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Productivity Commission
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Dear Mr. Rance

<u>Re: Energy Efficiency Enquiry.</u>

Please find attached an interim report commissioned by ICANZ on the Productivity Commission's draft report into energy efficiency.

As agreed with Greg Murtough on 22/04/2005 ICANZ will put in a full submission to the Productivity Commission by mid-June.

Yours Sincerely,

Dennis DÁrcy
ICANZ President.

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Evidence in support of policies to improve building fabric performance

A report prepared for:

The Insulation Council of Australia and New Zealand,

The Business Council for Sustainable Energy and

The Australian Glass and Glazing Association

By

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Evidence in support of policies to improve building fabric performance

1 Executive Summary

The draft report of the Inquiry into Energy Efficiency by the Productivity Commission recommends that further development of building energy efficiency regulations be deferred until 'ex-post' studies determine that the current regulations are effective. The Commission finds that the simulation technique for assessing the energy efficiency of a building is flawed and may not be a suitable technique for use in regulation. It bases these findings principally on the evidence submitted by one submission by Dr. Terry Williamson.[1]

Dr. Williamson's central thesis is that policy should be based on evidence and that there is no evidence to suggest that the application of an energy rating which simulates annual energy loads will result in lower actual energy consumption. He presents the results of research which he suggests provides evidence to support his thesis:

- A study showing no link between simulated load and actual consumption,
- A variety of case studies of houses which use little energy but obtain poor energy ratings, and
- He quotes a variety of studies which have found no link between the sort of improvements to building fabric that energy ratings would promote and energy consumption.

Williamson characterises a rating based approach to building regulation as a narrow technical solution to a problem that is multi-dimensional and criticises it for ignoring important determinants of energy use such as appliance efficiency and the thermal comfort preferences of occupants.

This report finds Williamson's arguments to be unconvincing and at times misleading. Williamson's research comparing actual energy consumption

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[1] It would also appear that these 'flaws' in simulation methodology have been applied to Commercial Buildings as well despite there being no evidence presented that this approach creates any problem. Simulations have been used for decades in the commercial sector to improve the energy efficiency of these buildings.

and the simulated load predicted by rating software does not demonstrate that a better rating will not lead to lower energy consumption. If the predicted loads are adjusted for appliance efficiency a surprising correlation is found. What Williamson has demonstrated is that the relationship between simulated load and actual consumption is not a 1:1 relationship but gives greater weight to air conditioning loads. This was a deliberate decision by government in framing the rating scheme due to the problems domestic air conditioners create for electricity utilities peak loads throughout Australia.

Williamson's case studies are similarly unconvincing. The low energy consumption of the houses appears to be solely due to the highly motivated occupants. The monitored conditions inside these houses reveal that they spend many hours at uncomfortable temperatures. Future occupants who are either less environmentally motivated or have more stringent comfort requirements may well need to use substantial amounts of energy in these houses. While some overestimation of cooling loads may be demonstrated for the case study houses which have been specifically designed to promote ventilation the latest rating tools address this issue.

Williamson implies that there are no studies showing that improved building fabric will result in lower energy consumption. This is not true. This report presents four Australian studies showing statistically significant energy savings due to the installation of insulation and associated with the use of north facing glazing. It would appear that Williamson is not well informed about the extent of research in this field. Not only do these studies show that energy savings are significant but that they achieve near the full theoretical savings with little or no "Rebound Effect". This is in stark contrast to the conclusions of the Commission and Williamson's submission.

Finally it is demonstrated that while the rating tools themselves do not take into account other determinants of energy efficiency like appliance efficiency and user behaviour the Regulatory Impact Statements which support these regulations do take ALL determinants of energy use into account. The private benefit estimated by the Regulatory Impact Statements is therefore likely to closely approximate the actual benefits. Furthermore, it is shown that there are government programs which have been specifically developed to address the other important determinants of energy use. Regulations must be seen in the context of these other programs.

Williamson's submission has given the Productivity Commission an inaccurate view of the efficacy of regulations in reducing the energy consumption of buildings. As a result the recommendations of the Productivity Commission's draft report are seriously flawed. At a time when the evidence of human impact on global climate is becoming overwhelming the Productivity Commission has called a stop to the development of regulations which are a vital element of Australia's Greenhouse response. It is the view of the organisations that have developed this interim response to the draft report that the Productivity Commission should act immediately to withdraw these recommendations due to the seriously flawed evidence they have been based on.

2 Introduction

The Productivity Commission's (PC) draft report into energy efficiency raises serious questions regarding the validity of the simulation methodology used for the purpose of demonstrating compliance with building regulation:

DRAFT FINDING 7.2

Energy efficiency standards for residential buildings are based on computer simulation models — such as the Nationwide House Energy Rating Scheme energy-rating software — that exclude many of the determinants of a building's actual energy efficiency.

DRAFT FINDING 7.3

A ranking of residential buildings by star rating (using energy-rating software such as Nationwide House Energy Rating Scheme) may be very different from a subsequent ranking based on actual energy consumption or efficiency.

These findings lead the Commission to conclude that all further changes to building codes should be delayed till 'ex post' evaluation of current standards demonstrates that the current standards are sufficiently effective. (Draft Recommendation 7.3, page 156).

These concerns originate with the analysis presented by one submission to the Inquiry by Dr. Terry Williamson, Dean of Architecture at Adelaide University, for example:

" … the Commission is concerned that the analytical basis for these regulations (computer simulation of energy loads within buildings in each climate zone) may be flawed. It therefore considers existing standards should be fully evaluated before new more stringent energy efficiency standards for residential or other buildings are introduced."[2]

and,

"… Dr. Terry Williamson submitted results from past research and case studies which suggest that the science of building energy efficiency is far from understood … If Dr. Williamson's observations are correct, the

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[2] Productivity Commission, 2005, Overview p. XXXVII

simulated energy performance may not be an indicator of energy efficiency."[3]

"Dr. Williamson suggests that building energy efficiency standards could distort the housing market in favour of designs that rate highly ... [with the result that] more cost effective improvements in energy efficiency may be overlooked in favour of those that are rated highly by the software."[4]

The PC quotes Williamson directly:

"There is little or no evidence to show that efficiency standards … will be in any way effective"[5] and his description of his case study results:

"Despite each of these houses having energy consumption results well below the 'average' house in the location, based on star rating results, none could now be built because they do not achieve the required rating criteria."[6]

Because this submission has been so influential on the PC draft findings it is important to evaluate the claims of the submission to see whether the evidence it presents supports the PC's conclusions.

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[3] Productivity Commission, 2005, P 145

[4] Productivity Commission, 2005, P 148

[5] Productivity Commission, 2005, P 148

[6] Productivity Commission, 2005, P 147

3 Evaluation of Williamson's own research

Attached to Williamson's submission are a range of case studies and papers presenting evidence that there is little relationship between real building performance and the energy rating. This analysis will focus on two of these papers:

"**NATHERS: SCIENCE AND NON-SCIENCE**" (Williamson et al, 2001), and

"**Perceived and prescribed environmental performance of award winning houses**" (Soebarto et al, 2004)

3.1 NATHERS: SCIENCE AND NON-SCIENCE

This paper presents the results of a study which compared actual energy bills with the NatHERS simulated energy load of 31 houses. Actual energy consumption and energy loads predicted by NatHERS show virtually no correlation. The paper concludes that because there is no correlation between simulated load and energy consumption a regulation based on simulated energy load can not be effective in reducing household energy consumption:

> "The results presented in this paper now indicate that the commonly held purpose of NatHERS, that higher Star Ratings will mean reduced household energy consumption and greenhouse gas emissions, could not be corroborated." [7].

It seems that Williamson either misunderstands or chooses to ignore the real commonly held purpose of NatHERS which is:

> "The intention of NatHERS 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."[8]

NatHERS estimates the annual net energy flows through the building envelope under specified usage patterns that determine the hours during which specified temperatures are maintained. This is not (and is not intended to be) directly related to the energy used by heating and cooling appliances to maintain comfort, as each type of appliance has its own

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[7] Williamson, submission 28 to Productivity Commission, 2005 p 50

[8] Isaacs, Ballinger and Pears, 2001 p 4

conversion efficiency. For example, to supply 10 GJ of heat, a gas heater may consume between 11 and 18 GJ of gas, depending on its efficiency. An electric reverse cycle air-conditioned may use as little as 3 GJ of electricity to provide the same amount of heat. So Williamson's 'finding' is actually a statement of the obvious to anyone who understands the laws of physics and chemistry.

It is therefore misleading to compare energy consumption with simulated building thermal loads without correcting for appliance efficiency and variable aspects of user behaviour such as areas heated and cooled, thermostat settings, and hours of use. Without this correction one could be comparing an inefficient house heated for a few hours a day with an efficient house heated for most of the day and come to the conclusion that the inefficient house is better because it has a lower energy bill.

Given the variability that can occur in heating and cooling energy use due to user behaviour the truly surprising finding in Williamson's paper is that with minor adjustment a relationship between the rated energy load and actual consumption can be identified without further adjustment for variations in occupancy and temperature settings. If appliance efficiency is used to adjust the NatHERS load predictions the energy performance shows a far better correlation with NatHERS results. The charts shown below show the relationship between actual energy use and NatHERS simulated load as shown in Williamson's. The second chart (not shown in the body of the submission, but in the attached paper) shows the impact of adjusting the NatHERS load to allow for appliance:

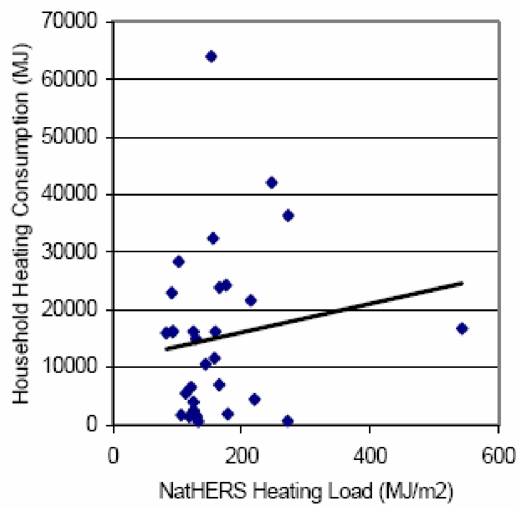

Figure 9: NatHERS Heating Load Only (MJ/m^2) vs Household Heating Energy (MJ)
Note: N=31, R^2=0.022, p>0.4

Figure 1 NatHERS simulated load versus actual consumption

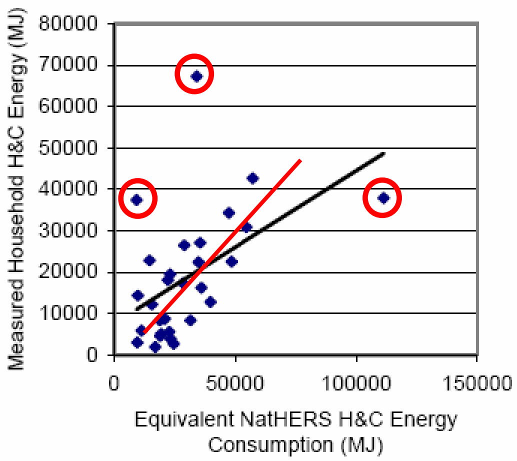

Figure 7: Equivalent NatHERS Energy Consumption vs Actual Energy Consumption
Note: N=31, R^2=0.185, $p<0.05$

Figure 2 NatHERS simulated load adjusted for appliance efficiency versus actual consumption

The chart above shows the measured energy consumption (y axis) plotted against the NatHERS simulated load adjusted for the efficiency of heating and cooling appliances. If it is valid to remove the circled outliers the outliers (for example, if they relate to homes with unusually short or long hours of occupancy) the correlation observed would be even stronger (R^2 value of approx.0.53 is achieved as opposed to the 0.18 shown in the chart above). This suggests that a lower heating and cooling load predicted by NatHERS **WILL**, on average, lead to a reduction in actual consumption. Williamson's own research does not support his conclusions that the use of ratings to improve building fabric efficiency would not save energy. Rather the paper shows that the impact of improvements will not be directly proportional to actual consumption because the efficiency of the heating and/or cooling appliance is not included.

This discussion raises an important issue that has been considered in the development of the rating Scheme: whether the significance of summer cooling loads should be adjusted downwards to reflect the high efficiency of air conditioners relative to the most common heating appliances (an air-conditioned is typically over 200% efficient while a gas space heater is 75% efficient at point of use). Adjusting simulated loads to allow for appliance efficiency would significantly diminish the ability of the rating to influence cooling energy use because the efficiency of typical heaters is 2 to 4 times worse than air conditioners. This would substantially reduce the relative weighting of summer performance and hence the ability of the rating to influence cooling energy loads at a time when the loads caused by residential air conditioning are causing problems with electricity supply all over Australia. While including appliance efficiency may appear to have some appeal it does raise some difficult issues. The BASIX tool addresses this problem by rewarding efficient appliances in proportion to their impact on energy use and effectively setting minimum performance requirements for heating and cooling separately. If it is necessary for appliance efficiency to be included such an approach may have some merit as it ensures that the appliance efficiency adjustment does not mean that summer performance is overlooked.

While the new approach used in BASIX may hold some promise it is important to remember that the exclusion of appliances from the rating was a deliberate decision and not some careless oversight as is implied. The reasons for this decision are outlined in the paper which responded to Williamson's findings (Isaacs, Ballinger and Pears, 2001). An extract from this paper outlining the practical difficulties involved in including appliance efficiency in ratings is shown in Appendix A. A number of the factors outlined in this paper are still relevant and the integration of appliance efficiency may still face some practical and regulatory hurdles.

3.2 Perceived and prescribed environmental performance of award winning houses

This paper and the case studies shown in Williamson's submission to the Commission (pp 26-30) provide examples of houses which in Williamson's opinion have achieved low energy consumption (compared to average houses) and a high degree of occupant satisfaction with thermal comfort and yet do not receive a high star rating. The paper concludes that because such houses which have met the intention of the regulation i.e. a low energy use but "would not be allowed to be built" by the BCA that the rating methodology is flawed. It recommends that the rating technique should be amended to allow the intended occupants to enter their own comfort preferences (and presumably other factors such as time of use, areas heated and cooled etc.) and that houses with no mechanical heating or cooling installed which are intended to be open to the outside be assessed on a different basis.

3.2.1 General Comments

Houses should be designed to meet the needs of all occupants

Simply because a house meets the comfort requirements of the specific individual(s) it was designed for does not mean that it will meet the requirements of future occupants. It is extraordinarily rare for a house to be occupied by the same people for the entire life of the house and even if this were the case comfort preferences and occupancy patterns will change over the building's lifecycle e.g. the elderly and very young are known to have less tolerance to extreme temperatures. The results of monitoring presented in the paper[9] show that these houses spend a substantial amount of time outside the ASHRAE comfort zone(the internationally accepted conditions desired for comfort by most people).. Subsequent occupants may find they need to consume far more energy to maintain comfort.

Most new houses are not designed for specific individuals but are purchased either from a range of builders' plans or a 'spec' house which has already been constructed. Houses may be constructed long before the occupant is known. The suggested change to the rating methodology would only be relevant for a small proportion of new houses, and would logically require modification of the dwelling to meet the comfort requirements of the new occupants each time it changed hands..

Application of regulatory requirements would benefit these houses

To say that these houses could not be constructed is a misleading statement. These houses could be constructed, but would require some modification and/or would be individually assessed under the provisions of the regulations to take into account their unusual features (see Section 3.2.2). As Williamson's own research suggests that a lower simulated load would lead to lower actual consumption these modifications would benefit the current occupants in terms of even lower energy consumption or improved comfort. Future occupants with more stringent comfort requirements or the present occupants with different occupancy requirements would benefit through more significant reductions in energy bills.

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[9] Soebarto et al 2004, as shown in Williamson 2005, p 56

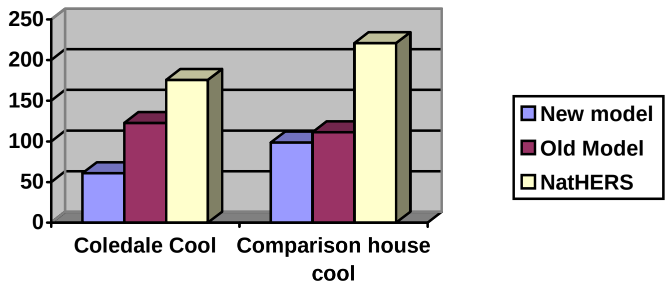
The same conclusions may not apply to the next generation of NatHERS rating tools

The findings of Soebarto et al 2004 apply to the NatHERS rating software. As a result of feedback from industry and research, particularly in regard to the rating failing to take into account the physiological cooling effect of air movement, a new rating tool called AccuRate has been developed and will soon be available for use. Regulatory trials have already begun in some states. This demonstrates that the regulations are evolving in response to improving understanding of the issues and identified shortcomings. The same can be said about most regulations in all fields.

In each of the three case studies reported in the Soebarto et al 2004 paper the house fails to achieve an acceptable rating at least in part because cooling energy load is predicted to be substantial when the occupants found no artificial cooling was necessary. To some extent this may reflect occupant tolerance of conditions, but it also seems that each of the case study houses include specific design features to enhance ventilation in summer to avoid the need for artificial cooling.

AccuRate predicts substantially reduced cooling loads. In part this is caused by modification to the assumed user behaviour pattern. This change has recalibrated the cooling thermostat setting to match Auliciems' neutral temperature. Williamson's paper was critical of NatHERS for not using these temperatures and this has now been addressed. Furthermore in AccuRate the occupants are assumed to wait until internal temperatures are 2.5°C above the neutrality temperature before commencing cooling. This behaviour is consistent with Williamson's research (Williamson and Riordan, 1993). In addition the software has been modified to predict air flows through houses when windows are opened and will not invoke cooling if this air movement makes the house 'feel' comfortable even if air temperatures are beyond the comfort zone.

Research undertaken by the author for the Australian Greenhouse Office (AGO) compares the cooling load predictions of AccuRate and NatHERS for a well ventilated house which has entire walls of window which fold away to promote ventilation and a standard spec house which has small windows with limited openable areas.. That is, it compares a house designed for effective natural ventilation against one that is not. The chart below shows one aspect of the findings:



The two houses are simulated in Sydney. Three cases are presented:

1. NatHERS predicted cooling load,
2. AccuRate predicted cooling load using the NatHERS model for estimating air exchange when windows are opened, and
3. AccuRate predicted cooling load using the new model for estimating air exchange when windows are opened.

The chart shows that AccuRate predicts a significant reduction in cooling energy load and that the reduction for the well ventilated house is much greater even when the old method for estimating air exchange is used. The new model does not predict significantly different cooling load for the typical house, however, cooling load is halved in the well ventilated house. Given these new findings it may well be that if assessed using AccuRate the houses presented in the paper would receive a more favourable rating. In this case the conclusion of the paper and case studies as presented by Soebarto, Williamson and others would no longer be relevant.

3.2.2 Specific comments on Kawanda Muna case study

This house has been the subject of a paper by a colleague of Dr. Williamson's as Adelaide University, Veronica Soebarto in a paper entitled: A LOW-ENERGY HOUSE AND A LOW RATING: WHAT IS THE PROBLEM? (Soebarto et al, 2000)

In this paper it is explained that after they moved in [presumably after the house energy rating was carried out] the owners have modified the house to reduce heat losses through the windows by applying a shrink wrap film to the window frames to, in effect, create double glazing, have installed weather strips to reduce air leakage and added external shading to reduce heat gains in summer. This would add in the region of one to two stars to the rating. It suggests that the performance of the house DID NOT initially meet the expectations of the owners. Importantly, this means that data collected on performance, as well as comments by the occupants, relate not to the house 'as rated' but to an improved house. Furthermore, simulations using an alternative simulation software tool showed the house to be "warm and uncomfortable (based on the standardised human comfort range)"[10]. Soebarto explains that "the occupants did not seem to feel that the house was warm as they were mostly out of the house during summer days"[11], but suggests "If the house was occupied all the time, however, the occupants may have had a different perception and the blinds may have been used to reduce the heat gain."[12]

No cooling is used in the house and heating is provided mainly through a wood fire. Based on estimates of wood consumption by the owner the annual energy use for heating is found to be 16.5 GJ. Occupants report that they heat only at night. By contrast NatHERS predicted 39 GJ heating per year.[13] Given that occupants heat only at night and heat only the living areas it is reasonable to halve the energy use predicted by NatHERS. In this case NatHERS appears to have predicted the heating load successfully once occupant use is accounted for.

Finally, the building contains a number of features that can not be modelled using NatHERS such as earth bermed walls and Trombe walls. It is therefore outside the scope of application of the rating tool. In this case compliance would need to be determined according to meeting Deemed to Satisfy prescriptive regulations or, more likely, by the expert opinion alternative approach, and a rating tool (probably with some sensitivity studies) might be used as one input to the expert assessment. It is therefore misleading to suggest this house could not be built under the BCA requirements.

The evaluation provided seems to lead to the opposite conclusion to the paper's title:

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[10] Soebarto et al, 2000, p 114

[11] Soebarto et al, 2000, p 114

[12] Soebarto et al, 2000, p 114

[13] It is unclear whether this energy use was predicted before or after the occupant improvements described above.

- Heating energy use is surprisingly well estimated given the reduced occupancy and the additional features which would reduce energy use but could not be modelled,
- Other simulation packages and the owners own experience seem to suggest the house is not comfortable in summer, and
- The modifications made to the house by the owners suggest it was not energy efficient as originally constructed.

3.3 Conclusion

Williamson's own data shows that there is evidence to suggest that the application of the rating will save energy because there is a link between consumption and simulated load when appliance efficiency effects are considered. All his work has proven is that which is already known: that the rating gives a greater weighting to summer performance because it does not adjust for appliance efficiency. In this respect the rating scheme is considering matters of public benefit which are beyond the 'individual benefit only' terms of reference of the Inquiry.

The case study information presented would only seem to identify that it is true that through conservative use a highly motivated occupant can achieve low energy bills. Given the many other features these buildings have implemented that would reduce the environmental impact of the house such as photo voltaic electricity generation, solar hot water, low embodied energy materials etc it would be reasonable to assume that the occupants are highly motivated. On this basis alone the case studies would appear to prove nothing.

Furthermore, the case studies do not establish that the houses would achieve low energy bills regardless of who was living in them or that the case study houses themselves performed well on the basis of comfort. It has identified that there may be a problem in the over-prediction of cooling loads but this has been accounted for in the next version of the rating tool.

Neither the case studies nor the field test support Williamson's central thesis that a regulation based on simulated loads will not save energy.

4 Research linking building fabric efficiency with energy consumption

The Productivity Commission's Draft report quotes from Williamson's submission which suggests there is no data linking energy consumption with the building fabric:

> "… the evidence submitted here based on data from surveys and case studies reveals that:
>
> - results are often counter intuitive (effects seem opposite to computer model predictions);
> - results are often confounding …; and
> - results are often inconclusive (small sample sizes, incomplete data of existing studies)[14].

The fact that some studies do not show a link between building element properties and energy consumption, given the variability of user behaviour and other factors is not surprising. However there are several studies where this link has been observed. This section reports some of these findings.

4.1 Gas and Fuel Corporation Gas Demand Management project in Victoria

The gas and Fuel Corporation undertook a number of significant studies of residential energy use in the 1980's and early 1990's. The Gas Demand Management Discussion Paper No. 9 released in December 1991 analyses the saving in gas heating due to the installation of ceiling insulation. This was a longitudinal survey of 300 houses households. It analysed the winter energy consumption of these households before and after they had installed ceiling installation. The project also surveyed these households to determine the type of heating, the extent of use in terms of rooms heated and times of operation and whether the occupants had changed the way they heat their houses after the installation of insulation.

Longitudinal studies give a much better indication of the impact of House Energy Ratings because they demonstrate how building fabric improvement affects the energy consumption of the same cohort of

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[14] Williamson, 2005,pp. 2-3

houses rather than try to draw inferences on energy savings by comparing different cohorts.

The study found that ceiling insulation did result in statistically significant energy savings at the 95% confidence level in centrally heated homes. The observed average saving of 22% is within the range of the full theoretical savings that might be calculated using heat flow analysis[15] indicating that there was little if any rebound effect.

The study also found that in space heated homes a saving of 6% was observed, but that this did not meet statistical confidence tests. This surprised the researchers who quote two earlier studies from 1982 and 1989 which found a statistically significant saving of 8%. Further they were confounded by the lower percentage savings as they had expected that the theoretical saving should approximate 25%. In fact theoretical savings can easily be closer to 13% in a space heated home because it there is proportionally less heat loss through the ceiling of a space heated home than a centrally heated home. See Appendix B for examples of these calculations. Furthermore the study failed to take into account the energy use of the space heater pilot light (around 4GJ per year or 15% of total consumption) and overestimated heating energy use. This overestimation was caused by assuming gas energy use for cooking and hot water is the same in summer and winter when monitored figures show this is not true (Coldicutt et al, 1983). This would casue an overestimation of heating in the order of 5 GJ for average hot water use. When this is properly accounted for the level of savings they actually observed is around 10% i.e. close to the full theoretical value. Had such adjustment been made at the time the study may well have found that the savings were statistically significant. Similar adjustment to the earlier studies which found an 8% saving would show that the full theoretical savings were obtained.

Because savings in space heating energy use had been lower than expected (erroneously as mentioned above) they also asked a number of questions to determine whether people had changed the way they used their heaters after the installation of insulation. The table below presents these results:

User	% of centrally heated homes	% of space heated homes

[15] See Appendix B for example calculations

behaviour affected	Increase	No change	Decrease	Increase	No change	Decrease
Hours of use	11	45	44	5	60	35
Heating thermostat	7	60	33	5	50	45
Area heated	17	76	7	21	71	8

The table above demonstrates that after installing insulation the majority of the sample did not change the way they use heating. For those households which did change most of them:

- reduced their thermostat setting: the better heat distribution afforded by insulation allows occupants to maintain the same temperature in the middle of the room with a lower thermostat setting when the insulation was installed. So they could set the heater thermostat to a lower setting while still maintaining the same level of comfort,
- reduced the hours of use: the ceiling insulation meant that the house did not cool down as quickly and so maintained comfortable conditions without heating for longer, and
- around 1 in 5 households increased the area heated.

The first two factors listed should act to reduce energy use while the increase in area heated will increase energy use. Taken together these changes to user behaviour suggest that there is NO SIGNIFICANT REBOUND EFFECT that can be associated with the installation of insulation in the GFC report. This is in stark contrast to the evidence submitted by Williamson and quoted by the Commission in their report.

4.2 Study of public housing in Tasmania

After earlier research projects into the energy use of public housing tenants failed to establish statistically significant trends in energy use Australian Housing Research Council Project 106 by Melbourne University (Coldicutt et al, 1983) was carefully designed to ensure that such effects could be observed. Earlier research used utility bills to estimate heating, hot water and other energy uses. This proved problematic because all energy uses are included in the consumption figures and consumption for individual appliances is difficult to estimate with accuracy. In this project, a sample of around 140 houses were fitted with meters which measured the energy use of individual appliances: off peak heating, auxiliary heating, hot water, lighting, cooking and general power for a period of 21 months. Meters were read on the same day for each house at monthly intervals. Householders were interviewed about the extent of their energy use and their understanding of and attitudes toward energy use. The sample was selected to include only a handful of house design types and only two types off peak heaters were used. This limited the variability of the sample in terms of heater type, area of house, design features and construction materials. Further the use of public housing tenants reduced the socio-demographic variability of the sample.

This study found that houses with wall and ceiling insulation used 12% less energy than houses with ceiling insulation only. This is close to the full theoretical value which again indicates that there is little rebound effect. Furthermore, respondents who considered that their living rooms received ‘plenty of light’ had a much higher proportion of north glass than the rest of the sample and used 14% less heating energy than other houses. This indicates that the north glazing when unshaded i.e. it ‘provided plenty of light’ led to significant heating energy savings.

Far from offering ‘counter intuitive’ and ‘confounding’ results this study demonstrates that when steps are taken to measure heating energy use directly and the overall variability of the sample is reduced statistically significant energy savings are observed due to improvements to the building fabric due to north glass and wall insulation.

4.3 Evaluation of the Home Energy Advisory Service in Victoria

The Home Energy Advisory Service was established in Victoria to provide energy saving advice and retrofitting for Commonwealth Health Card holders. To ensure the program was effective the energy use before and after receiving the service was analysed for 3000 clients i.e. a longitudinal study. Having a large sample allowed the researchers to ensure that the comparison of energy use eliminated other extraneous variables while still providing samples of sufficient size to ensure statistical significance.

The phase 2 report (DITR, 1985) showed that households who received ceiling insulation had 9.2% lower gas usage and 7.6% lower electricity usage indicating that supplementary heating using fans heaters etc. was also reduced. As described above, the full theoretical saving for a space heated home will be in the order of 13%, so again close to the full theoretical savings have been obtained with little or no rebound effect. This is a particularly important finding for if any sample is likely to be under-heating - and would therefore show potential for rebound - it would be those with lower incomes such as the clients of this service. It is evidence again that the rebound effect is not as large as many have claimed it to be.

4.4 Impact of retrofit wall insulation in the ACT

The ACT Government offers a rebate to those who install Cavity Wall Insulation. This product is a loose fill insulation which can be blown into existing walls. The ACT government engaged consultants to examine the impacts of the retrofit wall insulation on the energy use of a sample of households (Beckman, 2003). Over the 72 houses in the sample a total reduction in energy use for the 12 months after the installation of wall insulation energy saving including both gas and electricity was 15%. While this is less than the ACT Greenhouse plan forecast, it is in line with the theoretical savings that simple heat flow calculations would indicate. This aggregate saving was observed despite the fact that some households had installed new appliances, a small proportion of the sample admitting they had turned up their heater thermostat, and the fact that 1/3 of the houses performed other alterations to the house over the period.

4.5 Conclusion

The studies which Williamson refers to as showing counter intuitive or confounding results are generally not longitudinal studies which show the impact of changes to building fabric on the energy use of the same households before and after modifications. These studies also appear not to account for the variability of user behaviour and do not measure heating or cooling energy use directly. As shown in the Tasmanian study (Coldicutt et al, 1983) when the research design is modified to reduce sample variability and measure heating use directly a correlation between building fabric properties and energy consumption may be observed. Williamson claim that "There is little or no evidence to show that efficiency standards … will be in any way effective"[16] is seriously flawed. The research projects he refers to which do not show a link between building fabric properties

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[16] Productivity Commission, 2005, P 148

and energy consumption are hamstrung by their inadequate methodologies and he conveniently fails to mention the results of Australian studies with robust research design where significant effects are shown. Furthermore there is little or no evidence in Australian field studies supporting rebound effects that the Commission refers to with respect building fabric measures.

5 The use of simulated load in the evaluation of energy savings for Regulatory Impact Statements

The rationale for using regulation to deliver improved building fabric performance instead of other strategies has been documented in Regulatory Impact Statements. Indeed, the Australian Government in 1997 formally gave the Australian building industry a period of time to introduce effective voluntary measures to improve building energy efficiency. The industry, after various attempts, agreed that a regulatory approach was most practicable, as it provides a 'level playing field' and there is substantial infrastructure to support builders in achieving compliance. Regulation also reduces the risk for manufacturers who wish to introduce new products and systems that make achieving improved energy performance easier and cheaper, by creating new markets that value the features of their products and services.

A key argument in favour of using rating tools for building energy regulations is that they provide a means whereby designers and builders can achieve the required performance at least cost by trading off one element against another, as long as the overall result achieves the required level of performance. The evaluation for the 5 star regulations in Victoria showed that in fact the application of Deemed to Satisfy regulations is more expensive than performance regulations[17]. This has been shown to be more reliable, cost-effective and convenient than application of crude element by element requirements or 'deemed to satisfy' methods. The use of rating tools is consistent with policy that encourages regulators to apply 'performance based' regulation in preference to prescriptive regulation.

5.1 Constraint of energy savings predicted by rating tools to allow for other determinants of energy use

It is also not clear whether the Commission understands how the costs and benefits of improved fabric performance are evaluated for the purposes of regulatory impact statements. The rating is based solely on the energy load unadjusted for appliance efficiency and assuming a fixed, intensive user behaviour pattern. However, the estimates of energy savings used for

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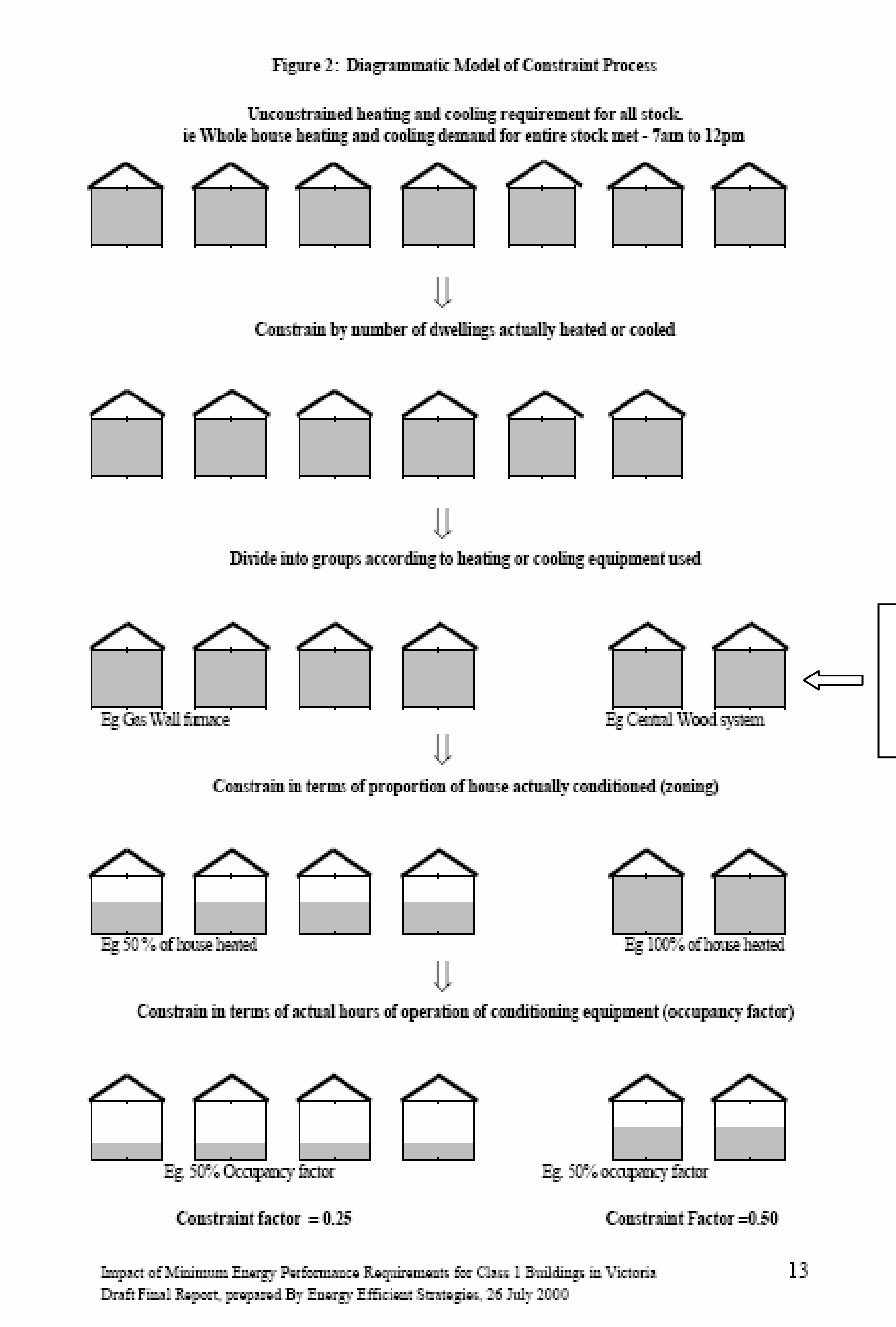
[17] Building Commission Victoria, 2002

RIS work are adjusted to reflect a variety of factors. This is shown in the diagram below:



Average appliance efficiency applied for each type of

Williamson's paper demonstrates that when adjusted for appliance efficiency the energy rated load does correlate well with energy bills. Therefore one can have some confidence that the private benefits estimated by the Regulatory Impact Statements are realistic because appliance efficiency is included. Furthermore, the other major determinants of energy use such as user behaviour including area heated/cooled and hours of use are accounted for in this analysis.

5.2 The use of average effects

RIS analysis shows the 'average' impact on households. The nature of an average is that half of households will receive greater benefit and half will receive less. It is therefore likely that some households will be negatively affected in terms of the balance of financial costs and benefits by the regulatory change. The Commission recommends that this RIS work should be revisited to "analyse the distributional impacts of standards on different socioeconomic groups, including first-home buyers and less-affluent groups". This suggests that there may be some groups who are permanently disadvantaged by the proposed regulations and that RIS work does not consider this. In fact a proper consideration of who will benefit and who will not would reveal that it is likely that each household will experience a variety of levels of benefit over the life of the household and that there is no single group who would consistently fail to derive benefit from the regulation.

A key determinant of the energy use of a home is occupancy. If the house is not occupied then in most circumstances the house will not be heated and cooled. Over the lifecycle of a family occupancy will vary considerably:

- The 'Dual Income No Kids' family: both partners in paid employment, occupancy mainly in evenings,
- The 'Young Family' where one parent is at home taking care of pre school children: house occupied all day, evening and there may be a demand for heating and cooling at night,
- The 'Established Family' where children are learning during the day and both parents may be in full or part time employment: house unoccupied during school hours. Note that though the house may be unoccupied during weekdays, if one accounts for weekends, public holidays, annual leave and sick leave the house is potentially occupied during the day 40% of the time.,
- The 'Empty Nest family' where children have left home and parents may both be working, but may also have chosen to return to study or start a business from home: occupancy variable, and
- The 'Retired family': occupancy all day and evening.

This analysis suggests that benefits will vary over the life of a household i.e. that the same households which currently derive little benefit are the same households who will derive the greatest benefit at different times of the household lifecycle. There are also times within these family phases where home occupancy – and therefore heating and cooling demand – may be greater, e.g. times of unemployment or illness.

When the home is occupied during the day it often means that one or more of the adults are not in full time employment. As a result the benefits of houses regulated to save energy will be greatest at those times when income is lower. The Regulatory Information Bulletin for the Victorian 5 star regulation makes reference to these effects. (Building Commission, 2003)

5.3 The conservatism of RIS work

The submission to the Productivity Commission by ICANZ criticises RIS work for being too conservative in the estimation of energy savings. The Federal Government predicts an increase in the ownership of air conditioners of 50% over the next ten years[18], while central heating ownership is also increasing. But this kind of trend involving increasing baseline energy use is rarely taken into account by RIS work. Furthermore, information on hours of use of heating and cooling is routinely taken from studies of heater and air conditioning hours of use by the ABS which is 20 years old and there is significant anecdotal evidence to suggest that today's use is significantly greater. These two conservative assumptions alone mean that the benefits of regulations are likely to be significantly higher than shown in previous RIS documents. As a result the proportion of households which do not (immediately) benefit from building regulations is likely to be significantly lower than the conservatively estimated average benefits would indicate, and the average savings are likely to be larger over time..

5.4 The value of ex-post studies into regulatory effects

There is no doubt that ex-post studies of the efficacy of building fabric regulations in reducing energy consumption would be useful. However, the Productivity Commission's finding that further development of regulations should be delayed until this work is done can not be supported. This recommendation appears to be virtually entirely based on the evidence

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[18] Energy Efficient Strategies, 2004

presented by Williamson's submission. As shown above not only is there evidence from field studies that building fabric improvement will be effective, but Williamson's own studies demonstrate this link when appliance efficiency is accounted for.

It is worth noting that NO GOVERNMENT IN THE WORLD has required the level of evidence the PC's draft report requires for building fabric regulation. Countries throughout the world have not only introduced regulations without conducting ex-post studies they have continued to increase stringency over time. This is because there is already evidence that such measures work from field studies such as those quoted above. Further, the simulation tools used in these countries to evaluate these impacts -which the NatHERS/AccuRate programs match in the BESTEST and IEA Empirical Validation Studies – have been shown to provide reliable results. These programs show that such substantial improvements in comfort are achieved through improving building fabric that it is inconceivable that this better house performance will not result in substantial energy saving even if it is not the full value of the savings that rating tools predict under standardised behaviour. This evidence together with the evidence from field studies is adequate for all other governments in the world and it is inappropriate for the Commission to call for a higher level of evidence in Australia before moving to further regulate building fabric performance. It must be noted that even the next round of building energy regulation for the residential sector falls well short of the standards required in locations with similar climates such as California.

Williamson quotes research from the US which compares energy ratings with consumption by Stein (Stein 1997) and finds no correlation between the two. It is interesting to note that the responses to this finding in the US were similar to those of Australian governments to Williamson's research:

> "**Rate the Home, Not the Occupants**--HERS rating tools assume typical occupancy assumptions relative to thermostat setpoints, internal heat gain, hot water usage, and other occupant related energy use factors (i.e. lights and appliance operating schedules and energy usage). The goal is to establish the energy efficiency of the home and potential for cost-effective improvements, not to establish the energy-consuming behavior of the occupants. Thus, I think it inappropriate to base an energy rating on utility bills. …
>
> "**Rating Tool Energy Cost Prediction vs. Utility Bills**--The goal of a HERS rating is not to match an existing home's utility bill. The home's occupants can influence energy costs by a factor of two. Rather, the rating tool attempts to predict likely

> energy use for the home under average or typical occupancy, just as the MPG test uses a standard driver protocol when establishing the MPG rating on a specific automobile."[19]

The relationship between ratings and actual energy consumption is well understood in those countries where these have been used as a technique for regulation building fabric performance. The supposed lack of correlation Williamson has observed is clearly not believed to important in other countries just as it is not a problem in Australia.

5.5 Energy efficiency regulation in context

Building fabric regulation also needs to be seen in the broader context of the various government policies and programs designed to reduce the energy use of households. It is true that the building fabric is just one element of the equation which determines the energy consumption of households. The other key effects, namely appliance efficiency and occupant behaviour have been targeted by other government programs:

Minimum Energy Performance Standards raise the efficiency of the worst performing appliances while star ratings help to promote more efficient appliances. The star ratings in particular have been so successful that for a number of appliance types the rating criteria have had to be revised to greater levels of stringency as there were simply no low rating appliances on the market. In terms of occupant behaviour all governments in Australia provide information resources for householders to assist them in containing their energy use. One such example is shown below. It is taken from a brochure was distributed to Victorian households to support the introduction of the 5 star regulations. It gives the following advice on appliance selection and user behaviour:

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[19] Michael J. Holtz, A.I.A.
Architectural Energy Corporation
Boulder, CO
<http://homeenergy.org/archive/hem.dis.anl.gov/eehem/98/980102.html>

A 5 Star house is more comfortable to live in, warmer in winter and cooler in summer, and can help reduce your heating and cooling costs. The extent of the savings will depend on you. Below are some tips to help you get the most out of your 5 Star home:

In winter

- Keep warm air in your house by drawing curtains on cold cloudy days and at night.
- Close windows and doors to avoid heat loss. Heating your home with a window open can increase your heating bills by as much as 25%.
- Reduce the area to be heated by closing doors to rooms which don't require heating.
- If you have central heating in your house you may be able to close off some vents. Check your manufacturer's instructions to see whether you can cut your heating and cooling costs this way.
- Every degree higher you set your heating thermostat adds 10% to your heating bill. Keep your heating thermostat to 21°C or lower.

In summer

- On hot days keep hot air out of your house by drawing curtains.
- Unless you have deep eaves above your windows, use external blinds to stop the sun from hitting east, north and west facing windows.
- When cooling the house set the airconditioning thermostat to 24°C or higher.

When choosing a new heater or air conditioner

- Select the product with the highest energy efficiency star rating.
- 5 Star houses need smaller capacity heaters or air conditioners. Make sure that your supplier sizes your appliance to take into account the fact that you are living in a 5 Star house.

The Productivity Commission's draft report states that:

> "Given that simulated energy loads exclude many of the determinants of building energy efficiency, it has to be asked whether building standards are an effective way to raise energy efficiency. Building standards may have little impact on actual energy efficiency, compared to, say, a policy that changes householder behaviour." (PC 2005, p 147)

This would seem to imply that governments have not explored other measures to influence energy consumption in housing when the large number of information sources available to consumers demonstrates this is clearly not the case. Further the assumption that the rating tools are flawed is based on Williamson's submission which has been shown here to be incorrect.

6 Conclusion

The PC draft recommendations have been framed in light of the evidence submitted by Dr. Williamson. This report shows that this submission has ignored studies showing contrary evidence and that the interpretation he offers of his own research is not substantiated by the data provided. Accordingly it is recommended that the Commission review its draft findings and recommendations in the light of the flaws this report has shown in Williamson's submission and the clear evidence field studies show supporting building fabric measures.

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Appendix A: Practical problems with including appliance efficiency in energy ratings

Extract from Isaacs et al, 2002:

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[20] 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 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

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[20] Pears, 1994

through the alteration of the house rating according to the efficiency of the appliance.

Appendix B: Simple heat flow calculations comparing the expected savings due to wall and ceiling insulation in space and centrally heated homes

The effect of ceiling insulation depends on the proportion of heat flow through the ceiling. Where this is the largest heat flow path energy savings will be high. However, where other heat flow paths are large the percentage savings observed will be lower. In a centrally heated home the proportion of total heat flow through the ceiling will be less if

- a timber floor is used instead of a slab because heat losses are lower through a slab floor,
- the uninsulated resistance of the ceiling/roof is higher because the air space above the ceiling is not well sealed as in an flat roof or a metal deck roof,
- the house is two storey and the ceiling therefore has a lower surface area, and
- the air leakage rate is high.

In addition the percentage savings due to ceiling insulation in a space heated home are likely to be lower because:

- Space heated homes are smaller and smaller homes have been observed to have a higher proportion of glazing in walls meaning that the total heat lost through glass as a proportion of the total heat flow is greater,
- Living areas are usually the spaces heated and these areas have a greater area of glass than bedrooms, and
- There are also heat losses to unheated areas through partitions and via air exchange.

The tables below show steady state calculations similar to those used by the Gas and fuel Corporation to determine the ‘theoretical savings’ due to insulation.

Case 1: Centrally heated, slab floor, unsealed attic, low air leakage, single storey

Uninsulated:

Element	Area	U value / AC* rate	Temperature Difference	heat flow
ceiling	200	2.5	12	6000
wall	112	2	12	2688
floor	200	0.67	12	1600
window	50	6	12	3600
air leakage	79.2	0.5	12	475
total heat loss				14363

* air change rate expressed in number of air changes per hour

Heat flows with insulation:

Element	Area	U value / AC* rate	Temperature Difference	heat flow
ceiling	200	0.4	12	960
wall	112	2	12	2688
floor	200	0.666667	12	1600
window	50	6	12	3600
air leakage	79.2	0.5	12	475
total heat loss				9323

Total savings 35.1%

Case 2: Centrally heated, timber floor, sealed attic, high air leakage, two storey

Uninsulated

Element	Area	U value / AC* rate	Temperature Difference	heat flow
ceiling	100	2	12	2400
wall	166	2	12	3984
floor	100	2	12	2400
window	50	6	12	3600
air leakage	316.8	2	12	7603
total heat loss				19987

Insulated

Element	Area	U value / AC* rate	Temperature Difference	heat flow
ceiling	100	0.5	12	600
wall	166	2	12	3984
floor	100	2	12	2400
window	50	6	12	3600
air leakage	316.8	2	12	7603
total heat loss				18187

Total energy savings: 9.0%

Case 3: Space heated, slab floor, unsealed attic, low air leakage, one storey

Uninsulated

Element	Area	U value / AC* rate	Temperature Difference	heat flow
ceiling	100	2.5	12	3000
wall	66	2	12	1584
floor	100	0.67	12	800
window	30	6	12	2160
air leakage	178.2	2	12	4277
partitions to unheated areas	54	0.5	6	162
air leakage to unheated areas				214
total heat loss				12197

Insulated

Element	Area	U value / AC* rate	Temperature Difference	heat flow
ceiling	100	0.4	12	480
wall	66	2	12	1584
floor	100	0.67	12	800
window	30	6	12	2160
air leakage	178.2	2	12	4277
partitions to unheated areas	54	0.5	6	162
air leakage to unheated areas				213.84
total heat loss				9677

Total energy savings: 20.7%

Case 4: Space heated, timber floor, sealed attic, high air leakage, one storey*

Uninsulated

Element	**Area**	**U value / AC* rate**	**Temperature Difference**	**heat flow**
ceiling	100	2	12	2400
wall	66	2	12	1584
floor	100	2	12	2400
window	30	6	12	2160
air leakage	178.2	2	12	4277
partitions to unheated areas	54	2	6	648
air leakage to unheated areas				214
total heat loss				13683

Insulated

Element	**Area**	**U value / AC* rate**	**Temperature Difference**	**heat flow**
ceiling	100	0.4	12	480
wall	66	2	12	1584
floor	100	0.67	12	800
window	30	6	12	2160
air leakage	178.2	2	12	4277
partitions to unheated areas	54	0.5	6	162
air leakage to unheated areas				213.84
total heat loss				9677

Total energy savings: 13.2%

* two storey option not evaluated for space heated homes as space heated homes are smaller and therefore less likely to be two storey, and in 1989 two storey construction was far less frequent

Comments with regard to the GFC Demand Management Study

The houses in the study were predominantly timber floored (70%). Over two thirds of the houses in the sample were constructed before 1984 and therefore most would have had wall vents and a significantly higher air change rate than houses constructed today. The energy savings observed in this sample would therefore trend toward the lower figures in the above cases.

Note that using the same methodology savings for wall insulation in the order of 10 to 20% for centrally heated and 10 to 12% for space heated houses are predicted.