AECB ENERGY STANDARD(S)

PRESCRIPTIVE VERSION

David Olivier 08.02.06

SUMMARY

This document sets out the rationale for the proposed AECB energy standards for new buildings. It outlines what levels of energy efficiency and renewable energy use they would require.

AECB believe that the government's target of a 60% reduction in CO_2 emissions by 2050 is too little, too late. Climate change demands a reduction of at least 85%. On reasonable assumptions, if the Silver Standard ™ became the norm for new buildings after 2010, and the Gold Standard ™ were the norm for new buildings after 2020, the UK's buildings could achieve this goal.

1. INTRODUCTION

The Energy Standards would provide two levels for AECB members to strive for. On a particular project, they may want to be pioneers, or they may wish to stick to more established technology and avoid risks. The standards give them the choice of doing both.

Either energy standard leads to such large CO_2 savings that it would markedly reduce future atmospheric CO_2 concentrations, assuming that it is applied *widely enough and quickly enough*. Thus two buildings which meet the Silver Standard ™ in full would save even more fossil fuel, and reduce CO_2 emissions even faster, than one building which meets the Gold Standard ™ in full.

2. CLIMATE CHANGE

Under the Kyoto treaty, the UK agreed to reduce its CO_2 emissions by 12.5% by 2012 relative to their 1990 level. In the Energy White Paper of February 2003, the government committed the UK to a 60% reduction in CO_2 emissions by 2050, compared to emissions in 1990. But there is growing doubt that the UK can meet its Kyoto obligations; after a period of decline, CO_2 emissions are now rising again.

More fundamentally, whether or not we meet the Kyoto target, we doubt that the UK's target of a 60% reduction is great enough to contain climate change. The 60% target is contained in a 2000 report from the Royal Commission on Environmental Pollution (RCEP). The RCEP report seems to misinterpret the International Panel on Climate Change (IPCC), which said some years ago that "an *immediate* 60% cut in CO_2 emissions" is needed *worldwide*.

Assuming a 60% worldwide cut in CO_2 emissions *and* allowing for the needs of developing countries, which cannot develop *and* make a 60% cut in emissions, most experts who have looked into the subject conclude that developed countries need to emit 80-90% less CO_2 by 2050. This major reduction in emissions by developing countries would be matched by smaller reductions in CO_2 emissions by developing countries. The result would be a weighted average reduction of 60% worldwide.

AECB support this argument. We believe that the UK should aim for at least an 85% reduction in CO_2 emissions by 2050. To be reasonably certain of meeting this goal, irrespective of minor pitfalls along the way, the target set now would need to be 90% less. This is an average reduction of 4.5% per year.

3. BUILDING ENERGY USE AND CO_2 EMISSIONS

Table 1 sets out UK energy consumption in the year 2000 compared to 1990.

Table 1. UK PRIMARY ENERGY CONSUMPTION (TWh/year).

SECTOR	**1990**	**2000**	**UNITS**	**GROWTH RATE**
1. Domestic buildings	767	913	TWh/year	+1.7%/year
2. Commercial and public buildings	423	530	TWh/year	+2.2 %/year
3. Industrial sector	794	736	TWh/year	-0.7%/year
4. Transport sector	662	766	TWh/year	+1.4%/year
TOTAL	2647	2945	TWh/year	**+1.1%/year**

NOTES:

1. Item 3 includes industrial processes themselves plus heating and lighting of industrial premises; e.g., offices and warehouses. So part of item 3 is also a buildings-related energy use; it is not entirely energy use for industrial processes.
2. As total UK energy use is rising, only an extensive shift from coal and oil to natural gas as a source of energy has prevented CO_2 emissions from rising in step. They fell by almost 10% in the 1990s but they have risen in three of the last four years.

Source: David Toke and David Olivier, *Alternative Energy Review*. Report compiled for the Green Party of England and Wales (March 2003). See www.greenparty.org.uk/files/reports/2003/aer_2003.pdf

As Table 1 shows, buildings make up ***the UK's fastest-growing source of CO_2 emissions***. Energy use by the domestic sector is rising faster than energy consumption by the transport sector. Energy use in non-domestic buildings is increasing as fast as fuel for air travel. The UK's dwellings consume *three times* more energy than the UK's private cars.

What happens if we require the buildings, transport and industrial sectors all to reduce their CO_2 emissions by 85% by 2050. Could we achieve a 85% reduction from domestic, commercial and public buildings?

Today's UK housing stock comprises some 25 M dwellings. We are constructing between 150,000 and 200,000 new dwellings per year. This rate needs to increase to deal with housing shortages. The rate of demolition is minimal, although it may increase. So let us assume that the rate eventually increases to 280,000 dwellings/year.

These trends could combine to give a stock of over 35 M dwelling units by 2050, a 1.5-fold growth from today. If the dwelling stock grows in total floor area by 50%, then to reduce total CO_2 emissions by 85% we have to reduce CO_2 emissions per unit floor area by 90%.

A possible way to meet the goal is to set the following three targets, of which targets 1 and 2 apply to new dwellings while target 3 applies to the existing dwelling stock:

1. New dwellings 2010-20 must have very low CO_2 emissions, say 30% of today's;
2. New dwellings 2020-30 must have almost zero CO_2 emissions, say 5% of today's;
3. New dwellings 2030-2050 must have zero net CO2 emissions.
4. Within about 50 years, we must modify the existing stock to reduce its CO_2 emissions per unit floor area by 90%. Assuming that renewables supply 65% of the UK's energy by 2050, this amounts to reducing existing buildings' overall energy use by about 70%.

The proposed AECB Silver Standard would be consistent with efforts to meet goal 1 and the Gold Standard would be consistent with efforts to meet goals 2 and 3. The Silver Standard is also broadly consistent with efforts to meet goal 4, so long as further renewables are introduced in years to come.

4. WHY THE ENERGY STANDARDS WOULD MAKE A DIFFERENCE

Energy efficiency is the key to a sustainable energy future. The scope for cheaply and easily reducing the energy consumption of buildings, via higher energy efficiency, far exceeds the scope for introducing renewables.

The UK has various published home energy efficiency/environmental standards - Eco-Homes, Best Practice, Advanced Practice, etc. These are the only mechanisms being used to quantify improvements in energy efficiency, but they focus on *fitting certain measures* to new homes. This is a serious limitation. Measures are necessary, but they are also insufficient. There is no monitoring of actual performance to see if it matches designers' expectations.

Also, the most prominent of these standards - Eco Homes - is not strict enough. A house could until recently gain an Eco Homes Excellent rating if it was constructed to the minimum levels in the 2002 Building Regulations!

Due to lack of research, we do not know exactly how much energy new UK homes use. But a growing body of anecdotal and circumstantial evidence suggests that measured consumption can be twice the predicted consumption or even more.

Table 1 sums up the overall UK statistics. Metered gas consumption by buildings is rising by several percent per year. This clearly conflicts with the UK's aims of cutting gas consumption and CO_2 emissions. It poses difficulty in meeting the EU's Energy Performance of Buildings Directive - that is, if we interpret "energy performance" as "measured consumption of fuels and electricity".

Is it possible for the measured energy consumption of buildings to equal the calculated consumption? Definitely, if we adopt precise calculation methods and good design and construction standards.

Germany, Switzerland and some other continental countries have a legal requirement that new buildings, from detached homes to office blocks, meet a certain energy budget. With rare exceptions, actual energy consumption in those countries is consistent with the insulation and draughtproofing measures which are specified.

Germany's first four Passive Houses were calculated to use 31 kWh/m^2yr - gas plus electricity - under standard occupancy conditions and average German weather. They actually used 32 kWh/m^2yr over the period 1992-97. So there was perhaps a 3% error.

The typical gas consumption of Lower Watts House (LWH), Oxon. has been 52 kWh/m^2yr since it was built in 1992. The calculated gas consumption was around 50 kWh/m^2yr making broad assumptions about the impact of the various thermal bridges. Due to limited design resources no more detailed analysis was made. So, there may be a small discrepancy between measured and calculated gas usage, but it is probably not very great.

The measured gas use of the Elizabeth Fry Building, Univ. of East Anglia since it was built in 1994-95 and commissioned in 1996-97 has been 25-30 kWh/m^2yr. This is consistent with a high-performance building envelope - opaque U-values 0.15-0.3 W/m^2K and window U-value 1.4 W/m^2K - although again no resources were available to analyse the building fabric in detail.

AECB consider that all buildings which claim to meet a specific energy efficiency standard need agreement between calculated and measured energy use at least as close as the two examples above - Kranichstein and LWH. Then we can accept that the standard has delivered real reductions in CO_2 emissions which are maintained over time.

No other UK energy standard requires any correlation whatever between predicted and actual performance. As such the AECB Energy Standards would be a huge step forward.

5. DETAILS OF THE STANDARDS

5.1. GOLD STANDARD

The Gold standard is on a par with the German Passiv Haus Standard but with greater requirements for use of renewables. Almost certainly no UK project yet built meets the standard in full.

The Gold Standard corresponds to best international practice in design of building envelopes and their services and equipment. All the technology is in use somewhere in Europe or North America in the more leading-edge buildings. The present leader is the region comprising Germany, Austria and the German-speaking cantons of Switzerland, where 5,000 buildings met the Passiv Haus Standard by spring 2005.

Using the standard in the UK might eventually encourage manufacture of similar technology. This should be strongly encouraged, but we would need imported products in the early stages.

This should not pose too many barriers. Some AECB members already have businesses importing materials and products from Austria, Germany et al and might become UK agent(s). Some AECB individual members imported products directly from overseas manufacturer(s) before there was a UK agent. Usually they did this because it was a good way to meet advanced energy efficiency standards without incurring excessive costs.

5.2 SILVER STANDARD

The Silver standard is on a par with the Canadian R-2000 Standard, the German Low Energy Standard and the Swiss MINERGIE Standard. It would probably be met or exceeded by the UK's top 5-10 housing projects, if these are judged on the basis of measured energy performance. Other more recent projects may meet it, but no research has been done since 1996.

It can be summed up as best widely-available technology. It does not push the technological boundaries radically forward but it is still a big advance on normal UK building practice. If applied in full, we estimate it leads to at least a 3X reduction in CO_2 emissions, although see section 7. See for instance the following projects built between 1992 and 1995:

1. Lower Watts House (Oxon). Measured energy use gas 52 kWh, electricity 13 kWh/m^{2}yr in the 1990s with 4 occupants, now 10 kWh/m^{2}yr with two occupants; total = 62-65 kWh/m^{2}yr;
2. Embleton House (Berks.) Total gas plus elec. use about 75 kWh/m^{2}yr;
3. Garnham House (Essex). Total LPG plus elec. use about 65 kWh/m^{2}yr;

and

4. Elizabeth Fry Building, UEA, Norwich. Measured gas use 25-30 kWh/m^{2}yr, electricity use 60 kWh/m^{2}yr initially. Its elec. use rose later to 70 due to limited use of electricity-efficient equipment and lighting. In short, its gas use meets the Silver Standard but its elec. use does not.

Here is a summary table of both standards with footnotes.

Table 2. SUMMARY ONLY OF PRESCRIPTIVE STANDARDS.

FEATURE		**SILVER**	**GOLD**	UNITS
Design to suit site		Basic passive solar design required; suitable area of wall or roof to be set aside to retrofit solar heating or electricity if needed.	As for Silver but solar energy system(s) would normally be installed now.	
U-values (1)	Roof	≤ 0.15	≤ 0.15 overall	W/m^{2}K
	Walls	≤ 0.25		W/m^{2}K
	Floor	≤ 0.20		W/m^{2}K
	Extl. doors	≤ 0.8	≤ 0.6	W/m^{2}K
	Windows (2)	≤ 1.5	≤ 0.8	W/m^{2}K
Window min. visible light transmittance		63	63	%
Protection against overheating (3)		To be designed to avoid both summer & winter overheating.	As Silver	
Air permeability (3)		≤ 3.0 for MEV or PSV, ≤ 1.5 for MVHR	≤ 0.75	m^3/m^{2}hr @ 50 Pa
Ventilation (4)		Balanced MVHR or whole-house MEV. Max. specific fanpower = 0.75 W per l/s (MEV) or 1.5 W (MVHR).	Balanced MVHR, max. specific fanpower = 0.75 W per l/s and min. seasonal heat recovery = 90% (excl. fans).	
Space heating (5)		Radiators or underfloor, cond. boiler with maximum NO$_x$ limit, earth-source heat pump or clean-burning biomass; e.g, liquid- or gaseous-fuelled CHP plant. Controls required so that; e.g., underfloor heating is compatible with passive solar design features.	Normally heater battery (fed from cond. boiler or heat pump) in ventln. ductwork. Min. pump efficiency.	
Hot water		Cond. boiler or heat pump or clean-burning biomass as for space heating.	Ditto plus solar (min. solar fraction 70%).	
Cooking (6)		No requirement	Gas, LPG, electric induction or clean-burning biomass (liquids or gases)	
Lighting (7)		CFLs, T5 or T8 everywhere except cupboards. Integral ballast CFLs permitted where their greater miniaturisation can be shown to maintain energy efficiency.	Efficient CFLs (hard-wired) or T5 (hard-wired) with electronic ballasts everywhere bar cupboards. All table lamps to be dedicated CFLs (electronic ballasts) or equiv. LEDs acceptable when their efficacy reaches that of CFLs.	
Major elec. appliances (8)		Either A+ or A++.	The best A++ on the market; e.g., Gram LER-200 fridge.	
Small elec. appliances (9)		No requirement	Standby power reduced to ≤ 1W for each and every device.	
On-site renewables (10)		No requirement	Carbon neutrality on elec. use for lights, appliances and ventilation.	

NOTES TO TABLE 2:

(1) The names of the two standards would be fixed for all time. They would be periodically revised as with Canada's R-2000 Standard to keep them well ahead of average building practice. There would be a version number to distinguish earlier from later revisions.

Attempts to fix the level of a standard for all time, and introduce higher standards with a new name later, have been considered. But colleagues abroad, with more experience than the UK, do not recommend it.

(2) Overheating falls into two different types: (a) summer overheating when windows are open, usually caused by hot weather combined with solar gains, and (b) late winter overheating when windows are closed, usually caused by low-angle solar gains overwhelming the building's thermal mass. There is enough data to issue guidance on how to avoid both. It requires limiting the window area in low thermal capacity buildings.

(3) The Gold Standard requirement of 0.15 W/m^{2}K matches Germany's Passiv Haus Standard. The Silver Standard is close to Germany's earlier Low Energy Standard. These are real U-values which include the effect of all significant thermal bridges, imperfect workmanship and design errors. Window U-values in the UK are now quoted on this basis but wall, floor and roof U-values are not.

The effects of thermal bridges are too complicated for most designers to calculate on a project-specific basis. So AECB would publish construction details which are pre-approved as meeting a certain U-value subject to certain restrictions. In principle this is a workable approach so long as in all cases of doubt designers are always required to err on the cautious side.

A merit of using accurate U-values is that our fabric U-values can at last be compared directly to those elsewhere in Europe; e.g., Germany, where the Passiv Haus Program began. We also need thermal bridge catalogues which provide another route for designers to use, again so long as they are required to be cautious and if necessary choose a case slightly worse than their proposal.

The UK's quoted U-values remain over-optimistic. For instance, a timber-frame wall U-value quoted as 0.38 W/m^{2}K may really be 0.55-0.60 W/m^{2}K due to thermal bridges which the designer did not allow for. A masonry wall U-value quoted as 0.35 W/m^{2}K may really be 0.51 W/m^{2}K, due to non-repeating thermal bridges. Most UK buildings contain design or construction defects which further increase the heat loss of a building element, by permitting unwanted air movement through or around the insulation layer. As a result, the U-value which designers think they have met is not met in practice. These effects are not yet fully incorporated into the models which are used to check compliance with the Building Regulations.

Designers may increase certain U-value(s) if they reduce other U-value(s) so that the building's specific heat loss does not increase relative to a reference building of the same shape and with the above reference U-values. However as-built U-values may not exceed the following maxima:

Silver - roofs 0.20, external walls 0.28, ground floors 0.25, external opaque doors 1.0, windows 1.7 W/m^{2}K.

Gold - roofs 0.16, external walls 0.16, ground floors 0.20, external opaque doors 0.8, windows 1.0 W/m^{2}K.

(3) Broadly speaking a window U-value of 1.5 W/m^{2}K can be reached by:

(a) low-e argon-filled double glazing (warm edge) in wood or fibreglass frames *or*

(b) low-e air-filled triple glazing (cold edge) in wood frames.

A window U-value of 0.8 W/m^{2}K requires triple glazing with krypton gas fill, two selective coatings, warm edge spacers and insulated GRP, plastic or wood frames. As of early 2005, there are thought to be over 45 producers in at least seven countries, namely: Finland (2), Sweden (2), Norway (1), Germany (35), Austria (5), Switzerland (1 or more), Canada (3 or more) and possibly the USA.

(4) The Silver Standard is slightly weaker than Germany's Low Energy Standard, part of which is now incorporated into their Building Code. Their air leakage must be ≥3 ac/h at 50 Pa, or ≥ 1.5 ac/h at 50 Pa for mechanically-ventilated buildings. Canada's R-2000 Standard requires air leakage of ≥ 1.5 ac/h @ 50 Pa. Silver sets virtually the same air leakage limit as Sweden's 1978 Building Code, which initially prescribed ≥1-3 ac/h @ 50 Pa for different building types and later changed to ≥ 0.8 litres/s @ 50 Pa. In UK units, this is ≥ 2.88 m^3/m^{2}hr @ 50 Pa.

The Gold Standard is equivalent to the Passiv Haus Standard, which requires air leakage of ≥ 0.6 ac/h at 50 Pa but we have expressed the UK limits in the same units as our Building Regulations; i.e., in m^3/m^{2}hr at 50 Pa.

UK air permeabilities are widely being calculated on the basis of the dwelling's whole surface area, including separating walls and floors.

This is not very helpful because these elements are not part of its thermal envelope, although they should be airtight in order to provide an acceptable level of acoustic insulation. The air permeability in the Silver and Gold Standards is the air leakage under pressure per unit area of thermal envelope.

To reach 3.0 m^3/m^2hr at 50 Pa under UK conditions is fairly easy if a design and building team understand the subject, especially in the solid, wet-type construction used on mainland Europe; i.e. with concrete upper floors. New German and Swiss buildings meet this standard without any major efforts on airtightness, so long as the windows and doors are of good quality.

An air permeability of 0.75 m^3/m^2hr at 50 Pa is very difficult to reach under UK conditions unless:

(a) at least one team member has enough experience to avoid construction materials, detailing and procedures which are prone to leak or to open up as the building ages;

(b) all components, including windows and doors, are good-quality;

(c) the building is constructed with reasonable care.

However, at least one housing project designed by an AECB member has been tested during construction, before it is closed-in, and seems on track to meet this figure.

The AECB catalogue of approved details would require construction details which stay airtight over time. Many UK buildings which have been re-tested became 30-50% leakier over the space of just 3-4 years. Some timber-frame houses constructed in the Orkney Islands in 1993 became ***three times*** leakier, a most disappointing result.

We know with some degree of confidence what has to be done because Canada has published design guidance in this field for 25-30 years. They no longer recommend some airtight construction details which were permitted in the late 1970s. Ditto Sweden.

Denmark, Germany and other continental countries have long experience with heavy masonry construction. Here airtightness is easier to achieve because all-“wet” construction defaults to airtight, subject to certain pitfalls being avoided. Their details are available too.

(5) Gold Std. ventilation could be either

(a) a very efficient heat exchanger *or*

(b) a smaller exchanger plus earth tubes to preheat the ventln. air an equivalent amount.

In our view, Silver Std. ventilation is best met by whole-house MEV. This is much cheaper than MVHR and uses little more primary energy if buildings are only moderately tight. It is widely-used in Sweden. The Silver Std. has been changed not to permit passive stack ventilation (PSV) since there is evidence that it does not reliably provide the required fresh air volumes.

(6) Space heating via a heater battery in the ventilation ducts is the Passive House norm & helps to keep down overall costs. The standard could not require this integration *per se* but it would happen anyway; it is the cheapest way to meet the target.

Both standards could set a limiting carbon intensity for space and water heating, with a numerical value for Silver of around 0.25 kg/kWh. This corresponds to a boiler of 85% seasonal thermal efficiency and parasitic power of 3% of the heat output. That is achievable with a gas-fired condensing boiler but points the way to other combinations of technologies.

With Gold the limit would be stricter. A requirement for gas condensing boilers with a 50% solar water heating fraction could be restated in fewer words as a maximum CO_2 intensity of water heating of 0.12 kg/kWh. The limiting figure for space and water heat combined might be around 0.18 kg/kWh.

In line with emerging AECB policy, the standards would not allow the use of electric resistance space and water heating. Earth source heat pumps which are sized and designed to avoid use of electric resistance backup heat, including the water heating load (although 1% resistance backup for legionella control might be tolerable), would be acceptable as long as the heat distribution system is compatible with other sources of low-temperature heat; low-temperature radiators, UFH, etc, normally are.

(7) Cooking with gas (LPG) emits 60-70 (40-50)% less CO_2 than electric cooking. The standard would not normally allow electric cooking, for the same reasons as electric resistance heating; the peak loads are severe and peaks present a long-term obstacle to running the electric grid on renewables. The Gold Standard would allow induction cooking as an alternative to gas or LPG if in blocks of flats, this avoids the need for internal gas distribution; e.g., blocks where all flats are heated by a single gas boiler or a CHP plant in the basement.

(8) Lighting would be regulated on the basis that occupant purchasing decisions play a role in meeting the standard, as well as decisions by the designer or builder. Ditto with 9 and 10 - white goods and small appliances. If the builder or developer provides appliances, he/she can ensure they are energy-efficient. With other electrical equipment, the occupant must buy electricity-efficient models.

(9) The Passive House Institute publishes data on consumption of the major electrical appliances sold in Germany and a list of acceptable models of fridge, freezer, washing machine, dishwasher, TV, etc. Hopefully we can cite the same list/web site in the UK.

We have to mandate the very best appliances, not just appliances in the top class, because the EU scale is too lax. One can easily find "A" appliances which use 2X times as much as the best "A" appliances on the market, yet both these are classified as "A" or even "A+".

(10) The US, Canadian and Swiss government have rules which aim to persuade people to buy more energy-efficient office equipment. The USA's legislation is directed at federal government departments, the Swiss federal government's "voluntary program" is aimed more widely. We shall need to check what government internet-based data is accessible to building owners or occupiers when they buy small domestic appliances and/or office equipment, then cite those government web site(s) in the standard.

(11) This requirement covers electricity-specific uses only. So a dwelling that uses 1,100 kWh/year for lighting, appliances and ventilation needs a wind, photovoltaic, hydro and/or other renewable electricity system which generates at least 1,100 kWh per annum, plus an allowance for grid losses in the proportion of generated electricity which is exported.

(12) Maintenance and commissioning. The standard would refer to the Bldg. Regs. logbook and would have more stringent requirements for specifying and tracking maintenance activities. This includes requirements for the setting-up and maintenance of MEV & MVHR systems. Otherwise we know that the tendency will always be to "turn the fan up" rather than maintain systems properly.

6. APPLICABILITY OF THE STANDARDS

Once the technical specifications are finalised, in principle we could apply the standards tomorrow to a new UK house, block of flats, or smaller non-domestic premises such as community/village halls and doctors' surgeries. The principles are the same for all these building types. The standards could also be applied to larger non-domestic buildings such as offices, hotels and schools. In Germany, several offices and at least one school already meet the Passiv Haus Standard.

The standards are not yet intended to extend to the largest or most complex types of building. In the government's *Energy Consumption Guide 19*, the standard would cover office building types 1 or 2 but not at present 3 or 4 - corporate headquarters, structures full of specialised computer equipment and the like.

The Standards would initially only apply to new buildings. In future, we believe that they could be extended to building refurbishments.

This has happened in Germany. The first new buildings meeting the Passiv Haus Standard were constructed in 1991. By the late 1990s, people thought of improving existing buildings to this level. A large block of flats in Ludwigshafen has been retrofitted almost to the Passiv Haus Standard; space heating energy is predicted to fall from 220 to 30 kWh/m^{2}yr - i.e. a drop of 87%. Equally ambitious "sustainable retrofits" have been undertaken in Switzerland.

7. CERTIFICATION OF THE STANDARDS

To meet either standard, a building must be designed, constructed and operated so that measured energy consumption equals calculated energy consumption within a small margin (assuming standard occupancy conditions). Otherwise the standards could soon become discredited. At a guess, we would find lots of “Silver Standard” buildings with predicted energy use of 60-80 kWh/m^{2}yr and measured energy use 100-200+ kWh/m^{2}yr, plus a few “Gold Standard” Buildings with predictions of say 30 to 40 and actual meter readings of 80 to 120+ kWh/m^{2}yr.

Higher energy standards are not just a matter of bolting on 25% extra insulation and writing a demanding air permeability specification. Most clients and architects involved in designing or procuring very energy-efficient buildings can confirm that one needs obsessive attention to detail to ensure that a project built by the UK construction industry is properly-designed and -constructed.

AECB does not yet have the resources to enforce the standard, unless a charge is made to users of the standard. Should this be done? If so how should it be organised? How should experts be accredited?

Should we enforce the standard by asking the professional who has designed the project to certify that design and build quality meet the technical specifications in the Standard? These professionals could be trained by AECB members who have the requisite knowledge and a track record of detailing buildings for airtightness.

This suggestion parallels what happens elsewhere in Europe. Most building projects have to be certified by an architect or engineer, who is under a duty of care to the owner. In Germany, the Low Energy Standard received grant aid from some state governments who required that the architect or engineer kept a photographic record and certified to the owner and the state government that the building met the Low Energy Standard. A similar system operates today with the Passiv Haus Standard.

Regardless of the way it is enforced, it is clear that a team need to produce ASAP:

1. A tightly-worded technical specification; and
2. Other detailed design guidance to convey to building teams *what they must do* to deliver buildings which meet the standard(s).
3. Information on energy performance and permitted variations in U-values, etc so that designers can check the acceptability of buildings which deviate slightly from the prescriptive standards given above; in short, several deemed-to-satisfy prescriptive standards.

What length are these documents? The technical specification for the Canadian Advanced House Standard is about 40 A4 pp., as was the R-2000 specification, but the Canadian books giving good practice details for timber-frame or recommended construction techniques for R-2000 houses are 500 pp. They are confined to timber-frame details; Canada has separate publications for tall concrete and steel buildings. In the UK, which uses masonry, timber, concrete and steel, we need them all.

The design guidance would include thermal envelope detailing and design and would sum up the requirements for proper specification and installation of the insulation layer. Small mistakes here lead to large heat losses. A possibility is to produce a short booklet first for domestic-scale construction - masonry, timber and concrete - and later a longer book of details for steel- or concrete-frame - aimed at designers of non-domestic structures.

The template for the technical specification on thermal envelopes and heating / ventilating systems can be a document which Leeds Metropolitan University produced for the government in 2002. We would need the same type of document albeit with different numbers. We would need to add clauses on lighting, cooking, major appliances and small electrical equipment.

8. BENEFITS OF THE STANDARDS

Here is a calculation of possible energy and CO_2 savings. Suppose that dwellings constructed after 2010 meet the Silver Standard and those built after 2020 meet the Gold Standard, with an average construction rate over the period of 250,000 dwellings/year. Take the CO_2 emissions associated with the Silver and Gold Standards as 25% and 5% respectively of the emissions of a normal new dwelling. Assume that new dwellings after 2030 are further improved, with 0% of the CO_2 emissions of today's construction instead of 5%.

Tables 2 and 3 set out details of domestic sector energy use, CO2 emissions and construction rates for dwellings built after the year 2006. Table 2 is a business as usual scenario with similar rates of improvement in energy performance, etc to those achieved over the last few decades. Table 3 is a low-CO_2 scenario. Here as much as possible is done to improve the energy performance of the dwelling stock and to introduce renewables into the UK energy supply mix.

Table 2. Business as Usual Scenario.

AGE RANGE		**2010**	**2020**	**2030**	**2040**	**2050**	**UNITS**
2006-10 homes	Delivered energy	185	185	185	185	185	kWh/m^2.yr
	CO_2 intensity of delivered energy	0.302	0.28	0.27	0.26	0.24	kg/kWh
	CO_2 emissions per unit area	57.1	52.6	50.4	47.6	44.8	kg/m^2.yr
	Number of homes	1	1	1	1	1	Million
	Floor area	78	78	78	78	78	km^2
	CO_2 emissions	4.5	4.1	3.9	3.7	3.5	million tonnes/year
2010-20 homes	Delivered energy		159.5	159.5	159.5	159.5	kWh/m^2.yr
	CO_2 intensity of delivered energy (2006 = 100)	0.302	0.28	0.27	0.26	0.24	kg/kWh
	CO_2 emissions per unit area		45.3	43.3	40.9	38.5	kg/m^2.yr
	Number of homes		2.7	2.7	2.7	2.7	Million
	Floor area		211	211	211	211	km^2
	CO_2 emissions		9.5	9.1	8.6	8.1	million tonnes
2020-30 homes	Delivered energy			137.4	137.4	137.4	kWh/m^2.yr
	CO_2 intensity of delivered energy	0.302	0.28	0.27	0.26	0.24	kg/kWh
	CO_2 emissions per unit area			37.4	35.3	33.2	kg/m^2.yr
	Number of homes			2.8	2.8	2.8	Million
	Floor area			218	218	218	km^2
	CO_2 emissions			8.2	7.7	7.3	million tonnes/year
2030-50 homes	Delivered energy				118.4	118.4	kWh/m^2.yr
	CO_2 intensity of delivered energy	0.302	0.28	0.27	0.26	0.24	kg/kWh
	CO_2 emissions per unit area				30.4	28.6	kg/m^2.yr
	Number of homes				3	6	Million
	Floor area				234	468	km^2
	CO_2 emissions				7.1	13.4	million tonnes/year
All post- 2006 homes	CO_2 emissions	4.5	13.6	21.2	27.2	32.2	million tonnes/year

CUMULATIVE EMISSIONS 2006-2050 936.4 million tonnes

NOTES *ctd overleaf*:

1. Assumes construction rates as follows: from 2006-10 - 250,000 dwellings/year, from 2010-20 - 270,000 dwellings/year, remainder of period -280,000 dwellings/year.
2. Assumes that delivered energy per unit area declines at the same rate as we calculate for the move from ADL1-2002 to ADL1-2006/7 and that this is repeated every five years.

3. Assumes that CO2 intensity per unit of delivered energy declines at 5% per decade. This is a greater rate than is foreseen from 2000-20, assuming that renewables supply 20% of electricity, or 3% of delivered energy, in 2020.

Table 2. Low-CO_2 Scenario.

AGE RANGE		**2010**	**2020**	**2030**	**2040**	**2050**	**UNITS**
2006-10 homes	Delivered energy per unit area	180	175	160	140	120	kWh/m^2.yr
	CO_2 intensity of delivered energy (0.309 in 2003)	0.29	0.27	0.23	0.15	0.09	kg/kWh
	CO_2 emissions per unit area	57.1	47.6	37.1	21.6	11.1	kg/m^2.yr
	Number of homes	1	1	1	1	1	Million
	Floor area	78	78	78	78	78	km^2
	CO_2 emissions	4.5	3.7	2.9	1.7	0.9	million tonnes/yr
2010-20 homes Silver	Delivered energy per unit area		81.0	80.0	78.0	75.0	kWh/m^2.yr
	CO_2 intensity of delivered energy (2006 = 100)		0.27	0.23	0.15	0.09	kg/kWh
	CO_2 emissions per unit area		22	18.5	12.1	6.95	kg/m^2.yr
	Number of homes		2.7	2.7	2.7	2.7	Million
	Floor area		211	211	211	211	km^2
	CO_2 emissions		4.6	3.9	2.5	1.5	million tonnes/yr
2020-30 homes Gold	Delivered energy per unit area			38.0	38.0	38.0	kWh/m^2.yr
	CO_2 intensity of delivered energy			0.23	0.15	0.09	kg/kWh
	CO_2 emissions per unit area			8.8	5.9	3.5	kg/m^2.yr
	Number of homes			2.8	2.8	2.8	Million
	Floor area			218	218	218	km^2
	CO_2 emissions			1.9	1.3	0.8	million tonnes/yr
2030-50 homes Improved Gold	Delivered energy per unit area				38.0	38.0	kWh/m^2.yr
	CO_2 intensity of delivered energy				0.00	0.00	kg/kWh
	CO_2 emissions per unit area				0.0	0.0	kg/m^2.yr
	Number of homes				3	6	Million
	Floor area				234	468	km^2
	CO_2 emissions				0.0	0.0	million tonnes/yr
All post- 2006 homes	CO_2 emissions	1.0	3.7	6.5	9.5	12.5	million tonnes/yr

CUMULATIVE EMISSIONS 2006-2050 305.2 million tonnes

NOTES *ctd overleaf*:

1. Assumes that new construction 2010-20 on average meets the AECB Silver Standard;
2. Assumes that new construction 2020-30 meets the AECB Gold Standard;

3. Assumes that new construction 2030-50 on average meets a modified AECB Gold Standard, with zero CO2 emissions, due to development of liquid or gaseous biofuels for cooking or CHP plant and the use of this plus solar, geothermal or wind-driven heat pumps with long-term/seasonal storage for space and water heating;
4. Assumes that some homes built from 2006-10 are partly retrofitted by 2050 to somewhat reduce their energy consumption, also that this happens to Silver Standard homes to a lesser extent.

The above program saves the emission of 600 million tonnes of CO2 by 2050 compared to business as usual; i.e. the difference between the cumulative totals in Tables 2 and 3. This refers to new domestic buildings only. The application of the Standards to non-domestic buildings, or to existing buildings of either category, further increases the saving.

How do these reductions compare to the hoped-for CO_2 reductions from other UK programs? They are both greater and easier.

From 2010 to 2020 the UK government hopes to raise the proportion of electricity generated from renewables from 10% to 20%. ***If*** that target is achieved, which needs ***a wind farm per week from 2010 to 2020***, the CO_2 savings are similar to what we obtain if new homes in that decade are improved from present levels to the Silver Standard. *Whereas wind farms need a government subsidy - and unsightly new pylons to reinforce the grid - the Silver Standard is cost-effective against present fossil fuel prices once initial barriers are overcome and needs just training and education.*

The government has a support program which has led to about 1,000 PV systems being installed. But we would need *1.5 M photovoltaic systems*, each rated at 2 kW, to save 1M tonnes/year of CO_2. By 2020 the Silver Standard could save ***15 times as much CO_2 as this large and so far hypothetical PV program***.

Applying the Silver Standard to new offices, schools, hospitals and hotels could more than double these savings. This is because these buildings are replaced more often than dwellings *and* use more energy per m^2. As Table 3 shows, the Gold Standard would make further massive savings beyond 2020.

Improved standards also need to be applied when existing buildings undergo major refurbishment. If we accept the suggestion from the Climate Change Institute, Oxford University, that some of the dwelling stock is inefficient and decrepit and is better replaced than patched-up, it is plausible that an *average* dwelling could be improved to the Silver Standard by 2050. Some within this total would be better but some; e.g. listed buildings, would remain much worse. We have not made a detailed analysis but in principle this program of action could reduce the domestic sector's CO_2 emissions by 85%.

9. CAVEATS

There is no UK research to ascertain the energy consumption of an average new dwelling. Figures submitted to councils with Building Regulation applications are calculations. There is no guarantee that actual energy performance equals predicted performance. There is a growing body of evidence suggesting that actual performance is markedly worse, although government has still not commissioned any research since the glaring lack of data was pointed out in 1999.

Thanks to work by William Bordass Associates since 1990, we know the actual energy performance of UK offices and schools and what amounts to typical, good, excellent, poor, etc. The schools sector has been analysed by DfES.

Offices are covered in Energy Consumption Guide 19, *Energy Consumption of Offices*. We know for this sector that typical figures are worse than design predictions, especially in newer buildings, which were supposed to meet tighter Building Regulations. Modern offices use as much energy per m2 as older ones, which is contrary to what one might expect from the UK's successively stricter Building Regulations.

Ironically, we know the energy performance of housing constructed to the Silver Standard *more precisely* than we know the energy consumption of ordinary dwellings! This is because a few owners of correctly-designed and -built low-energy houses, with specifications as per Table 2, have measured their fuel bills for many years. When they have done so, delivered energy has mostly been in the range 60-75 kWh/m^{2}yr for detached houses.

10. SUPPORT OF THE STANDARD

A useful role for the AECB would be to collect in-use performance data for a sample of certified houses and/or other buildings, compare the various systems and publish the results. Such a feedback loop could be used to reduce the amount of detailed prescription going into the standard.

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