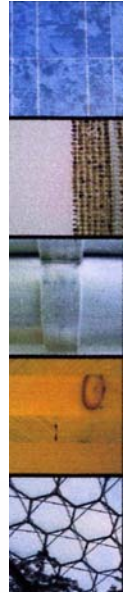


AECB

the sustainable building association



MINIMISING CO2 EMISSIONS FROM NEW HOMES

**A review of Building Regulations methodology:
How much energy will *actually* be saved?**

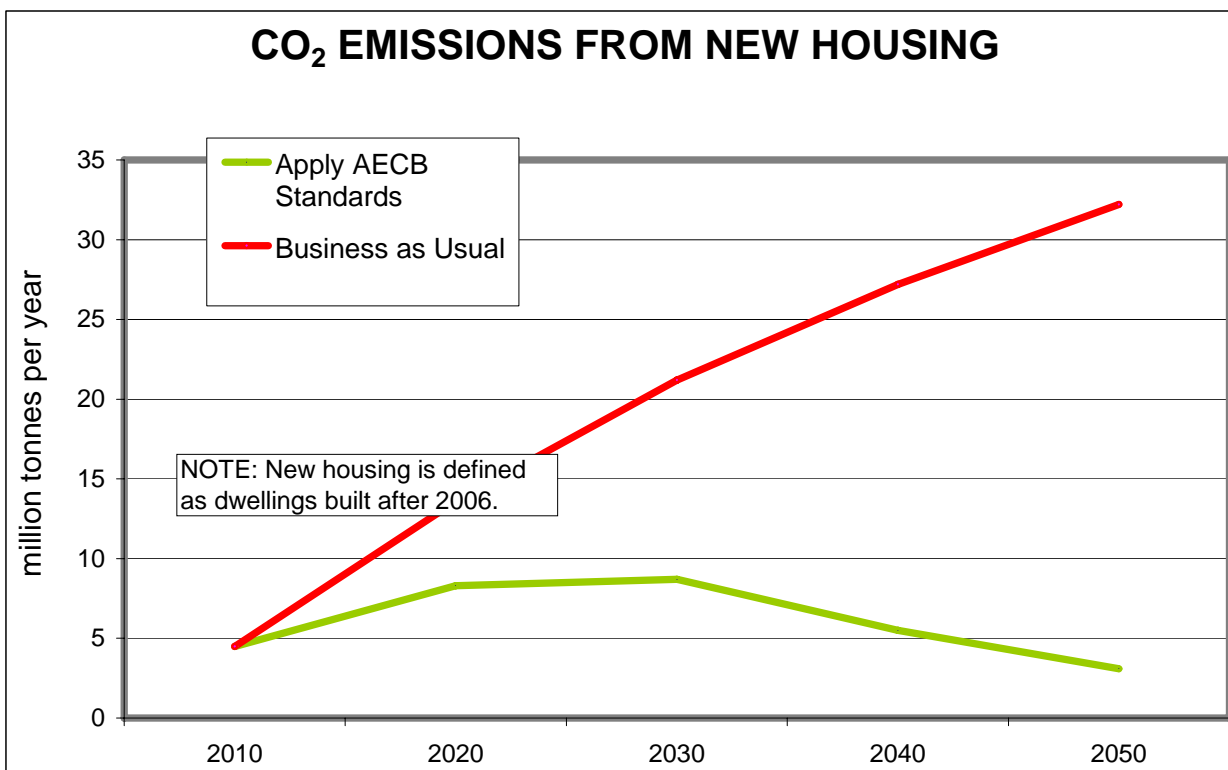
February 2006

EXECUTIVE SUMMARY

Domestic energy demand is rising. This groundbreaking research demonstrates that we are:

- *significantly* underestimating future energy use in new homes;
- passing up once-in-a-generation opportunities to make large low-cost savings in CO₂ emissions from new homes;
- one-third of the homes which will exist in 2050 will be built between now and then so that storing up large and avoidable rises in CO₂ emissions -

An integrated programme of high energy performance standards for new homes would save cumulatively the emission of 600 million tonnes of CO₂ by 2050 compared to business as usual. This is around four years' total emissions from the domestic sector at



current levels.

The proposed programme applies to new dwellings only. The application of the Standards to non-domestic buildings, or to existing buildings of either category, would further increase the saving.

The report demonstrates that the UK appears to be underestimating the potential savings from improved thermal envelope standards in particular, and improved energy efficiency standards in general. This discrepancy risks distorting UK energy and climate policy.

Using a semi-detached house for the analysis, it is possible that space heating energy use for dwellings built under the 2002 Building Regulations (ADL1-2002) could be more than double what is currently calculated using Standard Assessment Procedure ((SAP) - 2001/BREDEM).

It is possible that space heating energy use under the 2006 Building Regulations (ADL1-2006) could be 40% higher than what is currently calculated using the updates SAP (SAP-2005/BREDEM).

It is possible to meet ADL1-2006 using U-values that are improved by as little as 10% relative to ADL1-2002. This clearly does not represent the step change in energy efficiency which is being claimed by government.

The limitations of the Total CO2 Emissions Rate (TER) methodology include the fact that it *excludes* around 30% of domestic CO2 emissions - electrical appliances and cooking - and the fact that the SAP documentation omits many simple, cheap energy efficiency measures which have not yet been implemented in the UK.

MINIMISING CO2 EMISSIONS FROM NEW HOMES

Recommendations are made for the development of a national approach for constructing high-performance homes with low energy use and low CO2 emissions¹

A paper from the AECB

Authors: Liz Reason, David Olivier

Introduction

1. During the course of 2005, the AECB was in discussions with EST about the Trust adopting as its revised Energy Efficiency Best Practice standards, the AECB's own Silver and Gold Standards for building energy performance. These standards, if implemented in full, would lead to a reduction in CO2 emissions of 70% and 95% respectively against emissions from an average home. The EST and AECB were developing an ambitious programme of rapidly improving standards, leading to the Gold Standard being integrated into Building Regulations for all new homes possibly as soon as 2016.
2. The EST then asked its Programme Manager, BRE, to prepare a consultation document on the standards. When the document was complete, the Silver and Gold Standards represented headline CO2 emissions savings of just 40% and 65%. The AECB was surprised by this development so undertook detailed analysis of BRE's proposals.
3. The aim of this paper is to set out what the AECB's research showed and to demonstrate why the AECB Gold and Silver Energy Standards differ significantly in their energy and CO₂ performance from the "Silver" and "Gold" Standards developed for EST. *More importantly, our research shows how energy and climate change policies are in danger of being distorted by failures to correctly predict and measure building energy performance.*
4. The paper is written by a non-technical author for non-technical readers.

Background

5. Climate change is becoming the over-riding imperative of energy policy. Climate change is the main reason for the government's latest Energy Review², the principal aim of which is to explore the case for a new generation of nuclear power stations. The review also aims to assess other policy options for reducing CO2 emissions. It is

¹ This paper is the first of three. The other two are: 1. 'How much energy do the Building Regulations save?' and 2. Response to the EST consultation on its proposed new Best Practice standards.

² Announced on 23rd January 2006

taking place in a context of rising emissions and concern that the UK will not meet its self-imposed target of 20% reductions over 1990 emissions by 2010.

6. Every technology that can reduce CO₂ emissions needs to be rigorously analysed for its effectiveness, assessed for the cost of saving each tonne of CO₂, and policies must be carefully designed and implemented to ensure that theoretical savings are matched in practice.
7. Policy development – like any development in science – is a three-part process:
 - a hypothesis - a theory to be proved or disproved by reference to facts
 - experiments - undertaken to test a theory
 - measurements – derived from the tests to provide the facts against which to prove or disprove the theory
8. This three-part process can be likened to a three-legged stool. If one leg is missing, the stool is not fit for purpose.
9. If we are to manage our emissions down to the target set by government (currently 60% by 2050), we need to predict future emissions accurately. If we underestimate emissions from any sector, emissions will be higher than expected, and we will not meet the target, with all the risks inherent in that outcome.
10. The domestic sector is responsible for over 25% of emissions. Domestic energy demand has been growing faster than demand from the transport sector, CO₂ emissions are starting to rise again, and they are predicted to rise further - particularly due to plans to build millions of new homes over the next decade to meet growing demand for new households and population growth.
11. This paper explores some of the reasons why domestic energy demand is rising and summarises work which demonstrates that we are:
 - *significantly* underestimating future energy use in and emissions from homes
 - passing up opportunities to make large low-cost savings in emissions from new homes
 - storing up large and avoidable rises in CO₂ emissions.

The art (or science?) of estimating emissions from new homes

12. Building homes is becoming an increasingly scientific process. Where houses may have been built to provide shelter from wind and rain, they are increasingly required to keep us at a comfortable temperature when outside temperatures are either hot or cold. They provide the space that supports many elements of our lifestyle including high standards of hygiene, entertainment, communications and work.
13. The objectives of Building Regulations were originally related to health and safety issues; the energy performance of buildings was not introduced until the 1970s.

BREDEM³ was developed in the early 80s as a tool for modelling energy use in homes and has since been used to estimate energy savings from higher standards of energy efficiency in buildings. SAP⁴ was developed in the 1990s as a tool for architects and builders to calculate whether their designs meet the energy and CO2 performance targets set by the Building Regulations.

14. The underlying data for BREDEM was gathered during the course of government-sponsored programmes for monitoring energy use in homes in the late 70s and early 80s. These included half-hourly monitoring of indoor and outdoor temperatures, detailed records of heating and water use and controls, and social studies of how people lived. These programmes have not been repeated since, so over the last 20-25 years and five successive amendments to the Building Regulations, the data on which BREDEM is based have gradually moved away from real measurements to theoretically calculated data. Emissions reductions which are expressed as a saving of one set of Building Regulations over another, e.g ADL1-2006 over ADL1-2002, are in effect comparing theory to theory.
15. Does this matter? Yes it does, and for three key reasons. First, the monitored data gathered in the early 80s was based on homes with relatively little insulation. (For example, homes built under the 1976 regulations had no cavity wall insulation.) Second, lifestyles have changed dramatically in the intervening years with behavioural changes (e.g. higher indoor temperatures, daily showers) and appliance use multiplying. BREDEM's assumptions on temperature are unsupported and energy use by cooking and appliances is currently omitted from the model. Third, it is now widely understood that many new homes do not comply with Building Regulations. This is due to design errors, building defects and failures in enforcement, all largely based on a poor understanding on the part of those implementing the regulations as to how energy is used by and in buildings. Two short studies by the Energy Efficiency Partnership for Homes have provided evidence for this.
16. What this means in practice is that **the model has been gradually departing from reality**. To take our earlier analogy, the third leg of the stool has been taken away. As the examples described below will demonstrate, it seems that energy use in new homes and the savings available from improved insulation and airtightness are being underestimated significantly. So the Building Regulations are *masking* opportunities for real reductions in emissions which could go beyond the 60% target to 90% or more.

³ Building Research Establishment Domestic Energy Model

⁴ SAP (Standard Assessment of Performance) is a multi-layered spreadsheet with assumptions based on an underlying computer model – BREDEM – and on results from past building research.

The AECB's Gold and Silver Standards

17. The standards proposed by AECB, if implemented in full, would reduce emissions from new homes built to the Silver Standard by 70% and from homes built to the Gold Standard by 95%.
18. How did the AECB arrive at its standards for the energy and CO₂ performance of homes? First, they applied their experience of building low energy homes, of how to calculate energy use from different design elements, as well as what can be achieved with high standards of construction. With their Silver Standard, they looked closely at what had been achieved abroad in, for instance, Canada and Switzerland. Second, they based their Gold Standard on the German Passiv Haus standard, the energy and CO₂ performance of which is validated by measurements from hundreds of homes. Third, they took a baseline of real data from which to calculate their estimated emissions reductions.
19. The baseline data used were derived from DTI statistics for delivered energy to the domestic sector for 2003. This was done for convenience, but any baseline data could be used - provided they are real, monitored data.

Comparing EST's and AECB's Gold and Silver Standards

20. At present, the base case adopted by BRE for its consultation document on the EEBPH standards is the predicted energy consumption of a dwelling built to ADL1-2006. Compared to this baseline, BRE's predicted savings for Bronze, Silver & Gold are respectively 0-10%, 40% and 65%. *However, these reductions are based on the TER⁵; they are **not** reductions in total energy use or CO₂ emissions.*
21. AECB Silver and Gold are required to deliver around 70% and 95% CO₂ reductions versus the average dwelling stock. We know how much energy the dwelling stock consumes and how much CO₂ it emits. So by comparing Silver and Gold to this baseline, AECB is able to compare fact to fact. The methodology adopted by EST/BRE compares theory to theory, but theories which are increasingly departing from reality.
22. For the purposes of developing a joint set of standards, it would be necessary for all parties to adopt a common base case for comparison. The AECB is using the average delivered energy per unit area for the existing UK dwelling stock in 2003 of 278 kWh/m²yr and the associated CO₂ emissions. An alternative would be to use the figure which applied to the dwelling stock in 1990 - the base year for the Kyoto Treaty. The principle is that, *in the absence of monitored data*, other broad national statistics provide the nearest substitute.

⁵ Target Carbon Emissions Rate (or TER) is a CO₂ emissions rate for the dwelling's space and water heating and lighting, measured in units of kg CO₂/m².yr. (It excludes energy used for cooking and appliances.) The TER for the 2006 Building Regulations is set at 20% below the CO₂ emissions rate of a 'reference dwelling', whose characteristics are provided by ODPM in an Appendix to Part L.

23. It was trying to understand what had driven these different outcomes that prompted the AECB to undertake the detailed analysis of which a summary is provided below.

Results for BREDEM and SAP

24. So far as we can tell, SAP seems to be giving imprecise predictions (especially for space heating energy) in the following circumstances albeit for a variety of different reasons:

1. *Old dwellings*: it can over-predict space heating energy if one uses the standard SAP heating pattern because old dwellings are often heated to a lesser standard than modern ones; this is an understandable compromise between running costs and thermal comfort on the part of the occupants of older dwellings;
 2. *Contemporary dwellings*: it under-predicts space heating energy because:
 - a. actual U-values are poorer than assumed due to the presence of substantial additional thermal bridges (design and construction details that provide opportunities for cold/heat to travel through the thermal envelope);
 - b. actual air leakage is worse than the algorithm suggests;
 - c. workmanship is imperfect, leading to some air movement within and around the insulation layer;
 - d. mean 24-hr daily internal air temperatures in modern houses exceed the level assumed;
 - e. other thermal defects are present;
 - f. and so on.
 3. *“Future” dwellings such as Silver or Gold*: some energy efficiency measures, which are included in the AECB Silver Standard are not listed or available in SAP-2005. Some settings for lighting or ventilation system efficiency which would be appropriate to Silver or Gold are not available, causing SAP to over-predict electricity consumption. Passive solar design is poorly dealt with, causing SAP/BREDEM somewhat to over-predict gas or oil demand if a dwelling has generous south-facing glazing and high thermal capacity. Geometric thermal bridges become more significant in well-insulated dwellings, causing SAP to under-predict space heating energy.
25. Figure 1, which shows our preliminary results, demonstrates the differences in predicted energy use for the different standards compared to the average for the UK dwelling stock.
26. Figure 2 shows the resulting CO2 emissions compared to the average for the UK dwelling stock.

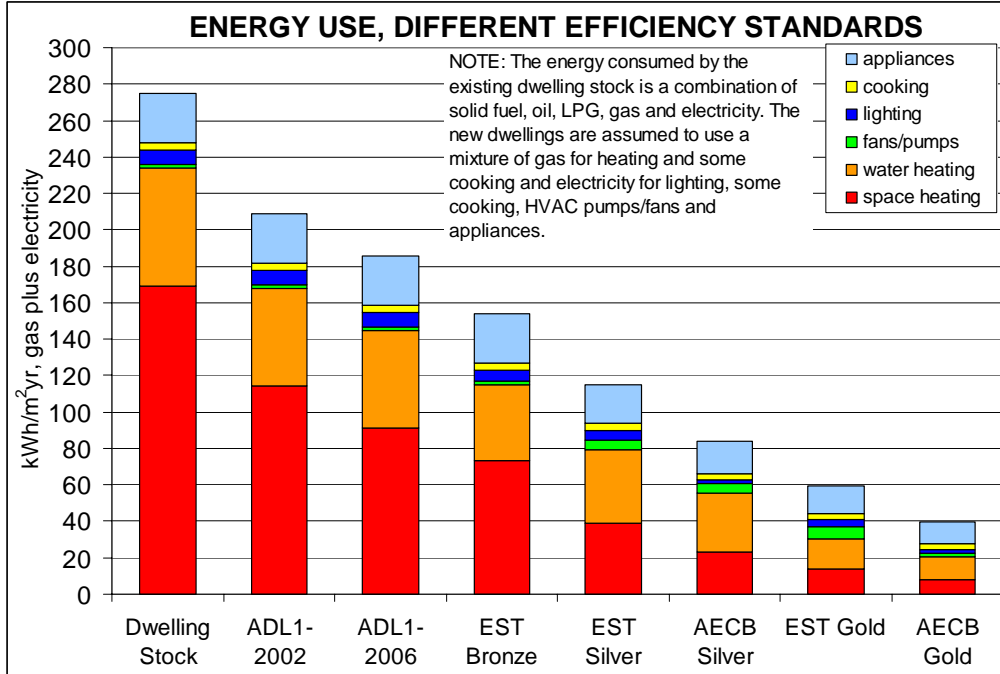
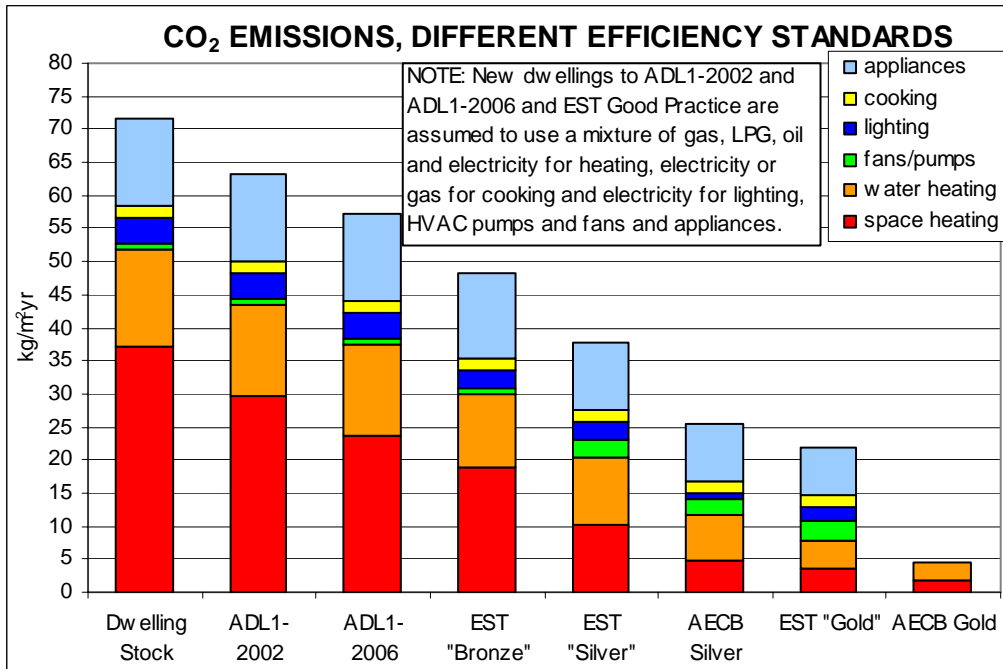
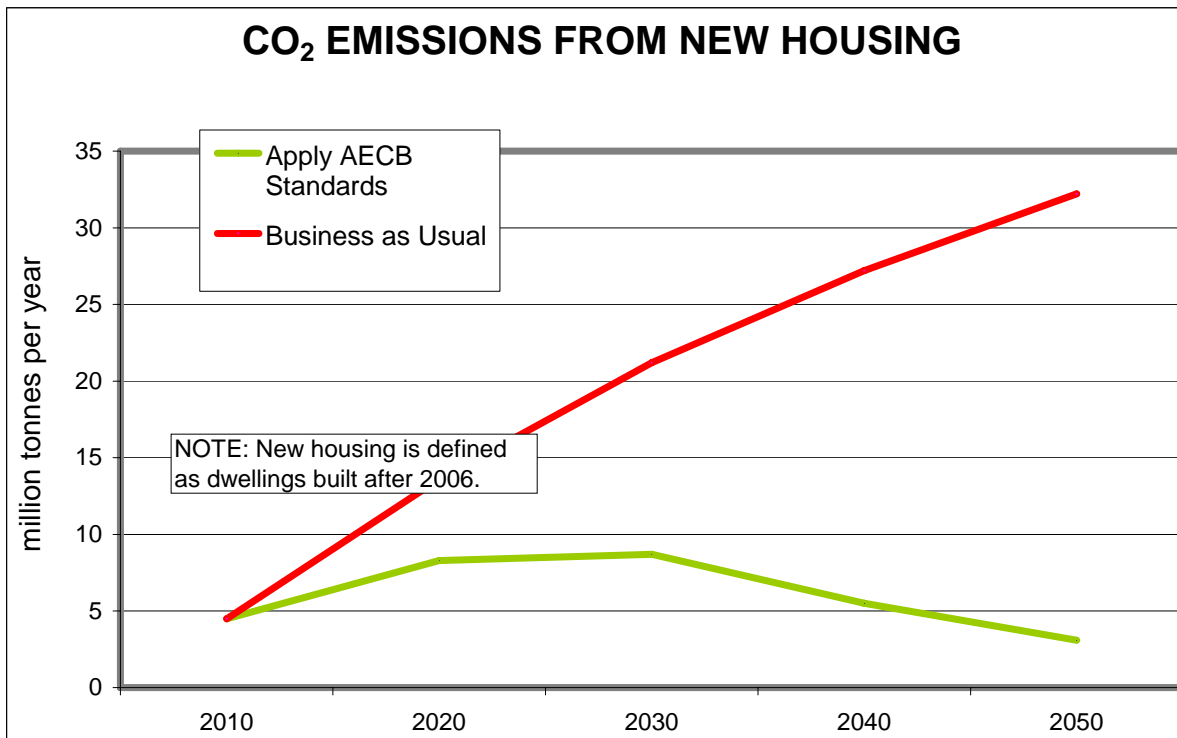


Figure 1. Comparative Energy Use, Different Energy Efficiency Standards



27. When the energy saving between the EST and AECB standards is translated into CO₂ emissions, the AECB Gold and Silver Standards would lead to CO₂ emissions 35% and 30% lower respectively than the EST Gold and Silver standards.
28. The above programme would save cumulatively the emission of 600 million tonnes of CO₂ by 2050 compared to business as usual. This is around four years' total emissions from the domestic sector at current levels.



29. This figure refers to new domestic buildings only. The application of the Standards to non-domestic buildings, or to existing buildings of either category, would further increase the saving.

Main conclusions

1. The UK appears to be underestimating the potential savings from improved thermal envelope standards in particular and improved energy efficiency standards in general. This discrepancy risks distorting UK energy and climate policies.
2. Using a semi-detached house for the analysis, it is possible that space heating energy use for dwellings built under ADL1-2002 could be more than double what is currently calculated using SAP-2001/BREDEM.
3. It is possible that space heating energy use under ADL1-2006 could be 40% higher than what is currently calculated using SAP-2005/BREDEM.
4. It is possible to meet ADL1-2006 using U-values which are improved by as little as 10% relative to ADL1-2002.
5. The limitations of the TER methodology include the fact that it *excludes* around 30% of domestic CO2 emissions - electrical appliances and cooking - and the fact that the SAP documentation omits many simple, cheap energy efficiency measures which have not yet been implemented in the UK.

Main recommendations

1. If we are to meet our climate change targets, the proposed standards need to be more ambitious than those currently being proposed by EST.
2. The calculation methods need to be reviewed to ensure that they are appropriate for low energy buildings. We need to count *everything*, if we are to succeed in building what we think we are building!
3. We need to publish a pattern book of simple, high-performance solutions.
4. We must gather and publish more much information on what actually happens in practice.
5. We should concentrate on getting the passive energy measures right before we add expensive kit – *build in, not bolt on*.

Detailed recommendations

6. We need to agree a base case against which the energy and CO2 performance of these standards is expressed.

7. We need to resolve the flaws in current methodologies by agreeing realistic conventions and methods which properly describe the physical reality of how a dwelling is designed and built.
8. We should start immediately a programme of monitoring, on a simplified basis, to establish real fuel and electricity use in a random sample of modern homes.
9. The main documents needed to support a higher standard include a technical specification and extensive guidance on suitable details.
10. SAP-2005 worksheets need to expand their coverage of energy efficiency technologies in order to give realistic results for international good or best practice standards; e.g., AECB Silver and Gold™, also EST “Gold” and possibly “Silver” Standards.
11. The AECB proposes defining the standards as:
 - a. Prescriptive versions of AECB Silver and Gold
 - b. Performance versions of AECB Silver and Gold expressed as
 - i. maximum kWh/yr of gas (or other fuel) and electricity, and
 - ii. maximum kg/yr of CO₂ and possibly primary energy
 - iii. both i. and ii. need to quote the size of the dwelling in m².
 - iv. the standards would retain the maximum fabric U-values quoted in the prescriptive versions of Silver and Gold, because the fabric cannot be retrofitted later⁶.
12. A Bronze standard could be positioned midway between the savings that will be achieved by ADL1-2006 and by Silver. So if ADL1-2006 saves, say, 25% versus the dwelling stock, and AECB Silver saves 70%, Bronze should aim at saving 45%, again using realistic assumptions and calculation methods.
13. The agreed energy performance methodology should be applied to the Code for Sustainable Homes with mandatory energy standards at levels 3 and above.

⁶ The AECB has listed since 2004 several documents which would need to be produced to support users of the standards, plus other actions.