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Productivity Commission Energy Efficiency Inquiry (Third Submission)

Introduction

One of the key questions in the inquiry on the question of building rating is: "…whether a building standard designed to reduce energy loads is effective in achieving the policy objective (improved energy efficiency that reduces greenhouse gas emissions)." (Draft report page 148)[3]

The commission needs to determine whether the evidence is strong enough now to continue with the proposed next stage of increases in required house rating (to 5 star) or whether we should wait for further evidence. Given that a question like this can't be proven conclusively, this decision needs to balance the risks of taking precipitate action against the very real risks of doing nothing. To some extent until we make the change we won't be able to prove that it was correct.

This paper summarises much of the data presented to the commission on this question and assesses the strength of the evidence, concentrating on the main points, to try and clarify the answer. To limit the time it will take the Commissioners to understand this issue I am limiting myself to studies that the commission has already been made aware of. As I neither participated in any of these studies nor am I involved in any aspect of the regulation of building energy use I believe I can make a reasonably unbiased assessment of these studies, tempered with my own experience of what actually happens in the market place.

The studies

Study	Strengths	Weaknesses	Conclusions	Comments
Gas and Fuel Corporation Gas Demand Management project in Victoria. From Isaacs[2]	Good sample size (300) [1] Longitudinal sample [2]	Used uncorrected household energy bills to estimate energy use [3]	Addition of ceiling insulation saves close to the full theoretical energy saving in a centrally heated home (what I call a capacity unconstrained home). In a space heated home (capacity constrained home) it saves close to the full theoretical saving when the calculation takes into account the loss of heat to other rooms, but about half of the percentage energy saving calculated by a rating based on the whole house.[4]	Strongly supports the premise that improving building energy rating will reduce energy use, **particularly when compared to projected growth in heating and cooling energy use.**
Study of public housing in Tasmania. From Isaacs[2]	Good sample size (140) given that variability within that sample size was minimised. [1] Separately metered heating (cooling not	Cross-sectional study [2] but the design of the study by restricting the variability of other factors allowed the energy savings to be seen without being swamped with	Showed that wall and ceiling insulated homes used 12% less energy than ceiling only insulation. Showed that north-facing windows do result in less heating energy use.	Strongly supports the premise that improving building energy rating will reduce energy use.

	relevant being Tasmania). [3]	'noise'.		
Evaluation of home energy advisory service in Victoria. From Isaacs[2]	Excellent size sample (3,000). [1] Longitudinal sample [2]	Appears to have used meter bills. [3]	In a space heated home (capacity constrained home) it saves close to the full theoretical saving when the calculation takes into account the loss of heat to other rooms, but about half of the percentage energy saving calculated by a rating based on the whole house.[4]	Strongly supports the premise that improving building energy rating will reduce energy use.
Case studies of award winning houses. From Williamson[4]	Located in many climate zones	Small sample size (6). [1] occupants not representative of the bulk of the population	Motivated individuals can make dramatic reductions in energy use particularly if they are prepared to accept greater temperature swings than the average preferred by the population as a whole. [5]	Outside the scope of the report as this is primarily energy conservation behaviour.
NEEHA project. From Williamson[4]	Reasonable sample size (146) although average sample size for each city is only 37. [1] Located in many climate zones	Self selecting sample.[6] Cross-sectional study [2]	The strongest correlations were for the type of and use of the heating and cooling plant and energy use.[4] A number of building features were shown to correlate with energy use, even given the large variability introduced due to the study design, and the skewed behaviour to be expected in the sample population.	Some support for the premise that improving building energy rating will reduce energy use. **Particularly when compared to projected growth in percentage of floor area heated and cooled.**
The ACTHERS Review From Williamson[4]		Small useable sample size (9).[1] Have used meter bills. [3] Cross-sectional study [2]	Suggests that the NatHERS calculations are an upper limit for energy use. Suggests there are two populations some houses following the NatHERS calculations but others may be dependant on plant capacity. Suggest that greenhouse gas production is a function of acthers rating, but sample size too small for statistical significance.	Some support for the premise that improving building energy rating using NatHERS will reduce energy use. **Particularly when compared to projected growth in percentage of floor area heated and cooled.**
Corroboration survey From Williamson[4]	Recent (1998-2001)	Cross-sectional study [2] small sample	When corrected for outliers, which are to be expected for a survey	Strongly supports the premise that improving

		size (31) for a cross-sectional survey with a wide variety of house types.[1] Have used meter bills although the analysis minimised the errors from this source.[3]	based on meter bills: Good support for the NatHERS calculations being an upper limit for energy use. Good support for there being a strong relationship between actual and estimated heating and cooling energy, in spite of the fact that the survey didn't correct for usage factor. The difference between the actual data points and the NatHERS line, is due to three items, experimental error, computer model error and the usage factor. I believe the largest of these is usage factor. When the 'constraint ratio' (what I call usage factor) from the AGO[1] is drawn in (Figure 1) it can be seen that nearly all data points have a larger constraint ratio than used in the projections, hence any RIS using the same data would be very conservative in its constraint ratio This is also strong additional support for my assertion that comfort expectations are increasing.	building energy rating using NatHERS will reduce energy use, **particularly when compared to projected growth in heating and cooling energy use.** Support that estimates of usage factor have been too low because of changes since data was measured. Many of Williamson's graphs for this study are plotting total figures (energy use, CO2 etc. against NatHERS MJ/m2 figures. This is not meaningful and the only relevant curves are either a total against another total or a per square meter value against another per square meter value.[7] This limits the discussion to Williamson's figures 4 and 7, both of which show correlations in the expected directions. This was inconclusive on the effect on greenhouse gases.

Notes

1. All other things being equal a larger sample size is better. However when comparing different studies you need to ensure that the large sample size has not been achieved at the expense of accuracy of measurement
2. A longitudinal sample (basically comparing before and after a change) has the advantage that it eliminates or significantly reduces many of the variables. For example even if on average the behaviour of the occupants changes this is likely to be representative of changes in the population as a whole and can be considered as a valid 'rebound effect'. It means it is not critical that the building stock sample is either controlled or representative of the building stock

in the wider population. It also reduces variations due to other factors like the presence of spa's and other heavy seasonal power draw items. (Of course this is not an issue if actual heating and cooling energy is metered). One disadvantage is that the results need to be corrected for differences in the weather between the before and after periods. The alternative is a cross-sectional study where different house designs are compared. With a cross-sectional study either the building stock must be representative of the stock as a whole, and behaviours must be uniform across the sample (unlikely) or the study must restrict the variability so that it can show that for a particular set of examples a particular trend can be seen. Another way of stating this is that a cross-sectional study is less likely to show a relationship as other variability will swamp small relationships, but if it does show a relationship then you know the relationship is probably strong and has broad applicability.

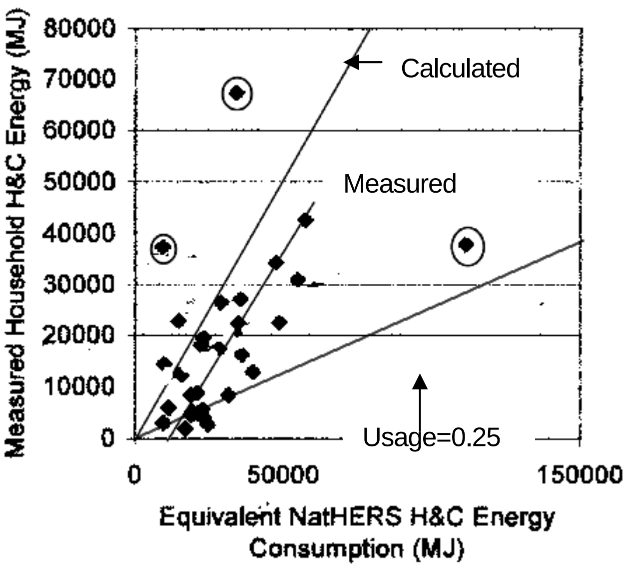

Figure 1 Equivalent NatHERS Energy Consumption vs Actual Energy Consumption (modified from Williamson [4])

3. Uncorrected energy bills tend to overestimate heating energy use and underestimate percentage energy savings because hot water, cooking and spas all use more energy in winter than summer. The ideal is separately metered heating and cooling.
4. NatHERS and similar ratings are based on the whole house, not the individual room, however although the percentage energy savings in a capacity constrained house are not as large as the savings based on the whole house, the resident does get additional benefits that all the evidence suggests they value. Because the heat which isn't saved passes into other rooms, this means those rooms are warmer than they would otherwise be. In addition the number of hours that the whole house is comfortable is increased as the improved building fabric traps internal heat and solar heat better. Finally there is a huge amount of evidence (some of which is detailed in my submission 108) that peoples expectations of comfort level and area they want heated and cooled is increasing (and has increased dramatically over the values used by most of the RISs. This means that future energy savings will approach the NatHERS calculation.
5. All the writers on this subject agree that occupant behaviour and occupancy profile are critical to actual energy use of a building. However occupant behaviour falls into several categories. One is behaviour, which is on the face of it irrational (for example leaving doors and windows open while heaters are operating). This behaviour can reasonably addressed by education if it is irrational or hardware (eg. Air to air heat exchangers) if there is a rational motive behind it. Other behaviour is rational, opening curtains in winter to let direct sunlight in. A third category is consciously choosing to accept a lower level of comfort. Although I personally am prepared to sit in an unheated room at around 18 degrees with a rug over my lap to keep my feet warm, I don't feel I have the right to impose that behaviour on others and if someone else comes into the room I would put the heater on to raise the temperature to around 20 Celsius. This action comes into the category that the commission calls energy **conservation** behaviour rather than energy efficiency behaviour, and is hence beyond the scope of the report. Although Williamson[5] in submission 133 argues that it is efficiency in the sense of being "…the ratio of satisfaction (output) and energy consumption (input)…", this is not what most people would understand from the term. More importantly, the majority of the population would not accept

these temperature swings being imposed on them and so this is not a useful strategy for overall energy reduction.

6. Where a sample is selected by responding to newspaper advertisements, the sample is self-selecting. This means they are all going to be interested in energy use and some are going to be passionate about it. This means that the behaviours of the sample are not going to be representative of the population at large with a much higher acceptance of energy conservation behaviour in addition to embracing energy efficiency behaviour.
7. I presume that Williamson keeps comparing for example total heating and cooling energy use with a per square meter NatHERS calculation because he is implicitly arguing that since that is the rating, it should correlate with energy use. However we know there is an area variation, and hence it is only meaningful to compare energy use with the corrected NatHERS value (with the area correction applied), unless you can show that for your sample there is no correlation between size of house and energy rating. (I suspect this data has a significant correlation.) In addition, you would need to show there was no significant relationship between type and size of heating and cooling equipment, and the energy rating, and no significant correlation between method of operation of the houses and star rating (unless you could reasonably argue that the differences in the method of operation were due to the differences in rating and not due to differences like wealth or stage in life cycle of the occupants). A re-examination of some of his data may in fact provide strong support for the application of an area correction in any the rating.

Discussion

The above experiments do show that computer predictions of energy use corrected for appliance efficiency are meaningful. It is difficult however to devise meaningful experiments to show whether computer predictions of energy use correlate with greenhouse gas production. This is because

1. The more factors affecting the outcome the larger sample size required. Greenhouse gas production is dependent not only on building rating but also on:
   - 1.1. Appliance efficiency
   - 1.2. Usage factor
   - 1.3. Floor area
   - 1.4. Appliance type (for example for the same energy delivered to the property, electricity will produce more greenhouse gas than gas will.)
2. If comparing old building stock with new building stock there are a number of factors, which are likely to be dependent on the stock and hide relationships. For example:
   - 2.1. New houses are more likely to have larger proportions of the house heated and cooled leading to greater greenhouse gas production for the newer house (even if it is a higher star rating). (I only claim that building rating will reduce the growth of greenhouse gas production, I don't claim it will lower it)
   - 2.2. New houses are likely to have a different mix of appliances (they are likely to be more efficient, but heating is more likely to be reverse cycle, leading to greater greenhouse gas production for the newer houses)
   - 2.3. People learn how to get the best out of their house over time, and someone who has been in a home for three or four years is likely to use less energy than someone who has just moved in. If the house is new, the occupants are in the learning period.
   - 2.4. Newer houses may have larger floor areas. (Leading to larger total energy use.)
3. Unless a researcher has an unlimited budget it is very difficult to devise an experiment that is both accurate and broad. In addition to do a longitudinal study is likely to take 4 years. If we want answers in less than a year the only way to do it is to use a cross-sectional study using metered bills. However as I have shown above, both of these add considerable uncertainties which tend to obscure any relationships (as other things are not kept equal). Another problem with a study is how to get a representative sample as unless you are in a position to force people to participate (or at the least are able to offer a strong inducement in order to get a good response rate) you are left with self selection which is definitely not representative. For these reasons I think it is unlikely that an accurate broad based study can be undertaken in the time-scale required to fully assess the proposed changes to the building code. However I am not arguing we shouldn't conduct what research we can in the time available, just that we shouldn't expect more from the research than it is capable of giving in the time available. This does also suggest we need to simultaneously start planning longer term research that is broader based, with the intention of seeing if an even higher level (say 6stars) will be economically justified in the future.

Although greenhouse gas emissions have not been estimated for many of the studies, it is highly likely that those studies which have similar appliances throughout the study, would show a corelation between energy saving features and greenhouse gas emissions. The acthers study suggests a relationship but the study size is too small for that to be statistically significant, however it is suggestive that a larger study probably would show a statistically significant relationship (note again that this study has the same fuel for heating in the majority of houses). In the corroboration survey no significant correlation was observed, but as I have shown there are a number of possible explanations for this. In other words this study is inconclusive on the question of whether energy rating reduces greenhouse gas production. What these studies do illustrate is that building rating alone is not sufficient to determine greenhouse gas production. It needs to be used in conjunction with strategies to address appliance efficiencies, appliance mix and user behaviour.

It seems to me it is unreasonable to ask the building rating to do something that it wasn't designed to do. For example we don't expect (or shouldn't) the energy rating of air conditioners to predict the energy use of the air conditioners. We only expect that all other things being equal, the energy use of the air conditioners would depend on energy rating. The problem is by definition, in a broad-based study, you are not keeping everything else equal. In the narrower studies quoted by Isaacs[2], other items can be kept equal or randomised out and hence the relationships are much clearer and show that computer predictions can give a reasonable estimate of actual savings, and for a given mix of appliances it will produce a corresponding reduction in greenhouse gas production.

Conclusions

1. There is strong experimental evidence that a number of well-known actions, do correlate with energy use and that the actual energy use correlates reasonably with computer predictions. These include:
   1.1. Ceiling insulation
   1.2. Wall insulation
   1.3. North facing glass
   1.4. Etc.
2. There is reasonable experimental evidence that NatHERS predictions correlate with heating and cooling energy use corrected for appliance efficiency.
3. The NatHERS predictions are an upper limit, however the data suggests that these days it is not far from the average relationship. Importantly it has a similar slope, so reducing the NatHERS predicted energy use should reduce the actual energy use.
4. All the data we have suggests that the usage factor (constraint ratio) is increasing rapidly (both from the data above and from other data presented to the commission).
5. The above two points mean that in the future the actual energy use will become closer to NatHERS predictions.
6. There is strong evidence that the assumptions in the AGO study[1] (and any RISs using the same data) are very conservative and more closely represent a minimum, not the average. From this it seems highly unlikely that many people were economically disadvantaged by making the fabric overly efficient under the first round of building rating requirements and any who were, only by a tiny amount. On the contrary, since recent data suggests the average person uses much more energy than assumed, it is probable that a significantly better fabric is cost justified.
7. The experimental data supports the argument that the minimum star rating should be increased. Because the trends are for increasing usage factor, and over time for the minimum usage factor to increase. (People pull out a space heater to put in ducted heating all the time, but I have never had a client pull out ducted heating to replace it with space heating! This means that even if a higher rating disadvantages a small number for a while (if ignoring the incidental benefit of reduced hours outside of the comfort zone), it is likely that within a reasonable length of time their usage factor will increase and they will recover the extra investment.
8. Minimum house energy rating is not the only strategy to use to reduce energy use and greenhouse gas production. It needs to be used in conjunction with strategies to address appliance efficiencies, appliance mix and user behaviour.

References

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