Monitoring Energy Efficiency Performance in New Zealand

A Conceptual and Methodological Framework

An approach for monitoring progress against the National Energy Efficiency and Conservation Strategy Targets

Prepared for the Energy Efficiency and Conservation Authority by
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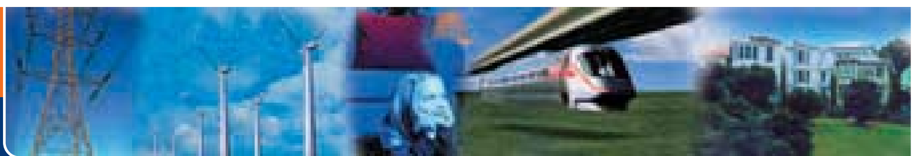

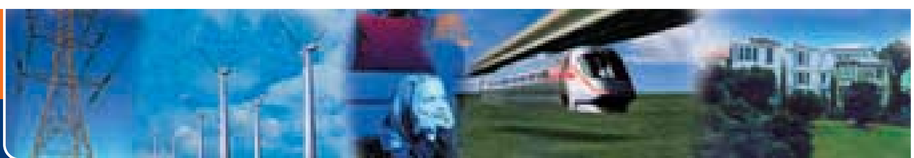

Monitoring energy efficiency performance In New Zealand: A conceptual and methodological framework.

An approach for monitoring progress against the National Energy Efficiency and Conservation Strategy Targets

The views expressed in the report are not Government Policy are not necessarily those of EECA or the Government of New Zealand.

Notice to Reader

EECA commissioned this report to inform the process of developing a system to clearly monitor the change in energy efficiency in New Zealand.

The need for this report stems from the development of the National Energy Efficiency and Conservation Strategy and the need to develop alongside the Strategy an effective monitoring system to:

- track the developing state of energy efficiency in New Zealand,
- identify the drivers for, and responses to, energy efficiency changes,
- monitor progress towards the targets and goals in the Strategy,
- inform future Strategy development

The report examines the state of the art in energy efficiency monitoring and makes recommendations for the system that will be developed for New Zealand.

During its development the report has undergone international expert review. The report authors have reflected the reviewer's comments in the final report.

EECA reiterates that any opinions expressed in this report are those of the authors.

Acknowledgements

In commissioning this report, EECA asked the following people to comment on the original draft. We would like to thank them for their stimulating and insightful comments, which have been incorporated into the final report.

- Dr Jacco Farla
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- Staff at EECA, and in particular Dr Harbans S Aulakh and Robert Tromop.

Any remaining errors are, of course, our own.

The views expressed are those of the authors, and are not necessarily those of the Energy Efficiency and Conservation Authority.

Executive Summary

The purpose of this report is to assist the Energy Efficiency and Conservation Authority (EECA) with its responsibility for monitoring progress against the National Energy Efficiency and Conservation Strategy (NEECS) 2001 targets.

Energy efficiency is defined as a change in the level of "net benefits (useful output) per unit of energy input". Net benefits are linked to a diverse range of areas, including economic growth, more comfortable living and working lifestyles, higher level food processing, energy security, health and environmental outcomes. There is no unequivocal quantitative measure of energy efficiency. Instead, EECA must rely on a suite of inidators relevant to the specific context.

Following a review of international best practice in energy efficiency monitoring, this report recommends that EECA operationalise energy efficiency by following the approach used in Canada. That is, through he use of the energy efficiency indicators pyramid and a Divisia factorisation method. The use of these two approaches is designed to enable EECA to track energy efficiency changes against the NEECS targets at the macro, sectoral and sub-sectoral levels and allow incorporation of additional data.

This report recommends a suite of indicators at the economy-wide, sectoral, and sub-sectoral levels. These indicators should be embedded within a Driving forces – State – Response framework.

This report also recommends the use of a factorisation technique to clearly identify underlying energy efficiency. Trends in total energy use and the energy:GDP[1] Gross Domestic Product ratio are informative, but they do not tell the whole story with respect to energy efficiency. They include effects that can swamp energy efficiency trends. The factorisation technique can isolate the underlying energy efficiency trends.

Using the Divisia factorisation method, changes in energy use or the energy:GDP ratio can be broken down into:

- A *structural effect*, indicating the effect on energy (or the energy:GDP ratio) of a changing economic structure. More specifically, the structural effect measures the change due to the change in relative size of energy intensive sectors. For example, an increase in the proportion of GDP derived from an energy intensive sector would cause an increase in the structural effect.

- An *activity effect*, representing the effect of changes in the level of activity in that sector (measured in different units per unit of value added depending on the sector; for example, population/$ for the residential sector, tonnes/$ for the industrial sectors, tonne-km/$ for the freight transport sector etc).

- An *underlying energy efficiency effect*, representing changes due to the efficiency of the energy-use process at the sub-sectoral level. More specifically, this effect reflects the contribution of changing energy efficiency of machinery through the replacement of old technology and retrofitting existing technology. This effect also accounts for energy efficiency changes as a result of energy management.

- A *wealth effect* representing changes in GDP. This represents changes in energy use directly related to GDP growth. (If the economic structure remained static, energy use would grow at the same rate as GDP). Note that if energy per capita remains constant at a time when GDP per capita is increasing, this will show up as a reducing energy:GDP ratio in the residential sector.

[1]Gross Domestic Product

The level of decomposition may be different for different economic activities, and will depend on what data is available and appropriate (e.g. floor area is an explanatory factor in commercial energy consumption, whereas tonne-km is more appropriate for transport). The recommended system is flexible and can be extended as more data become available.

The constraining factor in all of this analysis is the limited availability of energy and economic data.

The results of the factorisation technique can be used to compute an 'energy efficiency index'. This index is a useful device for communicating changes in energy efficiency in New Zealand and reporting progress against the

Other issues that do not fit easily into this formal structure, but nevertheless need to be addressed, include:

Health-related issues

CO_2 emissions

The 'rebound' effect where the implementation of an energy saving measure releases resources that are, in part, used to increase consumption. For example, higher insulation levels may result in warmer homes, rather than reduced energy consumption.

Recommendations

Energy efficiency should be measured as an index of changes in energy use (PJ) and energy intensity (Energy per dollar of GDP); with all non-energy effects removed. The non-energy effects include economic growth, changes in economic structure, and household size.

Energy efficiency should ideally be defined as the change in net benefits per unit of energy used. The aim is to approximate this as closely as possible.

Consumer energy should be measured. The supply side should be measured as a special sector.

A 'bottom-up' approach should be used; this takes data at the process level and aggregates it to sectoral and economy wide levels. All non-energy effects are removed. Indices of the underlying energy effect (based on total energy and on energy per unit of output) should be produced for the whole economy.

Sectoral level indices should be produced in a similar manner to the economy wide figures, producing sector specific physical energy efficiency indicators. However, in some cases physical efficiency indicators are not available, and it will be necessary to use energy use per unit of value added as an indicator.

Sub-sectoral level (e.g. dairy, hotels, metals, etc) should be monitored through physical energy efficiency indicators. Specific end use processes can be monitored individually. Examples include energy per square metre of floor area in the residential and commercial sectors, energy used per tonne of production in industry, and energy used per tonne-km (or passenger-km) in transport.

A number of important issues, which lie outside this formal structure and for which precise data is not available, will require judgement-based analysis. These include:

- Health related issues
- Environmental sensitivities
- Carbon dioxide monitoring
- Supply side studies
- Renewable energy use

The final set of indices produced must be guided by the available data. By adopting an open architecture approach, this can be expanded as data and resources become available.

1. Introduction

1.1 Report Objectives and Scope

The broad aim of this report is to assist the Energy Efficiency and Conservation Authority (EECA) with its responsibility for monitoring progress against the National Energy Efficiency and Conservation Strategy (NEECS) 2001 targets.

Specific objectives for this report, as defined by the project brief, are to:

- Provide a clear and precise interpretation of energy efficiency, which is operational and quantifiable from the data available in New Zealand
- Review the literature and international experience with respect to the use and specification of economy-wide and sectoral-level energy efficiency indicators, at different levels and from different decomposition approaches
- Provide a sound and practicable approach for tracking energy efficiency in New Zealand against the NEECS targets
- Build an energy efficiency index
- Ensure the scheme can be implemented by providing information on what data is required for monitoring, from where this data can be obtained, and an assessment of the reliability of that data.

In addition to these objectives, the consultants consider it necessary to place the monitoring of energy efficiency into an overall framework. Therefore, this report will also present a conceptual framework relevant to energy efficiency monitoring.

This report focuses on monitoring progress against the energy efficiency targets set out in the draft NEECS. The draft NEECS has specified a relatively clear economy-wide target for energy efficiency improvement.

This report provides guidance on economy-wide, sectoral and sub-sectoral indicators of energy efficiency as well as an analytical approach to tracking energy efficiency changes at different scales.

This report is structured as follows: The remainder of this section describes the background and rationale for energy efficiency monitoring as part of the NEECS design. Section 2 addresses the question "what is energy efficiency?" The aim being to provide a clear, operational definition of energy efficiency. A review of other countries' energy efficiency monitoring is presented in section 3. Section 4 describes the overall conceptual framework recommended for organising energy efficiency monitoring in New Zealand. Section 5 looks in detail at the proposed approach to monitoring the 'state' of energy efficiency and recommends the construction of an energy efficiency index as part of the package for monitoring progress against the NEECS targets. Sections 6 and 7 extend the report's scope to consider indicators of driving forces and responses. Section 8 covers other related monitoring activities and section 9 presents an eight-point action plan.

1.2 EECA's Past Energy Efficiency Monitoring and Analysis Work

Since its inception, EECA has had a strong mandate for monitoring energy efficiency trends. In 1993 EECA commissioned Dr Patterson to provide guidance on the approach EECA should take to discharge its monitoring responsibilities (Patterson, 1993). Two of the more significant recommendations to emerge from the 1993 report were that EECA should:

- Conduct a range of energy efficiency monitoring activities ranging from historical analysis, to short and medium-term monitoring, to forecasting

- Pursue a statutory review of energy statistics.

EECA has implemented many of the report recommendations and has produced a number of energy-use monitoring reports. We consider EECA's publications and internal resources can form the main database to implement the proposed monitoring activity.

1.3 The Energy Efficiency and Conservation Act 2000 and the Draft NEECS Targets

The Energy Efficiency and Conservation Act 2000 (the Act) represented a watershed in New Zealand's sustainable energy policy. The Act established EECA as a Crown entity. Notably, one of the functions of the Authority is "monitoring and reviewing the state of energy efficiency, energy conservation, and the use of renewable sources of energy in New Zealand" (section 21(1)(f) of the Act). The Act also requires the preparation of *a National Energy Efficiency and Conservation Strategy* (NEECS) (section 8 of the Act). This NEECS must state, *inter alia*, "targets" to achieve the policies and objectives in the strategy.

The current Draft NEECS identifies a target of "at least 20% improvement in economy-wide energy efficiency by 2012" (Energy Efficiency and Conservation Authority, 2001, p. 5). This target is equivalent to accelerating the economy-wide energy efficiency improvement rate to 2% per annum for the next 10 years.

Quantitative targets are not clearly specified at the sectoral and sub-sectoral levels. Exceptions include quantitative targets defined for the central and local government[2] and commercial buildings'[3] sectors, and the renewable sources of energy.

[2]Reducing energy use per employee or m^2 floor area by 15% by the end of 2005

[3]The NEECS sets 15-year targets for buildings - refer to page 15 of the draft NEECS.

1.4 *Rationale for Monitoring Progress Against the NEECS Targets*

Monitoring and evaluation are essential parts of any strategy. The Draft NEECS acknowledged the need for monitoring (see page 32 of the Draft NEECS). It is good practice to establish the monitoring approach as part of the overall strategy design. Developing the system of monitoring energy efficiency in tandem with the NEECS strategy development will help to:

- Clarify target definitions
- Ensure targets are specific and measurable
- Define data needs (which can be fulfilled as part of strategy implementation)
- Add credibility to the strategy targets and the strategy in general
- Reassure the New Zealand public of the government's commitment to meeting the targets.

This report attempts to contribute to the overall NEECS development by recommending a monitoring package for tracking progress against the NEECS targets. This monitoring package incorporates two key tools in the energy analyst's toolkit; energy efficiency indicators and analytical factorisation techniques (Natural Resources Canada, 1996). However, before we proceed to propose an energy efficiency monitoring approach, it is necessary to define the terms of energy efficiency and energy conservation, as used in this report.

2. What is Energy Efficiency[4]?

Although energy efficiency has an important place in the policy agenda, little attention has been given to defining it (Patterson, 1996). This comment applies equally to the literature on energy efficiency monitoring where the meaning of energy efficiency is often not explicitly defined. For example, in the Canadian report '*Energy Efficiency Trends in Canada*' (Natural Resources Canada, 1996) the definition of energy efficiency is not clear. At times in the report there are references to energy efficiency, energy savings and energy intensity, though none of these terms are defined explicitly.

Furthermore, among those authors that *do* proffer definitions of energy efficiency, there appears to be little consensus on what energy efficiency actually is. Some authors equate energy efficiency with energy savings. For example, early work in the Netherlands describes energy efficiency as a "reduction in the growth of energy use relative to historical trends" (Farla, 2000 p. 2). On a similar tack, Schipper *et* al. define energy efficiency improvement as lower energy consumption leading to the same amount of [energy] services. In contrast, Patterson (1996) describes energy efficiency not as energy savings, but as the 'simple ratio' of useful outputs (measured in either value added or in physical terms) to energy inputs.

[4]The contract specifications for this report ask for a definition of 'energy efficiency improvements'. However, a more fundamental question is what is energy efficiency? Once this has been answered, the notion of energy efficiency improvements (or decline) can be considered.

Without an accurate definition of energy efficiency, a robust monitoring framework is not possible; you can not monitor what you can not define or measure.

The following discussion attempts to define energy efficiency for the context of the NEECS in order to provide a foundation for the recommended monitoring approach that follows.

2.1 The Theory

Efficiency *per se* is a powerful concept that embodies the notion of "fitness or power to accomplish, or success in accomplishing, the purpose intended" (Simpson & Weiner, 1989). Contemporary understanding of efficiency is based on the interpretation developed by the physical sciences. These sciences have defined a 'core' meaning of efficiency (after Jordan, 1969); a measure of useful output divided by an input.

In the case of *energy* efficiency (e_{core}), the core meaning can be defined as useful output (such as value added, or kilograms of product) per unit of energy input (Patterson, 1996). That is,

$$e_{core} = \frac{\text{useful output}}{\text{energy input}}$$

The Energy Efficiency and Conservation Act 2000 follows the structure of e_{core} and defines energy efficiency as "a change to energy use that results in an increase in net benefits per unit of energy" (section 3 of the Act). In other words, energy efficiency is defined as the level of net benefits (useful output) per unit of energy input.

$$e_{NEECS} = \frac{\text{net benefits}}{\text{energy input}}$$

In this case, the numerator is specified as net benefits. These net benefits can be linked to a diverse range of areas, including economic growth, more comfortable living and working lifestyles, energy security, health and environmental outcomes.

The advantages of this definition over others (such as those equating energy efficiency with energy savings) are that:

- It allows clarification of the differences between energy conservation and energy savings
- It is flexible and can accommodate different sectoral contexts
- It incorporates 'net benefits' which provide for a broad perspective of the services energy provides. People require energy services as opposed to energy itself (Ministry for the Environment, 2000). Benefits from energy use range from the physical product itself, to warmth or cooling, illumination, motion, mobility, materials processing, and even health benefits.
- It conforms to both the statutory definition and e_{core}.

The actual measure of the numerator and denominator in the energy efficiency ratio (e_{NEECS}) will vary depending upon the context in which the ratio is employed.

This leads Patterson (1996) to claim there is no unequivocal quantitative measure of *'energy efficiency'*. Instead one must rely on a series of *indicators* relevant to the context in order to quantify changes in energy efficiency.

Patterson (1996) suggests the indicators used to monitor changes in energy efficiency fall into four main groups:

- Thermodynamic indicators rely entirely on measurements derived from the science of thermodynamics
- Physical-thermodynamic indicators are hybrid indicators where the energy input is still measured in thermodynamic units, but the output is measured in physical units. These physical units attempt to measure the service delivery of the process – for example, in terms of tonnes of product or passenger kilometres
- Economic-thermodynamic indicators are hybrids where the service delivery (output) of the process is measured in terms of market prices. The energy input is measured in terms of conventional thermodynamic units
- Economic indicators measure changes in energy efficiency purely in terms of market values ($).

The e_{NEECS} definition can be further clarified with the use of Figure 1 below.

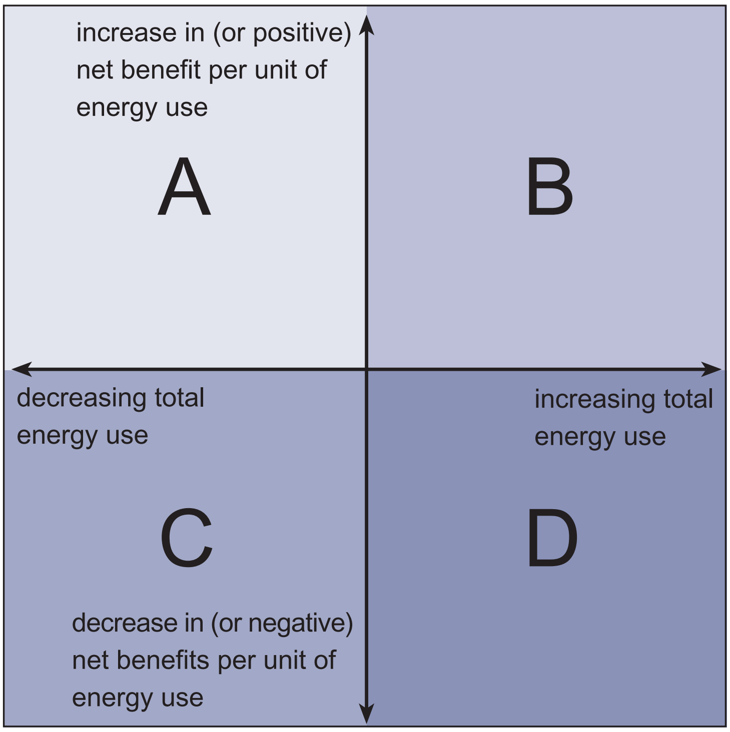

Figure 1: The four quadrants of energy efficiency and conservation

Figure 1 helps remove some of the confusion over the differences between energy efficiency, energy conservation, energy savings and the notion of energy efficiency improvement. An action or process is *energy efficient* if it delivers net benefits per unit of energy use (quadrant A or B). *Energy efficiency improvement* is also defined by quadrants A and B. That is, an energy efficiency improvement can be defined as any change in energy use that results in increased net benefits per unit of energy, whether or not total energy use increases or deceases (Energy Efficiency and Conservation Authority, 1997).

Therefore, energy efficiency improvements can be achieved in a number of ways:

- By increasing energy use while increasing net benefits per unit of energy use (quadrant B). For example, increased heating in a home to improve comfort or to reduce health problems associated with condensation
- By decreasing energy use while increasing net benefits per unit of energy use (quadrant A). For example, installing double-glazing on the south side of a house in the South Island.

Therefore, an energy efficiency improvement (as in quadrant B) does not necessarily imply *energy savings*. This makes the task of monitoring energy efficiency difficult. If energy efficiency were the same as energy savings, then all that would be required would be to estimate the amount of energy saved compared to some base year and add up energy savings across sectors. However, this does not necessarily equate to energy efficiency.

Energy conservation is an important complement to energy efficiency (EECA, 2001). Energy conservation is any action that reduces total energy use and is, therefore, defined by quadrants A and C. Energy conservation can improve energy efficiency when the energy savings lead to an increase in net benefits per unit of energy use (quadrant A). Energy conservation can sometimes reduce energy efficiency, as is the case with the proverbial "cold bath in the dark". Energy is saved, but the level of service is dramatically reduced (quadrant C) (Energy Efficiency and Conservation Authority, 1997).

In summary then, a discussion of the energy efficiency concept leads to several important conclusions:

- The definition of energy efficiency has received little attention in international literature, especially from the standpoint of energy efficiency measurement
- The preferred definition of energy efficiency is the level of net benefits (useful output) per unit of energy input
- Energy efficiency is a context-dependent concept
- Energy efficiency is not necessarily equivalent to energy savings
- There is no unequivocal quantitative measure of 'energy efficiency'. Instead, one must rely on a series of *indicators* relevant to the context (or level of sectoral disaggregation).

2.2 An Operational Definition of Energy Efficiency

EECA requires the exposition of a precise interpretation of energy efficiency that can be made operational and is quantifiable from the available data. However, there is a tension between this requirement and the theory outlined above, which suggests that there is no one unequivocal measure of energy efficiency. This tension can be addressed to a large extent using that which Natural Resources Canada (1996) refer to as two of the most useful tools in energy efficiency analysis; the energy efficiency indicators method and factorisation. During the past 20 years, a significant body of research has accumulated pertaining to energy efficiency indicators[5]. New Zealand can benefit from the results of this international work and operationalise the definition of energy efficiency (e_{NEECS}). This can be achieved defining measures of energy efficiency relevant to different levels of (sub-)sectoral disaggregation. The list of recommended energy efficiency measures at the economy-wide and (sub-)sectoral levels is given in section 5 below. This report recommends the use of the entire suite of suggested indicators for tracking energy efficiency changes in New Zealand.

[5]Much of this research was conducted in the USA (Lawrence Berkely Laboratory) (Schipper et al., 1992) and in France (Ademe, 1994).

At the economy or sectoral levels, the computation of changes in *total* energy use (as well as economic and physical energy intensity ratio trends) is informative, but does not tell the whole story. These changes also include affects that can swamp energy efficiency trends.

Underlying measures of energy efficiency can be derived from aggregate energy use and energy intensity, by factorising the effects of non-energy efficiency changes such as shifts in sectoral production (structural effect), output levels (activity), and energy mix changes (energy quality effect).

Mathematically, it can be shown that[6]:

$$\triangle \frac{Energy}{GDP} = \text{structural effect} + \text{activity effect} + (\text{technical effect} + \text{energy quality effect})$$

$$= \text{structural effect} + \text{activity effect} + \text{underlying energy efficiency effect}$$

The underlying energy efficiency effect is the closest we can get to an accurate estimate of energy efficiency improvements using available information. It is this underlying energy efficiency effect that can be used to report progress against the NEECS target. We recommend that this factorisation approach should be applied to study changes in economy-wide and sectoral energy use per value added (energy intensity), and energy use per annum.

In summary, this report recommends that:

The definition of energy efficiency is operationalised by the use of a system of concatenated energy efficiency indicators. These indicators will vary depending upon the level of sectoral disaggregation

At the macro and sectoral levels, indicators used to track progress against the NEECS target are the energy:GDP ratio and total energy use with all non-energy efficiency effects removed.

3. Review of Energy Efficiency in other Countries

The following section reviews some of the cutting-edge energy efficiency monitoring approaches being used internationally. The purpose is to identify lessons for New Zealand's energy efficiency monitoring programme.

3.1 Canada

Natural Resources Canada (NRCan) uses a similar approach to tracking energy efficiency to that which is recommended in this report. However, a significant lacuna in the Canadian's approach is the lack of attention to defining energy efficiency. For example, in the Canadian report *'Energy Efficiency Trends in Canada'* (Natural Resources Canada, 1996) the definition of energy efficiency is not clear. The report refers variously to energy efficiency, energy savings and energy intensity. Interestingly, energy intensity is defined[7], but energy efficiency is not (see the glossary in Natural Resources Canada, 1996).

[6] The factorisation of energy use is conducted along similar lines to the energy:GDP ratio.

[7] As the amount of energy use per unit of activity.

The Canadians “have adopted two of the most useful tools developed through [international] work; The indicators pyramid and the factorisation method” (Natural Resources Canada, 1996 p.4). The indicators pyramid is illustrated for the residential sector in Figure 2.

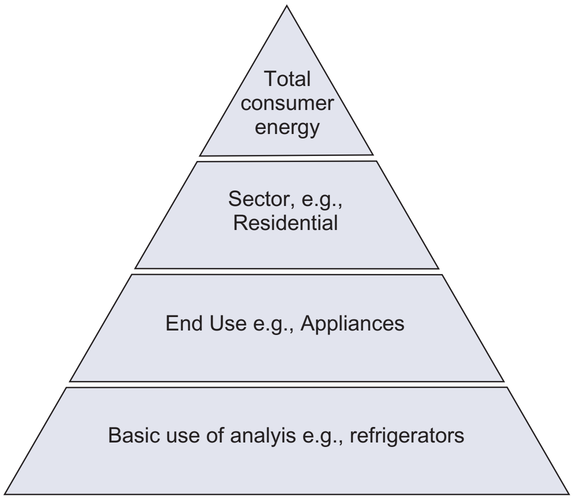

Figure 2: The indicators pyramid

The pyramid shows the differing levels of aggregation at which consumer energy can be analysed and indicators of efficiency can be developed. At the top level, one can examine total economy-wide energy use. At the sectoral level, interest shifts to residential energy use and aggregate sector-specific indicators, such as residential energy use per household. Or, one can look at the energy associated with the different categories of service being provided and examine such indicators as appliance energy use or heating energy use per household. At the most disaggreagated level, one can examine indicators related to specific pieces of equipment.

At each level of disaggregation, the Canadians isolate energy efficiency changes from other factors using factorisation.

NRCan uses the Laspeyres approach to factorise energy use (which incorporates the energy:GDP ratio[8] (Natural Resources Canada, 1996). This is because of their interest in energy savings. Their factorisation approach allows them to identify five factors; an activity effect, structure effect, weather effect, energy intensity effect and an interaction effect (or error term). The error term is a function of using the Laspeyres approach.

The Canadians report on energy efficiency for the economy as a whole, and also on six sectors: residential, commercial, industrial, passenger and freight transportation, and agriculture. The Canadian approach also treats each sector separately.

NRCan have developed an Energy Efficiency Index as a useful communication tool. The index is calculated as the sum of the sectoral technical (or in their terms the energy intensity) effects which are derived from their factorisation analysis as applied to energy use per annum. This index is a powerful tool for reporting energy efficiency at the macro level and would make a useful contribution to EECA's reporting approach.

[8]Although algebraically, the difference between factorising energy use and energy:GDP ratio is trivial.

It is also interesting to consider Canada's energy efficiency monitoring in the broader context of their work on environmental monitoring. The current Task Force on the Canadian System for the Environment (CISE)[9] is currently developing a system to provide timely access to reliable information relating to the environment (including energy). In their work they are investigating a range of conceptual frameworks to guide data collection and analysis. Two frameworks they are considering are the pressure-state-response and natural-capital frameworks.

3.2 The Netherlands

The official energy efficiency monitoring work in the Netherlands is conducted by the Netherlands Agency for Energy and the Environment (Novem[10]). Novem manages many national and international governmental programmes aimed at:

- Environmental improvement
- Increasing energy efficiency
- Introducing renewable energy sources.

It may be noted that they have had particular success in the transport sector.

Novem is responsible for monitoring progress against energy efficiency targets under the National Environmental Policy Plan (NMP). It is not clear how Novem define energy efficiency. In documentation on the NMP, the terms 'energy efficiency' and 'energy conservation' appear to be used interchangeably. For example, "the objective for energy conservation during the period 1990-2000 is to improve energy efficiency by an average of 1.6% per year"[11].

The most comprehensive attempt to define energy efficiency in the Netherlands appears to come from Farla (2000). Farla concurs with Patterson's (1996) assessment that energy efficiency is a ratio of outputs to inputs. Another interesting development to come from Farla's work is his focus on physical indicators of energy efficiency. Farla adopts a physical-based, rather than a value-added, approach to monitoring energy efficiency in the Netherlands. Physical-activity indicators are often preferred because of their close relationship with the 'specific energy consumption' (SEC)[12]. Another reason "is the fact that physical indicators may improve the comparability of energy intensity indicators between countries because they provide more information on product mix differences and other potential causes of observed differences in energy intensity" (Farla & Blok, 2000 p.610).

A particular problem often connected with Farla and Blok's approach is that summing up energy intensities to get sector or national aggregates is often difficult. This problem does not arise when value-based indicators are used. Farla and Blok (2000) provide a method for aggregating their physical-intensity indicators. This method has several operational challenges. The main difficulty relates to the data requirements; "data are needed on many products and many activities" (Farla & Blok, 2000 p.633). In particular, the specific energy consumption data for these products and activities are needed. Collecting this information is a time-consuming and costly exercise.

[9]See www.ec.gc.ca/cise/eng/Index.cfm

[10]http://www.novem.org/

[11]http://www.un.org/esa/sustdev/viaprofiles/NL_LTA.html

[12]Energy use per unit of physical product.

Farla also adopts a Laspeyres factorisation method. Using their approach, the results are affected by the choice of the base-year (p 634). This is essentially a function of the use of the Laspeyres index approach. The approach recommended in this report is based on the Divisia index method, which avoids the base-year error.

The choice of denominator, whether in value-added or physical units, depends upon the definition of energy efficiency. As noted above, a value-added denominator is consistent with the definition provided by the Act. However, this does not detract from the usefulness of physical indicator measures. Indeed, the method proposed in this report should include physical indicators.

3.3 The International Energy Agency

The International Energy Agency (IEA) has produced many international comparisons of energy efficiency (including the recent study of New Zealand). It is regarded as a centre of excellence for energy efficiency monitoring. The IEA acknowledge that there are multiple interpretations of energy efficiency.

"While energy efficiency is widely viewed as an important element of energy and environmental policy, there is little agreement on specific energy efficiency goals and the best ways to achieve them. The lack of consensus stems in part from differing views about the meaning of energy efficiency.

Energy efficiency refers to the relationship between the output (service) of a device or a system and the energy put into it. For a motor, it is expressed as the percentage of input energy converted into useful power output. For an automobile, it is often expressed in litres of fuel/100 km. This is only one of many output indicators; others include number of passengers and the weight of the cargo carried. Improved energy efficiency is doing more with equal or less energy input, e.g. more goods produced, fewer kilowatts per tonne of aluminium used, more travel, comfort, light provided"[13].

Clearly, the IEA support both Patterson's (1996) assertion that energy efficiency is a ratio of outputs to inputs, and the notion that energy efficiency is a multi-dimensional concept.

As with other countries, the IEA:

- Use a factorisation technique to break down changes in the aggregate energy:GDP ratio. In this case, the IEA use the Laspeyres index.
- Decompose the energy:GDP ratio to a fine level of sub-sectoral detail (where data allows).
- Provide rich contextual information to help interpret their results.

These are all useful lessons for New Zealand.

[13] http://www.iea.org/pubs/studies/files/danish/09-dan1.htm

3.4 The USA

The official work of monitoring energy efficiency in the USA falls to the Energy Information Administration (EIA) branch of that country's Department of Energy (DOE). The EIA state that they have taken a slow, deliberate approach toward defining energy efficiency and also to developing robust energy-efficiency indicators over several years. As a result, the EIA have developed a considerable level of expertise in the energy efficiency monitoring area. Early on in the EIA's development of their energy efficiency monitoring strategy, attempts were made to define what is actually meant by 'energy efficiency'. The EIA concluded that both the definition, and measurement, of energy efficiency are not easy tasks (Battles & Burns, 1998). "When it comes to trying to define "be energy efficient" or "energy efficiency", there does not seem to be a single commonly-accepted definition of energy efficiency"[14]. Rather, energy efficiency is clearly taken as a context-dependent concept. *"The central question in the analysis of energy efficiency may really be "efficient with respect to what?" Measurement of energy efficiency always relates to the specific policy objectives at stake"* (Battles & Burns, 1998).

The DOE note that most of what is defined as energy efficiency is actually energy intensity. This group defines energy intensity as 'the ratio of energy consumption to some measure of demand for energy services'. To illustrate, the transportation sector intensity measures could include gallons per passenger mile, or gallons per vehicle mile. Passenger mile and vehicle miles are the demand indicators in these two examples. However, the EIA note that energy-intensity measures are, at best, a rough surrogate for energy efficiency. This is because energy intensity may mask structural and behavioural changes that do not represent "true" efficiency improvements, such as a shift away from energy-intensive industries. In this context, the DOE state that the choice of intensity indicators in efficiency analysis is critical[15].

The Pacific Northwest Laboratory defines energy efficiency as:

"The amount of input energy required per unit of output energy service provided by an energy-consuming device; also, efforts or activities that aim at reducing the energy used by specific end-use devices and systems, typically without affecting the services provided. Examples include high-efficiency appliances, efficient lighting programs, high-efficiency heating, ventilating and air conditioning (HVAC) systems or control modifications, efficient building design, advanced electric motor drives, and heat recovery systems"[16].

There are two cornerstones to the EIA's approach to monitoring energy efficiency: Indicators and factorisation. The EIA is attempting to develop some type of index, or series of indices, to measure relative changes in energy efficiency. However, following from their attempt to define energy efficiency, the EIA note that measurement of energy efficiency always relates to the specific policy objectives at stake[17].

The EIA distinguish between two types of indicator approaches: the market-basket approach and the comprehensive approach. The *market basket* approach estimates energy-consumption trends for a controlled set of energy services (the market basket), with individual categories of energy services controlled relative to their share in the index. This method of indexing is a type of "bottom-up" approach. The comprehensive approach attempts to take all energy use into account. This approach initiates the measurement process with the broadest available measures of energy use and demand indicators available. Over time, changes in relative measures reflect changes in (for example) behaviour, weather, structure, and energy efficiency. The effects, unrelated to changes in energy efficiency, are then removed using factorisation. This approach can be thought of as a "top-down" approach - it is analogous to peeling away all the effects until energy efficiency is all that remains.

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[14]http://www.eia.doe.gov/emeu/efficiency/definition.htm

[15]http://www.eia.doe.gov/emeu/efficiency/definition.htm

[16]http://energytrends.pnl.gov/glose_h.htm

[17]http://www.eia.doe.gov/emeu/efficiency/measure_discussion.htm

Battles and Burns (1998) claim that measuring energy efficiency in the overall economy is more complex than in the individual sectors. Consequently, the EIA is considering two approaches to the development of aggregate national indicators. The first approach is to construct energy intensity measures using simple indicators of demand: Population and GDP. Battles and Burns (1998) claim that intensity measures constructed using these simple indicators can be useful for analysis. The USA measure energy efficiency at the economy-wide level using three core indicators: energy use per Gross Domestic Purchases, Gross Domestic Product (GDP), and population[18].

Another important component of the EIA energy efficiency monitoring is factorisation. The EIA have used both the Laspeyres and Divisia approaches to investigate changes in the energy:GDP ratio and energy consumption. The DOE do not make a claim as to the relative accuracy of the two approaches[19]. As part of the factorisation approach, the USA is also considering constructing an energy efficiency index along the lines of that employed by Canada (Battles & Burns, 1998).

The strength of the USA's analysis lies in its data collection. The large US economy allows for considerable refinement in sectoral analysis (manufacturing can be broken into 20 different industries, corresponding to the two digit Standard Industrial Classification code). It is also possible to undertake a rigorous statistical analysis of the data to measure the accuracy of the results. However, the EIA quite rightly point out that the development of energy-efficiency indictors, for any country, is limited by the availability of the data[20]. They note that data is limited for several reasons; cost, technological limitations and respondent burden. First, as the amount of data collected increases, so does the cost of collecting, processing, and analysing the data. The configuration of certain technologies and processes can also limit the possibility of obtaining micro-data. Finally, another reason data is limited, is the fact that some of this cannot be gathered because it imposes significant respondent burden.

It also appears that the USA typically uses a Pressure-State-Response conceptual framework for organising environmental-related information – including energy. The "Pressure-State-Response" approach has been adopted by the Environmental Protection Agency's (EPA) National Goals Project, the Interagency Sustainable Development Indicators Workgroup, and the Region five State Watershed Indicators Development Workgroup. Specific examples of its application include the environmental indicators work in the US-Mexico border area[21] and Lake Michigan[22]. The USEPA state that they hope the use of the PSR framework will promote consistency in the development and application of environmental indicators, resulting in regional goals that are consistent with EPA's 12 national goals".

3.5 Australia

It is also important to consider Australia's work in monitoring energy efficiency because of its proximity to New Zealand and the possibility of establishing useful collaborative links in this area.

Like most countries, energy efficiency policy is being driven by the climate-change debate. In this regard, EECA should maintain strong links with the AGO (Australia Greenhouse Office) – in particular the AGO's Analysis and Projections Team.

ABARE (the Australian Bureau of Agricultural and Resource Economics) have conducted some pioneering work (Bowen, Ho Trieu & Wilson, 1993) on decomposing the energy:GDP ratio. In particular, these authors applied

[18] http://www.eia.doe.gov/emeu/efficiency/

[19] http://www.eia.doe.gov/emeu/efficiency/measure_discussion.htm

[20] http://www.eia.doe.gov/emeu/efficiency/measure_discussion.htm

[21] www.epa.gov/oia/sielen.htm

[22] www.epa.gov/lakemich/Imlamp2000/

the Divisia technique and included an interfuel substitution effect. ABARE also produce authoritative reports on Australia's energy situation (see http://www.abareconomics.com/PUBCAT/energy.htm).

A strong point of the Australian energy efficiency-reporting framework is their biennial fuel and electricity survey conducted by the Australian Bureau of Statistics. This survey was mentioned in New Zealand's review of energy statistics and 1996. This survey provides a useful model for data collection at the sub-sectoral level in manufacturing in New Zealand.

Also, from a broader, environmental perspective, Australia follows the trends established in other countries and bases its 'state of the environment' reporting on the Pressure State Response framework (see www.epa.nsw.gov.au/soe/97/intro/4.htm).

3.6 Lessons from International Studies

From the review of international energy efficiency monitoring programmes, several important observations can be made. There are a number of common features in all the state of the art programmes. In particular they:

- Use both the indicators pyramid and a factorisation approach in tandem
- Use a conceptual framework for guiding indicator selection and reporting
- Conduct factorisation on either the energy:GDP ratio or total consumer energy use. The difference is methodologically trivial.
- Currently use the Laspeyres index decomposition approach. However, it is generally recognised that the Divisia approach is methodologically superior. Furthermore, recent analyses are beginning to use the Divisia approach (for example Murtishaw & Schipper, forthcoming).
- Decompose the energy:GDP ratio to a fine level of sub-sectoral detail (where the data allows). The minimum breakdown provided is at to least the six-sector level.
- Energy end-use data availability is important for energy efficiency monitoring.

4. A Conceptual Framework for Monitoring

A common theme emerging from the international review is that is the requirement to identify the driving forces behind changes in energy efficiency, and that a conceptual framework is necessary to organise the different indicators relevant to energy efficiency.

4.1 The Need for a Conceptual Framework

In addition to organising indicator sets in a coherent manner, indicator frameworks have several other uses. In particular, they:

- Are useful communication tools for decision makers, summarising key information
- Suggest logical groupings for related sets of information. This helps promoting integration
- Can help identify important issues for which adequate information is lacking, thus identify data collection needs
- Can help spread reporting burdens, by structuring the information collection, analysis and reporting across many areas and departments (United Nations Environment Program, 1995).

Different analytical frameworks have been used to identify, develop and communicate indicators[23]. A framework which is rapidly gaining in international prominence for use with issues with an anthropocentric focus (such as energy efficiency), is the 'Driving Forces-State-Response' framework, derived from the 'Stress-Response' framework, as applied to ecosystems (Friend & Rapport, 1979). The United Nations (1995) replaced the concept of 'stress' with that of 'driving forces' in an attempt to accommodate more accurately the addition of social, economic and institutional indicators when considering issues such as sustainable development with a clear anthropocentric focus. The DSR model provides a simple yet effective way to think about indicators by asking three important questions:

- What are the driving forces on energy efficiency?
- What is the state of energy efficiency?
- What is being done about these issues?

The DSR framework is also relatively easy to use and understand. However, it does have limitations. In particular, it is prone to oversimplification of the complex dynamics of the energy system. It also tends to suggest causal relationships where none may actually exist. Despite these limitations, the framework is used extensively as a way of selecting and reporting indicators.

This framework can be applied to energy efficiency. In this context:

- Driving forces' indicators represent human activities, processes and patterns that have an impact on energy efficiency. These indicators provide an indication of the causes of positive and/or negative changes in the state of energy efficiency (Mortensen, 1997 p.47). Driving forces can relate to developments at the company level or in economic sectors, and in social trends.

[23]These include 'media', ecological threshold, natural capital, stress-response, pressure-state-response and policy performance frameworks.

- State indicators measure the level of energy efficiency at a particular point in time. The energy:GDP ratio is an example of a state indicator (Mortensen 1997).

- Response indicators indicate policy options and other (societal) responses to the changes in the state of energy efficiency. Some of these responses to changes in the state of energy efficiency may be legislation, regulation, economic instruments, information activities etc.

Derivatives of this framework have been applied in many areas, including energy indicators as part of the Ministry for the Environment's Environmental Performance Indicators Programme (Natural Resources Canada, 2000).

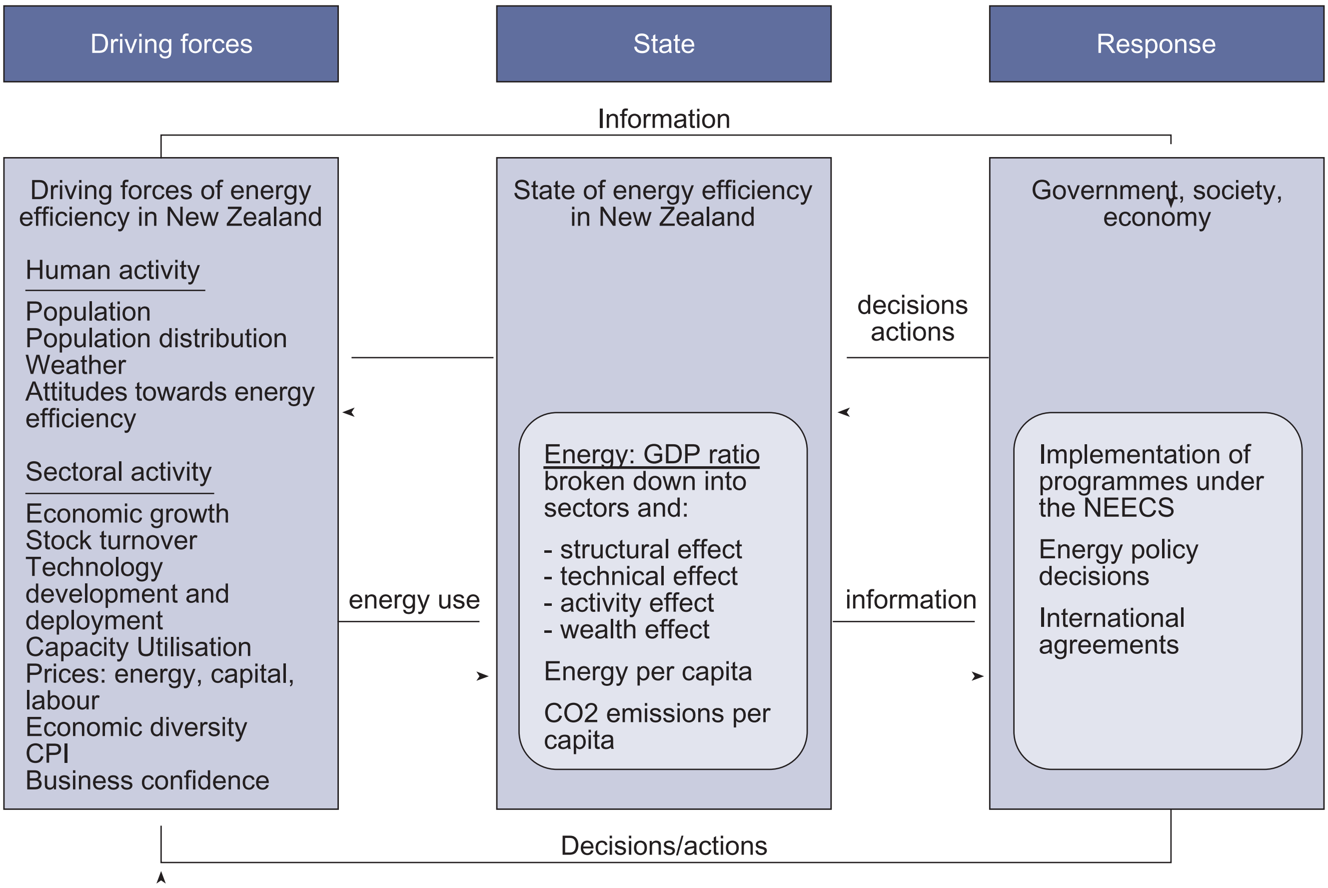
This report recommends that:

EECA adopt the Driving forces-State-Response framework as an essential component of the NEECS monitoring strategy.

The imperative to monitor progress against NEECS targets requires a focus on the 'state' of energy efficiency in New Zealand. However, for a rich picture of energy efficiency in New Zealand, EECA must monitor 'driving forces' and 'responses' as well. These will assist with answering the question of "why" energy efficiency changed as it did.

4.2 A Conceptual Framework for New Zealand

The following diagram summarises the recommended conceptual framework for monitoring energy efficiency.



4.3 What is an Indicator?

The DSR framework and the indicators pyramid to follow build on the concept of an 'indicator'. Gallopín (1997) defines indicators as "variables that summarise or otherwise simplify relevant information, make visible or perceptible phenomena of interest, and quantify, measure, and communicate relevant information". Another useful definition of an indicator is provided by the Ministry for the Environment (2000) "a quantitative measure … against which some form of policy performance can be measured".

Selection of indicators of energy efficiency is an important part of the energy efficiency monitoring process. Following Patterson (1993), Gallopín (1997) and Mortensen (1997), the following criteria should be considered when selecting any set of indicators:

- *Clarity of message* – the audience should understand what the indicator is attempting to convey. The indicator should also be able to convey the maximum amount of information about a theoretical concept as possible
- *Scientific basis and appropriate data transformations* – the theoretical basis of the indicator must be made explicit, and possible theoretical shortcomings minimised and acknowledged. Also, raw data is often not a good indicator, as indicators nearly always need to be expressed as ratios, indices, percentages etc.
- *Timeliness* – indicators must be made available to the potential target group as soon as possible after the event
- *Data availability and cost* – the data must be readily available and at reasonable cost.
- *Policy relevance* – the indicator should be relevant to the policy objectives.

These criteria can be used to assess the quality of the indicators outlined in the next section.

4.4 Indicators of Aggregated Activities

An important methodological issue that arises when dealing with energy efficiency indicators is the issue of aggregation. This concerns the calculation of indices of energy efficiency for sectors, and the economy as a whole built up from individual activities. Because energy efficiency is measured in different units in different sectors, it is not possible to simply add the indicators together to arrive at a single indicator.

The problem of aggregation can be overcome in several ways – all of which involve some form of weighting on sectoral energy efficiency indicators. The most common form of aggregation is using a factorisation approach such as Divisia or Laspeyres to derive an economy-wide energy efficiency index. Beside the aggregation of indices to larger economic groupings, the main purpose is to allow separation of the true changes in the underlying energy efficiency from changes in energy use that come about from changes in economic structure.

Using the analytical techniques described in Appendix 1, is possible to separate changes in energy use into the following *effects:*

- A *structural effect*, indicating the effect on energy (or the energy:GDP ratio) of a changing economic structure. This effect measures the change due to the change in relative size of energy intensive sectors. For example, an increase in the proportion of GDP derived from an energy intensive sector would cause an increase in the structural effect.

- An *activity effect*, representing the effect of changes in the level of activity in that sector (measured in different units per unit of value added depending on the sector; for example, population/$ for the residential sector, tonnes/$ for the industrial sectors, tonne-km/$ for the freight transport sector etc). Significant changes in the value of products can result from changes in prices (particularly for exports). This effect needs to be separated from the underlying energy efficiency effect.

- An *underlying energy efficiency effect*, representing changes due to the efficiency of the energy-use process at the sub-sectoral level. More specifically, this effect reflects the contribution of changing energy efficiency of machinery through the replacement of old technology and retrofitting existing technology. This effect also accounts for energy efficiency changes as a result of energy management, and the effect that represents true changes in energy efficiency. **This is the effect that is the primary measure of progress in energy efficiency.**

- A *wealth effect* representing changes in GDP. This represents changes in energy use directly related to GDP growth. (If the economic structure remained static, energy use would grow at the same rate as GDP). Note that if energy per capita remains constant at a time when GDP per capita is increasing, this will show up as a reducing energy:GDP ratio in the residential sector. Improved standards of living (approximated by increased GDP per capita) that do not change energy use will be picked up in this effect.

The activity effect can be separated out at the sectoral and sub-sectoral level, whereas the structural effect relates to how the economy is changing. The ability to separate these effects in practice will depend on the available data. Beside energy data, (down to the process level where available), economic data provides the backbone for this work. In effect, it provides a weighting for the various energy-consuming activities for use in the aggregation process.

The technical details for carrying out the aggregation process, and the separation of the various effects, are discussed in appendix 1.

5. Monitoring the State of Energy Efficiency in New Zealand

Following the DSR framework outlined above, this section will present a range of indicators recommended for measuring the state, or level, of energy efficiency at the economy-wide, sectoral, sub-sectoral and individual process levels. These indicators will be further organised using the indicators pyramid mentioned above in section 3.1.

The data requirements for the energy efficiency indicator method are highly demanding (Natural Resources Canada, 1996). In order to pursue this approach, and to further the understanding of energy use at greater levels of detail, an established process for the collection of these data is essential. Unfortunately, such a process is limited in New Zealand at present. As a result, it is not always possible to monitor energy efficiency at a fine level of disaggregation for all sectors due to data limitations. This is particularly the case in the commercial and industrial sectors. The issue of data limitations was addressed in the Energy Statistics Review of 1996 (Statistics New Zealand, 1996). Unfortunately, many of the recommendations made in the review report have not been implemented. As will be discussed below, it is essential that the recommendations from this review be implemented.

Attention must be given to implementing the recommendations of the Energy Statistics Review (1996).

The indicators recommended below are a mix of physical-thermodynamic and economic-thermodynamic indicators.

They were selected on the basis of their performance against the criteria set out in section 4.3. Each indicator is assessed against the criteria on a scale of 5 stars (excellent) to zero stars (inappropriate). The list of indicators proposed is not exhaustive. EECA may wish to monitor other energy efficiency indicators in addition to those proposed.

5.1 Economy-Wide Indicators

The following indicators are recommended for monitoring energy efficiency at the economy-wide level.

(1) Total consumer energy/total primary energy ratio

(2) Underlying energy efficiency – Consumer energy used, or the Energy to GDP ratio, with non-energy efficiency effects removed in each case. (Note that these are equivalent.) This can be expressed as an index.

(3) Renewable energy use trends (PJ/annum). This would be a primary indicator of progress toward a target for renewable energy.

The energy:GDP ratio, although not recommended as an indicator, is commonly used elsewhere. It may be of value, especially when comparisons are made with other countries. It does, however, require very careful interpretation.

These indicators can be used at the sectoral or at the economy-wide level. They are briefly described as follows

5.1.1 Ratio of primary energy to consumer energy per annum

The primary energy to consumer energy ratio, and its split into fuel type ratios, provides an insight into the major trends in energy transformation and the amount of fuel used for non-energy purposes (e.g. the production of methanol from natural gas).

This indicator measures changes over time in energy losses due to conversion, transmission and distribution. It is a basic measure of the efficiency of the energy system (Ministry for the Environment, 2000). An increase in the indicator shows that the efficiency of transmission and distribution is increasing, which means more primary energy is available as consumer energy.

Clarity of message	★★★★	Very clear, conveys useful information about the efficiency of the energy supply system as a whole
Scientific basis for appropriate data transformations	★★★★	Provides a clear representation of the efficiency of the energy supply system
Timeliness	★★★	There is generally a six month time delay for data necessary for calculation this indicator
Data availability and cost	★★★★★	This data is already reported by the Ministry of Economic Development
Policy relevance	★★★★★	The efficiency of the energy supply system is of direct relevance to the NEECS

5.1.2 Renewable energy use trends (PJ/annum)

Renewable energy sources are energy sources that can be tapped at a rate that allows them to be replenished through natural process. Therefore, this is a continuous source of energy flow. The underlying sources of most renewable energy are the sun, the action of gravity, the earth's rotational forces and internal temperature. The main energy carriers are the wind and ocean processes, the fall of water from lakes and rivers, contemporary biomass or plant materials and animal and human wastes.

It is suggested that the progress towards the renewable energy should be assessed through:

a) Renewable energy use trends (PJ/annum); and
b) Market share of consumer energy provided by renewables

These indicators are assessed in the table below:

Clarity of message	★★★★★	Very clear, conveys useful information about the level of renewable energy use in New Zealand
Scientific basis and appropriate data transformations	★★★★	Provides a clear representation of the level of renewable energy in New Zealand
Timeliness	★★★★	There is generally a six month time delay for data necessary for calculating this indicator
Data availability and cost	★★★★★	This data is already reported by the Ministry of Economic Development
Policy relevance	★★★★★	The level of renewable energy use in New Zealand is of direct relevance to the NEECS

5.1.3 Total consumer energy use by sector and energy type per annum – with all non-energy effects removed

Total consumer energy excludes energy used or lost in the process of transforming primary energy into other forms and in bringing the energy to final consumers. The removal of the non-energy efficiency effects provides an appropriate measure of efficient energy consumption. Some difficulty may be experienced in interpreting this measure (compared with total consumption), as significant manipulation of the original energy consumption data is required.

Clarity of message	★★★	May be difficult to interpret, as significant manipulation of the data is required
Scientific basis and appropriate data transformations	★★★	The generally accepted measure of energy use in an economy, although it does add energy types with different energy qualities. This is theoretically not correct
Timeliness	★★★★	There is generally a six month time delay for data necessary for this indicator
Data availability and cost	★★★★★	The energy data is reported by the Ministry of Economic development - interpretation and analysis is required
Policy relevance	★★★★★	Tracks the efficient utilisation of energy

5.1.4 Underlying energy efficiency indicator and the energy efficiency index

Underlying energy efficiency differs from the aggregate energy:GDP ratio, since it is obtained by factoring out the effect of non-energy efficiency changes (e.g. shifts in sectoral production, output levels, energy mix, etc) from the energy intensity ratios. This underlying energy efficiency indicator is a good surrogate for energy efficiency. The details of how this indicator is calculated are given in section 5.3. It is recommended that the results of this factorisation be presented using an energy efficiency index approach similar to that adopted by Canada (see section 5.4 below for a discussion of the energy efficiency index calculation). This can be expressed in energy or energy:GDP terms (these are the same since all non-energy effects have been removed). It can also be expressed as an index.

5.1.5 A comment on the energy:GDP ratio

This indicator is one measure of energy efficiency for the whole economy. In this case, the net benefits denominator is measured in dollars of value added and the numerator is total consumer energy (in Joules). Even without using the factorisation technique, the energy:GDP ratio is a headline indicator of energy efficiency, in much the same way as the CPI is used as a *headline* economic indicator, as long as the indicator is not taken as the sole indicator of energy efficiency in the aggregate (Murtishaw & Schipper, 2001). Other indicators are needed to provide a rich picture of energy efficiency in New Zealand.

The use of an economic measure of output (Lermit & Jollands, 2001) in the denominator of the energy:GDP ratio allows an aggregate, or economy-wide index to be calculated (see below). This is particularly useful for communication purposes. Despite the shortcomings of the energy:GDP ratio (discussed below), it is an internationally used indicator of ‘energy efficiency’.

The energy:GDP ratio is a pragmatic indicator. Accurate and timely GDP data is available to a fine level of sectoral breakdown. This enables annual or even six-monthly calculation of the energy:GDP ratio. This would not be possible if New Zealand adopted a physical approach to energy efficiency along the lines of Farla and Blok (2000). While Farla and Blok’s approach has many strengths, it requires access to sectoral physical production data which is not easily accessible in New Zealand. This information could be collected in the EECA-initiated sectoral surveys (see section 5.2 below).

The energy:GDP ratio has serious limitations. It suffers from all of the problems associated with the GDP statistic itself (see for example Mishan, 1984). In particular, the GDP statistic is not an adequate measure of economic welfare because it does not account for such things as:

- The value of leisure, lifestyle, health
- Quality of life
- Invisible services (such as the contribution of parents at home)
- The exploitation of natural resources
- Environmental quality
- Distribution of wealth.

Second, the energy:GDP ratio approach only measures the direct (or first order) intensities. Indirect, or 'systemic' intensities are not measured. EECA should ideally monitor both direct and indirect intensities (as recommended in "Patterson, 1996). However, this would require analysis of inter-industry tables – a task that would be costly and difficult, due to the lack of up-to-date tables.

The third limitation relates to perception of the ratio itself and the communication of results. In particular, the energy:GDP ratio has received bad press because it has the potential to be misinterpreted or used loosely as a surrogate for energy efficiency. In the final analysis, it is the considered opinion of the authors of this report that the merits of the energy:GDP ratio in the context of EECA's monitoring requirements outweigh the disadvantages.

5.2 Sectoral and Sub-Sectoral Energy Efficiency Indicators

The next level of the energy efficiency indicators pyramid is sectoral disaggregation: Industrial[24], commercial[25], residential[26], transport[27] and primary production[28] sectors.

Energy efficiency improvements in the above five sectors could be monitored employing the following:

(a) Sectoral consumer energy use trends with non-energy efficiency effects removed

(b) Sectoral energy to value-added ratio trend with non-energy efficiency effects removed

(c) Energy efficiency index built through sub-sectoral bottom-up approach

(d) Sub-sectoral energy efficiency indicators.

5.2.1 Primary Sector

At the aggregate level, the lead indicator of energy efficiency of the primary sector is energy use per dollar value added for that sector, with all non energy efficiency effects removed. This indicator ranks highly against the criteria. It is cost effective (it uses data that is already collected), it is simple and easily understood, and is policy relevant.

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[24]These sectors are defined in standard industrial classification codes (see for example Statistics New Zealand, 1996). In layperson's terms the industrial sector includes food processing; textiles; wood, pulp, paper and printing; chemicals; non-metallic minerals; basic metals, electrical equipment; buildings and constructions; and other industries "not elsewhere classified".

[25]The commercial sector incudes non-manufacturing business establishments such as hotels, motels, restaurants, wholesale business, retail stores and health, social and educational institutions.

[26]The residential sector refers to dwellings, holiday homes, beach houses, etc.

[27]The transport sector includes passenger transport and freight transport, which are further split into modes.

[28]The primary production sector comprises all types of farming, hunting, forestry, loggin and fishing.

Clarity of message	★★★★	Simple and easily understood
Scientific basis and appropriate data transformations	★★★★★	It is a valid proxy for energy efficiency in the primary sector
Timeliness	★★★	There is generally a six month time delay for data for this indicator
Data availability and cost	★★★★★	Data is already collected by MED and Statistics New Zealand
Policy relevance	★★★★	It is government policy to improve energy efficiency in the primary sector

At a sub-sectoral level, energy efficiency indicators will generally take the form of energy use (by energy type where appropriate) per unit of physical product. For example, in the dairy sub-sector, energy use per litre of milk produced. Similarly, for wool producers, energy use per kilogram of wool.

Data required for the primary sector is relatively reliable at the aggregate level. Energy data is available from the Ministry of Economic Development and value added data is available from Statistics New Zealand. More detailed data on physical production and energy use at a sub-sectoral level would assist in the understanding of this sector. In particular, sectoral surveys of the dairy production and forestry sectors would be useful.

Therefore, this report recommends that:

In the primary sector, EECA monitor energy use per dollar of value added as the lead indicator

EECA continue with periodic surveys of the primary sector (ensuring that the surveys collects data on energy use and physical production by sub-sector SIC code).

5.2.2 Industrial Sector

At the aggregate level industrial sector energy use can be tracked using energy use per dollar of value added, with all non energy efficiency effects removed. Compared with the indicator criteria, this indicator ranks highly. This indicator is clearly understood, is based on valid data transformations, is cost effective (it uses data that is already collected), and is policy relevant.

Clarity of message	★★★★	Simple and easily understood
Scientific basis and appropriate data transformations	★★★★★	It is a valid proxy for energy efficiency in the industrial sector
Timeliness	★★★	There is generally a six month time delay for data for this indicator
Data availability and cost	★★★★★	Data is already collected by MED and Statistics New Zealand
Policy relevance	★★★★	It is government policy to improve energy efficiency in the industrial sector

Energy use per dollar of value added can also be used at the sub-sectoral level along with the hybrid thermodynamic-physical indicators. That is, energy use per unit of physical output.

Where available, physical quantities should be used. These can be used as 'activities'. Where this is not possible, the value added figures should be used. In particular, the basic metals category (which should be split into ferrous and non-ferrous metals) should be analysed in terms of tonnes of metal produced, with the fluctuating market prices being relegated to the activity effect. This may also be possible for wood pulp and paper, where the physical energy intensity can be measured as the energy used to produce a unit of output. This is measured in GJ/tonne for pulp and paper, and also for basic metals. Panel and timber production is measured in GJ/m^3. The remaining sub-sectors are too diffuse for this approach, and it will be necessary in this instance to employ value added analysis. If there is any energy and production data available that can be matched to values added, the activity component of further (energy intensive) sub-sectors can be removed.

While the value-added data is reliable and available to a fine level of breakdown, energy end-use and physical production data is not. This problem was highlighted in the Energy Statistics Review (Statistics New Zealand, 1996). The review recommended a biennial survey of manufacturing sectors[29] as an important part of improving energy end-use information. This recommendation has not yet been implemented.

The industrial sector should be divided into the following sub-sectors

Basic metals

- *Wood, pulp, paper*
- *Printing*
- *Building and construction*
- *Petroleum, chemicals and plastic*
- *Food processing*
- *Textiles and apparels*
- *Non-metallic minerals*
- *Other industry.*

The current breakdown of sub-sectoral energy use in industry, is dictated to a large extent by the Ministry of Economic Development's 'Energy Supply and Demand Balances'. This provides for energy use by the following sectors: Food processing, textiles, wood, pulp, paper & printing, chemicals, non-metallic minerals, basic metal products, building and construction and non-specified (including mechanical equipment). There are significant problems with this breakdown. In particular, over half of the energy considered is in the unspecified sector[30]. Also, the specific SIC classification of each sub-sector is not clear. As recommended by the energy statistics review (Statistics New Zealand, 1996), the level of sectoral disaggregation needs urgent attention.

[29]Along the line of the Fuel and Electricity Survey conducted in Australia

[30]This is often due to a need for confidentiality

In summary, this report recommends that:

For the industrial sector, EECA monitor energy use per dollar of value added as the lead indicator

EECA continue with periodic surveys of the industrial sector (ensuring that the surveys collect data on energy use and physical production by sub-sector SIC code) in order to expand the level of sectoral disaggregation possible

EECA give attention to implementing recommendations of a biennial Fuel and Electricity Survey, and on sectoral disaggregation in the 1996 Energy Statistics Review.

5.2.3 Commercial Sector

Standard energy efficiency indicators for the commercial sector include energy use per square metre and energy use per employee. Both of these indicators have been identified in the draft NEECS document.

Clarity of message	★★★★	Simple and easily understood
Scientific basis and appropriate data transformations	★★★★	It is a valid proxy for energy efficiency in the commercial sector
Timeliness	★★★	There is generally a six month time delay for data for this indicator
Data availability and cost	★★	Data availability is poor
Policy relevance	★★★★	It is government policy to improve energy efficiency in this sector

Currently, official energy statistics do not provide sub-sectoral energy use estimates. If EECA considers it necessary to disaggregate the commercial sector, one approach is HORECA[31] - health and care; education and research; offices and administration; wholesale and retail, and communications buildings.

Alternatively, energy use could be broken down into space heating, appliances, and lighting sub sectors. Obviously, sectoral surveys will play an important role in this.

Unfortunately, the service sector remains the most difficult of all to understand for any country" (Schipper, Unander, Marie-Lilliu, Walker, & Martinshaw, 2000). In particular, more detailed surveys of end-use and efficiency in the commercial sector are needed.

This report recommends that:

For the commercial sector, EECA monitor two lead indicators: energy use per floor area, and energy use per employee

EECA continue with periodic surveys of the commercial sector (ensuring that the surveys collects data on energy use and floor area by sub-sector), in order to expand the level of sectoral disaggregation possible.

The commercial sector is a widely heterogeneous sector not amenable to just one or two indicators. We propose the following indicators for the key commercial sector components:

[31]Hotels, restaurants and cafes.

Hotels, motels and hospitals

Energy use per room, GJ/room/annum

Energy use per square metre of floor area, GJ/floor area/annum

Tertiary education

Energy use per student, GJ/room/annum

Energy use per square metre of floor area, GJ/floor area/annum.

5.2.4 Transport

Transport can be conveniently split into passenger and freight. Whereas individuals have control of passenger transport, and can change their mode of transport to suit their convenience, decisions on freight transport are largely made on economic grounds.

Passenger Transport

Passenger transport comprises cars, buses, rail, ferries and domestic air modes. Note that private cars are the dominant mode of passenger travel, followed by buses and domestic air and rail.

The lack of accurate data on passenger transport (including private passenger transport) in New Zealand makes monitoring this sector difficult.

The standard measure of 'output' for this sector is passenger-kilometres (where a passenger-kilometre is the total distance each person travels by any means of (motorised) transportation. (Schipper et al., 2000) Consequently, the usual lead indicator of energy efficiency in this sector is energy use per passenger-kilometre by mode (cars, utility vehicles, vans). It is also possible to measure passenger transport energy efficiency using energy use per capita.

Clarity of message	★★★★	Simple and easily understood
Scientific basis and appropriate data transformations	★★★★	It is a valid proxy for energy efficiency in the passenger-transport sector
Timeliness	★★★	There is generally a six month time delay for data for this indicator
Data availability and cost	★★★	Data availability is poor
Policy relevance	★★★★	It is government policy to improve energy efficiency in the passenger-transport sector

This report concurs with the findings of Schipper *et al's* report on New Zealand. That is, without a careful survey of car use and fuel consumption, an accurate description of energy efficiency trends in the passenger-transport sector is impossible.

This report recommends that:

For the passenger transport sector, EECA monitor the lead indicator of energy use per passenger-kilometre by mode

EECA devote attention to improving the information available on passenger transport energy use. A careful survey of car use and fuel consumption is urgently required.

Freight Transport

Data for freight activity and energy use are relatively reliable in New Zealand (Schipper et al., 2000). The lead indicator recommends for this sector is energy use per tonne-kilometre.

Clarity of message	★★★★	Simple and easily understood
Scientific basis and appropriate data transformations	★★★★	It is a valid proxy for energy efficiency in the freight-transport sector
Timeliness	★★★	There is generally a six month time delay for data for this indicator
Data availability and cost	★★★★	Data availability is relatively good
Policy relevance	★★★★	It is government policy to improve energy efficiency in the freight-transport sector

Energy data for this sector is ideally divided into road, rail and water transport. The activity measure commonly used for freight transport is tonne-kilometre. Tonne-kilometre data is obtained by the summing up of each tonne being moved one kilometre. The IEA (Schipper et al., 2000 p.67) quite rightly acknowledge that this measure of activity is an imperfect measure. This is especially the case for tracking where volume (m^3- kilometre) or value of goods (dollars-kilometre) might better reflect activity.

For the freight transport sector, EECA monitor the lead indicator of energy use per tonne-kilometre by mode.

5.2.5 Residential Sector

Energy efficiency in this sector can be measured as residential energy use per capita and energy use per household number and energy use per floor area. These indicators are assessed in the table below:

Clarity of message	★★★★	Simple and easy to understand
Scientific basis and appropriate data transformations	★★★★	These are valid proxies for energy efficiency in the residential sector. Ideally they should be reported by energy type
Timeliness	★★★	There is generally a six month time delay for data for this indicator
Data availability and cost	★★★★	Data availability is relatively good
Policy relevance	★★★★	It is government policy to improve energy efficiency in the residential sector

With reliable data, energy use could be further broken down into space heating, water heating, cooking, lighting and appliances. Residential energy can be broken down into sub-sectors (or end uses), being space and water heating, lighting and appliances. Additionally, consumption can be adjusted for abnormal weather, (which is in effect an 'activity').

Unfortunately, accurate time series information on energy use by 'sub-sector' is not available. Initiatives such as the Household Energy Efficiency Project (HEEP) and the Energy Efficiency Resource Assessment project, are attempting to fill this gap. Ongoing funding of these projects is essential to ensure that adequate monitoring of energy efficiency to a fine level of detail in the residential sector is possible.

In summary, this report recommends that:

For the residential sector, EECA monitor several lead indicators: residential energy use per capita, residential energy use per household and residential energy use per floor area

EECA ensure ongoing funding of initiatives such as the Household Energy Efficiency Project (HEEP) and the Energy Efficiency Resource Assessment project, so as to fill the sub-sectoral information gap.

5.2.6 Summary of Data Requirements

Sectoral energy use data is available on a six-monthly basis from the Ministry of Economic Development. Other sectoral data requirements for the lead indicators presented above, along with an assessment of data availability, are summarised in the following table.

Sector	Sub-sectors	Lead indicator denominator	Data availability
Primary	Agriculture & fishing	Value added/or physical production	Data relatively reliable. Energy data is obtainable from the MED's EDF[32]. Value added data is obtainable from SNZ (INFOS Series are SNBA.S2AAAT - SNBA.S2ABCT)
	Other		
Industry	Basic metals	Value added/or tonnes	Data for this sector are limited (except for value data - INFOS series are Series is SNBA.S2ACAT to SNBA.S2ACJT plus Series is SNBA.S2ADAT and SNBA.S2AEAT).
	Pulp & paper	Value added/or tonnes	
	Food	Value added	Particular problems with this sector include a lack of detailed sub-sectoral energy use breakdown beyond two digit SIC. Serious attention must be given to sectoral surveys, as well as implementing recommendation three of the Energy Statistics Review (biennial surveys of manufacturing sectors).
	Building & construction	Value added/or floor area	
	Textiles	Value added/or square metres	
	Other	Value added	
Commercial	Administration	Value added and/or Floor area	Value-added data is reliable (available from INFOS series SNBA.S2AFAT to SNBA.S2ALBT excluding the transport component of SNBA.S2AIAT).
	Wholesale & retail	Value added	
	Other	Value added	Again, sectoral studies are needed to expand database on sub-sectoral energy use and activity measures.
Public passenger transport	Surface	Passenger-kilometres	Sectoral studies are needed to expand database information on sub-sectoral energy use and activity measures.
	Air	Passenger-kilometres	
Freight Transport	Road	Tonne-kilometre	Data is relatively reliable. Best data source is Beca Carter.
	Rail	Tonne-kilometre	
	Water	Tonne-kilometre	

[32]Ministry of Economic Development Energy Data File

Residential	Space heating	Households, Weather	Information on activity measures is available from Statistics New Zealand (for example population estimates are available quarterly from INFOS Series DPEQ.SBEC). Data on energy end use is less reliable. Emerging data sources are the HEEP and EERA.
	Water heating	Population	
	Lighting	Households	
	Appliances	Households	
	Private transport	Passenger-kilometres	

5.2.7 Non-quantifiable Energy Benefits

In many cases, changes in energy consumption can lead to benefits which cannot be readily quantified, such as in health and the environment. For example, higher comfort levels from home heating may have health benefits. This can only be examined in qualitative terms, and a certain degree of judgement will be required. It is suggested that the formal analysis be carried out using the indicators presented above, and commentary provided to explain any significant changes in underlying energy efficiency.

In all sectors, the more activity information that is available (and can be matched with the value added data), the more the activity effect can be separated out. This will allow a more accurate assessment of the *underlying energy efficiency effect*. This is especially important for the more energy intensive activities.

5.3 An Integrative Monitoring Approach – Combining Macro, Sectoral and Sub-Sectoral Energy Efficiency Analysis

The previous section outlined the use of the indicators pyramid. However, there is another string to the energy efficiency monitoring bow; and that is the factorisation (or decomposition) approach. Factorisation essentially allows the energy efficiency analyst to take a headline indicator and separate out the underlying energy efficiency effects. This approach is not new (Murtishaw & Schipper, forthcoming) and has been applied in numerous studies[33].

Factorisation is commonly applied to two headline indicators; total consumer energy and the energy:GDP ratio. This report recommends primarily applying factorisation to the energy:GDP ratio for the reasons outlined above. Applying factorisation to consumer energy essentially provides the same information (see below).

This report also recommends use of the Divisia decomposition approach rather than the Laspeyres approach. The Divisia approach is recommended for the following reasons:

- It is consistent with international best practice
- It is flexible and expandable. That is, it can accommodate an expanding decomposition structure that is limited only by the availability of the data. The approach also makes use of both physical and monetary measures of activity

[33]See for example (Ang & Zhang, 1999; Ang, 1999; Lai, Ang, & Chew, 1998; Ang, Zhang, & Choi, 1998; Ang & Choi, 1997).

- It allows an open architecture approach that enables linking bottom-up analysis with top-down indicators
- It is the most accurate decomposition method available (more so than Laspeyres) and does not incur an error term implicit in other methods (Murtishaw & Schipper, forthcoming). Therefore, it will provide the most accurate assessment of energy efficiency trends for comparison with the NEECS target
- It can be used to calculate an energy efficiency index for reporting against the NEECS target.

The remainder of this section outlines the Divisia method used in this report, provides a simple work example, and demonstrates how this can be used to track progress against the NEECS target.

5.3.1 The Divisia Decomposition Method used in this Report

The Divisia decomposition method recommended in this report is based on the ground-breaking work of Ang and Choi (1997). Application of the method to New Zealand allows for changes in the energy:GDP ratio to be factorised into two major components (level 2 in Figure 2):

- *A structural effect*, indicating the effect on the energy:GDP ratio of a changing economic structure. More specifically, the structural effect measures the change in the energy:GDP ratio due to the change in the relative size of energy intensive sectors. For example, an increase in the proportion of GDP derived from an energy intensive sector would cause an increase in the structural effect
- An *aggregate technical effect*, indicating changes caused by all other effects, such as changing activities and changes in energy use.

The aggregate technical effect can be further broken down (levels three and four) into:

- An *activity effect*, representing the effect of changes in the level of activity in that sector (measured in different units per value added, depending on the sector; for example, population/dollars for the residential sector, tonnes/dollars for the industrial sectors, tonne-kilometre/dollars for the freight transport sector etc)
- An *underlying energy efficiency effect*, representing changes due to the efficiency of the energy-use process at the sub-sectoral level. More specifically, this effect reflects the contribution of the changing energy efficiency of machinery through the replacement of old technology and retrofitting existing technology. This effect also accounts for energy efficiency changes as a result of energy management
- A *wealth effect* representing changes in GDP. This represents changes in energy use directly related to GDP growth. (If the economic structure remained static, energy use would grow at the same rate as GDP).

Note that if energy per capita remains constant at a time when GDP per capita is increasing, this will show up as a reducing energy:GDP ratio in the residential sector.

This decomposition analysis builds on the sectoral indicators presented above. The extent to which the activity effect can be separated out will be different for each sector. For sectors where physical quantities are readily available, physical production data can be used. For some sectors (discussed above), access to physical production data will not always be possible. In this case, output in value added terms, can be used.

Although the units used for sectoral activities may differ (e.g. tonne-kilometres for transport and floor area for commercial), these effects can still be added, as it is the relative change that is important.

It is important to note that the approach recommended in this report differs from earlier studies employing the Divisia framework (see Lermit & Jollands, 2001). In particular, this report does not suggest separation of energy quality effect at this stage. Theoretically, it is important to account for the differences in energy quality, and algebraically it is relatively straightforward. Though, at a pragmatic level, the data required to estimate the energy quality effect is currently of a poor quality. More work is required to improve the energy end-use data in all sectors before it can be accurately introduced into the Divisia decomposition. Excluding the energy quality effect from the analysis does not affect the accuracy of the overall results, but it does limit the ability to understand the components of the underlying energy efficiency effect. Entering the energy quality back into the analysis at a later stage will improve EECA's ability to understand the changes in the underlying energy efficiency effect.

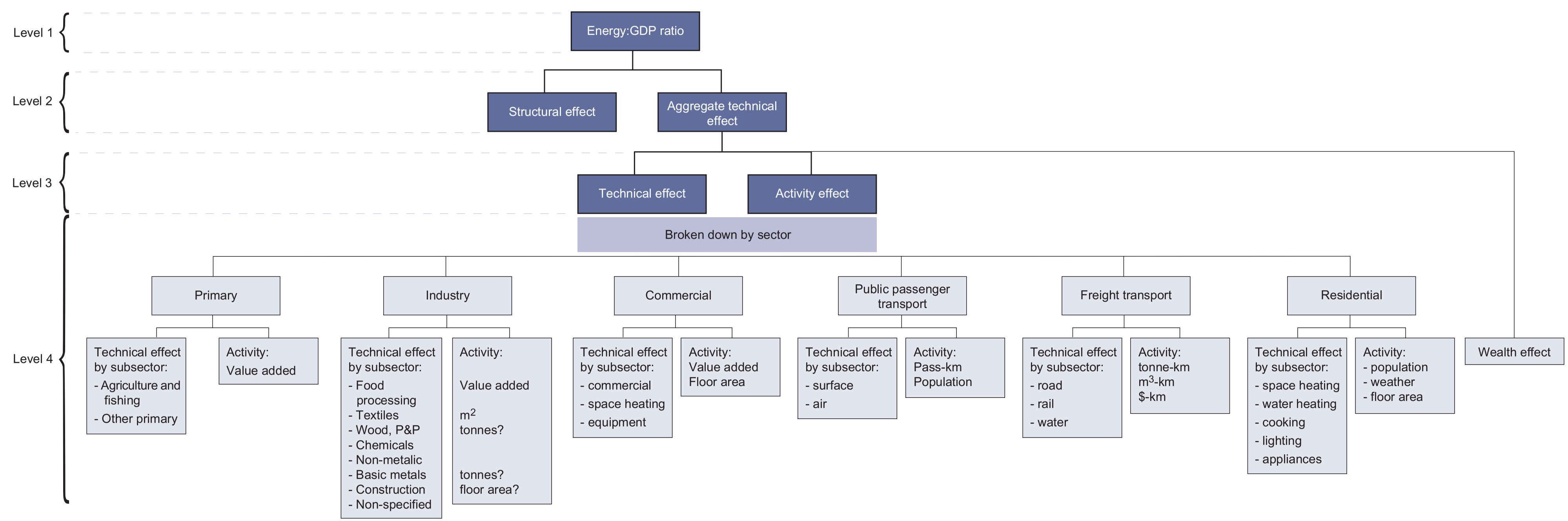
For this reason, this report recommends that EECA devote attention to improving and updating the energy end-use data in all sectors of the EECA energy use database, which is required for estimating the energy quality effect. The objective being to bring the energy quality effect back into the decomposition.

This report also expands past Divisia work in New Zealand by including the residential sector. The natural measure of activity in this sector is energy per capita, and in any case, there is no 'value added' in the sector. The Divisia framework handles this by introducing a 'household' term: 'Population per dollar of GDP', in this sector only. This leads to the *household effect.*

The actual decomposition method is described in detail in Appendix 1. The method is summarised diagrammatically in Figure 3 on the next page.

This report recommends that:

EECA adopt the Divisia decomposition method outlined in this report as the approach to measuring changes in energy efficiency against the NEECS economy-wide target.


Level 1
Level 2
Level 3
Level 4
Energy:GDP ratio
Structural effect
Aggregate technical effect
Technical effect
Activity effect
Broken down by sector
Primary
Industry
Commercial
Public passenger transport
Freight transport
Residential
Wealth effect
Technical effect by subsector: - Agriculture and fishing - Other primary
Activity: Value added
Technical effect by subsector: - Food processing - Textiles - Wood, P&P - Chemicals - Non-metalic - Basic metals - Construction - Non-specified
Activity: Value added m2 tonnes? tonnes? floor area?
Technical effect by subsector: - commercial - space heating - equipment
Activity: Value added Floor area
Technical effect by subsector: - surface - air
Activity: Pass-km Population
Technical effect by subsector: - road - rail - water
Activity: tonne-km m3-km $-km
Technical effect by subsector: - space heating - water heating - cooking - lighting - appliances
Activity: - population - weather - floor area

5.3.2 A Simple Example

The following is a simple example showing how the Divisia factorisation technique can be used to isolate changes in underlying energy efficiency. Consider a model economy, consisting of only three sectors - commercial, transport, and residential. Changes are measured between 1999 and 2000.

In order to implement this method, the following time series data is required:

- Energy use to as fine a level of sectoral breakdown as possible (preferably to energy end-use).
- Data pertaining to the activity of the sector and sub-sectors (for example, floor area for commercial, population for residential, physical production data for industrial manufacturing and tonne-kilometres for freight transport).
- GDP data by sector.

Assume total consumer energy increases by 4.5% from 600 to 627J, whereas GDP increases from $25 to $29 - a 16% increase. These numbers are represented as logarithms in the Divisia method. Therefore, these increases correspond to 0.0440 and 0.1484 respectively. The energy:GDP ratio changes by the difference between these: –0.1044.

This figure can be broken down as described:

- The population changes from 100 to 101, giving a household effect (the population:GDP ratio) of –0.0694
- The structural change is small as the economy now has a little more commercial proportion, compared with transport: -0.0022
- The remaining change (-0.0328) is broken down into the technical and activity changes. The commercial activity (floor area) changes from 5 to 7 square metres, with transport moving from 10 to 13 tonne-kilometres. Both of these changes are larger than the changes in energy use, so both sectors show a reduction in technical activity. Both are, however, larger than the corresponding value added figures, indicating and increase in activity intensity.

These can be summarised as percentage changes in the following table[34]:

	Energy:GDP	Energy
Structural change	-0.22%	-0.22%
Energy Efficient change	-9.88%	-9.88%
Activity change	0.18%	16.21%
Total change	-9.91%	4.50%

Note that the Energy Efficiency change is the same, regardless of whether changes are expressed in energy terms or as an energy:GDP ratio.

Year to year changes can also be broken down by energy consumption, rather than percentages, and split among the different industries. This gives the following table (in PJ):

[34] The calculations for this exercise are presented in Appendix 2.

	1999	2000	Change	Activity	Structure	Energy Efficiency	Interaction	Total change
Residential	300	315	15	3.0	N/A	11.8	0.2	15
Commercial	100	102	2	30.7	3.4	-30.5	-1.5	2
Transport	200	210	10	60.1	-4.6	-41.3	-4.1	10
Total	600	627	27	93.7	-1.3	-60.0	-5.4	27

5.4 Communicating Progress Against the Targets

Communication of progress against the NEECS targets is an essential part of the monitoring strategy. This report recommends that an annual report form the basis of the reporting role. The annual report would contain at least seven sections; a section summarising progress towards the economy-wide target, and six sections discussing energy efficiency trends in each of the sectors.

The *economy-wide section* of the annual report should present the macro indicators graphically. In addition, this section should summarise the results of the Divisia factorisation. Two useful formats for summarising the Divisia analysis are, graphically presenting an energy efficiency index, and presenting the results in a tabular form. Output from the Divisia factorisation approach can be used to develop energy efficiency indices for New Zealand (of energy or the energy:GDP ratio, with all non energy efficiency factors removed), which can be used to produce a graph such as Figure 4 below.

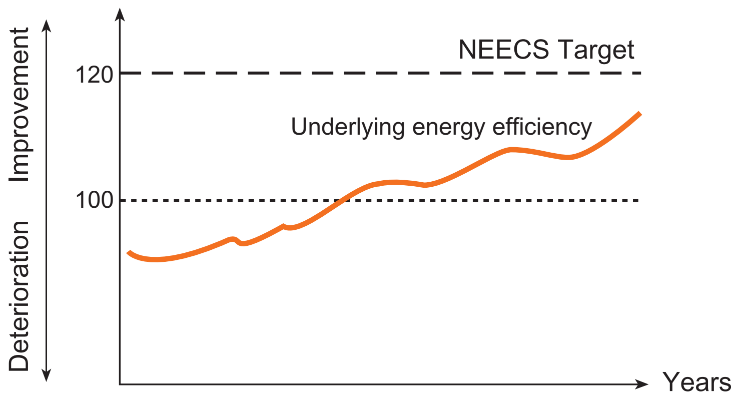


Figure 4 : An energy efficiency index

Alternatively, the results from the decomposition analysis can be reported in a tabular form similar to that used by Canada (Natural Resources Canada, 1996). In this case, this report recommends reporting in percentage terms.

Table 1: Recommended tabular format for reporting progress against target

Sector	Change in energy or energy:GDP ratio (base year to present)	Structural effect	Activity effect	Underlying energy efficiency effect	Household effect
Primary					
Industrial					
Commercial					
Transport					
- passenger					
- freight					
Residential					
TOTAL					
TARGET				20%	

Because of the lag in information availability from the data sources (principally the Ministry of Economic Development), progress will have to be reported in August of each year for the (March) year preceding it.

Other sections of the report should delve into more detail about changes in energy efficiency by sector. These sections should:

- Graphically display the lead indicator(s) for each sector
- Present the results of the sectoral decomposition analysis
- Attempt to explain the observed changes in the each sector's energy efficiency.

In addition to the annual report, it is recommended that EECA also investigate other reporting formats relevant to different audiences, such as:

- A summary report for the Minister of Energy
- Providing the information on EECA's web site
- Preparing a summary of the information for publication in EECA's Energy Wise Monitoring Quarterly
- Provision of the information to the Ministry for the Environment for the purpose of reporting on their environmental indicators web site
- Media releases describing changes in the energy efficiency index and other headline indicators.

6. Monitoring Driving Forces of Energy Efficiency in New Zealand

of energy efficiency in New Zealand, it is also necessary for EECA to attempt to understand the drivers of energy efficiency change. This section presents a set of potential driving forces indicators as part of the overall package of energy efficiency monitoring. This report recommends that:

EECA collects a minimum set of driving forces indicator data defined by Table 2.

Monitoring of these driving forces can provide EECA with an early-warning system of possible future trends in energy efficiency. For example, research conducted earlier this year for EECA identified that capacity utilisation lagged three years as a statistically significant explanatory variable for changes in energy efficiency (Lermit & Jollands, 2001).

A range of other potentially useful driving-force indicators is outlined in the table below, along with an indication of data frequency and availability.

Table 2: Driving force indicators

Driving force indicator	Frequency	Data availability
Population and population distribution	Annual	Accurate time series available from Statistics New Zealand (INFOS database series is DPEQ.SBEC)
Weather patterns	Annual	Heating degree day data
Attitudes towards energy efficiency	Ad hoc	Available on an *ad hoc* basis from EECA research
Economic growth	Annual or quarterly	Statistics New Zealand (calculated from INFOS series SNBA.S2AAAT)
Stock turnover	Annual	Statistics New Zealand (calculated from the sum of INFOS series MANA.S+23, MANA.S+43, MANA.S+33)
Technology development and deployment	Annual?	Difficult to identify a single source of data. Best to rely on key indicator technologies, such as sales figures of variable speed drives
Capacity utilisation	Annual	Statistics New Zealand (INFOS Series is BOSQ.SEUP)
Energy prices by energy	Annual	Available for Statistics New Zealand on request
Capital Goods, Price Index by sector	Annual averages	Time series available from Statistics New Zealand (INFOS database series is CEPQ.S++)
Labour cost index	Annual averages	Time series available from Statistics New Zealand (INFOS database series is LCIQ.SA51++)
Economic diversity	Annual	Calculated using method outlined by Templet (1999)
Consumer Price Index (all groups)	Quarterly	Time series available from Statistics New Zealand (INFOS database series is CPIA.SF91)
Business confidence	Quarterly	Time series available from Statistics New Zealand (INFOS database series is BOSQ.SZAN)

The actual relationship between many of these variables, and energy efficiency, is still uncertain. Therefore this report recommends that:

EECA conduct more work in order to identify which of the driving force indicators have a statistically significant relationship with energy efficiency.

7. Monitoring Energy Efficiency Response in New Zealand

Response indicators show policy options and other (societal) responses to changes in the state of energy efficiency. Three categories of response indicators that would be useful in the context of energy efficiency in New Zealand include policy, community and business-related indicators.

Policy-related indicators could include:

- Numbers of appliances etc. subject to MEPS
- Progress with building code amendments
- Levels of energy-related taxes or levies
- Transport related energy efficiency policies.

Community-related response indicators could be drawn from information contained in Energy Saver Fund applications and audits. Examples include the number of water heating wraps installed, or the kW of installed solar water heating capacity.

Industry/business-related response indicators could be drawn from Energy Wise Companies members.

- Sales of efficient appliances
- Sales of renewable energy capturing technology (solar water heaters, photovoltaics etc)
- Actual levels of insulation installed
- Share of new buildings with double glazing
- Share of new boilers at the high efficiency end of the market
- Fuel use per 100 kilometres for new cars.

8. Other Related Monitoring Activities

EECA should be aware of other related monitoring activities. There are several opportunities for cooperation and data sharing which could benefit EECA's monitoring work. In particular, relevant initiatives that could provide useful information include:

- Local government monitoring, under section 35 of the Resource Management Act (1991). Local government have a duty to gather information, monitor and keep records. Several councils have extended this role to energy and energy efficiency. Councils leading this area areEnvironment Waikato and Environment Canterbury.

- The energy indicator work of the Ministry for the Environment's Environmental Performance Indicators Programme (EPIP), and the environmental accounts development being led by the Ministry for the Environment and Statistics New Zealand. The purpose of the EPIP is to develop and use indicators to measure, and report upon how well New Zealanders are looking after the environment. The Ministry is in the process of an extensive indicator-selection programme. In conjunction with Statistics New Zealand, they are gathering a significant database on environmental issues, including energy. EECA should maintain a close relationship with the EPIP and environmental accounts work.

- The work on monitoring eco-efficiency currently underway in the business community – for example through the World Business Council for Sustainable Development (WBCSD). The WBCSD are actively promoting the use of eco-efficiency indicators to their members. One important eco-efficiency indicator is energy efficiency. EECA's monitoring work could benefit from cooperation with the WBCSD.

9. Recommendations: An Eight-Point Action Plan

This section summarises all of the recommendations made within the report. Following this, an eight-point action plan is presented.

9.1 Summary of Recommendations

9.1.1 Main Recommendations

Energy efficiency should be measured as an index of changes in energy use (PJ) and energy intensity (Energy per dollar of GDP); with all non-energy effects removed. The non-energy effects include economic growth, changes in economic structure, and household size.

Energy efficiency should ideally be defined as the change in net benefits per unit of energy used. The aim is to approximate this as closely as possible.

Consumer energy should be measured. The supply side should be measured as a special sector.

A 'bottom-up' approach should be used; this takes data at the process level and aggregates it to sectoral and economy wide levels. All non-energy effects are removed. Indices of the underlying energy effect (based on total energy and on energy per unit of output) should be produced for the whole economy.

Sectoral level indices should be produced in a similar manner to the economy wide figures, producing sector specific physical energy efficiency indicators.

Sub-sectoral level (e.g. dairy, hotels, metals, etc) should be monitored through physical energy efficiency indicators. Specific end use processes can be monitored individually.

A number of important issues, which lie outside this formal structure and for which precise data is not available, will require judgement-based analysis. These include: Health related issues, Environmental sensitivities, Carbon dioxide monitoring, Supply side studies and Renewable energy use.

The final set of indices produced must be guided by the available data. By adopting an open architecture approach, this can be expanded as data and resources become available.

9.1.2 Additional Recommendations

- The definition of energy efficiency is operationalised by the use of a system of concatenated energy efficiency indicators. These indicators will vary depending upon the level of sectoral disaggregation
- At the macro and sectoral levels, indicators used to track progress against the NEECS target are the energy:GDP ratio and total energy use with all non-energy efficiency effects removed
- EECA adopt the Driving forces-State-Response framework as an essential component of the NEECS monitoring strategy
- Attention must be given to implementing the recommendations of the Energy Statistics Review (1996)
- EECA continue with periodic surveys of the primary sector (ensuring that the surveys collects data on energy use and physical production by sub-sector SIC code)
- EECA continue with periodic surveys of the industrial sector (ensuring that the surveys collect data on energy use and physical production by sub-sector SIC code) in order to expand the level of sectoral disaggregation possible
- EECA give attention to implementing recommendation three (biennial Fuel and Electricity Survey) and the recommendation of the 1996 Energy Statistics Review regarding sectoral disaggregation
- For the commercial sector, EECA monitor two lead indicators: energy use per floor area, and energy use per employee
- EECA continue with periodic surveys of the commercial sector (ensuring that the surveys collects data on energy use and floor area by sub-sector), in order to expand the level of sectoral disaggregation possible
- For the passenger transport sector, EECA monitor the lead indicator of energy use per passenger-kilometre by mode
- EECA devote attention to improving the information available on passenger transport energy use. A careful survey of car use and fuel consumption is urgently required
- For the freight transport sector, EECA monitor the lead indicator of energy use per tonne-kilometre by mode
- For the residential sector, EECA monitor several lead indicators: residential energy use per capita, residential energy use per household and residential energy use per floor area

- EECA ensure ongoing funding of initiatives such as the Household Energy Efficiency Project (HEEP) and the Energy Efficiency Resource Assessment project, so as to fill the sub-sectoral information gap

- EECA devote attention to improving and updating the energy end-use data in all sectors of the EECA energy use database, which is required for estimating the energy quality effect. The objective being to bring the energy quality effect back into the decomposition

- EECA adopt the Divisia decomposition method outlined in this report as the approach to measuring changes in energy efficiency against the NEECS economy-wide target

- EECA collects a minimum set of driving forces indicator data defined by Table 2

- EECA conduct more work in order to identify which of the driving force indicators have a statistically significant relationship with energy efficiency

9.2 An Eight-Point Action Plan

An eight-point action plan is presented below, to assist EECA with implementing the report recommendations. The action plan can be divided into three main areas; Data collection, analysis and communication.

Data collection

1. Gather data on macro-level energy efficiency indicators. This will require collection of:

    • Annual measures of TPES and TCE by sector and energy type

    • Annual estimates of GDP by sector

2. Gather data on sectoral and sub-sectoral information. In addition to the collection of energy data mentioned above, this will require collection of:

    • Sub-sectoral energy end use data by way of detailed sectoral surveys

    • Other data set out in section 5.2

3. Gather data on driving forces and responses as outlined in sections 6 and 7

4. Implement the recommendations in the energy statistics review.

5. Analyse change in headline and lead sectoral energy efficiency indicators

6. Analyse change in energy efficiency using the Divisia decomposition model. This will require the development of a simple a software model to automate the process

7. Prepare an annual report of the changes in energy efficiency in New Zealand. This report should contain an overview/economy-wide chapter, as well as sector-specific chapters

8. Establish formal links with other energy efficiency-related monitoring work, both in New Zealand and overseas.

10. Conclusion

This report has provided a set of recommendations with the aim of assisting EECA with is responsibilities for monitoring progress against the NEECS targets. In particular, this report has:

- Provided a clear and precise interpretation of energy efficiency, which is operational and quantifiable from the data available in New Zealand
- Reviewed the literature and international experience with respect to the use and specification of economy-wide and sectoral-level energy efficiency indicators, at different levels and from different decomposition approaches
- Provided a sound and practicable approach for tracking energy efficiency in New Zealand against the NEECS targets using the indicators pyramid and factorisation
- Built an energy efficiency index
- Ensured that the scheme can be implemented by providing information on what data is required for monitoring, from where this data can be obtained, and an assessment of the reliability of that data.

In addition, this report has provided a conceptual framework within which to place the monitoring of energy efficiency. In addition to a series of detailed recommendation, an eight-point action plan is provided.

With the aid of the approaches recommended in this report, EECA will be able to accurately monitor changes in energy efficiency against the NEECS targets.

References

Ademe. (1994). *Cross Country Comparison on Energy Efficiency Indicators: Phase 1*. Paris: Agence de l'environment et de la maitrise de l'energie.

Ang, B. W. (1999). Is the energy intensity a less useful indicator than the carbon factor in the study of climate change? *Energy Policy*, *27*, 943-946.

Ang, B. W., & Choi, K. (1997). Decomposition of Aggregate Energy and Gas Emission Intensities for Industry: a Refined Divisia Index Method. *The Energy Journal*, *18*(3), 51-73.

Ang, B. W., & Zhang, F. Q. (1999). Inter-regional comparisons of energy-related CO2 emissions using the decomposition technique. *Energy, 24*, 297-305.

Ang, B. W., Zhang, F. Q., & Choi, K. (1998). Factorizing changes in energy and environmental indicators through decomposition. *Energy, 23*(6), 489-495.

Battles, S. and Burns, E. 1998. United States Energy Usage and Efficiency: Measuring Changes Over Time. ENERGY INFORMATION ADMINISTRATION, Washington, D.C.

Bowen, B., Ho Trieu, L., & Wilson, B. (1993). *Energy Efficiency Trends in Australia*. Canberra: ABARE.

Energy Efficiency and Conservation Authority (1997). *Improving New Zealand's energy use – background report* *to EECA's initiatives in energy efficiency and renewable energy*. Unpublished report.

Farla, J. (2000). *Physical Indicators of Energy Efficiency*. Utrecht: Utrecht University.

Farla, J., & Blok, K. (2000). The use of physical indicators all monitoring of energy intensity developments in the Netherlands, 1980-1995. *Energy, 25*, 609-638.

Friend, A., & Rapport, D. (1979). *Towards a comprehensive framework for environment statistics: a stress-response approach.* Ottawa: Statistics Canada.

Gallopín, G. C. (1997). Indicators and their use: information for decision-making. In: B. Moldan, & S. Billharz (eds.), *Sustainability indicators: report of the project on indicators of sustainable development* (pp. 13-27). Chichester: John Wiley.

Jordan, N. (1969). Some Thinking about 'System'. In: *Perspectives on Systems Thinking and Systems Analysis* (pp. 15-39).

Lai, Y. W., Ang, B. W., & Chew, E. P. (1998). Decomposition of aggregate defective rate in batch production. *Production Planning & Control*, *9*(3), 286-292.

Lermit, J., & Jollands, N. (2001). *Key influences on energy efficiency trends in New Zealand: decomposition of New Zealand's energy:GDP ratio 1987-2000*. Wellington: Energy Efficiency and Conservation Authority.

Ministry for the Environment. (2000). *Proposed indicators for the environmental effects of energy*. Wellington: Ministry for the Environment.

Mishan, E. J. (1984). G.N.P - measurement or mirage? *Quarterly Review*, 1-13.

Mortensen, L. F. (1997). The Driving Force-State-Response framework used by the CSD. In: B. Moldan, & S. Billharz (Eds), *Sustainability indicators: report of the project on indicators of sustainable development* (pp. 47-53). Chichester: John Wiley.

Murtishaw, S., & Schipper, L. (forthcoming). Energy saving and structural changes in the US economy: evidence from disaggregated data using decomposition techniques - draft paper submitted to Energy Policy Journal. *Energy Policy.*

Natural Resources Canada. (1996). *Energy Efficiency Trends in Canada*. Ottawa: Natural Resources Canada.

Natural Resources Canada. (2000). *Energy Efficiency Trends in Canada - 1990 to 1998*. Ottawa: Natural Resources Canada.

Patterson, M. G. (1993). *Energy Efficiency monitoring – an evaluation of possible indicators and implementation options*. Wellington: Energy Efficiency and Conservation Authority.

Patterson, M. G. (1996). What is energy efficiency? Concepts, issues and methodological issues. *Energy Policy, 24*(5), 377-390.

Schipper, L., Myers, S., Howarth, R., & Steiner, R. (1992). *Energy efficiency and human activity: past trends and future prospects*. Cambridge: Cambridge University Press.