

Personal Carbon Allowances:

Distributional implications associated with personal travel and opportunities to reduce household emissions

Project Paper No. 3

March 2013

Contributing authors:

Vicki White, Joshua Thumim, Ian Preston, Centre for Sustainable Energy

The analysis presented in this paper was undertaken as part of the JRF-funded study: '*Distribution of carbon emissions in the UK: implications for domestic energy policy*'.

The project was carried out by a team at the Centre for Sustainable Energy, Bristol; the Townsend Centre for International Poverty Research, University of Bristol; and the Environmental Change Institute, University of Oxford. The research uses advanced modelling techniques to develop and analyse the datasets necessary to support and further understanding of: the distribution of emissions across households in Great Britain; the impact of existing and forthcoming Government policies on consumer energy bills and household emissions in England; and exploratory analysis of alternative approaches for improving the energy efficiency and sustainability of the housing stock in England. The full project report is available at: <http://www.jrf.org.uk/focus-issue/climate-change>

This paper is designed to complement the analysis presented in the main project report, providing some exploratory analysis of personal carbon allowances utilising the nationally representative dataset of household carbon emissions created as part of the project. The analysis presented here aims to contribute to the discussion around policy and social justice implications by exploring the distributional impacts of a personal carbon allowance system that includes household level emissions from personal travel. It also explores the potential for households to avoid the negative impacts of a personal carbon allowance system by undertaking cost-effective measures to improve the energy efficiency of their home, thereby reducing household emissions.

1	Introduction.....	3
1.1	Background and context	3
2	Data and Methods.....	5
2.1	Creating the dataset.....	5
2.2	The ‘final’ dataset	7
2.3	Modelling Personal Carbon Allowances	8
3	Results	9
3.1	Headline results: who wins and loses under PCA.....	9
3.2	Distributional impacts of PCA.....	10
3.3	Who could avoid ‘losing’?.....	14
4	Conclusion.....	20

1 Introduction

This paper forms part of a wider research project, funded by the Joseph Rowntree Foundation and undertaken by the Centre for Sustainable Energy and the Universities of Bristol and Oxford, to explore the likely social distributional impacts of UK Government energy and climate change policies on domestic energy consumers.

The research study – ‘*Distribution of carbon emissions in the UK: implications for domestic energy policy*’- aims to further the development of socially just and environmentally effective carbon reduction policies, by:

- revealing the distributional consequences of current and possible future policies to reduce carbon emissions from UK households; and
- enhancing understanding of these social aspects of climate policy within energy, climate change and social policy arenas.

The focus of the wider research project is therefore largely on exploring the distributional impacts of energy and climate policies on householders in England. The analysis and discussion in the main project report is limited to understanding the policy implications for energy consumption in the home, with little attention given to transport emissions. Yet a key aim of the research project as a whole was to develop datasets that would facilitate analysis of policy implications in the context of personal travel as well as energy consumed in the home. A full and detailed assessment of transport policy is beyond the scope of this study. However, to demonstrate the potential of the datasets developed through the research, some additional analysis was undertaken to explore potential distributional implications of a personal carbon allowance system that includes emissions from personal travel.

1.1 Background and context

Box 1. What is personal carbon trading?

Personal carbon allowances (PCA) – or Personal Carbon Trading (PCT) - describes a cap-and-trade system whereby individuals are allocated a limited personal carbon emissions allowance. Carbon allowances must be surrendered when undertaking activities that cause emissions (e.g. paying a gas bill, or refuelling the car). Individuals who emit less than their allocation have the option of selling their surplus allowances; whilst individuals whose emissions exceed their allocation have the option of purchasing extra allowances. The tradeable system approach therefore offers an element of choice: individuals can opt to maintain existing lifestyle choices but pay the price by purchasing allowances; or reduce their emissions through abatement measures (e.g. insulating their home) or behavioural change (e.g. driving less). A PCT system therefore has the potential to constrain carbon dioxide emissions (by setting a cap on total allowances, which could be tightened over time) in an economically efficient, fiscally progressive (low income households tend to emit less therefore could sell surplus allowances), and morally egalitarian manner (all individuals have the same ‘right to emit’).¹

¹ Roberts, S. and Thumim, J. (2006). *A rough guide to individual carbon trading. The ideas, the issues and the next steps*. Report to Defra

Personal carbon allowances (PCA) – supported by personal carbon trading (PCT) - is a concept whereby individuals are allocated an allowance to “emit” carbon emissions and can trade these with other individuals (see Box 1). The analysis undertaken here builds on previous work by CSE that has explored the distributional impacts of a system of PCA covering household fuels only². This previous research, completed on behalf of Defra in 2008, explored the likely distributional impacts of a UK-based personal carbon allowance system, whereby allowances are allocated to all adults on an equal basis. This used estimates of household emissions from the consumption of energy in the home and petrol and diesel, derived from Expenditure and Food Survey data (EFS, 2003 - 2006). The analysis showed that on average personal carbon allowances offer a progressive approach to capping emissions and enforcing reductions. This is because of the distribution of emissions (higher income households emit the most) and the tradable quota system integral to a PCT system: households that emit less than their allowance can sell off their surplus permits, whilst households with emissions that exceed their allowance have the choice of either reducing emissions or purchasing additional allowances. However, despite the overall progressiveness of an equal per adult carbon allowance allocation system, the previous study by CSE showed a number of negative impacts, with particular implications for households with children.

Further research by CSE (on behalf of the Institute for Public Policy Research (IPPR)) in 2009³ explored the potential for moderating these apparent negative impacts of a personal carbon allowance system. This included the allocation of a proportion of an allowance to all children. The analysis showed that allocating children 1/3 of an allowance would minimise the disproportionate effects, and represent a reasonable compromise between allocating children a full allowance, and allocating them no allowances at all.

Research by Gough et al (2011⁴) considers the relative contribution of the number and ages of children in a household to household emissions. Utilising the income equivalisation scale, the analysis suggests that children over the age of 14 should be entitled to a carbon allowance equal to all adults and children under 14 allocated 30% of the adult allowance. However, when also considering the impact of ‘economies of scale’ achieved by larger households, the authors propose a ‘middle-ground’ of a 50% allowance allocation to all children⁵.

The studies discussed above considered the impacts of a PCT system incorporating emissions from the consumption of household fuels. Whilst the research by CSE also included petrol and diesel (derived from EFS expenditure data on these fuels), emissions from travel have been largely excluded from analysis of PCT to date. Furthermore, with the previous modelling undertaken on the EFS, there was no scope to analyse the impacts of PCT alongside potential for households to reduce their emissions, through the installation of measures (e.g. insulating their home, installing micro-renewables etc). A key question remaining in the context of PCT therefore relates to the extent to which those households that appear to lose out under a PCT system could in fact reduce their

² CSE, on behalf of Defra, March 2008, *‘Distributional Impacts of PCT’*.

³ CSE, 2009. *Moderating the distributional impacts of personal carbon trading*. Report to the Institute for Public Policy Research, August 2009.

http://www.cse.org.uk/downloads/file/Moderating_the_distributional_impacts_of_PCT_aug09.pdf

⁴ Gough, I., Abdallah, S., Johnson, V., Ryan-Collins, J., and Smith, C. (2011). The distribution of total greenhouse gas emissions by households in the UK and some implications for social policy. CASEpaper/152.

⁵ Taking the EFS definition of a child which is anyone under the age of 18.

household and/or transport emissions by the installation of low cost energy efficiency measures supported by publicly funded investment programmes, or funded by themselves, which is unlikely in low income households.

2 Data and Methods

A detailed report on the methodology applied in developing the dataset used in this study is provided as a separate document⁶. An overview of the methods is provided here.

2.1 Creating the dataset

To understand the distribution of household carbon emissions including personal travel, a dataset is needed to represent CO₂ emissions from the consumption of energy in the home, private road transport, public transport⁷, and aviation at the household level.

The information exists within, or is derivable from, a number of different survey datasets, representative of either the UK or Great Britain households (Table 2.1). Using data contained within each of the surveys, methods were developed to derive carbon emissions estimates. Using multiple imputation techniques, the resulting emissions estimates were then imputed from each of the source surveys to the EFS for Phase 1 of the project and the EHCS for Phase 2 of the project (see Figure 2.1). The main project report and separate Technical Report provide full details about the methods applied in developing these final datasets used in the analysis.

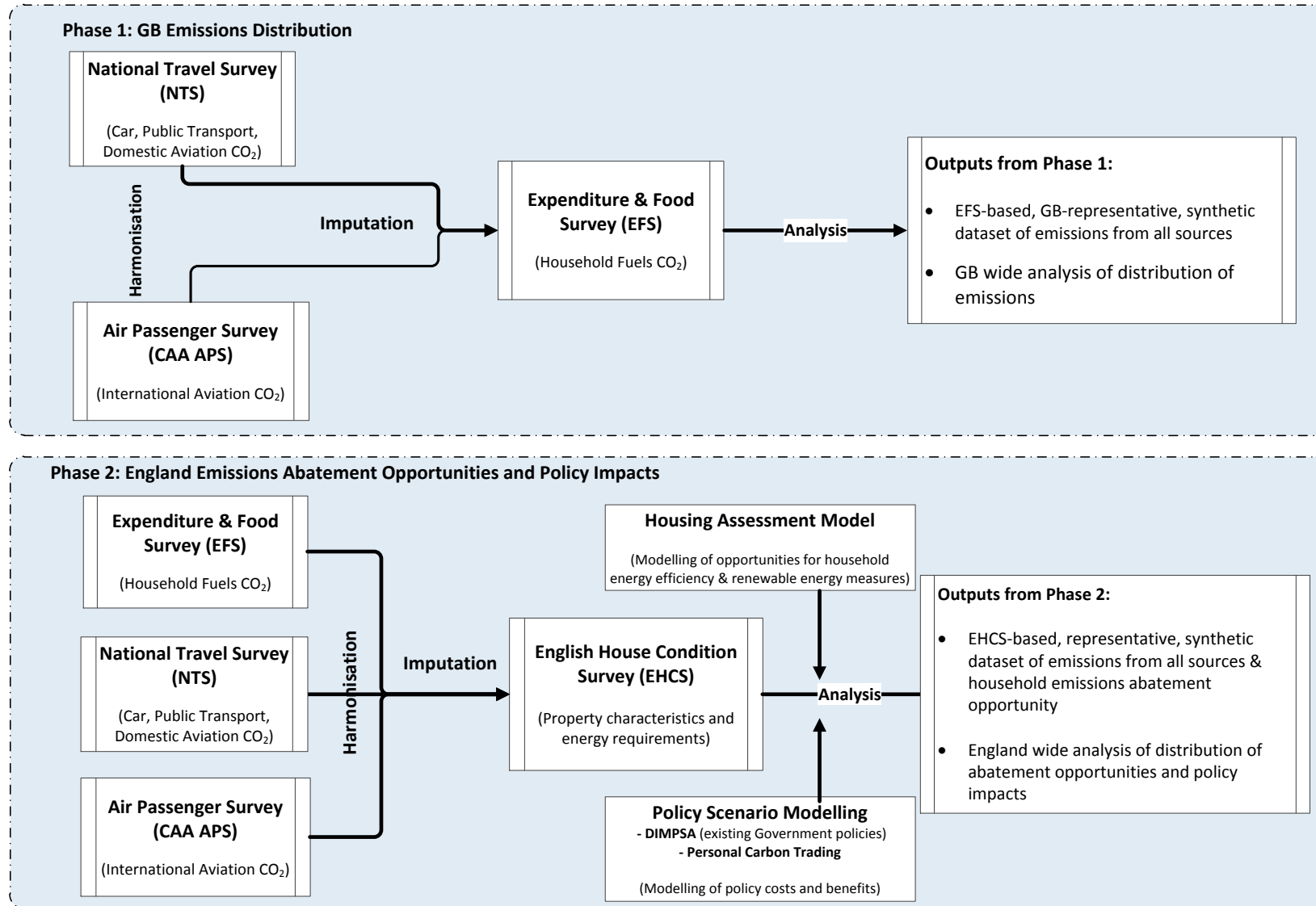
Table 2.1. Summary of surveys used to derive emissions estimates

Survey	Input (raw survey data)	Output
Expenditure and Food Survey (EFS)	Expenditure on all household fuels	Annual consumption of all household fuels (kWh) and associated CO ₂ emissions (kgCO ₂) for GB households.
National Travel Survey (NTS)	Private vehicle mileage Distance travelled - public transport Distance travelled - domestic flights	Annual CO ₂ emissions from all personal (non-business) travel by private vehicle, public transport and domestic aviation for GB households.
CAA Air Passenger Survey (APS)	Start airport, destination airport (international only) and flight class for all GB leisure passengers	Distance travelled and associated CO ₂ emissions from (non-business) international aviation for GB households.
English House Condition Survey (EHCS)	Physical property characteristics needed to assess the thermal performance and energy requirements of a dwelling.	Estimates of household energy requirements and associated carbon emissions and costs – and therefore fuel poverty status – for households in England.

⁶ Technical Report: Developing the datasets. Available at www.cse.org.uk/projects/view/1206

⁷ This includes: buses, coaches, surface rail, light rail, underground, taxis and ferries.

Figure 2.1. Methodological approach



The EHCS-based dataset, created under Phase 2 of the project is used in the analysis presented in this paper. This dataset includes imputed data on emissions from the use of energy in the home and personal travel (Table 2.2), alongside detailed data on physical household characteristics as provided by the EHCS. This dataset was preferential for the purpose of policy scenario modelling as it provides the detailed information on physical household characteristics therefore offering a new avenue to explore the potential for households to avoid the distributional impacts of personal carbon allowances by improving the energy efficiency of their home.

Table 2.2. Variables imputed to the EHCS dataset

Variables imputed from the NTS: • CO₂ Public transport - commute • CO₂ Public transport – leisure • CO₂ Private vehicle – commute • CO₂ Private vehicle – leisure • CO₂ Domestic aviation • Number of cars/vans
Variables imputed from the APS: • CO₂ International aviation (non-business) • A variable to flag non-flying households • Number of short haul flights to Europe in past year • Number of long haul flights further than Europe in past year
Variables imputed from EFS: • CO₂ from Heat Load • CO₂ from Power Load
⇒ England dataset of emissions from all direct sources + housing condition data

2.2 The ‘final’ dataset

The methodology developed and applied in this study was designed with the specific aim of creating a dataset representative of household carbon emissions in England. Some key statistics describing the final dataset used in the analysis in this paper are shown below.

Table 2.3 shows the number of households represented in the dataset (the ‘weighted count’); sum total of emissions across all households in the dataset (i.e. representing the population of England); and average (per household) estimates of carbon emissions.

It should be noted that no attempt has been made to reconcile the emissions estimates derived from survey data with national figures. The two differ significantly in methodological approach (‘bottom-up’ versus ‘top-down’); design purpose and population they represent.

Table 2.4 shows the average and range⁸ of incomes in each disposable income decile for the dataset. These are shown for reference, as this paper presents results by different income groups.

⁸ Under-reporting of incomes is a key issue in both the EFS and EHCS survey data, as indicated by the maximum values shown.

Table 2.3. Household emissions estimates in the imputed EHCS DATASET (England, 2006-07)

	Sum (MtCO ₂)	Mean (kgCO ₂)
Household fuels total	111	5,190
Private car total	57	2,657
Public transport total	6.6	307
Domestic aviation	0.4	17
International aviation	24	1,124
Total emissions	199	9,296
Weighted count of households ('000s)^a	21,380	

^a Annual survey weight adjusted to allow for multiple years in the dataset.

Table 2.4. Income deciles in the imputed EHCS Dataset (England, 2006/07)

Income decile	Count of Households ('000s)	Disposable annual income		
		N %	Mean	Range
1	2,138	10%	£6,130	£2,366 - £7,955
2	2,138	10%	£9,231	£7,956 - £10,556
3	2,137	10%	£11,915	£10,557 - £13,420
4	2,139	10%	£14,998	£13,421 - £16,758
5	2,138	10%	£18,416	£16,759 - £20,152
6	2,138	10%	£22,093	£20,153 - £24,169
7	2,138	10%	£26,302	£24,170 - £28,739
8	2,137	10%	£31,727	£28,740 - £35,270
9	2,139	10%	£40,096	£35,271 - £46,348
10	2,137	10%	£70,508	£46,349 - £359,578
Total	21,380	100%	£25,141	

2.3 Modelling Personal Carbon Allowances

The approach to modelling personal carbon allowances adopted in this study applies an equal per adult allowance allocation, with a 50% allowance for all children⁹ (as recommended by Gough et al, 2011). Allowances are allocated on this basis, setting the 'cap' on total emissions at the dataset baseline level. The average annual total carbon emissions per adult, as derived from our dataset of households in England, equates to some 5tCO₂ per year. The personal carbon allowance allocated to all adults in the dataset is however slightly lower than this to allow for some proportion being allocated to children, as shown below (Table 2.5).

Table 2.5. Personal carbon allowance allocation (based on total household emissions from actual energy use in the home and all personal travel, as derived from the EHCS (England, 2007) imputed dataset)

	Count (millions of people)	Allowance (tCO ₂ /yr)
per adult	39.8	4.336
per child	12.1	2.168

⁹ Defined here as aged 16 and under.

3 Results

3.1 Headline results: who wins and loses under PCA

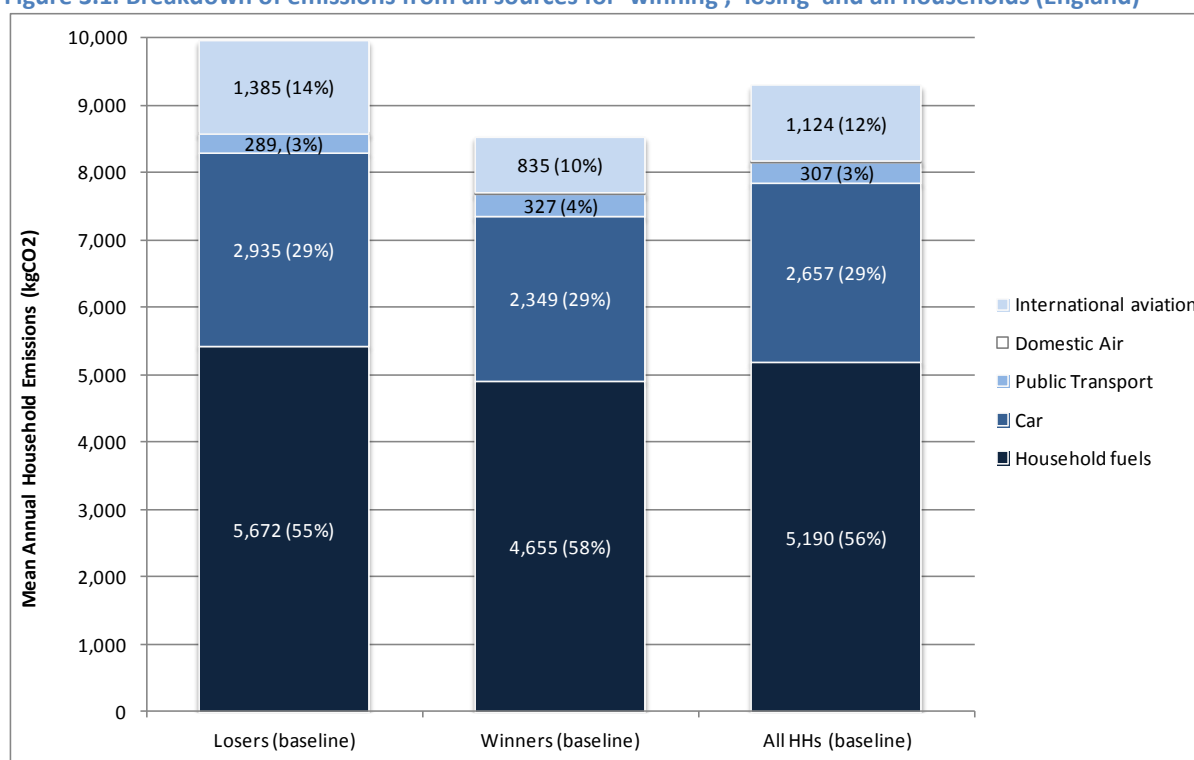
For just under half of all households, the allowance allocated under the personal carbon allowances system modelled here sufficiently covers their total annual emissions from all sources (considered ‘winners’ - Table 3.1). The average deficit for households that do not have sufficient allowances (‘losing’ households) is just under 2.5tCO₂ (2,461 kgCO₂).

Not surprisingly, households that have a surplus of allowances have more adults and children on average (2.2 adults and 0.9 children per household compared to the dataset average of 1.9 and 0.6 respectively). Whilst winning households have lower than average total emissions, there is little variation in the proportional make-up of emissions between winning and losing groups (Figure 3.1, percentages shown in brackets).

Table 3.1. ‘Winning’ and ‘losing’ households under an equal per adult personal carbon allowance system (England)

	Losers	Winners	All HHs
Count	11,389,412	9,990,665	21,380,077
Percentage	53%	47%	100%
Mean annual net loss/gain (tCO₂)	-2.461	2.806	0
Mean annual total emissions (tCO₂)	9.962	8.535	9.296
Mean no. adults per HH	1.6	2.2	1.9
Mean no. children per HH	0.2	0.9	0.6

Figure 3.1. Breakdown of emissions from all sources for ‘winning’, ‘losing’ and all households (England)

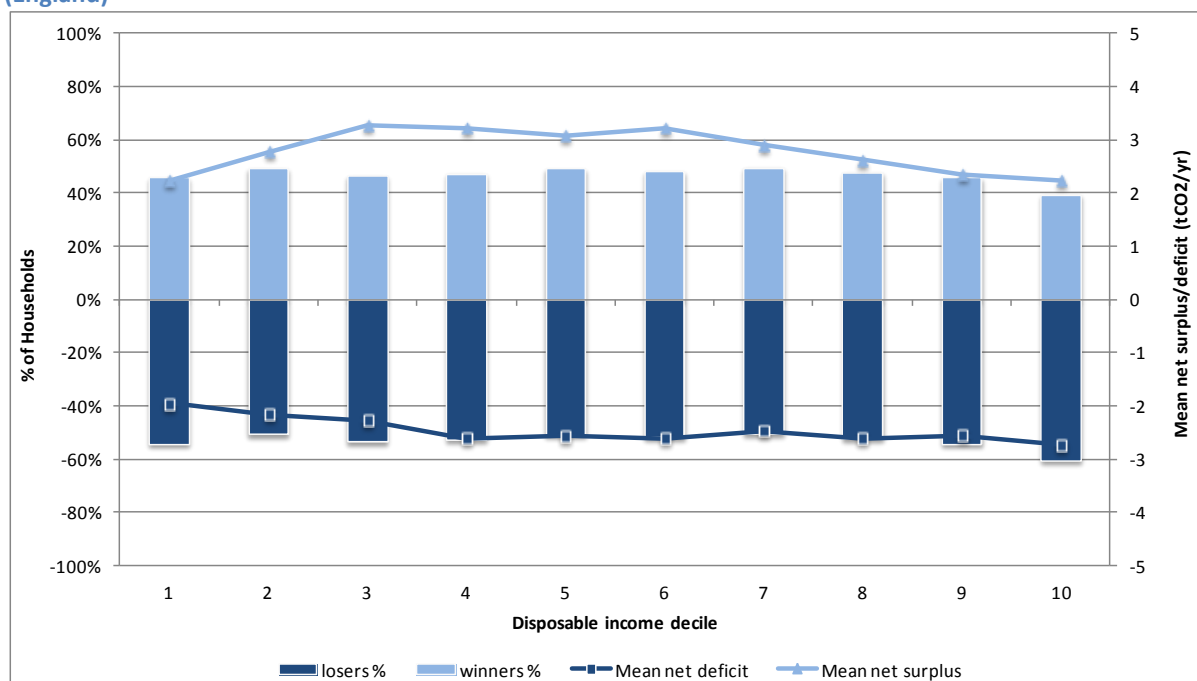


3.2 Distributional impacts of PCA

There will be a number of factors – in addition to simply the number of people in the household – that will be influencing whether a household appears as a ‘winner’ or ‘loser’ under a personal carbon trading system. The proportion of households classed as winning and losing, and their mean annual allowance surplus/deficit, is examined below, considering some key socio-demographic variables, where the bars correspond with the left hand axis to show the proportion of winning and losing households in each category and the lines correspond with the right hand axis to show the mean surplus/deficit of winning/losing households in each category.

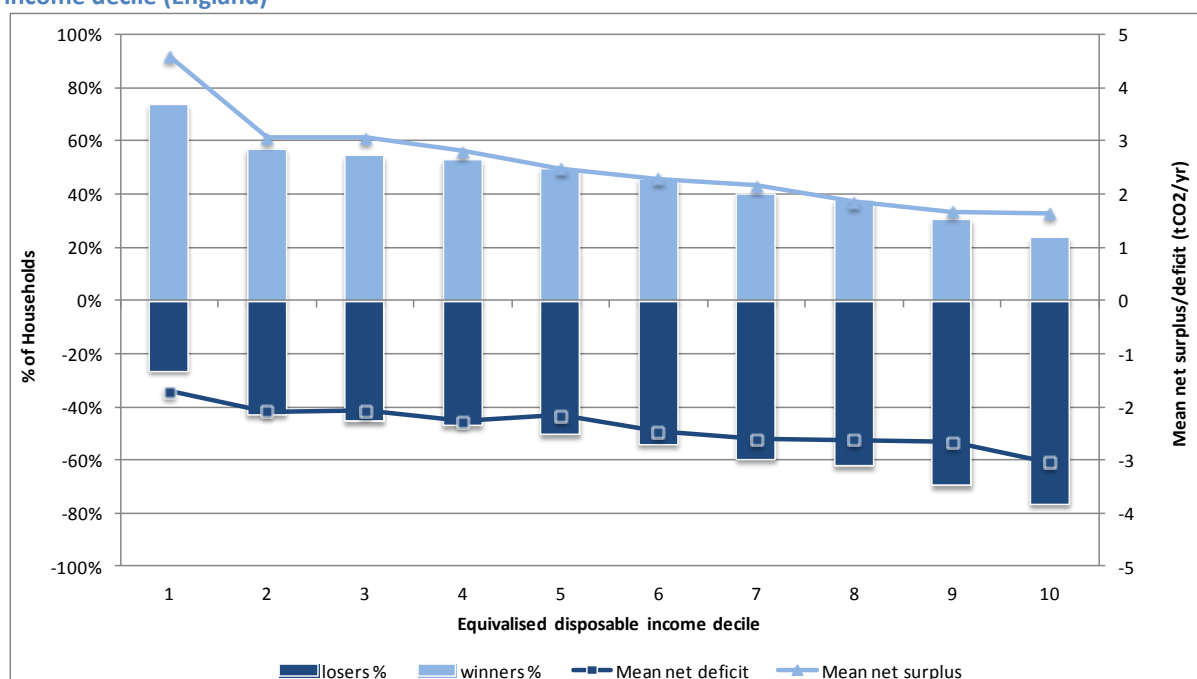
The pattern across income deciles appears quite different, depending on whether or not incomes are equivalised (adjusted to allow for the number of adults and children in the home). The pattern for disposable income is shown in Figure 3.2 whereas the equivalised income decile patterns are shown in Figure 3.3. There is a more direct pattern of the allowance allocation system modelled (half an allowance per child) when the equivalised income is taken into account as the number of people in the household is taken into account¹⁰. However, on the whole the system appears broadly progressive: 46% of the poorest 10% of households (non-equivalised income) are ‘winning’ compared to 39% of the richest 10%; of those in the lowest income group who do experience a deficit, this is lower in absolute terms compared to the deficit experienced by the highest income group.

Figure 3.2. Proportion and mean surplus/deficit of winning & losing households by disposable income decile (England)



¹⁰ See: Gough, I., Abdallah, S., Johnson, V., Ryan-Collins, J. and Smith, C. (2011). The distribution of total greenhouse gas emissions by households in the UK and some implications for social policy. Case Paper/152.

Figure 3.3. Proportion and mean surplus/deficit of winning & losing households by equivalised disposable income decile (England)



Analysis by other socio-demographic variables suggests that under the allowance allocation system modelled here (equal allocation to all adults, half an allowance to all children) household types that are more likely to experience a deficit of personal carbon allowances include: households in rural areas (Figure 3.4); detached properties (Figure 3.5); non-mains gas heated dwellings (Figure 3.6); households in which the HRP is aged between 55 and 70 (Figure 3.7); and single adults without children (Figure 3.8). These findings are highly consistent with the results of previous modelling of a personal carbon trading system. For example, in exploring the potential to moderate the distributional impacts of an equal per adult allocation system the following variables were identified (in addition to number of children) as significant: rurality, age of HRP, built form and central heating type¹¹. This previous analysis however only included emissions related to the consumption of household fuels and private vehicle fuel (petrol and diesel), whilst the analysis below shows the distributional impacts when all sources (i.e. with public transport and aviation) are included.

¹¹ White, V. and Thumim, J. (2009). *Moderating the distributional impacts of personal carbon trading*. Report to the Institute for Public Policy Research.

Figure 3.4. Proportion and mean surplus/deficit of winnings & losing households by settlement type (England)

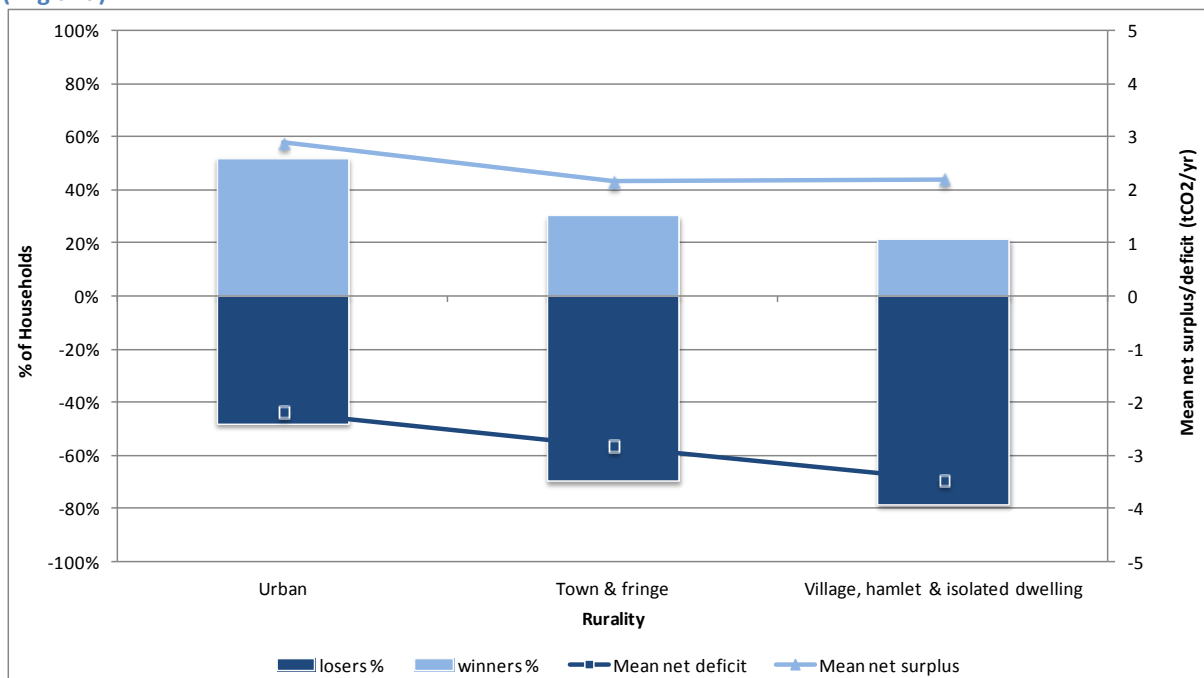


Figure 3.5. Proportion and mean surplus/deficit of winning & losing households by dwelling type (England)

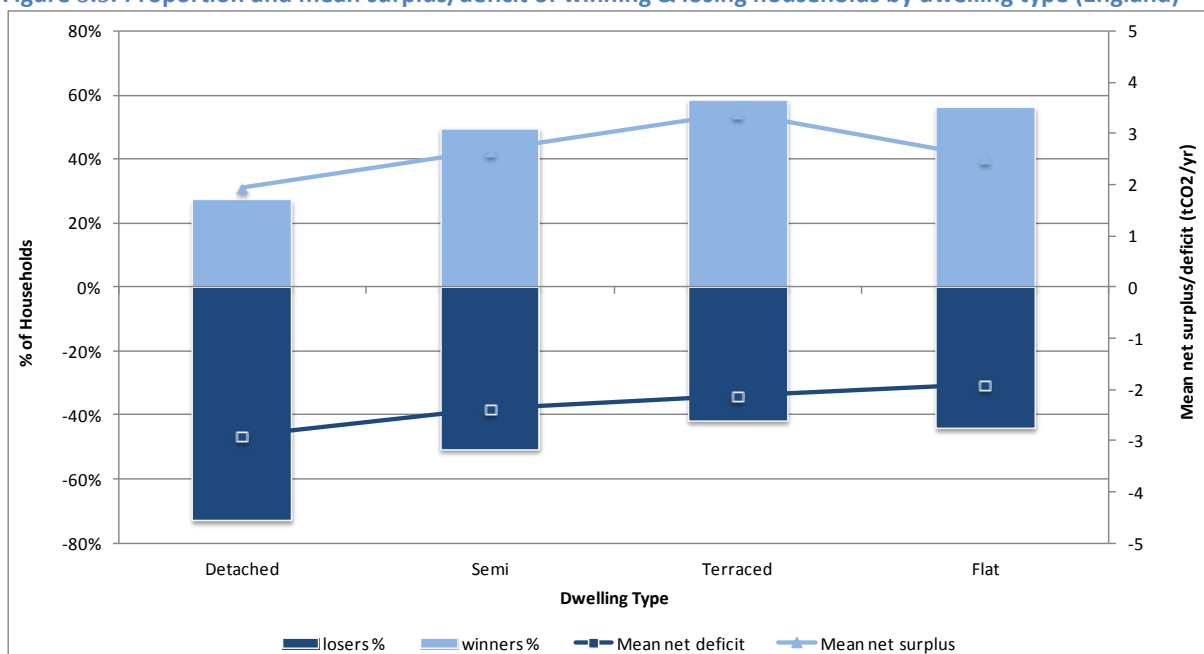


Figure 3.6. Proportion and mean surplus/deficit of winning & losing households by heating fuel (England)

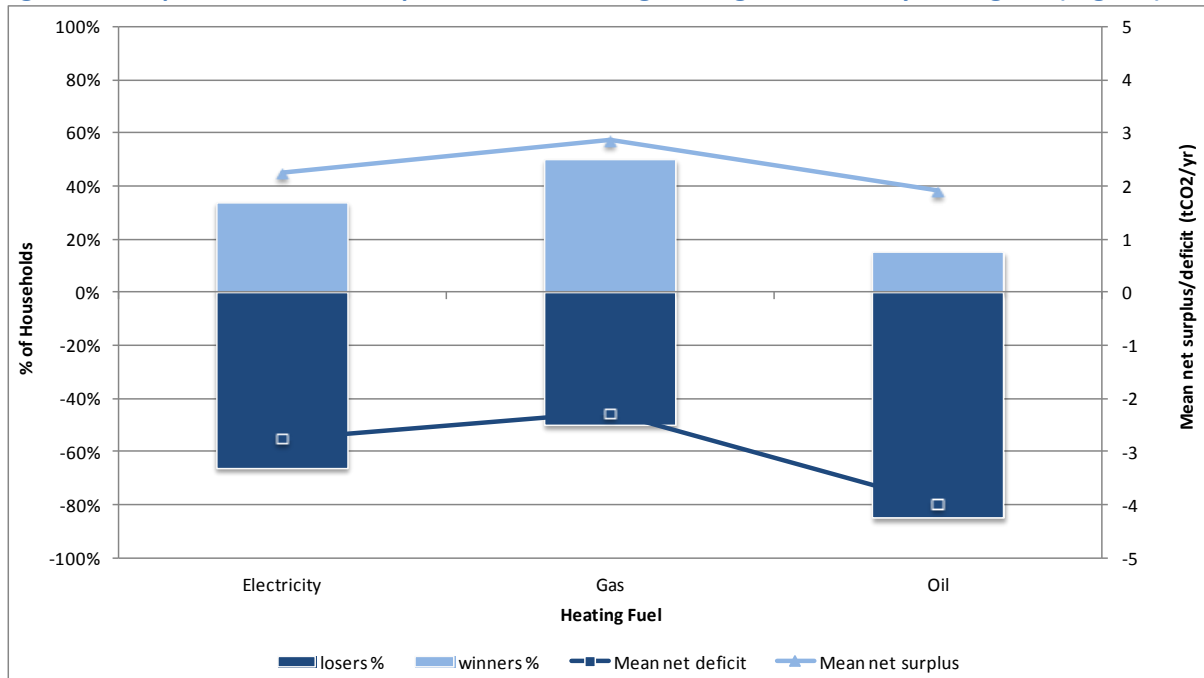


Figure 3.7. Proportion and mean surplus/deficit of winning and losing households by age of HRP (England)

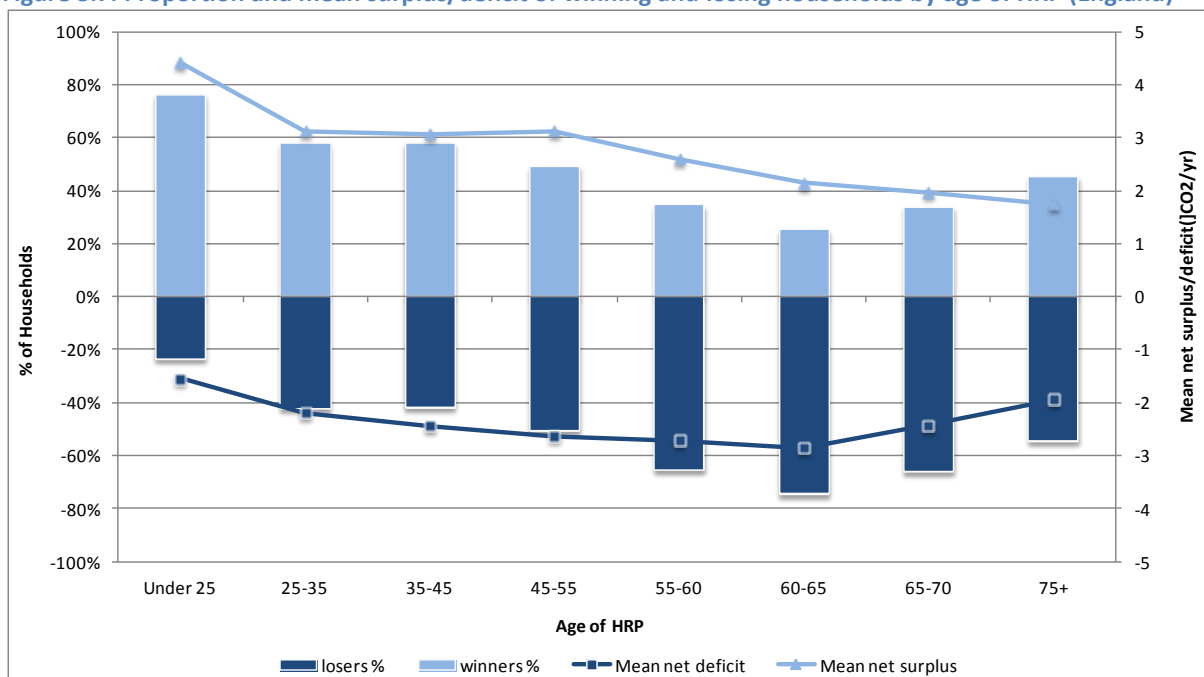
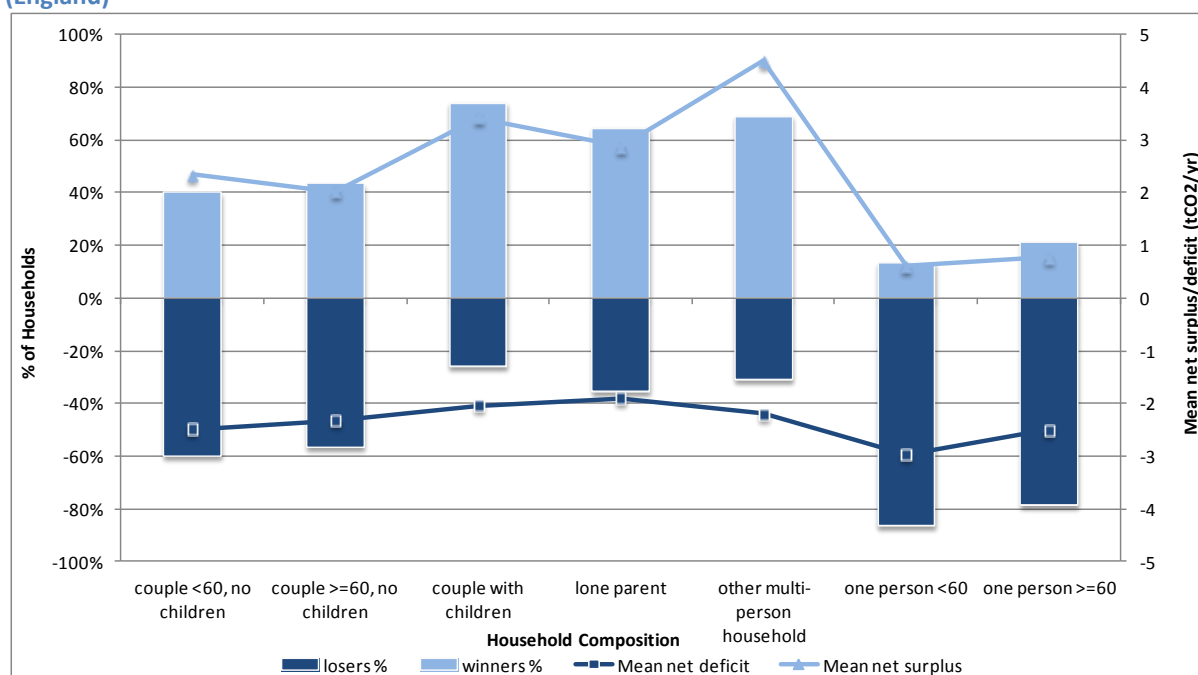


Figure 3.8. Proportion and mean surplus/deficit of winning and losing households by household composition (England)



3.3 Who could avoid 'losing'?

3.3.1 Approach

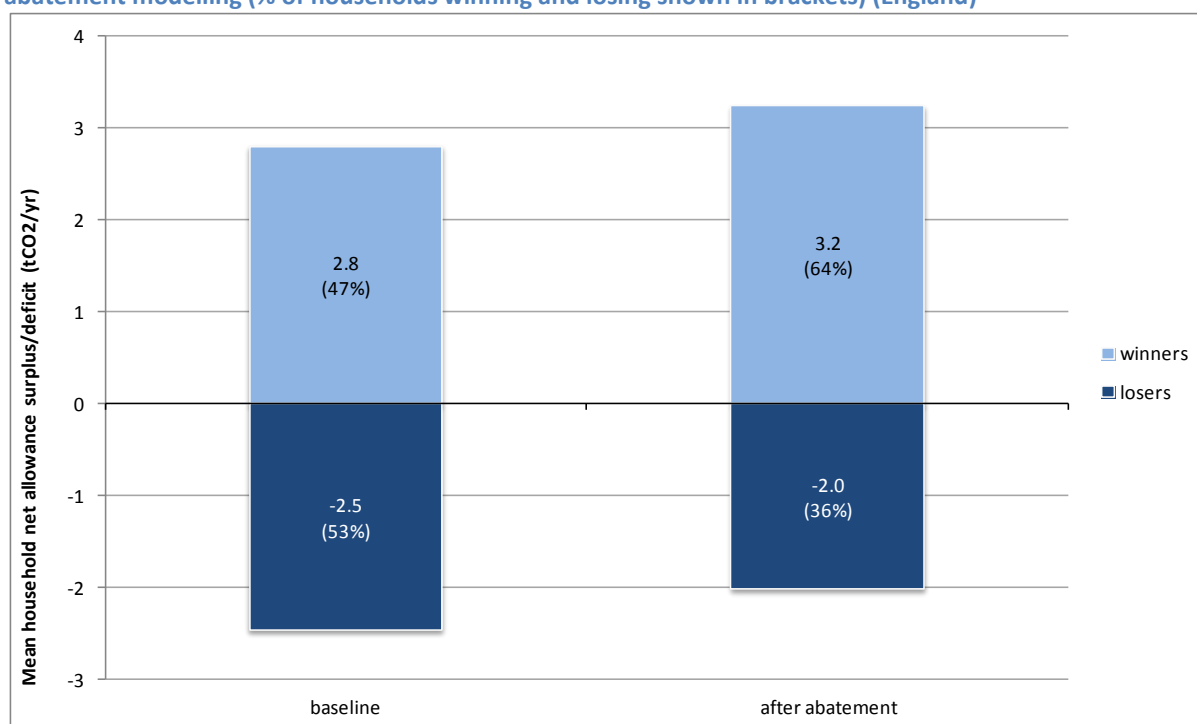
As shown above, based on the dataset 'baseline' emission levels, some 53% of households have insufficient allowances under the carbon allowance system modelled (i.e. their current emissions exceed their allowance allocation, Table 3.1 and shown again below in **Error! Reference source not found.**Figure 3.9). In the absence of moderating the allowance allocation system to compensate for certain factors (as discussed above and has been analysed in previous research¹²), these households face two options: (1) purchase additional allowances to cover their full emissions; or (2) reduce their emissions to within their capped allowance.

For households with sufficient income, the former option may be preferable in order to maintain the lifestyle to which they are accustomed. The second option could be achieved by simple lifestyle changes (regardless of disposable income levels) both in the home (e.g. ensuring appliances are not left on standby) and in travelling practices (e.g. choosing not to fly).

Alternatively (or indeed in addition) households could chose to invest in measures – energy efficiency and/or renewable energy – to reduce household energy demand and emissions, thereby mitigating the impact of a PCT system. CSE's Housing Assessment Model provides scope to explore the potential for this, as described in Box 2 below.

¹² White, V. and Thumim, J. (2009). Moderating the distributional impacts of personal carbon trading. Report to the Institute for Public Policy Research, August 2009.

Figure 3.9. Mean surplus/deficit in allowances of winning and losing households at baseline levels and after abatement modelling (% of households winning and losing shown in brackets) (England)



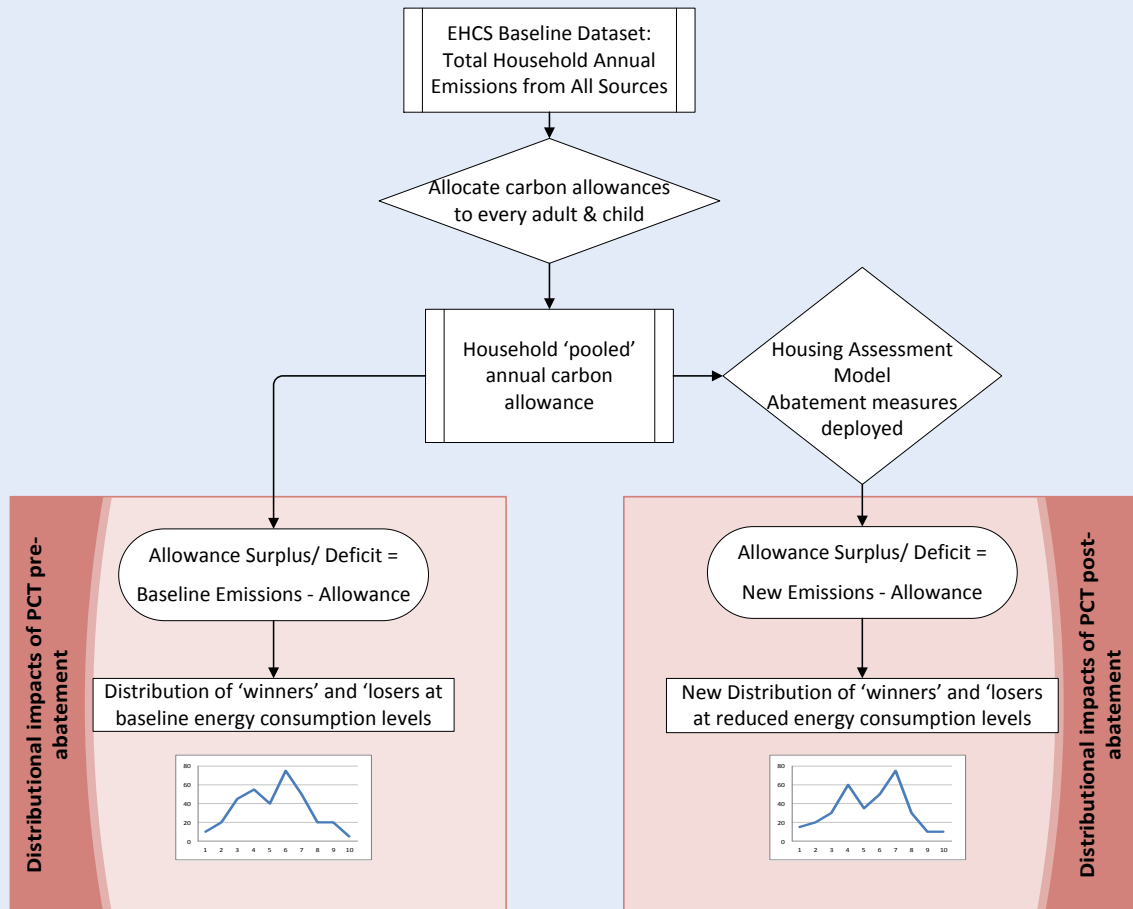
Box 2. Avoiding the impact of PCA: Opportunities to reduce household emissions

Summary of approach

The Housing Assessment Model identifies which households could install (cost-effective) measures to reduce their emissions, and - crucially for this element of the analysis - by how much. The results of the HAM give a new estimate of household emissions resulting from energy consumed in the home. Combining this new value with the estimates of household emissions from personal travel (i.e. the data imputed to the EHCS dataset for private vehicle travel, public transport, and aviation) gives a new 'total emissions' for every case (household) in the dataset. (NB For any household that is not identified as suitable for any energy efficiency/renewable energy measures, this new value will be the same as the baseline).

This new estimate of household emissions post-abatement can be compared with (subtracted from) the total household carbon allowance to give a new distribution of allowance surplus/deficit and winners and losers. This analysis will help in understanding which households may at first be worse off under a PCT system, but could avoid this impact by installing cost-effective measures. An example would be simple energy efficiency measures which would reduce the amount of fuel needed to heat a household and therefore reduce the amount of carbon emitted. The process for this stage of the analysis is illustrated below.

Modelling Personal Carbon Allowances & the impact of deploying cost-effective household energy efficiency measures



3.3.2 Headline results

As we saw previously, for some 10 million households – just fewer than 50% of all households in England – the carbon allowance allocated under the system modelled here is sufficient to cover their annual household emissions at baseline levels (Table 3.1, p.9).

However, this leaves some 11.4 million households with a deficit of allowances. Deploying measures identified in the Housing Assessment Modelling and comparing the resulting new emissions levels with the carbon allowance (as described above), suggests that some 64% of households in England now experience a surplus of allowances. This represents some 3.6 million households that have been “lifted out” of deficit purely as a result of reducing their household emissions through the installation of key energy efficiency and renewable energy measures. This is at an average cost per household of around £5,000.

Not only are a greater number of households now ‘winning’, but those households that do still experience a deficit do so at a lower average rate (just over 2tCO₂ per year compared to 2.5tCO₂ at baseline levels, Table 3.2). The lower the deficit experienced, the easier (in theory at least) it should be for a household to manage: households can either purchase additional allowances to make up

this deficit or undertake simple behavioural changes (e.g. driving less, turning appliances off) to reduce their emissions.

However, it should be noted that these results are based on the allocation of allowances derived from an emissions cap set at the (dataset) baseline levels (i.e. the sum total of allowances equates to 198.7bn tCO₂). A PCT system would need to review the allowance allocation regularly to reflect changes in household emissions levels and to ensure emissions are reduced overall over time and the system balances (for example, the average surplus/deficit across all households should be zero, as it is at the baseline allocation; when the impact of abatement measures are taken into account, the average surplus/deficit increases to over 1.3tCO₂. The allowance allocation would therefore need to be reduced to reflect this change).

Table 3.2. Winners and losers under the PCT system after HAM abatement measures are applied (where losers have a deficit of allowances and winners a surplus) (England)

	Losers	Winners	All HHs
Count of households	7,770,476	13,609,601	21,380,077
% of total population (households)	-36%	64%	100%
Mean household allowance surplus/deficit (tCO₂/yr)	-2.016	3,241	1,331

3.3.3 Distributional impacts of PCT after abatement

The graphs below show the proportion of households in each category who experience a deficit of personal carbon allowances at baseline levels (dark shaded bar) and after the application of abatement measures identified by HAM (pale shaded bar).

The difference between the two (indicated by the dashed line) shows the proportion of households that are “lifted out of deficit” following the application of some key, cost-effective energy efficiency measures identified by HAM. The graphs therefore illustrate both the distribution of losing households and the distribution of households that ‘could avoid losing’ by installing energy efficiency/renewable energy measures (see Box 2).

The results suggest that household energy efficiency and renewable energy measures could prove effective an effective response to PCAs for some 3.6 million households. The average cost to households making these improvements is some £5,000, which is the cost of installing measures such as cavity wall insulation, loft insulation and modern condensing boilers. This could reduce the negative distributional impacts of a personal carbon trading system – i.e. it makes it fairer. For example, the proportion of properties in rural areas; larger dwellings; non-mains gas heated homes; and older person households who lose under the system are notably reduced. However there remains an issue with single adult households, those over 60 being a particular group of concern. These households could potentially be compensated financially (e.g. through the benefits system) to ensure they do not bear a disproportionate impact of a PCT system.

In addition to the household energy efficiency measures, householders could choose to take actions associated with reduced transport emissions. The paper on the distribution of emissions shows that higher emission households emit significantly higher amounts than lower income households. Whilst there is no active policy model for transport, such as HAM, the cost to reducing emissions from

aviation is negligible i.e. there isn't a direct cost. There is an associated cost with alternative leisure activities but that is outside the scope of this study.

Figure 3.10. Proportion of losing households by disposable income decile before and after abatement (England)

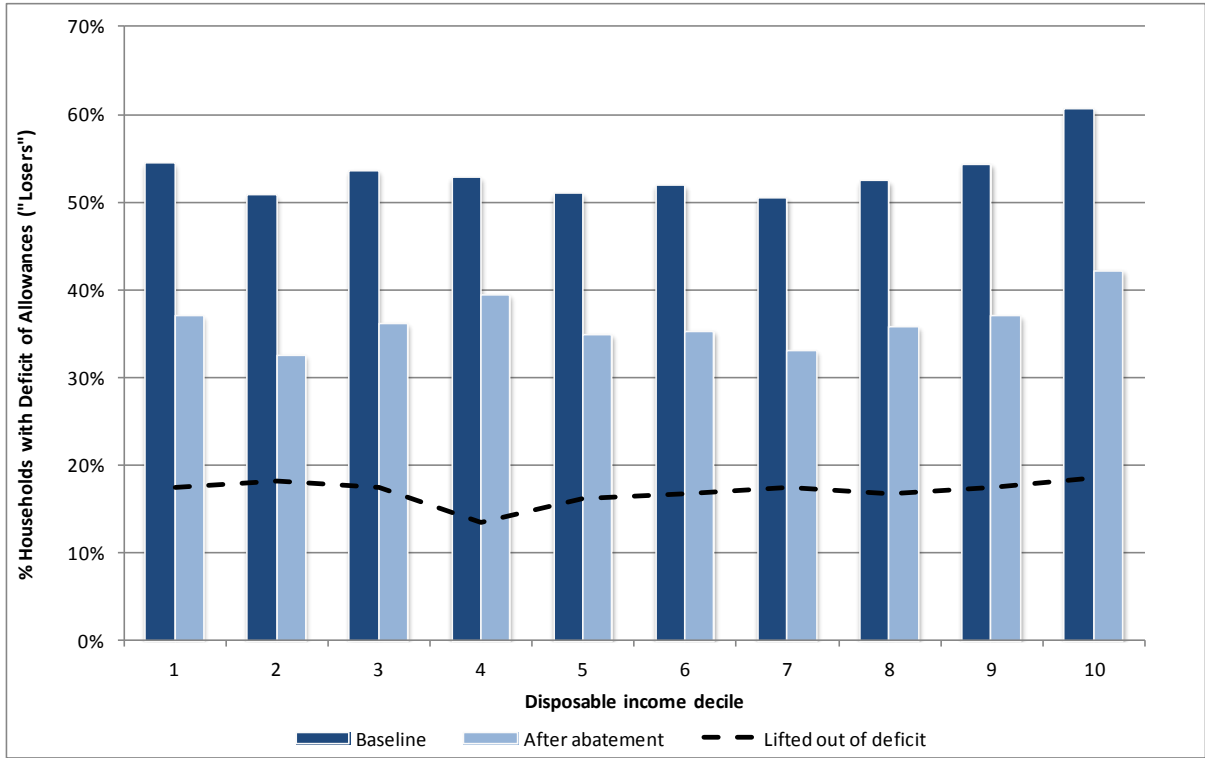


Figure 3.11. Proportion of losing households by settlement type before and after abatement (England)

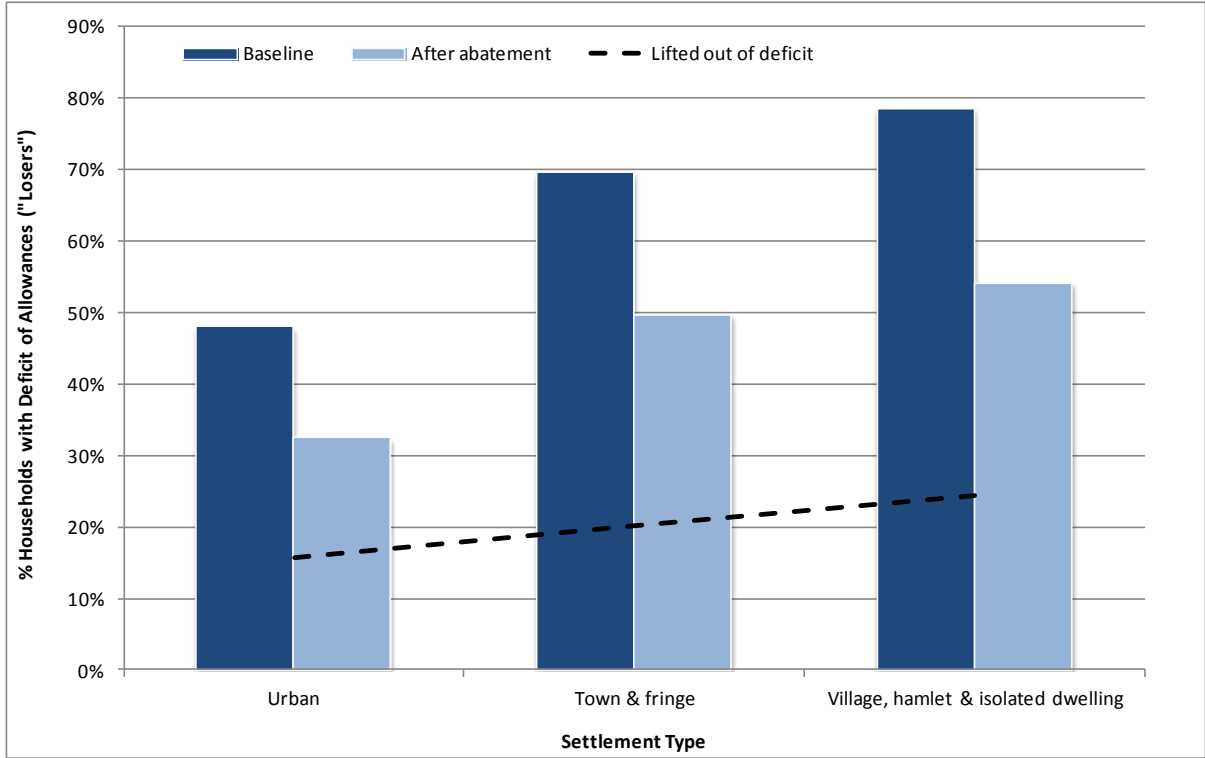


Figure 3.12. Proportion of losing households by dwelling type before and after abatement (England)

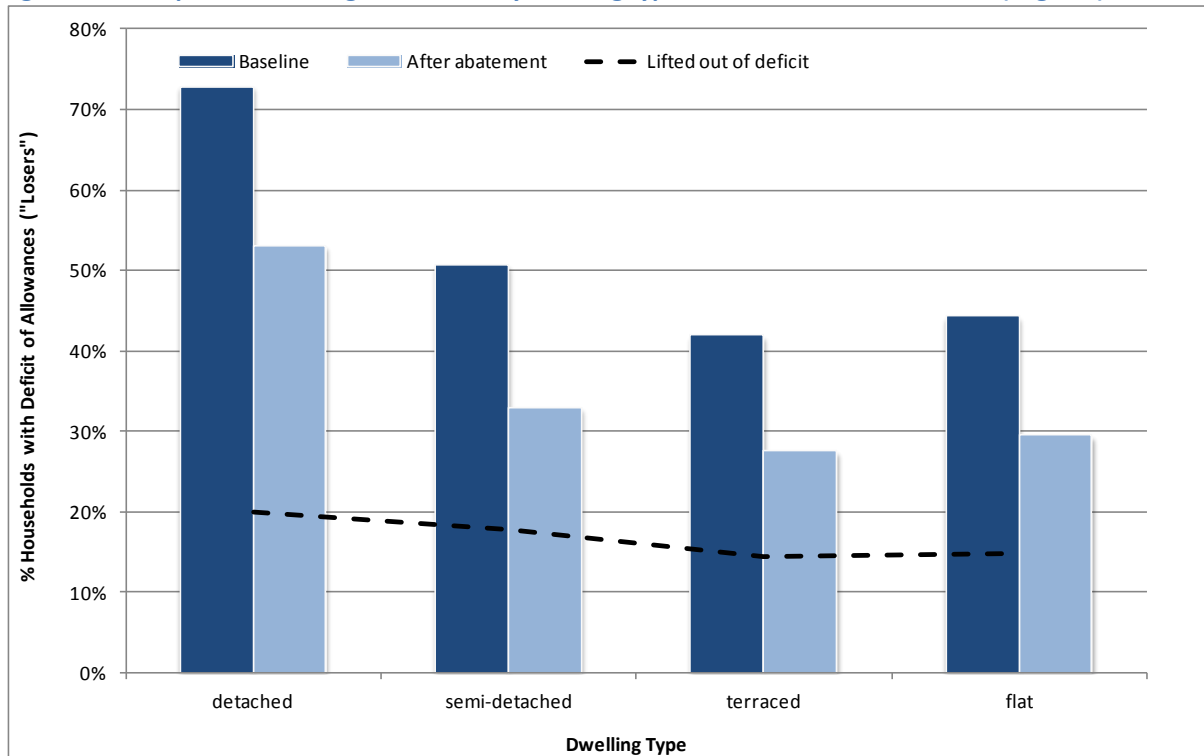


Figure 3.13. Proportion of losing households by heating fuel before and after abatement (England)

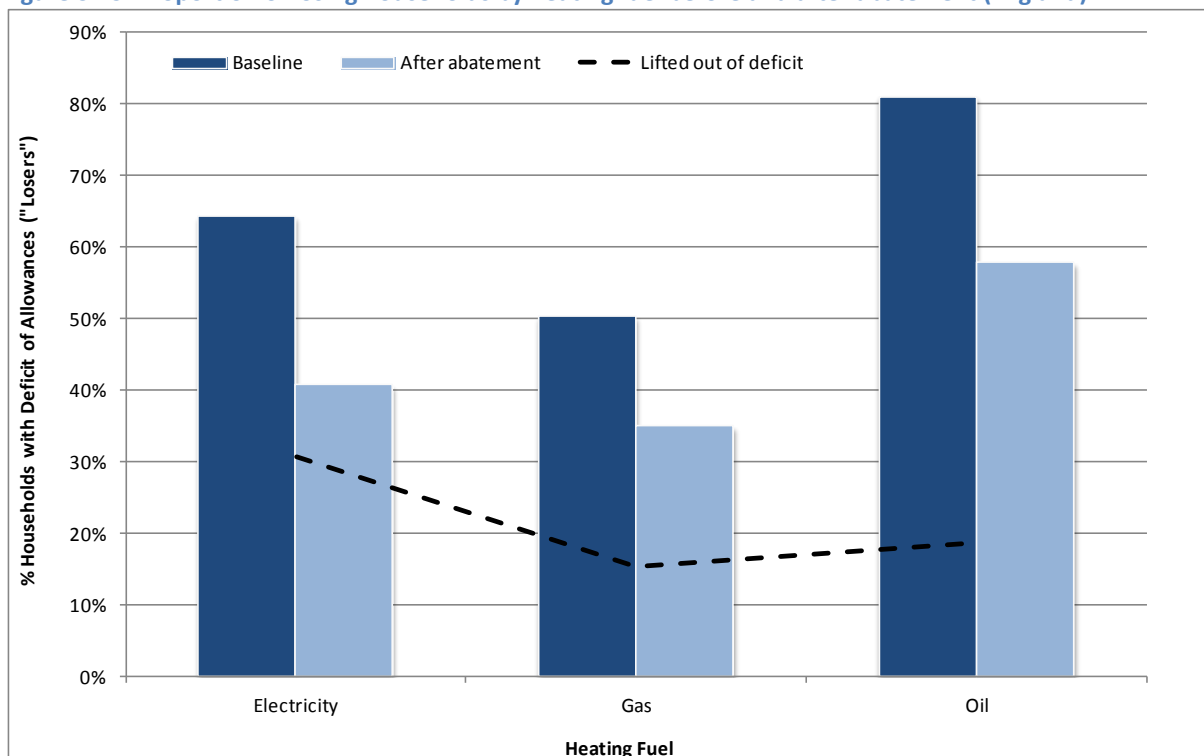


Figure 3.14. Proportion of losing households by age of HRP before and after abatement (England)

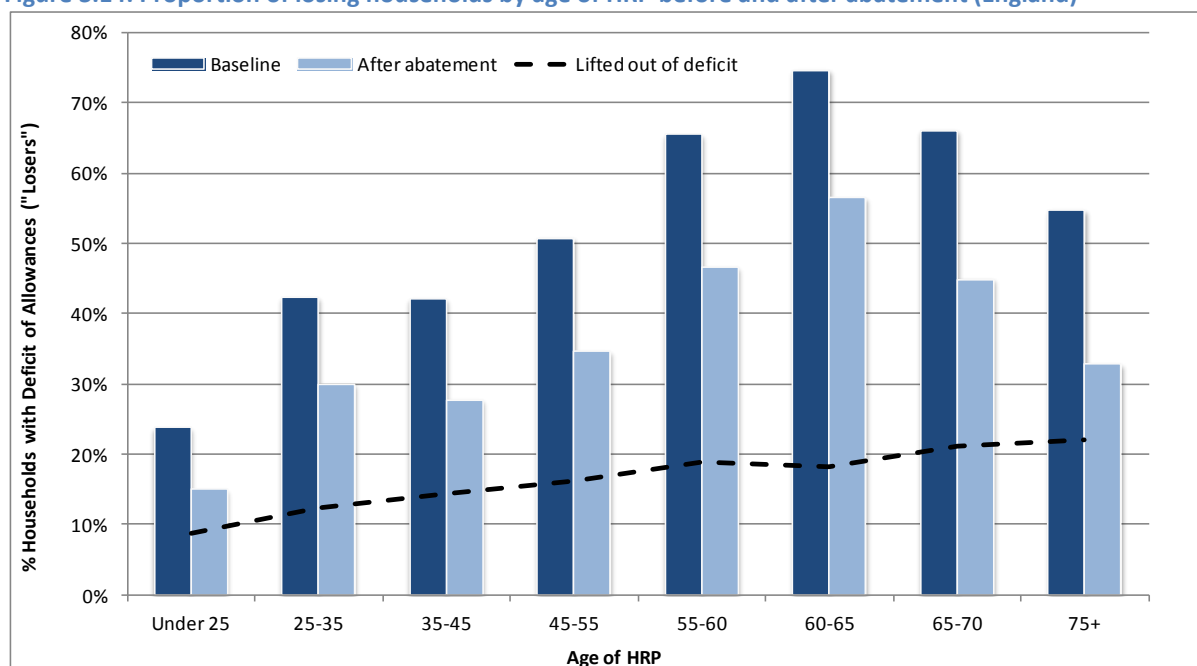
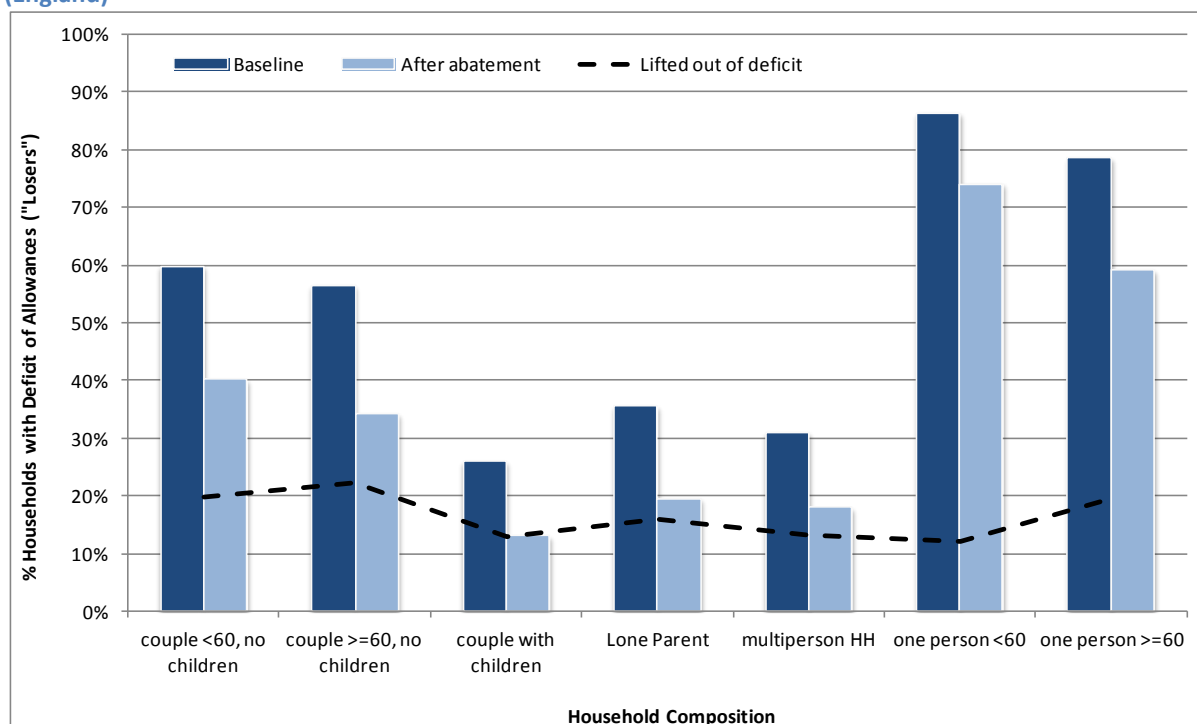


Figure 3.15. Proportion of losing households by household composition before and after abatement (England)



4 Conclusion

The analysis presented here explores the implications of a personal carbon allowance system, whereby all adults are allocated an equal allowance and all children half an allowance. It is assumed that members of the same household pool their allowances to cover all their emissions from energy consumption in the home and travel by private vehicle, public transport and aviation.

At baseline emission levels (2007), just over half of households in England experience a deficit of personal carbon allowances. This deficit can be explained by these households having higher than average baseline emissions overall, and fewer people per dwelling. On average, losing households have higher emissions from aviation and slightly lower emissions from the consumption of energy in the home. Being smaller households (in terms of number of people) there is less opportunity to benefit from the economies of scale achieved by larger households¹³.

By allocating allowances considering equivalised household income, the distribution of winners and losers across income deciles appears highly progressive. This is due to the difference in composition of households within different income deciles when equivalisation is applied: as shown by Gough et al (2011)¹³, 41% of households in the lowest equivalised income decile have children compared to 15% of the bottom non-equivalised income decile.

A number of factors, in addition to occupancy and income, appear important in determining whether or not a household experiences a deficit of allowances, namely: rurality, size and type of property and heating fuel. This is consistent with the findings of previous work by Thumim et al (2008), who found that the effect of these factors can be reduced by moderating the approach to allocating carbon allowances. However, such an approach poses administrative and feasibility challenges.

The team therefore explored here opportunities for households to mitigate the impact of a PCA system (i.e. avoid or reduce the deficit) by installing cost-effective energy efficiency, heating and renewable energy measures to reduce household energy consumption. The results suggest that this approach could prove effective for some 3.6 million households. The average cost to households making these improvements is some £5,000, which is the cost of installing measures such as cavity wall insulation and loft insulation. This cost is not realistic for the income poor, but may be covered by some government policy such as the Green Deal or Energy Company Obligation (ECO).

What this analysis does not show is the opportunity to reduce emissions by simple lifestyle changes, for example reducing the use of the car or simply choosing not to fly. Analysis of such behavioural change is beyond the scope of this project. However, the datasets developed through this study – which combine household and travel emissions in one dataset – provide new opportunity for research in this area.

¹³ Gough, I., Abdallah, S., Johnson, V., Ryan-Collins, J., and Smith, C. (2011). *The distribution of total greenhouse gas emissions by households in the UK and some implications for social policy*. CASEpaper/152.