BEACON PROGRAMME

NS1 NATIONAL SCORECARD Interventions and Assessment Models

October 2004

Authors: Ian Page (BRANZ)
Nigel Jollands, Nancy Golubiewski (Landcare Research)
James Turner (Forest Research)
Reviewer: Bob Frame (Landcare Research)

CONTENTS

National Scorecard NS1: Interventions and Assessment models

1. CLIENT

Beacon Pathway Ltd
49 Sala Street
Rotorua New Zealand

2. EXECUTIVE SUMMARY

This report documents research into NS1: National Scorecard, Assessment of the national impacts of the Beacon programme. The aim is to identify whether models can quantify the benefits and costs of the Beacon projects, and what influence these models may have on Government intervention. The key findings are:

- Government sustainability interventions in buildings in other countries have involved a three prone approach of regulation, economic instruments (taxes and subsidies), and information. Of these three, regulation is the most important as market-based approaches, on their own, have been insufficient overseas to achieve large scale take-up. However Government–private partnerships are a vital step to ensure building industry buy-in and to provide information, promotion, on-site examples, and design tools.
- The recently revised Building Act has new provisions for consideration of sustainability in buildings. Specific measures will need to be set out in changes to the Building Regulations, and all changes to Regulations require a Regulatory Impact Statement (RIS).
- The RIS process includes measurement of nationwide impacts, and in the Ministry of Economic Development guidelines these can range from financial analysis, cost benefit analysis, to macroeconomic modelling and multi-objective social/ environmental modelling. The nationwide economic and sustainability models discussed in this report will assist regulators in the RIS process.
- Macroeconomic models can quantify many of the national net benefits (or net costs) of the Beacon programme in terms GDP and employment effects. However the usefulness of these models, and relevance to the Beacon programme, would be improved if they were modified in a number of ways, as mentioned later in this report.
- National environmental and social impact modelling is less well developed in New Zealand than economic models. Development of these is seen as advancing the Beacon programme, by assisting in the RIS process, and work on the construction of a simplified multi-criteria model is recommended to test its usefulness.
- Without the Beacon programme an upgrade of new housing envelope insulation and glazing requirements, and possibly trade-offs for solar water heating, will likely occur within 12 months. The value of National Scorecard models are that could speed up the introduction of other mandatory sustainability requirements, and they are likely to influence decision makers toward Beacon type interventions and labelling tools.
- Social and environment impact assessment models include life cycle analysis (LCA), sustainable assessment models (SAM), and goals achievement matrix (GAM). The latter two can incorporate economic impacts and flows. The GAM is the preferred model because it is combines quantitative and qualitative data, makes the subjective decisions explicit, and can provide a single score for each package of sustainability measures.

Section 3 introduces the Beacon Programme and the National Scorecard stream. It identifies the Scorecard project's aims of, first, identification of Government's interventions in sustainability measures; second, what influence the Beacon programme may have on Government interventions; and third, assess the nation-wide impact models available and the development required.

Section 4 describes the types of Government sustainability interventions at a national level occurring overseas and locally.

Section 5 discusses expected developments in the Building Code relating to sustainability measures, and assess what effect the Beacon programme could have on code development.

Section 6 specifies the criteria used to evaluate the economic and social/environmental assessment models.

Section 7 identifies and assesses the types of economic assessment models available nationally and at a regional level. These are of three main types; input-output models, econometric models and applied general equilibrium models.

Section 8 identifies and assesses national social/ environmental assessment models. The main types are life cycle analysis (LCA), ecological multipliers models, and multi-criteria models.

Section 9 compares the advantages and disadvantages of the economic and social/ environmental models, and discusses the results.

Section 10 provides recommendations.

3. THE PROJECT

3.1 Background

Beacon Pathway Ltd (Beacon) is a research consortium funded by shareholders and the Foundation for Research Science and Technology (FRST). Much of the housing stock in New Zealand performs poorly on basic sustainability issues such as energy and water efficiency and in many cases are below World Health Organisation guidelines for human health requirements.

Beacon's goal is to establish a programme of interventions that will bring about uptake of greater levels of sustainability features in new and existing housing such that 90%+ of houses meet the 'standard' by 2012. In addition, the programme aims to improve neighbourhoods so that as they are developed and/or redeveloped, the principles of sustainability are taken into account.

Beacon has defined a programme of research to be carried out over 2004-2010 to determine the means by which these goals will be achieved. The first stage (July-September, 2004) involves eleven 'programme confirmation phase' projects to ensure the overall programme is well informed and that the structure of the programme is optimal. The projects are:

- SF1.1: Sustainability Framework Design
- INT1: Prioritisation/Optimisation Tool
- CON1: Consumer Research Impacts and Alternatives
- IND1: Industry Research Impacts and Alternatives
- NEW1: New Technology Impacts

- NOW7: Demonstration Home Hypothesis
- RF1: Housing Stock Analysis
- NBH1: Neighbourhood Research Baseline
- NS1: Macro economic and sustainability assessment models
- SF1.2: NOW Home vs. REF Home
- NOW1: NOW Home Knowledge and Future Monitoring Recommendations

For more information about the overall programme and the programme confirmation phase projects, refer to documentation available from Beacon Pathway Ltd.

This report documents the findings of **NS1: National Scorecard – Interventions and assessment models.**

3.2 NS1: National Scorecard interventions and models.

The three main aims of this National Scorecard project are:

- Identify the interventions that have been used locally and overseas to encourage sustainability measures and identify the types of models used to measure national economic and social/ environmental impacts.
- Assessment of the influence Beacon programme outputs may have on the types and stringency levels of Government intervention.
- Assessment of economic/ social-environmental nation-wide impact models and the model development required.

3.3 Relationship with SF1.2, RF1 and NBH1.

What inputs to NS1 are required from other programmes?
The assessment of the national scorecard models depends partly on the specific sustainability measures likely to be developed in the NOW house (SF1.2), the types of retrofit measures that are feasible for New Zealand houses (RF1), and what features a sustainable neighbourhood will incorporate (NHB1). The latter has reported and hence the broad parameters of a sustainable neighbourhood are evident. SF1.1 has also reported, and most details of the NOW house design are known. Lastly, preliminary work on RF1 indicates that retrofit measures for existing housing are in four broad groups (energy efficiency/ conservation, water efficiency/ conservation, material use, and health promotion). There is sufficient information from these programmes at their current stages of development to assess the types of impacts that economic and sustainability assessment models should be able to handle.

There may also be some links with IND1, industry structure, in that industry supply constraints may need to be included in any macroeconomic model that is specifically adapted for the Beacon programme. Finally, NS1 needs to provide input into the INT1 project (prioritisation tools) so that various levels of development of national models can be assessed against expenditure on other programmes.

4. SUSTAINABILITY INTERVENTIONS ON A NATIONAL SCALE

Building activity has a major impact on the economy, society and the environment, and often these impacts are not reflected in the market price mechanisms. Efforts of the private sector to encourage sustainability measures in buildings are often better done in partnership with Government policy measures. The instruments available to Government and/or the private sector can be divided into three categories;

Regulation - building regulations, and other regulations relating to waste disposal and water use;

Economic instruments - energy efficiency subsidies, tax exemption schemes, cheap loans, energy taxes, virgin material taxes, capital subsidies for waste process plant;

Information - environmental guidelines and labelling schemes, energy and sustainability audits, waste information exchange schemes, promotion and demonstration of sustainable buildings and retrofits.

4.1 Overseas interventions

Most OECD countries have long included energy efficiency requirements in building regulations. However most regulation targets new buildings only, and intervention for upgrading existing buildings is modest. Some countries have extended controls to include more general sustainability criteria in building regulations. For example the Scottish Executive passes building legislation in 2003 " The Scottish Ministers may for any of the purposes of …... furthering the achievement of sustainable development, make regulations with respect to the design, construction, demolition and conversion of buildings …" The recent revision of the Building Act in New Zealand has reference to sustainability performance, as discussed later. In Australia the Future Building Code (under development) is likely to have specific reference to sustainability, and the Australian Building Codes Board is currently consulting with the industry about what the code may include.

The OECD undertook a survey of its members in 2002 on sustainability measures[1]. The measures were reported in three main targets areas; mitigation of CO2 releases, reduction of construction and demolition waste, and prevention of indoor air pollution. The responses, from 20 OECD members, are summarised below. The numbers in brackets are the number of countries reporting the measure. The reporting is for buildings in general, but most responses apply equally to residential and non-residential buildings.

Regulation – new building regulation for mandatory energy efficiency performance of the envelope (19), mandatory energy labelling of buildings(5), obligations for utilities to improve the energy efficiency of their customers (UK), landfill bans (5), mandatory separation of waste (8), demolition licensing (6), ventilation regulations (15), regulation of building materials to reduce indoor air pollution (6).

Economic instruments - energy efficiency/ renewable energy subsidies (7) and tax exemption schemes (5), cheap loans for energy efficiency measures (6), environmental energy taxes (5), landfill taxes (10), virgin material taxes (4).

Information - voluntary environmental labelling of buildings (7), environmental labelling of materials and products (6), environmental guidelines for designers (10), embodied energy data (3), waste information exchange schemes (2), labelling schemes for recycled material (6), voluntary guidelines for concentration of pollutants (13).

Note that water efficiency and conservation measures were not surveyed by the OECD. However it is a component of most of the environmental labelling tools developed by the OECD

[1] OECD (2003) Environmentally sustainable buildings: Challenges and Policies."

countries, and several countries have mandatory water efficiency measures. The best known and among the earliest schemes is BREEAM, in the UK. Since the above report, produced in early 2003, some countries have further developed sustainability measures. For example, one area of expansion is in environmental labelling and green home schemes, and 9 countries are members of the World Green Building Council (Australia, Brazil, Canada, India, Japan, South Korea, Spain, Mexico and US). Other schemes are under development in Scandinavia and Hong Kong.

The following are selected interventions, mainly Government sponsored, that indicate the types of measures being implemented:

Australia

Your Home – A set of consumer and technical guide materials and tools to encourage sustainable new homes and retrofits. The website[2] is run by the Australian Greenhouse Office and there is a wide "buy-in" by industry organisations including state government environmental and building agencies, designer organisations, master builders, Housing Industry Association, and window associations.

In NSW builders and developers are required to use an assessment tool BASIX for new housing planning approval processes. There are nine indices of sustainability performance and it shows developers how their project rates on the aggregate sustainability index.

In Victoria the state government has amended regulations requiring all new homes to have a 5 star energy rating (uses FirstRate software from SEAV) for the building fabric and water saving devices. In addition, from July 2005, all new homes will require a rain water tank or a solar hot water system.

United Kingdom

The UK Government has brought forward the review of energy efficiency measures Part L of the Building Regulations by two years to 2005 because of the EC Directive on the Energy Performance of Buildings, which is a major driver for energy efficiency in Europe[3]. The UK draft includes mandatory energy labelling for all new dwellings, and mandatory energy performance upgrading of existing dwellings when making additions over a certain value. Also included is the provision of the energy rating of existing commercial buildings at the time of resale.

The Government commissioned Sustainable Buildings Task Group[4] reported in 2003 and its main recommendation was a single national Code for Sustainable Buildings be established. It recommends indicators based on BREEAM and Ecohomes, and incorporate clearly specified minimum standards in energy and water efficiency, and waste and use of materials. The standard would have a performance level above that required in the Building Regulation, and as the latter are upgraded over time, the Standard would also be upgraded above the statutory minimum.

The Housing Corporation runs a website[5] which provides a template for writing sustainable housing policies, based on the Ecohome model.

The Building and Social Housing Foundation (Private trust)[6] held a conference of industry participants in 2002 which developed an agenda for action in 4 main areas: use of regulations and standards, use of financial incentives, creating demand for sustainable housing (positive promotion, raising awareness, stakeholder analysis, eco-labelling), and creating capacity

[2] http://www.greenhouse.gov.au/yourhome/about/index.htm

[3] Proposals for amending Part L and implementing the Energy Performance of Buildings Directive www.odpm.org.uk.

[4] Sustainable Buildings Task Group (2004) "Better Buildings Better Lives" Office of Deputy Prime Minister, UK.

[5] www.sustainableworks.org.uk

[6] Building and Social Housing Foundation 2002 "Sustainable housing solutions- Transferring good practice from the margins to the mainstream." Leicester, UK.

(demonstrate the business case, incentives, training, public/ private partnerships, back-up/ support).
The World Wildlife Fund (WWF) addresses the barriers they see in the UK context, and the recommended strategies[7], as follows:
No fiscal incentives. Reduce VAT on new EcoHomes, capital allowances for expenditure on conversion to sustainability of rental houses.
Regulations are unfriendly to sustainable housing. Reform the planning system, encourage Government to set environmental targets for new buildings.
No investor interest. WWF has benchmarked the sustainability performance of the top 13 FTSE listed builders, in partnership with Halifax Bank of Scotland. The majority have inadequate performance but they welcome the report and most are reviewing their business practices.
Perceived high cost. WWF, the Housing Corporation, and the Southeast England Development Agency (SEEDA) have commissioned a study on the means for reducing the cost of sustainable materials and key products.
No agreed standards. There is a lack of consensus on a common standard, but the BRE Ecohomes is perceived as a good basis.
Lack of consumer demand. WWF and Halifax research indicates 84% of respondents saying they would be willing to pay an average of 2% more for a sustainable home.

Continental Europe
Mandatory energy labelling for new buildings is required in Denmark, France (dwellings only), Germany, Greece, and the Czech Republic. Denmark, and France also have mandatory energy labelling for refurbishment of buildings. Four countries have general obligations for recycling and reuse of materials during construction, but there are no specific standards. At the demolition stage the requirements are more frequent. Belgium, Denmark, Germany, Netherlands and Sweden have bans (on unsorted, or combustible waste) on demolition waste in landfills. Some of these countries, and others, also have mandatory separation, mandatory delivery of waste to specific sites, licensing of demolition contractors, and mandatory reporting of where waste is to be delivered. To minimise indoor air pollution Czech Republic, Denmark, Finland, Germany, and Norway have formaldehyde limits for building materials.

Canada
Mandatory insulation is required in most provinces and cities. Subsidies are supplied for renewable energy and insulation retrofit (the Energuide programme is very successful, see the RF1 report, which recommends this programme could be adapted for NZ and extended to other sustainability measures). The LEED labelling scheme is widely used in commercial buildings.

USA
Most states have mandatory thermal insulation requirements for new buildings. Several states and utilities offer low or zero interest loans for energy efficiency upgrades in existing buildings. A number of states and municipalities have enacted residential energy conservation ordinances (RECOs).[8] They are designed to bring existing housing stock (mainly focussed on multi-unit blocks and rental housing) up a minimum standard of performance. The various policy approaches in the US for existing buildings are assessed in reference [8] , see the table below:

The LEED labelling scheme (Leadership in Energy and Environmental Design) is well known and is in operation for commercial buildings. New versions are being developed for new homes, existing buildings, and neighbourhood developments (transport, stormwater, urban sprawl,

[7] www.wwf.org.uk World wildlife Fund (2004) "One Million Sustainable Homes."
[8] Thorne (2002) "Policy options for improving the efficiency of existing buildings: Experience to data in the US." OECD/IEA Joint Workshop on the Design of Sustainable Building Policies: Part 1, 2002.

infrastructure, health, safety, economic communities).[9] Some North American cities have supplements to the LEED Rating System, e.g. Seattle Capital Improvement Projects.[10]

Approach for existing bldgs	Advantages	Disadvantages
Residential subsidies	Cost-effective for large jurisdictions. Leverage is greater in combination with some private funding.	Expensive. Free rider unless targeted. Needs extensive marketing and education.
Residential regulation	Low cost to implement. Mandatory compliance.	Politically difficult. Small savings per household as the regulations are for the lowest common denominator.
Residential tax credits	Stimulates investment in large projects.	Free rider. Difficult to design effectively. Difficult to administer.
Home energy labelling.	Uniform national approach. Leverage is greater with private funds. Large savings potential.	High start-up costs for programme and marketing. Cost-effectiveness is uncertain.

OECD

Despite the considerable effort undertaken by the above countries the OECD has identified a number of problems and barriers, including:

- Market mechanisms are insufficient on their own to promote a significant increase in sustainable buildings, and regulation, economic instruments and information tools are important.
- In rental housing the incentives for owners to incorporate sustainability measures are often quite low, or zero, as the tenant bears the costs.
- Energy efficiency measures often have a short payback period and are attractive to owners. However the benefits of other sustainability measures may not be immediately apparent to owners. Often owners are reluctant to invest in other measures as the improved performance will not necessarily be reflected in the building resale price.

OECD has the following policy recommendations:

- Establish a national strategy for improving the environmental performance of buildings. It should include quantified goals within set time-frames.
- Set up a framework to regularly monitor the environmental performance of the building sector. It needs to be based on good data, updated at regular intervals, and it is suggested environmental labelling schemes are a good data source.
- Support environmental R&D and diffusion of technologies across the construction sector, and support government and industry partnerships.
- Direct public building procurement toward environmental friendly buildings. This supports the demand side by demonstration of sustainable technologies, and supports the supply side by helping reduce unit costs.
- Regulation is the most effective way to upgrade energy performance of new buildings at the "bottom end" of the scale, but for a large percentage of buildings further improvements are effective.
- As new buildings are upgraded the existing building stock becomes increasingly important. Since there is no regulatory framework to cover existing buildings in most

[9] Howard (2003) "LEED as a tool for green building in the US" OECD/IEA Joint Workshop on Sustainable Buildings: Towards Sustainable Use of the Building Stock", 2004.

[10] www.cityofseattle.net/sustainablebuilding

OECD countries, non-regulatory instruments are expected to play a greater role than for new buildings.

4.2 New Zealand interventions

New Zealand interventions are in line with these OECD recommendations in most areas, as follows:

National strategy- The strategies include; Sustainable Development for NZ :Programme of Action. (Sustainable Cities and energy programmes, e.g. NEECS), NZ Transport Strategy, NZ Waste Strategy, Research, Local/ central Government partnerships, Public Awareness and Education Programme. The NEECS targets include retro-fitting all pre-1977 houses with cost effective energy efficiency measures, by 2016. Specific activities can be classified into the OECD policy approaches, namely Regulation (Amended Building Act 2004, development of Standards including an insulation standard, and better/ best practice design standards; Economic instruments (Residential Grants Programmes, HNZC retrofit programmes, a energy carbon tax signalled for 2007); Information (pilot Canterbury HERS[11] scheme, HEEP programme to understand household energy use, Healthy Housing research programme and healthy house index).

Framework to monitor performance. Environmental labelling schemes exist locally (eg the BRANZ Green Homes Scheme) and new ones are being set up currently (e.g. NOW house).
A code of practice/ Tool for Urban Sustainability (TUSC) is being developed for new and renewal urban developments. Process toward the NEECS targets are monitored by a national energy efficiency index, and other indicators. The Beacon Programme has specific targets and dates.

Support environmental R&D and Government/ private partnerships. FRST is part funding the Beacon programme, and other Government funding includes the BRANZ Zero-low energy use house (Zelah) and House Energy Efficiency project (HEEP) projects. EECA is also part funding R&D work and partnerships.

Public building procurement to support sustainability. There is currently no specific Government policy for public buildings to have sustainable features apart from energy efficiency measures. HNZC has a policy to retrofit all their stock for energy efficiency over a number of years. Some Government funded buildings recently constructed demonstrate sustainability features e.g. Tamaki Campus Landcare building.

Regulation. The recent revision of the Building Act will facilitate greater sustainability in new buildings. Government is working with selected industries, including some building material industries to reduce carbon emissions.

Retro-fit. There is currently no specific Government programme (except for HNZC stock) for improving the sustainability of the existing housing stock by 2016, as proposed in NEECS. The Beacon programme recognises that the existing housing stock has significant potential for sustainability retrofits.

[11] Tool for urban sustainability code of practice – Funded by Waitakere City, and Ministry for the Environment.

5. SUSTAINABILITY MEASURES AND THE NZ BUILDING CODE

This section describes the structure of the building code and regulations, and the recent provisions for sustainability in the code.

5.1 New Zealand building control measures

The structure of the building control regime is in Table 1 in the Appendix. The Act contains statements of purpose and the revised version was passed by Parliament on 14 August 2004. It states:

> "The purpose of this Act is ……to ensure that – 3b) buildings have attributes that contribute appropriately to the health, physical independence, and well-being of the people who use them; ……3d) buildings are designed, constructed, and able to be used in ways that promote sustainable development."

Table 1 Sustainability measures in the new Building Act
Clause 3A (2) "In achieving the purposes of this Act, a person to whom this section applies must take into account the following principals….: 3A(2)(b) the need to ensure that any harmful effects on human health resulting from the use of particular building methods or products or a particular building design is prevented or minimised. 3A(2)(c) the importance of ensuring that each building is durable for its intended use: 3A(2)(e) the costs of a building (including maintenance) over the whole of its life: 3A(2)(m) The need to facilitate the efficient use of energy and energy conservation and the use of renewable sources of energy in buildings: 3A(2)(n) The need to facilitate the efficient and sustainable use in buildings of – (i) materials (including materials that promote or support human health); and (ii) material conservation: 3A(2)(o) The need to facilitate the efficient use of water and water conservation in buildings: 3A(2)(p) The need to facilitate the reduction in the generation of waste during the construction process."

The above clauses cover the following sustainability issues:

- Indoor air pollutants
- Durability
- Cost of the building over its whole life
- Energy efficiency and conservation, and renewable energy
- Material conservation
- Water use efficiency and conservation
- Reduction of construction waste.

The Building Regulations give effect to the Code purposes, and the above issues are addressed, or could be addressed, in the Regulations as follows. Materials with an adverse effect on indoor air quality are covered in clause F2 (hazardous materials), see Table 4 in the Appendix for a list of the clauses. Clause B2 specifies durability in terms of the life required for various components (either 5 years, 15 years or 50 years, depending on the component).

Whole life costs (e.g. initial, maintenance, operating and disposal costs) are not specifically addressed, though cost benefits studies are required for any proposed changes to the regulations, as discussed later. Energy efficiency already exists as Clause H1, providing a metric for energy use, and increments in efficiency requirements are currently being considered and are easily introduced.

Material conservation is more difficult to specify but could include, for example, an embodied energy target per sqm of floor area, as a proxy indicator of non-renewable resources. This could be a new H2 clause, however no country presently has mandatory requirements for embodied energy, and only two (Greece and UK) produce guidelines. Water efficiency could be included as a new clause in the services group (clause G). Waste minimisation may require use of recycled materials and/or design features to aid recycling. No country currently regulates the use of recycled materials in new buildings. Instead the regulatory measures that are used relate to demolition controls, sorting waste, and taxes on landfills and certain materials.

The new Act requires a review of all clauses on a 3 year cycle. The building code structure is presently being reviewed by BIA, with the aim of getting the users views on what they expect from the Code. It is the judgement of the authors that the clause structure is unlikely to change, apart from the need to introduce new clauses for sustainability performance. Discussions with BIA indicate that energy efficiency and conservation will be shortly reviewed (last upgraded in 2001) and water conservation will follow soon after. There were no indications in discussions with BIA as to how choice of materials or waste minimisation might be given practical effect in the building code.

The conclusion from the above is the framework exists for incorporating sustainability measures into the building regulations. The main criteria for any changes are believed to be:

- A Regulatory Impact Statement (RIS) that is able to quantify the net benefits (or net costs) for the proposed measure. A net cost outcome will not necessarily disbar a proposed measure, particularly when there are hard to quantify offsetting benefits such as health improvements, and progress in achieving other aims such as the Kyoto commitments.
- Political will, especially where the benefits are not immediate and the initial measures cost money.
- Practical tools for measuring compliance.
- Information, demonstrations, and examples, for both owners and technical audiences.

5.2 Influence of the Beacon Programme on NZBC measures

All policy proposals submitted to Cabinet which result in government bills or statutory regulations must be accompanied by a Regulatory Impact Statement (RIS). The Ministry of Economic Development Guidelines (MED 1999) indicate that an RIS is required when amendments are made to existing regulations, and this applies for the introduction of sustainability criteria into the Building Regulations. The RIS is usually 2 to 3 pages long and is a summary only, covering a statement of the problem, public policy objective, options, costs and benefits (including non-quantifiable), and consultation. The supporting documents may be quite extensive including a detailed cost-benefit analysis.

A cost-benefit analysis (CBA) is a framework for the evaluation of identification and assessment of all costs and benefits, direct and indirect, tangible and intangible, which may impact on the choice of options. It differs from a financial evaluation which is often limited to direct dollar costs and benefits. A CBA uses constant dollars as a common unit of measure between options. There will often be difficulties in converting some impacts into dollars, and the indirect approximations are often labour intensive. The MED Guidelines states “The level of quantification required will vary according to the importance of the proposal being analysed, the availability of the necessary data, and the resource constraints.” In some cases “it may be more appropriate to apply informal CBA, that is, to fully describe to the extent possible the magnitude, incidence and nature of all significant costs and benefits, rather than attempt to convert all those impacts into dollar values. Multi-criteria analysis is one systematic technique that can be used to undertake this type of analysis within the overall CBA framework." Further discussion of these techniques is included in Section 8.3.

Two examples of recent CBA are described, as follows. The Ministry of Economic Development employed PricewaterhouseCooper in February 2003 to report on costs associated with revising the Building Act, in the light of the weather-tightness problems becoming apparent at the time. They looked the damage costs associated with weathertightness problems, the cost effect on a typical house and multi-unit of the proposed remedial measures, and additional costs associated with practioners licensing, and monitoring compliance by the territorial authorities. There was no attempt to quantify the cost savings from the proposed NZBC measures in this study. In a second study the BIA employed the NZ Institute of Economic Research to carry out a cost-benefit analysis on the specific proposed measures to address weathertightness issues. They confined the cost estimates to building damage estimates, extra building costs associated with the revised B2 and E2 clauses, and they attempted to assess the reduction in risk of leakage and timber decay due to the revisions, and hence estimate the benefits of the proposed measures. Their study showed that the results (i.e. a net benefit or loss) were highly sensitive to the assumption made on reduction in risk factors, and what proportion of the new house stock would benefit from the changes.

These examples show that CBAs can be fairly narrow in scope. Though other costs and benefits are mentioned, such as health costs and economy wide flow on effects, the difficulty of quantifying these, and time constraints, were accepted as a reason for omitting them from the CBA.

Hence there is no particular reason to expect that if the Beacon programme was able to demonstrate economy wide economic benefits of its programme, that this would have a strong influence on the decision makers in terms of mandatory measures. However this is not say that such a demonstration would not be worthwhile, provided the costs of modifying and running existing models are reasonable, as discussed later. Also given its sustainability policy, Government needs to be able to quantify its progress toward the NEECS targets. A Beacon national model that quantified, at the least, energy, CO2 emission, and water savings, would be of interest to Government and would support the case for new mandatory measures or an upgrade of existing measures.

The above looks at the role of the National Scorecard models in encouraging Government intervention. But other Beacon programmes will also encourage intervention. For example, the sustainability framework and neighbourhoods framework will enable compliance to be measured for individual houses and neighbourhoods, which is a vital part of any regulation. The Beacon education, demonstration and information role will assist the industry to adapt, and assure Government that the capability is available. Other Beacon work will ensure the solutions that are developed and marketed to owners are appropriate, attractive and affordable. This package of Beacon projects will provide assurance to Government that the practical problems of implementing mandatory sustainability measures can be addressed, and that there is industry capacity to deliver sustainable houses.

6. CRITERIA TO ASSESS NATIONAL SUSTAINABILITY MODELS

Unsubstantiated claims of sustainability are not a sufficient basis for government intervention (as in the case of Mithraratne & Vale 2004). We, therefore, must rely on evaluation models and techniques to provide information about the sustainability impacts of an intervention. Many valuation techniques are available to measure these types of impacts. In order to select an appropriate evaluation technique for sustainability interventions, we need to consider the impacts that such techniques should measure. The Impact Assessment literature is full of discussions about the kind of impacts that should be considered (see for example Morris & Therivel 2001). In addition, the Fourth Schedule of the Resource Management Act (1991) provides further guidance. The impacts that are relevant to sustainability interventions include :

i) the social impact of the intervention (for example, health impacts).

ii) the (net) economic cost of the intervention.

iii) the environmental impacts, such as the implications of the intervention for the use of natural resources and pollution generation. For example, Taborianski and Prado (2004) note that houses and buildings use a substantial amount of energy– through construction and operation of heating and cooling systems, lighting, and appliances. One study reported that construction and operation of buildings was responsible for 1/3 of total energy consumption in 1992 26% of which was fossil fuel combustion (Taborianski & Prado 2004).

iv) the dynamic effects of the intervention, both temporally and spatially. That is, we need to know how the effects of the intervention will differ spatially. We also need to know whether the intervention is effective in the long-term and if it will be adaptable to future requirements. For example, Mithraratne and Vale (2004) report that many studies of life cycle have been limited to 25 or50 years (per requirements in the NZ building code). Obviously, this doesn't capture the full environmental benefit or building materials used longer-term.

v) the uncertainty associated with the intervention. That is, issues about specific interventions should be explored under conditions of uncertainty with respect to input costs, demanded levels, and quality over sustained periods of time.

vi) the system-wide impacts. It is important to understand both the direct and indirect impacts of the intervention. That is, there is a need to consider sustainability interventions within the wider infrastructural system of catchment, processing, delivery and disposal as part of an evolving system. In this context, it is also important to understand the scale, hierarchy, and complexity of the impacts.

In addition to these, the techniques and models should be easy to use and produce results that are meaningful.

Clearly, the range of issues and impacts that need to be considered is vast. It is unlikely that any evaluation technique or model will provide information about all of these impacts. Therefore, the logical extension of this argument is that several evaluation techniques will be necessary to help us understand if a sustainability intervention is actually 'sustainable' in a multi-dimensional sense. However, if many techniques are needed, we are still left with the question of which ones to select? The following section presents a typology of evaluation techniques to help in this selection process.

Rijsberman and van de Ven (2000) make the point that definitions of sustainability affect the approach used to evaluate the sustainability of policy interventions. Further, the difficulty with sustainability is that it is complex (as was clearly pointed out in the SF report1.1). According to Cartwright (1973), complex, or meta problems, have a number of characteristics. One is that they have multiple potential solutions. Another is that there is no common understanding on the procedure to evaluate the solutions to the problem. That is, there is no agreement on a universally applicable evaluation technique.

6.1 A typology for evaluation techniques and models

Rijbersman and van de Ven (2000) propose that differences in evaluation approaches can be reduced to two dimensions: (a) differences in perspective of the relationship between people and the environment, and (b) the attitude with respect to the importance of qualitative versus quantitative values.

6.1.1 The relationship between people and environment

In this dimension, the driving force behind the approach to sustainable development is either people or the environment. In a "people-driven" approach, people and their desires, needs, and objectives are the driving forces behind the approach to sustainable development. An example of an evaluation technique that could be considered people-driven is cost-benefit analysis due to its focus on human welfare maximisation. In contrast, with "environment-driven" approaches, such as life cycle assessment, "the environment, with its possibilities and limitations, is the driving force behind the perception of sustainability.

6.1.2 Qualitative versus quantitative

In addition to the relationship between people and the environment, the way in which people evaluate this relationship is important. Again, two ends of the spectrum can be identified. At one end are approaches that rely on quantitative assessment. These approaches implicitly assume that it is possible to quantify aspects of sustainable development and that society should only evaluate options based on measurable objectives or targets. At the other end of the spectrum, the qualitative approach holds that the important aspects of sustainable development cannot be quantified. Indeed, authors like Spash and Hanley (1995) suggest people exhibit strong lexicographic preferences. That is, utility functions are essentially unquantifiable. Using these two dimensions, a four quadrant model can be drawn within which evaluation approaches can be located.

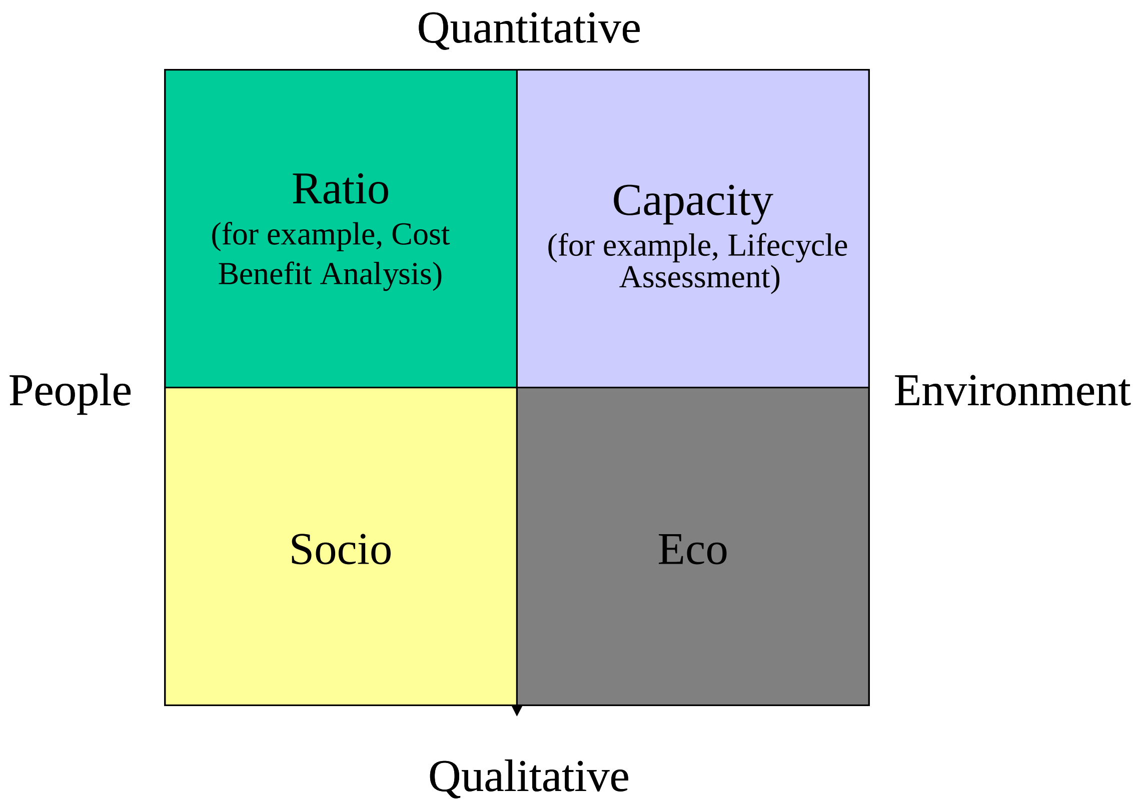


Figure 1 Four basic approaches to sustainability evaluation
(Related to "people and environment" and "qualitative and quantitative" (After Rijsberman & van de Ven 2000)

The four quadrants have been labelled for communication purposes:

- The 'Capacity' quadrant encompasses those techniques that are environment-driven and quantitative.
- The 'Ratio' quadrant encompasses quantitative, people-driven approaches.
- The 'Socio' quadrant includes those techniques that rely on qualitative assessment and people-driven objectives.
- The 'Eco' quadrant encompasses qualitative, environment-driven approaches.

To illustrate this typology, it is useful to attempt to locate examples of evaluation approaches. Consider life cycle assessment (LCA). This approach draws on thermodynamic theory – in particular first law considerations. That is, that economic activity is necessarily bounded by biophysical limits. LCA also relies on quantification of energy and material flows. It would therefore be located within the "Capacity" quadrant (Figure 1). In contrast, cost benefit analysis (CBA) is primarily people driven given its underlying theoretical objective of maximising welfare. Like LCA, CBA relies on quantification. Thus, CBA would be located in the "Ratio" quadrant (Figure 1).

This typology helps to explain an important tension between evaluation approaches as applied to policy interventions. Because of people's sense of self-importance with respect to the environment and sustainability as well as a tendency to want to quantify phenomena, it is common for "people-driven quantities" evaluation techniques such as CBA and economic models to dominate evaluation. However, it is clear that these evaluation approaches do not cover the whole gamut of sustainability issues. Nor do they satisfy everyone's interests, viz the need to acknowledge the central importance of the environment.

6.1.3 Conclusion with regards to the evaluation approach

Rijsberman and van de Van (2000) state "a system for assessment of sustainability ... can not be based on only one approach.” This means that an evaluation of policy interventions should incorporate all (or as many of the) four basic approaches as possible. Focusing on a single evaluation is bound to limit our ability to assess the sustainability of policy interventions.

7. FINANCIAL AND MACROECONOMIC MODELS

Financial models examine immediate costs and benefits in dollar values, and ignore the flow-on effects into the economy. Macroeconomic models have a wider perspective and attempt to model the flow-on effects into the economy at large, quantified in dollars.

7.1 Financial modelling

Financial models are based on a typical dwelling(s), or a model house, and the proposed measures are applied to this house to assess the cost effects, and the benefits. The following model dwellings are suggested:

- New standalone house, use the NOW house (148 sqm).
- Retrofit existing house – use at least two typical houses, one from the 1920/30s average size about 140 sqm, and one from the 1950/60s of average size 130 sqm. (Source QVNZ).

The NOW house is smaller than the typical new stand-alone house currently being built, which averages about 203 sqm. For input into a national model it will be necessary to scale up the costs and benefits, adjusting for expected future average floor areas. For the retrofit costs and benefits it may be necessary to use several typical houses of different eras, depending on the actual measures used in the retrofit programme. If the neighbourhood sustainability measures are also included in the national model, a typical development will need to be selected, and the costs and benefits estimated.

Financial models can express the results in net benefits (i.e. benefits less costs) for the individual unit. The net present value can also be calculated, in which future cash flows are discounted using a given discount rate (eg the cost of borrowing). The results may be expressed as a cost/benefit ratio, or as an internal rate of return on investment, and these parameters enable various sustainability options to be compared. These results for a unit can be scaled up to a national scale.

7.2 Macroeconomic models

Models for assessing the macroeconomic affect of public policy and regulation include input-output, econometric, and applied general equilibrium models. These models provide predictions of the impact of policies on economic variables, such as, production, wages, inflation, unemployment, gross domestic product, and welfare. The outcome of the intervention is compared to the base case which is no intervention.

The three types of economic model are briefly described as follows.
Input-Output Models. They model the economic interdependencies of the various sectors of the economy and have been used in New Zealand for a variety of purposes including assessing environmental management, and modelling regional economies. Their limitations are that they are static and don't show the time adjustment path of interventions, they have simplistic assumptions on technology and production effects, and relative price effects are not considered.
Econometric models. They are structural models of the economy derived from econometric equations of macroeconomic data (i.e. GDP, consumption, investment, imports, exports, employment, production, prices, interest rates, etc). The Treasury and the Reserve Bank operate these types of models. They have been used overseas for assessing environmental regulations. They are tailored for specific purposes, e.g. monitoring monetary and fiscal effects, and unless specific designed, they are unable to handle sustainability impacts.
Applied general equilibrium models. They are based on input-output models but allow for price changes, capacity constraints, substitution effects, and technology changes. They include flow-on effects to all industry sectors and can be expanded for a particular sector that is of interest (eg housing). They have been widely used for assessing interventions in various sectors of the economy and are generally well behaved and produce useful results. They have already been used to measure the effects

of increased insulation in new housing on the economy in New Zealand (GDP, employment, etc)[12]. The Appendix has further details of the use of these models in environmental studies.

These models are assessed in Table 2 against criteria in the previous chapter.

Table 2 Assessing the economic models

Assessment of Financial and Economic models										
Criteria / **Models**	Identify social impacts	<------------ Identify net economic cost Direct costs & benefits	NPV	Cost/ benefit ratio	------------> Economy Flow-on effects	Identify Environmental impacts	Handles Dynamic effects	Handles Uncertainty	System-wide impacts	Costs to develop & run.
Modal houses	N	Y	N	N	N	N	N	N	N	low
Financial models	N	X	Y	Y	N	N	N	N	N	low- med
Econometric models	N	X	Y	Y	Y	N	N	N	Y	high
Applied GE models	N	X	Y	Y	Y	N	Y	Y	Y	med-high
Y= Yes, N = No, X = Requires input from the Modal House(s)										

It is recommended that the applied general equilibrium (AGE) models be used for assessing national economic benefits. Theses models for the NZ economy are available from Business and Economic Research (BERL), NZ Institute of Economic Research, Informetrics Consulting Ltd, and McDermott Fairgray Group. A number of these firms have also constructed regional models, similar in structure to the national models, for examining issues such as roading projects in Auckland, America Cup impacts, etc.

The data and other work required for running an AGE model are as follows:
1 Estimate energy savings nationwide for new housing and retrofit. The estimate includes assumptions about the rate of retrofit by era of house and sector of tenure (i.e. owner occupier and rentals), and the rate of new house building. The financial model in the previous chapter describes the selection of houses for costing.
2 Estimate the initial and running costs of the energy savings measures. Different costs and energy savings will apply to different sectors. EECA has commissioned a number of studies on this which will need to be modified for the specific Beacon measures.
3 Water savings. As for 1 and 2 above. Some water savings data is available from the Earthsong[13] project, and some BRANZ work.[14]
4 Estimate the <u>other</u> costs associated with the NOW house and retrofit measures, and the benefits (if these can be quantified.). A California task force paper provides examples of this which may prove suitable as a template for New Zealand.[15] Scale up for nationwide costs and benefits.
5 Estimate the savings associated with a typical sustainable neighbourhood including roading, transport, water/stormwater/waste infrastructure, and any additional initial costs for this. Scale up to the national level.
6 Modification of the AGE model to include a separate water supply sector, (this allows for reduced water use in housing to be specifically modelled). Set up and run the model. The water supply industry is the probably the only modification specifically related to Beacon measures. However if the neighbourhood measures where to be included, there would need to be a separate stormwater/waste industry, and a local roading sector. In addition BERL advise that the input-output coefficients in their

---

[12] Nana, G. 2003. Economy-wide impact of improved insulation and reduced power use in new homes. *Business and Economic Research Limited (BERL) Report to BRANZ.* August 2003.

[13] http://www.earthsong.org.nz

[14] Hargreaves, Allan (2003) "The Building Act 1991 : Inclusion of sustainable development." Issues Paper No 1 Prepared for EECA by BRANZ.

[15] Kats G, et al (2003) "The costs and financial benefits of green buildings" California Sustainable Building Task Force.

model could be updated to incorporate likely changes in technology for selected industries. These would be for the Beacon related industries, namely residential building, energy supply, wood and wood products (because of the substitution to more sustainable materials), non-metallic metal industries (insulation, plasterboard, etc), and transport. They also advise that since energy use is a major consideration in sustainability they should incorporate an update in their energy price forecasts into the model. As other users of the BERL model would benefit from these changes, Beacon should not bear the full cost of the coefficient updates.

7.3 Costs for modifying and running an applied general equilibrium model

The estimated costs of the above work are:
Items 1 to 4 Costs and benefits for individual houses, scaled up nationwide, and forecast 10 years ahead, approximately $20,000. This work would be better undertaken by building industry related sources, rather than an economic consultancy, though the latter would advise on the required format of the output.
Item 5 Savings (resources and costs) and any extra initial costs for typical sustainable neighbourhoods.
Item 6 Modification and running the AGE model. Without further updates of the technical coefficients, and energy price forecasts approximately $15,000. This would include a report, presentation of the results, and a limited follow-up service providing interpretation and clarification of results. Modification of the technical coefficients and energy prices would be another $15,000 to $30,000, of which the Beacon contribution would need to be negotiated.

8. SOCIAL/ENVIRONMENT MODELS

There has been increasing interest in the wider sustainability of dwellings – both in NZ and internationally. As a result, there are now more than 70 different tools for evaluating sustainability aspects of individual buildings. These tools include the Ecoprofile (Norway); EQUER and ESCALE (France); Eco-Effect (Sweden); Eco-Quantum (Netherlands); LEED (USA); and HK-BEAM (Hong Kong). Most attempt to quantify a range of environmental considerations and present their results in readily understandable scores that are intended to demonstrate improved environmental performance, reduced operating and/or full life cycle costs. Their aims include encouraging more sustainable design, summarising or indicating overall performance, facilitating regulatory approval and instigating market change. In New Zealand, the Building Research Association of New Zealand (BRANZ) has adapted the BREEAM (UK) system to local conditions in its Green Home Scheme. BASIX and NABERS have been developed for use in Australia, and further local tools are also being developed.

Unfortunately, most of these tools focus at the building scale, with little ability to provide information at the national level. However, there do appear to be three possible candidates for sustainability evaluation at a national level: life cycle assessment (LCA), ecological multipliers and multi-objective decision assist tools (such as the sustainability assessment method (SAM) and the goals achievement matrix (GAM)). The following discussion presents each of these tools and evaluates them against the criteria in chapter 6.

8.1 Lifecycle Assessment

A review of 26 tools conducted by the International Energy Agency (2002) found that one tool has the potential to offer information about aspects of sustainability at the national level: life cycle analysis (LCA).

Within New Zealand, Mithraratne and Vale (2004) developed a computer model to perform a LCA of individual residential buildings so that designs could be evaluated on embodied energy, operating energy, and life cycle energy as well as the initial and life cycle cost of buildings. This allows the building to be evaluated both on energy requirements and cost, including furniture and appliances, so that the net present value of the total investment can be estimated.

Unfortunately, the focus on single dwellings limits interpretation of the results to the individual building-related financial costs: "The decision to invest or not in additional insulation would depend on the cost... although the marginal increase in cost does not provide benefit to the individual house owner, it could buffer the owner against any sudden increases in energy prices while providing improved comfort and additional health benefits" (Mithraratne & Vale 2004). Sidelining health as well as ignoring global environmental benefits (and, therefore, reduced costs in a broader sense), limits the benefit of this and similar studies. It is informative, perhaps, in highlighting direction for national efforts (e.g. insulation), but will not suffice. Broader consideration of societal impacts is also important. As Johnstone (2001) notes, "Studies of individual buildings can be used to estimate energy and mass flows of the total building stock, the results of which are expressed as a flux."

In contrast to the multitude of LCAs evaluating single buildings, relatively few LCAs have been conducted at broader scales. Notable exceptions include Johnstone (2001) and work by the Technical Research Centre of Finland and the Institute for Industrial Production in Germany (IEA, 2002). For the most part, these are studies of energy and mass flows, perhaps best described as a partial LCA. A procedure has been developed to estimate the resources required for a proposed new housing program on a regional basis by forecasting the number and size of dwellings necessary for a future population; quantifying building elements; and estimating material and labour input per unit of building (Woodhead and Rahilly as cited in Johnstone 2001). Using a materials accounting method, Glenck and Lahner estimated the waste management requirements of Upper Austria by combining 12 methods to assess material stocks and flows of buildings, infrastructure, and industrial processes (Johnstone 2001). Another study simulated energy and mass flows of buildings during their life cycle comparing a macroeconomic approach (using statistical data and input-output tables for overall flows) against a process-oriented one (consisting of detailed flows created by new construction, refurbishment, demolition, and utilisation of buildings) (Kohler et al. as cited in Johnstone 2001).

In order to expand the life cycle analysis of housing stock beyond buildings to a broader scale, regional or national, the mortality schedule of the stock must be considered (Johnstone 2001). Johnstone (2001) converted a stock and flow model of rehabilitation to create an energy and mass flow model of housing that would estimate the energy flows of New Zealand housing stock and the energy required to sustain dwelling services.

While the insights provided by a life cycle assessment are useful, the technique is clearly located in the 'capacity' quadrant of figure 1 above. That is, it is a technique that attempts to quantify the biophysical environmental impacts (energy and materials). LCA performs relatively well against the 7 criteria in chapter 6. LCA is not well suited for measuring social impacts, although it can elucidate the health implications of using certain materials.

The LCA technique is a 'static' technique. That is, it tends to evaluate the environmental implications at a point in time. It is not well suited to addressing the dynamic implications of an intervention. LCAs can accommodate uncertainty in at least two ways. First, several proprietary LCA software tools are available that facilitate the generation of scenarios (see, for example, GABi and SimaPro). That is, it is relatively easy to rerun the LCA model with changed assumptions and to look at the sustainability implications. Second, LCA software tools also allow the user to store data estimates on upper and lower bounds.

The LCA tool is specifically designed to accommodate system-wide impacts. Finally, LCA is relatively easy to apply, and produces accessible results especially at a building scale. However, it is a particularly data hungry tool, and this problem is exacerbated when trying to apply it to evaluate national-level impacts.

Overall, we consider that the life cycle assessment tool provides useful insights into aspects of the sustainability implications of policy interventions, but should not be used alone.

8.2 Ecological multipliers approach

A couple of authors (principally Treloar 1997) promote the use of input-output tables to calculate national-level ecological multipliers for the goods and services required to construct a building. Ecological multipliers measure the embodied energy, or system-wide environments, requirements associated with the good or service used in construction.

This modelling approach uses standard augmented input-output table methods (for a more detailed description, refer to the appendix 11.5). Essentially, the approach requires both an environmental requirements matrix and a standard Leontief Input – Output table.

It is common to use this method to calculate embodied energy, as in the work by Treloar (1997). However, the technique is quite able to accommodate any number of environmental inputs (as in the case of Hendrickson & Horvath 2000).

Again, this technique is focused on quantitative, environmental information (the capacity quadrant of figure 1). While the multiplier is a useful analytical method in its own right, it is not well suited to analysing the impacts of sustainability interventions in the building sector. The strength of the technique lies in its ability to efficiently calculate system-wide environmental impacts. However, the multiplier approach cannot easily accommodate economic or social impacts. Nor is it easily able to provide a dynamic picture of impacts over time. It is also difficult to address uncertainty concerns. These drawbacks suggest that the approach should not be used alone as a national scorecard. Given that it is relatively easy to apply, it could be used to complement other sustainability measures.

Overall, we consider that the multipliers approach provides useful insights into the sustainability implications of policy interventions. Unfortunately, the method is limited in several important ways, and should not be used alone to evaluate the sustainability of policy interventions.

8.3 Multi-objective methods

The approaches to evaluating the sustainability of building-sector interventions, discussed above, all focus on single objectives. For example, some focus on understanding the economic implications (such as the financial models), while others attempt to quantify the environmental impacts (such as LCA). However, sustainability is a multi–objective concept (see SF1.1 report). Therefore, it would make sense to use an evaluation method that could accommodate these multiple objectives.

Faced with the need to constantly select among alternative interventions, the policy analysis literature refers to several techniques for dealing with multiple objectives. These methods all attempt to display alternatives so that decision makers can select the alternative that performs best across multiple objectives. These multi-objective methods range from those that make basic comparisons (such as Lexicographic ordering, satisficing and non-dominated ordering) to more sophisticated approaches that attempt to incorporate the relative information in a scorecard or matrix.

Two approaches that are potentially useful in the context of this report are the Sustainability Assessment Method and Goals Achievements Matrix.

8.4 Sustainable Assessment Model

The sustainable assessment model as proposed by Bebbington and Frame (2003) provides a mechanism for evaluating how organizational "activities create sustainable development profile or signatures". As an outgrowth of full-cost accounting and LCA, it employs a 4-step full-cost-accounting approach. There are definitive boundaries: the model focuses on a distinct project and its scope of analysis is "cradle-to-grave". The inputs required by the project and outcomes generated by it are described in physical terms (or units) and then monetary ones. Each step is described in turn.

1) *Define the cost objective*: The focus of the cost exercise is defined as a discrete project. Bebbington and Frame (2003) note that, for an organizational assessment rather than a project-based one, it would be "less easy to pinpoint specific causes of sustainable development impacts".

2) *Conduct a life cycle analysis*. In other words, cradle-to-grave impacts are assessed.

3) *Identify and measure the impacts of the project through four "flows"*:

> a) *Economic flows*– represent "the total economic benefit that accrues from the project to the economic entity" under analysis (Bebbington & Frame 2003).
>
> b) *Resource use flows* – capture the value of resources used since economic flows do not fully account for these. Intellectual capital and infrastructure are also included in this category (Baxter *et al.* 2003).
>
> c) *Environmental impact flows* - encompassing the environmental externalities from damage incurred by activity, which comprise four categories. Namely, these are: (i) pollution, e.g. damage cost estimates from atmospheric emission including product use; (ii) nuisance, e.g. depreciation of properties resulting form noise, odour, and visual nuisance; (iii) footprint, e.g. land area unavailable for use due to installation; and (iv) waste, e.g. damage costs that arise from waste created in the process of activity (Baxter *et al.* 2003; Bebbington & Frame 2003).
>
> d) *Social impacts flows* – identifying positive and negative social consequences of the activity, including: (i) the external impact of employment; (ii) broad contribution to a socially sustainable society (e.g. tackling poverty and social exclusion, building skill sets and fulfilling potential of human capital, reducing the proportion of unfit housing stock, and decreasing occurrence and fear of crime); and (iii) the social impact of the products that arise from the activity.

4) *Monetise the externalities*

The display of the four flows in step #3 together comprise the SAM signature. A SAM indicator has also been developed to combine the categories into an overall measure, where a score of 100% indicates a sustainable project with no negative sustainable development impacts (Baxter *et al.* 2003).

According to Bebbington and Frame (2003) "SAM seeks to model (in fairly simplistic terms) the changes in capital that arise from the transformative activity." Although SAM was developed by BP to assess an oil and gas field development, they propose that this tool can be used for any kind of organisation, to encourage sustainable operations (Bebbington & Frame 2003). SAMs have also been conducted on a landfill project and a forestry planting project. It is also supported as a tool for analysing industry sectors (Baxter *et al.* 2003).

SAM attempts to quantify, in both physical and monetary units, the economic, environmental, and social effects of organizational operations. By doing so, the authors of the technique intend to evaluate sustainable development activity rather than simply report attempts to undertake such endeavours. SAM attempts to address all areas of concern in the list of criteria: economic, social, and environmental. To this extent, it is comprehensive. Note, however, that the environmental and social "flows" may not themselves be comprehensive. Also, meeting the social criteria is problematical, which may be an universal problem. Certainly, the authors noted that quantifying the social impacts was very difficult (Bebbington & Frame 2003).

The remaining criteria are not met as well by SAM. The model is basically a snapshot in time of a specifically-defined project and does not consider adaptation to changing conditions; so it does not meet the dynamic criterion. While the model can be used to consider different project approaches (e.g. Baxter *et al.* 2003), it does not take into account variations in input costs, demand levels, etc. and so does not fully meet the uncertainty criterion.

By using a "cradle to grave" approach, SAM does attempt to assess a project's impact on a system-wide basis. For instance, it takes into account the pollution generated by products developed in the activity (e.g. air pollution generated by cars was included in the assessment of oil and gas field development (Bebbington & Frame 2003)). On the other hand, SAM's first step limits this by constraining the scope of the project. This occurred in the assessment of methane extraction from an existing landfill; only the gas extraction was accounted for since the landfill already existed. Thus, the comprehensive sustainability of the landfill was not considered, only one activity occurring at the landfill site (Baxter *et al.* 2003). The presentation of the four flows as positive and negative externalities allows consideration of the different parts of the system affected, but does not consider accumulation through time and space.

SAM is not necessarily easy to use. Since the core of the assessment requires both an LCA and monetization of flows, it suffers from all the difficulties of data gathering and analysing of both these methods. The graphical results are easily interpretable by any audience and they may alert those who do not normally consider externalities to consider the wider implications of their projects. The explanation and illustration of the results, though, causes concern insofar as they would be easy to abuse and misinterpret. The details of the simple, colourful bar graphs are not explained, e.g. no legend is included. More importantly, although there is discussion about negative and positive externalities for all four flows- social, environmental, resource, and economic—each category is represented as either completely positive or negative. This is oversimplified and misleading. The SAM indicator offers another easily digestible result- one number on a scale of 0 to 1 (or percentage), but this indicator may not be overly useful considering that it doesn't allow cross-project comparisons (which, in effect, would be an apples to oranges comparison) (see figure 3 below).

Overall the Sustainability Assessment Method's main strengths lie in its ability to present easily interpretable results of economic, social and environmental concerns. However, the SAM is easily open to misinterpretation and should be used with caution.

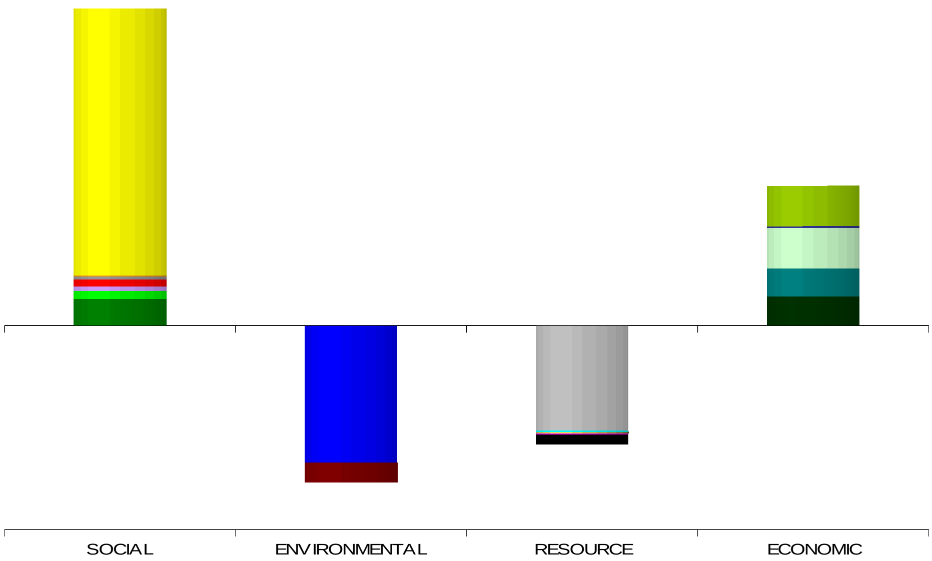


Figure 2: Example SAM signature for a typical oil and gas field development

8.5 Goals Achievement Matrix

The Goals Achievement Matrix is another specific application of multi-objective decision making. Morris Hill (1968) developed the goals- achievement matrix (GAM) as an extension of the methods that attempt to determine the extent to which alternative plans achieve predetermined goals or objectives. The GAM extends the checklist approach by attempting to quantify the extent to which the objectives are fulfilled, rather than simply ranking them. In the GAM approach, a separate matrix is prepared for each alternative. For example, if one wanted to compare the relative merits of different insulation regimes, three matrices might be needed covering business as usual, no insulation and high insulation.

In GAM, objectives are arrayed at the top of the matrix and stakeholders down the side. Objectives and stakeholders remain constant across alternatives. For example, figure 4 shows a possible layout of the matrix for evaluating alternatives.

GAM: OPTION 1

		GOALS				
		Min economic cost	Maximise health benefits	Minimise environmental impacts	Minimise embodied resource use	……
Goal wt →		1	1	1	1	
	Stakeholder wt					
Local govt	1					
Residents	1					
Building sector	1					
:						
Target goal						
Actual Goal achieved						
% Actually achueved						

OPTION 2

OPTION 3

Figure 3 : Example layout of goals achievement matrix

In GAM, the objectives and stakeholders are established prior to the design of options and analysis (GAM can accommodate any range of goals or stakeholder groups). Both quantitative and qualitative objectives are established, the ways in which the objectives will be measured are specified, the objectives are ranked or weighted in terms of their relative importance before analysis is undertaken, and the importance of each objective to various groups is ranked. These rankings are presented in numerical terms as much as possible. The extent to which each alternative meets each objective is estimated, and these values are then weighted by the relative importance of the objective and the weight of the relevant groups and are displayed in the matrix. Then the values for each objective are summed for each alternative to obtain the overall goals-achievement for each alternative.

Relatively sophisticated derivations of the GAM approach can be applied using proprietary software such as Logical Decisions[16].

The strengths of the GAM (and related approaches) are flexibility in that it can accommodate virtually any goal and stakeholder groups. It can also accommodate both qualitative and quantitative data. By including multiple stakeholder groups, it also encourages consideration of where impacts fall.

---

[16] See http://www.logicaldecisions.com/

Despite these benefits, GAM has been criticised primarily because it:

- Is data hungry (Patton, 1986). This is a fair criticism. The GAM approach is a summary tool. It can draw together information from a range of other tools (e.g. LCA, CGE models etc) in a framework that aids the comparison of alternatives.
- Requires subjective decisions, especially in the choice of weights (see Jesinghause, 1997). While this is the case, it must be stated that all approaches are subjective. All that GAM does is encourage those subjective decisions to be made explicit.
- Another potential limitation of the GAM approach is that it has not, to our knowledge been applied to building interventions.

The GAM performs well against our evaluation criteria:

- It can (theoretically) account for social, economic and environmental goals.
- It can incorporate uncertainty through the use of data ranges rather that data point estimates.
- It can incorporate LCA and system wide considerations
- It has the ability to produce a single score for each alternative if required for choosing between options.

However, GAM is limited in its ability to consider dynamic and spatial impacts. The technique is also relatively difficult to apply – both because of the subjectivity issues and because of data requirements.

Overall, the GAM approach is well suited to the task of evaluating the sustainability impacts of policy interventions.

8.6 Environmental/ social assessment model choice

The results of the evaluations above are summarised in the following table. Based on the discussion above, it appears that multi-objective decision assist tools such as the Goals Achievement Matrix are well suited to a sustainability assessment of policy interventions.

Table 3 Summary of findings for social/ environmental models

Assessment of social/ environmental models									
Criteria **Models**	Social	Economic	Environmental	Dynamic	Uncertainty	System-wide	Ease to use	Results easy to interpret	Costs to develop & run.
LCA	P	P	Y	N	Y	Y	P	Y	med
Ecological multipliers	N	N	Y	N	N	Y	Y	Y	high
SAM	Y	Y	Y	N	P	P	N	P	v.high
GAM	Y	Y	Y	P	Y	Y	P	Y	high
Y= Yes, N = No, P= partly Yes									

8.7 Costs for developing a SAM or GAM model

It is suggested that three options be considered in these models, namely no sustainability measures, a “moderate level” package of sustainability measures, and a “comprehensive” package of sustainability measures. The time involved in developing fairly comprehensive models are as follows.

For the Beddington–Frame SAM the steps required for each sustainability package of measures are; define the cost objective, carry out the LCA, identify and measure the four flow impacts, and assign money values to externalities. The estimated time is about 70 person days or approximately $84,000. The steps involved for developing a GAM model appropriate for New Zealand includes setting up the framework, identifying the stakeholders and the options, identifying and setting target goals, assembling the experts, and getting them to apply weights to the goals. The time involved is estimated at about 40 person days or approximately $48,000.

It would be feasible to develop simplified versions of the above and run them using approximate data . This would provide a guide on the usefulness of the model and whether it was worthwhile to proceed to full development. The approximate costs for initial development would be 40% of the above costs.

8.8 References for sustainability assessment models

Baxter T., Bebbington J. & Cutteridge D. (2003) The sustainability assessment model (SAM): Measuring sustainable development performance. In: *Offshore Europe 2003*. Society of Petroleum Engineers International, Aberdeen, UK.

Bebbington J. & Frame B. (2003) Moving from SD reporting to evaluation: the sustainability assessment model. *Chartered Accounting Journal of New Zealand* 82: 11-13.

Cartwright T. (1973) Problems, solutions and strategies. *AIP Journal*.

Hendrickson C. & Horvath A. (2000) Resource use and environmental emissions of US construction sectors. *Journal of Construction Engineering and Management-Asce* 126: 38-44.

Hill M. (1968) A Goals-Achievement Matrix for Evaluating Alternative Plans. *Journal of the American Institute of Planners* 34: 19-29.

International Energy Agency (2002) Resources of Annex 31 to the international research project Energy related environmental impact of buildings . IEA-BCS Annex 31.

Johnstone I. M. (2001) Energy and mass flows of housing: a model and example. *Building and Environment* 36: 27-41.

Mithraratne N. & Vale B. (2004) Life cycle analysis model for New Zealand houses. *Building and Environment* 39: 483-492.

Rijsberman M. & van de Ven F. H. M. (2000) Different approaches to assessment of design and management of sustainable urban water systems. *Environmental Impact Assessment Review* 20: 333-345.

Spash C. & Hanley N. (1995) Preferences, information and biodiversity preservation. *Ecological Economics* 12: 191-208.

Taborianski V. M. & Prado R. T. A. (2004) Comparative evaluation of the contribution of residential water heating systems to the variation of greenhouse gases stock in the atmosphere. *Building and Environment* 39: 645-652.

Treloar G. J. (1997) Extracting embodied energy paths from input-output tables: towards an input-output based hybrid energy analysis method. *Economic Systems Research* 9: 375-392.

9. DISCUSSION

A study of overseas interventions for sustainable buildings shows that a mix of policies are used, consisting of regulations, economic measures such as taxes and subsidies, and the provision of information, including demonstrations and labelling schemes. In New Zealand we are also using this mixed approach, and the specific measures were discussed in Section 4.2. In addition the Beacon programme will have an important role in education, demonstration, and provision of a labelling scheme. While the role of Government is considered pivotal, a lot of the initiatives overseas are in public-private partnerships, and this approach is inherent in the Beacon process.

Hence it is apparent that New Zealand is following the sustainability path used overseas and many of the lessons from overseas will be applicable here. One of the most important, from the National Scorecard viewpoint, is that market based approaches on there own do not achieve wide success, and that Government intervention, in particular, regulation is necessary for widespread uptake of sustainable buildings. Section 5.3 described the need for a Regulatory Impact Statement for all new regulations in New Zealand. Quantification of the savings (in dollars and volumetric terms) are a vital part of the RIS and if the Beacon programme can provide these it will improve the likelihood of success of getting mandatory sustainability measures introduced, particularly for new buildings. Even if the net benefits turn out to be negative this would not necessarily rule out the measures, because other factors, such as the achievement of broad environmental policy goals may be a deciding factor. In any case the decision makers need to know what the net cost of the policy is, and the financial and AGE models will provide that.

The situation for retrofit of buildings is less certain. No overseas countries have mandatory requirements to upgrade existing buildings for energy efficiency or other sustainability measures, except for large multiunit apartments in some countries. The reason seems to be the political difficulties involved, plus difficulties in monitoring compliance. The NZ Building Code requires upgrade of fire safety and disabled access for the whole building when doing additions and alterations. Apart from this no retrospective measures apply. Hence it is very unlikely that Government will regulate for mandatory sustainability upgrading of existing housing. In this situation the quantification of the national savings (volumes and/or in dollars) for retrofit would not influence the provision of mandatory requirements. Though it would be of interest to Government for monitoring progress in achieving the NEECS targets, Beacon expenditure on modelling of retrofit nationwide benefits may not be justified, given the low likelihood of mandatory measures in the existing housing stock. However provision of data for home owners on the costs and benefits of sustainability measures would most likely be worthwhile in influencing their decisions to retrofit.

While mandatory sustainability retrofit measures through the Building Code appears unlikely at this time, there are other policy measures that could affect retrofit. These include landfill charges and taxes, compulsory water metering, energy taxes such as via the carbon charge, and subsidies. In particular, subsidies via an adapted Canadian Energuide programme appears to have potential in NZ, reaching all income groups and covering most sustainability measures (see the RF1 report). Evidence of nationwide benefits from these programmes would help the case for Government subsidies. So there may well be some value in having a national scorecard model that considered measures outside the Building Code for retrofit.

To what extent would the development of SAM or GAM models improve the likelihood of success of the Beacon programme? The MED guideline document mentions multi-criteria analysis as a method to be considered in doing the RIS for regulatory changes. The development of either of these models would help to get mandatory measures for new housing introduced into the regulations. These models would also be useful in assessing non-regulatory measures, such as subsidies. This report favours the GAM model because it is cheaper to develop, and the simplified version may produce results acceptable to the decision makers as covering the RIS requirements. Note that the GAM model has parallels with the INT1 optimisation process. The latter attempts to optimise and prioritise Beacon spending, and the GAM tool would show what package of sustainability measures has the most favourable national outcome.

One of the questions for the National Scorecard project was; what are the likely contents of the Building Code (and regulations) with and without the Beacon contribution? Previous discussion has shown that new regulations require a RIS and that quantifying the volumes of resource saved, and their macroeconomic impact, will aid this process. The RIS also looks at compliance, and the sustainability labelling being developed and tested in the NOW house will provide a compliance tool. These Beacon projects will encourage regulation.

However in the absence of the Beacon programme what sustainability measures would be regulated, in any case? It is true that the Building Act now has sustainability items under the purposes of the Act. But until tools and methods are developed for providing and measuring for sustainability in buildings, Government is unlikely to regulate. Piecemeal measures may be incrementally introduced over a period of time, as for example in the State of Victoria. The Energy Minister[17] has said that solar water heating systems, and double glazing in cooler climates, will be compulsory for new homes within a few years, and BIA is already doing some work on this. But to make progress in sustainable housing, a comprehensive set of measures are required, applicable to a range of new housing in different locations, and this is what the Beacon programme is designed to facilitate. Just as the UK is heading toward the BRE EcoHomes as the basic model for its Sustainable Housing Standard, so the Beacon Now house can be the NZ model standard, and an Approved Solution in the NZ Building Code.

[17] NZ Herald "Sun-power heating in Govt plans." 6th September 2004.

10. RECOMMENDATIONS

Beacon commission the following work:

1. A study to estimate the volumes and $ value of energy, water, construction waste, and other resources that will be saved in new sustainable housing over the next 15 years. An estimate of the health cost savings from sustainable housing should also be included. The study should be based on the NOW house, modified as necessary for different house sizes, including multi-units. Identify the additional costs of the NOW house by comparisons with standard housing. The estimated cost is $12,000.

2. An analysis of the impact of new sustainable housing on the NZ economy using an AGE from an economic consultancy. Input for this model is to be from recommendation 1. Discussion be held with the preferred consultant on the required modifications of their existing models, but that these be limited to the creation of a separate water supply industry, and the upgrade of critical technical coefficients relating to the building industry. The estimated cost is $18,000. The preferred consultant for this work is BERL as preliminary discussions have been held with them regarding modification of their AGE, and they have already proved their model's suitability for insulation upgrade modelling.

3. Beacon consider modelling the economic impact of the retrofit programme and sustainable neighbourhoods programmes. The outputs of this work is unlikely to influence Government to regulate for sustainable retrofits and neighbourhoods, given the problems discussed in Chapter 9, however demonstration of net benefits may encourage Government subsidies, information programmes, and further research. The cost to quantify retrofit resource savings is about $8,000, and for neighbourhoods another $8,000. Running the results in a AGE, with some modifications would be about $14,000.

4. Development of the first stage of a sustainability assessment model of the GAM type costing approximately $20,000, to assess it potential usefulness, and consider expenditure of another $30,000 for full development of the model.

11. APPENDIX

The appendix contains the following:

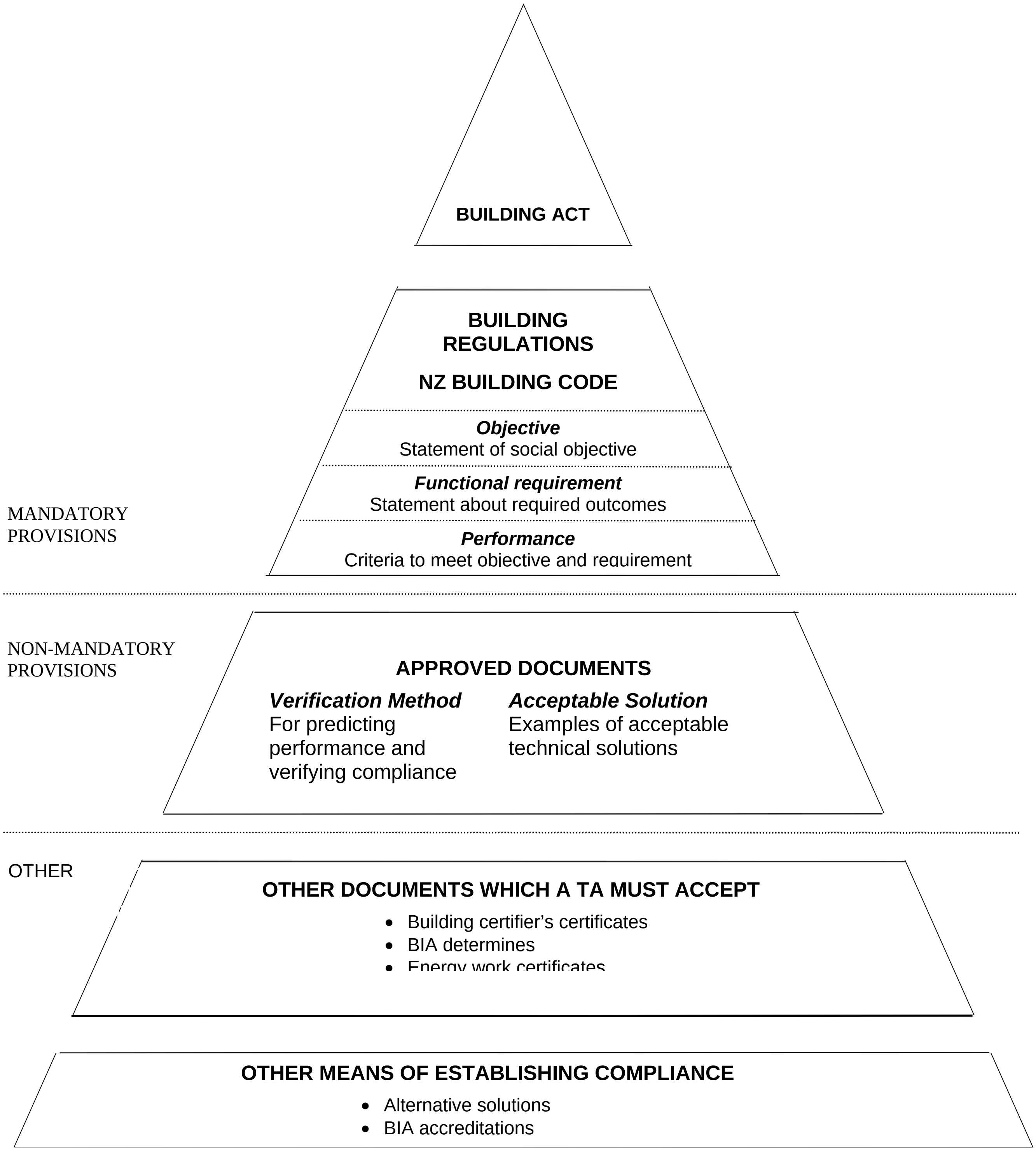
- The building controls structure
- The types of economic models
- A description of input output matrices and the ecological multipliers.

11.1 Building controls

Figure 1 shows the building control pyramid. The Building Act, Building Regulations, and the NZ Building Code are at the top, and are mandatory. The latter two set out in detail the performance requirements for the various parts of the building. The lower part of the pyramid are the methods for achieving compliance with the regulations. The approved documents named in the code can be used, or designers can provide alternative solutions as a means for establishing compliance.

The role of the building inspectors is very important because they check the documentation in the consent application and determine whether it complies with the mandatory provisions. If the designer is using approved documents, BIA determinations and accreditations, or a building certifier provides certificates, then the TA must accept them as compliance with the code. However difficulties can arise where alternative solutions are used, which may involve a new product or system, or design calculations. As some sustainability measures may be a little out of the ordinary some inspectors may reject their use. The ideal solution for sustainable housing is for the Building Regulations to refer to an Approved Document, which may be a sustainable housing standard, or a Beacon sustainable housing index. Even if the Beacon NOW house framework was not referenced as an Approved Solution it could gain acceptance among TAs as an established Alternative Solution.

Figure 4 The building control pyramid



The Building Regulations have not been revised since the new Act was passed and clauses relating to sustainable materials, water conservation and waste reduction are yet to be written. Mandatory provisions with direct sustainability implications are listed below by their clause and objective:

Table 4 Building Code sustainability clauses

Building Performance	**Clause**	**Objective**
STABILITY	B2 Durability	Building will throughout its life continue to satisfy the other objectives.
FIRE SAFETY	Nil sustainability	
ACCESS	D1 Access Routes	Safeguard people from injury during access, ensure people with disabilities are provided with reasonable access.
MOISTURE	E2 External Moisture	Safeguard people from illness and injury from water entering the building.
	E3 Internal Moisture	Safeguard people from illness and injury from accumulation of internal moisture.
SAFETY OF USERS	F2 Hazardous Building Materials.	Safeguard people from illness and injury from exposure to hazardous building materials.
SERVICES AND FACILITIES	G4 Ventilation	Safeguard people from illness or loss of amenity due to lack of fresh air.
	G5 Interior Environment	Safeguard people from illness caused by low air temperature.
	G7 Natural Light	Safeguard people from illness or loss of amenity due to isolation from natural light and the outside environment.
	G12 Water Supplies	Safeguard people from illness caused by infection from contaminated water or food.
ENERGY EFFICIENCY	H1 Energy Efficiency	Facilitate efficient use of energy.

11.2 Input-Output Models

Input-output (IO) models (Leontief 1966) describe, for a number of sectors in an economy, the inputs in the production process (such as, labour, capital, goods and service from other sectors), along with the outputs of goods and services realised by using the inputs (Meister 1990a). IO models are concerned with the economic interdependence of activities within an economy (Leontief 1988), and so ensure that changes in activity in one sector are reflected in the activities of sectors that supply it (Binkley et al. 1994, Statistics New Zealand 2003). There are a number of New Zealand examples of regional IO models (Statistics New Zealand 2003). IO models have been extended to the analysis of environmental management (Førsund 1985, Lonergan and Cocklin 1985), for example, the income, production and employment effects of pollution control (Mesiter 1990a).

IO models are used for economic analyses such as; measuring the composition of economic activity, understanding the inter-relationships among industries, and studying the effects of changes in supply and demand throughout the economy (Statistics New Zealand 2003). Binkley et al. (1994) identify several limitations with IO models. Firstly, IO models are static, therefore, no information is provided on the time path of adjustment. Secondly, they have a simplistic representation of technology; the transformation of inputs to outputs. In particular IO models assume no capacity constraints on production, no scale effects, and no substitution of factor inputs. This means that impacts on relative prices are not considered. Finally, IO models assume that government activities and investment are independent of industrial activity.

11.3 Macroeconometric Models

Macroeconometric models are structural models of the overall economy. They make use of econometric equations, estimated from macroeconomic data, to represent relationships among model variables. For example, household consumption and labour-supply decisions are a function of the price of goods, the wage rate, non-labour income, interest rates, and initial wealth (Fair 1988).

New Zealand examples of macroeconometric models are the Treasury New Zealand Model (NZM, Murphy 1998) and the Reserve Bank Forecasting and Policy System (FPS, Black et al. 1997)[18]. Both models were developed to analyse policy issues relating to monetary policy and provide short-term (quarterly) macroeconomic forecasts (Reserve Bank of New Zealand 1997). They describe the interaction of five economic agents: households, firms, government, a foreign sector, and the monetary authority (Drew and Hunt 2000). They are, therefore, highly stylised and aggregated (Black et al. 1997). For example, the FPS models the firm as a single representative firm (Drew and Hunt 2000).

Macroeconometric models have been used to assess the impact of environmental policy on productivity growth, inflation, and employment (Christainsen and Tietenberg 1985, Meister 1990b). These studies have found environmental regulations have had an adverse impact on economic performance in the United States, though the impact was not large in magnitude (1.5 percent to 2.0 percent of United States gross national product) (Christainsen and Tietenberg 1985).

---

[18] Model parameters in the FPS are estimated using calibration (Black et al. 1997), as well econometric estimation, therefore it is a slightly less formal macroeconometric model.

11.4 Applied General Equilibrium Models

Applied general equilibrium (AGE) models (Johansen 1960), also known as computable general equilibrium models, incorporate the full range of inter-industry linkages and ensure constraints imposed by economic theory, such as household expenditure does not exceed household income, are met (Binkley et al. 1994). AGE models permit prices and quantities of commodities, inputs, labour and capital to vary with respect to changes in output prices and production (Binkley et al. 1994). They account for impacts not fully considered by macroeconometric models, and extend IO models by incorporating substitution effects in production and demand (Xie 1996). For example, AGE models capture the industry response to increased wages of utilising capital in place of labour.

An AGE model of the New Zealand economy, based on Statistics New Zealand input-output tables, is used by Business and Economic Research Limited (BERL, Nana 2003). This model has been used to estimate the economic impact of improving insulation and energy use in new homes in New Zealand (Nana 2003). The BERL AGE model is a dynamic model. It covers 51 industries including, residential building, ownership of owner-occupied dwellings, gas supply, and water supply, 22 export commodities, and eight household commodities including, transportation, household operation, and food.

The central component of an AGE model is the accounting matrix (AM) of production coefficients, which accounts for flows of income and expenditure between agents within an economy (Bowen et al. 1998). Rows and columns of the accounting matrix denote groupings of economic agents, with entries being the expenditure-income flows among agents. The level of disaggregation within the AM reflects the degree of detail of the AGE model (Bowen et al. 1998). Data in the AM is drawn from national income accounts and input-output models (Shoven and Whalley 1984). The effect, in terms of prices, employment, production, GDP, and welfare of policy changes is estimated by recalibrating the AGE model for changes in the empirical data in the AM (Turner and Buongiorno 2003).

The details of each AGE model vary with the interests of the modeller, and the set of policy questions to be examined (Bowen et al. 1998) (Table 1). Decisions regarding model selection (for example, country specific versus multilateral) and specification (for example, perfect competition versus monopolisitic competition) are also influenced by the sectors of the economy of interest, say the residential built environment, and the availability of data. Analysis of policies affecting the New Zealand residential built environment, might require an AGE model with good detail of the building and allied industries, household commodities, and perfect competition.

Table 5 Elements of applied general equilibrium models.

Element of AGE	Representation of Element	Issues
Country coverage	Country specific	Greater detail regarding industry structure and consumer behaviour
	Multilateral	Used for trade analysis
Behavioural structure	Perfect competition	
	Monopolistic competition	
Specification for production	Increasing returns to scale	
	Constant returns to scale	
Functional forms of supply and demand	Cobb Douglas, constant elasticity of substitution, Leontief	
Treatment of time	Static	No path of changes
	Dynamic	Path of adjustment
Disaggregation of the AM	Sectoral/ economic agent coverage	Level of disaggregation reflects degree of detail desired
Estimation method	Global solution	
	Johansen	Local approximations to global changes

A number of studies have incorporated environmental policies and impacts into AGE models (Xie 1996). Approaches taken include:

i) pollution associated with production of outputs captured using fixed pollution coefficients
ii) pollution removal activities included as an additional sector in the economy, with pollution removal driven by government demand
iii) Stone-Geary utility functions which include the impact of pollution and cleaning activities on consumer utility
iv) markets and market prices for tradable emission permits sold by the government
v) exogenously changing prices or taxes affected by environmental regulations
vi) environmental feedback into economic systems introduced through the inclusion of pollution control costs in production functions
vii) environmental quality indices incorporated in production functions to capture the effect of environmental quality on productivity
viii) environmentally extended AM which includes pollution abatement activities and treats pollutants removed as special goods.

Successful inclusion of environmental policies and impacts in AGE models is largely constrained by the availability of data on environmental impacts and parameters for capturing environmental impacts on production and utility functions.

Hertel (1999) identifies a number of advantages of AGE models. Firstly, AGE models' reliance on the AM for their empirical structure ensures consistency within the model; households cannot spend more than they earn, the same unit of labour cannot be simultaneously employed in two places. The AM also ensures the financial integrity of the analysis, by including an explicit budget constraint for the government (Hertel 1999). Secondly, AGE models' inclusion of inter-industry linkages are important given the many industries linked to residential housing; residential construction, industries supplying construction materials, financial services, the energy sector.

A number of criticisms have been levelled at AGE models. Firstly, the values calculated from them have no statistical foundation, so it is not possible to assess the reliability of estimates (Shoven and Whalley 1984, Xie 1996, Bowen et al. 1998). The procedure of systematic sensitivity analysis (SSA, Harrison and Vinod 1992, Harrison et al. 1993) begins to address this criticism. SSA is an explicit and systematic method of assessing the sensitivity of model predictions to changes in model parameters. Secondly, AGE models are very data intensive (Xie 1996). It is often the availability of data, and ability to specify key parameters, which constrain model applications (Shoven and Whalley 1984). As previously mentioned, this is a major constraint in the application of AGE models to environmental policy analysis. Thirdly, AGE models lack a representation of money and financial sectors, making them unsuitable for fiscal policy analysis (Xie 1996). However, approaches are being developed to begin to address this limitation (Robinson 1991).

11.4.1 References for input-output models, macroeconomic models, and AGE models.

Binkley, C.S., M. Percey, W.A. Thompson, and I.B. Vertinsky. 1994. A general equilibrium analysis of the economic impact of a reduction in harvest levels in British Columbia. *The Forestry Chronicle* 70(4): 449-454.

Black, R., V. Cassino, A. Drew, E. Hansen, B. Hunt, D. Rose, and A. Scott. 1997. The Forecasting and Policy System: the core model. *Reserve Bank of New Zealand Research Paper No. 43*. Reserve Bank of New Zealand, Wellington.

Bowen, H.P., A. Hollander, J-M. Viaene. 1998. *Applied International Trade Analysis*. The University of Michigan Press, Ann Arbor.

Christainsen, G.B. and T.H. Tietenberg. 1985. Distributional and macroeconomic aspects of environmental policy. In A.V. Kneese and J.L. Sweeney (eds.) *Handbook of Natural Resource and Energy Economics, Volume 1*. North-Holland, Amsterdam. pp. 345-393.

Drew, A. and B. Hunt. 2000. A comparison of the properties of NZM and FPS. *Reserve Bank of New Zealand Discussion Paper Series DP2000/02*. Reserve Bank of New Zealand, Wellington.

Fair, R.C. 1988. Macroeconometric models. In J. Eatwell, M. Milgate and P. Newman (eds.) *The New Palgrave: A Dictionary of Economics Vol. 3*. The Macmillan Press, London. pp. 269-273.

Førsund, F.R. 1985. Input-output models, national economic models, and the environment. In A.V. Kneese and J.L. Sweeney (eds.) *Handbook of Natural Resource and Energy Economics, Volume 1*. North-Holland, Amsterdam. pp. 325-341.

Harrison, G.W., and H.D. Vinod. 1992. The sensitivity analysis of applied general equilibrium models: Completely randomized factorial sampling designs. *The Review of Economics and Statistics* 74(2): 357-362.

Harrison, G.W., R. Jones, L.J. Kimbell, and R. Wigle. 1993. How robust is applied general equilibrium analysis? *Journal of Policy Modeling* 15(1): 99-115.

Hertel, T.W. 1999. Applied general equilibrium analysis of agricultural and resource policies. *Staff Paper 99-2*. Department of Agricultural Economics, Purdue University, Lafayette, IN.

Johansen, L. 1960. *A Multi-Sectoral Study of Economic Growth*. North-Holland, Amsterdam.

Leontief, W. 1966. *Input-Output Economics*. 2nd Edition. Oxford University Press, New York.

Leontief, W. 1988. Input-output analysis. In J. Eatwell, M. Milgate and P. Newman (eds.) *The New Palgrave: A Dictionary of Economics Vol. 2*. The Macmillan Press, London. pp. 860-864.

Lonergan, S.C. and C. Cocklin. 1985. The use of input-output analysis in environmental planning. *Journal of Environmental Management* 20: 129-147.

Meister, A.D. 1990a. Economic analysis of environmental impacts and issues: A survey of analytical techniques. *Discussion Paper in Natural Resource Economics No. 14*. Department of Agricultural Economics and Business, Massey University, Palmerston North.

Meister, A.D. 1990b. Environmental regulation and use of economic instruments for environmental planning and management: An overview. *Discussion Paper in Natural Resource Economics No. 15*. Department of Agricultural Economics and Business, Massey University, Palmerston North.

Murphy, C. 1998. New Zealand Model 1998 (NZM98). *Report of September 1998 by Econtech*, Commissioned by the New Zealand Treasury.

Nana, G. 2003. Economy-wide impact of imprve insulation and reduced power use in new homes. *Business and Economic Research Limited (BERL) Report to BRANZ.* August 2003.

Reserve Bank of New Zealand. 1997. The Forecasting and Policy System: an introduction. *Reserve Bank Bulletin* 60(3): 225-235.

Robinson, S. 1991. Macroeconomics, financial variables, and CGE models. *World Development* 19(11): 1509-1525.

Shoven, J.B. and J. Whalley. 1984. Applied general-equilibrium models of taxation and international trade: An introduction and survey. *Journal of Economic Literature* 22(September 1984): 1007-1051.

Statistics New Zealand. 2003. *Regional Input-Output Study*. Report prepared by Statistics New Zealand. Statistics New Zealand, Wellington.

Turner, J.A. and J. Buongiorno. 2003. Issues and prospects in global forest sector modelling. In F. Helles, N. Strange and L. Wichmann (eds.) *Recent Accomplishments in Applied Forest Economics Research*. Kluwer Academic Publishers, Dordrecht. pp. 193-206.

Xie, J. 1996. *Environmental Policy Analysis: A General Equilibrium Approach*. Ashgate, Aldershot.

11.5 A description of input-output matrices and ecological multiplier mathematics

11.5.1 Structure and mathematics of input-output matrices

An input-output (IO) matrix is both a descriptive framework and an analytical tool. An IO matrix describes the relationships between sectors for a given period. These relationships are established by a representation in which one sector's outputs are the inputs to other sectors (Duchin, 1996, p. 290).

Originally, the IO table provided an analytical tool for measuring the impact of autonomous disturbances on an economy's output and income. Indeed, one of the main analytical purposes of conventional IO analysis was to determine the effects of specified changes in final demand (which is regarded as autonomous) upon gross output, given the direct-input coefficients matrix[19].

Conventionally, an IO table is presented as a matrix. Each sector in the economy is assigned a row and a column. Each cell in the table represents the flow of goods from the row sector to the column sector. Thus, the element x_{ij} in row *i* column *j* indicates the volume of goods sold from (or outputs of) sector *i* as inputs to sector *j*. For instance, row 1 in the table below shows the sales of sector 1 to all other sectors (intermediate demand) and to consumption, private investment, government spending and exports (final demand). Conversely, column 1 indicates the purchasing pattern of sector 1 from all other sectors (intermediate inputs) and primary inputs (labour, capital etc), which are value, added entries taking the form of wages, profit, depreciation, interest and taxes, and from imports.

IO analysis describes the interaction of three elements of an economic system: the input requirements of each sector (intermediate demand and primary inputs), final demand and gross output. The design of a standard IO matrix reflects these elements by dividing the economic structure of the economy into quadrants (see Fig xxx). Vertically the matrix is divided into the inputs into the production process of the productive industries, and the sales to the final demand sectors. Horizontally, each part may the further subdivided into two sections so as to distinguish between intermediate inputs and primary inputs.

	Sector 1	...	Sector j	...	Sector n	Sub Total	Household	Govt Expenditure	Other Final Demand	Exports	Sub Total	Total Gross Output
Sector 1	x_{11}		x_{1j}		x_{1n}		C_1	G_1	I_1	E_1		X_1
⋮												⋮
Sector i	⋮		**Quadrant 1**		⋮		⋮	**Quadrant 2**		⋮		X_i
⋮												⋮
Sector n	x_{n1}		x_{nj}		x_{nn}		C_n	G_n	I_n	E_n		X_n
Subtotal												
Labour	L_1	...	L_j	...	L_n		L_c	L_g	L_I	L_E		L
Other value added	V_1	...	**Quadrant 3**	...	V_n		V_c	**Quadrant 4**		V_E		V
Imports	M_1	...	M_j	...	M_n		M_c	M_g	M_I	M_E		M
Sub Total												
Total Gross Input	X_1	...	X_j	...	X_n		C	G	I	E		X

Figure xxx: A simplified input-output matrix

Quadrant 1 is commonly referred to as the intermediate or inter-industry demand quadrant (Leontief, 1986, p. 23). This quadrant depicts the flows of commodities produced and used in the intermediate stages of production. In a standard Leontief IO table, Quadrant 1 is a square matrix with the same number of rows and columns. An important characteristic of this matrix is that the total value of output of each intermediate sector must always equal its total expenditure on inputs.

The matrix of intermediate demand sectors by final demand (Quadrant 2) records the delivery of the products of each sector to the various types of final demand. As such, this quadrant describes consumer behaviour in a number of important markets. Quadrant 2 is of special importance because it is regarded as autonomous, from which changes occur that are transmitted throughout the rest of the model (Miernyk, 1965, p. 13; Schaffer, 1976).

[19] However, aspects of final demand could be endogenised, in which case, these aspects of final demand would no longer be autonomous.

The matrix of primary input sectors by intermediate demand sectors (Quadrant 3) shows the contribution to intermediate production of primary inputs, which (excluding imports) correspond to the national accounting concept of value added. These inputs are described as 'primary' because they do not form part of the output as defined by rows forming quadrants 1 and 2. The total of the primary inputs for each sector less imports represents the value added to commodities consumed in the production process.

Quadrant 4 describes the primary inputs that are used directly by final demand sectors.

As will be discussed below, one of the strengths of IO matrices is that they allow several consistency checks. Two accounting identities that are particularly important are calculated by summing across the rows and down the columns. Summing across row 1[20]:

Equation A4-1[21]

$$X_1 = \sum_1^n x_{1j} + (C_1 + G_1 + I_1 + E_1)$$

Where:

X_1 = total gross output from row 1

$\sum_1^n x_{1j}$ = sum of sales of sector 1 to all sectors

C_1 = household consumption of sector 1 goods

G_1 = government consumption of sector 1 goods

I_1 = other final demand of sector 1 goods

E_1 = exports of sector one goods

n = number of sectors.

A frequent convention with IO matrices is to aggregate the final demand components into a single vector, $Y_1 = (C_1 + I_1 + G_1 + E_1)$ (Ferrer & Ayres, 2000, p. 21), and, therefore:

Equation A4-2

$$X_1 = \sum_1^n x_{1j} + Y_1$$

Where Y_1 = final demand for sector 1 goods.

In other words, Equation A4-2 shows that gross output (X_1)= intermediate demand ($\sum_1^n x_{1j}$) + final demand (Y_1).

Also, summing down column 1[22]:

Equation A4-3

$$X_1 = \sum_1^n x_{i1} + (L_1 + V_1 + M_1)$$

Where:

$\sum_1^n x_{i1}$ = sum of purchases (inputs) by sector 1 from all sectors

L_1 = labour inputs to sector 1

V_1 = other value added inputs to sector 1

M_1 = imports to sector 1.

[20] Row 1 is used for demonstration purposes. This accounting identity can be applied to all sectors in the transaction matrix (Quadrant 1).

[21] The algebra used throughout this thesis uses the following conventions: matrices are in upper case boldface letters (e.g. **X**). Vectors are represented by lower case boldface letters (e.g. **x**) and the matrix and vector elements are designated by lower case italic letters with the appropriate subscripts (e.g. x_{ij}).

[22] Column 1 is used for demonstration purposes. This accounting identity can be applied to all sectors in the transaction matrix (Quadrant 1).

However, since the value of inputs to sectors must equal outputs, total gross input to a sector must equal total gross output. Hence, X_1 (column total) equals X_1 (row total). A similar accounting identity can be shown for the economy as a whole (Ferrer & Ayres, 2000, p. 20).

Direct-input coefficients and direct effects

From an IO matrix, direct-input (or technical) coefficients (a_{ij}) can be estimated. Direct-input coefficients show "the amount of inputs required from each sector to produce one dollar's worth of the output of a given sector" (Miernyk, 1965, p. 21). For example, from appendix 1.1.2 it can be seen that, in 1994/95, the sheep, beef & mixed livestock sector requires approximately \$0.09 worth of inputs directly from the Dairy sector per \$1 of output.

A direct-input coefficient a_{11} is calculated as:

Equation A4-4

$$a_{11} = \frac{x_{11}}{X_1}$$

$$x_{11} = a_{11} X_1$$

Repeating the calculation in Equation A4-4 for all a_{ij} and substituting Equation A4-4 into Equation A4-2 gives

$$X_1 = a_{11}X_1 + a_{12}X_2 + a_{13}X_3 + \ldots a_{1n}X_n + Y_1$$ **Equation A4-5**

A complete set of input coefficients of all sectors of a given economy arranged in the form of a square table is called the direct-input coefficient (or **A**) matrix of that economy (Leontief, 1986, p. 22).

Calculating system-wide effects using multipliers from input-output matrices

It is important to note that the direct-input coefficients **A** matrix only shows the *direct* purchases that will be made by a given sector from all other sectors within Quadrant 1 for each dollar's worth of current output. It does not represent the *total* addition to output resulting from additional sales to final demand. An increase in the final demand for the products of a sector will lead to both direct and indirect increases in the output of all sectors in Quadrant 1.

One of the main analytical purposes of conventional IO analysis is to determine the total effects of specified changes in final demand upon gross output, given the direct-input coefficients matrix. The multipliers in the inverse Leontief matrix capture these direct and indirect (or multiplier) effects (Bicknell, Ball, Cullen, & Bigsby, 1998). To capture the flow on effects in the IO system, Equation A4-5 for row 1 can be rewritten as:

Equation A4-6

$$X_1 - \sum_{1}^{n} a_{1j} X_{1j} = Y_1$$

The entire set of equations for all rows in quadrant 1 can expressed in a matrix form:

$$\mathbf{x} - \mathbf{A}\mathbf{x} = \mathbf{y}$$ **Equation A4-7**

Where:

$\mathbf{x}$ = $n \times 1$ vector of total gross output

$\mathbf{A}$ = $n \times n$ matrix of direct-input coefficients

$\mathbf{y}$ = $n \times 1$ vector of total final demand.

Calculation of the multipliers (total addition[23] to output) resulting from additional sales to the final demand sector, requires calculation of the inverse Leontief matrix. Initially this involves taking the difference between an identity matrix **I** and the direct-input coefficients matrix (see Equation A4-8). Thus Equation A4-7 becomes:

$$(\mathbf{I} - \mathbf{A})\mathbf{x} = \mathbf{y}$$ **Equation A4-8**

Where **I** is an $n \times n$ identity matrix and **(I-A)** is the Leontief matrix of order $n \times n$.

Under the condition that **(I-A)** has an inverse[24] the inverse Leontief matrix can be used to express gross output as a function of (exogenous) final demand (Miernyk, 1965; Richardson, 1972):

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y}$$ **Equation A4-9**

Where $(\mathbf{I} - \mathbf{A})^{-1}$ is the inverse Leontief matrix[25].

[23] That is, the first, second, third and higher-order flow on requirements.

[24] In practical circumstances this condition will be met if the **y** vector contains at least one non-zero element.

The inverse Leontief matrix[26] shows the "total dollar production directly and indirectly required from the industry at the top (of the table) for each dollar of delivery to final demand by the industry at the left (of the table)" (comments in brackets added, Miernyk, 1965, p. 26). The elements of the inverse Leontief matrix are referred to as multipliers and are expressed in dollars per dollar. In this way, the inverse Leontief matrix maps the economic system-wide requirements to meet one dollar of final demand in a sector.

Calculating ecological multipliers

The two essential elements required to calculated ecological multipliers are (1) the inverse Leontief matrix of the IO matrix of the New Zealand economy, and (2) a matrix showing the flow of environmental inputs from and outputs to the economy.
Algebraically, the approach is outlined as follows. Consider the following equation:

$$e_{kj} = \frac{q_{kj}}{X_i} \qquad \textbf{Equation 11-1}$$

Where e_{kj} is the output (or direct) ecological multiplier[27] of resource inputs or pollution outputs k in sector j, q_{kj} is the physical quantity of resource inputs or pollution outputs k used by sector j and X_j is the total output of sector j in $.
Rearranging Equation 11-1

$$q_{kj} = e_{kj} X_j \qquad \textbf{Equation 11-2}$$

Consider a situation of m resource inputs to, or pollution outputs from, n economic sectors. The set of all e_{kj} arranged in a matrix of order $m \times n$ is called **E**. In matrix notation:

$$\mathbf{q=Ex} \qquad \textbf{Equation 11-3}$$

Where **q** is a vector of order $m \times 1$ resource inputs or pollution outputs and **x** is a vector of gross economic output of order $n \times 1$. It can be shown that (see Appendix 4):

$$\mathbf{x=(I-A)^{-1}y} \qquad \textbf{Equation 11-4}$$

Where:
$\mathbf{(I-A)^{-1}}$ is the inverse Leontief matrix of order $n \times n$
y is an $n \times 1$ vector of final demand.
Now substitute Equation 11-4 into Equation 11-3 above.

$$\mathbf{q=E(I-A)^{-1}y} \qquad \textbf{Equation 11-5}$$

And substituting **F** for $\mathbf{E(I-A)^{-1}}$ gives

$$\mathbf{q=Fy} \qquad \textbf{Equation 11-6}$$

---

[25] Essentially, the $\mathbf{(I-A)^{-1}}$ matrix captures the direct and second, third-level and so on requirements of commodity production. It can be shown that $\mathbf{(I-A)^{-1}=I+A+A^2+A^3+ \dots}$
where **I** gives the direct effect and $\mathbf{A+A^2+A^3+ \dots A^n+\dots}$ gives the second, third, etc order indirect effects.
The proof of this equation is as follows. Multiply each side by the Leontief matrix **(I-A)**.

$$\begin{aligned}(I-A)(I-A)^{-1} &= [I+A+A^2+A^3+ \dots](I-A)\\ I &= I(I-A)+A(I-A)+A^2(I-A)+A^3(I-A)+\dots\\ &= I^2-AI+AI-A^2+A^2I-A^3+A^3I-\dots\\ I &= I\end{aligned}$$

[26] There is a fundamental condition that must be met by the inverse Leontief matrix. This condition is known as the "Hawkins-Simon condition." Basically, this condition states that *there can be no negative entries in the table of direct and indirect requirements*. What would a negative value mean? In essence, it would mean that each time the sector with a negative entry expanded its sales to final demand, its direct and indirect input requirements would decline (an economic absurdity).

[27] Sometimes this ratio is referred to as eco-intensity. Eco-intensity is the reciprocal of eco-efficiency and the difference between the two terms is mathematically trivial. The main difference from an interpretation point of view is that eco-intensity is an increasing scale indicator, whereas eco-efficiency is a decreasing scale indicator. This difference affects the appropriate aggregation function (see Chapter 8). Eco-intensity can be accommodated within the definition of an eco-efficiency indicator tendered in Appendix 1.

Where **F** is a matrix of order $m \times n$ of the system-wide eco-efficiency (direct and indirect) multipliers of final demand expressed in terms of physical units per dollar.