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**Will global warming reduce the carbon emissions of the Yorkshire Humber Region's domestic building stock – a scoping study.**

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**Summary**

*There is evidence from the International Panel of Climate Change that the UK will experience a mean rise in ambient air temperature over the coming years. Such a rise in temperature will change the requirements for heating and cooling of domestic buildings. This scoping paper explores this issue with respect to the housing sector in the Yorkshire Humber Region of the UK and comes to the conclusion that the regions*

*domestic sector poses major problems with respect to the stated carbon savings required by the UK Government.*

## 1. Background

Global Warming is now recognised as one of the driving forces for climate change [1]. In order to combat the problems posed by global warming there have been several meetings of Governments to try to agree on measures to reduce the emission of chemicals known to have an effect on the atmosphere of the globe. These meetings started in the early 1990's with the Rio de Janeiro Convention at which international agreements on the control of these harmful emissions were discussed and countries encouraged to adopt measures to reduce these emissions. Since then there have been further meetings at which agreements on Climate Change issues ranging from de-forestation through sustainable development to the use of renewable energy have been agreed by many countries.

Currently the UK is committed to reducing Green House Gas emissions by 14% from those produced in 1990 and in the UK Government's White Paper on Energy [2] there is an aspiration that by 2050 carbon emissions will be reduced by 60%. The International Panel on Climate Change have identified buildings as being one of the main contributors to global warming, being responsible for the use of nearly 31% of the energy used globally in 1995 with an annual growth rate of 1.8% since 1971[2] . These are significant energy consumption figures and to achieve the desired level of carbon reduction by 2050 will inevitably mean significant changes in life style, the design and operation of our buildings, approaches to transport and methods of producing energy both electricity and heat. With the implementation of the Kyoto Protocol this year governments are now committed to reducing carbon emissions by the agreed amounts.

Much research has been carried out into the effects of climate change on the possible changes to our environment. Depending on how we develop globally the effects may be very severe or relatively mild. In a recent publication by the Institute of Building Services Engineers [3], they predict the likely increase in mean monthly air temperatures for several locations in the UK and shown in Figure 1. It is clear from this figure that a significant increase is predicted.

## 2. Building energy usage

Global warming will have a significant effect on both the amount and way we use energy in the built environment and it is therefore necessary to have an understanding of how the energy usage patterns could change before embarking on implementing measures which may not achieve their ultimate goals.

In 2002 the total UK energy consumption was 157.2 million tonnes of oil equivalent [4]. The domestic sector used 47.9 million tonnes of oil equivalent, transport used 54.5 million tonnes oil equivalent and industry and services using 54.8 million tonnes oil equivalent. These figures emphasise the fact that that buildings and transport are important in the drive to reduce both national and global consumption of resources. Historical information on how the energy use has changed by sector indicates quite strongly that the domestic sector is remaining static [3] , One reason for this could be that although the housing stock is increasing with the new housing being more energy efficient, the older stock is not being replaced at a fast enough rate to make a significant improvements in the sector consumption.

However in the CIBSE report [3] they give general scenarios for the likely performance of some typical dwellings and estimate that by 2050 the percentage of occupied hours of living rooms and bedrooms will see a significant increase in average temperatures as shown in Figure 2. These figures suggest that given the likely increase in temperatures then the way in which occupants use their house may change.

## 3. Yorkshire/ Humber Domestic Energy Use

### 3.1 Housing sector breakdown

In the Yorkshire Humber region there are some 2,207,000 dwellings with over 50% being pre 1945 [5,6] . Figures 3 & 4 give a general breakdown for this region. Some 67% of the dwellings are either semi-detached or terrace, which is slightly larger than the national average (60%).

The dominant housing types within the region are therefore the terraced and semi-detached dwellings, particularly those built pre 1945.

### 3.2 Energy use

One of the factors reported in the English Housing Condition Survey [7] is an estimate of the likely annual energy consumption based on the SAP score. The SAP (Standard Assessment Procedure) is a method adapted from the Building Research Establishment's Domestic Energy Model (BREDEM) [8] to estimate the energy performance of dwellings. It has been incorporated into the Building Regulations (Part L) [9] as the standard method of evaluating energy performance and hence the carbon emission. In the pre 2004 regulations there was a procedure whereby a dwelling could pass the regulations by demonstrating that the dwelling met a specific SAP value. This has been superseded, in the current regulations, by converting the SAP rating into a Carbon Emission Index. However the SAP rating is still used as a mechanism to evaluate a dwelling in terms of its energy usage and to allow comparisons to be made. Under the pre 2004 regulations to pass by this route required that the dwelling met a minimum SAP value of 80 (for a dwelling of $80m^2$), which rose to 85 for a dwelling of over 150m$^2$. In relation to the SAP scores, Yorkshire and Humber are slightly poorer than the national average overall but in the social sector they are almost 4 SAP points below.

Using the SAP assessment procedure it is possible to determine the likely annual energy usage for dwellings by reducing these values to an energy usage per square metre of floor area it is possible to arrive at a likely energy usage for dwellings in the Yorkshire Humber region (Figure 5).

Superimposing the average SAP value for the Yorkshire and Humber Region onto the age and type of dwelling stock it is possible to arrive at likely energy savings by the successive improvement in the SAP rating. Figure 6 shows the possible effect of SAP improvements if all dwellings were to be tackled, and it is clear that if possible improving to the current Building Regulation standards would result in just over 50% reduction in the regions energy usage for domestic dwellings.

It is clear from this figure that overall the energy consumption would reduce by about 10% for a 10 SAP point improvement, rising to 25% for a 30 point improvement. A ten point improvement can usually be obtained by looking at such issues as loft insulation, weather stripping and double glazing. A 20 point improvement would additionally require the installation of a more efficient heating system – boiler, controls, wall and floor insulation. A 30 point improvement (to current Building Regulation standards) may not be possible in all older dwellings because of their construction – solid walls where dry lining may significantly reduce the usable floor space.

There is obviously great potential for the region to make a significant reduction in the energy used for heating in the domestic sector by embarking on major improvement schemes to all housing. At the individual house level taking the Yorkshire/ Humber average typical energy consumption for heating is in the order of 21,420 kWh/yr costing around £350. By increasing the efficiency of the house by 30 SAP points the heating consumption would be 15,130 kWh/yr costing around £240 – an annual saving of £150 per year. The corresponding saving in carbon dioxide is almost 3 tonnes per year.

## 4. Effect of climate change on domestic energy consumption

With climate change predicted to increase the mean outside air temperatures it is to be expected that there will be a reduction in the demand for heating.

In order to estimate the energy usage of a domestic building under global warming an in-house developed thermal admittance computer model was used. This programme was also evaluated against other commercial packages (Integrated Environmental Solutions [(10)] and Ecotect [(11)]) and found to give results which were within 3%. This gave some degree of confidence in this programme.

The output consists of monthly loads in tabular form along with graphs of the monthly heating/cooling loads and a breakdown of the individual elemental loads. This model was then used to evaluate the energy demands of housing for a range of scenarios.

### 4.1 The effect on the demand for heating

A "typical" house from the region was used in the simulation model to determine the impact of higher air temperatures on the demand for heating. The "typical" house was one with a SAP rating of 52 and a floor area of 85 $m^2$ . Increases in air temperature from a mean of 1C to 5C were used in the programme. Simulating the range of house types for a range of improvements in SAP along with climate change produced Figures 7 and 8.

This analysis shows that by improving the SAP score to 80, heating energy savings without taking into account climate change are in the region of 50%. However by including climate change these savings could reach 70% with a 5C rise in temperature.

Table 1 shows the potential carbon dioxide savings for the range of house ages and SAP scores. This table demonstrates that by increasing the SAP Scores by say 30 points would make significant carbon dioxide savings and climate change will add further significant savings.

### 4.2 Domestic air conditioning

Information from the Building Services Information and Research Association (BSIRA) [12] strongly suggests that there will be a significant increase in the use of domestic air conditioning units over the next few years. They report that in 2003 there was strong growth in this market, driven by the warm summer. More recently with the introduction of cheaper products from the Far East to the DIY chains at prices in the £120 - £150 range this has made the product more affordable. Also they suggest that as the price falls and particularly if it reaches £100 then it will fall into the "impulse purchase" bracket, further fuelling the market. Domestic air-conditioning has also featured in *questions to Ministers* in the House of Commons [13] where the MP for Lewes (Mr. N Baker) asked the secretary of state for information on the projected increase in the UK domestic air conditioning market. The answer by Mr. Morley (the Minister of State, Environment and Agriculture) indicated that evidence was sparse but the projections by the Department for Environment Farming and Rural Affairs (defra) point to a significant increase in usage. Defra predict that by 2050 the market for domestic air conditioning will be in the order of 2.3 million units per year from a current base of 0.5 million.

### 4.3 Computer simulations

In order to estimate the likely change in the energy consumption of domestic buildings a range of computer simulations were carried out using the package outlined previously. In the simulations a "typical" Yorkshire Humber house with a SAP score of 52 was used. The inputs to this programme were then modified to simulate over the range of SAP rating form 50 to 90 in order to ensure that all house types were correctly analysed.

The baseline assumptions made in the simulation were that when the inside temperature reached 23C then air conditioning was used.

The simulations did predict that to maintain this temperature some cooling was required but in reality occupants tolerate the resulting internal temperatures. However with an increase in the mean outside temperature due to global warming it was anticipated that in this situation air-conditioning would be used. Given the indications with respect to the increase in the domestic air conditioner market, it has been assumed that a 1C mean rise would trigger the occupants to purchase such a system. It is recognised that not all houses will install cooling systems but by doing so, the “worst case” scenario is established. It is then possible to investigate how a range of market penetrations would affect consumptions. Figure 9 shows how the energy used by a “typical” Yorkshire Humber house would respond to climate change if air conditioning was used, and Figure 10 shows the corresponding carbon dioxide emissions.

By extrapolating the results from an individual house to all the house types in the region it is possible to arrive at potential energy usages for both heating and cooling.

### 4.4 Total carbon dioxide emissions from the regions housing stock

The above analysis has clearly indicated that significant savings can be achieved by improving the housing stock, but to some extent these will be reduced by the increased use of domestic air conditioning.

In order to establish under what design and operational strategies houses could meet the Governments target of 60% carbon dioxide reduction the analysis was extended to include the possible market penetration of air conditioning. Table 2 shows the effect of energy efficiency measures (improvement in SAP scores), climate change and the market penetration of domestic air-conditioning. The shaded boxes in this table show the scenarios under which the Governments 60% target would be met. Table 3 shows the same information but excluding the use of air-conditioning.

## 5. Conclusions

The analysis carried out in this paper has demonstrated that there are significant energy and associated carbon dioxide savings to be made in the Yorkshire/ Humber housing stock. The current emissions are in the range of 14 million tonnes of carbon dioxide per year. If climate change delivers a 5C mean temperature rise then the emissions could be reduced to almost 9 million tonnes.

If on the other hand extensive use of domestic air conditioning takes place the emissions would only reduce to about 11.8 million tonnes. What is more interesting is the possible impact of energy saving measures implimented to reduce the demand for heating in winter. If all properties were brought up to even the minimum standard of SAP 80 then with the increase use of air conditioning there is a possibility that the benefites accured by heating demand improvements are negated by the use for air conditioning and the emissions would be about the same as a house built to current building regulation standards. Increasing the thermal efficiency of the dwellings further may actually increase the carnon dioxide emissions.

Issues raised by this analysis:

- In today’s climate without improving the thermal efficiency of the dwellings there is a possibility that as more air-conditioning is used that there will be an increase in the carbon dioxide emissions.
- As the climate warms the potential savings may not be realised unless measures are taken to restrict the use of air-conditioning.

- SAP scores of 90 and above (these are now common with new build properties) may not deliver the 60% carbon dioxide savings unless air conditioning is restricted to no more than 50% of the market.
- Designers should be encouraged to ensure that new housing is not only energy efficient but must include measures to ensure that thermal comfort can be obtained without the need to resort to air-conditioning.
- With no air-conditioning new properties with SAP scores of 90 will deliver the 60% carbon dioxide savings with no climate change issues taken into consideration.

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Figure and tables

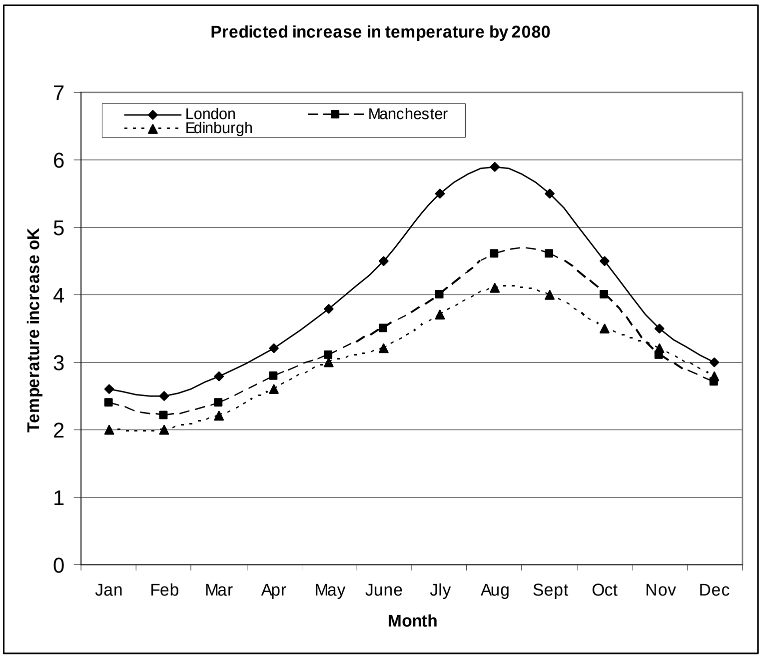


**Figure 1: Predicted increase in monthly mean temperatures (CIBSE TM36)**

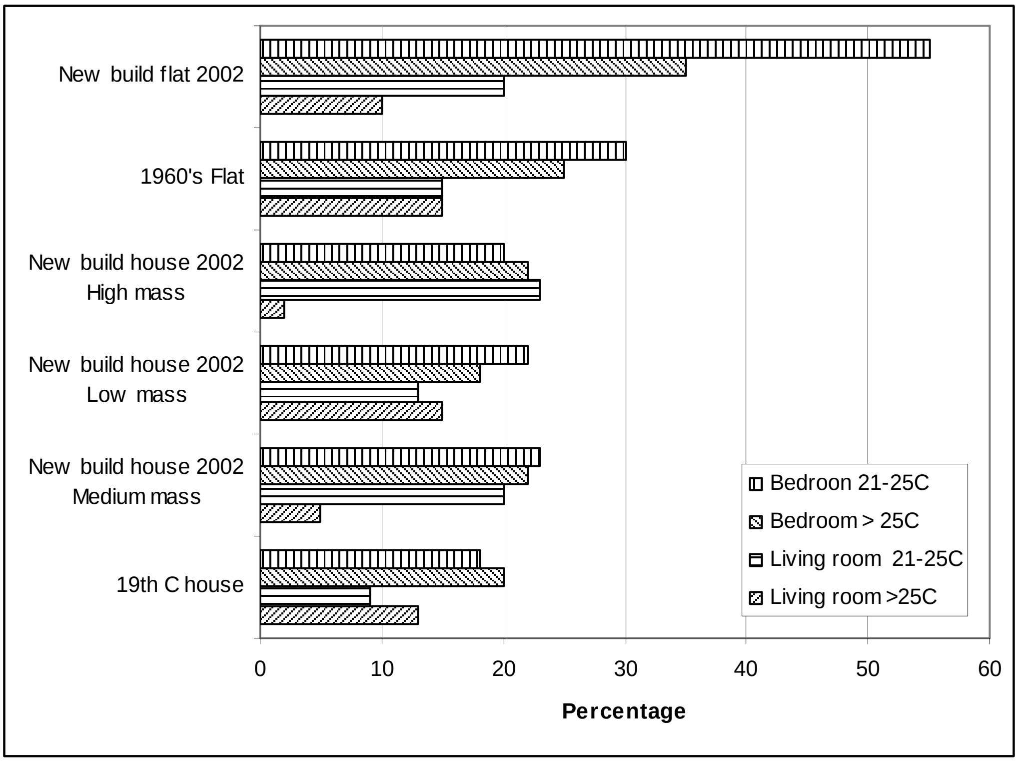


**Figure 2 Percentage of occupied hours when temperatures in living rooms and bedrooms will be within specific ranges by 2050 (CIBSE)**

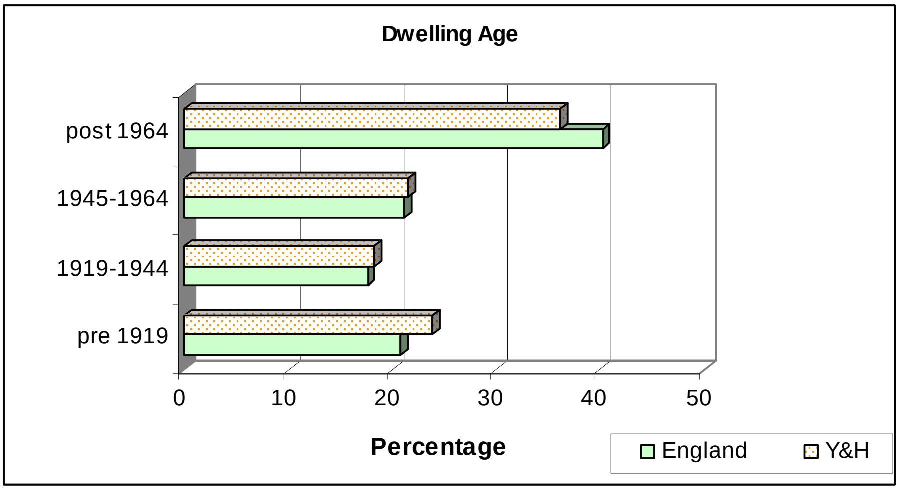


**Figure 3 Breakdown of age of housing in the Yorkshire/ Humber Region**

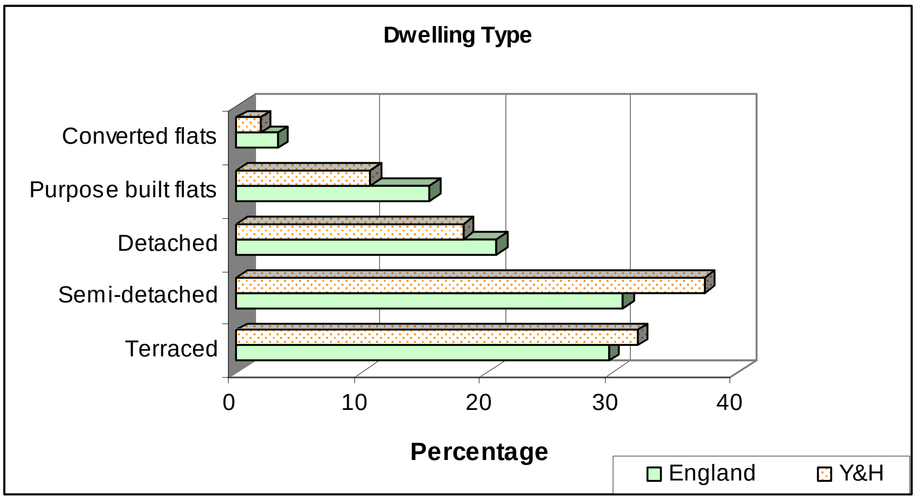


**Figure 4 Breakdown in housing type**

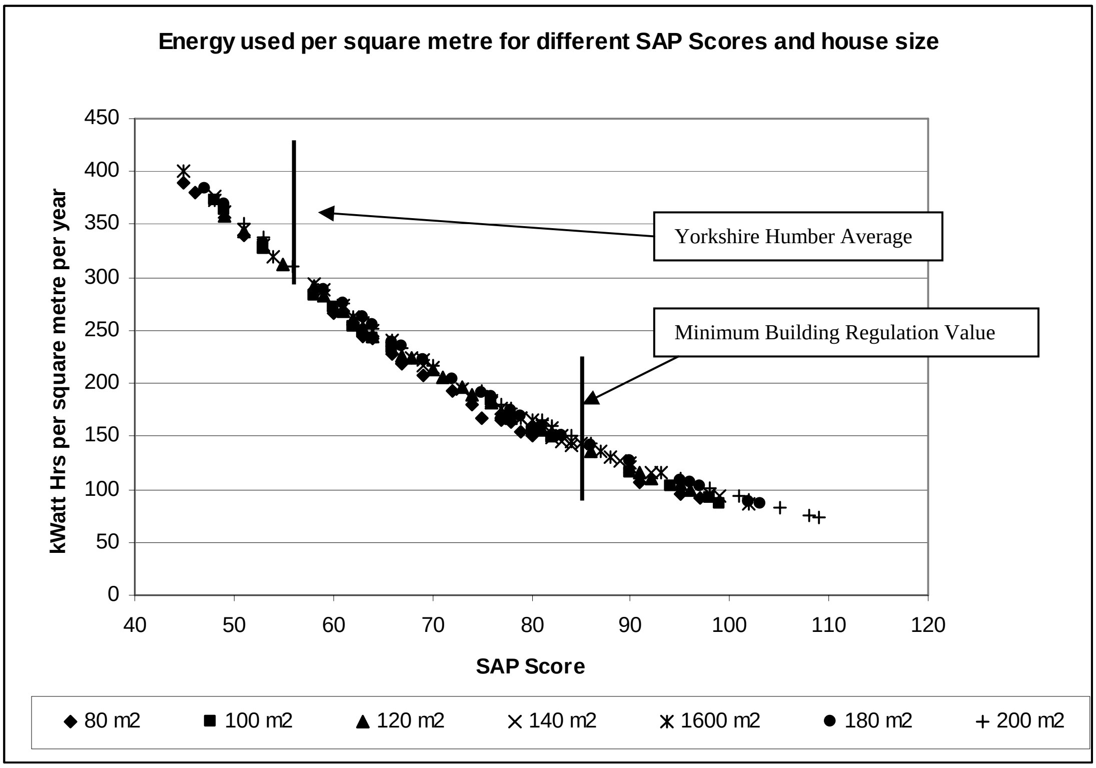


**Figure 5: Annual energy usage per square metre as a function of SAP rating and floor area**

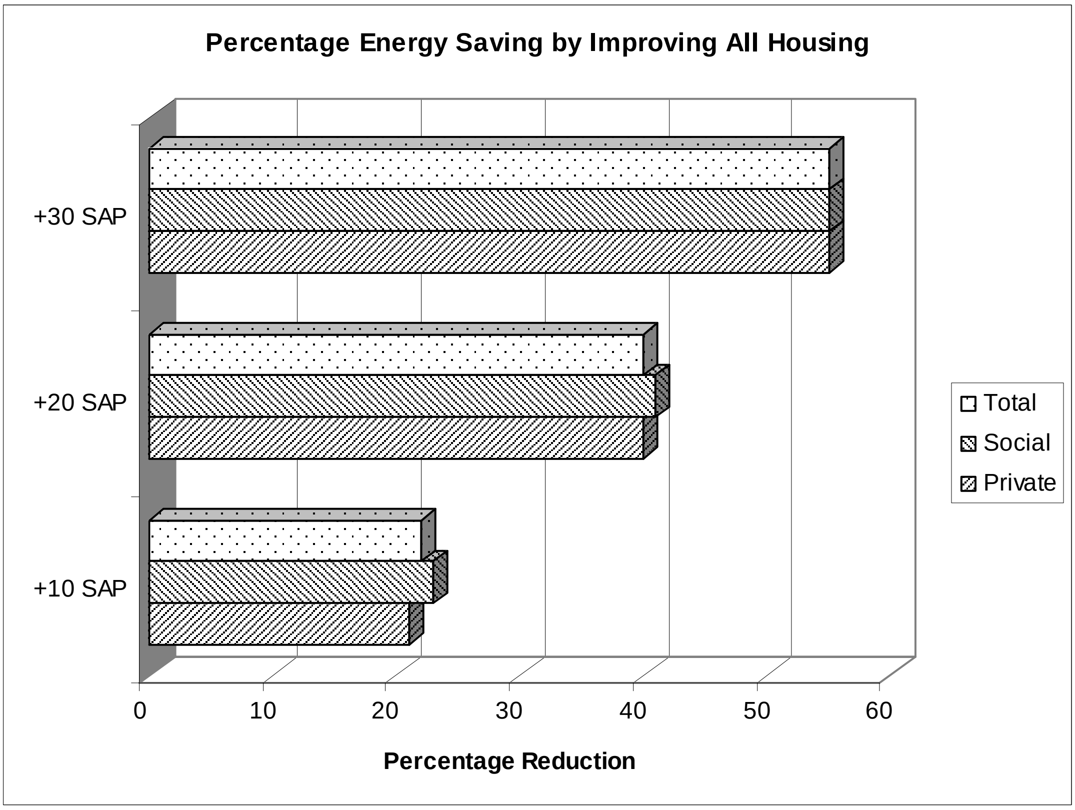


**Figure 6: Potential percentage energy saving by improving SAP rating of all housing**

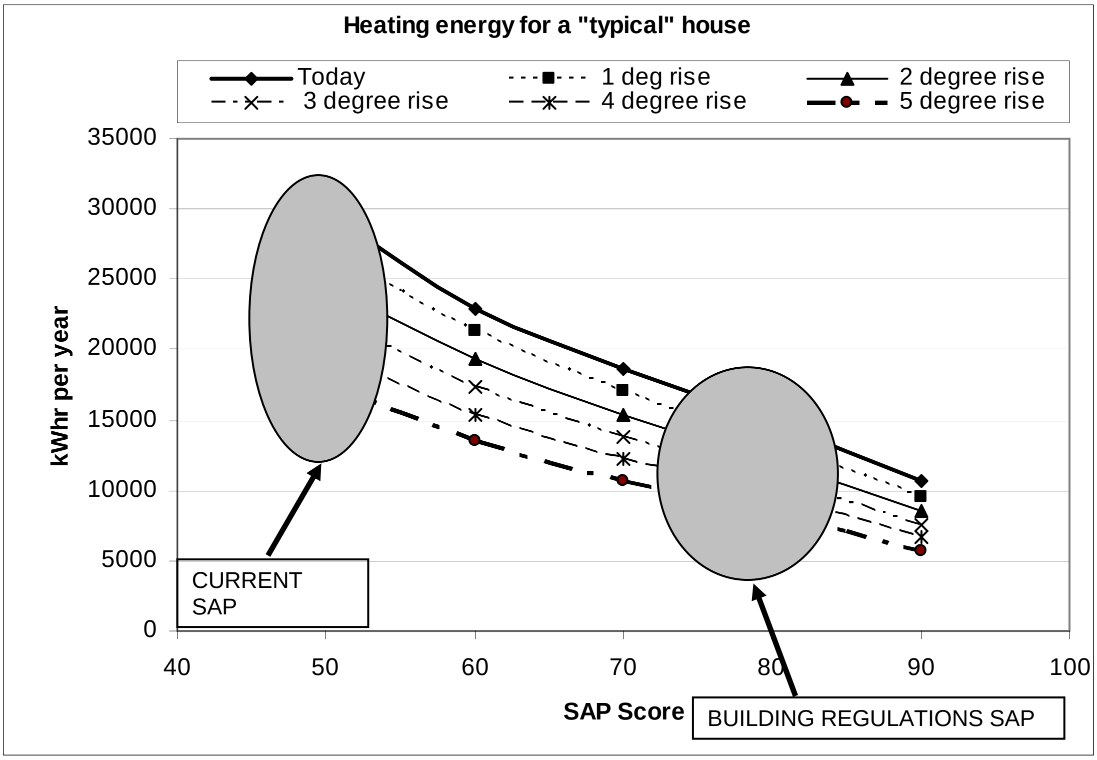


**Figure 7 Change in heating energy consumption with climate change**

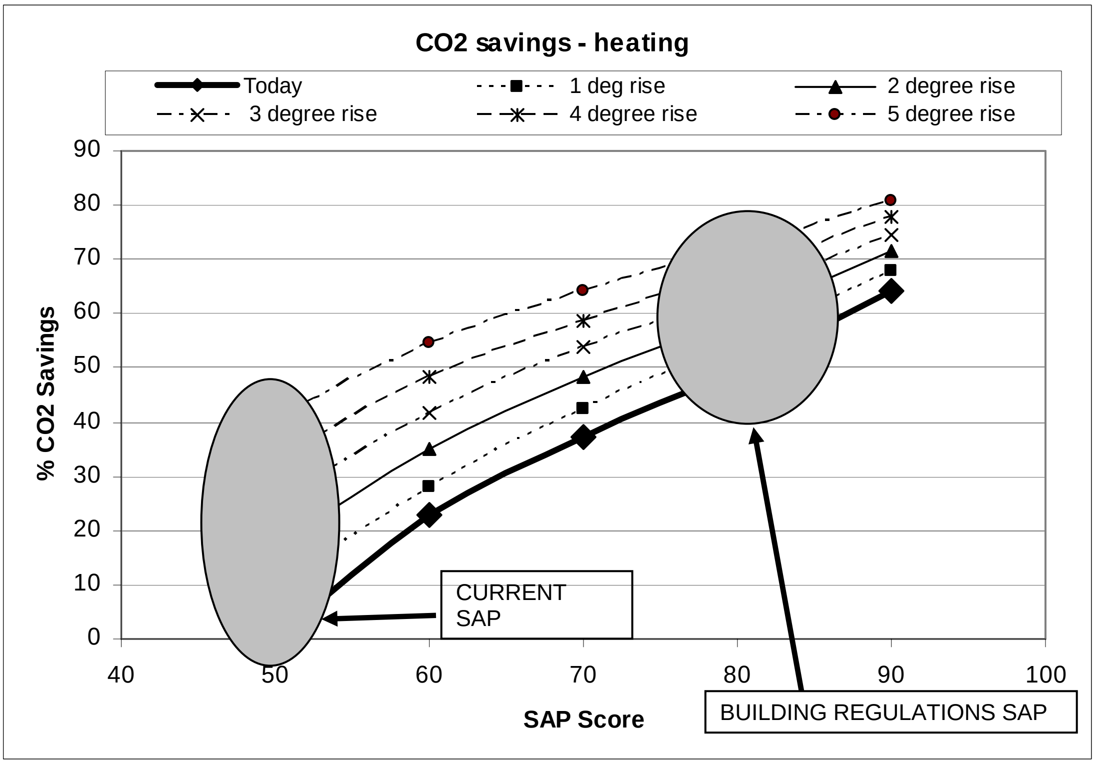


**Figure 8 Effect on carbon dioxide savings by improving SAP and mean outside temperature rise**

| | SAP | Today | +1 C | +2C | +3C | +4C | +5C |
|---|---|---|---|---|---|---|---|
| POST 64 | 50 | 5.17 | 4.71 | 4.29 | 3.87 | 3.47 | 3.07 |
| | 60 | 3.99 | 3.71 | 3.35 | 3.01 | 2.67 | 2.35 |
| | 70 | 3.25 | 2.97 | 2.67 | 2.39 | 2.13 | 1.86 |
| | 80 | 2.59 | 2.35 | 2.11 | 1.89 | 1.67 | 1.46 |
| | 90 | 1.85 | 1.66 | 1.48 | 1.32 | 1.15 | 0.99 |

| | SAP | Today | +1 C | +2C | +3C | +4C | +5C |
|---|---|---|---|---|---|---|---|
| 1945 - 64 | 50 | 3.16 | 2.88 | 2.62 | 2.37 | 2.12 | 1.88 |
| | 60 | 2.44 | 2.27 | 2.05 | 1.84 | 1.63 | 1.44 |
| | 70 | 1.99 | 1.82 | 1.63 | 1.46 | 1.3 | 1.14 |
| | 80 | 1.58 | 1.44 | 1.29 | 1.16 | 1.02 | 0.89 |
| | 90 | 1.13 | 1.01 | 0.9 | 0.8 | 0.7 | 0.61 |

| | SAP | Today | +1 C | +2C | +3C | +4C | +5C |
|---|---|---|---|---|---|---|---|
| 1919 - 45 | 50 | 2.59 | 2.36 | 2.14 | 1.94 | 1.74 | 1.54 |
| | 60 | 2 | 1.85 | 1.68 | 1.51 | 1.34 | 1.17 |
| | 70 | 1.63 | 1.49 | 1.34 | 1.2 | 1.06 | 0.93 |
| | 80 | 1.29 | 1.17 | 1.06 | 0.95 | 0.83 | 0.73 |
| | 90 | 0.92 | 0.83 | 0.74 | 0.66 | 0.58 | 0.5 |

| | SAP | Today | +1 C | +2C | +3C | +4C | +5C |
|---|---|---|---|---|---|---|---|
| PRE 1919 | 50 | 3.45 | 3.14 | 2.86 | 2.58 | 2.32 | 2.05 |
| | 60 | 2.66 | 2.47 | 2.24 | 2.01 | 1.78 | 1.57 |
| | 70 | 2.17 | 1.98 | 1.78 | 1.6 | 1.42 | 1.24 |
| | 80 | 1.72 | 1.57 | 1.41 | 1.26 | 1.11 | 0.98 |
| | 90 | 1.23 | 1.1 | 0.99 | 0.88 | 0.77 | 0.66 |

| | SAP | Today | +1 C | +2C | +3C | +4C | +5C |
|---|---|---|---|---|---|---|---|
| ALL | 50 | 14.37 | 13.1 | 11.9 | 10.76 | 9.65 | 8.54 |
| | 60 | 11.08 | 10.3 | 9.32 | 8.37 | 7.43 | 6.53 |
| | 70 | 9.03 | 8.25 | 7.43 | 6.65 | 5.91 | 5.17 |
| | 80 | 7.18 | 6.53 | 5.87 | 5.25 | 4.64 | 4.06 |
| | 90 | 5.13 | 4.6 | 4.11 | 3.65 | 3.2 | 2.75 |

**Table 1 Carbon Dioxide emissions from Yorkshire/ Humber housing by dwelling age (Million Tonnes $CO_2$)**

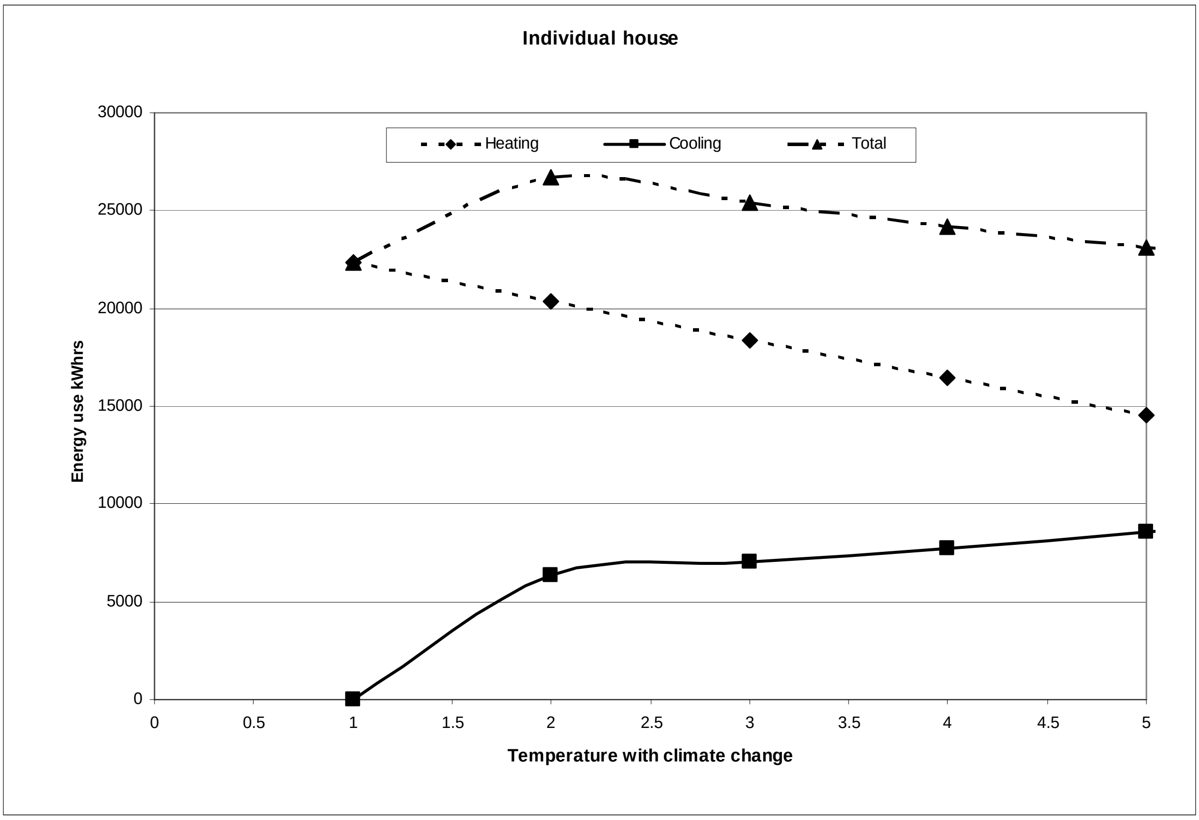


**Figure 9 Energy performance of a "Typical Yorkshire/ Humber Region" house**

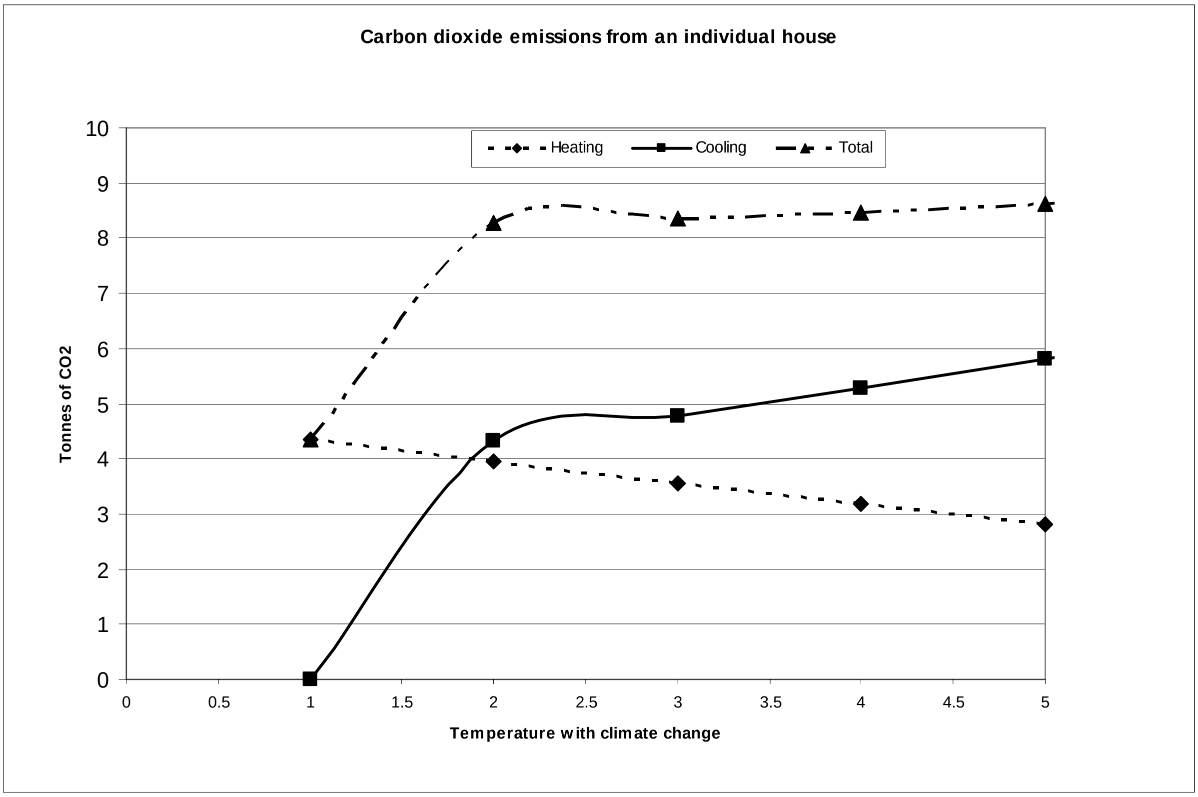


**Figure 10 Carbon dioxide emissions for a "Typical Yorkshire/ Humber Region" house with summer cooling**

| | SAP | % with cooling | Climate today | +1C | +3C | +5C |
|---|---|---|---|---|---|---|
| ALL | 50 | 0 | 0 | 8.8 | 25.1 | 40.6 |
| | | 25 | -2.92 | -3.43 | 20.69 | 34.93 |
| | | 50 | -5.85 | -6.85 | 16.25 | 29.3 |
| | | 75 | -8.77 | -10.28 | 11.81 | 23.66 |
| | | 100 | -11.69 | -13.71 | 7.38 | 18.02 |
| | 60 | 0 | 22.9 | 28.3 | 41.8 | 54.6 |
| | | 25 | 19.54 | 24.62 | 37.11 | 48.92 |
| | | 50 | 15.51 | 20.91 | 32.46 | 43.28 |
| | | 75 | 12.82 | 17.21 | 27.82 | 37.65 |
| | | 100 | 18.9 | 13.5 | 23.17 | 32.01 |
| | 70 | 0 | 37.2 | 28.3 | 41.8 | 54.6 |
| | | 25 | 33.59 | 38.59 | 48.94 | 58.32 |
| | | 50 | 30.03 | 34.59 | 44.15 | 52.61 |
| | | 75 | 26.46 | 30.58 | 34.59 | 46.9 |
| | | 100 | 22.89 | 26.6 | 39.37 | 41.2 |
| | 80 | 0 | 50 | 42.6 | 53.7 | 64 |
| | | 25 | 46.17 | 50.35 | 58.54 | 71.75 |
| | | 50 | 42.31 | 46.14 | 53.62 | 60.33 |
| | | 75 | 38.45 | 41.93 | 48.7 | 54.63 |
| | | 100 | 34.59 | 37.72 | 43.77 | 48.92 |
| | 90 | 0 | 64.3 | 68 | 74.6 | 80.9 |
| | | 25 | 60.02 | 63.48 | 69.45 | 80.86 |
| | | 50 | 55.74 | 58.98 | 64.3 | 69.28 |
| | | 75 | 51.46 | 54.47 | 59.15 | 63.48 |
| | | 100 | 47.18 | 49.97 | 54 | 57.69 |

**Table 2 Percentage carbon dioxide savings as a result of the use of air-conditioning, climate change and energy efficiency improvements**

| | SAP | Climate today | +1C | +3C | +5C |
|---|---|---|---|---|---|
| ALL | 50 | 0 | 8.8 | 25.1 | 40.6 |
| | 60 | 22.9 | 28.3 | 41.8 | 54.6 |
| | 70 | 37.2 | 42.6 | 53.7 | 64 |
| | 80 | 50 | 54.6 | 63.5 | 71.7 |
| | 90 | 64.3 | 68 | 74.6 | 80.9 |

**Table 3 Percentage carbon dioxide savings as a result of climate change and energy efficiency improvements but no air-conditioning**