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Review of sustainability in buildings

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Abstract

At present, It is estimated that the building sector contributes up to 45% of annual greenhouse gas emissions primarily through the use of fossil fuels during their operational phase and consumes up to 40% of all energy in UK. Given the massive growth in new construction in economies in transition, and the inefficiencies of existing building stock, if nothing is done, greenhouse gas emissions from buildings will be more than double in the next 20 years. This is a review paper describe the extent and nature of sustainable buildings in UK, either within new or refurbishing old ones, in order to move away from traditional methods of construction and to look at multi-disciplinary and integrated approaches, as well as end-user perspectives.

Key words: Built environment, climate change, energy-efficient buildings, GHG emissions.

1.0 Introduction

Today, it is widely accepted that human activities are contributing to climate change. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) estimated that between 1970 and 2004, global greenhouse gas emissions due to human activities rose by 70 percent (IPCC, 2007).

The Fourth Assessment Report of the IPCC estimated building-related GHG emissions to be around 8.6 million metric tons CO_2 eqv in 2004 (Levine et al, 2007). What is particularly worrying is the rate of growth of emissions: between 1971 and 2004, carbon dioxide emissions, including through the use of electricity in buildings is estimated to have grown at a rate of 2.5% per year for commercial buildings and at 1.7% per year for residential buildings

(Levine et al, 2007). So a Large fraction of the energy delivered to buildings is wasted because of inefficient building technologies. Building of future have to take into account the challenges and the opportunities brought about by technological, environmental and societal changes. Energy savings can be made not by reducing the standard of living, but by utilizing more efficient technologies to provide the same, or higher, levels of comfort and convenience we have come to enjoy and appreciate (Granqvist, 2014). Today significant energy can be saved by making cost-effective efficiency improvements in buildings and their equipment—which will reduce our nation's energy consumption and GHG emissions and provide significant economic savings to consumers.

The world's governments can successfully tackle climate change by harnessing the capacity of the building sector to significantly reduce GHG emissions. Doing so can create jobs, save money – and most importantly, shape a built environment that is a net positive environmental influence – not simply a 'less-bad' version of what we currently have (UNEP, 2009). Investing in achieving such results in the building sector also has the potential to boost the local economy and improve living conditions.

Given the UK's commitment to cut GHG emissions by at least 80% by 2050 relative to 1990 levels, the government recently updated the details of its strategy and milestones for the next five years in its Carbon Plan. Energy efficiency measures in the UK have historically been primarily delivered by government-backed schemes and supplier obligation programmes (which set targets for energy suppliers) (Mallaburn & Eyre, 2014; Rosenow, 2012). However, to deliver projected energy efficiency measures in the future, the UK government has proposed a combination of market- based and government-regulated interventions, under the 'Green Deal' , the 'Energy Company Obligation' (DECC, 2012a) and 'Renewable Heat

Incentive (RHI)' . These schemes are designed to help people make energy efficiency improvements to buildings by allowing them to pay the costs through their energy bills rather than upfront.

2. Research Problem and Method

This study takes a brief look at the concept of sustainability in existing UK building through the review of relevant literature. It is aiming to present sustainable measures and to investigate how these measures would contribute to energy saving in UK. It is considering the history for sustainability in the built environment and also argues that energy efficiency in building need to take account of some factors such as people attitude and constraints for these measures.

The authors developed a hierarchical pathway incorporating categorized techniques in a sequential process. A goal of this a hierarchical pathway is to minimize energy demand and match energy demand with local Low/Zero Carbon energy supply. It can offer a clear vision and choices of sustainable techniques for relevant stakeholders involved in building sectors and policy analysis domain.

The review paper contributes to the ongoing information exchange helping to remove barriers to energy efficiency improvements, and to increase the transparency of policy and measures.

3. Carbon Emission from UK Buildings

The building sector is the largest contributor in terms of GHG emissions, therefore requires specific attention in order to save energy and CO_2 (Koch, et al., 2012). Residential emissions account for 66% of buildings emissions, with commercial and public sector emissions accounting for 26% and 8%, respectively (Parliament Committee, 2013). Figure 1 shows delivered carbon emissions in the UK buildings broken down by end-user. Domestic buildings (Figue1-a) heating accounts for over half of all emissions (53%) and hot water has a significant use also (19%). Other sources such as appliance, lighting and cooking come after that (16%, 7%, and 5%) respectively. For non-domestic buildings (Figue1-b), heating accounts for 41% of total related carbon emissions (8.9 $MtCO_2$). Lighting is the next largest emission source produces 23% of the total emissions due to electricity having a higher emission factor compared to fossil fuels. Similarly computing and cooling produce 4% and 5% of the carbon emissions, respectively, with 5% from other sources (Pout et al., 2002). As more and more electrical items are used within the non-domestic sector it is likely that the proportion of emissions that are attributed to heating will fall, although this does not mean that absolute carbon emissions from heating will fall. It is also worth noting that a 1% drop in total energy consumption caused by savings in lighting will lead to a 1.6% drop in total carbon emissions.

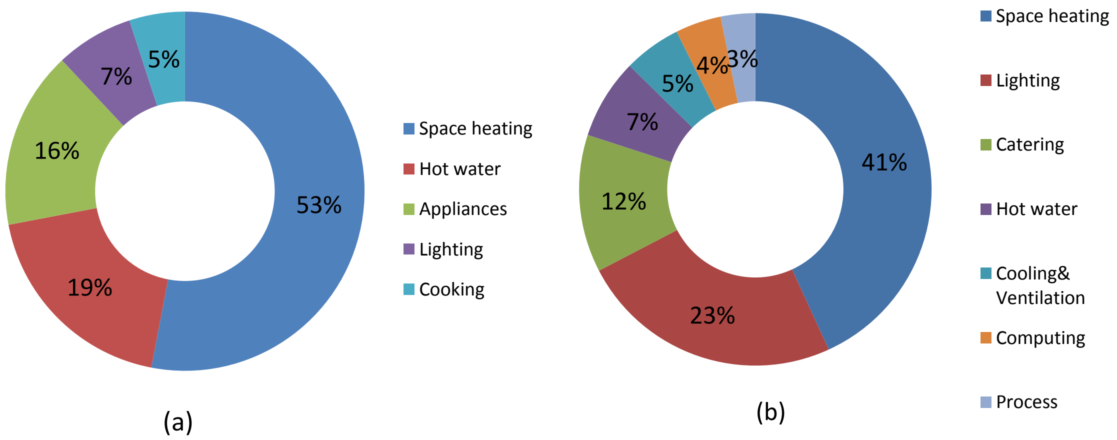

Figure 1 Source of carbon emissions by end use for (a) Domestic and (b) non-buildings

Between 2003 and 2008, buildings CO_2 emissions fell by 3%, mainly due to improved energy efficiency. Since 2008, buildings emissions have fallen by 8% but have shown year-to-year fluctuations due to economic and temperature effects; while in 2009, emissions dropped 10% due to rising fuel prices and the recession, the emission also increased by 7% in 2010 due to cold weather, but fell again (by 14%) in 2011 due to warmer winter months and rising fuel prices (Parliament Committee, 2013). In 2012, preliminary data suggests that both direct and indirect emissions rose across all buildings sectors by 11% to 202 $MtCO_2$ (Figure 2). Indirect emissions rose by 11 $MtCO_2$ (11%), largely due to an increase of highly carbon-intensive coal generation at the expense of gas in the power sector (Parliament Committee, 2013). This was driven by a low global whole sale price of coal and a low carbon price, which increased the carbon intensity of electricity by 10%. Although temperatures in 2012 were not colder than the long-term average, direct emissions nonetheless rose by 10% due to the colder temperatures compared to 2011, which had particularly mild winter temperatures (Figure 2).

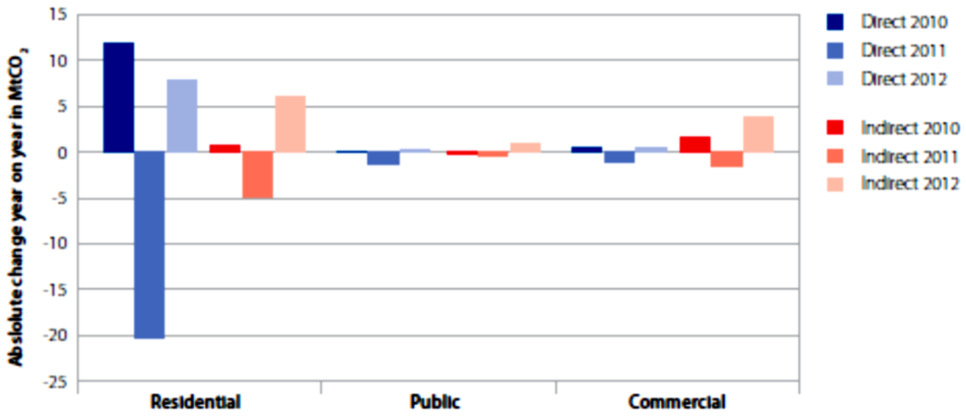

Figure 2 Change in direct and indirect buildings CO_2 emissions. (Source: Parliament Committee, 2013)

4. Measures for Reducing GHG Emissions from Buildings:

There has been growing interest in the construction of green and energy-efficient in the building and generally there are five main measures to reduce GHG emissions (UNEP, 2009) as follow:

- Increase the energy efficiency of new and existing buildings (both the physical envelope, and the operational aspects such as energy systems for heating, ventilation and other appliances).

- Increase the energy efficiency of appliances (white goods, entertainment, personal computers and telecommunication equipment).
- Encourage energy and distribution companies to support emission reductions in the Building Sector.
- Change attitudes and behaviour.
- Substitute fossil fuels with renewable energies.

The above measures can be grouped into three ways of buildings design for sustainable buildings (Tang, 2012), first Smart buildings which are controlled by a computerised network of electronic sensors and controls to monitor and operate certain building functions such as mechanical and lighting systems. Offices and homes can find ‘intelligent’ ways of saving more energy, for instance, by replacing wall-mounted thermostats with individual, virtual sensors controlled by PCs (Mitchell, 2005; Tang, 2012). Factories and shopping malls can switch off lighting and air conditioning when not needed based on motion sensors, and airports can link their flight information databases to heating, lighting and air- conditioning systems at individual gates to restrict energy use to when gate areas are occupied (Mamidi et a., 2012). A study by Weng and Agarwal, (2012) designed an occupancy sensor that improves upon existing one in order to eliminate significant false positives (when the sensor detects a person, but no one is actually there) and false negatives (when a sensor fails to detect a person in the room). This sensor includes a magnetic reed switch that can determine when an office door is closed or open and based on this the light switch On/Off. Lu et al., (2012) propose a solution called the smart thermostat that uses occupancy sensors to automatically turn off the HVAC system when the occupants are sleeping or away from home. The approach uses wireless motion sensors and door sensors, which are inexpensive and easy to install. The sensors demonstrate a 28% energy saving using 12-20 sensors per home.

Second, Green building design by utilising any opportunity to incorporate environmentally sustainable measures and solutions into design. Green building can be achieved by encourages sustainable solutions in the design not only in terms of building services (eg. use of renewable energy, LED lighting) but also in the architectural design, built form (green roof, green walls, glazing), orientation (exposure to sun light, wind), materials selection, site planning, water and waste strategies (eg. rainwater and grey water recycling, automatic taps, dual flush WCs) and ensures that proposed design strategies meet targets for reduced life cycle impact and life cycle costs (Tang, 2012).

Lighting energy use can be reduced by 75–90% compared to conventional practice through combing daylighting, energy efficient lighting (LED) and control (Hinnells, 2008). Apart from low energy lighting, passive methods have been explored to improve daylighting penetration and visual comfort, e.g. passive solar glazed sunspace. However, doubts have been raised previously as to whether any real energy savings are possible and whether in fact these spaces increase energy consumption. Researchers (Mihalakakou, 2002) argued that sunspaces can be an appropriate and effective system all over Europe during the winter. It demonstrated that sunspace can be an effective way to ensure good day lighting in a refurbished high-rise social housing building in Germany (Wilson, 2000).

Renewable energies include wind, waves, solar and tidal sources, which are often beset with variability as a result of the weather, season and time of the day (Hall, 2010). Chow, (2009) reminds that true carbon neutral sources which rely on the sun and wind are not reliable and suffer from intermittency perhaps due to their incompatibility with the existing urban form. Most renewable technologies might require the combination of two or more different renewable technologies to adequately meet the demands of households. Chow, (2009) surmised that the most suitable technologies are PV panels coupled with biomass boilers. As

PV panels that made up of amorphous or crystalline silicon could provide up to 6% and 15% efficiency levels respectively (Boardman et al., 2005).

Fabric efficiency can generally be improved by the adoption of insulation materials such as mineral wool, expanded polystyrene beads and urea formaldehyde, cellulose insulation and hydrophilic mineral wool (Xing, 2011) which results in low energy consumption. The windows also form a relevant part of the building shell and constitute the least insulating part of the thermal envelop (UNEP 2007). Passive dynamic glazing like photochromism and thermochromism; active dynamic glazing like electrochromism and dynamic façade control also play a vital role in light and heat conservation and control.

Energy efficient glazing such as triple glazing has better sound insulation properties than double glazing and can thus be used as extra advantage in areas with sound problem (Bosschaert, 2009). Moreover triple glazing has less problems with condensation issues than double glazing. The most effective glazing systems have a fairly high construction cost, but users recoup these losses in long-term savings. Until recently, building industry professionals, in designing a structure, have tended to consider only capital cost and ignore potential savings in long-term costs (Silverstein, 2007).

Green roofs are generally built to enhance the energy efficiency of their buildings, but many other benefits exist. Green roofs essentially prevent the penetration of solar heat to the covered building components [Castleton et al., 2010; Morau et al., 2012; Jaffal, 2012; Chen, 2012). Liu et al. (2003) denoted that ‘‘they improve the thermal performance of a building through shading, insulation, and thermal mass’’. Similarly, Saiz et al. affirmed ‘‘the key property of a green roof is its low solar absorptance (Saiz, 2006). Several studies stressed the advantages for urban hydrology, storm water quality, and ecological habitats for wildlife [26]. Deeper green roofs produce lower heat gain and loss, and they often have a better thermal performance (Berardi, 2014). A 10 cm increase in soil thickness increases the thermal resistance of dry clay soil by 0.4 m2 K/W (Wong et al., 2003). However, the presence and quantity of the water largely influence the thermal properties of the green roof. In fact, a wet roof provides additional evapotranspiration, which prevents the heat flux into the building and acts as a passive cooler by removing heat from the building (Emilsson, (2008); Rowe, (2012); Wolf, (2008); Nagase and , Dunnett (2010)).

Rainwater Harvesting (RWH) for sustainable building can reduce flood risk, save energy/carbon emission (at least that associated with the displaced water) and save householders money (Hassell, 2014). Saving is moderate and depend on the annual rainfall in the region. A number of factors have so far contributed to the lack of progress in RWH. Ambiguity in the financial viability of RWH systems is a key reason; lack of experience and the absence of well-run demonstration sites is another (Ward et al., 2010). Nevertheless, there has been a rise in the number of RWH systems being implemented in residential properties, new commercial buildings and in schools.

Some research has shown that sustainable buildings may be healthier than buildings constructed using traditional methods and materials. Palanivelraja and Manirathinem (2010) contend that sustainable buildings use resources such as energy, water, materials and land more efficiently, with more natural light and better air quality so that these buildings contribute to improved health, comfort and productivity.

The third way of design is people –friendly buildings. It is important to take into account users' societal needs as buildings should be seen as a living part of sustainable communities. Living spaces and gathering points for communities should form part of a building's function as well as pleasing aesthetics and living comfort; these are not always recognised by green labels or smart systems. Efficient lighting, heating and cooling have measurably increased worker productivity, decreased absenteeism, and improved the quality of work performed by reducing errors and manufacturing defects (Romm and Browning 1994); but on the other hand, environmental stressors such as vibration, poor air quality and inadequate lighting usually result in negative stress.

The UK government has adopted a preferred approach which is articulated in the carbon compliance triangle illustrated in Figure 3. Reducing the demand for energy is addressed first through the Fabric Energy Efficiency standard. This is at the bottom of the triangle. Next, house builders seek to mitigate the energy requirements of the dwelling through the use of the LZC technologies in the property. This is the next section of the triangle. Any remaining unmitigated carbon is then accounted for through allowable solutions, although these have yet to be defined. The summit of the triangle is the carbon stemming from emissions not addressed in the Building Regulations (ZCH, 2011; Lees and Sexton, 2014).

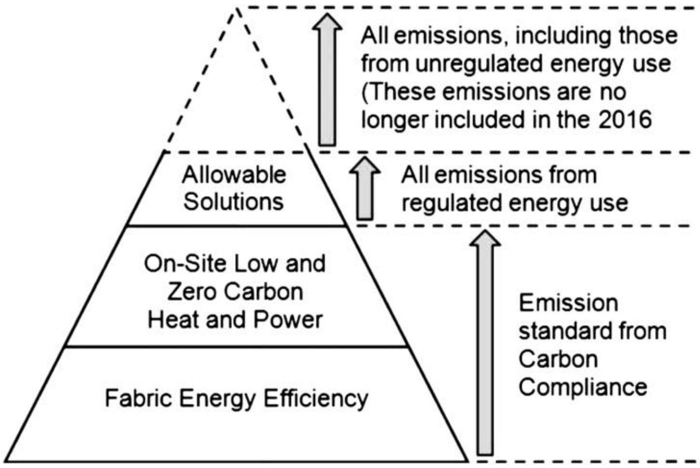

Figure 3 Carbon Compliance triangles

5. Barriers of Low and Zero Carbon Technologies

The UK has already taken steps towards reducing greenhouse gas emissions from the Building Sector, but these steps have had a limited impact on actual emission level. This is due to a number of barriers which reflect the nature of the sector, such as (UNEP, 2009):

- The fact that there are many small reduction opportunities spread across millions of buildings; different stakeholders are involved at the various stages in a building's life; these stakeholders have different economic interests in terms of valuing investments in energy efficiency measures.
- Energy efficiency investments are perceived to be costly and risky.
- There is still a lack of practical knowledge about how to implement energy efficiency measures.
- People' awareness and access to programmes, and their ability to invest, along with uncertainty about the energy or financial savings following a measure (Brechling & Smith, 1994).

Although these constraints the main mechanism through which energy efficiency measures have been delivered in the UK has been through government- backed programmes and supplier obligations (Dowson et al., 2012; Mallaburn&Eyre, 2014; Rosenow,2012). In a recent review of the evolution of the UK's supplier obligations since their inception in 1994, Rosenow (2012) sets out how the obligations were initially conceived to stimulate the efficient use of energy for reasons of economic productivity in the newly deregulated energy market, but how they evolved over time to be the main mechanism by which to tackle issues of climate change, energy costs and fuel poverty. Further, in an extensive review of UK energy efficiency policy from 1973 to 2013, Mallaburn & Eyre (2014) highlight the role that policy has had on uptake of interventions in the building stock. They point out that the most effective policies (i.e. those that have been adopted and achieved a high rate of uptake) are a fine balance between market support and government intervention.

6. Current Levels of Energy Efficiency Take up in UK Buildings

Little detailed evidence has previously been available regarding the uptake rate or prevalence of energy efficiency interventions among domestic and non-domestic buildings. Table 1 shows the some of the Energy Efficiency technologies used in the buildings for UK compared with other European countries which were supported by local governments. It is clear that UK is the most country that widely used these techniques with Italy and France come after. Flanders is considered the least country that used these mitigated approaches of carbon footprint (WEC, 2008).

Table 1 Selected measures eligible for savings under the Energy Efficiency Obligations schemes in four countries. (Source: WEC, 2008).

Measure	Flanders	France	Italy	U.K.
Condensing boilers	√√	√	√	√√
Compact Fluorescent Lamps (CFL)	√√	√	√√	√√
Fuel switching			√√	√
Glazing	√√	√	√	√
Heating controls		√	√	√√
Heat pumps	√	√	√	√
Insulation: Attic	√√	√		√√
Insulation: draught proofing				√
Insulation: Hot water tank				√
Insulation: Wall		√		√√
Low flow showerheads	√√		√√	
PV panels			√	√
Solar water heating	√	√	√	√

√√ Widely used. √ used.

For the domestic building analysis of 2000–2007 data indicates that approximately 40% (9.3 million) dwellings in England had approximately 23.7 million efficiency measures installed, with an average of 2.5 measures per dwelling. Building fabric-related measures were the most frequent (e.g. cavity wall insulation, loft insulation and glazing) with an average of 2.1 million installed each year (Hamilton et al, 2014).

The annual uptake of reported energy efficiency measures in England increased between 2000 and 2007 for all measures, with the exception of draught proofing (Figure 4). The highest increase is associated with double glazing installation particularly for the period 2003-2007 from 34 000 installations per year in 2000, to 2.8 million installations per year by 2007, an 81-fold increase (Hamilton et al, 2014). Other measures (Loft insulation, cavity wall insulation, Condensing boiler replacement, Drought proofing, Hot water cylinder) have increased also and follow a relatively stable incidence trajectory; however solar hot water install showed very slight upward trends between 2000 and 2007.

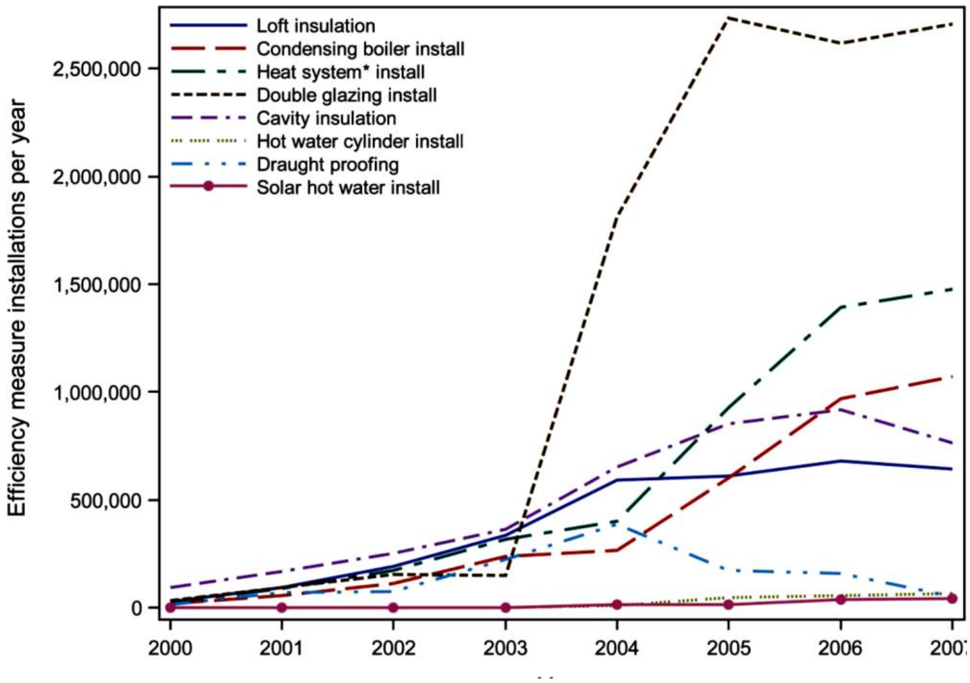

Figure 4 Number of energy efficiency measure installations per year in England between 2000 and 2007. Heating system includes: Condensing and standard boiler and hot water cylinder replacement and solar hot water. (Source: Hamilton et al, 2014)

Figure 4 shows the current installation levels of some key domestic energy efficiency measures for 2010-2012, using the most recent data available. The most common energy efficiency measure shown is hot water tank insulation, with 98 per cent of suitable homes having the measure in place. Almost three quarters of homes have double glazing installed throughout the whole property. Cavity wall insulation is present in 68 per cent of homes with cavity walls. Loft insulation is the next most common measure, with 65 per cent of homes with lofts having at least 125mm in place (DECC, 2012 b).

In domestic properties it is estimated that 45 per cent of light bulbs are energy efficient light bulbs. It is also estimated that 46 per cent of domestic appliances with an EU Energy Label are rated A or better. Condensing boilers have a similar level of deployment, with only two out of five homes having the measure installed in place, although this is increasing rapidly. The least common energy efficiency measure shown currently is solid wall insulation, with only two per cent of solid wall homes having the measure in place (DECC, 2012 b). The chart in Figure 5 clearly shows that whilst significant progress has been made in the installation levels of some energy efficiency measures there is plenty of remaining potential in the domestic sector.

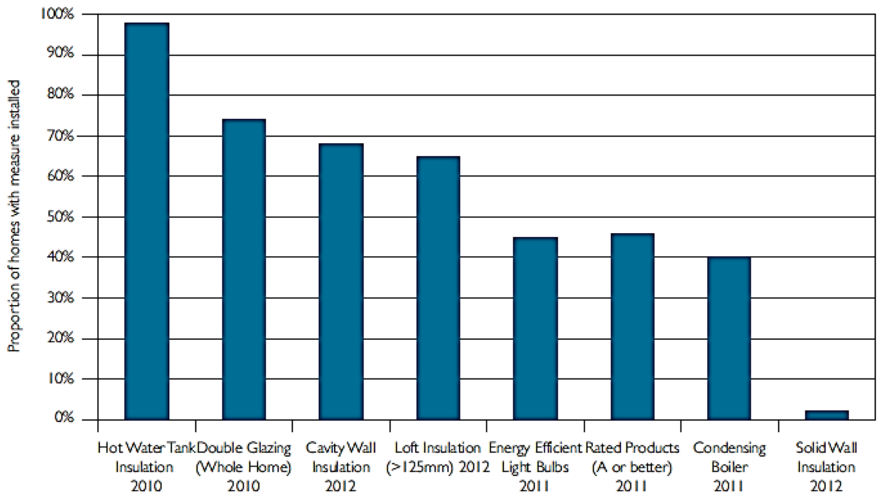

Figure 5 Level of energy efficient measures in place in homes. (Source: DECC, 2012 b)

7. Projected Saving From Efficiency Measures

Innovation in the domestic and non-domestic buildings sector represents a significant opportunity to help meet the UK's greenhouse gas emissions targets. Innovations for domestic buildings can be split into four major technology areas (LCICG, 2012):

- Pre-construction and design eg. modelling and software tools, tools to identify retrofit opportunities quickly, cheaply and accurately ; design tools and services,
- Build process eg.industrialised retrofit techniques, and smart manufacturing processes.
- Building operation: smart controls and systems diagnostics and assisting behavioural change by providing users with clear information, incentives and innovative tools with which to interact with buildings.
- Materials and components eg. Low carbon cooling and ventilation and advanced insulation products.

These Innovative measures could save an additional £16bn and 73MtCO_2 by 2050. The savings would result from energy savings of 393TWh, or 2.4% of counterfactual energy demand (LCICG, 2012). Figure 6 shows the annual carbon savings resulting from these energy savings.

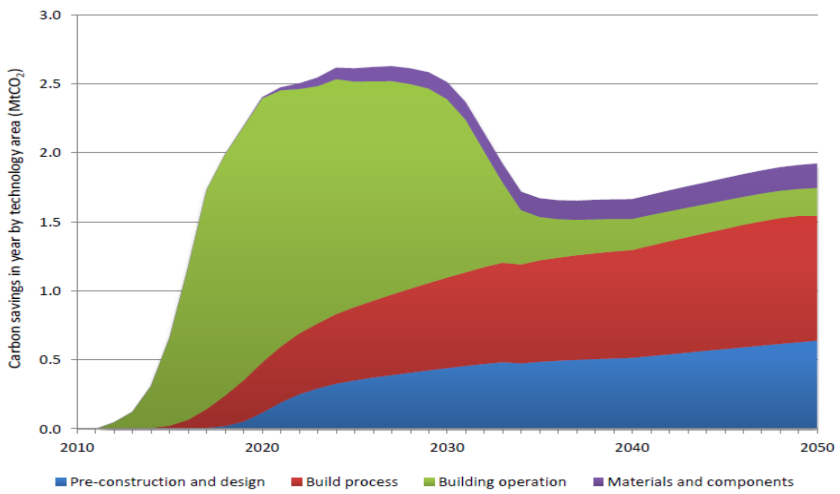

Figure 6 UK Annual carbon savings for domestic buildings. (Source: LCICG, 2012)

Innovations for non-domestic buildings can also be split into four major technology areas:

- Integrated design eg. modelling &software tools, and design tools and services.
- Build process; smart manufacturing processes and industrialised retrofit techniques.

- Management and operation eg. Smart controls and systems diagnostics; carbon management services and assisting behavioural change by providing users with clear information and incentive.
- Materials and components eg. Advanced façade materials and integration; advanced daylight technologies, advanced natural ventilation systems and low carbon cooling.

Innovation measures for non-domestic in UK could save an additional £13bn and 86MtCO2 by 2050. These savings would result from energy savings of 460 TWh or 4% over counterfactual energy demand (LCICG, 2012). Figure 7 shows the annual carbon savings resulting from these energy savings. Note that while carbon savings generally decrease with time due to grid decarbonisation, energy savings are still significant out to 2050.

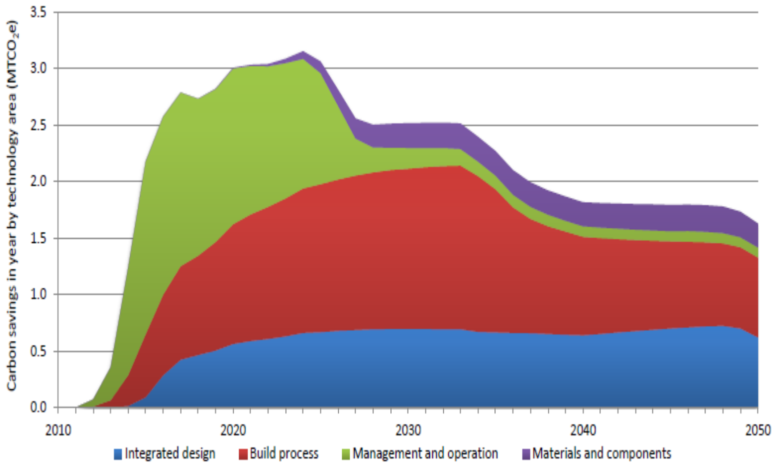

Figure 7 UK Annual carbon savings for non-domestic buildings. (Source: LCICG, 2012)

8. Conclusions

The review in this paper describes current and potential measures adopted in UK buildings and the impacts on energy save. When comparing between the domestic and non-domestic buildings, the first one contributes more carbon dioxide emission of 27% of UK emission than the non-domestic buildings of 18%. Adopting energy efficient measures in UK buildings contribute to reduce the CO_2 emission and save the energy by up to 35%. The trends for energy efficient measures show that the traditional methods of insulation double glazing and hot water insulation are the most common used. Furthermore it is worth to mention that the diverse in innovation techniques could save additional energy by the mid of this century.

The paper suggests that healthy buildings can be achieved through sustainable construction approaches. However, whilst the initial outcomes of existing research look promising, substantial research is now required into the areas of indoor comfort and building user perceptions in sustainable buildings due to the knowledge gap in this area.

Renewed interest in modern methods of construction might facilitate the delivery of zero carbon building in the UK built environment sector. It is however evident that the UK needs to tighten the loose ends on its approach to zero carbon housing in order to achieve its projections of carbon savings by 2016. If current and emerging cost-effective energy efficiency measures are employed in new buildings, and in existing buildings as their heating, cooling, lighting and other equipment are replaced, the growth in energy demand by the building sector could be reduced from the projected 30 percent increase to zero between now and 2030.

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