Reducing carbon emissions in construction and housing

Introduction

In recent times new buildings have been the main focus in terms of improving energy efficiency in the construction industry. This agenda has been led by the introduction of minimum energy performance standards in Part L of the buildings regulations back in 2006.

In recent times ‘ the code for sustainable homes’ has already set the target of net zero carbon emissions by 2016 for all new domestic buildings. Recent Part L amendments are geared towards ensuring the target is met. The proposal for 2010 is for a saving of 25% in CO2 emissions per year compared with 2006 levels. (Rabin, 2009) These challenging standards proposed for the building regulations in regards to new builds means that the industry’s attention will continue to focus heavily on new buildings.

However, new buildings only account for 1-2% of the total building stock each year, meaning that, if the government is to get close to its target of cutting carbon 80% by 2050, (Summers, 2008) significant CO2 reductions will need to come from existing buildings.

87% of the homes that will be standing in 2050 are already built, (DCLG, 2008) which is why government, industry and home owners are all looking into the benefits of refurbishing the existing housing stock.

Aims

The main aims of the research project are to:

- Investigate how existing housing can be upgraded to reduce carbon emissions

- Investigate whether eco-refurbishment is cost-effective in terms of both monetary costs and Co2 emission reduction.

Objectives

The main objectives of the research project are:

- To introduce the concept of eco-refurbishment
- To explain why upgrading an existing housing stock is necessary
- To investigate options for fabric & service upgrades.

Existing housing stock & Carbon emissions output

The code for sustainable homes is pushing forward in terms of the new build sector and the aim of zero carbon construction by 2016. The focus on the new build sector overshadows the existing housing stock despite it having an even bigger role to play in terms of reducing Co2 Emissions.

Current predictions estimate that in 2050, the existing (pre-2006) housing stock will still make up two thirds of the UK's housing. This stock is typically poorly performing when measured by today's heightened energy efficiency standards, and hence it is essential that measures are taken to reduce its associated carbon emissions. (Greenbang, 2009)

Each household in the UK creates around five and a half tonnes of carbon dioxide a year. That's five and a half times the weight of the rubbish a household throws away in a year. It's also nearly double the carbon dioxide emissions that the average car produces in a year. (Energy Saving Trust, (n/d))

Options for fabric upgrade

Priorities

From the outset consideration must be taken as to which measures are cost effective in terms of both monetary cost and Co2 emission reduction. The options for fabric upgrade can be split into ten specific groups-

- Walls – Most post -1930 homes have cavity walls and still the majority in the UK do not have the benefit of cavity-fill insulation. (Smith, 2004) Immediate increases in comfort, as well as lower energy bills could be met if this deficiency was to be rectified.
- Roofs – Poorly insulated roofs offer rising heat the ideal escape route.
- Floors – The British climate causes floors to be a particular drain in terms of heat lost.
- Windows – Double Glazing has gained a hold on the housing sector, not least because of the assertive marketing tactics of some double glazing companies. In part, this is because it is perceived as a fashion accessory to a home. (Smith, 2004) High performance double glazing which uses low emissive glass is now required by the building regulations.
- Doors – Double glazed doors can now be manufactured in a similar fashion to double glazed windows.
- Space heating and hot water – A number of central heating systems remain in use within the UK which are well below current best practice.
- Air tightness – straightforward draught-proofing can have a benefit out of all proportion to its cost. However, if the draught sealing has been

carried out really effectively, it may be necessary to provide fan-assisted ventilation. (Smith, 2004)

- Ventilation – Controlled ventilation is necessary to provide a healthy internal environment.
- Lighting and Appliances – Appliances and white goods are often major energy drains, especially fridges and freezes. (Smith, 2004) When replacing appliances it is vital the appliance carries an energy saving recommended certificate mark
- Renewable and low carbon technologies – Renewable technologies can offer additional reductions in environmental impact.

The energy saving trust – Best practice in refurbishment

The energy saving trust produced a report in which a refurbishment standard was designed to give optimum balance of environmental performance and practicality. Using the best practice specification ensures that refurbishment work is carried out to the highest practical standard, and the maximum cost and carbon savings are realised for residents, and the environment. (The Energy Savings Trust, 2008)

Table : Summary of Energy Saving Trust best practice in refurbishment standard

Areas of Improvement

Walls

Where possible, walls should be insulated to achieve a maximum U-value of 0. 30W/m²K.

Roofs

For best practice, aim for a U-value of 0. 16 W/m²K when installing insulation between the joists or rafters. Flat roofs should be insulated to achieve a U-value of 0. 25 W/m²K or better.

Floors

Exposed floors should be insulated to achieve a maximum U value of 0. 20-0. 25 W/m²K.

Windows

Replacement windows should have a BFRC rating in band C or above. Any retained windows should be draught-stripped.

Doors

Replacement doors should have a maximum U-value of 1. 0 W/m²K if solid, or 1. 5 W/m²K if half-glazed. All existing doors should be draught-stripped

Space heating and hot water

Domestic wet central heating systems and hot water should be installed to meet ' central heating system specification (CHeSS – Year 2008' standard HR6 or HC6. Where electricity is the only option, the recommendation contained within ' Domestic heating by electricity' should be followed

Air tightness

Air leakage paths can be identified using a pressure test and removed by undertaking remedial sealing. The best practice recommendation is to aim for an air permeability of 5m³/(hm²) at 50Pa.

Ventilation

A purpose-provided ventilation system should be installed.

Lighting and appliances

When re-wiring dedicated lamp fittings should be installed which accept only low-energy bulbs. Ideally greater than 75% of all fixed luminaries should be dedicated low energy fittings. Low energy appliances should be specified which carry energy saving recommended certification mark.

Renewable and low carbon technologies

After all basic energy efficiency improvements have been undertaken the specification of renewable technologies, such as solar hot water heating or photovoltaics, is encouraged where appropriate to further reduce environmental impact.

Source: Figures taken from ‘ Roadmap to 60%: Eco-refubishment’ P. 8

The Building Fabric

Insulation Assumptions

The costs and paybacks shown in tables under each area of potential fabric upgrade are approximations made by the energy saving trust; they are based on a gas heated semi-detached house with 3 bedrooms. A gas price of 3. 80p/kWh has been used in their calculations.

External Walls

To reduce the amount of heat lost through external walls, the installation of insulation is required. Three common methods are traditionally used, the most cost effective being cavity wall insulation. Alternative methods include external wall insulation, or internal insulated dry-lining, these are generally used if the wall has no cavity.

Cavity Wall Insulation

Typically all masonry cavity walls built since the 1930's are suitable for the installation of insulation. Polystyrene beads or mineral fibre with a U-value of 0. 30W/m²K are blown in the wall cavity through a hole. It is recommended that installation be undertaken by an approved company using an approved system under the British Board of Agreement (BBA).

Internal Wall Insulation

When either a cavity wall or solid masonry wall are un-suitable for cavity insulation then internal wall insulation can be a cost effect solution. This is most cost effective when the existing plaster is being renewed. The wall should be insulated to achieve a maximum U-value of 0. 30W/m²K. (Energy Saving Trust, (n/d))

External Wall Insulation

External wall insulation offers an alternative method of insulating a masonry wall. The installation and design is a specialist job, and advice should be sought from an approved company. External wall insulation is the most expensive of the three methods (Smith, 2004) but can be cost effective when other works are being carried out. (City of Westminister Council, (n/d))

Pitched Roofs

Typically insulation is fitted between ceiling joists and rafters, covering the ceiling area. Any pipes which run through the loft space need be insulated as best possible. The insulation must be at least 250mm thick and have a U-value of 0. 16 W/m²K. Two layers of insulation is preferred, one between joists and one across the top. Loft Ventilation is required to maintain air flow.

Flat Roofs

For best practice insulation should be placed above the structure as part of the roof finish, referred to as a ‘ warm deck’. If this is not possible the insulation may be fitted within the roof structure, often referred to as a ‘ cold deck’. To keep costs low it is recommended to replace the insulation in roofs when the covering requires replacing. A rigid board material of 100mm thickness should be used; a U-value of 0. 25 W/m²K or better is required.

Ground Floor

Heat is typically lost through the ground floor; the amount lost is dependent on the shape and size of the flooring area. It is best to insulate a ground floor whilst works are being carried out. The floor should be insulated to a U-value of 0. 20-0. 25 W/m²K.

Intermediate Floors

Intermediate floors allow for rooms over an un-heated space, such as a garage or storage room to be insulated. Where there is access from below this can be cost effective. (City of Westminister Council, (n/d)) Mineral fibre insulation should be used to achieve a U-value of 0. 20-0. 25 W/m²K.

Windows

Traditional windows are usually single glazed without draught proofing and by today's standards offer a poor standard of energy efficiency. (City of Westminister Council, (n/d)) Switching to double glazed windows offers many benefits. Double glazed windows consist of two specially made glass panels with a space in between them; a gas such as argon is generally filled in this cavity as a form of insulation. They also often have a UV coating, which can be customised to the British climate. In many instances when frames are worn out and need replacing cost effective energy efficiency improvements can be made.

External Doors

Double glazed doors as well as windows are now a common sighting throughout the UK. They offer a much better standard of thermal insulation in comparison to that of a solid timber door. Glazing units in doors can be made to the same standards as windows. (City of Westminister Council, (n/d)) And as such should be replaced when frames are worn out.

Draught Proofing and Ventilation

A ventilation and airtightness strategy should be part of any refurbishment works. (The Energy Saving Trust, 2007) The main objective of draught proofing and ventilating is to provide a balance between energy efficiency and the indoor air quality.

Air leakage is the infiltration of air via unwanted gaps and cracks in the building envelope.

Too much air leakage leads to heat loss as well as discomfort from cold draughts. As thermal insulation standards improve the proportion of total heat lost via infiltration increases significantly. Ventilation of the dwelling is desirable and necessary to remove moisture and other pollutants from the air.

Airtightness

The potential to improve airtightness of a dwelling will depend on the nature of the existing building and the type of works being undertaken. It is therefore difficult to set absolute targets but the best practice recommendation is to aim for an air permeability of 5m3/(h. m2) @ 50Pa. (The Energy Saving Trust, 2007)

Some simple measures can be taken to improve the airtightness. Draught proofing around windows, door; sealing around service pipes which pass thorough floors, walls and roofs; block up unused chimneys, but include ventilation to the room by means of a ventilator.

Ventilation

Purpose-provided ventilation (e. g. ventilators and windows) and extract fans are required to replace stale indoor air with fresh outdoor air. (The Energy Saving Trust, 2007)

Adequate ventilation is needed for both the comfort and the safety of occupants, as it removes or dilutes pollutants that accumulate in the dwelling. Once the dwelling is sufficiently airtight, controlled ventilation can be installed.

One of the more beneficial ventilation systems is the single room heat recovery ventilator. This is a development of the extract fan which incorporates a heat exchanger. It recovers 60 per cent or more of the heat in the outgoing air. (The Energy Saving Trust, 2007) This can then be used to preheat incoming air.

Options for Service Upgrade

Domestic Heating & Hot Water

By upgrading predated boilers a significant reduction in energy consumption can be achieved. Furthermore it is very cost effective. If the house has been insulated prior to the replacement or installation of the energy efficient boiler further improvement in the energy efficiency of the house can be felt.

The followings points need to be considered when choosing an energy efficient domestic heating system

The system is correctly sized to warm up the dwelling from cold taking account of heat gains from the sun, people, lights and appliances

It uses fuel as efficiently as possible

Provides heating and hot water only when required and where needed

Have controls that are easy to use and understandable.

The installation of an energy efficient boiler such as a condensing boiler will reduce running and costs and will in most cases add value to a property.

The energy performance standard for new and replacement boilers was raised in England and Wales in April 2005, Northern Ireland in November

2006 and Scotland in May 2007. When replacing a boiler, a condensing boiler (with a seasonal efficiency of greater than 86 per cent) must now be installed in the majority of cases. (The Energy Saving Trust, 2007)

Heating assumptions

Below, savings are shown for the upgrade of a condensing boiler from a ' G' rated boiler to an efficient ' A' rated boiler. These savings are approximations made by the energy saving trust and are based on a gas heated semi-detached house with 3 bedrooms. Savings assume a gas price of 3. 80p/kWh.

Lighting

Electricity for lights and appliances (including cooking) can account for a significant proportion of total energy costs and CO2 emission. Energy demand for lighting can be reduced by:

- Using energy efficient lamps and luminaries (light fittings).
- Directing light to where it is needed.
- Controlling lighting use.
- Making the most of daylight.
- Immediate results can be made in the first three areas through basic home improvements.

75% of all fixed luminaries should be dedicated low energy fitting for best practice. The annual savings shown in the table below are based on a home owner changing 3 light bulbs to energy efficient light bulbs a year.

Table : Annual Savings and Paybacks for ' Energy Efficient Light Bulbs'

- Measure: Energy-efficient light bulbs

- Annual saving (£/yr): Up to £30
- CO_2saving a year: Around 136kg

Source: http://www. reduceyourco2. co. uk/tips. html

Appliances

Appliances account for a large proportion of total domestic energy use. As energy efficient appliances use less electricity, they are less expensive to run and are responsible for lower CO_2 emissions. (The Energy Saving Trust, 2007)

Appliance assumptions

The table below shows the energy ratings and savings when upgrading appliances. These savings are approximations made by the energy saving trust, they also assume replacing an average appliance purchased new in 1998 with an Energy Saving Recommended model of similar size and an electricity cost of 12. 96p/kWh.

Source: http://www. energysavingtrust. org. uk/Energy-saving-assumptions

Renewable and low-carbon technologies

Several types of renewable technologies can generate electricity for a dwelling, including photovoltaics (PV), wind and micro-CHP.

Other renewable or low-carbon technologies can also provide heating and hot water, such as heat pumps, biomass and solar hot water.

Solar Water Heating

By installing a solar water heater the house can use the sun’s energy to produce hot water. For a more cost effective approach it is advised to install a solar collector where other heating improvements are already being undertaken. There are two main types of solar water heaters, a flat plate collector or evacuated tube collectors. Both types have liquids in them which collect heat from the sun, this then passes through a coil in a hot water cylinder.

These systems are typically only used for water heating, and are rarely used to provide space heating. Solar Water Heaters are amongst the most cost-effective renewable energy systems for existing dwellings. During the summer months, a typical system can supply between 80 and 100 per cent of hot water demand, the percentage being much lower in winter, of course. (The Energy Saving Trust, 2007)

Even when it is decided not to include solar water heating, it is worth making properties ‘ solar ready’, to allow systems to be added later with minimal disruption.

Photovoltaics

PV panels allow solar energy to be converted into electricity. The panels can generate power to satisfy some of buildings electrical demand even in the northern latitudes, in some cases all of the building’s electrical demand can be met.

The PV's are versatile and can be installed in numerous locations, glass roofs and conservatories being one option, a more common option being to install an array of them on a south facing roof.

Grants

Most of the grants and offers you can benefit from are provided by three main groups.

- The Government
- Energy Suppliers
- Local Authorities

The Government

A number of schemes are funded by the government, in some cases up to £3, 500 can be given to help people improve their heating and energy efficiency. In England the scheme is known as Warm Front, in Wales it is known as the Home Energy Efficiency Scheme.

The eligibility criteria for the schemes differ between both countries, some schemes you need to be in receipt of certain benefits, whilst others are available to anyone over a certain age. Guidance as to the availability of these grants can be found on their websites. Examples of Home Energy Efficiency Scheme eligibility criteria;

Home Energy Efficiency Scheme (Grant of up to £2, 000)

Householders who either have a child aged under 16 or are pregnant and have been given maternity certificate MAT B1 and are in receipt of one or more of the following benefits:

- Income Support
- Working Tax Credit (with income less than £16, 040)
- Council Tax Benefit
- Child Tax Credit (with income less than £16, 040)
- Housing Benefit
- Income-based Jobseeker's Allowance
- Income-related Employment and Support Allowance

Source: http://www. heeswales. co. uk/do-i-qualify. htm

The following websites offer further examples and information regarding eligibility criteria.

- Warm Front grant (England) – http://www. warmfront. co. uk/do-i-qualify. htm
- Home Energy Efficiency Scheme (Wales) – http://www. heeswales. co. uk/do-i-qualify. htm

Energy Suppliers

The Carbon Emissions Reduction Target (CERT) came into effect in April 2008, obliging electricity and gas suppliers in Great Britain to help reduce carbon dioxide (CO2) emissions from homes. (Energy Saving Trust, (n/d)) This means energy suppliers with a certain number of customers operating in Great Britain are obliged to achieve targets for improving home energy efficiency. The suppliers therefore provide a range of offers which significantly reduce the cost of installing energy efficiency measures.

Local authorities

Most Local authorities provide grants and offers for local residents to install certain energy efficiency measures in their home. (Energy Saving Trust, (n/d))

Case Study

There are a number of case studies which show the benefits and tribulations of eco-refurbishment, one of particular interest is describe below.

Nottingham Eco-home

Architect Gil Shalom and his wife Penney Poyzer set out the task of refurbishing their Victorian home whilst reducing emissions by 85%. As well as reducing emissions by 85% they hoped to use only low impact materials. In the process they hoped to demonstrate how green design can appeal to a wider audience and be an aspiration lifestyle choice. (Sustainable Development Commission, (N/D))

Overview

A typical 5-bedroom semi detached Victorian house that was refurbished over a six year period in a low energy and ecological way.

Dating from around 1898, it was in a very run-down state and has been thoroughly upgraded by the owners, to provide a good example of eco retrofit. It is a demonstration of a variety of eco-friendly features including super-insulation, solar hot water and wood burning boiler, rainwater harvesting and waste composting systems. (Sustainable Development Commission, (N/D))

The project set out specific priorities to aim for during the refurbishment, they were to:

Upgrade thermal performance through insulation, heat recovery ventilation and air tightness and thermal mass improvement

Be as autonomous as possible in energy, water, sewage treatment and food

Experiment with different low-impact materials

It was estimated that an overall energy saving of 85% in terms of Co2 and 75% in terns if costs was made. This was a direct result of the refurbishment work which took place.

‘ Image 1’ shows the areas of the house the refurbishment took place. The list below corresponds to ‘ Image1’. (Sustainable Development Commission, (N/D))

1. Flat-Plate solar collectors for heating water
2. Roof insulation 300/400mm thick (shredded newspapers)
3. Roof lights with insulating low-emissivity glass
4. Natural plasters- clay and lime based
5. Super insulated hot water tank
6. 100mm ozone friendly drylining to front face to maintain brick appearance
7. 150mm external wall insulation with rendered finish
8. Space saving bath and thermostatic shower controls
9. Heat recovering fans
10. Environmental-friendly paints

11. Draught lobby

12. triple- and double-glazed timber windows treated with natural fungicides and stains

13. Energy efficient appliances

14. Second hand reclaimed furniture

15. tripped floorboards

16. Copper rainwater goods with filters for rainwater harvesting

17. 160mm natural floor insulation

18. Rainwater storage for use in WCs and washing machine

19. Low-flush toilets

20. Non-PVC waste pipes

21. Composting chamber for solid waste from WCs

22. Separator lets liquids drain off and solids into composting chamber

23. Decking

24. Organic garden utilizing the principles of permaculture

Table: Case Study- Energy and costs at the Nottingham Eco-home

Research findings and discussion

Fabric and Service upgrades

In cases considered cavity wall insulation is shown to be highly cost-effective, however the current savings potential from the installation is beginning to tail off. The resultant reduction in Co2 emissions following the installation is a clear indication that the measures taken are cost effective in terms of both monetary cost and Co2 emission reduction. From the outset this was a main priority. ‘ Table : Costs and Paybacks for Cavity Wall

Insulation' issued by the Energy savings trust illustrates these potential savings.

Although cavity wall insulation is reaching saturation point in terms of potential savings and cost-effectiveness, its counterpart solid wall insulation is not likely to reach this point for the next few years, this is a result of slower uptake. There are still significant potential savings to be had. Currently solid wall insulation is barely a cost-effective upgrade unless other work is being carried out. This may be the cause of a slower uptake. Advances in the technology behind solid wall insulation are likely to improve over coming years and the potential savings could be realised quicker as a result. The annual CO2 saving shown in ' Table : Annual Savings and Paybacks for ' Internal Wall Insulation' shows significant savings could be made despite not being the most cost effective in terms of monetary cost

' Table : Annual Savings and Paybacks for ' Roof Insulation' illustrates that loft insulation is a cost effective way to save energy and reduce domestic carbon emissions. The greatest saving is made when the loft previously had less than 150mm of insulation. If the loft previously had 150mm of insulation or more, the table shows that it is not cost effective to add more.

Floor insulation can offer some potential Co2 savings, but is only truly cost effective if the floor is undergoing repair anyway. ' Table : Annual Savings and Paybacks for ' Floor Insulation' gives us a figure of two years for the payback time which isn't the most cost effective.

Older, less eco-friendly windows are slowly being replaced by low-emissivity double glazing, the potential savings will be realised gradually over the coming years. Currently replacing windows unnecessarily is highly inefficient in terms of cost-effectiveness, this is mainly because of high capital costs. ‘ Table : Annual Savings and Paybacks of ‘ Installing Double Glazing’ illustrates the potential reductions in CO_2 emissions is significant, despite not being very cost-effective.

Draught proofing is one of the more cost-effective fabric upgrades, though the potential CO_2 emission savings are fairly low. To gain the most beneficial results from draught proofing, central heating upgrade, as well as glazing upgrade is advised. The full potential of draught proofing is realised when combined with these upgrades.

‘ Table : Annual Savings and Paybacks for ‘ Condensing boiler upgrade’ suggests that the installation of a class ‘ A’ condensing boiler and heating system offers potentially large CO_2 emission savings, whilst also being one of the more cost-effective service upgrades a dwelling can undergo. Again the true potential of the installation is only realised when the dwelling receives draught proofing and glazing upgrades.

Replacing at least 3 light bulbs with energy efficient bulbs is proven by ‘ Table : Annual Savings and Paybacks for ‘ Energy Efficient Light Bulbs’ to be both cost-effective and offer small savings of CO_2 Emissions. It is one of the easier service upgrades to achieve.

‘ Table : Appliance Energy Ratings and Savings’ shows upgrading to energy efficient appliances of class ‘ A’ or more is a cost-effective energy measure, significantly cutting down on CO_2 emissions, especially if all appliances are replaced.

There is potential to save a considerable amount of carbon emissions with the use of solar water heating; as illustrated in ' Table : Annual Savings for installation of Solar Water Heater'. The cost-effectiveness is currently very inefficient though with advancements in technology this may become more cost-effective within a few years.

PV offer similar results to solar water heaters, despite offering significant savings in Co2 emissions; they are still not a cost-effective service upgrade. The cost far outweighs the reduction in Co2 emissions.

Analysts predict that the cost of PV will fall dramatically over the coming decades, slowly becoming more cost-effective over time.

Case Study

The case study looked at was the Nottingham Eco-home, an ambitious refurbishment of a Victorian house. The owners set out specific priorities at the start of the project which they were aiming to achieve;

Upgrade thermal performance through insulation, heat recovery ventilation and air tightness and thermal mass improvement

Be as autonomous as possible in energy, water, sewage treatment and food

Experiment with different low-impact materials

The case study shows that as ambitious as it was initially, with the correct information and guidance, as well as clear aims & objectives, eco-refurbishment offers attainable goals.

‘ Table : Case Study- Energy and costs at the Nottingham Eco-home’ clearly indicates that significant reductions in the energy costs led to savings per year for both money and Co2 emissions. With additional upgrades the table shows that even more improvements are to be had. Although some of the fabric upgrades and service upgrades are slightly out dated by today’s standards, the case study shows that cutting Co2 emissions is very achievable, and the benefits of eco-refurbishment should not be overlooked

The owners clearly achieved the specific goals they set out initially; an eco-refurbishment was carried out with beneficial results in regards to the cost-effectiveness and savings in Co2 reductions.

Summary and Conclusion

87% of the homes that will be standing in 2050 are already built, (DCLG, 2008) There is evidence that the eco-refurbishment of these homes is definitely a viable option, though whether or not they will achieve the proposal for a 80% reduction in Co2 Emissions by 2050 (Summers, 2008) is still unclear.

The cost-effectiveness and carbon savings of the fabric and service upgrades looked at varies tremendously. Many ‘ Assumptions’ have to be made when calculating the cost-effectiveness and annual Co2 saving of an upgrade, be it fabric or service. This is partially due to there being so many varieties and options for the upgrades. Technological advancements take place daily, and will have a dramatic impact on many of the upgrades looked at, the cost-effectiveness as well as the potential for carbon savings will rise slowly year by year.

There are almost 25 million dwellings throughout the UK, if only half of these were to adopt energy efficient measures, the savings would be highly significant in driving the UK's housing stock emissions down towards the target 80% r