



**Forecasting UK household expenditure and associated GHG
emissions: outlook to 2030**

by

Mona Chitnis, Angela Druckman, Lester C. Hunt, Tim Jackson and Scott Milne

RESOLVE Working Paper 02-12



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Abstract

This paper describes scenarios to 2030 for UK household expenditure and associated (direct and indirect) GHG emissions for 16 expenditure categories. Using assumptions for real household disposable income, prices, exogenous non-economic factors (ExNEF), average UK temperatures and GHG intensities for each of the 16 expenditure categories, three future scenarios are constructed. In each case, real expenditure for almost all categories of UK expenditure continues to grow up to 2030; the exceptions being 'alcoholic beverages and tobacco' and 'other fuels' (and 'gas' and 'electricity' in 'low' scenario). Furthermore, this leads to an increase in GHG emissions for most of the categories in the 'reference' and 'high' scenarios other than 'food and non-alcoholic beverages', 'alcoholic beverages and tobacco', 'electricity', 'other fuels' and 'recreation and culture'. The GHGs emitted from 'direct energy' use by households are responsible for about 30% of future total emissions with nearly 70% of future emissions attributable to 'indirect energy'. UK policy makers therefore need to consider a range of policies if they wish to curtail expenditure and the associated emissions, including economic incentives such as taxes alongside measures that reflect the important contribution of ExNEF to changes in expenditure for most categories of consumption.

Keywords: household expenditure; GHG emission; forecasting; scenarios, consumption emissions.

1. Introduction

Through its Climate Change Act, the UK has a legally binding target to reduce greenhouse gas (GHG) emissions by at least 34% by 2020 relative to the 1990 baseline (the 'Interim'¹ budgets) and by at least 80% by 2050 (HM Government 2008). This target is based upon a 'production perspective', which considers all emissions produced within the UK on a territorial basis. It thus includes all emissions that arise within the UK in the production of goods and services that are consumed overseas, but excludes emissions produced in other countries in the production of goods and services consumed in the UK. The contrasting perspective is the 'consumption perspective', which includes emissions that arise overseas and are 'embedded' in the production and distribution of goods and services consumed in the UK, but excludes those that arise within the UK in the production of goods and services exported abroad. Both the production and consumption perspectives are valuable for different aspects of policy but, arguably, the consumption perspective is more appropriate for consideration of policies concerning household consumption.

When considered from the consumption perspective, UK households are responsible for over three-quarters of total UK GHG emissions (Druckman

¹ 'Interim' budgets are one of the two sets of budgets proposed by the Committee on Climate Change and apply for the period before a global deal is reached.

and Jackson 2009a)². Furthermore, although production perspective emissions have fallen since 1990, when looked at from the consumption perspective, estimates show that levels have risen (Druckman and Jackson 2009a; Wiedmann et al. 2010). Indeed, Druckman and Jackson (2009a) estimated that GHG emissions rose by around 3% per annum between 2000 and 2004. Although the economic downturn may have had the effect of reversing this trend, as demonstrated in this paper, unless there are significant changes in UK government policies, the direct and indirect emissions attributable to household consumption will continue the long-term trend of rising into the future. Policies aimed at reducing these emissions are therefore required, and in order to achieve greatest future GHG reductions, the household expenditure categories associated with the highest levels of GHGs emissions should arguably be targeted.

Accordingly, in this paper, future household GHG emissions are modelled based on past trends to construct three scenarios up to 2030: a 'reference' scenario, a 'high', and a 'low' scenario. The Econometric Lifestyle Environment Scenario Analysis (ELESA) model is used. ELESA uses estimated household expenditure functions to build future scenarios encompassing 16 UK household expenditure categories. The scenarios are

² Of the remainder, 13% are attributed to capital expenditure and 11% to government expenditure. These percentages are averages for 1990-2004).

constructed using assumptions about future real household disposable income, real prices, exogenous non-economic factors, (ExNEF)³, and temperatures. Trends in the GHG intensity of each of the expenditure categories are derived from the Surrey Environmental Lifestyle Mapping (SELMA) framework (Druckman and Jackson 2009a). In this way, the household consumption categories associated with the highest GHG emissions are identified to help policy makers and aid better planning and future GHG mitigation.

ELESA differs from other scenario forecasting tools in two key ways. The first is that ELESA estimates future emissions from the consumption perspective, and can thus be used to explore policy options concerning household consumption. The second is that it attempts to model non-price and non-income effects through ExNEF, described in more detail in Section 2.

The paper is organized as follows. The next section (Section 2) describes ELESA. This is followed by a description of the scenario assumptions (Section 3.1), with the scenario results being presented in Section 3.2. Finally, a summary and conclusion are presented in Section 4.

³ The inclusion of ExNEF is an important and innovative feature of ELESA - see Section 2.

2. Econometric Lifestyle Environment Scenario Analysis (ELESA)

ELESA is an econometric scenario modelling tool in which Structural Time Series analysis (Harvey 1989) is used to estimate household expenditure equations for 16 categories of UK household expenditure, using quarterly time series data for 1964:q1 to 2009:q1 (Chitnis and Hunt 2010, 2011). The expenditure categories are based on COICOP⁴ categories, which comprises 12 high level categories. As our focus is on GHG emissions, we separate out four lower level categories of ‘direct energy’⁵ use (‘gas’, ‘electricity’, ‘other fuels’, and ‘vehicle fuels and lubricants’) for individual treatment, giving 16 categories altogether ⁶.

The Structural Time Series analysis used in ELESA enables examination of the relationship between household expenditure, income, price *and* a stochastic (rather than a deterministic) underlying trend, which is arguably important when estimating the elasticities of demand, as discussed by Hunt and Ninomiya (2003). This underlying trend is due to what may be called ExNEF which are expected to include factors such as technical progress, changes in

⁴ Classification of Individual Consumption According to Purpose (COICOP) (UN 2005).

⁵ ‘Direct energy’ is consumed directly by households in form of vehicle fuels, gas, electricity and other fuels.

⁶ These 16 categories are: ‘food and non-alcoholic beverages’, ‘alcoholic beverages, tobacco and narcotics’, ‘clothing and footwear’, ‘electricity’, ‘gas’, ‘other fuels’, ‘other housing’, ‘furnishings; household equipment and routine maintenance of the house’, ‘vehicle fuels and lubricants’, ‘other transport’ ‘health’, ‘communication’, ‘recreation and culture’, ‘education’, ‘restaurants and hotels’ and ‘miscellaneous goods and services’.

consumer tastes and preferences, socio-demographic and geographic factors, lifestyles and values. Individual ExNEF are not easily measurable in terms that would provide suitable data for further disaggregation. However, their existence may still be confirmed by the analysis, and is important in terms of understanding the underlying drivers of expenditure and associated emissions. Finally, the Structural Time Series Model (STSM) allows for stochastic seasonality so that this is also included in the long-run expenditure model:

$$exp_t = \mu_t + \lambda_t + \pi p_t + \tau y_t + v_t \quad v_t \sim NID(0, \sigma_v^2) \quad (1)$$

where exp_t is real household expenditure; μ_t represents ExNEF; λ_t represents the seasonal component p_t is the real price; y_t is real household disposable income; π and τ are unknown parameters to be estimated; and v_t is a random white noise disturbance term. For 'electricity', 'gas' and 'other fuels' expenditure, temperature is also included in the equations.⁷

GHG intensities for each of the 16 expenditure categories are modelled in a similar way to that in Hunt and Ninomiya (2005), again using the STSM as

⁷ For more details and estimation results see Chitnis and Hunt (2010, 2011).

presented in Chitnis and Hunt (2012). Historical GHG emissions⁸ (1992-2004) attributed to household final demand are estimated using the Surrey Environmental Lifestyle Mapping (SELMA) framework (Druckman and Jackson 2008; Druckman and Jackson 2009b). There are two types of emissions attributable to household final demand: one is the GHG emissions from 'direct' energy use. These are relatively straightforward to estimate as they are recorded in the UK Environmental Accounts (ONS 2008). The other type is 'embedded' or 'indirect' emissions which accounted for around two thirds of the total average UK household carbon footprint in 2004 (Druckman and Jackson 2010). Some embedded emissions arise within the UK, but, due to the globalisation of supply chains, many arise outside the UK. Estimation of embedded emissions is carried out using the Quasi-Multi-Regional Input-Output (QMRIO) model incorporated within SELMA. For the purposes of ELESAs, GHG emissions due to investment are attributed to household and government expenditure within the QMRIO sub-model. Details of SELMA's methodology, data sources, assumptions and limitations are provided in Druckman and Jackson (2008; 2009b; 2009a). GHG intensities are calculated by dividing the GHG emissions that arise due to household expenditure in the COICOP category in question by the household real expenditure in the

⁸ This study estimates a basket of six GHGs: carbon dioxide, methane, nitrous oxide, hydro-fluorocarbons, perfluorocarbons and sulphur hexafluoride (ONS 2008). The unit of measurement is carbon dioxide equivalent (CO₂e).

COICOP category. ELESAs is then used to model GHG emissions for each category and for each time t up to 2030 using the scenario assumptions described in the next section and the following equation:

$$\text{GHG emission}_t = \text{GHG intensity}_t * \text{expenditure}_t$$

3. Forecasting emissions

3.1. Scenarios and assumptions

In this section, ELESAs is used to construct quantitative scenarios by making assumptions for the economic and non-economic factors. Three scenarios are considered: 'high' (H), 'reference' (R) and 'low' (L), where the values for real household disposable income (y), real price (p), ExNEF (μ), temperature ($temp$) and GHG intensity (ci) are chosen accordingly. Therefore, to forecast household expenditure and GHG emissions for each of the 16 categories, three cases are considered as follows:

- *'Reference' case*: This is similar to a 'business as usual' scenario, where the assumptions for the growth in real household disposable income, real prices, temperature, trend and GHG intensities represent the 'consensus' or 'most probable' outcomes as explained below, resulting in a 'business as usual' or 'reference' scenario for real expenditure and GHGs growth (Ry , Rp , $Rtemp$, $R\mu$, Rci).

- *'Low' case:* The aim of this scenario is to represent conditions where GHG emissions attributable to households are lower than in the reference scenario. Accordingly, in this scenario real household disposable income growth is lower than in the reference scenario and real price growth is higher. Also the growth in underlying trend caused by ExNEF, is lower than in the reference scenario. In this scenario GHG intensities are assumed to be lower than in the reference scenario. These conditions will give rise to lower expenditure growth than in the reference scenario, and lower growth in GHG emissions. In this scenario the average UK temperature growth is assumed to be higher than in the reference scenario, and consumption of electricity, gas and other fuels for space heating is assumed to reduce with higher temperatures. This assumption does not take account of the increase in use of air conditioning that may be expected with increasing temperatures (Hekkenberg et al 2009) and therefore electricity emissions may be under-estimated.

In summary, the 'low' case is characterised by lower household disposable income growth, higher real price growth, higher temperatures, lower ExNEF growth and lower GHG intensities ($L_y, H_p, H_{temp}, L_{\mu} L_{ci}$).

- *'High' case:* In contrast to the low scenario, in this scenario real household disposable income growth is higher than in the reference scenario (H_y), real

price growth is lower (Lp), the growth in ExNEF is higher ($H\mu$), average UK temperature is assumed to be lower ($Ltemp$) and GHG intensities are higher (Hci). This results in the 'high' case scenario for real expenditure and GHGs growth ($Hy, Lp, Ltemp, H\mu, Hci$).

The actual assumptions for the key variables in the scenarios are as follows:

Real household disposable income

To guide the assumptions for the 'reference' scenario, the average independent growth rate forecasts from 2011 to 2012 are used for real household disposable income, taken from HMT (2011a). The average independent growth rate forecasts for GDP from 2013 to 2015 are taken from HMT (2011b) and converted to real household disposable income growth.⁹ Thereafter, assuming that economic conditions will return to 'normal' the assumption is based upon the long run growth rate for real household disposable income. For the 'low' and 'high' scenarios the assumed growth rates are 0.5% per annum lower and 0.5% per annum higher than the reference growth assumption respectively. These assumptions are shown in

⁹ To do this, the relationship between real household disposable income growth and GDP growth is estimated; using the UK annual time series data from 1948 to 2008:

$$\Delta y = 0.011994 + 0.57869 \Delta gdp$$

where y and gdp are logarithm of real household disposable income and real GDP respectively. Note that the first difference of logarithm of a variable is equal to its growth.

Table 1.

{Table 1: see figures and tables at the end of the paper}

Real prices

For real prices, the assumptions for the ‘reference’, ‘low’ and ‘high’ cases for ‘electricity’, ‘gas’ and ‘vehicle fuels and lubricants’ categories are guided based upon the Department of Energy and Climate Change (DECC) predictions¹⁰ for 2009 to 2030. For all other categories, ‘reference’ assumptions are set with regard to historical price data i.e. the business as usual with modification where required. The categories with modified price are mentioned in the Appendix; otherwise the historic average annual growth rate is applied for the future.

For the ‘low’ and ‘high’ scenarios the assumed growth rates are lower and higher than the reference growth assumption respectively. The price assumptions for each of the 16 expenditure categories are summarised in Table 2.

{Table 2: see figures and tables at the end of the paper }

ExNEF

¹⁰ www.decc.gov.uk

For the future projection of the ExNEF component, the slope at the end of the estimation period (over the whole sample) is assumed to continue into the future for the ‘reference’ scenario (equation 2) for each of the 16 expenditure categories with variation around this for the ‘low’ and ‘high’ scenarios, as shown in Table 3.¹¹

{Table 3: see figures and tables at the end of the paper }

Temperature

As mentioned above, the temperature component is used for estimating household expenditure for ‘electricity’, ‘gas’ and ‘other fuels’ only. When estimating expenditure in these categories, future UK temperatures are estimated using the future trend of temperature equation¹² as the ‘reference’ scenario, with the ‘high’ and ‘low’ assumptions 0.5 Degree Celsius higher and

¹¹ This excludes ‘miscellaneous goods and services’ where the expenditure equation has a fixed level but stochastic slope. In this case, for consistency, the average slope 1990q1-2009q1 at the end of the estimation is assumed to continue into the future for the ‘reference’ scenario with appropriate variation around this for the ‘high’ and ‘low’ scenarios.

¹² The estimated STSM for temperature, using the UK quarterly time series data from 1964q1 to 2009q1 (leaving 8 observations for prediction Failure test), is as follow:

$$temp_t = \tau_t$$

where $temp_t$ is temperature and τ_t is the stochastic trend.

Std. Error= 0.75; Normality= 5.26; H(57)= 1.14; $r_{(1)}$ = - 0.02; $r_{(4)}$ = 0.14; ; $r_{(8)}$ = - 0.06; D.W.= 2.02; $Q_{(8,6)}$ = 11.81;

Rs^2 = 0.48; Normality_(itr)= 3.98; Normality_(L.v)= 0.70; Failure= 10.33; LR= 11.37.

The nature of trend is local level with drift. For more information regarding diagnostics please see Chitnis et.al

2010, 2011.

0.5 Degree Celsius lower than the reference assumption respectively. The resulting average annual increases in average UK temperatures are shown in Table 4.

{Table 4: see figures and tables at the end of the paper }

GHG intensities

Future GHG intensities for the 'reference' scenario are estimated using a similar equation as that used to estimate future temperatures. The 'high' and 'low' assumptions are higher and lower than the reference assumption respectively; the resulting assumptions concerning increase in GHG intensity in each of the 16 expenditure categories is shown in Table 5. When looking at these estimated future GHG intensities it must be remembered that these figures are a result of historic changes in both the real expenditure in each category and the emissions in the same category.

{Table 5: see figures and tables at the end of the paper }

3.2. Results and discussion

Expenditure

Future predictions for expenditure are generated through the estimated expenditure equations for each category as described above. The assumptions discussed in the previous section and summarised in Tables 1 to 5 are applied to the explanatory variables in the estimated household expenditure

equations. This gives the expenditure forecasts for the 16 COICOP categories which are shown in Figure 1. The actual data in Figure 1 are shown from 1964 to 2008 and thereafter predicted from 2009 to 2030 with three different scenarios; 'reference', 'low' and 'high'.

{Figure 1: see figures and tables at the end of the paper }

Figure 1 shows that household expenditure in almost all categories is predicted to increase throughout the period to 2030 under the different scenarios. The only exceptions are 'alcoholic beverages and tobacco' and 'other fuels' expenditure which are predicted to decrease in the future under all three sets of assumptions. Also, 'electricity' and 'gas' expenditure is predicted to decrease under the 'low' scenario only.

Figure 2 presents total household expenditure in all 16 categories for the 'high', 'reference' and 'low' scenarios in terms of actual values. As shown in this figure, total expenditure is predicted to increase in 2020 by 27% (41%, 15%) and in 2030 by 74% (114%, 42%) compared to 2010 level under the 'reference' ('high', 'low') scenario(s). From this, we can see that, without a change in policy and barring any unexpected exogenous shocks, the expenditure is predicted to continue to increase over time. Assuming policy makers do not wish to curtail income, possible policies that could be introduced to counteract this trend include, for example, price taxation,

incentives for higher saving rates¹³ or 'softer' types of intervention, such as increasing environmental awareness to bring about behavioural change.

Figure 2 also shows the contribution of each category of expenditure to total expenditure in each year. In 2010, according to the scenarios, 'other housing' and 'other fuels' will have the highest and lowest expenditure respectively. While 'other fuels' are predicted to remain the lowest expenditure category in 2020 and 2030, our estimates show that 'recreation and culture' will take over 'other housing' as the highest expenditure category in these years.

{Figure 2: see figures and tables at the end of the paper }

Although from Figures 1 and 2 the amount of expenditure in most of the categories is predicted to increase in the future, the share of each category within total household expenditure is predicted to vary with time. Figure 3 shows the predicted percentage shares of expenditure for each COICOP category to total expenditure for the different scenarios. This suggests that the share will *decrease* for the categories 'food and non-alcoholic beverages', 'alcoholic beverages and tobacco', 'furnishings; household equipment & routine maintenance of the house', 'health', 'restaurants and hotels', 'miscellaneous goods and services', 'electricity', 'gas', 'other fuels', 'other

¹³ Higher saving rates could be incentivised through for example, an extension of tax fee saving such as the ISA accounts in the UK.

housing' and 'vehicle fuels and lubricants'.¹⁴ In contrast, Figure 3 suggests that the share will *increase* for 'clothing and footwear', 'communication', 'recreation and culture', 'education' and 'other transport'.

The estimates show that over 50% of future predicted total expenditure in 2030 will come from only four categories i.e. 'recreation and culture', 'miscellaneous goods and services', 'other housing' and 'other transport'. With regard to GHG emissions then, what really matters is how GHG-intensive these categories are relative to other categories; whether these four are the categories associated with the highest amount of GHG emission and whether reducing expenditure in these categories will lower the future emissions appreciably. This is investigated further below.

{Figure 3: see figures and tables at the end of the paper }

GHG Emissions

Estimated GHG emissions attributable to each category from 1992 to 2030 are illustrated in Figure 4. The graphs suggest that total GHG emissions for most of the COICOP categories will generally increase in the 'reference'¹⁵ and 'high' scenarios. However, 'alcoholic beverages and tobacco' and 'other fuels' are

¹⁴ The expenditure share for 'vehicle fuels and lubricants' would increase in 2020 compared to 2010 under the 'low' scenario only.

¹⁵ The exceptions are 'food and non-alcoholic beverages', 'electricity' and 'recreation and culture' which the GHG emissions will decrease in the 'reference' scenario.

the two exceptions in which GHG emissions are predicted to decrease in the future under all three scenarios.

Figure 5 presents total GHG emissions in all 16 categories for the three scenarios and shows that total emissions are predicted to increase by 8% (36%, -15%) in 2020 and by 27% (107%, -22%) in 2030 compared to 2010 under the 'reference' ('high', 'low') scenario(s). These results show that, in the 'reference' and 'high' scenarios, rather than seeing emissions *falling*, emissions are predicted to *rise*, unless expenditure is controlled through the previously mentioned policies, any unexpected exogenous shocks occur or GHG intensities are controlled more substantially by relevant policies.¹⁶ Moreover, the rate at which they are predicted to rise increases with time up to 2030.

Figure 5 also shows the composition of total emissions and the contribution of each category to total emissions. In 2010, 'other transport' and 'alcoholic beverages and tobacco' are predicted to be the highest and lowest emissions categories, respectively. Whilst 'other transport' continues to remain the highest emission category in 2020 and 2030, 'other fuels' will replace 'alcoholic beverages and tobacco' as the lowest emissions' category in these years.

¹⁶ Such policies are mainly related to production side of goods and services. This paper is looking at emissions from 'consumption' perspective.

{Figure 5: see figures and tables at the end of the paper }

As shown in Figure 4, the actual amount of GHG emissions in most of the categories is predicted to increase in the future under the 'reference' and 'high' scenarios; but the share of each category to total GHGs emitted by households will not necessarily follow the same pattern. The predicted percentage share of emissions for each category of consumption to total emissions is therefore presented in Figure 6 for the three different scenarios. This shows that the share is predicted to *decrease* for 'food and non-alcoholic beverages', 'alcoholic beverages and tobacco', 'clothing and footwear' (except under 'high' assumption), 'electricity', 'gas', 'other fuels', 'furnishings; household equipment & routine maintenance of the house', 'communication' and 'recreation and culture'. In contrast, the share is predicted to *increase* for 'health', 'vehicle fuels and lubricants', 'education', 'other transport', 'restaurants and hotels' and 'miscellaneous goods and services'. For 'other housing', the share will increase in 2020 but decreases in 2030.

However, 'direct energy' use by households for 'vehicle fuels and lubricants', 'gas' 'electricity' and 'other fuels' is predicted to be responsible for about 30% of total emissions in 2030. This means that nearly 70% of GHG emissions

could be attributable to ‘indirect energy’¹⁷ use by households, with ‘other transport’¹⁸ having the largest share of any single category, at almost 20% of total emissions from direct and indirect energy.¹⁹ Consequently, ‘other transport’ will have the highest emission share in 2030 despite not having the highest expenditure share in this year. Therefore, reducing consumption in this group could significantly lead to lower future emissions. Obviously not all categories with high expenditure are associated with higher GHG emissions as they may have a lower GHG intensity which more than compensates for the high expenditure resulting in lower GHG emission for that particular category of consumption.

{Figure 6: see figures and tables at the end of the paper }

4. Summary and conclusion

This paper describes the ELESAs model and its use to produce future scenarios up to 2030 for 16 categories of UK household expenditure and the GHG emissions associated with each of these categories. As mentioned in the Introduction, ELESAs differs from other scenario tools in that it takes the consumption perspective, and also models ExNEF.

¹⁷ ‘Indirect energy’ or ‘embedded energy’ is the energy used in supply chains in the production and distribution of goods and services purchased by UK households.

¹⁸ The category ‘other transport’ includes buses, trains and air travel.

¹⁹ These shares are similar in 2010.

The scenarios suggest that total household expenditure and GHG emissions in the 'reference' and 'high' scenarios will increase up to 2030. This implies a radical departure from the targeted *reduction* of at least 34% in UK emissions by 2030, from a production perspective; unless expenditure and GHG intensities are controlled or any unexpected exogenous shocks occur.

Clearly, some of the policies designed to meet the production perspective target will have a desirable impact from a consumption perspective also, e.g. through reduced GHG intensity of electricity. However, the prediction within these scenarios of 70% of total emissions being attributable to 'indirect energy' use, highlights the need for a complementary consumption perspective, particularly one that teases out the relative share of embodied emissions resulting from production in the UK versus other regions. In the absence of such a shadow accounting perspective, there is a risk that production perspective policies may in fact exacerbate consumption emissions by encouraging further off shoring of energy intensive industry, perhaps to less energy efficient economic regions, and requiring increased transportation to bring those goods to the UK market (Milne, 2011).

The scenarios act as a reminder that in order to move towards future GHG mitigation the focus should be on the categories of consumption that show high and increasing patterns of associated GHG emissions. According to our

results, the highest GHG emissions in 2030 will be the categories 'other transport' and 'vehicle fuels and lubricants' (those concerned with the transportation sector) and 'gas'. The goods and services comprising the latter two categories are self explanatory, however the 'other transport' category would ideally be subject to further disaggregation and estimation in order to gain a more comprehensive understanding of the relative share of expenditure on road, rail, air and sea transport, and the GHG intensity associated with each. Even a cursory examination of the historical data suggests that these sub-categories have undergone very different trajectories, and may be expected to continue along unique pathways according to the assumptions adopted in the context of a scenario forecast.

A novel feature of this study is that modelling of expenditure (and thus GHG emissions) is based on not just the standard factors such as prices and incomes but also on ExNEF. As noted above the ExNEF is derived from the estimated underlying trend that encompasses unobserved components that are usually too hard to actually measure, such as technical progress, changes in tastes, consumer preferences, socio-demographic and geographic factors, lifestyles and values. Our study finds that ExNEF makes a contribution in all of the household expenditure categories, which demonstrates the importance of considering these factors when devising policies to reduce expenditures and associated GHG emissions. Specifically, ExNEF has a relatively high

contribution to changes in expenditure in 'other transport', 'vehicle fuels and lubricants', 'gas' and 'miscellaneous goods and services' categories: thus influencing ExNEF could be particularly effective in attempts to reduce household expenditure and associated emissions in these categories. Policies that influence ExNEF include, for example, educational campaigns to increase environmental awareness, R&D in new technologies, incentives to increase savings and investments (particularly in low carbon technologies (Druckman et al 2011) restrictions on advertising and so on (Jackson 2011). The results suggest that such policies might be especially effective in these specific expenditure categories. Of course, beside such policies, economic incentives such as price increases through (carbon) taxes should be carefully considered, while, of course, keeping in mind possible negative side effects such as price increases in other associated sectors. It is also particularly important that policies are put in place to protect against regressive effects.

ELESA is a unique scenario-modelling tool, and in this paper, we have illustrated its power by modelling three specific scenarios based on the current conditions. The assumptions on which these scenarios are based are, of course, all uncertain and, as with any scenario-forecasting tool, appropriate assumptions will change as time progresses. This is especially true at the time of writing this paper when Western economies are in extreme economic turbulence, with countries such as the USA and France having lost their AAA

credit rating (S & P 2012) and the Euro in danger of collapse (The Economist 2011).

Finally, it should be noted that the ELESAs model quantifies the effect of all non-economic factors as one composite factor called ExNEF. Clearly, it is possible and indeed likely that components of ExNEF have competing (positive and negative) impacts on expenditure, such that these forces may cancel each other out to some extent, leaving a relatively small overall effect. As a result it is impossible to determine the true significance of non-economic as opposed to economic factors unless more work is done to isolate the contributions to ExNEF made by different factors. These may include technical progress, changes in consumer tastes and preferences, socio-demographic and geographic factors, lifestyles and values etc. Crucially, identifying such factors would be a step towards understanding the real mechanisms of change which may be more or less subject to intervention by policymakers, thus aiding the transition towards lower carbon lifestyles.

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Figures and Tables

Table 1: Real household disposable income average annual growth rate assumptions 2009-2030 (%)

	Ly	Ry	Hy
Real household disposable income	1.37	1.85	2.33

Table 2: Real price average annual growth rate assumptions 2009-2030 (%)

	Lp	Rp	Hp
Food and non-alcoholic beverages	-1.14	-0.66	-0.19
Alcoholic beverages and tobacco	1.24	1.71	2.19
Clothing and footwear	-5.62	-3.71	-1.80
Electricity	1.18	2.12	2.98
Gas	-0.47	0.66	1.75
Other fuels	3.70	4.18	4.66
Other housing	3.22	3.69	4.17
Furnishings; household equipment & routine maintenance of the house	-1.67	-1.19	-0.72
Health	0.10	0.58	1.05
Vehicle fuels and lubricants	0.60	1.63	2.26
Other transport	-0.23	0.25	0.73
Communication	-5.47	-3.56	-1.65
Recreation and culture	-2.42	-1.47	-0.52
Education	2.90	3.38	3.85
Restaurants and hotels	0.63	1.11	1.58
Miscellaneous goods and services	-0.58	-0.11	0.37

Table 3: ExNEF average annual growth rate assumptions 2009-2030 (%)

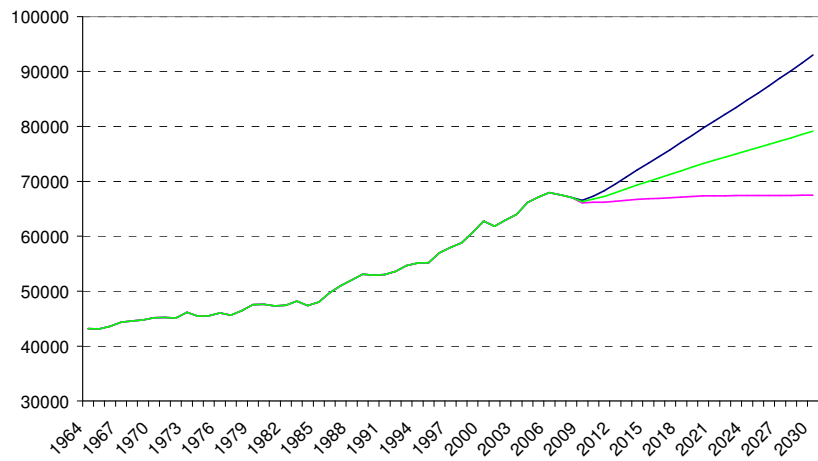
	Lμ	Rμ	Hμ
Food and non-alcoholic beverages	-0.2	0.3	0.7
Alcoholic beverages and tobacco	-0.8	-0.5	-0.2
Clothing and footwear	0.4	0.8	1.1
Electricity	0.1	0.2	0.3
Gas	0.3	0.4	0.6
Other fuels	-6.0	-3.6	-1.7
Other housing	1.3	1.7	2.2
Furnishings; household equipment & routine maintenance of the house	-0.3	-0.1	0.1
Health	1.6	2.0	2.3
Vehicle fuels and lubricants	1.9	2.3	2.7
Other transport	1.8	2.3	2.8
Communication	3.5	3.8	4.1
Recreation and culture	2.6	2.8	3.1
Education	0.8	1.0	1.2
Restaurants and hotels	0.5	0.7	0.9
Miscellaneous goods and services	0.9	1.1	1.4

Table 4: Temperature average annual growth rate assumptions 2009-2030 (%)

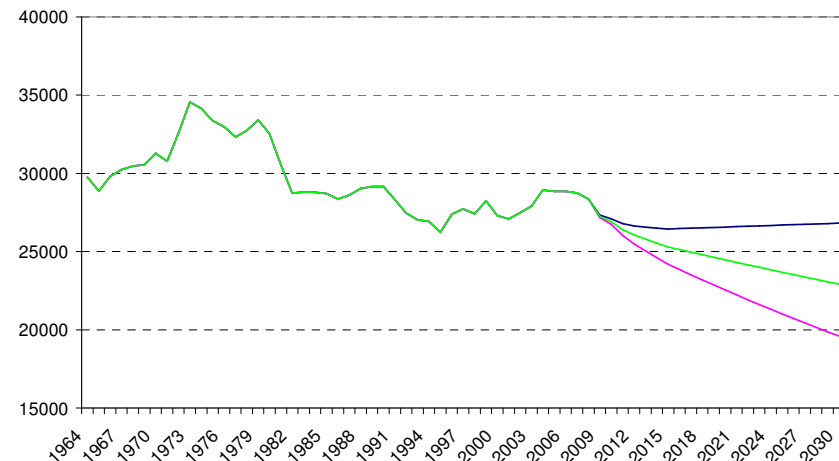
	Ltemp	Rtemp	Htemp
Temperature	-0.47	-0.0001	0.47

Table 5: GHG intensity average annual growth rate assumptions 2005-2030 (%)

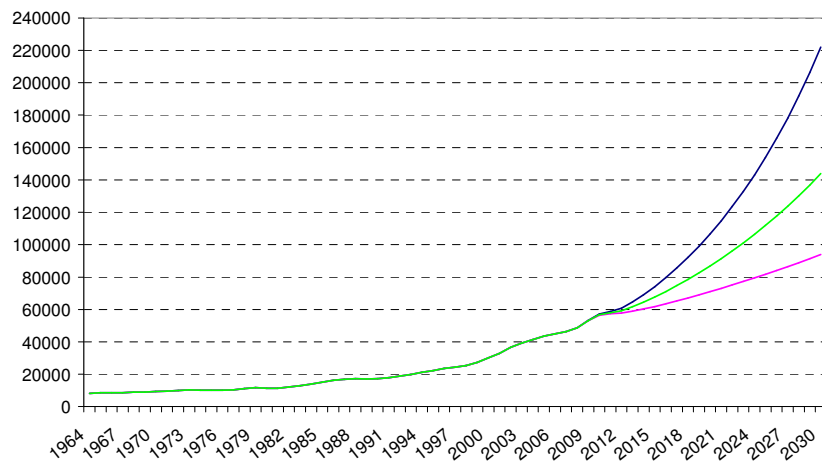
	Lci	Rci	Hci
Food and non-alcoholic beverages	-3.4	-2.0	-0.6
Alcoholic beverages and tobacco	-6.7	-4.9	-3.0
Clothing and footwear	-6.3	-4.5	-2.8
Electricity	-3.4	-2.3	-1.3
Gas	-0.9	0.0	0.9
Other fuels	-6.3	-5.2	-4.1
Other housing	-1.2	0.4	1.9
Furnishings; household equipment & routine maintenance of the house	-3.5	-2.0	-0.5
Health	-1.1	0.5	2.1
Vehicle fuels and lubricants	-1.0	0.2	1.4
Other transport	-2.1	-0.7	0.6
Communication	-7.2	-5.5	-3.8
Recreation and culture	-8.0	-6.2	-4.5
Education	2.2	3.6	4.9
Restaurants and hotels	-0.5	1.0	2.4
Miscellaneous goods and services	-1.5	0.00	1.5



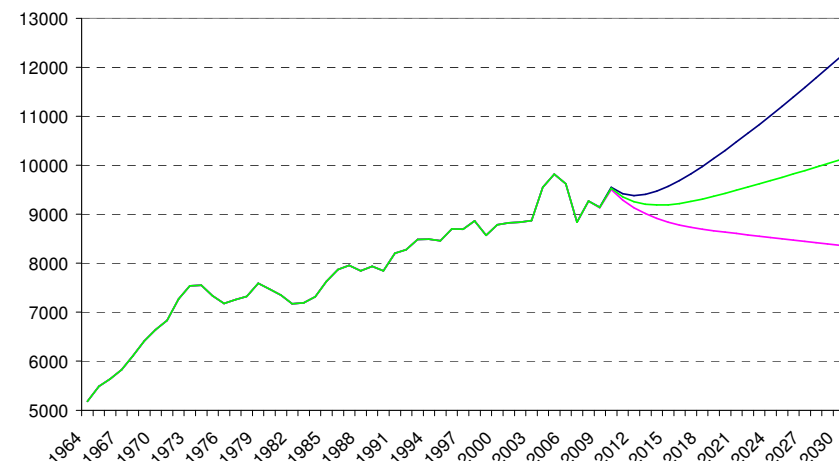
Food and non-alcoholic beverages



Alcoholic beverages and tobacco



Clothing and footwear



Electricity

Figure 1: Household expenditure (million pounds) 1964-2030

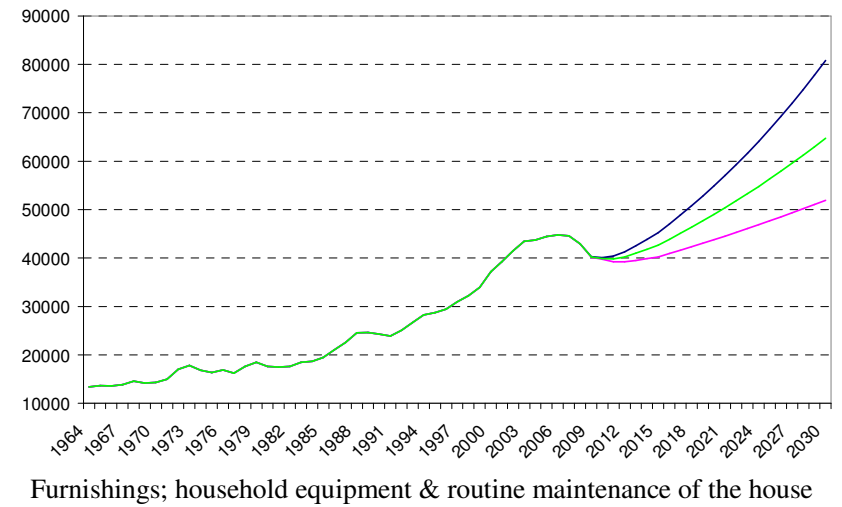
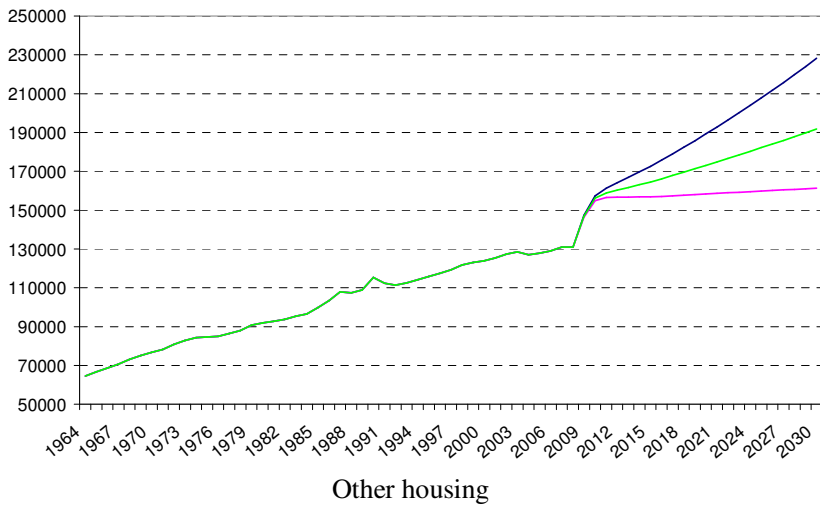
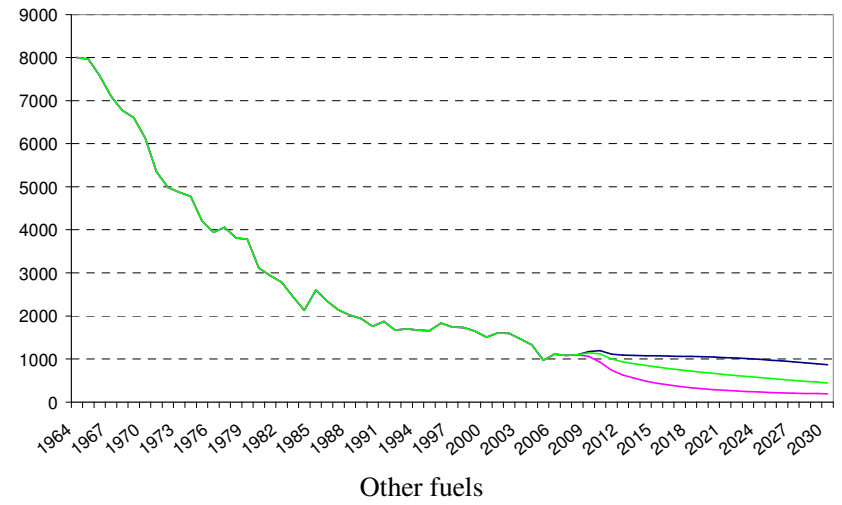
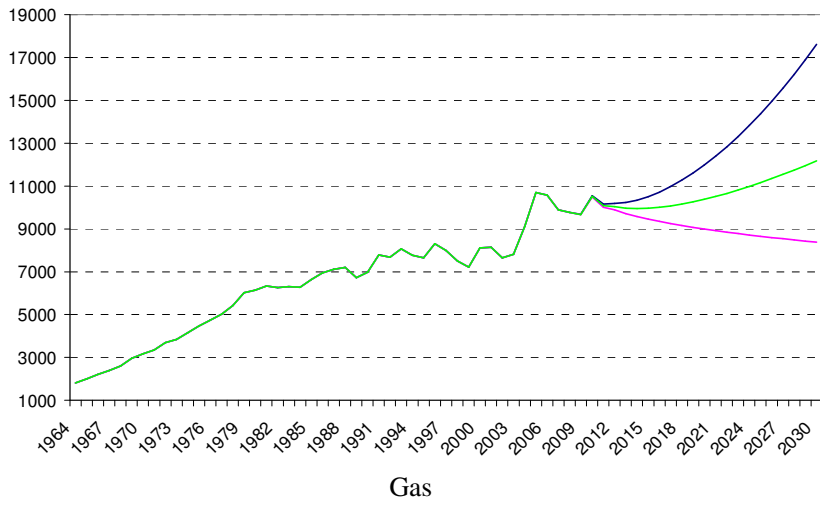
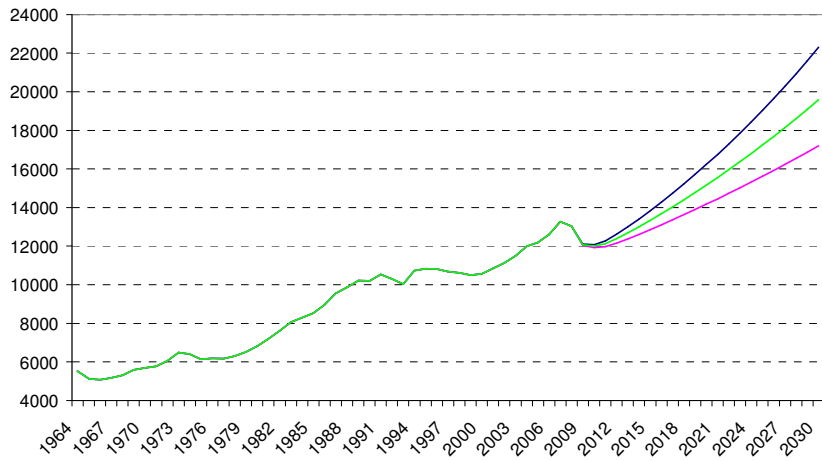
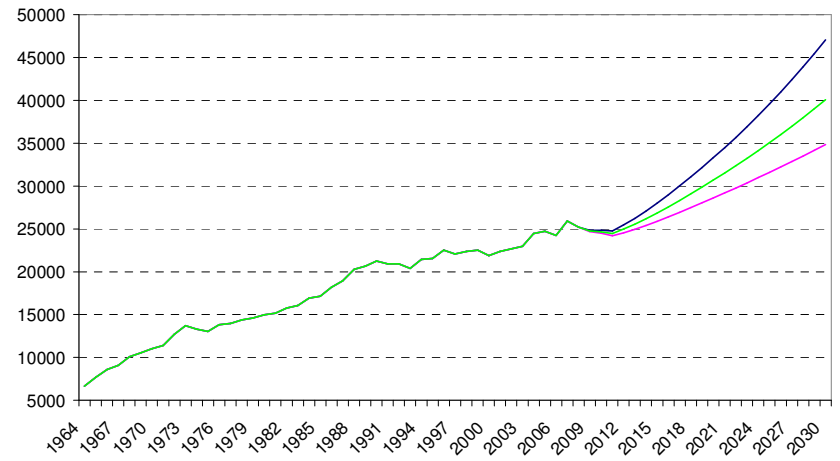


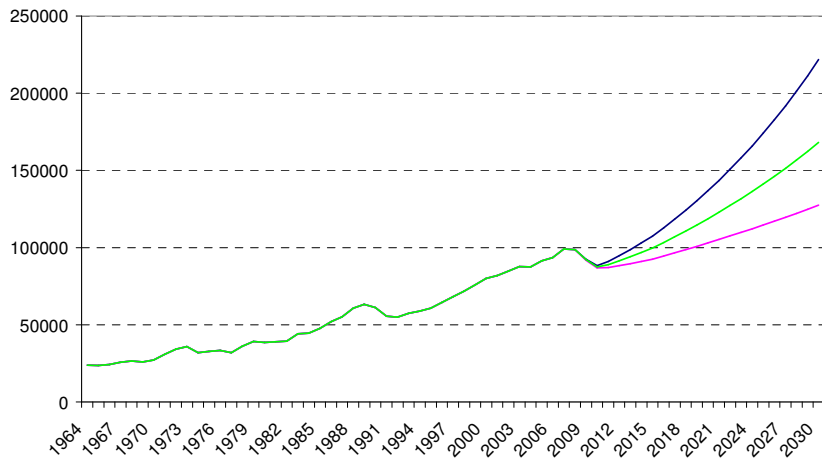
Figure 1 (continued): Household expenditure (million pounds) 1964-2030



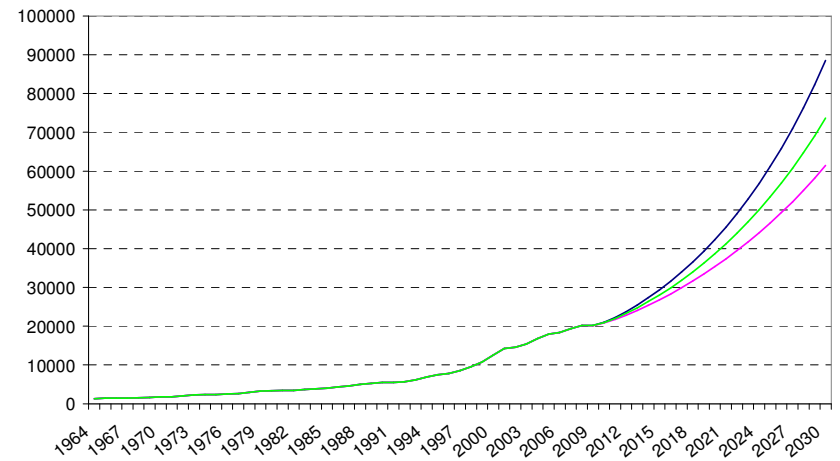
Health



Vehicle fuels and lubricants

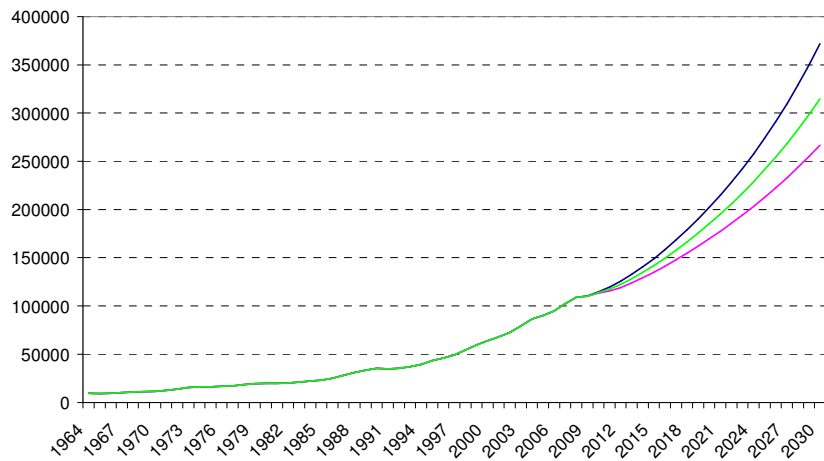


Other transport

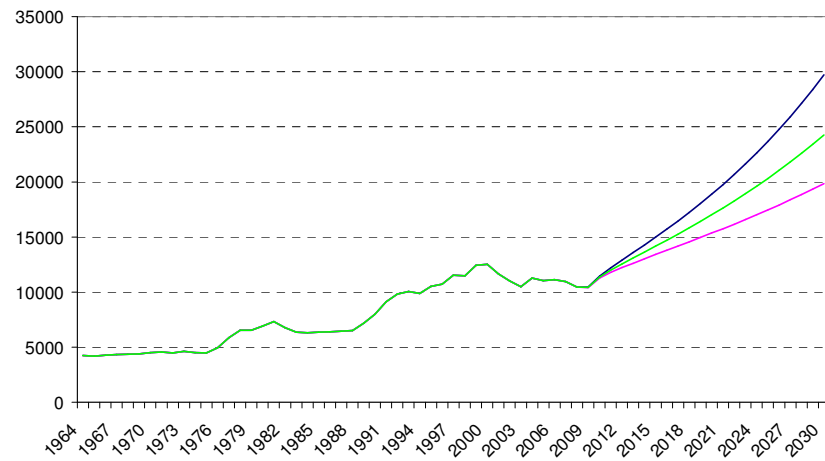


Communication

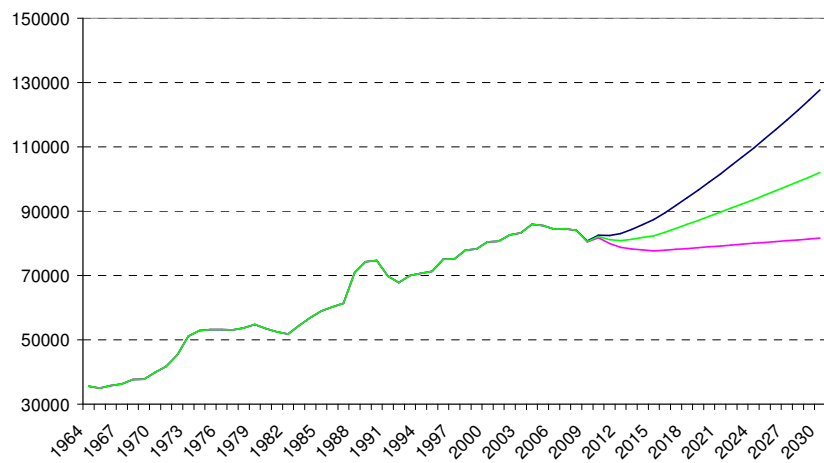
Figure 1 (continued): Household expenditure (million pounds) 1964-2030



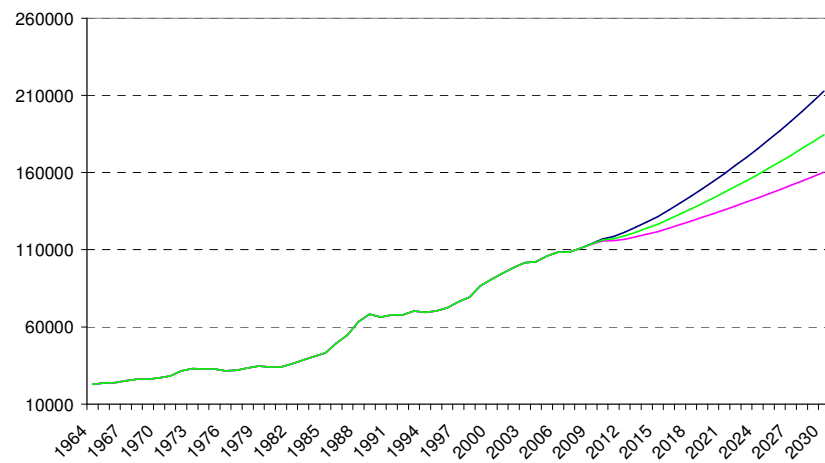
Recreation and culture



Education



Restaurants and hotels



Miscellaneous goods and services

Figure 1 (continued): Household expenditure (million pounds) 1964-2030

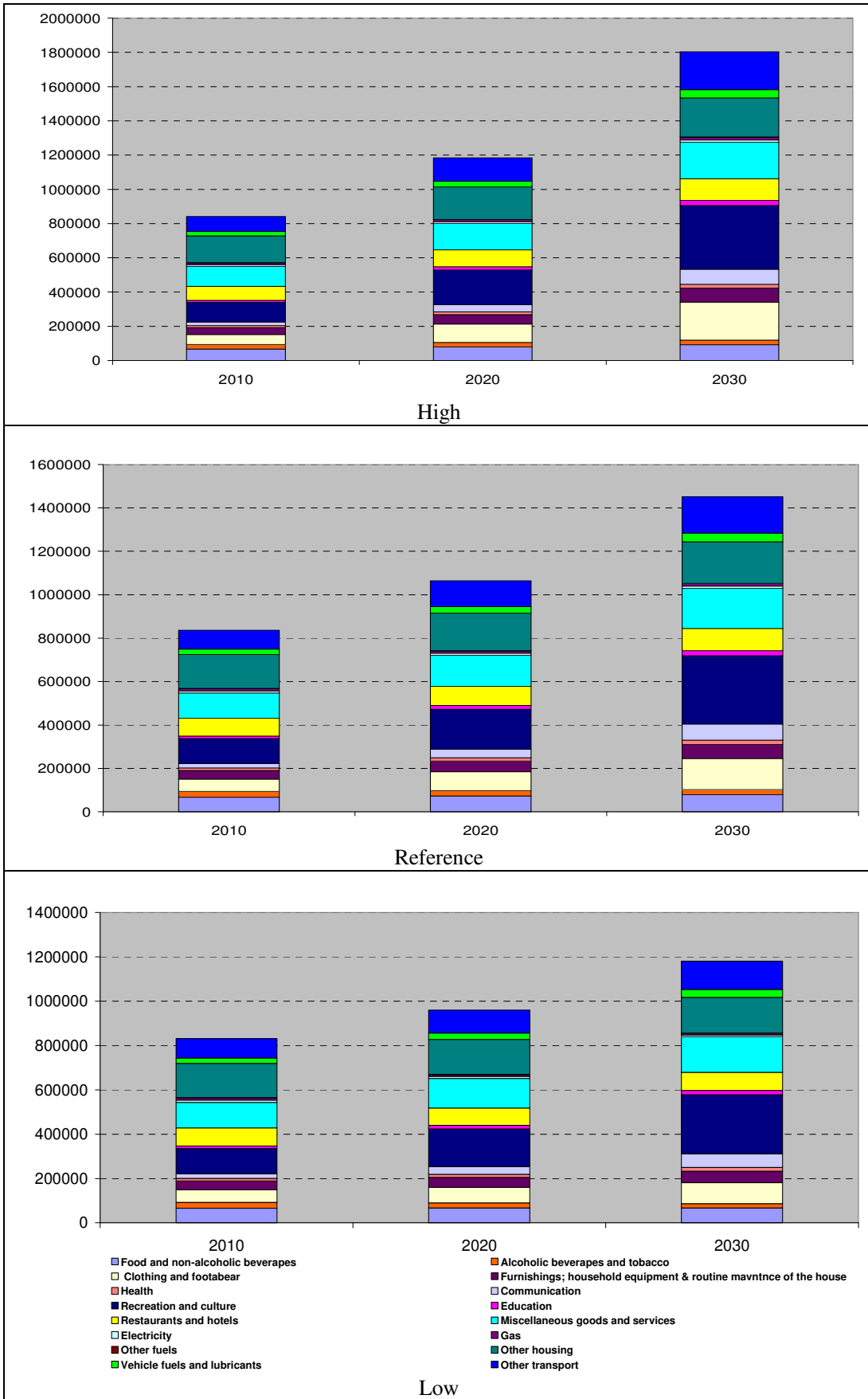


Figure 2: Household expenditure (million pounds) 2010, 2020 and 2030

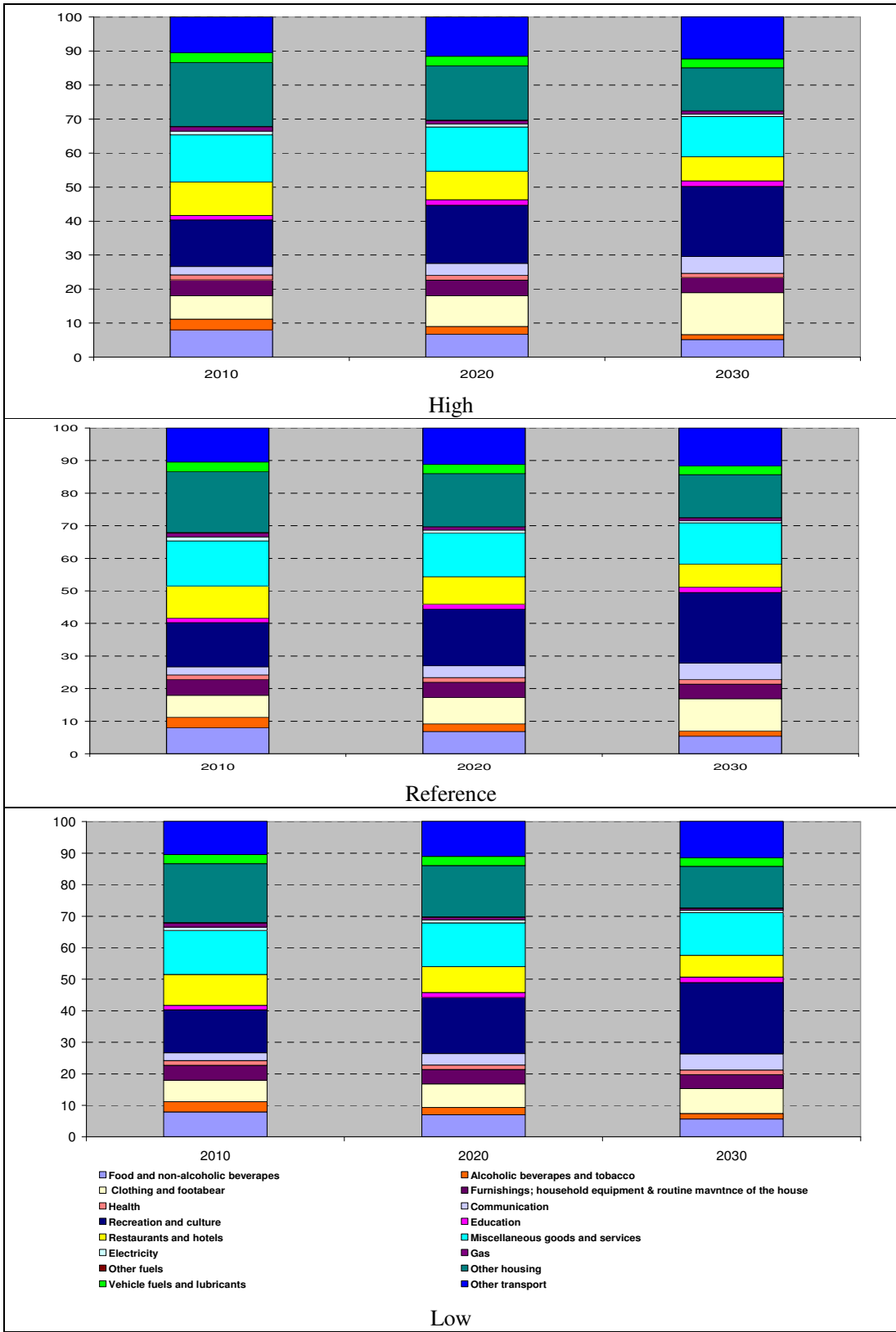
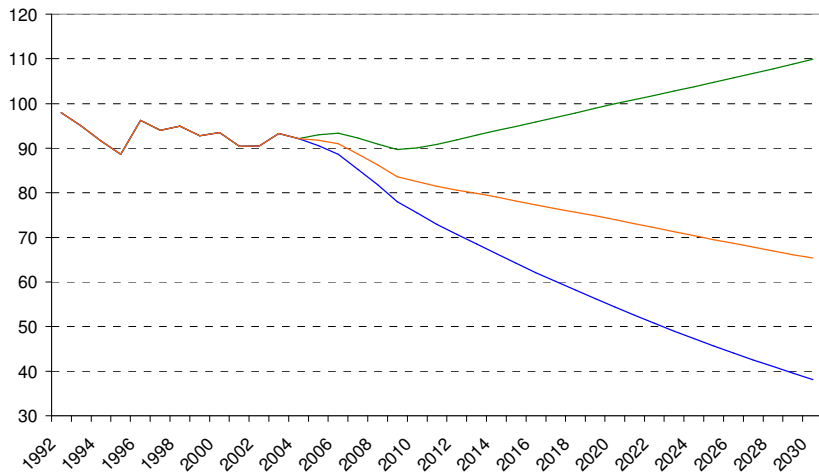
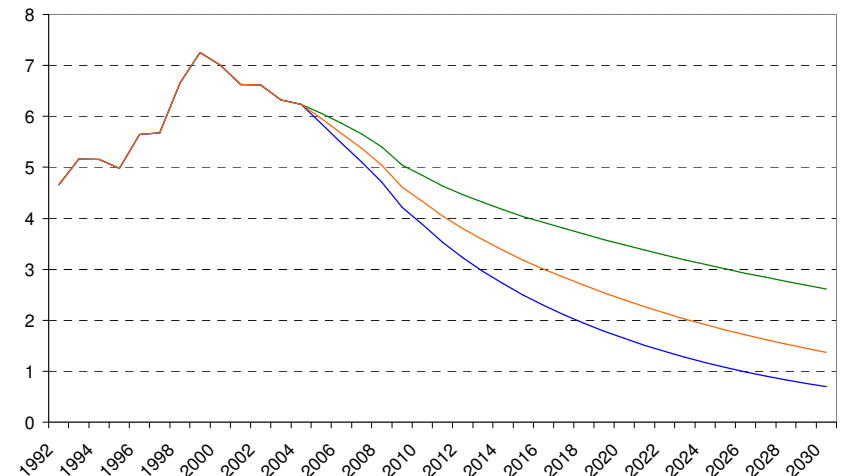


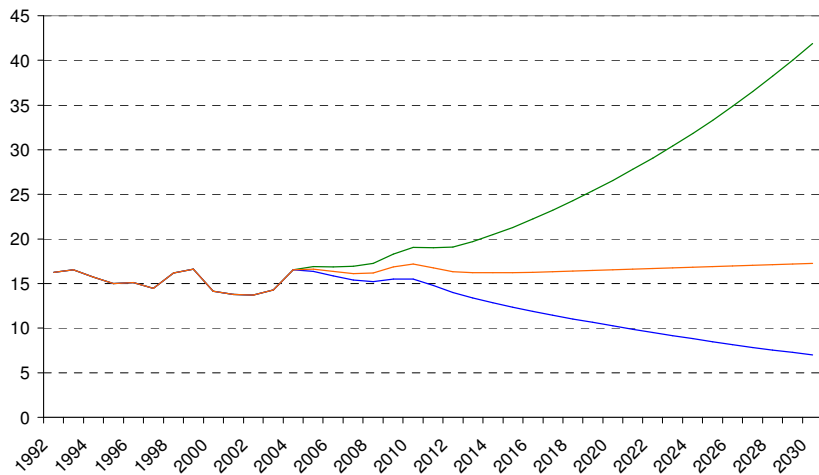
Figure 3: Percentage share of household expenditure (%) 2010, 2020 and 2030



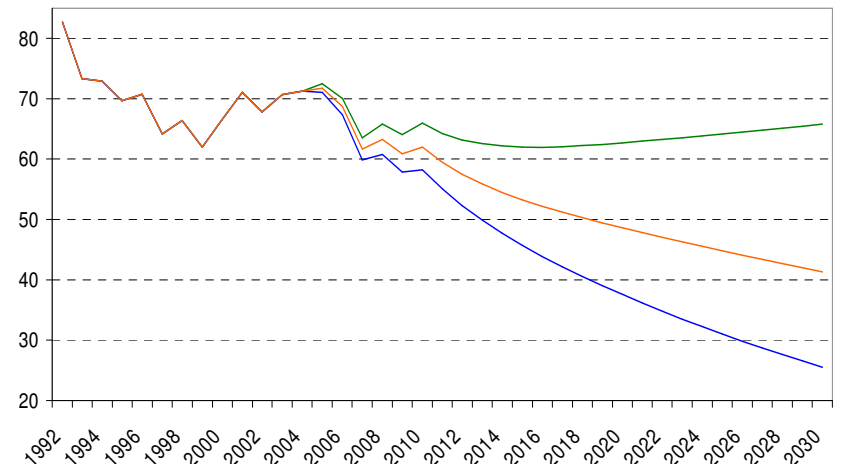
Food and non-alcoholic beverages



Alcoholic beverages and tobacco



Clothing and footwear



Electricity

Figure 4: GHGs associated with household expenditure (mtco2) 1992-2030

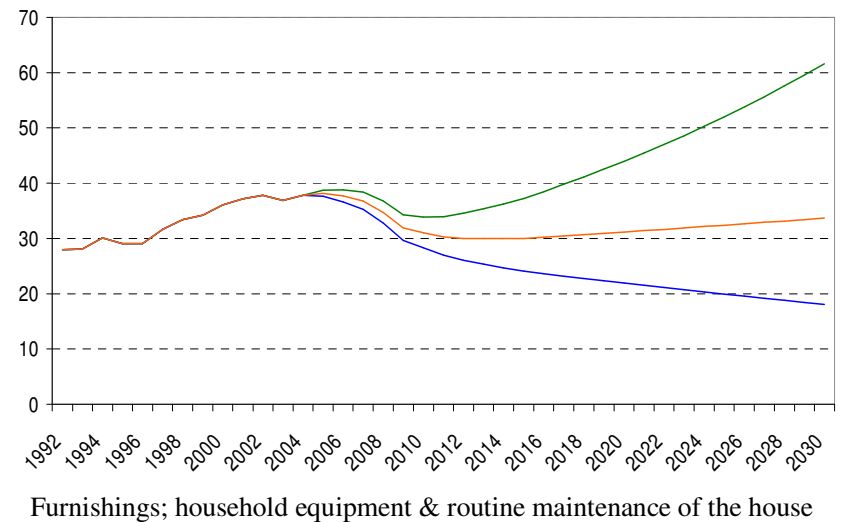
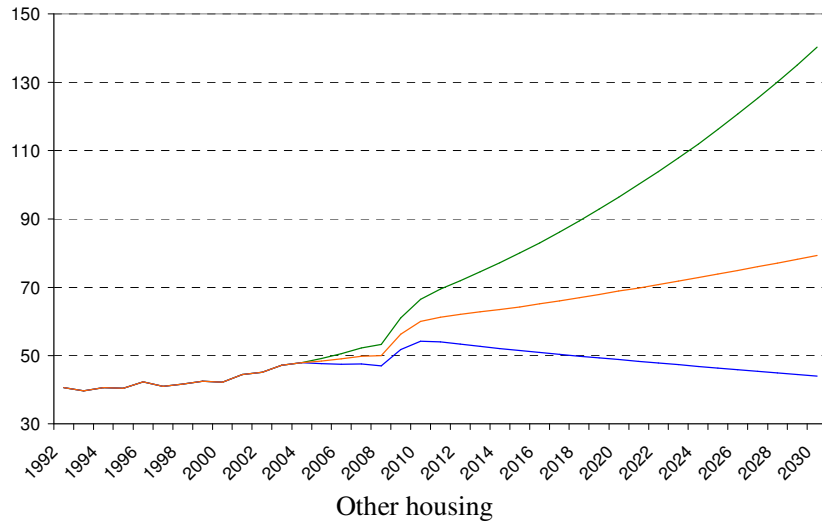
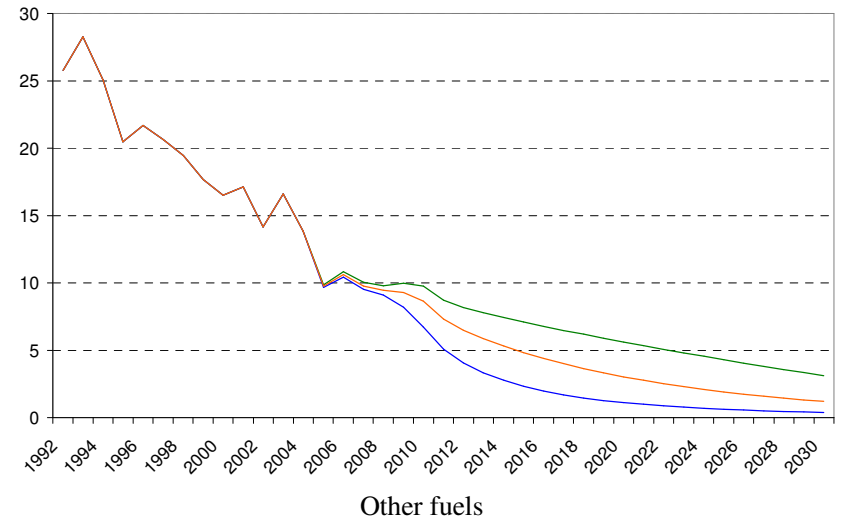
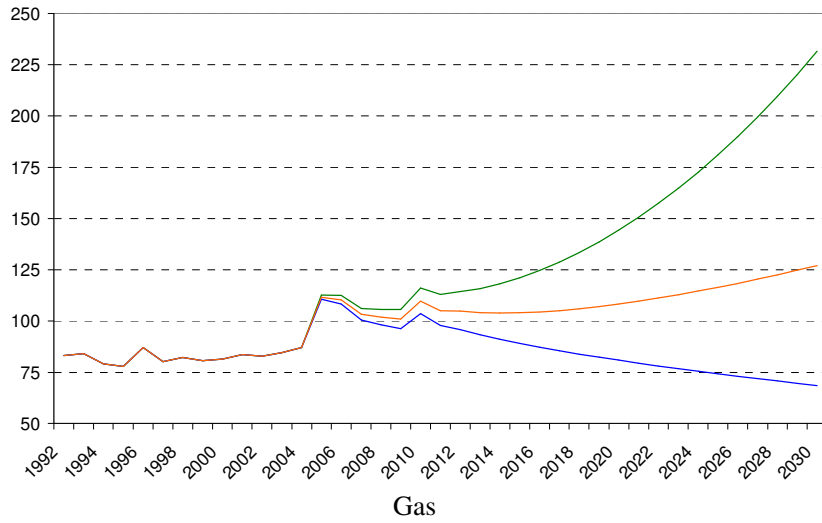
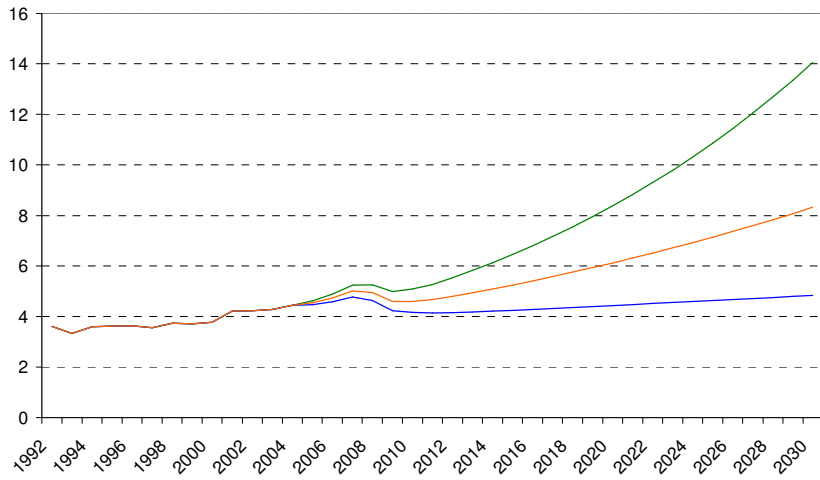
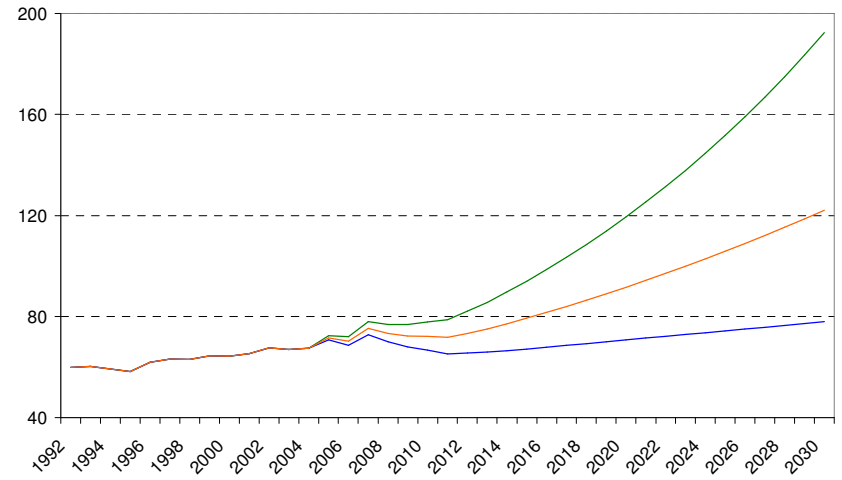


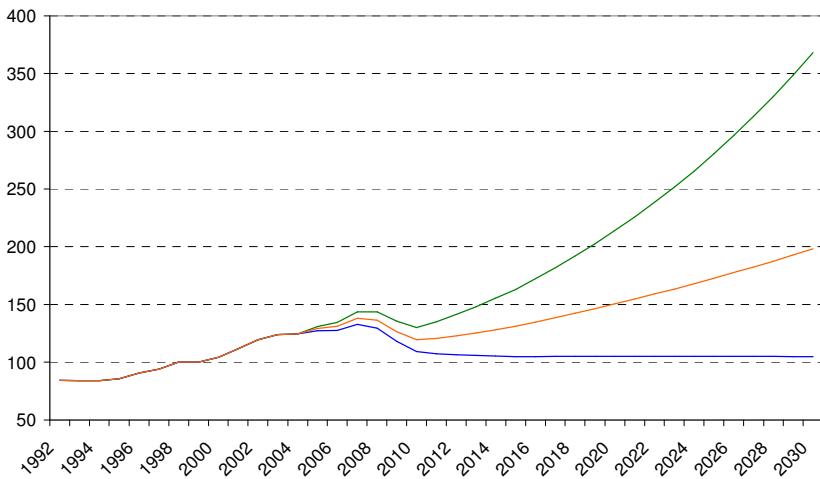
Figure 4 (continued): GHGs associated with household expenditure (mtco2) 1992-2030



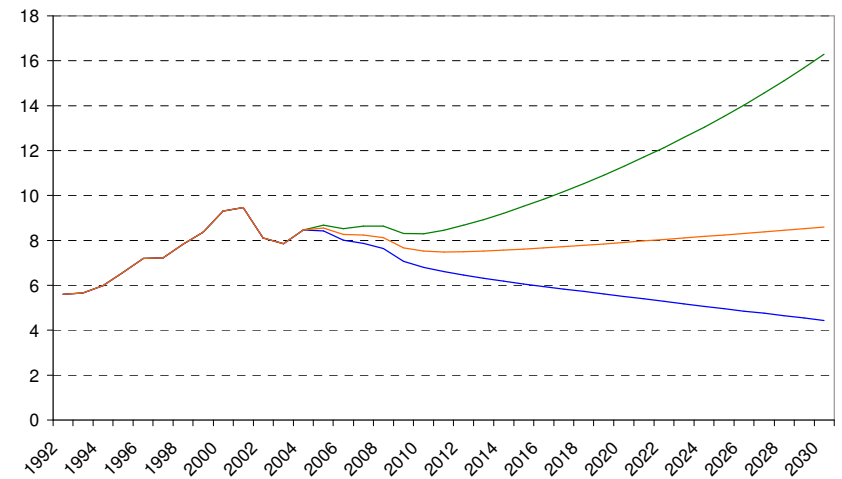
Health



Vehicle fuels and lubricants

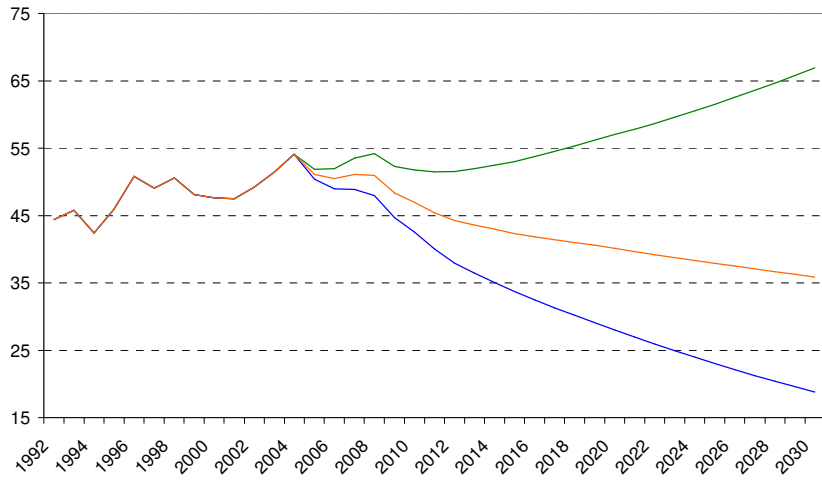


Other transport

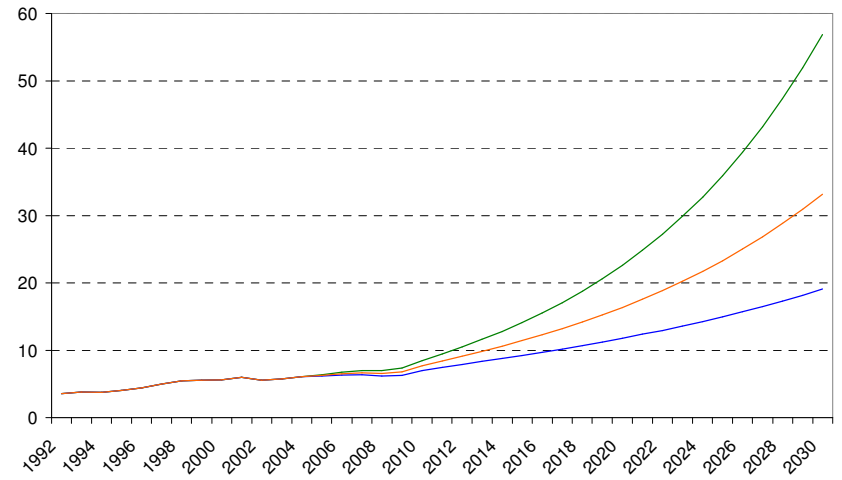


Communication

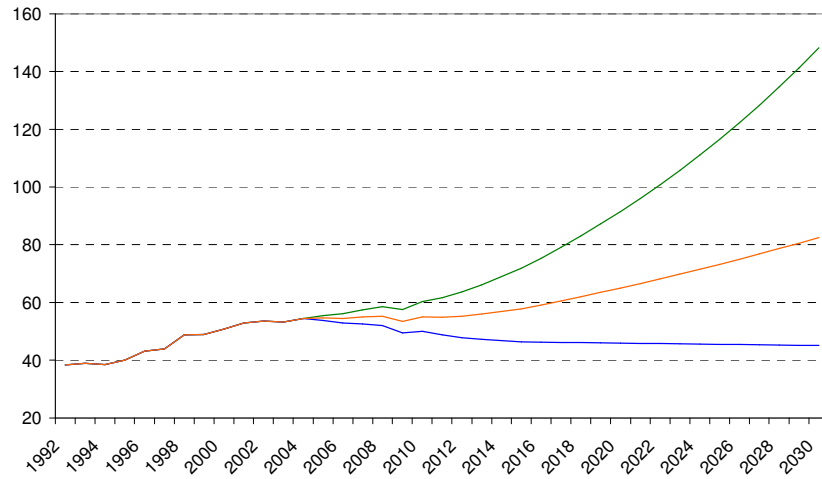
Figure 4 (continued): GHGs associated with household expenditure (mtco2) 1992-2030



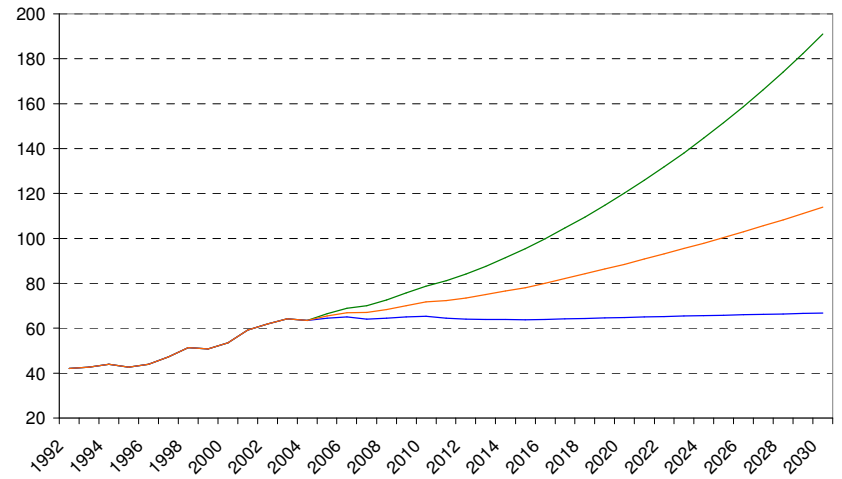
Recreation and culture



Education



Restaurants and hotels



Miscellaneous goods and services

Figure 4 (continued): GHGs associated with household expenditure (mtco2) 1992-2030

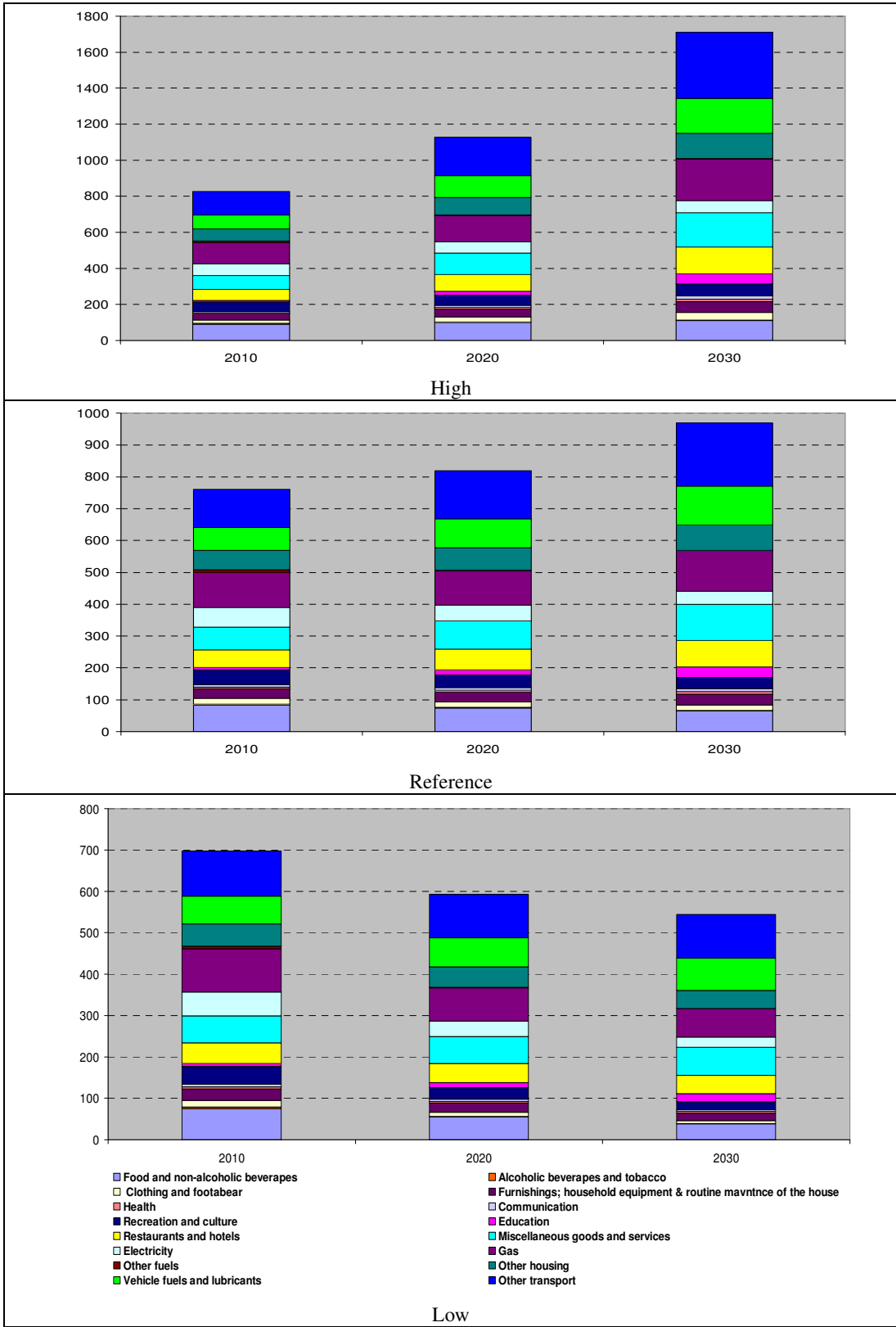


Figure 5: GHG emissions associated with household expenditure (mtco2) 2010, 2020 and 2030

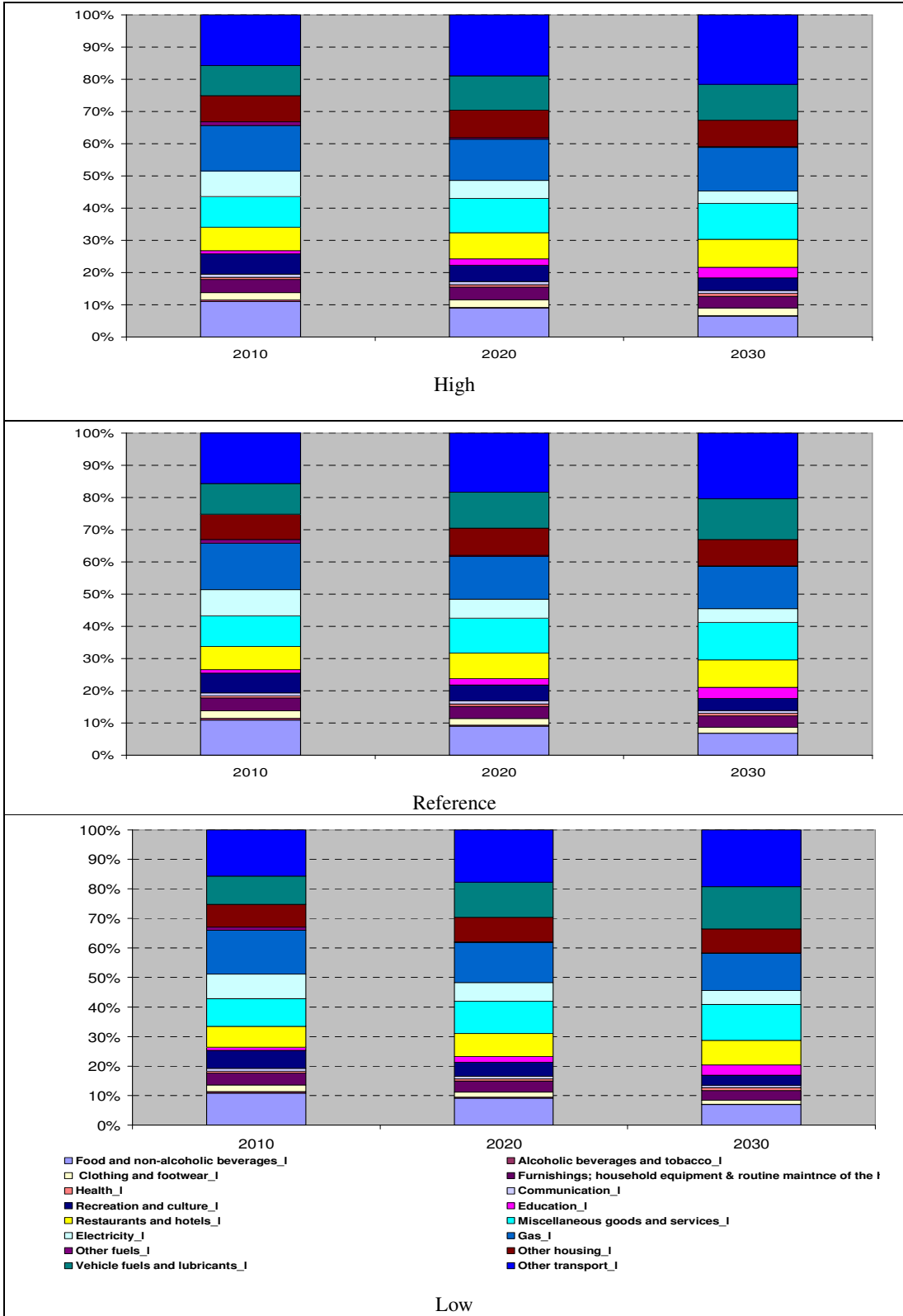


Figure 6: Percentage share of GHG emissions associated with household expenditure

APPENDIX : Price growth rate assumptions for the reference scenario for selected COICOP categories

'Food' real prices generally decreased between 1977 and 2006, with a slight reduction in the rate of decrease 2001-2006. In 2007 the international food price increased dramatically and this, coupled with the depreciation of sterling, caused UK food prices to increase sharply. In our scenario it is assumed that 'food' real prices will return to their long term trend of negative growth with a rate between the rate seen before and after 2001.

'Health' real prices generally increased between 1975 and 2003, after which they levelled off and decreased slightly. It is assumed that 'health' real price will continue to increase in the future but with a lower growth rate than it had before 2004.

The 'other transport' real price had a very stochastic pattern in the past. However, since 2004 the real price has decreased significantly. Assuming that the car and train prices will continue to decrease and increase respectively, these two will almost offset each other's effect. Therefore, it is assumed that the real price will continue to reduce for few years and then stay relatively constant until 2030.

The real price of 'communication' has reduced sharply since 1986, which is

not surprising given the internet has to a large extent replaced conventional communication tools such as post, phone calls etc. It is expected that the real price will continue to decrease in the future with a similar (negative) growth rate to past.

The real price of 'recreation and culture' has been decreasing since 1972 with the rate of decrease being higher since 1996. High energy prices affect the price in this category and it is assumed that the real price will continue to decrease but with a less negative growth rate than before.

The real price of 'restaurants and hotels' has been increasing since 1975, with the rate of increase being higher since 1997. It is assumed that the real price will continue to increase in the future with a rate between the rate seen before and after 1997.

The category 'miscellaneous goods and services' has a discontinuity as jewellery was added to the category in 1987. Since 1987 the real price has been relatively stochastic, but with a slight increase. It is assumed that real prices will rise in line with the average annual growth rate since 1987.