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THE CONTRIBUTION OF HOUSING TO CARBON EMISSIONS AND THE POTENTIAL FOR REDUCTION: AN AUSTRALIA-UK COMPARISON

ABSTRACT

Housing is the predominant land use in most cities and also a major contributor to greenhouse gas (GHG) emissions. The sources of these emissions vary depending on climatic factors, building designs and occupant behaviour. Government driven initiatives seek to affect all of these aspects in a drive to reduce GHG emissions. This review examines the profile of emissions from housing in the UK and Australia as well as comparing current policy initiatives to shift towards a low carbon future. We assess the potential for GHG reduction from an economic, technical and behavioural perspective seeking to determine where opportunities for GHG reduction exist in the housing profiles of these two very different situations and whether practice in either country can inform the other.

Keywords: housing, carbon emissions, green house gas.

INTRODUCTION

Whilst politicians continue to debate the most cost effective and equitable ways to mitigate emissions and adapt to a changing climate, there is now a broad level of agreement amongst the scientific community on three aspects. The first is that manmade climate change is real. The second is that we need to take action. The third is that, to avert catastrophic effects on both humans and ecosystems, we should seek to prevent global temperatures from rising by more than two degrees above pre-industrial levels (IPCC, 2007, Monbiot, 2006). Climate models have been used by the Intergovernmental Panel on Climate Change (IPCC) to anticipate global warming of between 1.4 °C to 5.8 °C over the next hundred years. The main causes, namely carbon dioxide (CO_2) and methane (CH_4) derive from numerous sources but the most important relate to fossil fuel burning either for direct use or to generate electricity.

Since the UN Conference of 1987 when the Bruntland definition of sustainable development as '*Development that meets the needs of the current generation without compromising the ability of future generations to meet their own needs*' was put forward, the UK government has adopted environmental aims and targets. The design, construction and occupancy of buildings have been identified as areas where more could be done to minimise waste and reduce energy consumption as well as providing healthier and safer working and living environments (Keeping and Shiers, 2004). Similarly Australian governments since 1992 have argued for Ecologically Sustainable Development (ESD) as a basic principle of urban expansion (Commonwealth of Australia, 1992). Both nations are major GHG emitters and in both, the residential sector plays an important role both in the economy and in respect of GHG emissions. In both the UK and Australia a range of policy interventions have been attempted to control and reduce these emissions. In this paper we seek to compare the nature of the problem in each nation, examine the policy interventions which have been attempted and question the relative successes and failures of each.

THE CONTRIBUTION OF UK HOUSING TO GREENHOUSE GAS EMISSIONS

Global climate change and the need to reduce greenhouse gas emissions necessitate decisive and timely action to improve the energy efficiency and performance of housing (Horne and Hayles, 2008). Reducing the amount of natural resources buildings consume and the amount of pollution given off is crucial for future sustainability. The energy used in constructing, occupying and operating buildings represents approximately 50% of greenhouse gas emissions in the UK. Emissions from the domestic building stock were responsible for 41.7 million tonnes of carbon (MtC) in 2004 - 27% of total UK carbon emissions (DEFRA, 2006). Domestic energy use represents 25 per cent of total national energy use (DECC, 2010). A standard 4 bedroom house in the UK uses 22 700 kWh of energy per year and produces 6 tonnes of CO_2. It is clear that too many existing buildings are environmentally inefficient and do not make best use of limited resources such as energy and water. At present rates of improvement, it might take until 2050 before cavity wall insulation is present in all homes for which it is suitable.

As one of the UK's leading industries, responsible for 8% of GDP and employing 1.5 million people, construction can lead the way in integrating sustainable development in all of its activities. Promoting sustainable construction is difficult, however, because of the industry's size and fragmentation. The construction business in the UK is responsible for nearly a third of all industry-related pollution incidents. Construction and demolition waste alone represented 72.5 million tonnes of total UK waste of 177 million tonnes (40.9 per cent) in 2000 (Martin and Scott, 2003).

The rate of construction in the UK is set to increase (assuming the recession of 2008-11 is a temporary or cyclical setback). The Government's *Sustainable Communities Plan* seeks to accelerate the current house-building programme and increase the house-building target by about 200,000 on top of the 900,000 new homes planned between 1996 and 2016 in the South East (Department of Communities and Local Government, 2008). This new emphasis on growth represents an opportunity to shift development towards delivering more sustainable homes and construction. Energy (and greenhouse gas) savings can be achieved by increasing building code stringency (Horne and Hayles, 2008).

The Department for Communities and Local Government (DCLG) published a 'Code for Sustainable Homes - A step change in sustainable home building practice' in 2006. The Code is the national standard for the sustainable design and construction of new homes. The Code aims to reduce our carbon emissions and create homes that are more sustainable. It set design principles for energy, materials and water usage and to improve health, reduce pollution and minimise waste. The Code measures the sustainability of a new home against nine categories of sustainable design, rating the 'whole home' as a complete package. The Code uses a one star (least efficient/sustainable) to six star (most efficient/sustainable) rating system to communicate the overall sustainability performance of a new home. The Code sets minimum standards for energy and water use at each level. It is intended to provide valuable information to home buyers, and offers builders a tool with which to differentiate themselves in sustainability terms.

In July 2007 the UK Government's *Building A Greener Future: Policy Statement* announced that all new homes will be zero carbon from 2016. Following up the commitment in the Policy Statement to consult further on the definition of zero carbon, in December 2008 the Government published *Definition of Zero Carbon Homes and Non-Domestic Buildings: Consultation*. This proposed an approach based on:

- high levels of energy efficiency in the fabric of the home
- a minimum level of carbon reduction to be achieved onsite or through directly connected heat; and
- a list of allowable solutions for dealing with the remaining emissions (including from appliances)

In the Budget of 2008, the UK government announced its ambition that all new non-domestic buildings should be zero carbon from 2019 (with earlier targets for schools and other public buildings). (*Zero Carbon for New Non-domestic Buildings: Consultation on Policy Options*, November 2009). The DCLG has established the 2016 Taskforce, jointly led by the Minister of Housing and Planning and the Executive Chairman for the Home Builders Federation, to identify barriers to implementation of the zero carbon 2016 target and put in place measures to overcome them. The number of certificates issued in 2009-10 according to the Code for Sustainable Homes: number of certificates issued (post-construction stage) was as follows:

Table 1: Code for sustainable homes certificates UK

code level	0	1	2	3	4	5	6	Total
certificates	49	34	75	4326	290	37	7	4818
%	1	1	2	90	6	1	0	100

Source: Communities.gov.uk 20/05/2010

The total number of certificates issued at 4818 from a total of housing completions of 113 420 is unimpressive. And the number of level 6 certificates issued - 7 is derisory given that all new homes should achieve this standard by 2016.

Housing is a key aspect of the UK's challenging carbon targets for 2010 and 2050. Buildings contribute half of the UK's CO_2 emissions and energy consumption is rising. These emissions of CO_2 are attributed to the consumption of fossil fuels for the generation of power and heat, with around 80% for space heating and hot water (see Table 2). Energy efficiency has been identified in the Government's Energy White Paper (Department of Trade and Industry (DTI), 2003) as the cheapest, cleanest, safest way of reducing carbon emissions. Existing housing may be refurbished to a high standard of energy efficiency and this has clear benefits to occupants through improved comfort and reduced running costs.

Table 2: UK household energy consumption by end use

Space Heating	60%
Hot Water	21%
Cold Appliances	3%
Consumer Electronics	3%
Cooking	3%
Lighting	3%
Wet Appliances	2%
Miscellaneous	2%

Source: Sustainable Development Commission 2006

Measures to improve the thermal efficiency of the building envelope depend on the type of construction of the building. Insulation, heating and ventilation measures should be considered in a combined package in order to avoid risks of condensation and fumes. There is a range of data and guidance available for the building stock of England and on appropriate thermal improvement measures from the Energy Savings Trust Energy Efficiency Best Practice Programme (Energy Saving Trust, 2008).

Energy efficiency savings through improved thermal performance of building fabric could be outweighed by rapid increases in energy consumption from electrical appliance demands. The energy use of lights and appliances is increasing by 2% annually. It will therefore be necessary to promote energy efficient lights and appliances in order to reduce overall consumption which in turn may be met by the lower energy density available from the renewable sources (i.e. solar, wind and biomass).

Except over very long periods, however, we are dealing with a stock of housing in the U.K. In 2001, 24.5 million dwellings in Great Britain increased by only 161,900, the lowest level of completions for 54 years. In 2008 the downturn in the housing market in the UK reduced the number of completions to 147,000. Even if the construction industry could raise its annual output by a third (which would be a considerable achievement) the yearly rate of increase in the standing stock would only rise from 0.66 per cent to 1 per cent. A 1 per cent per annum replacement rate for the existing stock would mean that it would take 70 years to replace the entire stock. For comparison, in Australia the number of dwellings constructed is approximately 162,000 per year, which is equivalent to almost 2 per cent of the existing stock of about 8.2 million dwellings. Here it would take 35 years to replace the existing housing stock.

Considerable savings of carbon emissions can be made through improvements to existing houses, however. Energy efficiency measures, water saving measures and renewable energy technologies can offer significant savings on a home's energy costs and environmental impact.

THE CONTRIBUTION OF AUSTRALIAN HOUSING TO CARBON EMISSIONS

Australia operates a federal system of government with significant legislative and policy making powers vested in state governments. Urban planning for example is entirely a state responsibility with each jurisdiction operating its own system. Each state is responsible for setting its own targets for house building and monitoring these internally. The Building Code of Australia, which governs construction standards for all types of buildings, is however, a national regulation which is administered locally. As in the UK the house building industry is diverse in that it consists of a few large players such as AV Jennings, Metricon and Home Australia, which operate nationally, producing thousands of dwellings each year, and at the other end of the scale numerous small building firms which construct a small number and are usually spatially constrained in their activity. Because of different GHG reporting protocols it is not possible to make direct comparisons between Australian and UK emissions in every case. However across Australia residential electricity consumption accounted for 24% of GHG emissions in 2009 (DCCEE, 2009, p6). Total residential sector energy consumption across Australia was 401 PJ in 2008, forecast to rise to 467 PJ in 2020 (DEWHA, 2008) It should be borne in mind that the continent consists of various climate zones which range from tropical in the north to temperate in the south with some extensive coastal and high alpine areas. Thus the Building Code of Australia specifies eight climate zones each with different standards relating to construction, heating and cooling characteristics for residential property. In Queensland, while in the summer months most property owners would consider mechanical air conditioning a necessity, in winter no heating may be used. In Victoria and South Australia, despite very high summer temperatures, which have in recent decades prompted many households to install air conditioning systems, more household income is generally spent on space heating than cooling. A further complicating factor when looking at Australian residential energy use is that Australian houses are vary variable in form and size, ranging from apartments and single storey units to large multi-roomed detached houses with numerous energy hungry facilities such as swimming pools, spas, home theatres and multiple fridges increasing in popularity. Indeed new Australian dwellings are a third larger than 20 years ago and are the largest in the world in median floor area at 214.6 square meters in 2009 (ABS). This compares very unfavourably in energy demand terms with UK housing where the average floor area of new stock is just 75 square meters.

Table 3 demonstrates the profile across Australia for energy demand within the home. It should be noted that regionally the share of heating/ cooling load can vary as result of different climate conditions. For example in South Australia an average figure for energy use for a household using electricity only is 7,500 kWh per year. Of this total electricity demand around 35% is used on heating and cooling and 25% on water heating.

Table 3: Australian household energy consumption by end use

Space Heating / cooling	20%
Hot Water	23%
Standby	5%
Fridges/ freezers	12%
Lighting	11%
Appliances	24%
Cooking	5%
Standby	2%

Source: Government of Australia (2011)

Despite using less energy than the average UK home Australian dwellings typically account for higher emissions at around 8 tonnes of CO_2 per annum, because of the high proportion of coal used in electricity generation. Over the last few years gas availability for direct space heating has increased and residential solar installation has expanded, resulting in an 8% reduction in generation from black coal (DCCEE, 2011). Nevertheless the proportion of electricity used by the residential sector continues to rise so emissions are likely to increase in proportion to energy demand in the residential sector for the foreseeable future (DWHA, 2008, p20). It is also notable that electricity use by appliances is increasing rapidly at 1.3% per annum between 1990 and 2020 and demand is set to almost match space heating by 2020 (DWHA, 2008, p22). A key concern is the poor historic standard of insulation in Australian homes. Horne and Hayles (2007) analysed a range of Australian homes against others in similar climate zones in the UK, USA and Canada, and concluded that the Australian homes built to 2006 energy efficiency standards generally achieved significantly lower thermal performance than their international counterparts. Generally apartments and town houses performed better than detached dwellings. This finding needs to be set in the context of a housing stock which is made up of over 70% detached dwellings nationally (ABS, 2010). The Australian housing stock is also increasing rapidly due to a rising population as result of immigration and until recently falling average household size. Between 1990 and 2020 the total housing stock is forecast to increase by 61 % from six million to almost 10 million, which implies an increase of around 56% in residential energy consumption. Whilst average household consumption may not rise as a result of energy efficiency measures counteracting the increased size of dwellings and numbers of appliances, overall, the sector share of energy demand and GHG emissions will rise (DEWHA, 2008).

POTENTIAL ENERGY EFFICIENCY MEASURES IN UK HOMES

The possible savings that can be made by measures to improve energy efficiency in UK homes are summarised in Table 4.

Table 4: Average costs and savings from typical energy efficiency improvements (UK)

Measure	**Cavity Wall Insulation**	**Internal Wall Insulation[1]**	**External wall Insulation[2]**	**Energy Saving Trust Recommended double glazing**
Annual saving (£/yr)	Around £110	Around £365	Around £385	Around £130
Installed cost £	Around £250	£5,500 - £8,500	£10,500 - £14,500	£2,500 - £6,500[3]
Installed payback	Around 2 years			
DIY cost	-	-	-	-
DIY payback	-	-	-	-
Annual CO_2 saving	Around 560kg	Around 1.8 tonnes	Around 1.9 tonnes	Around 650kg

Measure	**Draught proofing**	**Filling gaps between floor and skirting board**	**Hot water tank jacket**	**Primary pipe work insulation (visible hot water pipes)**
Annual saving (£/yr)	Around £25	Around £20	Around £35	Around £10
Installed cost £	Around £100			
Installed payback	Around 4 years			
DIY cost	Around £100	Around £20	£15	Around £10

DIY payback	Around 4 years	Around 1 year	5 months	Within 1 year
Annual CO_2 savings	Around 120 kg	Around 100 kg	Around 170 kg	Around 60 kg

[1]Assumes insulating to a U-value of 0.45 W/m²K.
[2]Assumes insulating to a U-value of 0.35 W/m2²K.
[3]Costs for double glazing are highly variable and dependent on the specific work needing to be done in each home.
[4]Floor Insulation DIY cost represents the cost of the insulation only.

Source: Energy Saving Trust 2010

The costs and paybacks shown are approximate, and are based on a gas heated semi-detached house with 3 bedrooms & cavity walls. Installed Costs assume that installation is undertaken by a professional installer and are subject to a discount from an energy supplier. Some of the savings may of course be taken in increased comfort. The possible energy savings that can be made by use of energy efficient appliances are summarised in Table 5.

Table 5: Energy saving possible by use of efficient appliances

Appliance	**EU Energy rating**	**Saving a year (up to)**	**CO_2 saving a year (up to)**
Fridge freezer	A+ or A++	£38	155 kg
Upright/ Chest Freezer	A+ or A++	£23	95 kg
Refrigerator	A+ or A++	£13	55 kg
Dishwasher	A	£11	47 kg
Integrated digital televisions	(no EU label for TV's)	£7	24 kg

Savings assume replacing an average appliance purchased new in 1998 with an Energy Saving Trust Recommended model of similar size and an electricity cost of 12.50p/kWh.

Source: Energy Saving Trust 2010

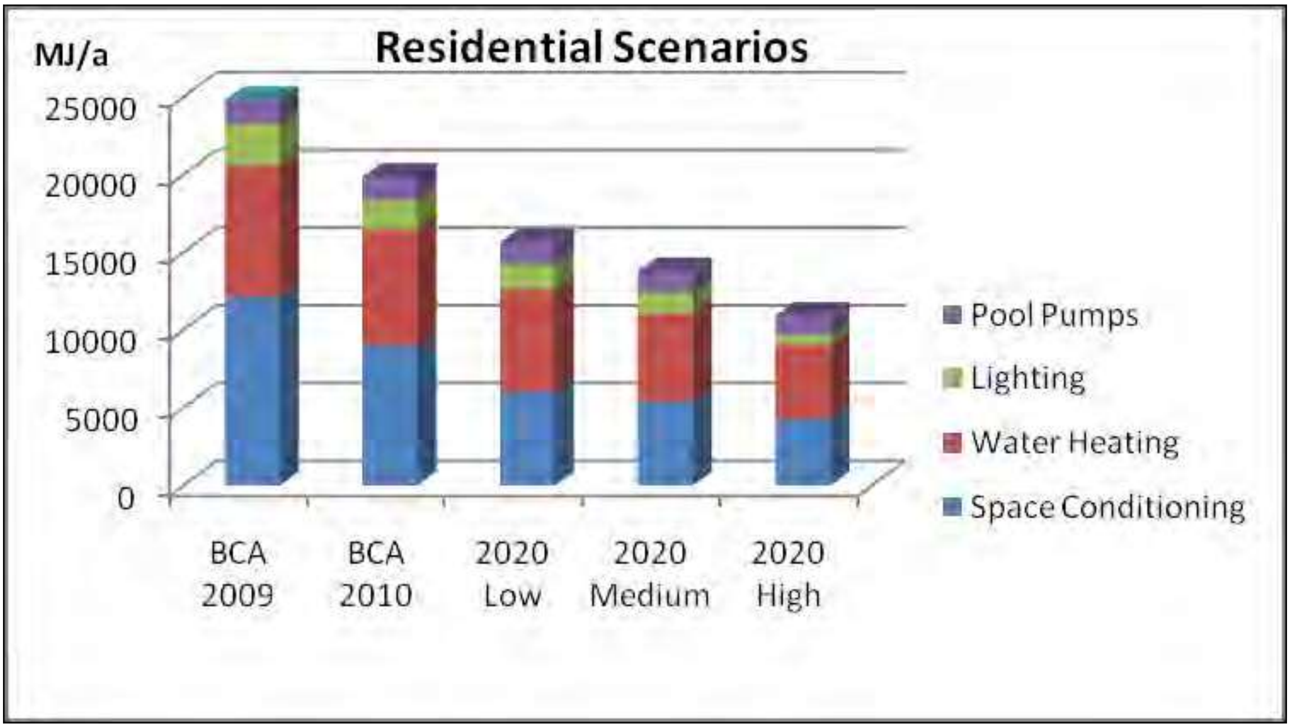
POTENTIAL ENERGY EFFICIENCY MEASURES IN AUSTRALIAN HOMES

A range of measures exist which could both reduce energy demand and substitute fossil based energy by renewable energy across the Australian housing stock. These include:

- Switch from electric to gas space heating and cooling
- Install or upgrade ceiling & loft insulation
- Insulate walls
- Draught proof around doors and windows
- Install zoning controls on centralised heating cooling systems
- Install solar PV
- Install solar hot water
- Switch to green electricity
- Install WELS 3 star rated shower heads
- Locate water heaters close to main points of use
- Insulate hot water pipes
- Shade windows and glazed areas in summer
- Switch to compact fluorescent light globes
- Update with 6 star energy rated appliances

The potential savings that can be made by measures to improve energy efficiency in Australian homes are summarised in Figure 1. This figure is based on modeling work for typical Australian residential forms of construction and presents the potential results in terms of reduction in energy demand for such properties in 2020 against a 2009 baseline. Low, medium and high scenarios are presented.

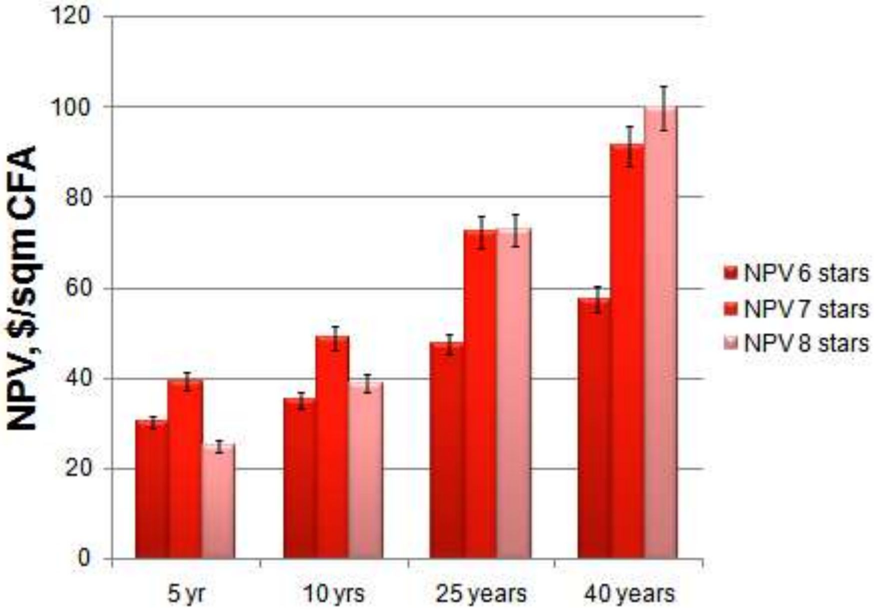
Figure 1: Potential energy reduction in Australian homes to 2020



Source: DCCEE, 2010

Significant scope exists to reduce residential energy consumption in Australian homes through a combination of energy efficiency measures, fuel switching and behaviour change. Whilst space heating is not as significant a load as in the UK, the combination of space heating and cooling, the balance of which will vary between different climate zones, remains the predominant energy use in Australian housing, so measures aimed at this aspect are most likely to provide gains in terms of GHG emissions. Analysis suggests an approximate 25% reduction in space conditioning load for each additional star above 6 is possible (DCCEE, 2010, p 49). The increasing size of Australian dwellings is a concern which needs to be addressed through planning policy since efficiency gains may be neutralised by floor space increases.

Figure 2: Financial savings over time from improving energy efficiency in selected Australian homes



Source: Morrissey & Horne (2010)

In respect of the existing housing stock retrofit potential has been costed for range of house types by Morrissey & Horne (2010). As Figure 2 shows, raising the energy efficiency performance of a selection of typical house designs in Victoria can effectively reduce the cost per square meter of floor space through reduced energy bills over the lifetime of the housing. In Figure 2 savings over time increase with increased star ratings as compared to a net present value of $0 at the point of origin which represents a 5* rated property today. Of course the drawback in this type of analysis is that it could potentially induce a rebound effect whereby houses might become even larger because they effectively cost less when considered over their entire life, so provisions are still needed to limit floor space in the upper range.

A key concern in some states, the extreme case being South Australia, is the peak load problem. Periods of extreme heat (defined as days with a maximum over 35 C) are common in summer. During such periods electricity demand can double as domestic air conditioners are switched on. As a result very high levels of standby power generation are required which boosts the cost of base load provision in such locations. Various methods are used to deal with the problem including importing from other states and maintaining old, inefficient generation stations which are already paid for as an alternative to investing in more efficient new plant. A novel approach, focussing on demand management rather than supply side approaches, was trialled in Adelaide in 2007/8. This involved fixing remote controlled regulators on household air conditioning units. These could be triggered remotely to switch off the compressor for several minutes every hour whilst leaving the fan running. Trials ascertained that the optimum down time for compressors was 13 minutes per hour with no loss of thermal comfort discernible by residents. Widespread application of this technology has the potential to reduce the peak demand from residential air conditioning units by about 25%.

UK GOVERNMENT INITIATIVES

Carbon budgets

The Climate Change Act 2008 set legally binding emission reduction targets for 2020 – a reduction of 34 per cent in greenhouse gas emissions – and introduced five-yearly carbon budgets to help ensure these targets are met. Carbon budgets are a cap on the total quantity of greenhouse gas emissions over a specified time. Every tonne of greenhouse gas emitted between 2009 and 2050 will count. Where emissions rise in one sector, corresponding falls will have to be achieved in another.

Each carbon budget covers a five-year period, with three budgets set at a time. In May 2009, the levels of the first three carbon budgets were made law as set out below in Table 7.

Table 7: UK carbon budgets

	Budget 1 2008-12	Budget 2 2013-17	Budget 3 2018-22	Budget 4 2023- 27
Carbon budgets Million tonnes of carbon dioxide equivalent ($MtCO_2e$)	3018	2782	2544	1950
Percentage reduction below 1990 levels	22	28	34	50

Carbon accounting will be used to determine compliance with the carbon budgets and targets established under the Climate Change Act. However, secondary legislation is needed to establish the details and so the UK Parliament approved the Carbon Accounting Regulations 2009 which sets out the detail of the carbon accounting system. The net UK carbon account for 2008 was 606.7 $MtCO_2e$ (including 19.3 $MtCO_2e$ worth of carbon units bought by UK companies operating under the EU Emissions Trading System (EU ETS)) or 22 per cent less than net UK emissions in 2007 (base year). For 2009, the net UK emissions were 575.3 $MtCO_2e$ (including 13.5 $MtCO_2e$ worth of carbon units sold by UK companies operating under the EU ETS) or 26.5 per cent less than base year emissions (DECC, 2011). So far this looks like a policy success – but emissions were always going to fall in a recession and the picture will not be clear until there has been a reasonable period of economic growth. If the policy is successful, however, it will reduce greenhouse gas emissions by 4 million tonnes a year by 2020, the equivalent of taking 1 million cars off UK roads.

The Green Deal

In December 2010 the UK coalition government announced a new ‘Green Deal’ initiative to begin operating in 2012. The foreword to the summary of the Government’s proposals (DECC, 2010) contains this statement:

> “Britain has some of the oldest building stock in Europe. Our draughty homes are poorly insulated, leaking heat and using up energy. As consumers, we pay a high price for inefficient housing – and so does the planet. A quarter of the UK’s carbon emissions come from the energy we use to heat our homes, and a similar amount comes from our businesses, industry and workplaces.”

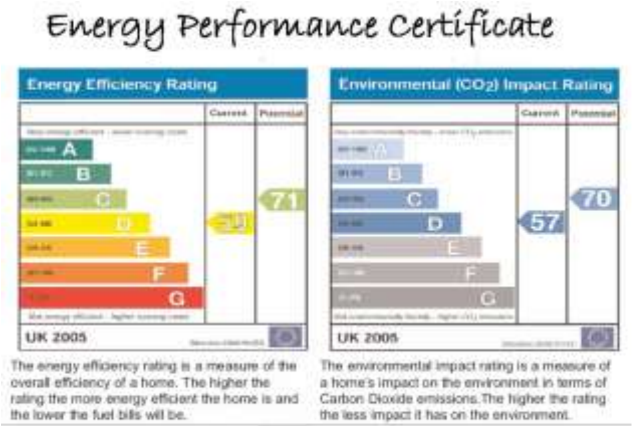
Under the Green Deal, the UK government aims to establish a framework to enable private firms to offer customers energy efficiency improvements to their homes at no upfront cost, and recoup payments through a charge on installments on the energy bill. A Green Deal plan is to be offered to customers which enables them to finance work recommended by an accredited adviser and undertaken by an accredited installer. The ‘golden rule’ of the Green Deal is that the expected financial savings must be equal to or greater than the costs attached to the energy bill. The Green Deal payments remain with the property and, therefore, subsequent occupiers.

Energy Performance Certificates

Energy Performance Certificates (EPC) were introduced in the UK to help improve the energy efficiency of buildings. Anyone buying or selling a home now needs a certificate by law. From October 2008 EPCs have been required whenever a building is built, sold or rented out. The certificate provides 'A' to 'G' ratings for the building, with 'A' being the most energy efficient and 'G' being the least, with the average up to now being 'D'. Accredited energy assessors produce EPCs alongside an associated report which suggests improvements to make a building more energy efficient.

The EPC is part of a series of measures being introduced across Europe to reflect legislation which will help cut buildings’ carbon emissions and tackle climate change. Other changes include requiring public buildings - for example town halls, libraries, hospitals - to display certificates showing the energy efficiency of the building and requiring inspections for air conditioning systems.

Figure 3: UK Energy Performance Certificate



Integrated renewable energy

Further savings are possible through the installation of micro-generation technologies. These systems may be installed in existing buildings and are applicable in all regions of the UK. The costs and benefits of these technologies are listed in Table 8. High initial (capital) costs can deter households from investment. Therefore uptake of these technologies is largely driven by grant programmes. In light of this fact, the DTI announced proposals for the *Low Carbon Buildings Programme* (DTI, 2006). Under phase one of the UK Department of Trade and Industry's low carbon buildings programme grants totalling £10.5 million were made available to householders and community organisations for micro-generation technology. A further £18 million was made available to public, not for profit and private sector organisations for medium and large scale micro-generation projects. The low carbon buildings programme provided grants for micro-generation technologies to householders, community organisations, schools, and the public and not for profit sector and private businesses.

Table 8: Costs and benefits of micro-generation energy technologies

Micro-Generation Technology	Cost	Saving/yr	Cost of Savings (£/tonne CO_2 Saved)
Micro CHP	£2,500-£3,500	£150	Approx £600
Solar Water Heating	£2,000-£3,000 for - 4m^2	£35-£100	£130-£600
Wind Turbine	£1,500 - £3,000	£150-£300	£195 - £220
Photovoltaic PV	£2,000-£4,000 - 5m^2	£32	£550-£1,100
Ground Source Heat Pump	£800-£1,000 per kW heat		£30-£350

Source: Department of Trade and Industry 2006

Solar water heating systems comprise solar collectors (evacuated tubes or flat plates) a heat transfer system (a fluid in pipes) and a hot water store (e.g. a domestic hot water cylinder). A 4m^2 collection area will provide between 50% and 70% of a typical home's annual hot water requirement in the UK.

Solar photovoltaic (PV) systems generate electricity from sunlight. Small-scale PV modules are available as roof mounted panels, roof tiles and conservatory or atrium roof systems. A typical PV cell consists of two or more thin layers of semi-conducting material, which is most commonly silicon. The electrical charge is generated when the silicon is exposed to light and is conducted away by metal contacts. In Germany, the application of PV is at least 10 times greater than in the UK both at domestic and commercial level. This is due to a combination of government support and reduced costs of installation of the systems. The reduced costs arise because the large scale installation of PV has pushed prices down sharply. A typical 3kw PV system costs about £17,000 in Britain but less than £10,000 in Germany, where prices have halved in the past seven years and it is estimated they may do so again in the next seven. The government support is fundamentally due to a policy termed the "feed-in tariff" (FIT). Anyone generating electricity from solar PV, wind or hydro gets a guaranteed payment of four times the market rate - currently 43.3 pence a unit retrofit and 37.8 pence a unit new build - for 25 years. This reduces the payback time on such technologies to less than 10 years and offers a return on investment of 8-9%. The cost is spread by generating companies among all users and has added about one penny/kWh to the average bill, or an extra £1 a month.

Feed-in Tariffs (FITs) became available in Great Britain from 1st April 2010. Under this scheme energy suppliers make regular payments to householders and communities who generate their own electricity from renewable or low carbon sources such as solar photovoltaic (PV) panels or wind turbines.

The scheme guarantees a minimum payment for all electricity generated by the system, as well as a separate payment for the electricity exported to grid. These payments are in addition to the bill savings made by using the electricity generated on-site.

Households receiving the FIT benefit in 3 ways:

1. Generation tariff – a set rate paid by the energy supplier for each unit (or kWh) of electricity generated. This rate will change each year for new entrants to the scheme (except for the first 2 years), but then be continued on the same tariff for 20 years, or 25 years in the case of solar electricity (PV).

2. Export tariff - a further 3p/kWh from the energy supplier for each unit exported back to the electricity grid, that is when it isn't used on site. The export rate is the same for all technologies.

3. Energy bill savings –savings on your electricity bills, because generating electricity to power appliances means not buying as much electricity from an energy supplier. The amount saved will vary depending on how much electricity is used on site.

Domestic FIT installations are likely to have their export deemed (estimated) at 50% in most cases until smart meters are rolled out

Once household have a micro generation technology installed they should experience a monthly reduction in their electricity bill and then receive an income from the feed-in tariff (clean energy cash back) provider. If a loan has been taken out to pay for the installation the household will have to make monthly repayments to the loan company. Feed-in tariffs are designed so that the average monthly income from the installation will be significantly greater than the monthly loan repayment (with a 25 year loan).

A number of businesses in the UK are offering 'PV for free' to households and housing associations, who benefit from electricity generated – in return for all of the revenue from the Feed in Tariff. In November 2011, because of the success of the Feed in Tariff in the UK, the UK Climate Change and Energy Minister announced that the FIT rates would be cut by more than 50 per cent for any domestic installations completed after December 12, 2011. The tariff for solar installations up to 4kWh in size was cut from 43.3 pence/kWh to 21 pence/kWh. The suddenness of the change – only six week's notice, stunned the fast growing solar industry and risks its collapse. The UK government's justification for this was that the cost of a typical photovoltaic installation had fallen from £13000 in April 2010 to £9000 in November 2011 and that leaving tariffs as they were would cost £980 million a year by 2014-15 adding £26 to domestic bills by 2020. There were 16000 solar installations in September 2011, twice the number installed in June and the total number of installations was 100 000 with a capacity of 400 MW which was three times the projection. A case of a government policy initiative that was too successful!

Micro-wind turbines convert wind to electricity. The most common design is for three blades mounted on a horizontal axis, with the blades driving a generator (directly or through a gear-box) to produce electricity. Most systems are mounted on a tall mast, but building-mounted turbines are now starting to come onto the market.

Micro combined heat and power (CHP) - these technologies use natural gas as a fuel but provide electricity as well as heat. The two main systems use either reciprocating engines or Stirling engines. Fuel cells are also an alternative source of power.

Ground source heat pumps use the warmth stored in the ground to heat fluid circulating through pipes, a heat exchanger extracts the heat and then a compression cycle (similar to that used by refrigerators) raises the temperature to supply hot water for heating purposes. Air source and water source heat pumps operate in a similar fashion using temperature differentials in the air and water (these types of heat pump are not quite as efficient as ground source heat pumps).

Biomass stoves and boiler systems can provide space and/or water heating from burning wood (pellets, chips and logs) and non-wood fuels. The biomass fuels are derived from forestry products, energy crops (willow and miscanthus) and waste wood products (sawdust, pallets or untreated recycled wood).

The Renewables Obligation (RO) is the UK Government's main mechanism for supporting generation of renewable electricity. Support is in the form of electronic certificates called Renewable Obligation Certificates (ROCs), one certificate being issued for each megawatt hour (MWh) of renewable electricity generated. The price of a ROC is set by the market and could be as much as £40. Zero carbon content electricity has a value and energy producers have to buy ROCs. This effectively shortens the payback periods for renewable electricity generation schemes.

UK Eco-towns

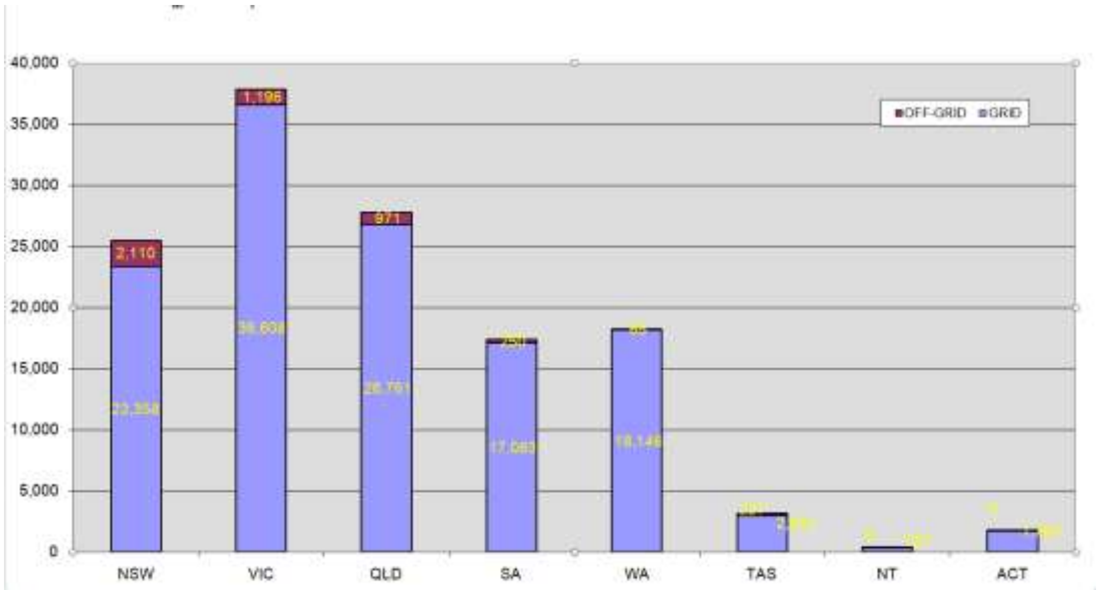
A plan to create hundreds of thousands of homes in ten new ‘eco-towns’ was scaled down in 2009 to just four of 5-15 000 new homes each. The planned zero-carbon developments – some on Greenfield land – caused protests and a legal challenge. Construction of the four still proposed (St. Austell, Cornwall; Bicester, Oxford; Rackheath, Norfolk; and Whitehill-Borden, Hampshire) is to begin in 2016. The towns are to include smart meters, charging points for electric cars and community heat sources. Green space will be 40 per cent of their area. Affordable homes would use renewable energy sources and be within ten minutes walk of public transport.

AUSTRALIAN GOVERNMENT INITIATIVES

As in the UK there have been numerous programmes at both federal and state level to address issues of greenhouse gas emissions in Australia and several of there are specific to the residential sector. Firstly the Australian government belatedly signed the Kyoto Protocol on 2007. Secondly, the federal government, in the face of some opposition, has pushed through with a carbon tax which is due to commence in mid 2012. Thirdly, several states including South Australia and Victoria have set emissions and renewable energy targets for the medium and long term. The incoming federal Labor government of 2007 introduced the Green Loans scheme aimed at improving residential energy efficiency through a programmed range of energy audits, and free loft insulation to householders in a bold bid to improve insulation standards across the national stock. In total 600,000 assessments were carried out under the scheme. However the program was poorly managed and several high profile cases of house fires resulting from poor standards of installation resulted in the scheme being prematurely halted in 2010 (Van Onselen, 2010). In 2008 the federal government banned the sale of incandescent light bulbs, effectively paving the way for the large scale introduction of compact fluorescent bulbs. These are much more efficient since a 60 watt incandescent light globe x 8 hours a day = 480 watt hours whereas a 15 watt CFL bulb x 8 hours a day = 120 watt hours. (Energy Matters, 2011). Across Australia there have been a number of government sponsored area based initiatives designed to address residential energy use through boosting solar energy demand and improving energy efficiency. The Solar Cities programme which received $7 million of public funding, nominated locations in all the main states and Northern Territory, with the aim of demonstrating how technology, behaviour change and innovative approaches to energy pricing could be employed to reduce reliance on fossil fuel based electricity. In most cases the scheme was driven by private utility companies which suggests it was as much about changing the market perception of suppliers as changing the behaviour of consumers. Smart metering was often a central aspect, allowing consumers to monitor their electricity consumption and better understand the relationship between appliances, environmental conditions and energy price/ consumption. At state level various energy efficiency schemes have been introduced. For example the Victorian Energy Efficiency Target (VEET) commenced in 2009 with the intention of supporting householders wishing to install a large number of energy efficiency devices by encouraging retailers to offer discounts. The similar but rather more limited South Australian Residential Energy Efficiency Scheme (REES) scheme has similar aims.   Energy labeling of domestic appliances such as fridges, freezers, washers, dryers and dishwashers was introduced in Victoria and NSW in the mid 1980s and is now mandatory across Australia. Appliances must be tested and conform to Australian Standards to receive an energy star rating before they can be sold to the public.

The federal Government introduced the Solar Homes and Communities Plan in 2000. This effectively halved the cost of purchase and installation of solar PV panels on residential buildings and proved extremely popular. The number of applications across Australian increased from 420 per week in may 2008 to 6,043 in June 2009. This scheme was then modified into the Renewable Energy Target (RET) scheme. The RET scheme guarantees a market for additional renewable energy generation using a mechanism of tradeable Renewable Energy Certificates known as RECs. The Australian Government has set a target to achieve a 20 per cent share of renewable energy in Australia's electricity mix by 2020. The expanded RET scheme absorbs state and territory renewable energy targets into a single national scheme. Systems installed on or after 9 June 2009, where no application has been made up to that date for pre-approval under the Solar Homes and Communities Plan, now receive Solar Credits under the REC scheme rather than the previous photovoltaic rebate scheme. Owners transfer the right to create RECs to their installer in return for a discount on the equipment being installed. The number of credits offered for PV installations varies since insolation rates vary across the country. So installations in the north for example Darwin, will earn more credits than those in Melbourne or Tasmania. The first 1.5kW installed earn 5 RECs and the balance of the system earns 1 REC. The value of the solar credits which constitute the REC will vary over time with market fluctuations. All eligible systems must be grid connected. Figure 4 below, which shows the relative uptake of the scheme by state, clearly demonstrates its popularity.

Figure 4: Australian solar PV systems installed by state to July 2011



Source: DCCEE (2011)

Solar hot water (SHW) is also strongly encouraged by Australian governments. RECs are used to subsidise the federal scheme and in several states extra subsidies are offered. So in SA a means tested $500 discount is offered for new SHW installations in addition to the discount offered by RECs.

All the Australian states have introduced feed in tariffs to further incentivise the uptake of solar PV. South Australia for example until recently offered a 44c per kW which has since reduced to 22c, which is roughly the cost of grid supplied electricity. Most of these are net feed in tariffs, which pay an enhanced rate for surplus energy which is exported to the grid. The Northern Territory (NT), Australian Capital Territory (ACT) and New South Wales (NSW) initially offered gross feed in tariffs which pay a premium rate not just for surplus electricity but for every kW produced. These incentives fairly quickly proved too expensive and were withdrawn or modified.

Table 9: Current Australian state feed in tariff arrangements

State	Current status	Max size	Rate paid	Program duration	Model
VIC	Commenced Nov 2009	5kW	60c kW/h	15 years	Net
SA	Commenced July 2008	30kW (10kW per phase)	44c/22c	20 years	Net
ACT	Commenced March 2009	200kW	30.16c kW/h	20 years	Gross
TAS	Commenced	tbc	20c kW/h	tbc	Net
NT	Commenced	tbc	As consumption rate	tbc	Gross

WA	Ended 1August 2011		20c kW/h	10 years	Net
QLD	Commenced July 2008	5kW	44c+	20 years	Net
NSW	Closed	10kW	60ckW/h & 20c kW/h	7 years	Gross

Source: Energy Matters, 2011

As Table 9 demonstrates there is tremendous variability in the provisions between the states and the early withdrawal or modification of schemes suggests either a higher than expected uptake or poor modelling of the original concept in some instances.

Mandatory disclosure of building energy efficiency is currently under discussion and is likely to be introduced soon. All owners of residential property who wish to sell or rent their property will be required to disclose information on the energy water and greenhouse performance of their property. In the ACT a system of mandatory disclosure of energy performance has operated since 1999 and research has demonstrated that homes with a higher energy efficiency rating may have a higher market value (DEWHA, 2008b).

Finally all the Australian states have now introduced more stringent requirements for the energy performance of new dwellings. A 10 star energy rating system is employed where 1 star indicates that the building structure has little or no effect on moderating the outdoor climate conditions, 5 stars is a reasonable standard of performance and 10 stars implies no heating or cooling is required as the thermal insulation and performance is highly efficient. In 2010 a minimum rating of 5 stars was standard and this has now risen across Australia to a 6 star mandatory minimum requirement under the Building Code of Australia.

DISCUSSION

Readily available heating, cooling and power are taken for granted in developed societies. As we become less tolerant to fluctuating temperatures in our homes and more reliant on products requiring electricity, demand for heating, cooling and power is likely to grow even in the face of increasing strides being made in greater energy efficiency. The context to this growing demand is one where the UK will no longer be a net exporter of oil and gas, where there is increasing urgency in the need to tackle climate change and rising energy prices are hitting the most vulnerable. In Australia the context is one where the economy is largely driven by a natural resource exports, including large quantities of fossil fuel energy to China and India. The mining lobby is an extremely powerful influence on government arguing vociferously against a carbon tax, linking employment concerns to national and state energy policies and thereby supporting continued large scale use of coal, gas and oil for power generation. Meeting the challenges of reducing residential energy demand and GHG emissions will require a portfolio of measures, including energy efficiency, renewable energy and other low/zero carbon energy sources. It will also require strong policy direction from central government. The UK with its strong centralised political structure and declining fossil energy resources is better positioned in this respect to address the problem than Australia. The technical ability to install retrofit measures to greatly improve the energy performance of existing homes in the UK was demonstrated earlier in this paper. Micro-generation technologies have significant potential as a part of the portfolio of measures to reduce greenhouse gas emissions. In Australia there are encouraging signs in respect of the application of solar energy onto domestic roofs. Given the high insolation resource across most of the country, as compared with the UK and Europe, and the often generous subsidies offered by federal and state governments, this is hardly surprising. But the expertise to manage a major roll out of residential energy efficiency has been shown to be lacking. Furthermore the high dependence on electricity as the main domestic fuel, allied to the very generous proportions of Australian houses, which are approximately three times larger than the floor area of average UK houses, means that energy demand in Australian homes is just as serious an issue as it is in the UK, despite Australia's generally more favourable climate.

Rising fuel prices and greater environment awareness are encouraging buyers to pay close attention to a home's running costs and their environmental impact in both countries. In the UK Energy Performance Certificates became compulsory for anyone selling their home after 1st August 2007. When homes are sold or rented, this information must be made available by the seller or landlord to buyers or tenants. Making this information available to home buyers will influence property values. In addition 80% of home buyers want to know if their home is environmentally friendly. Research from the Energy Saving Trust has found that nearly 70% of British residents believe that energy efficiency is important when buying a home (Energy Savings Trust, 2008). Almost half (45%) are willing to pay up to £10,000 more for an environmentally friendly home. Sellers are choosing insulation, modern water heating boilers and double glazing over frivolous fixtures and fittings to add real value. The economic potential for greenhouse gas reductions is therefore demonstrated for the UK. Australia appears again to lag behind in consumer attitudes. There is little evidence available on the actual price differential between energy efficient and standard homes but the introduction of mandatory disclosure of energy efficiency on residential transactions and the carbon tax, which will increase energy prices across the board, are likely to further concentrate consumers' minds on the alternatives.

In both nations provisions dealing with the energy performance of new built dwellings are progressing. The UK is particularly ambitious in aiming for carbon neutrality in the next few years, though the evidence to date suggests limited success in implementation though the aim is laudable. Australia's adoption of 6 star energy rating for new homes is a lesser but still important step. The major problem remains the existing housing stock, which will take many decades to replace and in both cases remains inefficient and wasteful of energy, GHG and money.

Homeowners are much more likely to adopt the measures outlined above if:
a) they believe their actions will be economically beneficial to themselves, and
b) the costs can be spread over a period of time during which savings can be made to considerably offset those costs. Of course the problem is how to persuade home-owners to undertake these measures. In this regard, the UK Green Deal initiative outlined earlier could be very important in assessing homeowners' behaviour and it is unfortunate that Australia appears to have failed to implement a similar scheme.

CONCLUSION

The UK and Australia are both advanced economies which use significant amounts of energy per capita, the majority of which derives from fossil fuels. The residential sector within each country is an important source of energy demand. In both cases space heating or a combination of space heating and cooling is the main energy use within the sector, though increasing home appliances are rapidly becoming more important. Australian homes use less energy per household than UK homes, but emit more GHG per household because they are highly reliant on electricity and because of the fuel mix used in electricity generation. Both countries have developed packages of measures aimed at retrofitting existing homes to improve their energy efficiency and shift their energy supply towards renewable sources. They also have both instituted measures to raise the energy efficiency and reduce the GHG emissions of new homes, in the UK case aiming at zero carbon emissions by 2016. The take up rate and success of these schemes varies for a range of reasons. Overall it could be argued that Australia lags behind the UK, largely because of macro scale economic and political factors which are slowing the acceptance of such programmes.

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