AGO Comments on Submission #28 (Dr T. Williamson)

Summary

In his submission and presentation to the PC Inquiry, Dr Williamson questions the value of the NatHERS (and related) house energy rating tools and the usefulness of building energy efficiency regulations. This document seeks to address some of these criticisms, in particular:

- NatHERS is not intended to measure actual energy performance of a house. Rather it measures the inherent thermal performance of the building shell all other things being equal. It is therefore not surprising that there is limited correlation between NatHERS ratings and actual heating and cooling energy consumption, although this correlation rises markedly once energy performance of appliances is adjusted for.

- While there has been limited empirical testing of ratings systems in terms of assessing predicted versus actual performance (due to the very high cost of such testing), the limited available evidence supports the validity of NatHERS. The tool has also been independently assessed as a valid simulation model.

- The weakness of NatHERS in addressing natural ventilation issues was recognized some years ago, and has been addressed in the latest version of NatHERS, called AccuRate. Notably, AccuRate also addresses the large/small house issue, which was also previously identified as a weakness of NatHERS.

- Developing a building energy rating system which accounted for individual occupant behaviour, as suggested, would be theoretically challenging, intrusive and prohibitively expensive.

- Use of house energy rating systems has in fact delivered real and significant energy efficiency savings.

Having said this, any modeling tool has its imperfections. NatHERS and its predecessors have been regularly improved over time. The AGO is also developing proposals to do more physical testing of NatHERS outcomes as part of this continuous improvement process.

Introduction

The thrust of the submission is criticism of the NatHERS (and AccuRate) approach to regulating the thermal performance of building shells. The starting point is to make a claim ("rating schemes reflect actual energy reductions" – page 1), produce evidence to the contrary, and then conclude that rating schemes fail to deliver more energy efficient housing.

The question is not whether NatHERS quantifies actual energy consumption, but whether NatHERS provides households with information about the intrinsic appropriateness of the house design for the local climate. In other words, for the same family, which house will require less energy to maintain thermal comfort.

NatHERS has <u>never</u> claimed that the energy use figures calculated in the course of a rating measure actual energy use (i.e. the energy measured at the meter). A rating is a comparative figure that ranks the intrinsic thermal performance of the building shell. Much of the argument presented is based on Attachment 1 of the submission. Following a presentation at the RAIA Conference in Adelaide in November 2001 "NatHERS and Bad Building Science" along the same lines as Attachment 1, a rebuttal was written by Tony Isaacs (then an employee of SEAV, and now a private consultant), Professor John Ballinger and Adjunct Professor Alan Pears. All are highly regarded practitioners in the use of building energy rating schemes. This document is included at Attachment A.

The paper by Isaacs provides considerable detail on what NatHERS claims to do and how it works. This paper will proceed by developing an analogy between refrigerator energy modelling and rating and corresponding issues for houses. The paper will then focus on some of the NatHERS issues raised, and address the claims made against the use of NatHERS in regulation of house energy efficiency.

Refrigerator as a Simple House

A refrigerator is a simple box, the thermal performance of which can be very accurately modelled by solving equations relating to heat flow (always from a higher to a lower temperature), which depend on temperature difference, surface area and the thermal conductivity. The inverse of thermal conductivity is characterized by an R-value, the higher the R-value the better the insulator. When designing a new refrigerator, extensive modelling is much cheaper than trial and error construction.

The manufacturer knows the performance requirements defined in minimum standards and star ratings, and proceeds to combine an electric motor with a compressor unit (to remove heat from inside the box) with appropriate thermal resistance of walls and door (including door seals) so that the refrigeration performance requirements in the standard can be delivered in accordance with the energy requirements in the standard. The refrigerator works by using a temperature sensor to turn the motor on/off as appropriate to maintain a pre-set temperature band within the refrigerator.

Obviously there are trade-offs in developing an optimal business outcome for the manufacturer. A compressor motor with a high energy efficiency of turning electrical energy into mechanical energy may deliver the required outcome with less wall insulation – a good marketing result as there is greater interior space for fixed external dimensions. Both energy and refrigerator performance requirements must be met (e.g. time to pulldown to operating temperature, capacity to maintain food a specified temperature for health reasons), and in meeting energy standards refrigerator performance cannot be compromised. Thus, a refrigerator with very thick insulation (and relatively small interior volume) with a tiny motor would be very energy efficient, but would not meet performance requirements (e.g. days to cool to 4°C, hours to re-equilibrate when a litre of milk was put inside).

Having settled on a basic design which meets a standard, the modeller could explore what happens in terms of energy performance under a variety of circumstances: change external temperature, open the door for any specific length of time, open the door many times (modelling a house full of kids), place a bottle of warm beer inside (note that a refrigerator works harder to cool liquids with high specific heat than to "replace the cold air than falls out" whenever the door is opened), etc. One could define 100 different family types on the basis of the usage pattern of the refrigerator, and model the energy use and provide a star rating for each and every type. With carefully characterized usage patterns, the manufactured product could have its energy use measured against the 100 daily use patterns. Simplicity of the refrigerator means that the modelling and real measurements would be very close. The modelling calculates the actual electrical energy used by the refrigerator to deliver the required performance.

Does this happen? Of course not, we don't expect consumers to match themselves against the 100 usage patterns and select on the basis of energy efficiency accordingly. We know that within a few years their family usage pattern will have changed as kids grow or the beer-drinker goes on the wagon. Nor do consumers expect to reveal their lifestyles to anyone.

What happens is that we standardize on a conservative test procedure. The door remains shut and the refrigerator is tested under summer conditions in a room at a constant 32°C with a measurement of the energy required to fulfill the test procedure. We can then compare the intrinsic energy performance (star rating) of many refrigerators, and assure consumers that a star rating difference between two products means one will use less energy than the other, <u>all other things being equal</u>.

Energy Modelling of Houses

A house can be characterized as a vastly more complex refrigerator. The heat flow equations required to be solved are much more complex, but the physics is exactly the same. Ultimately, a house can be characterized by the average R-value of each part of the building shell (which governs the heat flow in or out depending on the temperature difference between inside and outside), and the rules which have been set in relation to temperature comfort bands within conditioned spaces and the times at which spaces are to be conditioned. The calculations for houses are further complicated by windows, which contribute to overall average R-values, but allow direct solar energy into the house, and the internal mass that regulates internal temperatures by storing and releasing heat energy at known rates.

The modelling begins by taking a particular weather file with hourly details for a whole year of temperature, solar radiation, wind, etc and calculating according to the rules built into the program whether heat must be put into the house or taken from it to maintain thermal comfort. After 8 760 such calculations the heating and cooling energy required for the whole year is summed and expressed in terms of MJ/m2 which is then turned into a NatHERS star rating according to the climate. Every calculation involves ensuring heat and air flows are consistent with the underlying physics and the rules for conditioning spaces. At the simplest level, a house could be divided into living, sleeping, and unconditioned spaces – in the revised NatHERS tool (AccuRate) up to 99 separate spaces can be modelled. The model uses rules such as temperatures less than 20°C or greater than 26°C result in heating or cooling, respectively, being provided to maintain the 20°C – 26°C comfort band at specific times of the day in different parts of the houses. The paper by Isaacs (Attachment A) provides considerable detail on the basis for the rules underpinning NatHERS.

As discussed for the refrigerator, we could identify 100 annual use patterns for each house and calculate separate energy ratings accordingly. A house, however, is likely to be occupied for 50 to 100 years and over that period every one of the 100 annual use patterns could occur. The primary purpose of a house to provide services such as shelter, comfort, safety, security, public health, privacy, etc. The number of combinations of lifestyle and utility of housing services is very large. As with refrigerators, the purpose of NatHERS star ratings is to indicate to consumers that one house will use less energy than the other, <u>all other things being equal</u>. The approach taken is to focus on the thermal performance of building fabric and good design features (e.g. winter sun in cool climates, good cross ventilation to benefit from winds in temperate and warmer climates).

Actual energy consumption is a measure of the household's behaviour for a particular period of time, and according to its unique circumstances. A rating scheme like NatHERS is a measure of the building's <u>inherent</u> design characteristics within a particular climate. To be useful for building regulatory purposes, it is important to remove the householder's influence on overall energy consumption, and focus on the characteristics of the building. The difference in approaches is tabulated below.

Comparison Tools	*Actual Energy Consumption*
Typical Meteorological Year	Variable weather patterns
Standardised behaviour logic	Constantly changing behaviour
Average thermal comfort settings	Individualised thermal comfort
Heating and cooling energy required to maintain comfort calculated without regard to appliance efficiency	Measured heating and cooling energy adjusted by appliance efficiency values that vary from e=0.1-3 and change over the life of the house

Comparisons of Modelled and Actual Energy Use – the Key Role of the Efficiency of Heating and Cooling Appliances

Some experimental work is available in Australia for verifying the performance of NatHERS against actual measurements. In contrast to a refrigerator (which can be physically tested to a high degree of accuracy in a commercial test laboratory for a few thousand dollars), the actual measurements necessary to prove the validity of NatHERS modelling for a single house would cost hundreds of thousands of dollars (to build the house with appropriate data logging and operate it according to the rules), and have not been undertaken.

A more critical question is – does NatHERS work? The energy modelling performance of NatHERS is consistent with the international BESTEST program. This is the international benchmark for energy modelling, accepted by building physicists around the world, and based on the collective effort of many thousands of man-years of research and practice.

Work to verify the capacity of computer modelling to predict temperatures within a house have been undertaken. The basis for calculating energy consumption for heating and cooling is to be able to calculate the weather induced temperature within the house and decide to turn on or off heating or cooling on the basis of a pre-determined comfort band. Prior to the development of NatHERS, its predecessor (ZSTEP) successfully (i.e. compared to actual measurements) predicted temperatures in houses in locations across Australia. (T.Williamson et al, *An Evaluation of Thermal Performance Computer Programs*, Australian Housing Research Council, Project 89, 1984)

It should be noted that the capacity to model the temperature is at the heart of programs such as NatHERS – temperature is the trigger for switching on/off the heating and cooling devices according to a predetermined comfort band and assumptions about occupancy, and other factors.

Would the heating and cooling energy used by a real house with a real family acting in the same way as NatHERS equal measured energy consumption? The answer is no, and upon this failure rests Dr Williamson's criticism of NatHERS. The claim that NatHERS should model actual (as measured at the meter) energy use is false. NatHERS calculates according to its very specific rules the amount of heating and cooling required over every hour of the year, and expresses that energy in terms of MJ/m2. The real house buys its energy from the market as measured at electricity or gas meters or at the weighbridge for firewood. The actual energy then passes through a heating or cooling appliance to deliver the heating or cooling service that is calculated by NatHERS. If, and only if, every such appliance had an efficiency e=1 (e.g. electric bar radiator) would the equivalence of calculated an actual occur. Consider a typical house with the following heating and cooling appliances with the corresponding efficiencies shown below.

	Appliance	Efficiency
Heating	Open wood fire	0.1
	Good wood heater	0.7
	Ducted gas heating	0.7
	Electric radiator	1.0
	Reverse cycle aircon	2.7
Cooling	Reverse cycle aircon	2.7

The correlation we should expect to find is between NatHERS heating and cooling energy and the actual heating and cooling energy used by each appliance divided by its respective energy efficiency.

Despite its criticism of NatHERS, Williamson's Attachment 1 appears to contain quite strong evidence in support of NatHERS modelling – the correlation of modelled heating and cooling energy consumption and actual energy adjusted for efficiency of the heating and cooling appliances is encouragingly good. In the Williamson submission (Figures 6-9) there was a focus on measurements undertaken and published on houses in Adelaide. This work is covered in detail in Williamson's Attachment 1 (*NatHERS Science and Non-Science*), and if one examines Figure 7 (measured energy after adjustment for appliance efficiency against NatHERS heating and cooling energy), and removes three obvious outliers from the data set (leaving 28 of the original data points), there is an encouragingly good correlation between properly adjusted actual and modelled energy.

We have not seen the original data, and cannot comment on the validity of the method chosen to extract the actual heating and cooling energy from the energy bills data. Given the complexity of the NatHERS modelling and the behaviour of actual inhabitants of houses and the uncertainty over accuracy of the heating and cooling energy, the correlation is good support for NatHERS. The attachment notes that: "Refinements in the occupancy patterns and other factors would no doubt reduce the unexplained behaviour and make possible a viable house energy rating scheme."

The efficiency of heating and cooling appliances is not incorporated in NatHERS for several reasons relating to added complexity for data requirements, uncertainty about appliances prior to construction, changes as wealth increases, and regular upgrading to more efficient appliances of the 50-100 year life of the dwelling.

Ultimately, for any particular house, and irrespective of occupants, house operation style and the installed heating and cooling appliances, consumers will use less energy, be responsible for less greenhouse gas emissions, and be more comfortable without space conditioning for a longer period of the year with improved thermal performance that comes from design and materials features that improve the NatHERS rating, <u>all other things being equal</u>.

Modelling the Benefits of Natural Ventilation

At the PC hearing in Melbourne on 24 November, Dr Williamson noted that current modelling software (i.e. NatHERS) does not adequately account for benefits of natural ventilation. He also suggested that ventilation was not accommodated in the software, and that assumption of airconditioning is somehow a substitute for modelling the benefits of natural ventilation.

While is it true that the weakness of NatHERS in addressing natural ventilation, particularly for tropical climates, has been recognized, that aspect is being addressed in the latest version (AccuRate). AccuRate, like all computer simulation software, is a simplified model of a hugely complex set of inter-relationships, and therefore there are inherent limitations. One major limitation of early NatHERS tools has been their inability to recognise the physiological cooling benefit due to air flow. Over the past two years the Ministerial Council on Energy has allocated significant resources to build this capacity into the AccuRate calculation engine, and to establish the system of logic that allows the cooling benefit of ventilation to be considered before the appliance derived cooling is switch on.

Testing of AccuRate has shown that house designs that enhance natural ventilation receive higher ratings than with NatHERS. A recent trial in North Queensland involving building professionals working with AccuRate on actual house designs has shown that designs with good natural ventilation are rewarded with higher ratings, with some indications that the new software may give too much credit to natural ventilation. Further trials are underway with a set of over 400 house designs to compare NatHERS, FirstRate, and AccuRate (further revised following the North Queensland and other trials).

NatHERS does model natural ventilation, and houses are not treated as airconditioned sealed boxes. Isaacs (Attachment A) has covered this issue in some detail.

- “The simulation software has also been said to not adequately take into account the benefits of ventilating houses in summer. A project is soon to be initiated to develop a new ventilation model for the simulation software.

While, in the simulations for rating, windows are opened for significant periods and this does substantially reduce cooling energy use, the modelling of ventilation by the simulation software is limited. The scheme does not provide adequate reward for those houses which have been very well designed to maximise cross ventilation, and it does not allow for the cooling effect of the internal air speed. It should be noted that few simulation programs do.

There have also been some who have stated that the simulation software models a sealed air conditioned box in summer. Nothing could be further from the truth. The simulation software does assume that windows are opened to cool down the house whenever the outside temperature is below the inside temperature. Not only does it open windows, but it tests whether comfort can be maintained by opening windows opened. If the internal temperature is not below the thermostat setting it goes back to the start of the hour and calculates the energy requirements to maintain comfort. The software makes sure than no benefit that could be obtained by ventilation is lost. In Sydney one simulation showed windows were opened for over 1,500 hours in order to maintain comfort. This is far from a sealed box. Further, the thermostat temperatures used for cooling have been increased to 2 or 3 degrees above the usual air conditioner thermostat settings to allow for the fact that people will turn on fans, ventilate, put on light clothes etc.

> before turning on the air conditioner. The ventilation routines do need to be improved. They are not, as some have suggested, virtually absent."

It is important to understand that NatHERS and AccuRate do not require airconditioning to be installed in houses. Both heating and airconditioning energy are indicators of comfort for a conservative occupancy pattern (e.g. family with young children or an elderly couple requiring comfort all day) that may be encountered over the lifetime of the house. Good design, insulation and natural ventilation are features that reduce the size and frequency of temperature excursions beyond the assumed comfort band.

Energy Consumption in Houses – Trends

Some studies on energy consumption of houses in Australia that measure actual heating and cooling energy are available. A study undertaken for the AGO in 1999 (Harrington and Foster, *Australian Residential Building Sector Greenhouse Gas Emissions 1990-2010*) outlines data available at that time. Studies were generally undertaken by vertically integrated utilities prior to deregulation of energy markets. Their focus was to develop an understanding of contributions to peak load as well as energy demand. Such information was necessary for long term planning of generation, transmission, and distribution facilities. Since deregulation, the individual agents in the deregulated market do not have the same incentive to invest in expensive studies.

As previously noted, there is no study of an individual house that collected all the data necessary to "prove" NatHERS (annual heating and cooling energy, appliance efficiency, the annual weather file, hourly temperature measures in every conditioned space, house plans, hours of operation by the occupants and other lifestyle issues). Collecting annual heating and cooling energy consumption is a non-trivial and expensive task involving monitoring and measuring only heating and cooling energy use – separating cooking and heating gas use, monitoring all power points at which heating and cooling appliances were used. . More difficult is the monitoring of occupant behaviour including the operation of the windows, curtains, external blinds and doors. The complexity of collecting energy, occupant behaviour and weather data for individual houses means that it is extremely difficult and very expensive to completely validate every aspect of NatHERS.

NatHERS is a suitable tool for energy modelling of houses for regulatory purposes. Future research with single houses (including proposed work at the University of Newcastle in conjunction with the brick industry) will inform on the validity of individual algorithms utilized by the software, and provide feedback to allow NatHERS to be improved. By focusing on the intrinsic thermal performance of building fabric, NatHERS allows appropriate samples of housing to be modelled to provide an understanding of aggregate behaviour of new houses or the whole building stock.

A study (*Impact of Minimum Energy Performance Requirements for Class 1 Buildings in Victoria*) was undertaken in 2000 for the AGO and the

Sustainable Energy Authority Victoria (SEAV) to examine the impact on the housing stock of requirements for insulation that came into force in March 1991. Statistically representative samples of building plans from 1990 (100 plans of houses built in 1990) and 1999 (240 plans of houses expected to be operational in 2000) were modelled using *FirstRate* (a member of the NatHERS family) to determine the impacts on statewide energy and greenhouse emissions over the period 1990 – 2000.

New houses in 1990 were found to average thermal performance of less than 1 Star (FirstRate), and this had increased to an average of 2.2 Stars by 2000. The pre-regulation BAU scenario incorporated common industry practice for insulation usage in developing a stock model of Victorian housing – there is no claim that insulation was not used at this point, but rather that it became mandatory. Estimates of statewide energy consumption for heating and cooling energy show a 9 percent reduction (about 8PJ) between 1990 and 2000 when the impact of regulations on the 2000 sample was compared with the 2000 sample modelled as 1990 BAU. During this period the housing stock grew by about 20 percent.

This and other studies show that for housing total energy use and heating and cooling energy use continue to grow despite more energy efficient housing designs and performance requirements. These changes are driven by strong increases in the average size of houses and wealth, the increasing array of increasingly energy efficient appliances, and life style choices. The improvements in energy efficiency of housing (reduced MJ/M2) are being overwhelmed by increases in house area (M2). These changes provide a stronger case for driving energy efficiency in houses, particularly when real wealth changes allow consumers to purchase more comfort (i.e airconditioning) with significant impacts on peak load.

A disaggregation of the 1999 National Greenhouse Gas Inventory undertaken by Wilkenfeld for the AGO indicated that space conditioning was responsible for 45 percent of total residential energy consumption of 381PJ (of which: electricity, 8%; gas, 40%; petroleum, 4%; wood, 48%) and for 18 percent of total residential greenhouse gas emissions of 62 Mt (of which: electricity, 36%; gas, 40%; petroleum, 4%; wood, 20%). Thus, the regulation of the thermal performance of houses influences the consumption of about 9 percent of total energy consumed in Australia. This data is climate sensitive across Australia, and the situation is different for each jurisdiction. Victoria dominates the use of energy for heating due to using 81 percent of national gas heater energy.

Airconditioning energy is a surprisingly small, but growing, share of total national residential energy (7.2PJ out of 381PJ, or 1.9%) and total residential electricity use (7.2PJ out of 171PJ, or 4.2%). Of Australia's total housing stock of about 7 million dwellings (unattached and attached), about 4.5 million have one or more airconditioners. With the housing stock growing by about 2 percent per year some 150,000 new houses are built each year, and currently about 900,000 airconditioners are sold each year. While some of the airconditioners must be replacement units, new homes are more likely to contain airconditioners than in the past, and the airconditioner penetration of the total housing stock is growing.

This will have a very modest impact on total energy consumption, but a huge impact on summer peak loads for electricity grids, both in terms of power availability from generation sector and capacity within the transmission and distribution networks. This is just as true in Victoria (a cold climate state in energy terms) as it is in warmer climates. In Victoria, the difference between a pleasant summer day and an extreme heat event for the entire electricity system is an increase from about 6,000MW to 8,000MW, mainly due to residential airconditioner load. The economic cost of meeting peak load is enormous, whereas the energy implications are very small.

Regulatory building energy efficiency improvements and consumer interest in best practice are both supported by energy modelling tools like NatHERS. Studies undertaken for the Victorian Government have shown that modelling identifies lower cost options to meet energy performance standards than determined-to-satisfy requirements, and that more energy efficient building shells require smaller heating and cooling appliances (i.e. lower capital cost) to maintain comfort. Taking a longer term view, energy efficiency in buildings (both new and through energy efficiency requirements for refurbishments) can contribute to future reductions in peak power demand. Such changes take time due to the low rates of addition to the stock through new dwellings and changes due to refurbishment, but coupled with ongoing progress in improvement of airconditioning appliances in the market through minimum energy performance standards, future summer peak loads can be reduced.

ATTACHMENT A

(Circulated to Commonwealth, State and Territory officials responsible for NatHERS in early 2002)

Is NatHERS bad building science?

By Tony Isaacs, Manager Building Performance, Sustainable Energy Authority of Victoria, with assistance from John Ballinger and Alan Pears.

Abstract

This paper responds to criticisms made by Williamson et al in the paper "NatHERS and bad building science". It outlines the way in which the rating scheme was developed to show that the scheme does have a rational, if untested, basis. The paper then outlines the criticisms and provides a response to these. In general, while the authors of this paper agree with the need for validation of the energy savings - which is the core of the criticisms - they do not believe the lack of this work constitutes bad science. The outcomes of using the rating scheme in terms of the effect on house design are outlined and they appear to be in general agreement with other papers by some of the authors criticising the rating scheme.

The authors of this paper contend that the outcomes described will deliver energy savings. It is suggested that the best way to debate the usefulness of the scheme is to focus on its outcomes, i.e. how does its application alter the design of houses seeking better ratings, rather than to discuss the rating methodology. It is believed that by focusing on the most appropriate outcomes the best settings for the scheme can be discovered. While it is agreed that the House Energy Rating scheme could be improved the scheme is believed to provide useful improvements to the energy efficiency of houses and it is hoped that this paper will give some confidence to users of the scheme that this is the case.

Introduction

This paper is written in response to criticisms made of the Nationwide House Energy Rating Scheme (NatHERS) by Williamson et al in a paper entitled "NatHERS and bad building science". One criticism made in the paper that can be fairly levelled is that the process of development of NatHERS has not been transparent. It is hoped that this paper will commence a process of increased transparency. Note that the acronym NatHERS refers to both a particular software based rating tool developed by CSIRO and the overall scheme and this often leads to confusion. In this paper the term NatHERS will be avoided. Where the NatHERS software is referred to this will be called the simulation software, where as the Nationwide House Energy Rating Scheme will simply be called the House Energy Rating scheme or the scheme.

Background to the House Energy Rating scheme

The process for the development of House Energy Rating scheme has not been well understood by those not involved in its development, so it is useful before responding to the criticisms of the scheme to outline how it was developed and what it is intended to achieve.

Rating of the house fabric to facilitate lower household heating and cooling energy use

The House Energy Rating scheme provides a rating of the energy efficiency of the external fabric of a house for its climatic conditions on a scale from 0 to 5 stars, where 5 stars is the most efficient. By promoting more efficient building fabric the heating and cooling loads of houses will be reduced, facilitating lower energy use. Those experienced with the scheme will understand that the application of rating tools will generally encourage the use of higher levels of insulation, smaller areas and better shading of poorly oriented single glazed windows, the use of higher performance glazing products, the use of northern windows and thermal mass, reduction of unwanted air leakage, and promote better natural ventilation of houses to keep cool in summer. In this respect its outcomes are similar to those promoted through programs and energy efficient housing guidelines since the early 1970's. And while passive solar houses still do well in the rating scheme it has also showed that there are many other ways to be energy efficient.

Calculation of performance allows trade offs

The difference between the House Energy Rating scheme and guidelines is that it provides a detailed calculation of the thermal performance of a house, allowing trade offs between different parts of the building envelope to achieve the desired rating level. This is a major advantage over guidelines and prescriptive systems which find it difficult to provide quantitative advice when site constraints make some of the guidelines or prescriptions impossible to follow. This allows users of the scheme to design an energy efficient house fabric in a way that meets the other competing design constraints of the project as well as the need for energy efficiency.

Selection of an intensive energy use occupancy pattern

A decision was taken early in the development of the scheme to calculate the heating and cooling loads of houses assuming all spaces except utility areas were heated or cooled during all waking hours. While this is not an average use pattern and will lead to a significant overestimation of energy loads for many houses, this was believed to be the best option because:

- The scheme is not intended to predict energy bills but to provide a relative ranking of one house compared to another. The actual amount of the energy load is therefore not important.
- If some parts of the house are not conditioned at some times then their performance will not affect the rating. For example, if only living areas were cooled in the rating, unbearably hot bedrooms would not affect the rating.
- Appliance ownership of cooling and central heating systems is rising and by assuming that the house is centrally heated and cooled one

ensures that its performance will be adequate should these appliances be installed at a later date.

- By maintaining comfortable conditions in most of the dwelling for most of the time, the notional cost of the energy used can act as a surrogate indicator of the value of comfort – and a conservative one at that.

House performance appropriate for climate

The House Energy Rating scheme has divided Australia into 28 climatic types. Climates were allocated by comparing the simulated energy loads of houses in around 60 locations throughout Australia and correlating these energy load predictions against climatic averages data. By establishing a relationship between this general data and climatic averages a technique was developed for allocating the thousands of locations with data on climatic averages to one of the 60 locations which have data adequate for simulation. This list of 60 locations was found to be able to reduced to 28 without too great a loss of accuracy.

The House Energy Rating scheme is really just a device to rank the performance of one house compared to the other, so climatic allocation can afford to be coarse eg. while one would expect the ranking of the energy efficiency of houses to be very different between Hobart and Darwin and these should be in different zones, one would not expect to see nearly as much difference between Canberra and Ballarat and consequently they are allocated the same zone.

Balancing performance between seasons

In most locations throughout Australian houses can experience periods where they becomes too cool as well as periods where they become too hot. The relative importance of discomfort in each season depends on the specific climate. A key element of the House Energy Rating scheme is that a five star house would logically be expected to perform well in both winter and summer in those locations which have significant summer and winter periods. In the development of the scheme much time was spent considering thermostat temperatures as these affect the balance of summer and winter performance in the rating.

It was found that in order to ensure that at least reasonable performance is obtained in each season, the energy load predictions of the simulation software would have to achieve a ratio of heating and cooling energy loads which had a much greater weighting to summer performance than the observed energy use in the community. Literally tens of thousands of simulations were performed to test the effects of various thermostat regimes on the relative importance of each season on the rating in each climate zone. Only after an exhaustive process over several months were the final thermostat settings selected.

Appliances not included in the rating

The House Energy Rating scheme does not weight the heating and cooling energy loads according to the relative efficiency of the plant used in the house. This decision was taken for a number of reasons:

- If appliance efficiencies were included in the rating then two otherwise identical houses could be given quite different ratings simply because they have different appliances. It is already difficult for the consumer to know whether a house is energy efficient simply by its appearance and this further complication was believed to be unhelpful.
- Appliances for heating and cooling have a useful life of 10 to 20 years, while a house may last over 100 years. It was felt that it would be unwise to allow the performance of the building fabric to be traded off against the performance of higher efficiency heating or cooling appliances as there is no guarantee that appliances would be replaced with equally efficient models, or even appliances using the same fuel.
- It is difficult and costly to improve the fabric of a house once it is constructed. If the performance of the fabric is allowed to be reduced because efficient appliances are used there will be little opportunity to improve the fabric at a later date. And we should keep in mind that scientists and policy analysts now suggest that developed countries will have to reduce greenhouse gas emissions by 60-80% to limit climate change to manageable levels, so it is important to ensure long-lasting infrastructure such as building envelopes are compatible with low emissions
- Appliances may not be installed at the time of construction, and in mild climates may not be installed at all. How can appliance efficiency be allowed for if the appliance is not present?
- The efficiency of appliances is promoted through star ratings and regulated by Minimum Energy Performance Standards. Star ratings have been shown to be very successful in raising the general level of performance of all appliances. These schemes have been consciously introduced to complement the House Energy Rating scheme.
- Not all appliances have a star rating, and it is difficult to obtain accurate efficiency levels for appliances not covered by rating schemes. For example, the furnace of gas central heating is rated but the air distribution system is not. A paper by Alan Pears[1] shows that a poorly designed air distribution can halve the effective efficiency of the system. In order to include central heating an estimate of the efficiency of the air distribution system would need to be developed as the effect can vary from house to house. Indeed, many heating and cooling systems would need new efficiency rating techniques to be developed.

A further complication with including appliance efficiencies is whether end-use of primary energy efficiencies should be used. Typically the electricity industry favours use of end-use efficiency, while the gas industry prefers primary energy efficiency. A resistive electric heater may be 100% efficient at end-use, but when losses from power stations and powerlines are considered, its primary energy efficiency is more like 30%.

This is not to say that appliances will not be included at a later date, or that the problems outlined above have no solution. It was simply beyond the

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[1] A. Pears, “Towards a systems approach to low cost, energy efficient design”, conference proceedings of Energy Victoria “Energy and Housing Conference and Exhibition, Melbourne, 1994

resources allocated to the development of the scheme to allow the inclusion of appliances. Most jurisdictions see any further development of the scheme to include appliances through inclusion of minimum efficiency requirements attached to a particular house rating level rather than through the alteration of the house rating according to the efficiency of the appliance.

Defining rating levels

Star bands i.e. the minimum simulated energy load needed to qualify for each star rating level, were set in all states after simulating the performance of hundreds of houses. This was done independently by each state and not through one consolidated project. Once states had interim star bands a process of harmonising star bands in shared climates was undertaken. Only Queensland has used different settings and star bands for its shared climates with NSW. In all other shared climates which cross jurisdictional borders the same house gets the same rating. Even in the unfortunate circumstances where identical houses in the same climate region are not assessed on exactly the same basis in NSW and Qld. star ratings still do not differ by much. Furthermore, star bands were derived by each jurisdiction using an agreed set of guiding principles to determine what sort of houses should be assigned to each of the rating levels. These guiding principles are shown in table 1 below.

Star rating	Generic description
5	Excellent performance, achieved at cost, to produce equivalent outcomes to the old GMI 5 star rating where this was in use
4	Very good performance, to be aimed for by most of the building industry, achieved at a reasonable cost
3	Reasonable performance, some improvement over average
2	Average house with ceiling insulation & in more severe climates wall insulation
1	Typically uninsulated house, poor performance
0	Very poor, unsuited to the climate

Table 1 Rating level principles

Note that in the above paragraphs the word greenhouse has not been used. While the House Energy Rating scheme was developed under the auspices of the National Greenhouse Response Strategy it remains primarily an energy saving scheme. The scheme was included in the strategy as energy saving without substantial shifts toward less greenhouse friendly fuel sources or lower appliance efficiencies (which are trending to greater efficiency anyway) will generally have a positive effect on greenhouse gas emissions. This assumption is, of course, one of the key criticisms made by Williamson et al in their paper.

Criticisms of the House Energy Rating Scheme

No process of dialogue can begin unless each side of the debate understands what the other is saying. To this end we shall first attempt to explain the problems Williamson et al have described in their paper.

Williamson et al spend some time quoting from the few published documents available about the scheme. They conclude, quite reasonably, that the aim of the scheme is to reduce both the energy use of Australian households for heating and cooling and the subsequent greenhouse gas emissions that result from this energy use. The paper contends, however, that this will not be the case:

> "Because the scheme does not include consideration of appliance/plant type and has built in exaggerated occupant assumptions, NatHERS (the simulation software) can not predict actual or typical household energy use (for heating and cooling), and therefore can not address explicitly energy efficiency, greenhouse gas emissions or cost. Rather the rating is intended only to demonstrate the potential of the house to have low energy requirements, taking on faith that the implied (political) objectives will follow." (p. 3)

In summary the criticisms of the NatHERS scheme made by Williamson et al as understood by the authors of this paper are as follows:

1. It does not take into account the fact that building envelope, appliance selection and occupant behaviour interact with each other and this limits the potential of the scheme to meet its objectives.
2. The star rating levels were based on arbitrary criteria.
3. The predicted energy use of the simulation software seems to have no relationship to actual household energy use and so can not reflect the design priorities of real houses.
4. Energy loads of the software are not modified by appliance efficiency and so the relative value of saving energy in each season is not properly reflected.

It should be noted that the basis for the paper to conclude that 'NatHERS is bad building science' is not because there are technical deficiencies in the CSIRO simulation software. Indeed, the paper acknowledges the verification using the BESTTEST procedure that has occurred. What constitutes bad building science, in the opinion of the authors, is that in the light of the criticisms made the assumption that a higher rating invariably leads to a lower energy use is questionable and the energy savings the scheme assumes must be verified independently if the scheme is to be credible. This is not an unreasonable conclusion and the authors of this paper would support Williamson et al in their assertion that such verification is would be of value but would differ in the conclusion that the lack of such a study constitutes bad science or a major flaw in the scheme.

Criticism 1: The NatHERS scheme does not take into account the fact that the building envelope, appliance selection and occupant behaviour interact with each other

The building fabric is not the only influence on the heating and cooling energy use of a household. The efficiency, type and tariff of appliances and the thermal comfort preferences and extent of occupancy of the house will also affect the actual energy use. Williamson et al contend that all these factors interact and are not independent. They propose that as the 'essential presumption' of the scheme is that these factors are independent, when in fact they are not, the scheme will fail to deliver its stated outcomes. In other words, if the extent of use of heating and cooling is greater in a more efficient house, or the additional cost of improving the efficiency of the house fabric leads to the use of a less greenhouse friendly appliance then the energy and greenhouse gas emission savings which might be attributed to an improved building envelope may simply fail to be realised at all.

Influence of the building fabric on appliance selection

The energy efficiency of the building fabric can and does affect selection of appliances and the extent of use of these appliances. One example of how improved building fabric may influence appliance selection is in the selection of heating appliance. If in achieving a 5 star rating one offsets the cost of improvements to the building fabric by changing from a more expensive appliance (such as gas or reverse cycle electric) to direct electric resistive heating on a day rate tariff then both greenhouse gas emissions and the cost of heating may actually be increased due to the high greenhouse intensity of direct resistive heating and the cost per kWh of day rate electricity.

If this switch to day rate electric resistive heating were to occur on a large scale it would be a serious shortcoming limiting the potential of the House Energy Rating scheme to reduce bills and greenhouse gas emissions. It is important to note that many factors are involved in appliance selection and is does not necessarily follow that just because home buyers spend more on their house that they will change to a cheaper and less greenhouse friendly heater.

While fuel shifting to day rate electric resistive heating is a potentially serious shortcoming, and there is anecdotal evidence to support that it is occurring, it appears to be happening rarely. At a recent accredited raters meeting at Sustainable Energy Authority only one out of twenty raters had ever experienced this change to day rate electric resistive heating, and then only reported one case. Indeed, the reverse seems to be occurring far more frequently.

Australia's largest builder, Henley Properties, has just upgraded all the houses they build in Victoria to five stars. The cost of the improvements has been absorbed by the builder, and they are charging no more for their houses since the change. Furthermore, they have upgraded the gas heating and hot water appliances they specify to higher star ratings. The builder's clear interest in achieving a better result for the environment and their clients has in fact lead to them using more efficient, more greenhouse friendly appliances. The House Energy Rating scheme is not applied in a vacuum. Henley Properties worked closely with the Sustainable Energy Authority of Victoria to develop a solution which extended beyond just the rating of the house fabric and looked at broader environmental considerations. The Sustainable Energy Authority routinely promotes the use of energy efficient and greenhouse friendly heating and cooling appliances. One of the often promoted advantages of a 5 star home is that you can achieve central heating comfort with just a space heater. This is a lower capital cost and low energy solution. A range of brochures are available showing the costs of heating using different appliances and their greenhouse gas emissions. These show what a poor choice it would be to change to day rate electric resistive heating in

Victoria. When the scheme is implemented in this type of environment it is far less likely that the potentially serious consequences outlined in the Williamson et al paper will occur.

Influence of the building fabric on occupant behaviour

The performance of the building fabric can also affect the extent that heating and cooling appliances are used to maintain comfortable temperatures in the house. Early field studies into the effect of insulation showed that savings attributed to insulation were found to be less in the field than would be predicted by thermal performance simulation.

One possible theory developed to explain the difference between observed and simulated energy savings is the hypothesis known as 'comfort creep'. In an uninsulated house, it is suggested that the thermal performance of the house is so poor that it is difficult to maintain reasonable levels of comfort at an affordable cost, if at all. In houses which have installed insulation it is suggested that some of the improved performance is used to improve comfort i.e. heat larger areas and/or heat to higher temperatures. Consequently the actual energy savings are significantly less than the theoretical energy savings.

It should be noted that this is not the only possible explanation, and other theories may explain this phenomenon. Indeed, these same field studies have shown that energy savings in centrally heated houses do approach those predicted by simulation software. Further, it is not clear that comfort creep would be observed in comparing houses at different efficiency ratings where both average and highly rated houses are insulated. Regardless of the explanation of the lower than expected savings in these studies, it is generally accepted that the full energy savings predicted by the simulation software are unlikely to occur on average.

That the full amount of energy savings predicted by simulation software are not the energy savings which actually occur is only important if consumers are given the mistaken impression that the software's predicted savings will occur or if these are used to justify the program at a government policy level. On both counts this is not the case. In government policy work it has become a standard practice to constrain the energy savings predicted by the simulation software to reflect the actual appliance ownership, efficiency, area heated/cooled, and hours of use[2]. In a regulatory impact statement for measures proposed to be introduced into the BCA by the ABCB the energy savings predicted by the CSIRO simulation software were reduced to, on average throughout Australia, 32% of the simulated value.

In brochures developed by Sustainable Energy Authority Victoria which communicate the extent of typical energy savings which can be achieved, the basis of these savings is always qualified by describing the user behaviour and occupancy they assume. In the business plan for Sustainable Energy

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[2] For example, Energy Efficient Strategies (1999), *Australian Residential Building Sector Greenhouse Gas Emissions 1990 – 2010*. Australian Greenhouse Office.

Authority Victoria where energy savings achieved through the implementation of the rating scheme in Victoria are estimated the energy savings assumed are well below the simulation software's predicted savings, particularly for cooling. Cooling savings are discounted by more than an order of magnitude. It would be better science to know more accurately the extent to which the energy savings predicted by the simulation software will translate to lower energy bills. In making their criticisms of the scheme, however, Williamson et al fail to take into account the way in which it is implemented which rarely sees the disastrous consequences predicted in the paper come to fruition.

Criticism 2: The star rating levels were based on arbitrary criteria

The paper also contends that the definition of the energy required to achieve the various rating levels was the result of an arbitrary process. This is a misrepresentation of the actual process, though it is understandable that people not intimately involved with the process may perceive it to be arbitrary. As described above, the star bands were set as a result of a very deliberate if drawn out and less than optimal process.

Criticism 3: The predicted energy use seems to have no relationship to actual household energy use

As explained above the House Energy Rating scheme was not designed to predict energy bills. For those involved in the scheme the disparity between actual household energy use and predicted energy use is explained with a simple illustration, eg.:

> If you heat a one star house for three hours a day, it will use less energy than a five star house heated eighteen hours per day. The intention of the scheme is that the five star house should use less energy *than it otherwise would have* given that the occupants would have heated and cooled that house in the same way regardless of the rating.

Of course Williamson et al have pointed out that appliance selection and occupant behaviour may well be different in the 5 star house compared to a 2 star version of the same house. With a 5 star house simulated to use approximately half the energy of a 2 star house, however, it would take substantial changes in user behaviour and a substantial change in appliance selection across many homes before these savings were completely forgone. But, is it a problem that the energy use predictions of the software do not match the actual energy use of households? There have been a number of decisions made in the development of the scheme that virtually guarantee that the software's predicted energy use will not match actual or even average energy use and it is contended that these decisions are soundly based. To illustrate this two of the decisions described in the "Background to the House Energy Rating Scheme" above will be examined in more detail:

The weighting of summer and winter performance

In Victoria energy use for cooling in houses represents under 1% of total household non transport energy use while heating represents 50%. One could argue that in constructing a house energy rating scheme the predicted energy use of houses should show, on average, a 50:1 weighting in favour of heating. If this is done, however, the performance of a house in summer has almost no effect on the rating at all. From a public policy point of view this is not acceptable:

- It is the aim of the rating scheme at the five star level to produce houses which will perform well all year round. In order for the rating to show any sensitivity to summer performance the extent of use of cooling must be at least an order of magnitude greater than the community average level of energy use.
- Even in a heating dominated climate like Melbourne residential air conditioner use makes a significant contribution to summer peak electrical loads. Despite its low proportion of energy use (less than 1%) the SECV estimated that in 1996 the contribution of residential air conditioners to peak loads was 9.4%[3]. Because of this contribution to peak loads the importance of air conditioning energy use in summer is far greater than its proportion of total household energy use from a societal point of view. However, if the settings in the CSIRO simulation software were based on observed user behaviour the impact of summer performance on the rating would be so diminished that it would fail to provide any improvement to the summer performance of houses at all. Indeed, unshaded west windows would prove beneficial in winter under some circumstances, but could create solar ovens in summer.
- Air conditioner ownership is growing. One simply needs to walk through a new housing subdivision and count the boxes on the roofs to see that. ABS appliance ownership data has also shown a significant growth in ownership. To base a scheme on today's appliance ownership patterns may significantly underestimate their importance in the future.

The choice of all day occupancy and whole house conditioning

Another example of soundly based decisions which cause the software to overestimate actual energy use is the decision to look at the energy requirements of the whole house, despite the fact that most houses in Australia heat only a proportion of the home, and to heat and cool from 7 am till midnight despite the fact that most household probably only condition in morning s and evenings and not during the day. To understand why this is a reasonable decision one must look at the implications of choosing more average occupancy levels on the way in which the scheme would influence building design:

- to heat only in the morning and evening would significantly diminish the value of north facing glass despite the fact that this is universally promoted as a 'good' design feature,
- if only living areas were heated the performance of bedrooms would have no impact on the rating. The poor performance of these unrated rooms may lead to use of portable day rate electric appliances which have a much greater greenhouse and cost impact than other appliances for the same amount of heat delivered,

[3] Alan Pears, quoted from 1986 SECV demand management report, projection for 1996.

- while the average user pattern may be morning and evening space conditioning as the majority of the population are at work or school during the day the number of days per year where the home may be occupied during the day (due to weekends, public holidays, annual and sick leave) is around 156 or 43% of all days,
- if a space is not conditioned at all or for part of the day then its performance in this unconditioned period does not affect the rating. Even if it will not be heated or cooled the performance of this part of the house is still important and by heating or cooling it one is simply attaching a value to the quality of performance of that part of the house at that time of day. There is also no guarantee that these unconditioned parts of the house will not be conditioned at a later date.

The House Energy Rating scheme simply provides a relative measure of the performance of a house in living areas and bedrooms during waking hours. The rating has been constructed to rank buildings in order of performance under these criteria. That these criteria may lessen the correlation between actual bills and predicted energy use by the rating is a deliberate policy decision. In the case of summer performance it is intended to slow the growth in demand for air conditioners or at the least produce lower loads if they are installed. In this way the rating seeks not to reduce an actual energy use but guard against its growth. In the case of winter performance the decision to include all areas of the house at all times of the day guards against unwanted supplemental electric heating and seeks also to minimise future loads in areas of the house which may well be heated over the life of the house.

Criticism 4: Energy loads of the software are not modified by appliance efficiency.

The last half of the Williamson et al paper presents the findings of a study which compared the actual energy use with the simulated energy use of 31 houses in Adelaide. A technique for disaggregating heating and cooling energy use from quarterly energy bills is described and is the basis for deriving the 'actual' energy use which is then compared to the simulated energy use. This technique itself is not validated, so that we do not know whether the simulated energy use is compared with actual heating and cooling energy use at all. The lack of correlation could be as much a product of the error of the disaggregation technique as a limitation of the scheme. Further, one should be careful of drawing conclusions from a limited study as a sample of 31 is far from conclusive.

Studies into the effect of the Home Energy Advisory Service in Victoria had samples of several thousand and yet still found that observed trends failed to meet tests for statistical significance. While a sample of houses with ceiling insulation had lower average energy bills, the differences were not statistically significant at the required level of confidence. When studies of thousands of homes can not detect a statistically significant difference in energy bills due to ceiling insulation, it is hardly surprising that a study of 31 houses finds no relationship between simulated and 'actual' energy use particularly when one is not sure that the actual energy use is accurate, and the model itself does not pretend to estimate actual use at all. In the USA, where appliance efficiency is part of the rating and also includes energy uses other than heating and cooling, studies have shown little relationship between the rating and actual energy use. These studies do not allow for user variability, so that it is not clear whether the energy use of higher rated houses would have been even higher had they not achieved such a high rating. The difficulty in establishing a relationship between building thermal properties and metered energy use illustrates that to conduct a similar study in Australia would require substantial resources, yet may not be conclusive at all. This is not to say that it would not be good science to do so, simply that undertaking such a study has been beyond the resources of Australian governments to date.

The paper presents the findings of the research in a series of graphs plotting modelled energy loads against total energy use, energy use per square metre, and greenhouse gas emissions and reports that no relationship was found between modelled energy loads and any of these parameters. When energy bills are plotted against NatHERS simulated energy loads and no correlation is achieved Williamson et al assume implicitly that if a house has a lower energy bill, it is more efficient. But this is like trying to find out which car is more efficient by comparing annual petrol bills without allowing for the distance each car has travelled. By not considering the actual duration, timing and thermostat settings for heating and cooling in the research the authors do not evaluate efficiency, merely consumption, and consequently no conclusion can be drawn on whether highly rated houses are more efficient or not.

The appliance efficiency scheme works in the same way. A standard test is applied to the appliance, and the energy label reports the consumption when used in accordance with this test. If the user operates the appliance differently to this standard test their energy use will be different to that shown on the label. Appliance ratings have been remarkably successful, yet if subjected to the same evaluation to that used by Williamson et al a similar finding would obtained.

In making any modification to the scheme, however, it is sensible to evaluate the implications of any change in terms of how it would affect the design advice the scheme gives. In a significant proportion of urban Australia the most greenhouse friendly appliance for heating is gas and for cooling is reverse cycle electric. The efficiency of reverse cycle cooling is over 200% while gas heating is around 70%. If the software's predicted loads were modified by appliance efficiency then the impact of summer performance on the rating would be reduced by around a factor of three. At such levels it would take quite extraordinarily poor design before summer performance had any effect on the rating.

As described above, the relative effect of summer performance has been deliberately increased with a logical, if untested, rationale. Simply applying appliance efficiency to the current loads with the aim of improving the correlation between predicted and actual energy use would have the unintended consequence of removing any effect the rating may have in reducing current or future air conditioning energy use.

There is also a reasonable argument for applying primary energy efficiency rather than appliance energy efficiency as this relates more directly to the consumption of the resource and bears a reasonable relationship to greenhouse gas emissions. However, as the primary energy efficiencies for reverse cycle cooling and gas heating are almost identical in this situation there would be almost no change to the rating where these fuel and appliance types are used and the criticised lack of correlation between predicted energy loads and monitored energy use would remain.

The implication for electric resistive heating of applying primary energy efficiency would be to de-rate houses with this form of heating by typically about 2 stars. While the authors of this paper would not mind this implication from the point of view of greenhouse gas emissions, it may be a difficult decision for government to make as it would virtually eliminate this form of heating. Such a decision would face significant resistance from industry. That does not mean such a decision would be wrong, simply that it is difficult for governments to balance economic and environmental benefits.

Judge the meal by the taste, not the recipe

Debating the settings used by the simulation tool or the need to weight energy use according to the appliance efficiency is to some extent a dry academic exercise. It is conceivable that the settings could be completely revised and yet the nature of changes to a house design required to obtain a 5 star rating may not. At the end of the day in order to reduce the energy use for heating and cooling in Australian houses the scheme will need to influence the design of houses to encourage them to change in the following ways:

- Reduce heat loss in winter,
- Increase heat gain through windows in winter,
- Reduce heat gains in summer, and
- Encourage increased heat losses through ventilation in summer.

Depending on the severity of summer and winter for the location the relative importance of these factors in the rating will vary. By and large the application of the rating scheme does improve all these four fundamental parameters. Whether it has got the right weighting of each for specific climate conditions is something which a comprehensive study comparing energy ratings and energy use, such as that suggested by Williamson et al, would be particularly valuable in helping to resolve. In looking at how the rating has influenced the design of houses in the field, however, it is difficult to see how a ‘better’ rating scheme would produce different results. For example, in upgrading their houses to 5 stars Energy Smart Builders in Victoria have generally modified their houses in the following way:

- Higher levels of wall and ceiling insulation,
- Use of weather-strips and other techniques to reduce air leakage in winter,
- Use of improved aluminium window frames to reduce heat loss,
- Some reductions in window area (for houses which are standard plans and not designed for the site a reduction in general window area guards against the impact of poor orientation),
- Limited use of double glazing, and

- Provision of external blinds to some windows (depending on siting in some cases).

It is difficult to conceive of any conditions under which such modifications will not reduce the energy use of these houses. None of the Energy Smart Builders have changed the type of heating or cooling system used as a result of changing the house design to a less greenhouse friendly product, though some builders have upgraded the efficiency of their systems. While the improved performance of the house may be used to improve comfort as well as reduce bills, the simulated savings are not used in communicating the benefits of the scheme (without qualification) or in government policy. The authors suggest that the best way to judge the rating scheme is to evaluate the implications of its use, not in debate over the rating methodology itself. If a consensus can be achieved on how best to modify the design of houses to achieve real energy savings, then the settings will flow from this. While the rating scheme is not perfect the effects of its use are leading builders and designers to take positive steps to improve their houses. It is difficult to see how some energy savings could not be achieved given the extent of the changes made.

A publication by the National Association of Forest Industries, developed by one of the authors criticising the House Energy Rating scheme (Williamson et al 2001[4]), promoting the environmentally friendly use of timber products proposes quite similar design strategies to those which can be used to obtain a high House Energy Rating. In this publication and others, the concept of the 'Snug' house is described. A Snug house is explained to be a house is lightweight, well insulated, sealed against excessive air leakage, with modest glass areas and well shaded in warmer months. Such houses have obtained 5 stars through the scheme in Melbourne. It has been a matter which has perplexed the authors of this paper that these criticisms have been made when authors of both papers agree on the principles of house design that need to be adopted to yield lower energy using houses and that the outcomes of using the rating scheme generally support these principles. It is hoped that these shared principles indicate that the authors of the two papers are somewhat closer to each others position than the names of the two papers would indicate.

Further improvements for the software and the scheme

So, is the rating scheme just fine the way it is? While the rating scheme is felt to generally lead to good outcomes, particularly in colder climates, there are several areas where it could be improved. In particular, there are two areas where the implications of the use of the software has been shown to lead to inappropriate outcomes. In both these areas projects have been initiated to develop solutions:

- The basis of the rating is energy use per square metre. This makes the rating requirement too strict for small houses and too easy for large houses. An adjustment factor is being developed to remove this bias.

[4] T. Williamson et al, *Environmentally Friendly Housing using Timber – Principles,* National Timber Development Council, 2001

- The simulation software has also been said to not adequately take into account the benefits of ventilating houses in summer. A project is soon to be initiated to develop a new ventilation model for the simulation software.

While, in the simulations for rating, windows are opened for significant periods and this does substantially reduce cooling energy use, the modelling of ventilation by the simulation software is limited. The scheme does not provide adequate reward for those houses which have been very well designed to maximise cross ventilation, and it does not allow for the cooling effect of the internal air speed. It should be noted that few simulation programs do.
There have also been some who have stated that the simulation software models a sealed air conditioned box in summer. Nothing could be further from the truth. The simulation software does assume that windows are opened to cool down the house whenever the outside temperature is below the inside temperature. Not only does it open windows, but it tests whether comfort can be maintained by opening windows opened. If the internal temperature is not below the thermostat setting it goes back to the start of the hour and calculates the energy requirements to maintain comfort. The software makes sure than no benefit that could be obtained by ventilation is lost. In Sydney one simulation showed windows were opened for over 1,500 hours in order to maintain comfort. This is far from a sealed box. Further, the thermostat temperatures used for cooling have been increased to 2 or 3 degrees above the usual air conditioner thermostat settings to allow for the fact that people will turn on fans, ventilate, put on light clothes etc. before turning on the air conditioner. The ventilation routines do need to be improved. They are not, as some have suggested, virtually absent.

Conclusion

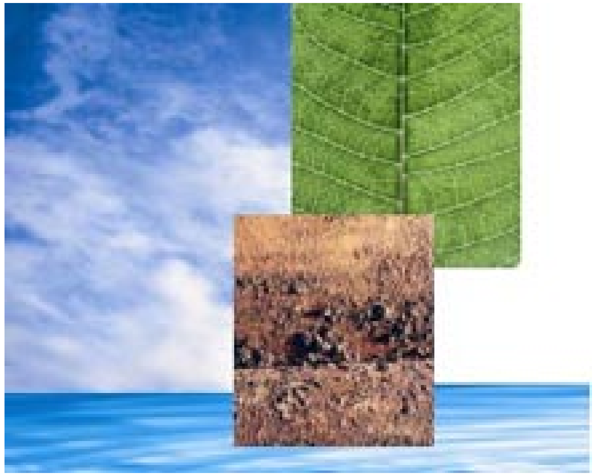
Is the Nationwide House Energy Rating Scheme bad science? It is true that there has been no study to determine the actual extent of the energy savings that are delivered when the rating is improved. The authors of both papers agree that the undertaking of such work is needed. However, it is not as if the energy saving predictions of simulation software are ever used in raw form to support policy decisions. The modelled energy load figures are always significantly discounted, and appliance efficiency and type, and the actual extent of heating and cooling is used in making these decisions. The extent of the discounting may not be completely accurate, but it is done on a rational and logical basis.

To call something 'bad science' is to pour scorn on it, whether that was the intention or not. Bad science is the ultimate in futility and waste. Bad science is responsible for nuclear accidents and the damn computer crashing again! To apply the term bad science to something is to suggest to some that it is utterly worthless. There is no doubt in the authors' minds that this is not true of the scheme.
The Nationwide House Energy Rating Scheme has a logical and rational basis:

- the science of the building simulation has been validated by internationally recognised benchmarks,

- the settings have been carefully selected to provide an appropriate mix energy saving strategies for each climate,
- the star bands were developed after analysing the performance of thousands of houses and with a consistent set of principles,
- the changes that have been made to the design of houses which are improved by the use of the scheme would seem to logically lead to lower energy demand.

This is not to say that the scheme needs no improvement. This paper has acknowledged a number of the shortcomings of the scheme and software. But it is the conclusion of the authors of this paper that the scheme is not bad science. It could be described as imperfect or in need of improvement, but not bad science.



Australian Government

Department of the Environment and Heritage
Australian Greenhouse Office

Productivity Commission Inquiry into Energy Efficiency

Australian Greenhouse Office

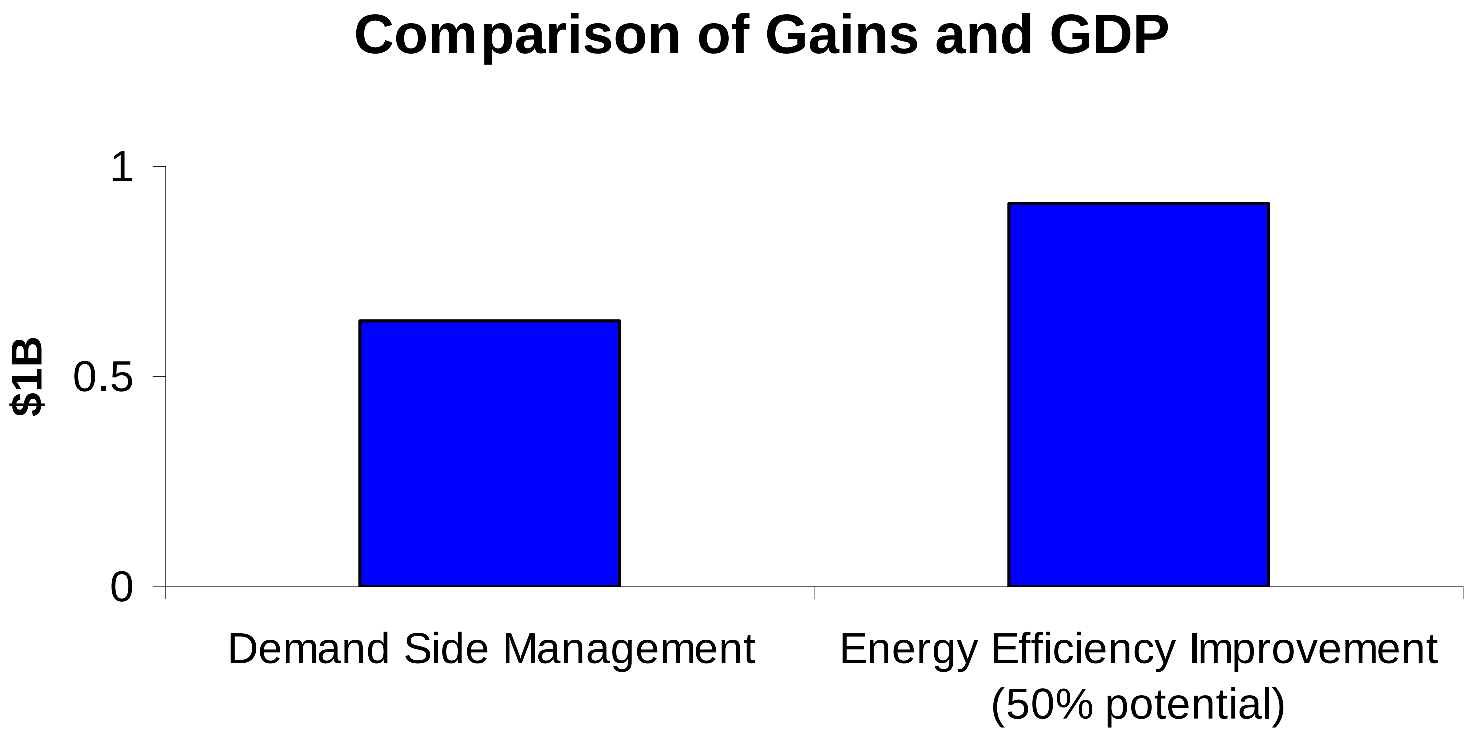
Department of the Environment and Heritage

Economic Impacts across Australia

Variable	Scenario 1 Average 4 year payback	Scenario 2 Up to 4 year payback
Real GDP ($ Billion)	**+1.8** (+0.2%)	**+0.97** (+0.1%)
Real Private Consumption ($ Billion)	**+1.8** (+0.35%)	**+0.72** (+0.1%)
Employment (Persons)	**+9,200** (+0.09%)	**+2,600** (+0.02%)
Greenhouse pollution (megatonnes)	**-32** (-9.2%)	**-10** (-2.8%)
Stationary final energy consumption (PJ)	**-213** (-9.1%)	**-76** (-2.8%)

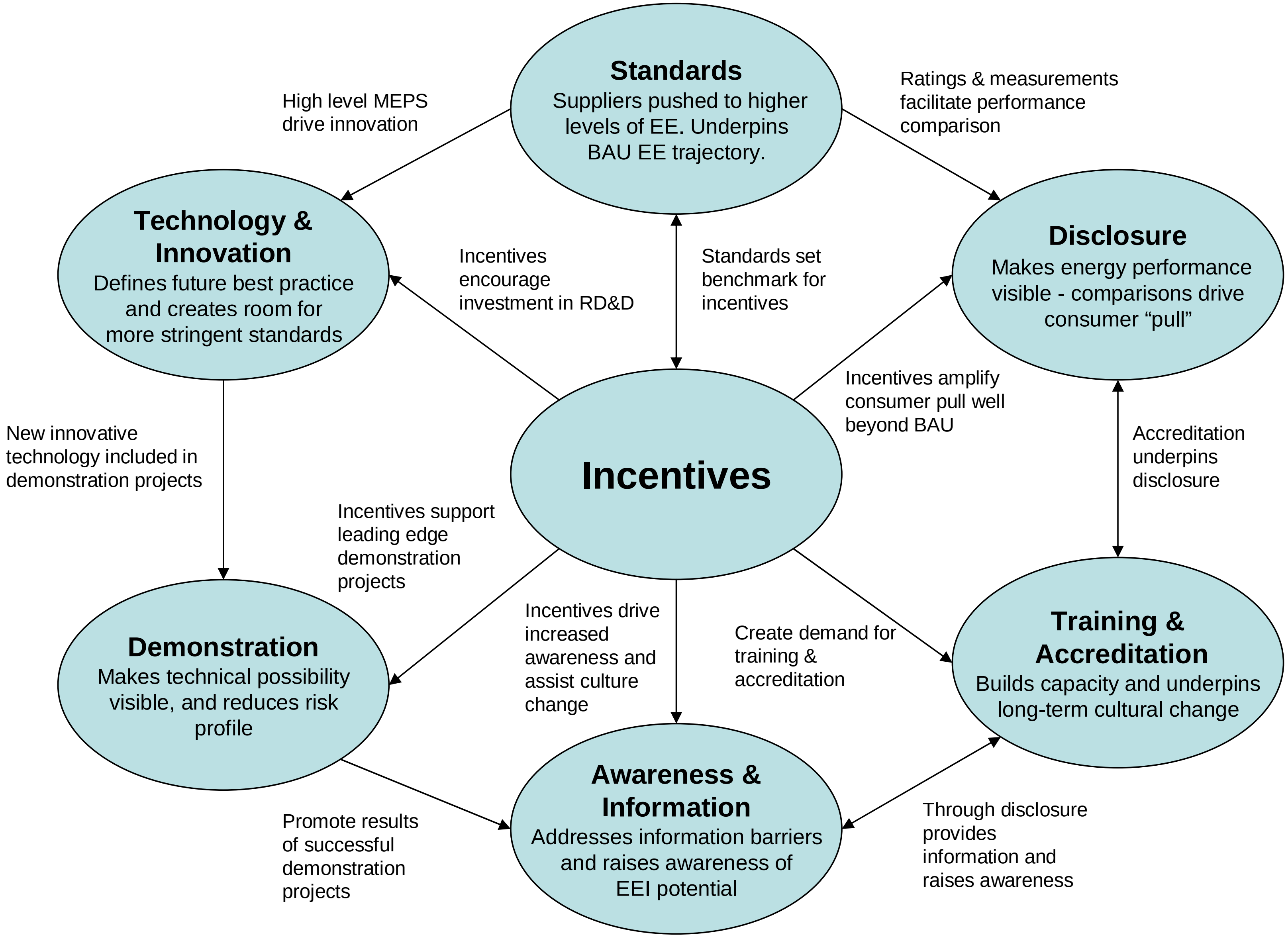
Source : Allen Consulting Group, Centre of Policy Studies Monash University

Comparison of Economic Gains
(Impact of annual gross domestic product)



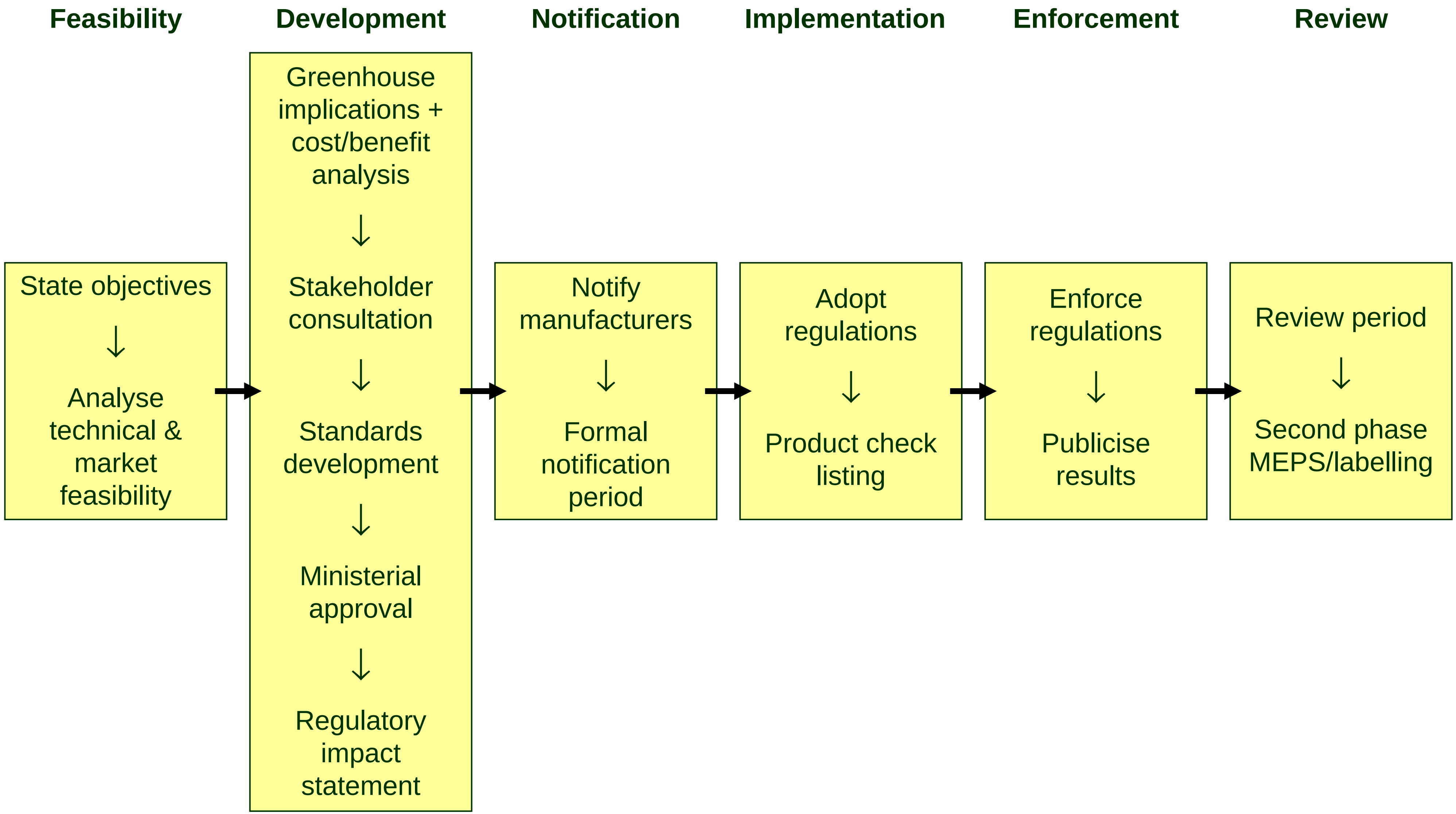
Sources: Parer Review of Energy Markets analysis and National Framework on Energy Efficiency (NFEE)

NFEE Policy Framework

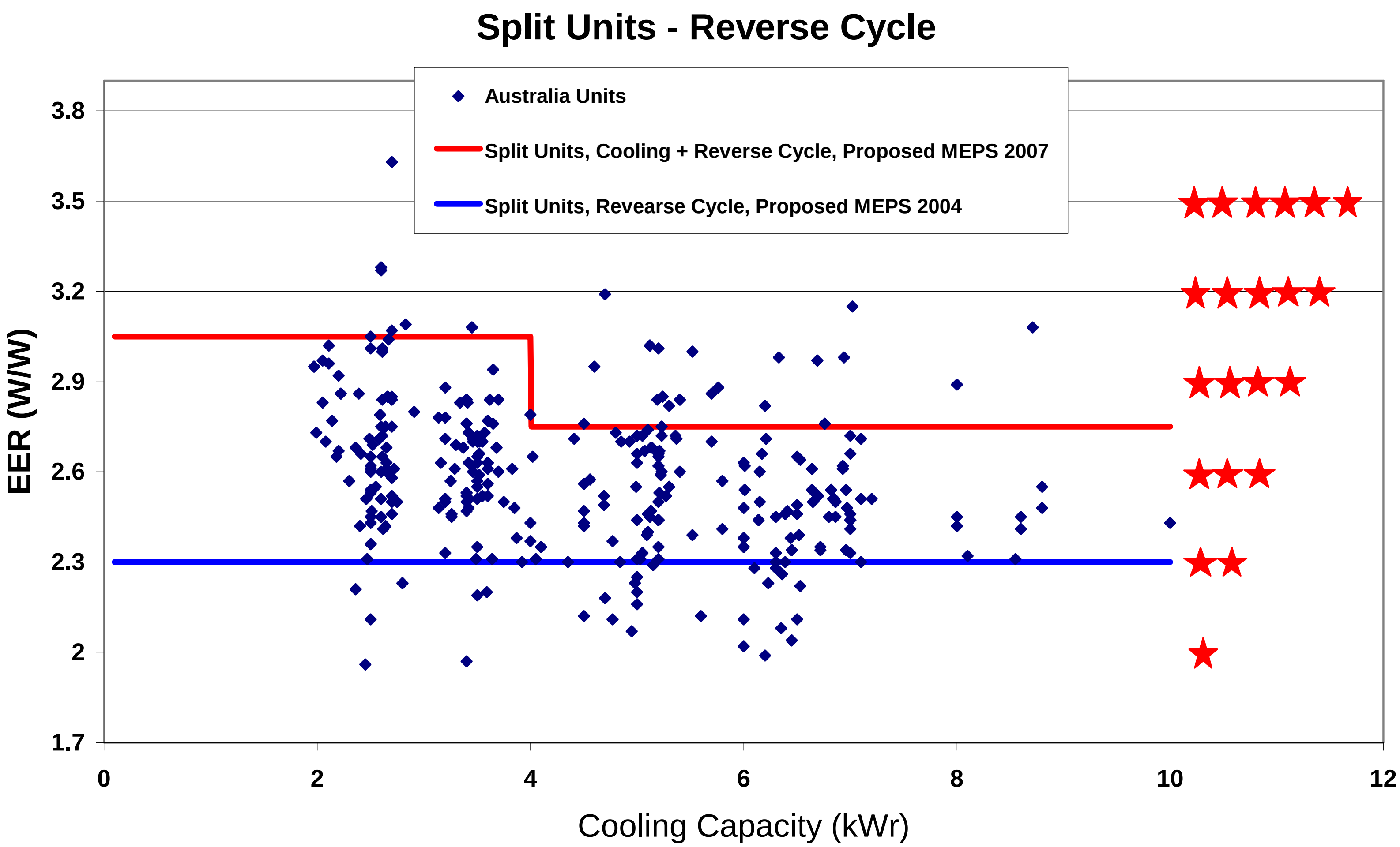


Minimum Energy Performance Standards

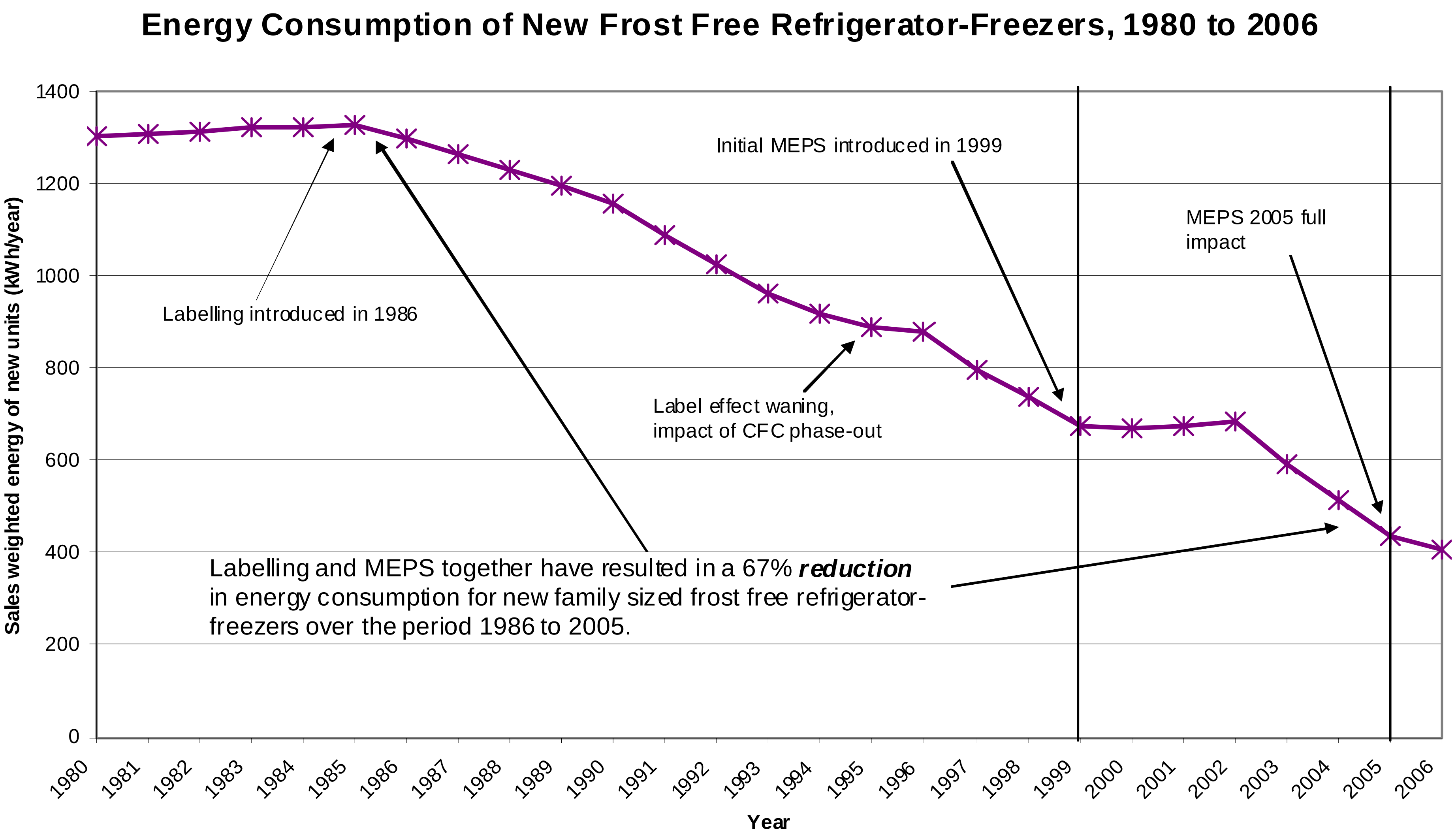
MEPS and Labelling Process Flowchart



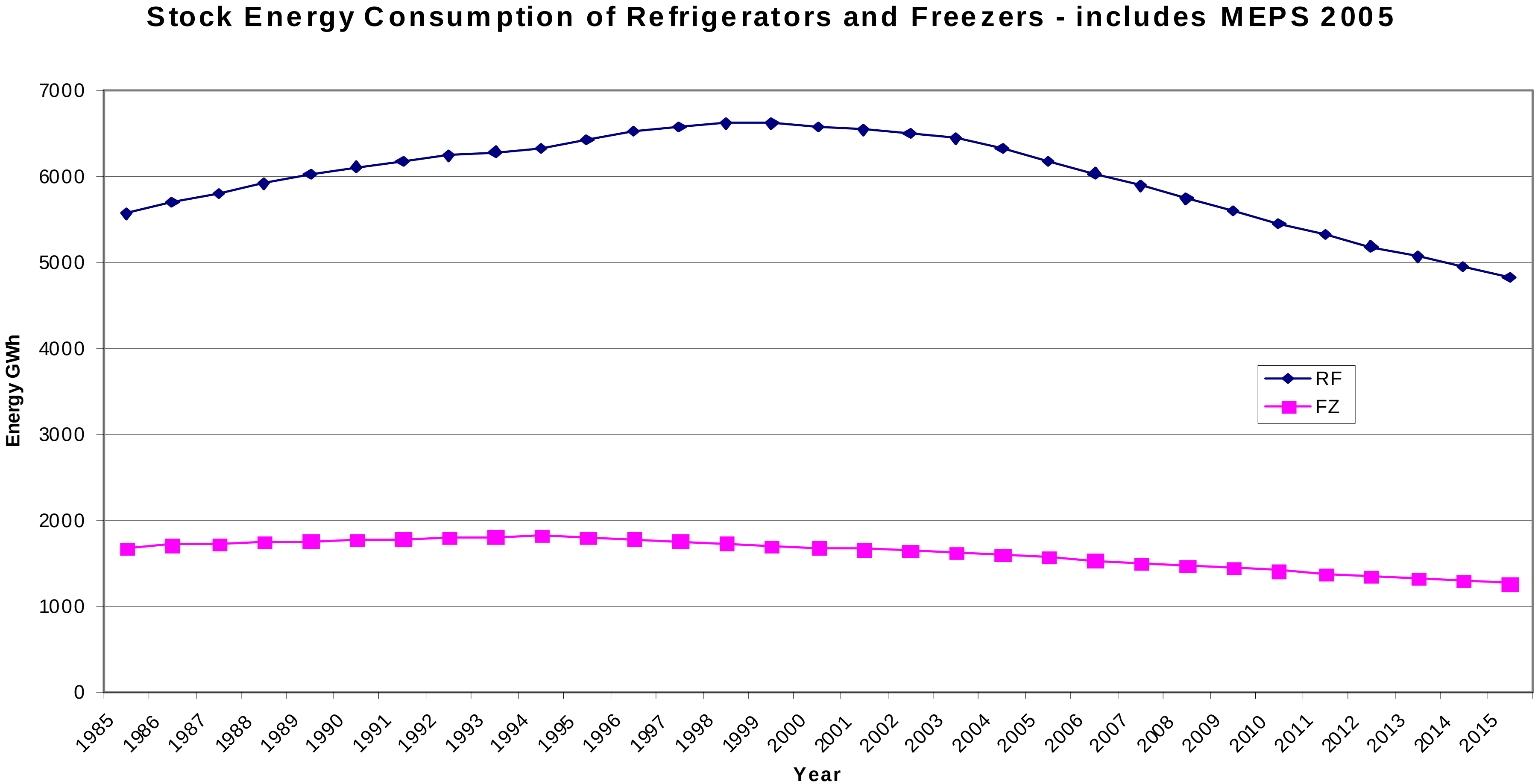
MEPS for Air-Conditioners



Refrigerators – Energy Performance

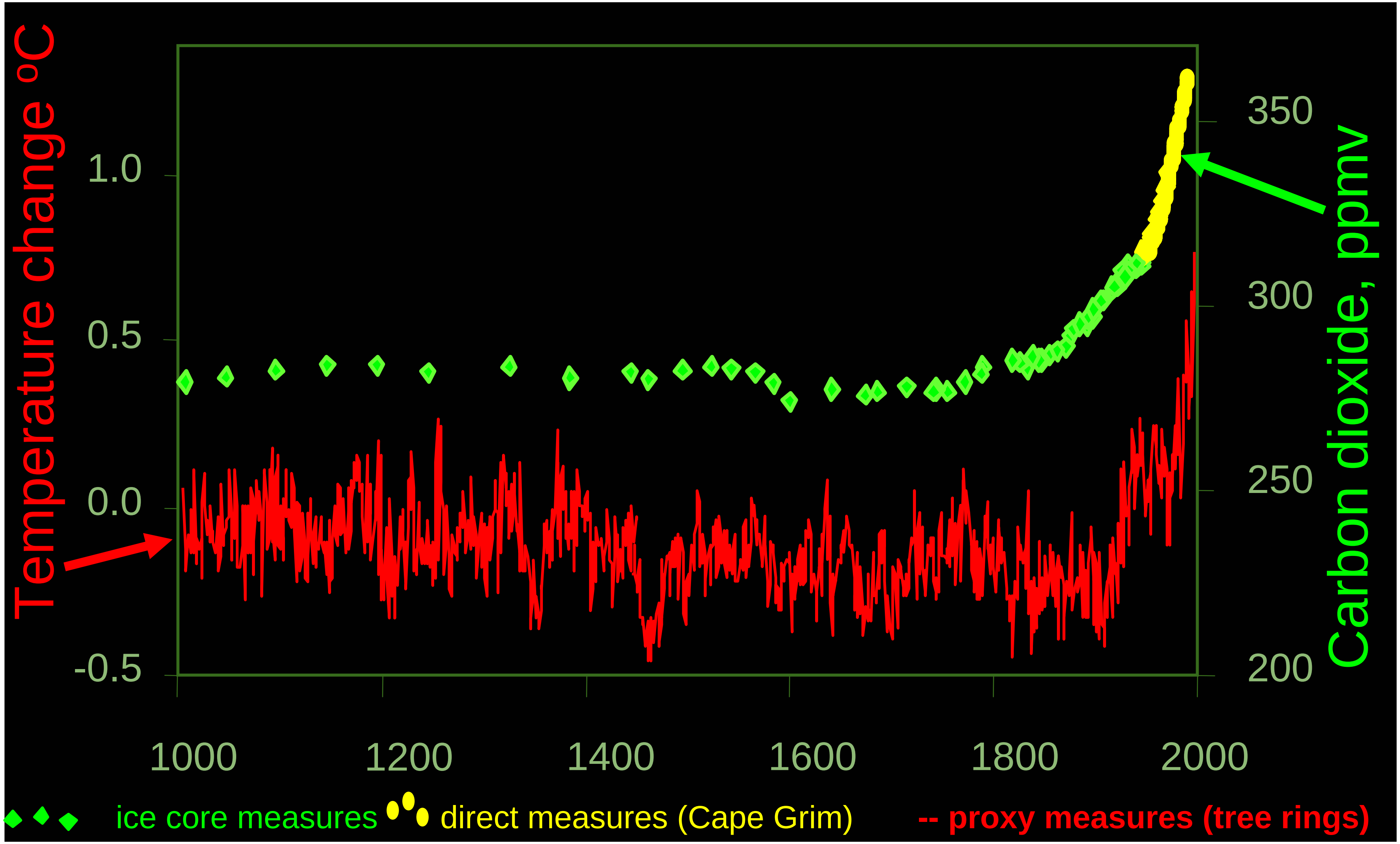


Refrigerators – Energy Consumption



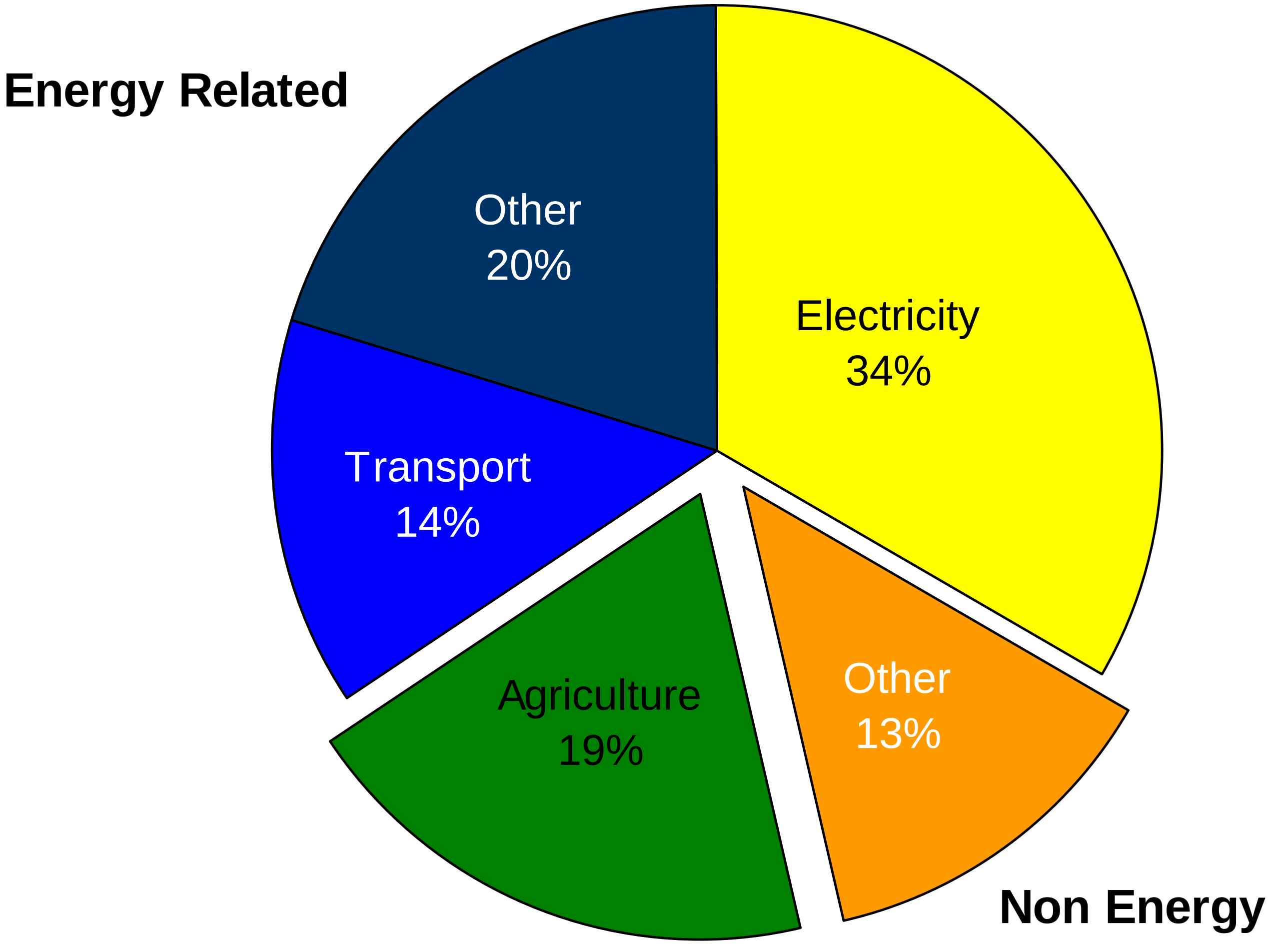
Climate Change

CO_2 Concentrations and Earth Temperatures



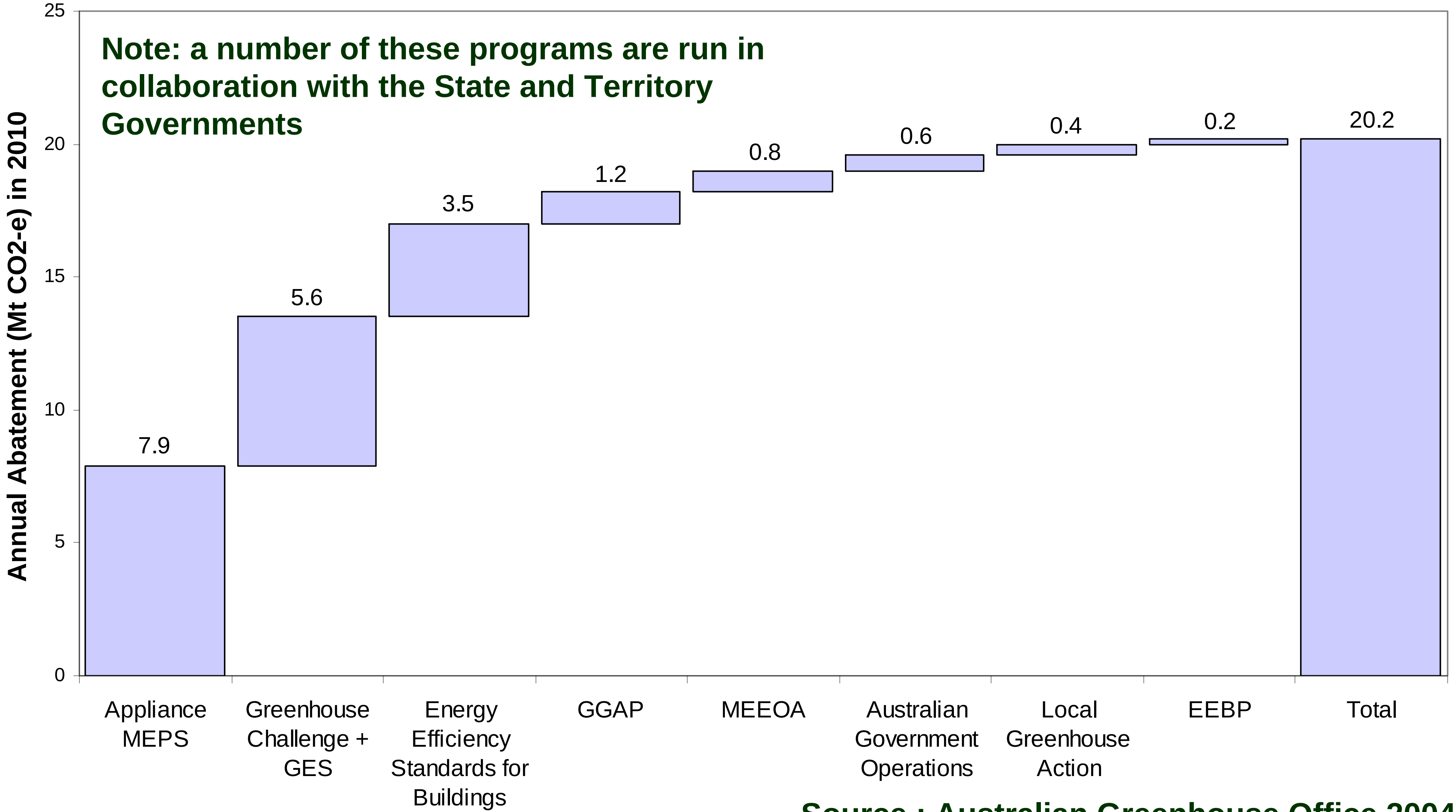
Source : CSIRO 2002

Sources of Greenhouse Emissions
(2002, CO_2-equivalent)



Source : National Greenhouse Gas Inventory 2002

Abatement from Australian Government Energy Efficiency Programs

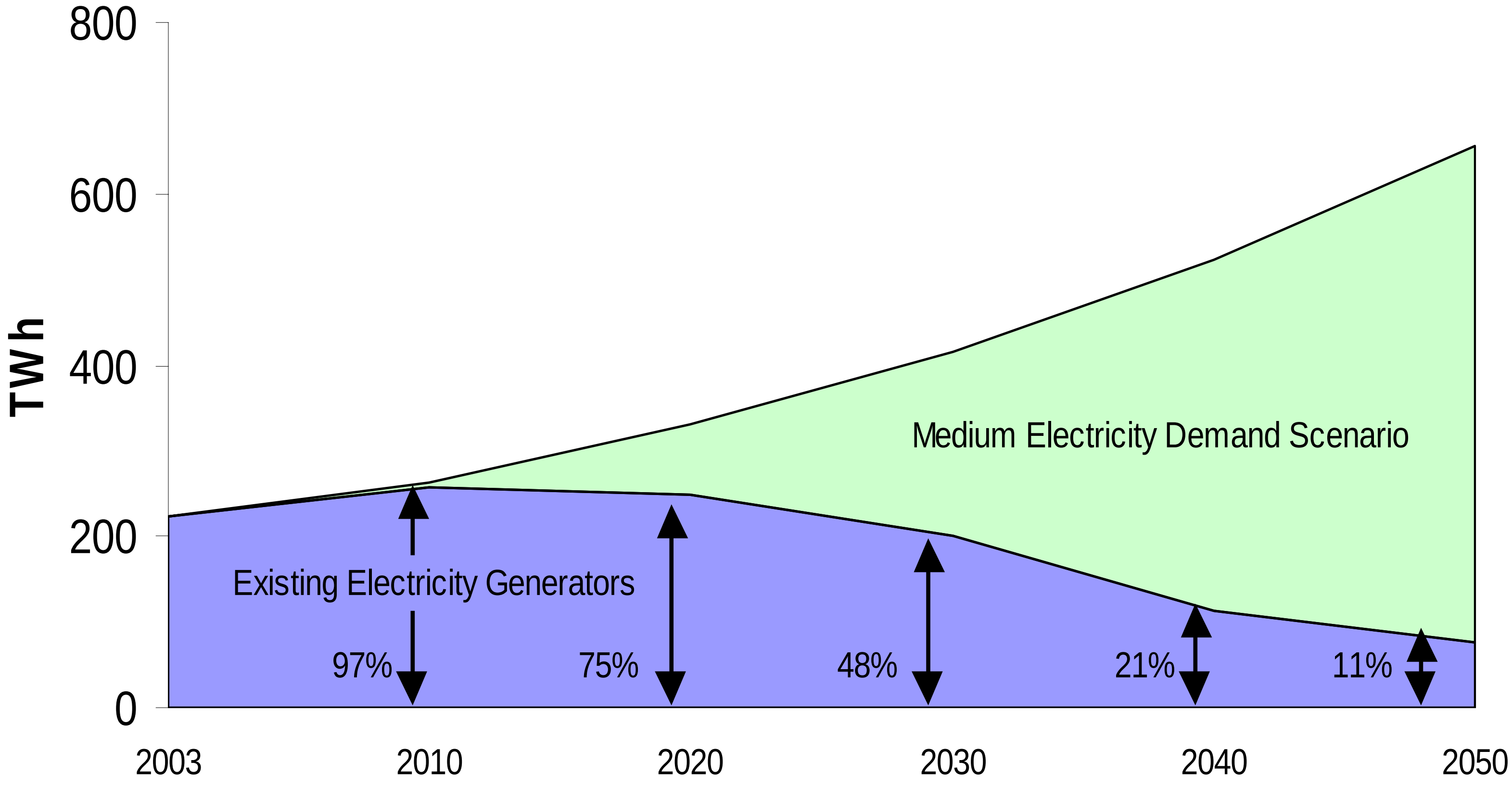


Source : Australian Greenhouse Office 2004

Deferring Investment

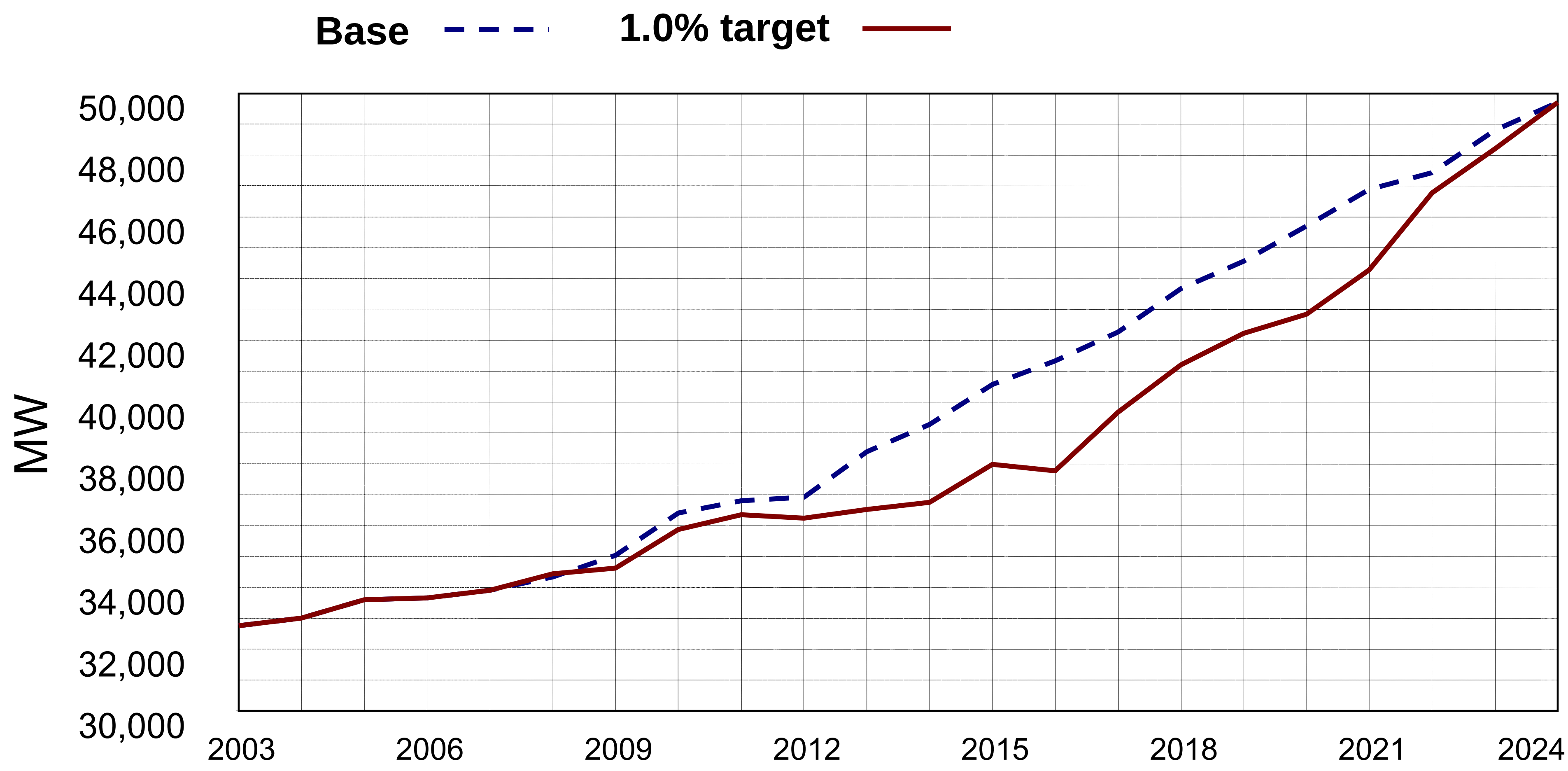
Demand/Supply Gap

(Electricity Generation)



Source : Energy White Paper

Projected Generating Capacity Requirements

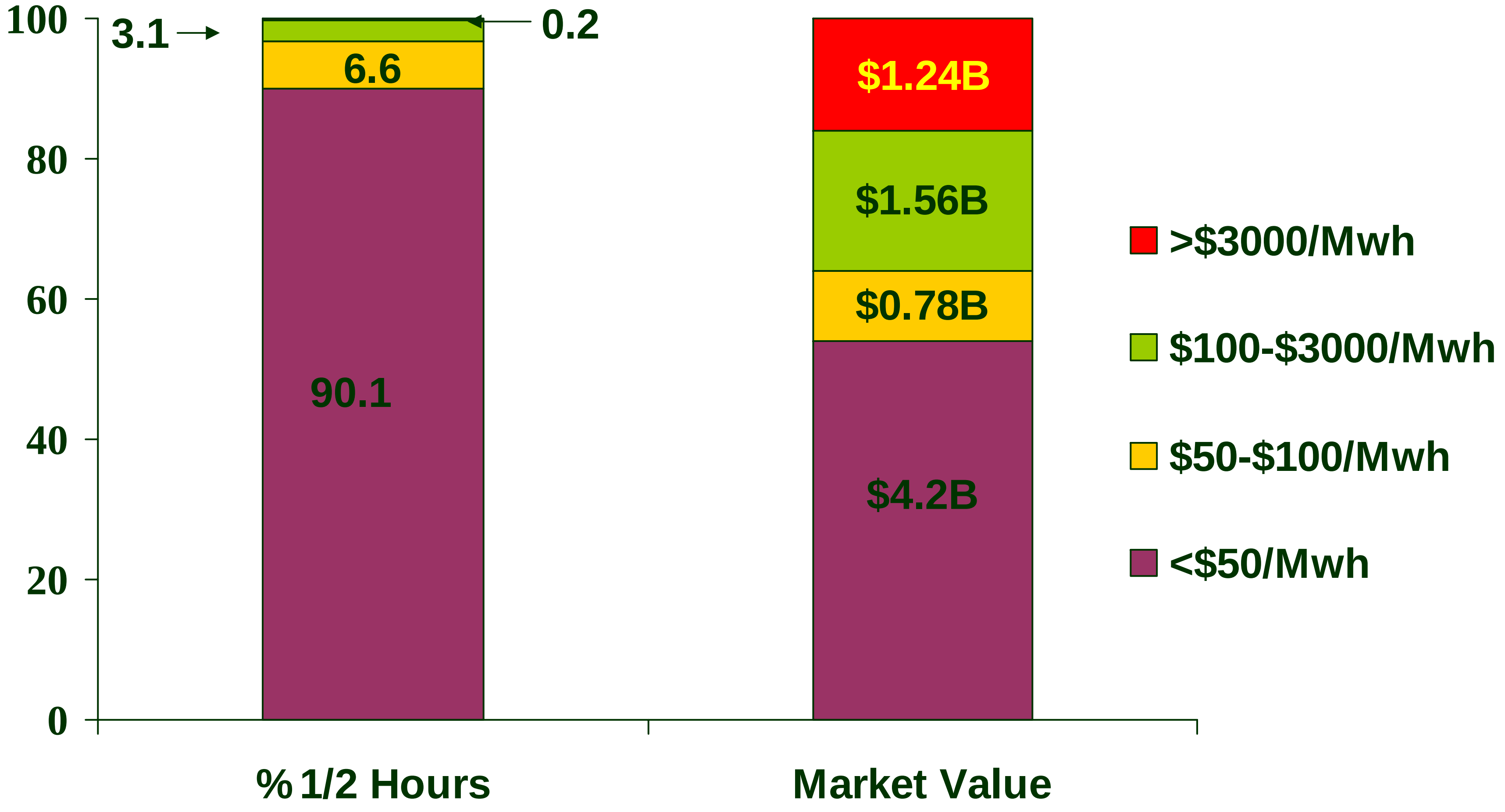


Source : Allen Consulting Group 2004

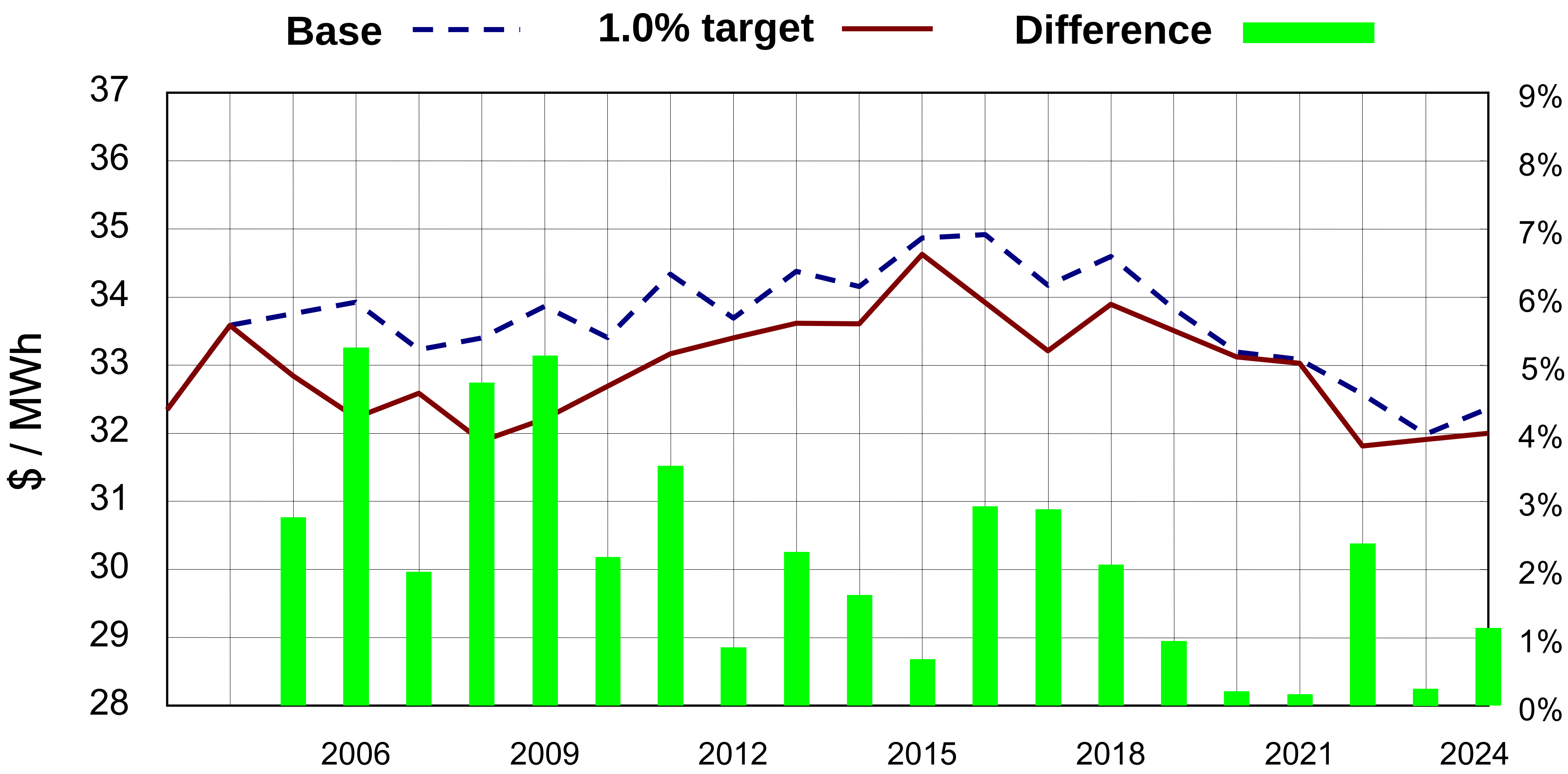
Peak Load
&
Electricity Prices

Value of Spot Market - NEM - 2002

TOTAL VALUE $7.79 Billion

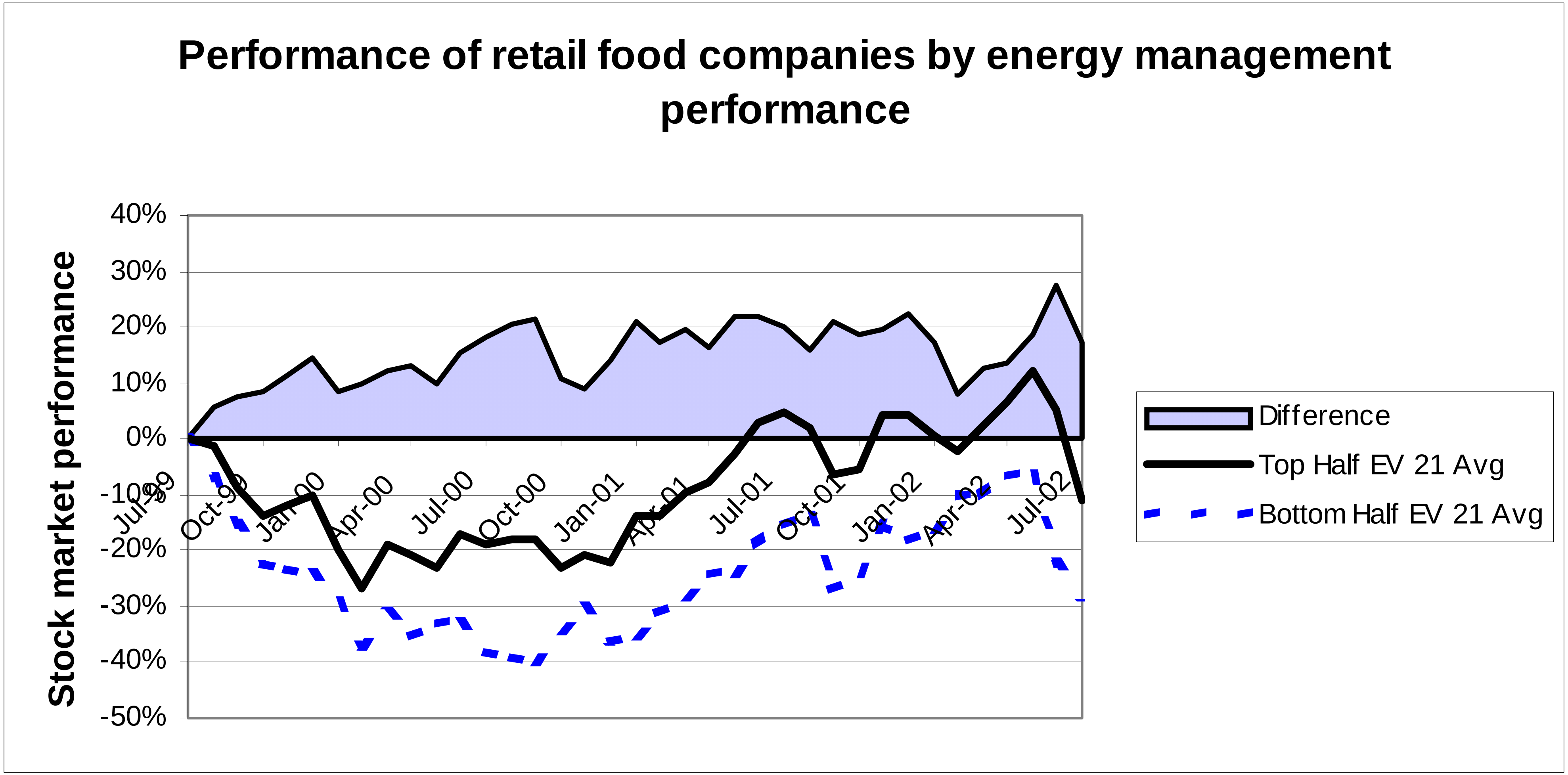


Impact on Wholesale Electricity Prices

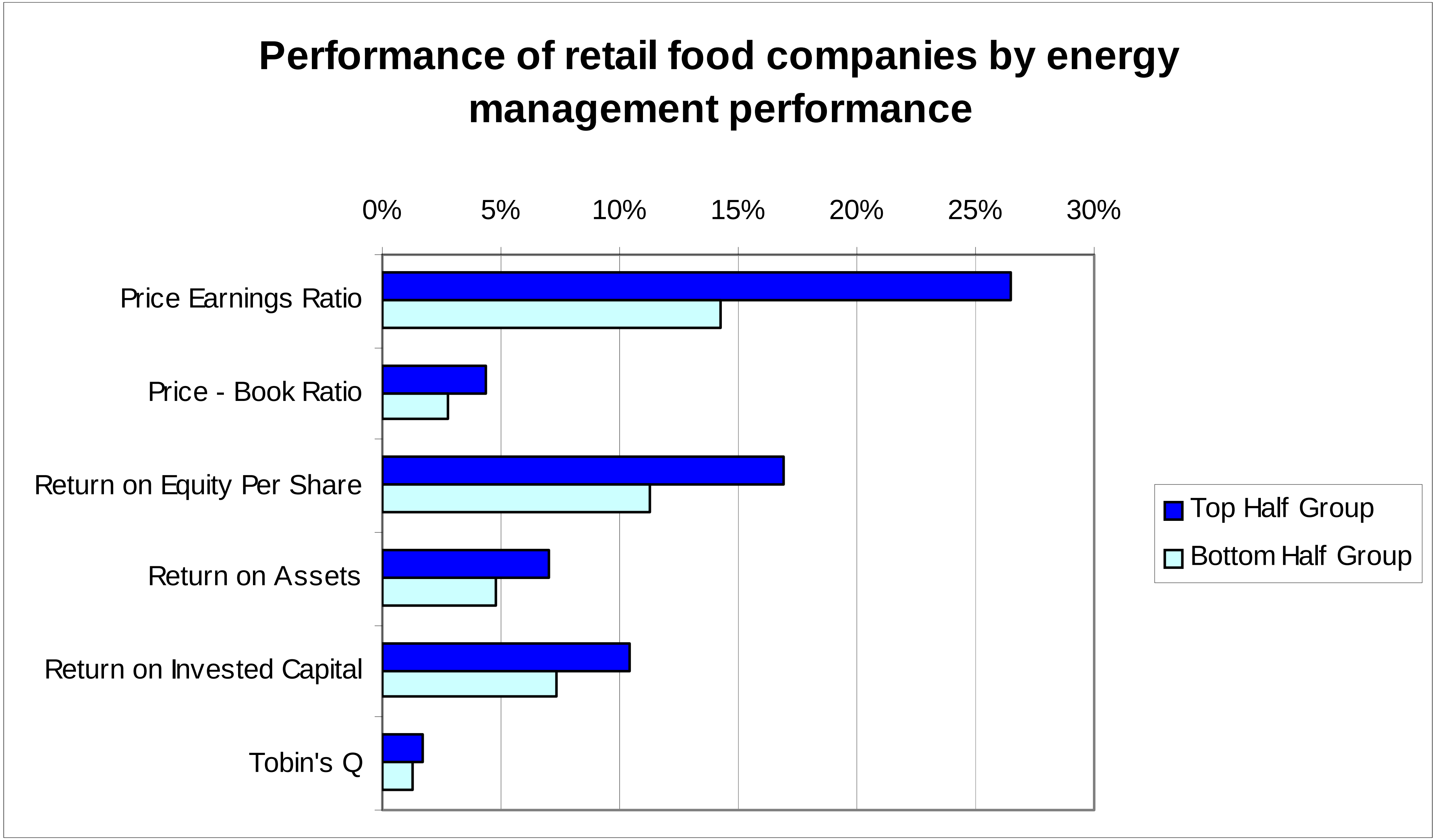


Source : Allen Consulting Group 2004

Effect of Energy Management on Performance



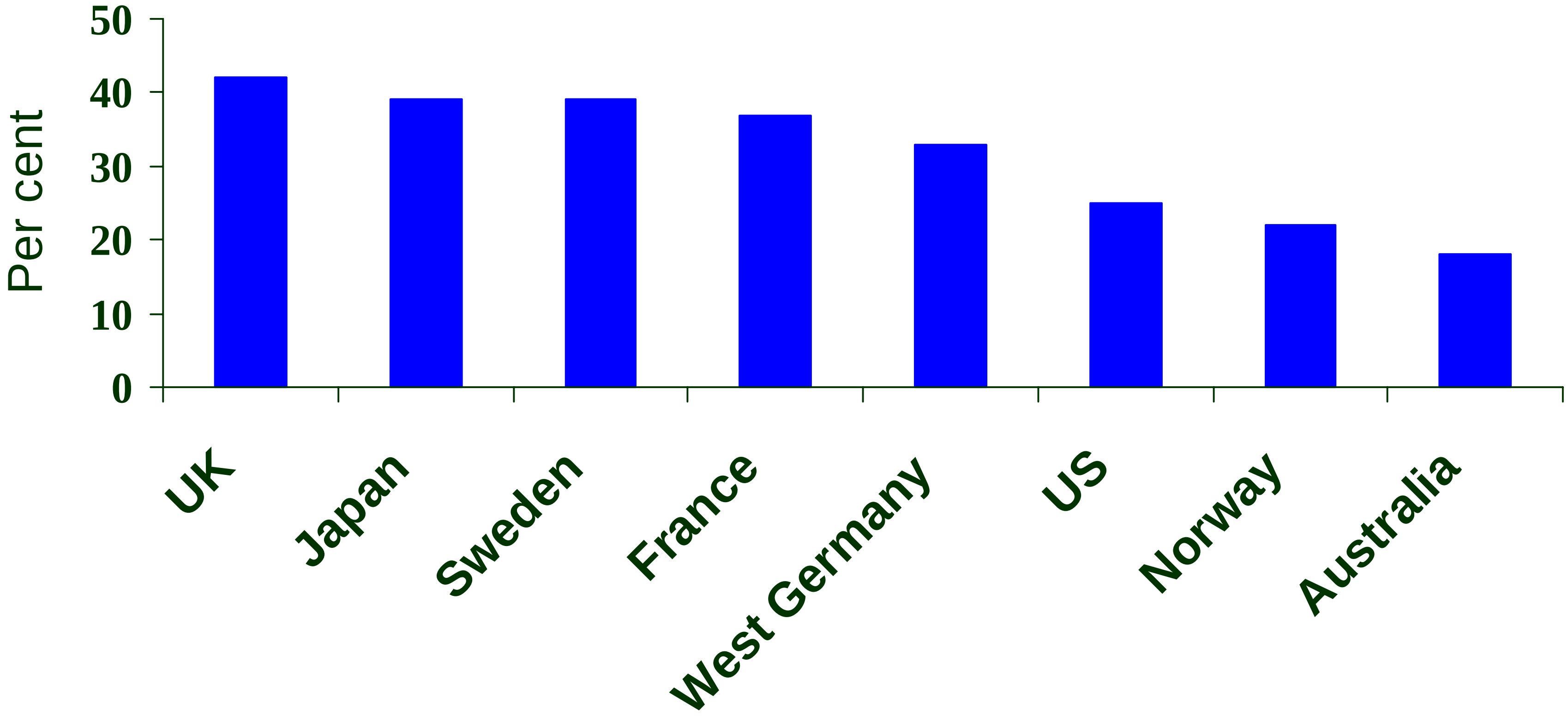
Source: *Energy Efficiency and Investor Returns: The Retail Food Sector*, Innovest 2002



Source: *Energy Efficiency and Investor Returns: The Retail Food Sector*, Innovest 2002

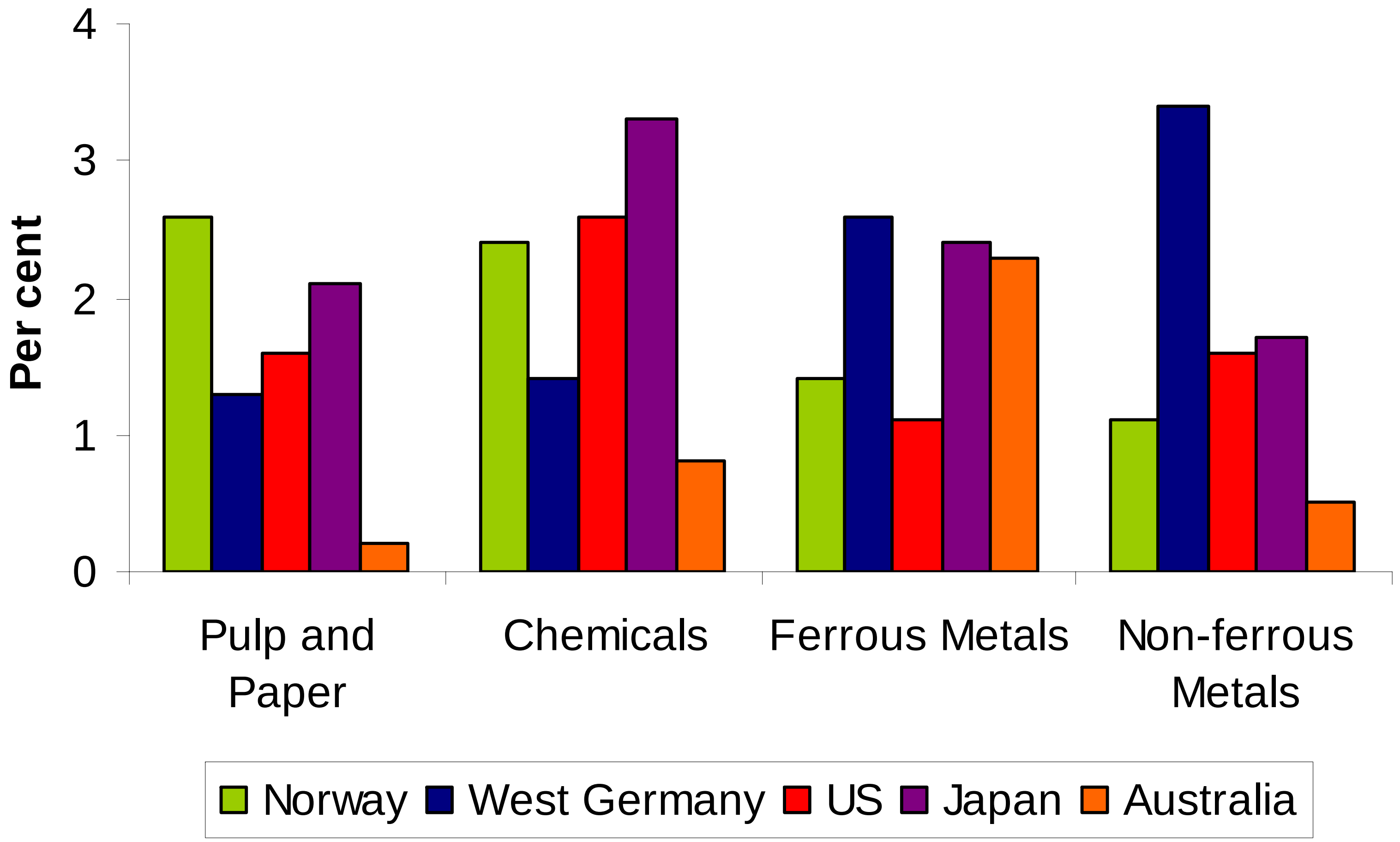
Australian EE Performance

Improvements in Energy Efficiency 1973 - 1995



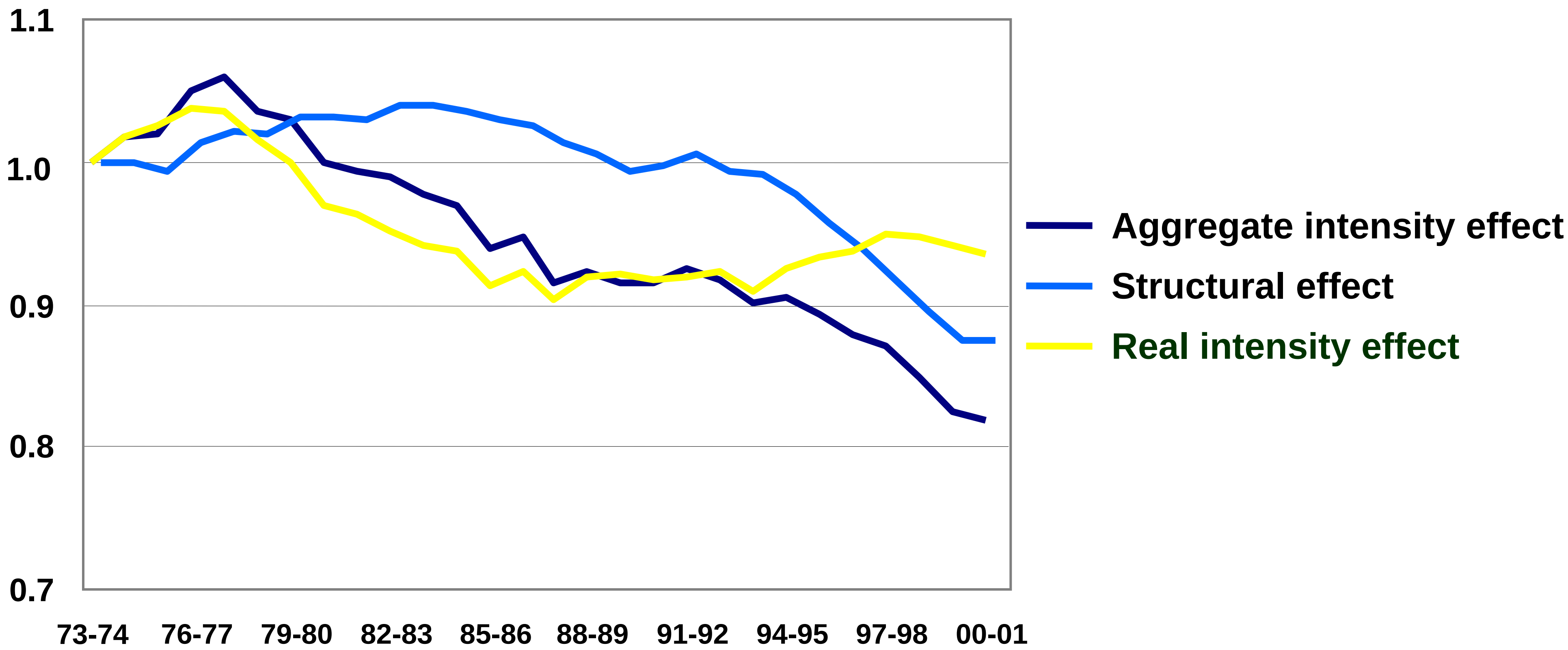
Source : IEA 2001

Energy Intensive Sectors
(Average Annual Improvement 1973-1995)



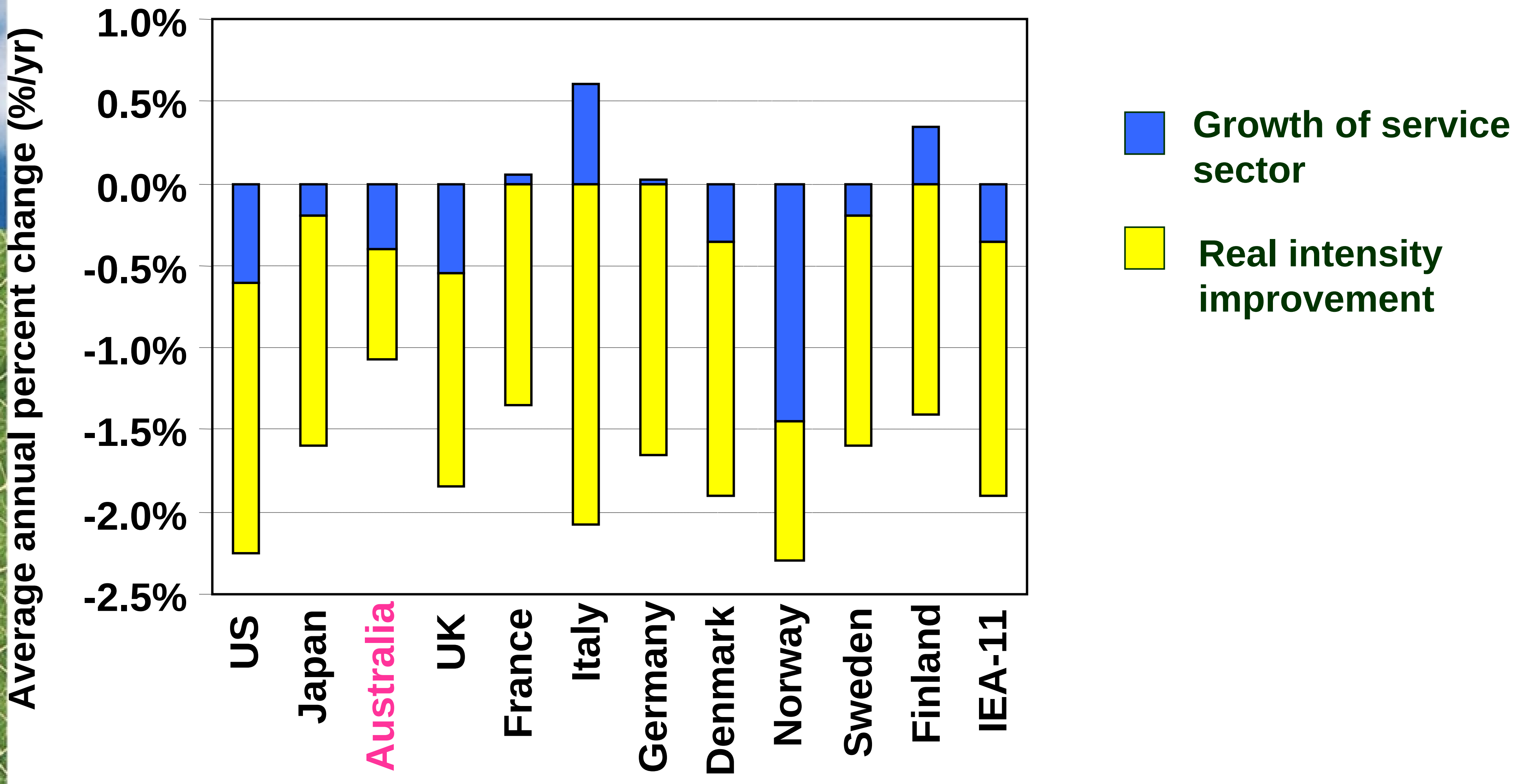
Source : IEA

Change in Energy Intensity of the Australian Economy



Source : ABARE (2003)

Energy Intensity Reduction – International Comparisons 1973-1998



Source : IEA 2004