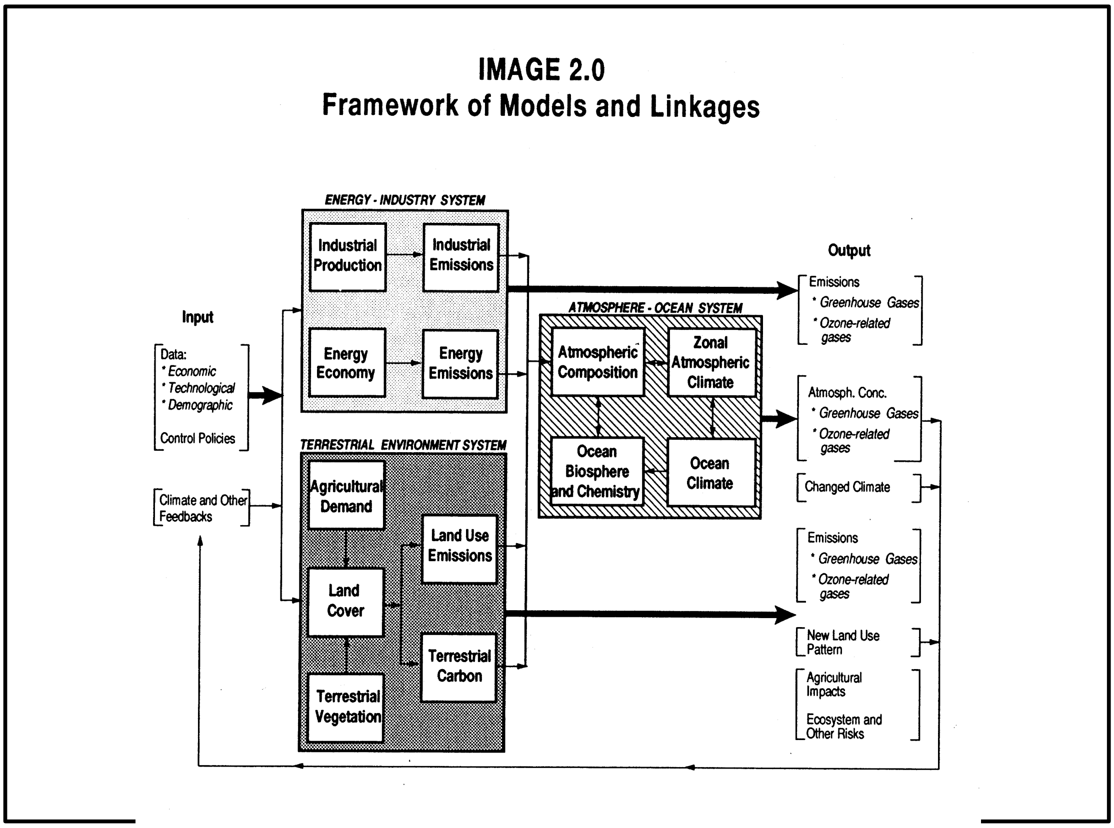

Figure 1.2. A schematic representation of the IMAGE 2.0 integrated assessment model (From Alcamo et al., 1994)

The *OzEcco* embodied energy model

The *OzEcco* model is designed to integrate the driving forces of population, lifestyle, organisation and technology and to explore their possible impacts on the environment within the context of Australia’s physical and economic structure. The model integrates the structure of the national economy and its energy accounts so that capital stocks are expressed in a physical measure of petajoules of embodied energy rather than in monetary terms. Activities within the economy are expressed as energy flows, in petajoules per year. In this way, economic activity has been converted to physical activity, which is consistent with the first and second laws of thermodynamics. All economic transactions are represented by the physical transformations which underpin them. This representation is consistent with the long term physical processes which are central to the functioning of any modern economy.

Conceptually the *OzEcco* model has five broad components: natural resource stocks, the energy transformation sectors, consumption activities, pollution generation and whole system indicators. The core modelling concept is that access to and transformation of energy (typically stocks of fossil fuel) are the determinants of physical growth in a modern industrial economy. Thus, all goods and services are expressed in terms of the chain of energy processes that eventually become included (embodied) in a final good (a motor car) or a service (banking and education). Some sectors, such as domestic housing, act as long-term accumulators of fixed energy capital (embodied energy), whereas personal consumption dissipates embodied energy relatively quickly. The concept is shown in Figure 1.3. The capital stock of industry (stock of embodied energy) is the primary focus through which human made capital is created. Industry contributes to other sectors such as agriculture (fertiliser, machines), domestic housing (bricks, carpets, stoves) and so on.

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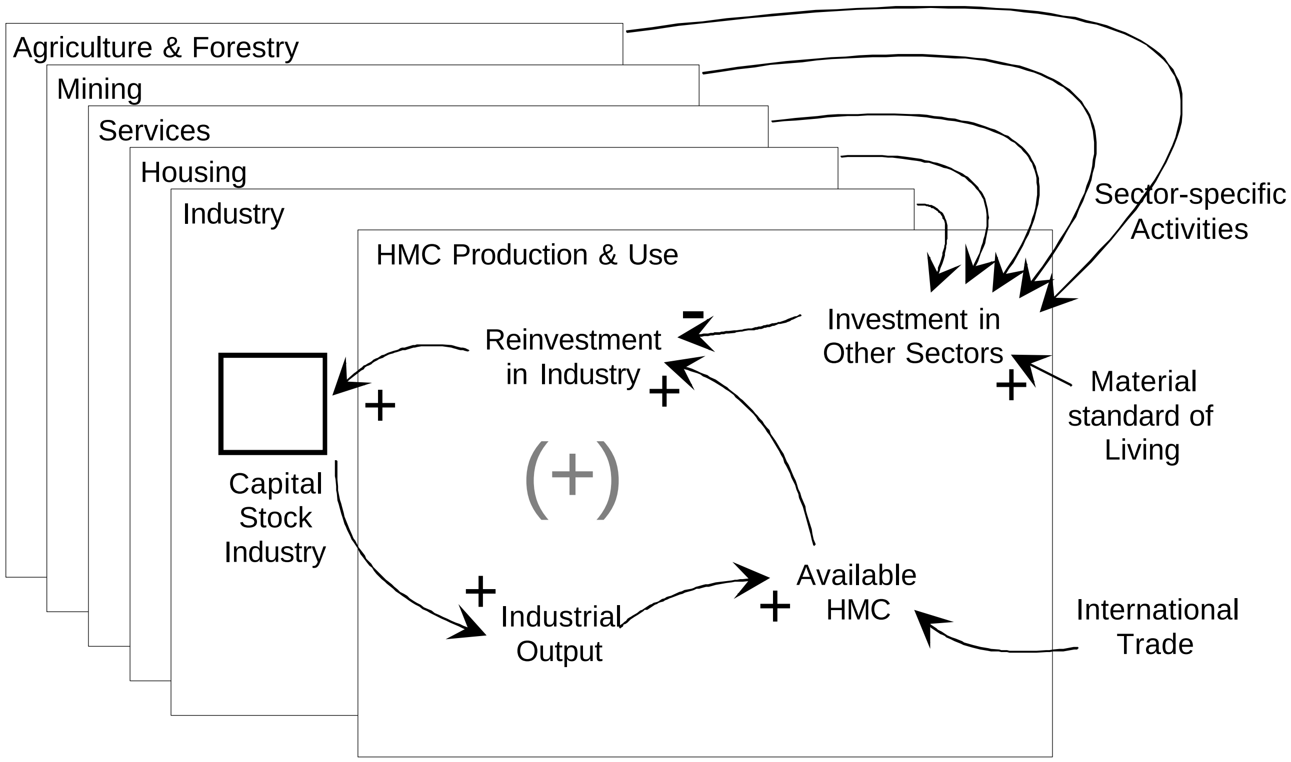

Figure 1.3. The central growth-determining loop in the *OzEcco* model, with the aggregated industrial sector depicted here as the core resource for growth. The processes of fixed, or human made, capital (HMC in diagram) are depicted as an influence diagram, illustrating the main causative features represented in the model. The total human made capital available is the sum of imports and domestic production.

The rate at which industry can grow in a year is limited by the contribution which this sector makes to other sectors of the physical economy and the consumption activities of the population at large. Both of these activities (industrial growth and personal consumption) act as negative feedbacks to restrict the rate at which the physical economy can grow. The effects of international trade and financial flows can be both positive and negative. Exports are regarded as negative because they reduce the amount of embodied energy that can be used nationally. Physical imports and monetary inflows are interpreted as positive influences because they increase a nations capability to undertake physical work. All of these factors are linked in a systems dynamics framework (Richardson and Pugh, 1981). The simulated economy is allowed to grow as fast as is physically feasible (governed by the first and second laws of thermodynamics) in a physical economy constrained by the availability of fossil energy, and the requirement to maintain national infrastructure together with personal consumption activities. Global monetary issues (e.g. balance of payments and international debt) are regarded as flows and stocks of virtual embodied energy which, in the short term, might override a number of resource and infrastructure issues confronting the physical economy.

For a number of reasons, both the science and the policy community have found it difficult to accept the *OzEcco* approach. The use of an integrating concept such as embodied energy is difficult for some policy analysts to comprehend, although it is functionally similar to the use of money as a numeriare in economic analysis. However, two recent developments in the energy and greenhouse area of the physical economy have increased the potential acceptability of this approach. The first is the acceptance of static analyses of energy embodiment using input-output tables of the monetary economy to determine the energy use and greenhouse gas generation by different sectors of the economy (Lenzen, 1998). The second is the use of *OzEcco* in designing transitions towards a biomass based transportation cycle, which is attracting a degree of national technical interest (Foran and Mardon, 1999; Foran and Crane, 2000).

The Australian stocks and flows framework (ASFF)

General description

ASFF is a highly disaggregated simulation framework which keeps track of all physically significant stocks and flows in the Australian socio-economic system. In this context, stocks include people, livestock, trees, buildings, vehicles, capital machinery, infrastructure, land, air, water, energy and mineral resources — disaggregated, as appropriate, according to their physical characteristics and importantly, age or 'vintage'. Flows, resulting from physical processes of many kinds, represent the rates of change of stocks and constitute the development of the system in more or less desirable directions.

The framework contains a simulation model and a database. The model consists of 32 hierarchically connected modules or calculators which account for the physical processes of demography, consumption, buildings, transport, construction, manufacturing, energy supply, agriculture, forestry, fishing, mining, land, water and air resources and international trade. Each calculator deals with the stocks and flows relevant to a sector and with the physical processes through which they interact.

Calculator assumptions are based on technical and scientific understanding of the processes involved and are intended to provide a plausible representation in physical terms of the workings of the sector. One of the criteria used to validate the calculator, is that a professionally informed person should be able to understand its structure and conclude that the process description and the parameter values, are plausible and appropriate to the level of aggregation of the treatment.

An overview of the whole framework is given in Figure 1.4, where the arrows link calculators arranged in functionally similar and hierarchically related groups (note that the arrows do not represent sector linkages or information flows, — these are shown in Figure 1.5).

The model calculators

At the highest level, the Australian socio-economic system is conceived of in terms of people (**Demography**) and the physical needs of their way of life (**Materials and Energy**). Population is an important driver in the framework and, other things being equal, more people require more materials and energy. Other things are not necessarily equal, and one of the goals of the ASFF approach is to explore the interplay and trade-offs among issues such as Population, Lifestyle, Organisation and Technology, — the PLOT factors.

The five **Demography** calculators deal with population (including overseas and internal migration) and issues which depend directly on population and its distribution over age, sex and location: education needs, morbidity and health needs, internal travel, household formation, labour force participation, demand for personal services and inbound tourism. Population and inbound tourist numbers are independent drivers in the framework, that is, the parameters which determine their level and growth are specified outside the model in the control space. Information from these demography calculators is passed to later calculators and used to determine the requirements for infrastructure, goods and services of all types.

The **Consumables** calculator determines the need for food and other consumable items directly from population (including overseas visitors) on a per capita basis. The four **Buildings** calculators use information from demography to determine the needs of the population for residential, commercial, educational, health care and institutional buildings.

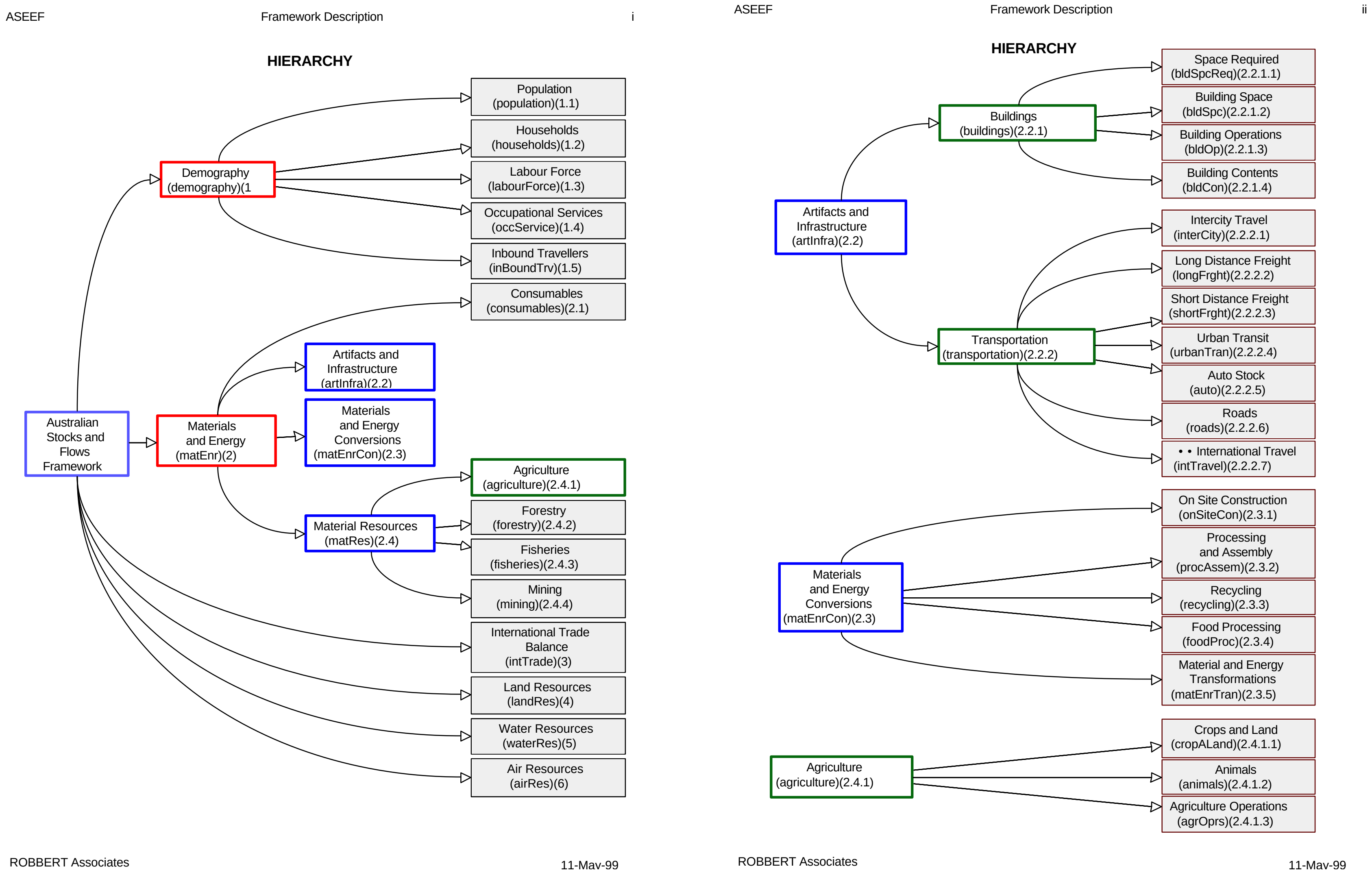

Figure 1.4. Hierarchy of calculators in the *Australian Stocks and Flows Framework*. The clear boxes with bold borders represent hierarchical groupings, shaded boxes represent calculators. See Figure 1.5 for information flow between calculators.

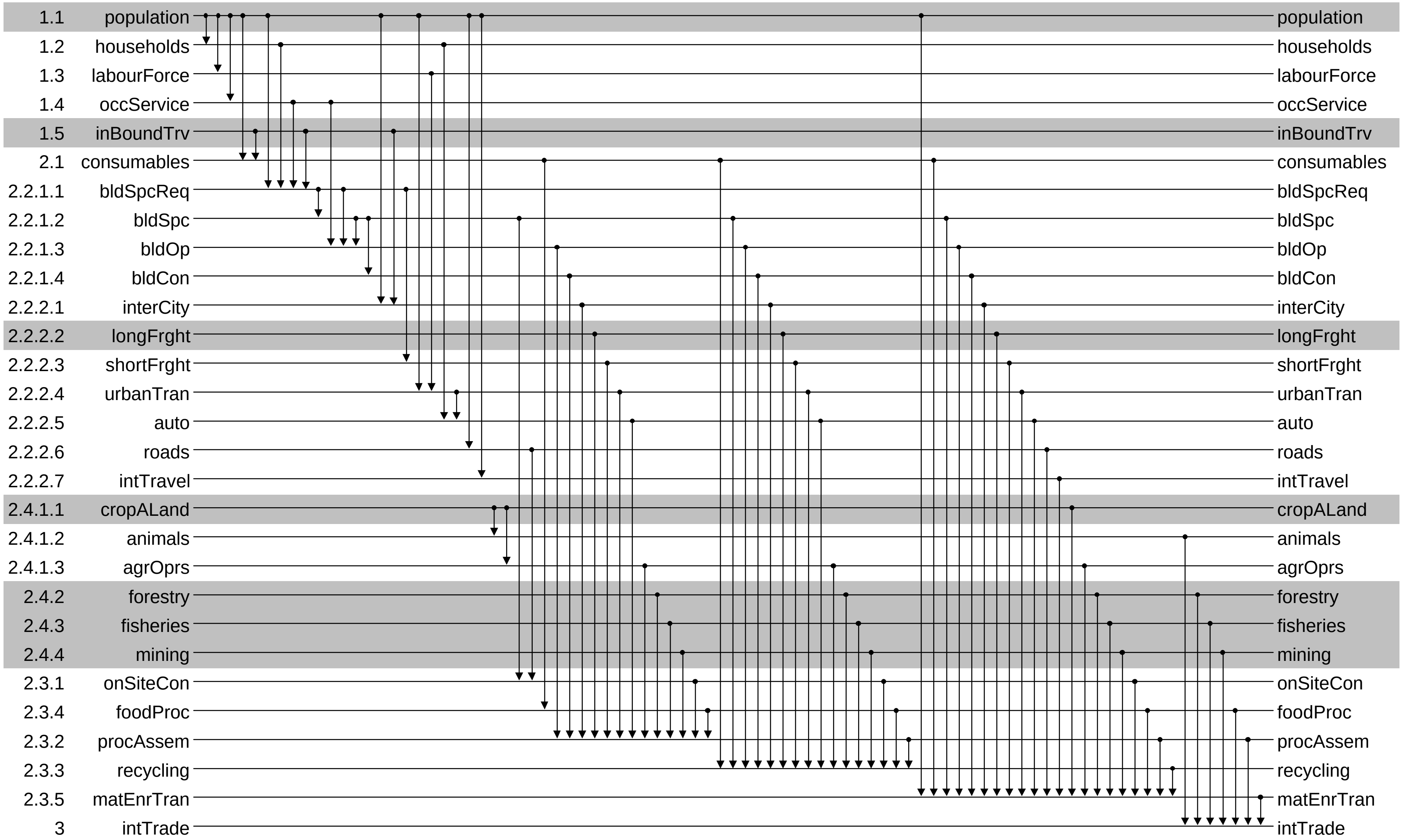

Figure 1.5. One way information flow (vertical arrows) between calculators (horizontal lines) of the *Australian Stocks and Flows Framework*. Shaded calculators receive only exogenous input (no arrow heads on shaded lines).

Seven calculators deal with various aspects of **Transportation**. Broadly, these cover domestic passenger and freight transport in urban and rural areas. Separate calculators deal with the car fleet, roads and their maintenance, and fuel for international travel. In most cases, a transport task is determined in relation to demographic parameters and, with the help of load factors and average yearly distance travelled, the task is translated into a need for vehicles. The **Material Resources** calculators describe production processes in the primary industries: agriculture, forestry, fisheries and mining. Like population, tourism and long distance freight, they are independent drivers in the framework and receive no information from earlier calculators. Their planned levels of production are specified exogenously because much of the produce from Australian primary industries is destined for export.

Agriculture is covered by three calculators which deal with crops and land, livestock and agricultural operations in each statistical division. Cropping deals with the areas of land devoted to each of 10 different crops (or land may remain fallow or idle), the impact of cropping activity on four indicators of soil quality (acidity, dryland salinity, irrigation salinity and soil structure) and the effect on yield of genetic improvements to crop varieties, the application of fertiliser and irrigation and of declining soil quality due to the cumulative effects of previous cropping. The **animals** calculator deals, in each statistical division, with the stocks of animals of different types, the quantities of animal products they yield and their feed requirements in terms of crops and area of grazing land.

Forestry deals with 15 different types of forest managed under regimes which vary from full protection, to clear cutting and managed plantations. Fire frequency and tree growth and survival rates are taken into account. Inventories are kept of land areas and tree numbers and wood volumes by age. **Fisheries** deals with both wild fishing and aquaculture. Wild fish stocks vary in response to reproduction and mortality rates, and to the level of fishing. Each fishery can sustain a moderate level of fishing but, if overfished, the stock collapses to a level at which catch per unit effort no longer warrants fishing. Fishing effort is allocated among fisheries in an attempt to meet planned production levels at minimum effort.

Mining covers exploration for mineral and energy resources, evaluation and classification of resources as reserves, and extraction of minerals and energy materials to meet planned production. 'Resources ever found' is the estimate of the nation’s total endowment of a material. Unless augmented by new discoveries, cumulative production will never exceed this quantity. The **Materials and Energy Conversions** group of calculators covers construction, manufacturing and energy supply. Its calculators deal with the need for materials, energy, goods and infrastructure identified in earlier calculators. **Processing and Assembly** consolidates the requirements for vehicles, machinery, building contents and operating goods of all types from previous calculators and, allowing for imports and exports, determines the level of domestic production of these goods. **Recycling** consolidates all discarded goods, vehicles and machinery and determines the proportions to be recycled or disposed of to land fill. The material content of the recycled fraction is determined by a knowledge of the material composition and vintage of the goods and vehicles. **Material and Energy Transformations** ensures that the needs of the whole economy for materials and energy are met.

The **International Trade** calculator consolidates domestic production and domestic requirements for primary materials, secondary materials, vehicles and machinery, intermediate and final demand goods and determines import and export quantities. These are combined with a set of import and export prices and an interest rate, to determine the value of the trade flows, the current merchandise trade balance in nominal dollar terms and its contribution to the international debt (or surplus) again in nominal dollar terms. Finally, **Land Resources**, **Water Resources** and **Air Resources** consolidate information from the whole framework into accounts which provide an overview of the state of these important resources.

The framework is grounded in a database for a 50-year historical period which is complete (all data gaps are filled) and where variables are consistent with each other and with the assumptions in the calculators. These assumptions are based on technical and scientific understanding of all the processes required to describe physical stocks and flows underneath the Australian socio-economic system. At the most basic level this ensures that fundamental requirements such as the conservation of matter and energy and the laws of thermodynamics are observed. For particular calculators, the assumptions need to be consistent with a specialist's understanding of the processes involved.

Calculator linkage, feedback and tensions
The calculation linkages are shown in Figure 1.5 where arrows flow downwards only, indicating that feedbacks caused by demand and supply imbalances are controlled by the user, who separates 'control space' from 'design space'. In order to calculate the quantities demanded within the physical economy, the population calculator (1.1 in Figure 1.5) passes down

- the requirements for households (1.2) through an age and sex determined household formation rate)
- the availability of a labour force (1.3) through an age and sex determined participation rate
- the demand for employment in non-physical sectors of the economy, such as services (1.4) as a proportion of the total population
- consumables such as food, plastics, paper, pharmaceuticals and chemicals (2.1) on a per capita per year basis
- the demands for building space (2.2.1.1), intercity travel (2.2.2.1), urban transit (2.2.2.4), roads (2.2.2.6), international travel (2.2.2.7) and material transformations (2.3.5)

This process is continued down the hierarchy of calculation procedures giving a complete set of quantities demanded by the population driver and subsequent flow-on effects. In order to supply the quantities demanded, production or control variables are set in the primary material sectors (agriculture, forestry, fishing, mining) or the international trade sector, so that the quantities demanded by the population might equal the quantities supplied over the period of the simulation.

The design approach which lies behind the implementation of the ASFF model distinguishes 'control space' from 'machine space' (Figure 1.6). The user or analyst who makes assumptions on the basis of current knowledge and future expectations and then alters control variables in the ASFF, model occupies 'control space'. The modelling code and the equations which describe the processes which drive the physical economy, occupy 'machine space'. This is the domain of materials, energy and physical processes.

What happens in machine space depends on physical laws and on choices made in control space according to people's values. However, people's control of the physical world is imperfect both because the physical world is very complex, and also because their goals and values conflict with those of others. From control space, the analyst can monitor what happens in machine space during model simulation and evaluate the outcomes according to goals and values set by a policy analyst or a research group. In practice, the iterative nature of design and testing can be slow and spasmodic as simulation outcomes are delivered to clients as documents with scenario graphs and written interpretations. In a perfect world, a policy client and a simulation analyst could sit together at the computer screen and accelerate the process of learning and design.

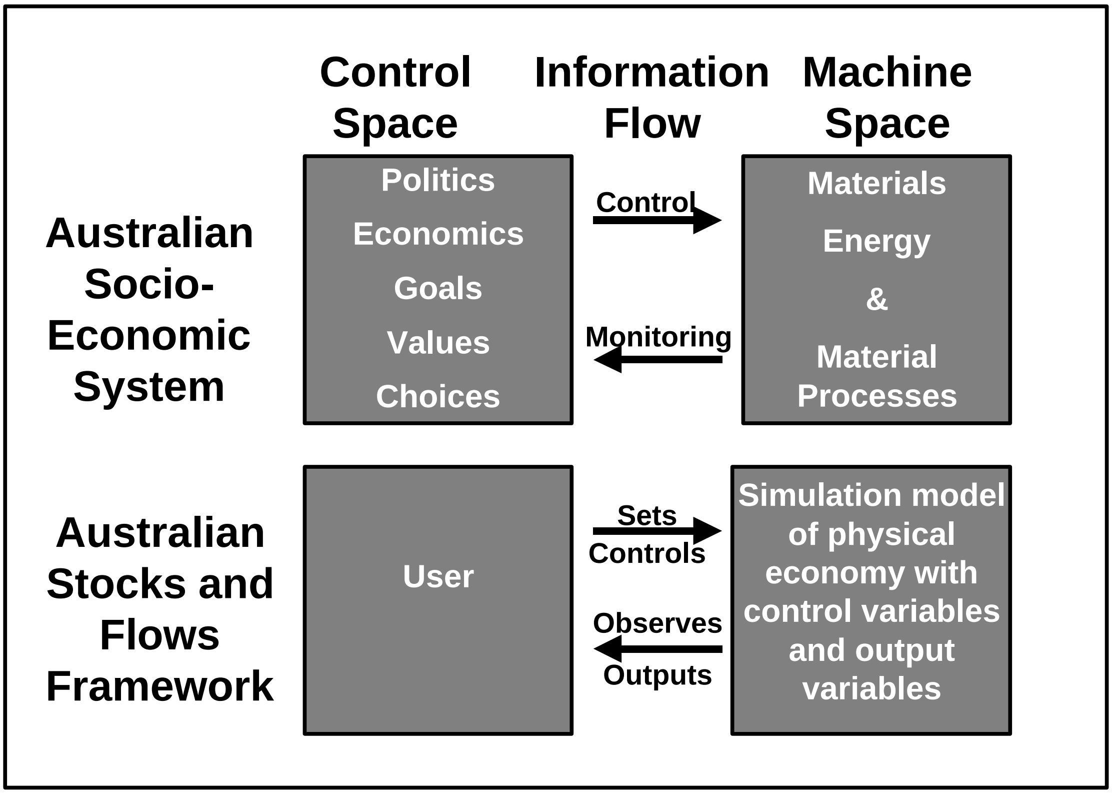

Figure 1.6. Content and information flow between control space and machine space in the reality of the Australian socio-economic system and in the control and machine space of the *Australian Stocks and Flows Framework*.

In the design approach used in ASFF, only the physical processes in machine space are modelled. The user occupies control space, observes the situation in machine space and makes decisions about the settings of the control variables. The user is therefore an integral part of the feed back loop, acting as a proxy for society and its political and economic agents, and is in a position to learn a great deal about the system behaviour.

Resolving tensions (imbalances between quantities demanded and quantities supplied) may be obligatory or optional. If a tension indicates a physical or accounting inconsistency, it must be resolved. For example, if insufficient primary energy is supplied to meet electricity and transport requirements, then its supply and delivery must be increased. Another form of tension might indicate the failure to meet some non-physical goal or desirable criterion. In this case, its resolution is judged to be optional, e.g. an imbalance between labour demand and the labour supply. Where labour supply exceeds demand, there is unemployment and the scenario is still physically feasible. If labour demand outweighs supply, then the production goals might be regarded as infeasible. Production goals might have to be decreased, or the labour force increased.

APPLICATIONS AND RESULTS

The OzEcco embodied energy model

For a policy client interested in alternative landuse scenarios to help re-mediate landscapes suffering from dryland salinity, scenarios were implemented within *OzEcco* to produce alcohol fuels from woody biomass (Foran and Mardon, 1999; Foran and Crane, 2000). A number of assumptions underpinned this methanol production scenario: (i) The scenario would aim to supply 90% of Australia’s total oil requirements specifically to meet 100% of the requirements for transportation fuels; (ii) The feedstock share would be 100% woody material from plantation biomass resources, which are currently managed as forests with a 20-year rotation and an average 20 m^3 per year mean annual increment; (iii) Approximately 60% of the woody biomass would be derived as logs and the remainder as branches and waste wood; (iv) The rate of plantation biomass establishment (basically forests) would be 400,000 hectares per annum; (v) The capital cost in constant dollar terms of the methanol plant was $50 million per petajoule of production capacity and the lifetime of plant was 20 years.

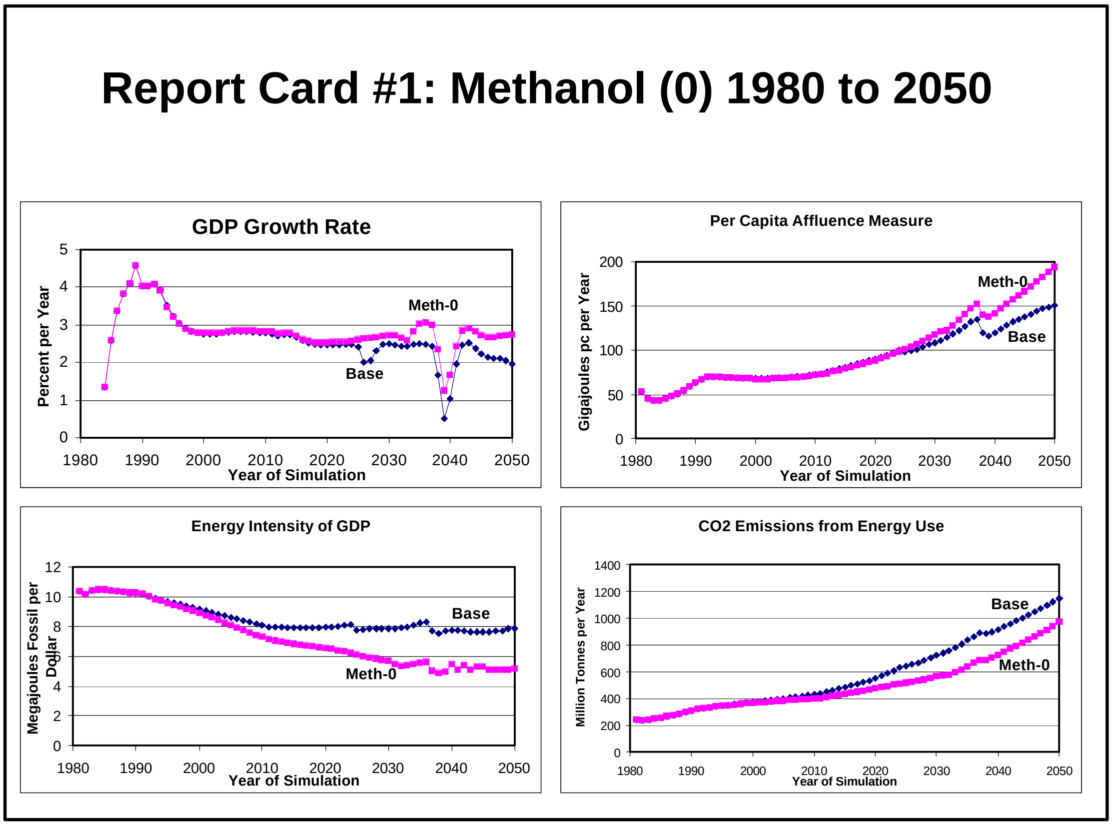

Figure 1. 7. Report card #1 for the methanol scenario (Meth-0) compared to the base case (Base) showing growth rate in GDP, per capita affluence index, energy intensity of GDP and carbon dioxide emissions from energy use.

The aggregate indicators simulated by the *OzEcco* model with these scenario assumptions are shown in Figure 1.7. The simulated growth rate in GDP for the methanol scenario tracks with or above the base case scenario for the duration of the simulation. The first dip in the curve due to oil depletion is avoided, and the second drop due to the depletion of natural gas stocks is not as large. The per capita consumption measure (gigajoules (10^9J) per capita of energy embodied in personal consumption) tracks with the base case until 2030 and then takes a higher trajectory. The energy intensity of GDP (megajoules (10^6J) of fossil energy per constant dollar of GDP) is decreased by about 30% (from 8MJ to 5MJ per dollar) by 2050. The emissions of carbon dioxide from the energy sector diverge from the base case after 2005 and rise gradually to 1000 million tonnes per annum by 2050, a reduction of 200 million tonnes per year compared to the base case.

Analyses such as these are not predictions in a traditional sense. Rather they test the likely behaviour of the simulated physical economy to policy innovations and new structural designs. A measure of their success is the degree to which indicators for a scenario under test diverge from (CO2 emissions) or remain with (GDP growth rate) the base case scenario. While physical processes drive the *OzEcco* model, it is possible to derive a number of economic indicators such as nominal GDP because of the strong relationship in the current structure of the economy, between the valued-added dollars and fossil energy usage. These relationships are well analysed in studies by Lenzen (1998).

Each scenario is able to display hundreds of indicators. These are grouped into a number of report cards displaying four indicators simultaneously. Figure 1.7 shows the macro-level indicators, which are then supplemented by more detailed report cards of the operations of the physical sectors being restructured in particular scenarios. What constitutes a successful scenario in a policy or industry context is difficult to say. The advantage of the physical modelling approach, compared to the indicator sets commonly used in state of environment reporting, is that the indicators are structurally linked to each other within a quantitative analysis of the physical economy. Provided that the modelling is philosophically and bio-physically sound, this provides a thorough basis for interpretation and understanding, as well as a cogent and robust look-ahead capability.

The Australian stocks and flows framework

The following scenarios show how the ASFF approach can be applied. The first is a single sector approach which concentrates on population issues. The second is a multi-sector approach linking population scenarios and vehicle scenarios and the resultant demand for energy use and generation of emissions. The third application seeks to identify possible bottlenecks or constraints to the availability of water in urban situations.

Single sector scenarios

Within the ASFF approach, the population calculator is implemented as one of the main drivers of demand of food, paper, water and energy and subsequent flow-on effects. However, many analytical insights are important in their own right, particularly in Australia where immigration policy is an important policy lever. Future population stocks or targets will depend on the degree to which immigration is used to offset declining birth rates. Three scenarios of net immigration (zero, 70,000 per year, and 0.67%pa (two-thirds of 1% of total population per year)) were combined with the declining total fertility rate (from 1.78 to 1.65 children per woman), and increasing longevity (1 years life extension for each decade of the simulation out to 2050). The results are presented for the years 2050 and 2100 (Table 1.1).

Australia in 2050 could be home to 20, 25 or 32 million people depending on its choice of net immigration rate. While a zero net immigration is the policy position of several environmental groups, detailed demographic analysis (McDonald and Kippen, 1999) shows that this option produces eventual population decline, and substantial falls in the size of the labour force. The ASFF analysis is consistent with this more detailed work, and shows total population declining from 20 million in 2050 to 17 million in 2100 under the zero net immigration scenario. Under the 70,000 net immigration scenario, the population increases by 0.4 million people between 2050 and 2100, and with 0.67%pa net immigration it increases by 18 million people to 50 million people over the same period, and is still growing at 2100.

Table 1.1. Scenarios for Australian population size based on zero, 70,000 and 0.67%pa (two-thirds of 1% of total population each year) net overseas migration, declining fertility rates and increasing longevity.

Year	Zero Net Immigration per Year	70,000 Net Immigration per Year	0.67%pa Net Immigration per Year
2050	20.6	25.1	32.5
2100	16.7	25.5	50.6

Higher rates of net overseas migration are assumed to result in a younger population. The scenarios modelled here assume that future immigration has the same age and gender distribution as the immigration that took place over the last decade. The results show a higher proportion of population over 65 years of age with zero immigration (Table 1.2). On a proportional basis, 27% of the population is older than 65 years in 2050 for zero immigration, versus 25% for 70,000 net immigration and 20% for the 0.67%pa scenario. While the more detailed analyses of McDonald and Kippen (1999) show that levels above 80,000 net immigration do not slow the ageing of the population, under the 0.67%pa scenario, immigration is constantly increasing and the scenario includes specific assumptions about the younger age distribution of the immigrants.

Table 1.2. The effect of three population scenarios on the percentage of the population over 65 years of age in the year 2050

Scenario>	**Zero Net Immigration per Year**	**70,000 Net Immigration per Year**	**0.67%pa Net Immigration per Year**
Proportion >65 years of age (percentage)	27	25	20
Number >65 years of age (millions)	5.65	6.32	6.52

Another insight to the data is given if absolute numbers are viewed instead of proportions. There are 5.65, 6.32 and 6.52 million people over 65 in 2050 for the zero, 70,000 and 0.67%pa scenarios respectively. So, social tasks such as aged care, personal security and pensions could be larger in absolute terms with higher net immigration rates, if all other policy variables are kept neutral. The effect of population ageing is distributed unevenly throughout Australia. In a number of lower population states, younger people are moving in and people are leaving. If this trend continues, these states (and particularly their capital cities) will maintain a relatively younger population.

Multi-sector scenarios

While a wide range of specialist research agencies can supply the analyses from any of the ASFF calculators, it is the onward chain of computation through other parts of the physical economy that allows scenarios to become more technically explicit and useful to policy. For the 70,000 net immigration population scenario, this example shows how population and location parameters can be linked to motor vehicle usage, fuel consumption and subsequent vehicle emissions (Figure 1.8). The driving variable for vehicle ownership in ASFF is the individual household, which locates vehicle ownership in capital cities and regional areas around Australia. Each household is assumed to require 1.3 vehicles, each vehicle is driven 15,000 kilometres per year in non-commuting use, and the fuel use per kilometre driven declines by 60% over the next 100 years.

The analysis from these explicit assumptions shows that the total energy used by the automobile fleet and the subsequent vehicle emissions reach their peak around 2030 and then start to decline. The continued demand for vehicle ownership is built into the continued growth in population and therefore younger households coming into the market for car ownership. At the mature end of the population age distribution, people are living and staying healthy and active longer, and car ownership and usage might be maintained longer than in the past.

These simulated outcomes might change in many ways, particularly by technological innovation. Car ownership per household might decline, less kilometres per year might be driven, and engine technology might leapfrog the current energy use parameters and solve the problem of vehicle emissions entirely. However Australian lifestyles may also dictate that more cars are demanded per household and more kilometres are driven per year. The long timeframes required to alter vehicle energy use under these particular assumptions could help frame a policy trade-off, where the capacity to overcome the inertia facing technological innovation is judged against the political risks inherent in forcing a change in consumer behavior.

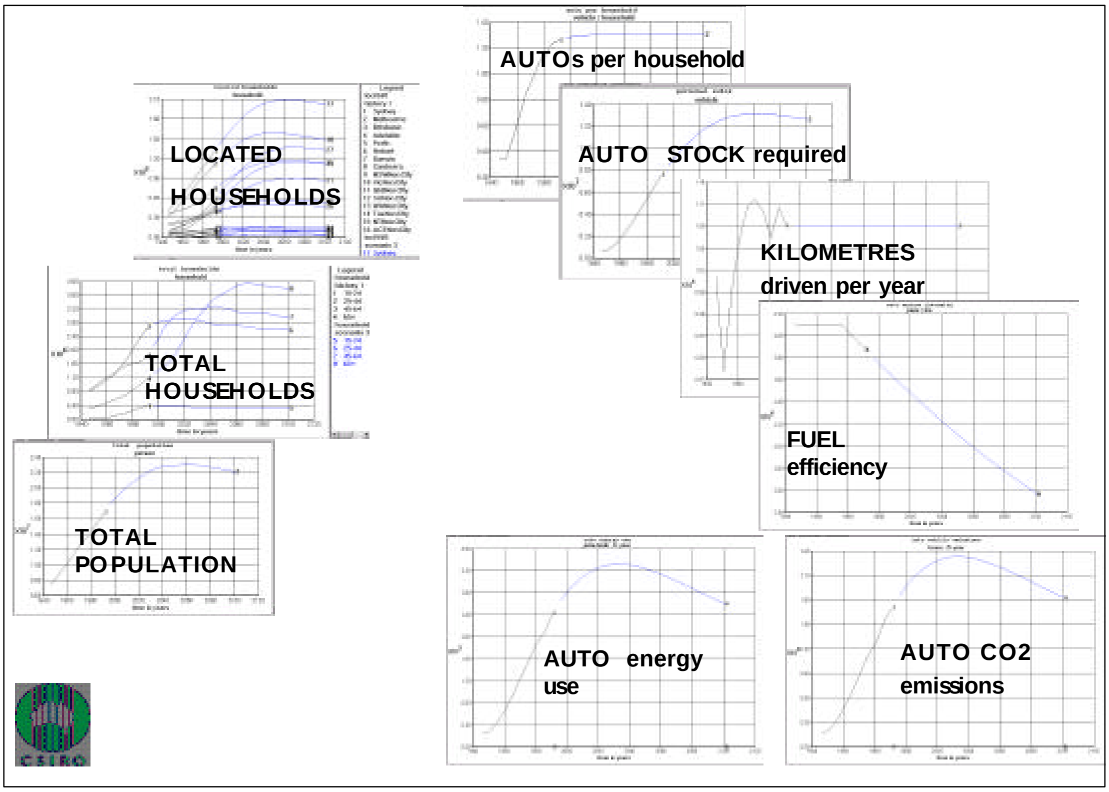

Figure 1.8. The stepwise computation within the *Australian Stocks and Flows Framework* linking population change scenarios to the personal vehicle calculator, total energy use, and vehicle emissions.

Identifying possible bottlenecks

Australia is a relatively dry continent with a highly variable annual rainfall and a reliance on irrigated agriculture for many of its higher-value commodity exports such as wine, cotton and dairy products. In the more populated parts of Australia there is competition for the use of water and concerns for both the quality and quantity of future water supplies (Thomas et al., 1999).

In considering people's direct requirements for water, significant infrastructure and management issues are directed towards maintaining clean catchments and ensuring the chemical and biological quality of water supplies for most major cities. If Australia's population continues to grow at its current rate, it will be about 25 million by 2050 (the base case scenario) which suggests urban requirements of about 6,000 gigalitres (10^9L)of water per year (Figure 1.9). This assumes that water can be transferred from agricultural usage. However, if that were not possible, for the base case scenario a sufficent range of options exists in terms of take-back from other uses and industries for sufficient water savings to ensure that enough water is available.

When the other population scenarios are compared to the base case, the requirements are 2000 GL per year more for the higher scenario with 32 million people and 1000 GL less for the lower scenario with 20 million people. By 2100 however, a number of water availability tensions could appear as the direct population requirements are 12,000, 6,000 and 3,000 GL per year for the higher scenario, the base case and the lower scenario respectively. The requirement for the higher population scenario is six times that of current urban consumption (2,000 GL per year) and approximately half of current total Australian consumption (24,000 GL per year).

It is likely that the high value of urban water would result in extra dams, interbasin transfers and pipelines being made available to supplement urban water supplies. Thus the perceived resource problem becomes one of allocation of available water, rather than a lack of water. The problem then enters the preserve of economics and politics, and moves outside the sphere of physical analysis. The modelling framework has helped quantify the size and nature of a possible problem. The eventual solutions are deemed to be more social and political, rather than than physical.

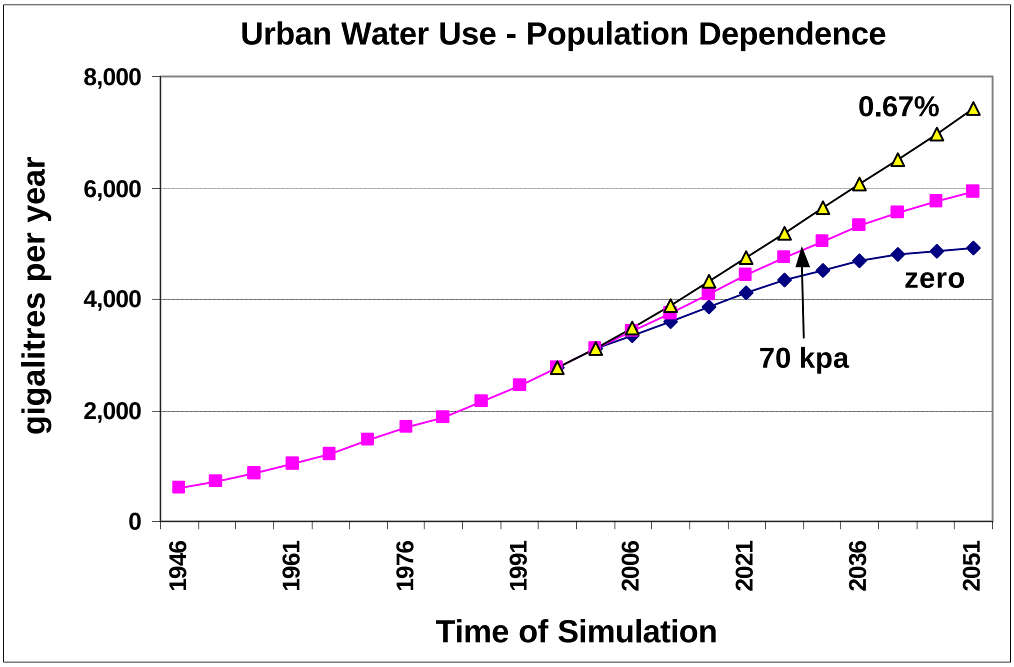

Figure 1.9. Simulated urban water requirement to 2050 in gigalitres (10^9 litres) per year , for three population scenarios: the base case of 70,000 net immigration per year (70kpa), zero net immigration per year (zero) and 0.67% of current population as net immigration per year (0.67%pa).

STRATEGY FOR NATIONAL INFLUENCE

Strategic plan

The strategic plan for the project where the ASFF and *OzEcco* models are used, has three linked goals. The first is to underpin the debate for transforming the physical economy to more sustainable modes of operation such as the dematerialised, Factor-4 or Factor-10 economy as detailed by von Weizsacker et al. (1997), Ayers (1998) and others. A factor-4 economy aims to halve energy and material usage while doubling the financial returns. The second goal is to have the concepts of physical analysis of the national economic function accepted at national policy levels. The third goal is to contribute to changing national policy on a number of key aspects relating to the physical economy.

The route to achieving these goals is complex and difficult, with two important considerations. The first is the dominance of economic theory and debate in assessments of national population-development issues allied with the belief that market mechanisms will deal with environmental problems if they are sufficiently important to require a solution. Allied with these economic views is the belief that technological innovation is a driver of progress in its own right which will bypass those functions of the physical economy which require change. The second consideration is that integration and modelling within these physical economy models is a challenging task where scientific proof (in a traditional reductionism sense) is difficult. In addition, a modelling framework is always open to improvement. In a project management sense, this can result in an imbalance between investment into modelling, the outputs from scenario simulations and subsequent contributions to long-term analysis of national policy issues.

Given these constraints, the route chosen to reach the project's strategic goals is a partial and iterative one with an overall integration phase in the final two years of the process. Although the insights into strategic policy require an analysis of the whole physical economy, the way forward requires that 20 important sectors such as agriculture, building, manufacturing, and energy are each partially investigated for a client who will underwrite the task and with whom we might investigate and learn about an important physical sector. The base case scenario is also further developed in an iterative manner, with additional insights from the client and the particular analysis undertaken. With this approach, it could take 10 years or longer to fully analyse 20 important sectors of the physical economy. Using this client focussed partial approach, it is possible that important whole-economy insights might be lost in a welter of detail, or simply not recognised. Thus a project which sought to move beyond the marginal nature of national decision making, might itself be bogged down by marginalism.

Analyses underway

The plan is being implemented with three main tasks underway. The study reported in this document is the main one. It details the infrastructure requirements and environmental loadings resulting from three alternative population scenarios out to the year 2050. The second project, funded by Land and Water Australia, develops alternative scenarios for land and water use out to 2050 and beyond. It aims to maintain national agricultural productivity, export income, food security in parallel with improving the ecological integrity of farmed landscapes. The third project, funded by the Fisheries Research and Development Corporation, aims to develop scenarios for the management of Australia's marine fishery resources, and to explore the linkages between growth in population and tourism, domestic and export demand for fisheries product with the marine resources in the south east region of Australia. Another project will deal with the energy metabolism of Australia, particularly the use of fossil energy resources and subsequent greenhouse gas emissions. Most of the work is of a government or quasi-government nature and direct links with industry policy remain elusive. Attracting business clients requires a focus on seeking future opportunities, rather than seeking solutions for perceived problems. In the next year, an analysis of the top 100 companies will attempt to match the analytical capability of the project with strategic directions of suitably orientated companies.

DISCUSSION

The approach

This chapter has described a framework of analysis for the opportunities and problems relating to future population-development-environment issues in Australia's physical economy. The approach aims to help reveal physical flaws in national plans, assist in designing for approaches which are physically feasible and to display the scenario consequences for stocks of infrastructure (buildings, roads and power plants) and natural resources (oil, natural gas, marine fish and forests).

The project relies on three key criteria if it is to achieve its stated goal of influencing national policy directions. The first is that policy makers, together with model analysts, become active learners within the analytical process. Central to the analytical approach is that the analyst or user is seen as the human dimension within the modelling procedure, rather than being a value-free controller outside the simulation process. The second criterion concerns the understanding of the physical economy and its relationship to the monetary economy. The physical economy is used to represent the vast array of physical transactions that underpin the function of the economy and it should obey the laws of thermodynamics and material mass balance. By its more virtual nature, the monetary economy is open to a wider array of innovation, beliefs and behaviour than the physical economy. Both views of the economy are valid and should be used together to inform national policy making.

The third criterion concerns the nature of predictive analysis versus scenario analysis. The concept of scenario analyses used in this approach relies on a wide array of expert opinion and data analysis. These help set the control variables which drive simulation outcomes in a transparent and explicit manner. A simulation of a scenario may seek to test the physical feasibility of a particular national policy. Alternatively, it may seek to design the pathways along which a policy must progress, if it is to reach an explicit goal in future. The use of scenario design and testing is linked to the world views and analytical methodologies of the four quadrants proposed in the introduction to this chapter. To what degree policy analysts regard themselves as either observers or architects in national affairs may be important. An observer may anticipate incremental policy changes at the margin, whereas an architect may seek to redesign and foster entirely new structures that could force the transition towards concepts of long-term sustainability.

Advantages and disadvantages of the physical modelling approach

The approach to simulation modelling, which combines the design of physical economy functions with a complete and consistent database that underpins it, is proposed as the key advantage for integrated physical models. Within this concept are complex calibration and validation procedures which set a foundation for the model in the historical period before the scenario is run forward to the future. These 'grounding' procedures enable the modellers to display a proof of concept and gain an acceptance that the underlying modelling procedures compute appropriately. The treatment of stocks of people, cars, houses, agricultural fields and so on, is central to the concepts of momentum and inertia within the physical economy which were introduced with the four quadrants of world view in Figure 1.1. Most forms of economic analysis do not implement a full description and vintaging of stocks but this process is central to the concept of environmental sustainability. The associated concept of physical realities within the production process is also vital, and usually not included in economic models.

The modular and stepwise nature of model design and computation procedure allows partial simulations to be undertaken relatively easily, and for further model development to be undertaken on a component, without disturbing the integrity of the whole. The level of detail is reasonably flexible and ranges in the ASFF model from 58 regions for agricultural productivity to 16 regions for human population dynamics to eight city airsheds for vehicle emissions and one national account for balance of trade computation. An advantage in national and international terms is that a limited amount of simulation modelling of physical economies has been undertaken in a policy context, when compared to the dominant force of econometric modelling. This provides a possible advantage in the policy marketplace for concepts and analyses pertaining to physical sustainability. However, there is little historical precedent in the promotion and refutation of integrative theories which deal with population-development-environment linkages and concepts.

The size and complexity of the analytical undertaking present an immediate disadvantage to scientific management, funding agencies, national policy analysts and scientific colleagues. The gulf between the constrained boundaries and reputable sureness of traditional reductionist research approaches, and a nationally scaled modelling approach which uses scenarios, has never been greater. Lutz (1994) noted the challenge of population-development-environment modelling as one of combining "a hard-wired model which only includes unambiguous relationships on which scientific consensus can be expected" with "the soft model which can quantify all kinds of feedbacks and interactions that the user wants to define".

This approach in design and implementation appears to be meeting these philosophical goals. However the absence of price mechanisms in both the ASFF and *OzEcco* models, which equilibrate shorter-term imbalances of supply and demand, seems to pose a significant barrier to acceptance by analysts dealing with national policy issues. Some argue that the physical and economic approaches should be hybridised and blended, whereas others are satisfied to keep them as distinct and separate analytical approaches, each of which contributes discrete insights to the policy process. The philosophical approach behind the development of physical economy simulators agrees that prices and market mechanisms are critical to balancing the economic concepts of supply and demand in the short term. However, strategically long-term physical modelling approaches are designed to provide an information flow from longer-term horizons to current market, policy, and business agendas. For these long-term horizons, price and market mechanisms become diffuse and indeterminate, while the workings of the physical economy will still depend on people and the flows of energy and materials.

Future designs and policy insights

Once distilled though a process of repetitive design and testing, future design options and policy insights do not seem particularly innovative. So it is, with initial distillations from the many partial analyses so far performed by these physical economy simulators. Before the analysis of population issues and with a view to 2050, the lower population stocks given by the zero net immigration flow may have seemed preferable since they stabilised a wide range of environmental loadings such as vehicle emissions. However, with the advantage of the 2100 view, the medium population scenario might seem preferable since it avoids a rapid decline in total population and the available workforce later in the 21st century and beyond. Thus, the societal and policy requirement to balance non-environmental with environmental criteria was an insight that emerged. With hindsight it is rather obvious and does not require the whole modelling process to reach this conclusion.

However within a stabilising population, the design challenge is to seek technological and behavioural changes which rapidly stabilise environmental loadings and then decrease them. Unfortunately the age profile of most big ticket infrastructure items may dictate that many environmental pressures might trend upwards for at least the next human generation. This may be so for vehicle emissions where increasing car ownership and kilometres driven are possible for at least the next 20 years. After that a stabilising human population causes energy use and subsequent emissions to plateau and then slowly decline. The rapid penetration of new car technologies using much less energy may be limited by a relatively saturated vehicle ownership and a relatively old car fleet which is slowly replaced. Combined with these factors is a market demand for larger, more powerful vehicles, the use of which balances out the declining energy use by smaller more energy efficient vehicles. Thus, consumer behaviour may continue to outpace technological innovation, potentially giving neutral outcomes for potential opportunities to decrease resource use.

As analyses and policy interactions proceed, the design task for the next generation of physical economy becomes more skewed. Simple solutions to resource use and environmental loadings such as behavioural change and reducing personal consumption levels are often deemed less acceptable because of the flow-on effects on the monetary economy. The technological challenges then become more difficult as the redesign of the physical economy evolves to also include the redesign of the monetary economy and the social system. While this chapter describes a modelling approach centred on the physical economy, it recognises the importance of the monetary economy and seeks to ground financial and monetary viewpoints in physical reality. However, the physical concepts underpinning the concept of long-term sustainability suggest that more profound changes might be required. If fundamental changes occur, then economic structures, consumer behaviour and environmental technology will have to form radical new configurations.

THE POPULATION STUDY: DESIGN AND STRUCTURE OF THIS REPORT

The purpose of this study was to increase the range and depth of insights into the effect of future population size on infrastructure and environmental issues within Australia's physical economy. Three population scenarios driven by the yearly rate of net immigration formed the organising structure of the report. The **base case scenario** has a net immigration rate of 70,000 persons per year and represents a contemporary policy position. The **zero scenario** had a net immigration rate of zero persons per year where the number of immigrants equalled the number of emigrants. The zero scenario represents the philosophical position of a number of non-government organisations concerned primarily with environmental issues. The **0.67%pa scenario** had a net immigration rate of two-thirds of one percent of the domestic population in each year of the simulation and represented the position of a number of national business organisations.

The Department of Immigration and Multicultural and Indigenous Affairs as the policy client requested that an issue-based reporting structure be used to present the results from the simulation experiments (Figure 1.10). In an attempt to simplify the complex nature of the population effect, a four-level system of population influence (from primary to quaternary) was used. This grading scheme is presented at the end of Chapter 2 and is used in each chapter to describe the more-direct and less-direct effects of population size.

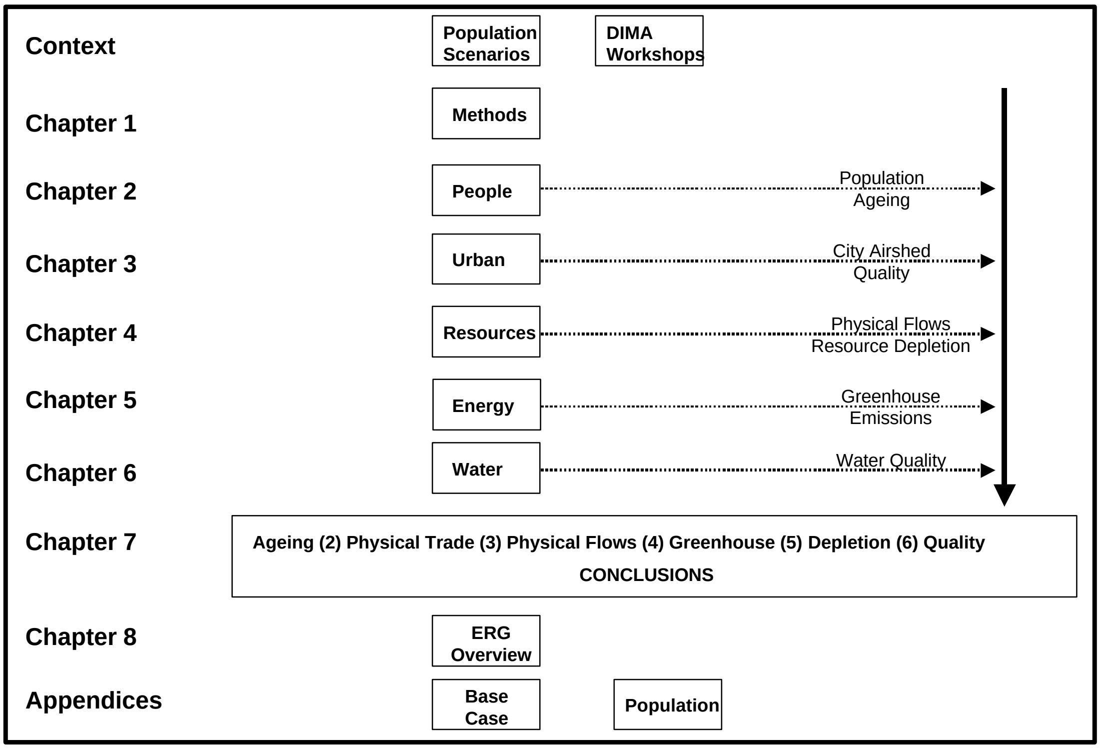

Figure 1.10. Schematic structure of population report which contrasts three population scenarios driven by different rates of net immigration.

Chapters 2 to 6 are essentially issue based and cover people, urban issues, natural environment, energy and water. However, because of the interactions between different sectors of the physical economy, a number of interactive effects emerged from the issue-based chapters. These issues are presented in Chapter 7 in the form of six future dilemmas. Apart from the demographic assumptions which drive the population scenarios, there are a wide range of starting assumptions for future trends and technological progress in all sectors of the physical economy. These are presented under 20 sectors in Appendix 1. Finally in Appendix 2 a comparison is made between the population projections from the ASFF simulator and those produced by the Australian Bureau of Statistics.

REFERENCES

Alcamo J Kreileman GJJ Krol MS and Zuidema G (1994). Modelling the global society-biosphere-climate system: part 1: Model description and testing. in *Image 2.0: Integrated Modelling of Global Climate Change*. (Eds) J Alcamo, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Alcamo J Kreileman E Krol M Leemans R Bollen J van Minnen J Schaeffer M Toet S and de Vries B (1998). Global modelling of environmental change: An overview of IMAGE 2.1. in *Global Change Scenarios of the 21st Century: Results from the IMAGE 2.1 Model*. Eds J Alcamo R Leemans and E Kreileman. Pergamon, Elsevier Science, Oxford UK.

Ayers RU (1998). *Turning Point: An End to the Growth Paradigm*. Earthscan Publications, London.

Boserup E (1999).*My Professional Life and Publications 1929-1998*. Museum Tusculanum Press, University of Copenhagen.

Brown LR Renner M and Flavin C (1998). *Vital Signs 1998: The Environmental Trends That are Shaping Our Future*. Worldwatch Institute, Norton and Company, New York.

Cocks D (1996). *People Policy: Australia's Population Choices*. University of New South Wales Press, Sydney, 347 pp.

Cocks D (1999). *Future Makers, Future Takers: Life in Australia 2050*. University of New South Wales Press, Sydney, 332 pp.

Cohen JE (1995). *How Many People Can the World Support?* Norton and Company, New York.

EPAC (1994). *A Comparison of Economy-Wide Models of Australia: Responses to a Rise in Labour Productivity*. Economic Planning Advisory Commission. Papers resulting from an EMBA symposium held in Canberra on 13 April 1994. Edited by Colin Hargreaves, October 1994.

Ehrlich PR (1968). *The Population Bomb*. Ballantine Books, New York.

Ehrlich PR and Ehrlich AH (2002). Population, development and human natures. Environmental and Development Economics 7,158-170.

Forrester JW (1961). *Industrial Dynamics*. Cambridge Ma, The MIT Press.

Foran BD and Crane D (1998). The OzECCO embodied energy model of Australia's physical economy. In *Advances In Energy Studies: Energy Flows in Ecology and Economy* Conference held at Porto Venere, Italy, 26-30 May 1998. pp 579-596.

Foran BD and Mardon C (1999). Beyond 2025: Transitions to the Biomass-Alcohol Economy using Ethanol and Methanol. CSIRO Resource Futures Working Document 99/07. http://www.cse.csiro.au/research/Program5/RF/publications/Biomassfuels.pdf accessed 07-05-02

Foran BD and Crane D (2000). Modelling the transition to a biofuel economy in Australia. in *Advances in Energy Studies: Exploring Supplies Constraints and Strategies*. Conference held at Porto Venere Italy, 24-27 May 2000, pp 423-439.

Gault FD Hamilton KE Hoffman RB and McInnis BC (1987). The design approach to socio-economic modelling. Futures 3-25, February 1987.

Goudriaan J Schugart HH Bugmann H Cramer W Bondeau A Gardner RH Hunt LA Lauenroth WK Landsberg JJ Linder S Noble IR parton WJ Pitelka LF Stafford Smith M Sutherst RW Valentin C and Woodward FI (1999). Use of models in global change studies. in *The Terrestrial Biosphere and Global Change: Implications for Natural and Managed Ecosystems.* B Walker W Steffen Canadell J and Ingram J (eds) IGBP Book Series 4. Cambridge University Press, Cambridge UK.

Godet, M (1991). *From Anticipation to Action: A Handbook of Strategic Prospective*. UNESCO Publishing Paris.

Long Term Strategies Committee (1994). *Australia's Population Carrying Capacity: One Nation-Two Ecologies*. House of Representatives Standing Committee for Long Term Strategies, Australian Government Publishing Service, Canberra.

Lenzen M (1998). Primary energy and greenhouse gases embodied in Australian final consumption: an input-output analysis. Energy Policy 26,6,495-506.

Lutz W (editor) (1994). *Population-Development-Environment: Understanding Their Interactions in Mauritius.* Springer-Verlag, Berlin.

Meadows DH Meadows DL Randers J and Beherens WW (1972). *The Limits To Growth: A Report for The Club of Rome on the Predicament of Mankind.* A Potomac Associates Book, Universe Books, New York.

Meadows DH Meadows DL and Randers J (1992). *Beyond The Limits: Global Collapse or a Sustainable Future.* Earthscan Publications. London.

Mentor Books (1960). *Three Essays on Population: Thomas Malthus, Julian Huxley, Frederick Osborn*. Mentor Books New York.

McDonald P and Kippen R (1999). The impact of immigration on the ageing of Australia's population. Discussion Paper, Department of Immigration and Multicultural Affairs, May 1999, 36pp

Richardson GP and Pugh AL (1981). *Introduction to System Dynamics Modeling with DYNAMO.* Productivity Press Portland, Oregon.

Robbert Associates (2000). Web Site. http://www.robbert.ca/demog.html accessed 07/05/02

Ruitenbeek J and Cartier J (2001). The invisible wand: Adaptive co-management as an emergent strategy in complex bio-economic systems. Centre for International Forestry Reserach Occasional Paper No 34, October 2001, Bogor, Indonesia.

Santa Fe Institute (2000). Web Site: http://www.santafe.edu/index.html accessed 07-05-02

Simon JL (1990). *Population matters: People, resources, environment and immigration*. New Brunswick, NJ/London.

Slesser M (1992). *ECCO User Manual Part 1. Third Edition*. The Resource Use Institute, Edinburgh, Scotland.

Slesser M King J and Crane DC (1997). *The Management of Greed: A BioPhysical Appraisal of Environmental and Economic Potential*. The Resource Use Institute, Edinburgh, Scotland. 332pp.

Thomas JF Adams P Hall N and Watson B (1999). *Water and the Australian Economy*. Australian Academy of Technological Sciences and Engineering, April 1999.

University of California Berkeley (2000). *Sketch for a Historical Picture of the Progress of the Human Mind (1795)*. Condorcet: The Education of Progress. Web pages http://ishi.lib.berkeley.edu/~hist280/research/condorcet/pages/progress_main.html accessed 20-04-2000

von Weizsacker E Lovins AB and Lovins LH (1997). *Factor 4: Doubling Wealth-Halving Resource Use*. Allen and Unwin, St. Leonards, Australia.

Waldrop, MM (1994). *Complexity: The Emerging Science at the Edge of Order and Chaos*. Penguin Books, London.

Wackernagel M and Rees W (1996). *Our Ecological Footprint: Reducing Human Impact on The Earth*. New Society Publishers, Gabriola Island and Philadelphia.