Department
of Health &
Social Care

# Technical Consultation Document

## Department of Health and Social Care (DHSC) Calorie Model

August 2018

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- Parents and families
- Charities and non-governmental organisations
- Nutritionists and dietitians
- Educational professionals and organisations
- Local government
- Research organisations
- Industry bodies
- Businesses
- Regulators
- Members of the public

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# 1. Introduction

1. This document provides a detailed description of the rationale and methodology of the DHSC Calorie Model. Its purpose is to outline the modelling process used to estimate the benefits in the consultation Impact Assessments (IAs) listed in the section below.

2. At its simplest, obesity is caused by an imbalance between energy in and energy out. The purpose of the DHSC Calorie Model is to model the long-term benefits (in terms of health outcomes and savings to the NHS and social care costs) of policies aiming to reduce the calorie imbalance at a population level.

3. Whilst it is appreciated that obesity is a complex system with several factors thought to play a role, a quantitative approach considering all these factors would be very difficult to model. The main input to the model is a reduction in calorie imbalance, which comes from the policy being implemented. Hence, a model is necessary which can take the input of a change in calorie imbalance, and turn this into long-term benefits. For this reason, a more simplistic cohort-based model was deemed an appropriate way of modelling the effects of the policies.

# 2. Overview of the DHSC Calorie Model

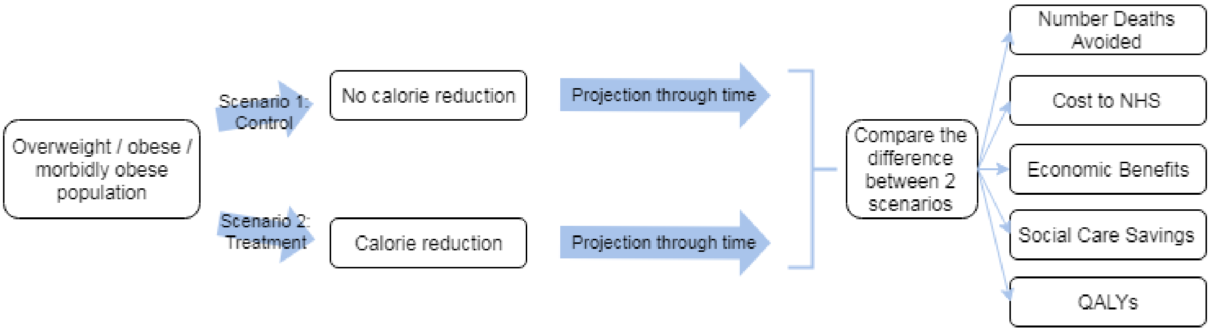
4. The DHSC Calorie Model has been developed to specifically assess the impact of the following consultation IAs:
   - Ending the sale of energy drinks to children IA.
   - Mandating energy labelling of food and drink in out-of-home settings IA (to be published).
   - Restricting price promotions for HFSS foods IA (to be published).
   - Restricting checkout, end-of-aisle, and store entrance sales of HFSS food and drinks IA (to be published).

5. The DHSC Calorie Model is a model implemented in Microsoft Excel. The model uses a yearly iterative approach to estimate the impact of policies on representative examples of the population, i.e. the effects are modelled for every year following the implementation of a reduction in calorie imbalance. The impacts of the calorie reduction are modelled using a control and a treatment scenario: the control scenario is modelled each year assuming no policy implementation, while the treatment scenario models the effects seen by a calorie imbalance reduction (see Figure 1).

## 2.1. Time Horizon

6. The chosen period for assessing the impact of a calorie reduction was 25 years. This decision was a pragmatic one, principally because this is long enough to show significant health benefits from the policies in question. In fact, annual benefits would continue to rise beyond 25 years, so the net present value of these policies would increase further as more years are added to the model. However there is also growing uncertainty as the time increases, so 25 years was considered a reasonable compromise between these opposing factors.

**Figure 1: Two scenarios are generated for each population: a control scenario with no calorie reduction, and a treatment scenario which implements the calorie reduction.**



## 2.2. Including Children

7. Early results from modelling children and adults together and comparing it to modelling adults only showed that, in a 25 year period, the health benefits are predominantly in adulthood. As most impacts on children's health resulting from obesity occur later in life (the exception is diabetes, but this is still significantly less prevalent than adult diabetes: adult diabetes prevalence in the UK is 4%, while childhood diabetes prevalence is 0.1% for type 1 diabetes, and much less for type 2 diabetes [1]), it was decided that, in modelling terms, it was preferable to only include the impact during adulthood. This simplified the model significantly without compromising its quality. While impacts are not modelled in childhood, benefits for today's children are modelled when they become adults.

## 2.3. Cohort Modelling

8. The cohorts consist of adults grouped into two age groups: 19-64 and 65-79 years, and children in two age groups: 4-10 and 11-18 years. Each population contains a male and female group, which are further grouped based on their body mass index (BMI) as overweight (BMI of 25-30), obese (BMI of 30-40), and morbidly obese (BMI of 40+). Each group is assigned the mean weight and height in order to calculate the mean BMI. The BMI groups are justifiable because it has been found that the risk of 5 major conditions (diabetes, coronary heart disease, stroke, colorectal cancer, breast cancer) can be reasonably approximated to being linear with BMI from a BMI level of 22 onwards [2]. This means, even though the distribution of weight loss would vary from individual to individual, the overall benefits would be the same as if all individuals had the same size of benefit. This finding is also of particular importance because it means the health benefits of multiple policies that impact individuals' calorie intakes can be added together. It is assumed that reductions in calorie intake have minimal impact on the health of healthy weight and underweight people and these groups are therefore excluded.

9. The fact that evidence suggests a linear relationship with risks exists from a BMI of 22 upwards is also significant. This justifies the model's consideration of cohorts with a starting BMI of at least 25 when the policy is introduced, as long as their BMI does not reduce below 22. To fall below 22 would require a policy that reduces calorie imbalance by *c.* 320 kcal per day (derived based on evidence from Hall et al. [3]) averaged across all individuals with a BMI of 25. Given evidence suggests people with a BMI of 22-25 would also experience a benefit, the model potentially underestimates the benefits of the policies evaluated.

## 2.4. Age and Timing of Benefits

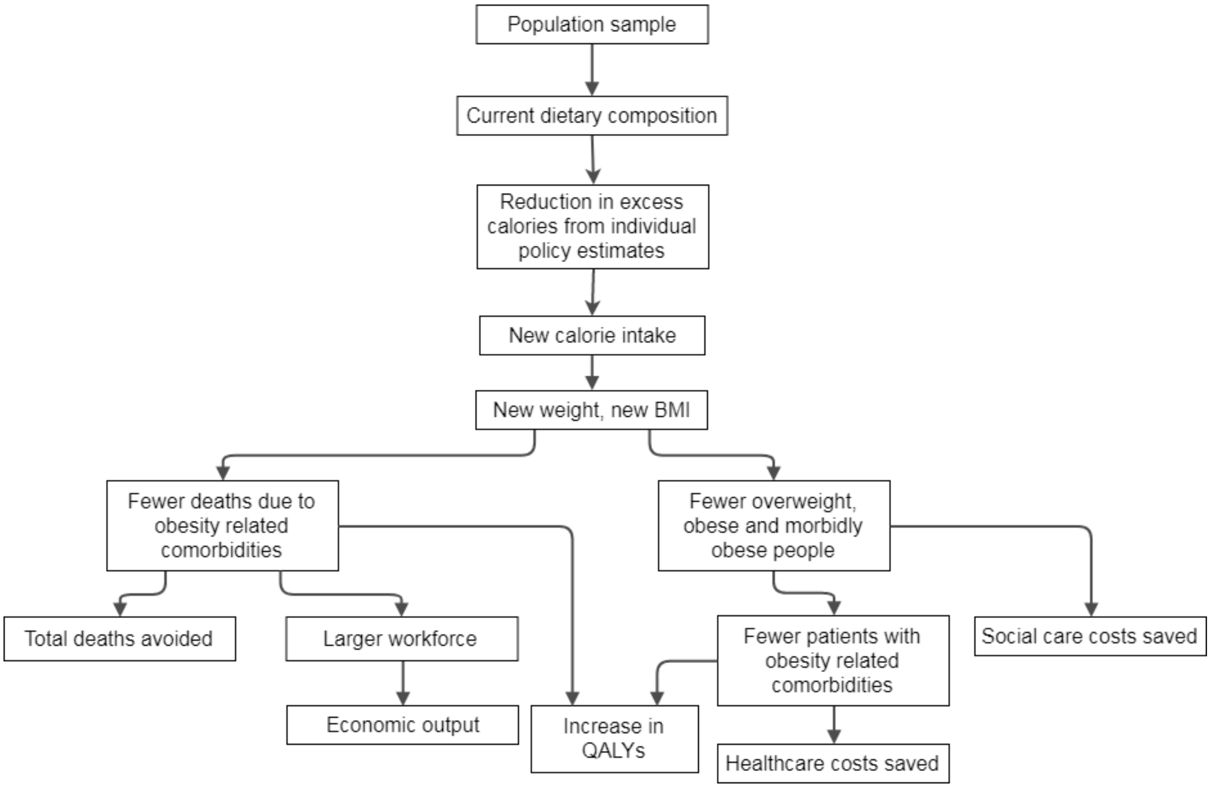
10. For each cohort, the starting age is considered to be the middle age of the group. This does mean that there is a small inaccuracy in the timing of benefits, and this will be addressed in future versions of the model.

# 3. Methodology of the DHSC Calorie Model

## 3.1. Model Structure

11. The structure of the model is displayed in Figure 2. The main inputs to the model are the expected reduction excess daily calorie intakes from the policy, the weight in kg lost per calorie reduction, and the number of years the policy will take to achieve its target, i.e. how many years it will take for populations to start reducing their daily excess calories. The impacts of the model are then considered on various groups over a period of 25 years.

**Figure 2: High level overview of model structure for a scenario of reduced calorie imbalance.**



12. The model begins by considering changes in weight and BMI caused by a reduction in excess calories (this could be through reduced intake of calories via food, or from taking more exercise). This information is then used as a starting point throughout the remainder of the analysis.

13. The model then considers the implications of the calorie reduction policy on 5 diseases associated with obesity: diabetes, coronary heart disease, stroke, colorectal cancer, and breast cancer. The model looks at changes in prevalence and mortality rates of each disease and from this considers how many deaths are

avoided due to the implementation of the policy. The model also considers how much money is saved by the NHS due to the reduced treatment of each illness.

14. Next, the model uses the reduction in mortality to consider how an increased population would have an impact on economic output due to an increase in the size of the workforce. In other words, more people alive would result in more people in work, and hence a greater economic output.

15. The model then looks at the costs of social care saved due to a reduced proportion of overweight, obese, and morbidly obese individuals. The probability that individuals will have a need for local authority community based social care is based upon their age, gender, and BMI, and hence the reduction of BMI can be used to model the savings to social care costs.

16. Finally, the model considers the quality-adjusted life years (QALYs). QALY is a measure of disease burden, and factors in both the quality and quantity of life lived. An increase in QALYs is modelled by considering both the number of reduced deaths by the introduction of a calorie reduction, as well as the reduction of people living with disease.

17. All previous calculations are carried out on a year-by-year basis following the implementation of the policy. The model finishes by summing the benefits over all cohorts producing a summary of the overall savings over the modelled 25 years.

## 3.2. PHE Weight Management Economic Assessment Tool

18. Before further discussion, it should be noted that this model has been designed to be consistent with the PHE Weight Management Economic Assessment Tool [4] in its assumptions and methodology. For example, the PHE Weight Management Economic Assessment Tool and this model both consider the effects on the same obesity-related diseases, and the same relative risks are used for each disease.

19. The PHE Weight Management Economic Assessment Tool is a tool designed to support public health professionals in understanding the economic case for investing in weight management interventions. The tool estimates the health impact of weight loss in any group of people who have participated in an intervention or policy. It is based on robust evidence relevant to the English population.

20. This documentation references original sources of data, but many of the values taken for this model were taken directly from the PHE Weight Management Economic Assessment Tool.

## 3.3. Model Cohort

21. The cohort consists of adults grouped into ages 19-64 and 65-79, and children in two age groups: 4-10 and 11-18 years. The effects on the child cohorts are not considered until they reach age 18. Each population contains a male and female group, which are further grouped as overweight (BMI of 25-30), obese (BMI of 30-40), and morbidly obese (BMI of 40+). The model assumes the cohort moves together over time, and assumes the average characteristics of that group.

## 3.4. Inputs to the Model

22. As mentioned previously, there are 3 main inputs into the model for each policy: the excess calorie reduction, the weight in kg lost per calorie reduction, and the number of years the policy will take to achieve its target reduction in excess calories per day. Both the calorie reduction target and the number of years to achieve the target are estimated from individual policies.

23. The weight lost in kg per calorie reduction is based on research by Hall et al. [3]. This work finds that, for an overweight adult on average, every change of energy intake of 100 kJ per day will lead to a bodyweight change of 1 kg. This is equivalent to 10 kcal per day per pound of weight change. Based on this research, the model assumes that 0.042 kg is lost per calorie reduction. It should be noted that this weight loss per calorie reduction is used across all weight categories. Due to the difference in net energy required to lose the same amount of fat as the same amount of lean tissue, larger weight losses are expected for a higher initial adiposity, meaning the weight loss in the obese and morbidly obese groups within this model are likely to be underestimated.

## 3.5. Excess Calorie Calculations

24. The first stage of the model is to consider the effect the implementation of the policy would have on the weight (and hence BMI) on the groups of the populations. The average height and weight for each population group and weight status is found using data from Health Survey for England (HSE) [5]. The height is only dependent upon the age group and gender, and hence is the same for all weight statuses. The weight varies depending on age group, gender, and weight status.

25. The weight and height of each group are then used to calculate the average BMI (the weight (in kg) divided by the square of the height (in m)) for each group.

26. The excess calorie reduction is multiplied by the weight lost per calorie, in order to give a weight loss that would arrive if the policy was implemented. This is subtracted from the original weight to give a new weight that would result from the policy. This new weight is then used to calculate a new BMI: the average BMI

of the group that would arise from the target calorie reduction. This new BMI is subtracted from the original BMI to give a reduction in BMI for each group.

27. This reduction in BMI is used in the remainder of the analyses within the model.

## 3.6. Starting Conditions

28. A starting population is assigned to each group based on people that age from the 2016 mid-year population estimates from the Office of National Statistics (ONS) population samples [6], multiplied by the percentage of people estimated to be at that weight status from HSE [5]. For example, for overweight men in the 19-64 age-group, the population of all men aged 19-64 would be summed, and multiplied by the percentage of men aged 19-64 who are overweight. The same starting population is used for each scenario (control and treatment).

29. For the control scenario, the average BMI (calculated from average weight and height of that group: see *Excess Calorie Calculations*) is given to each group in year 0. Each year following the implementation of the policy, the BMI is increased to reflect on the findings shown by Ara et al. [7]. In this work, BMI trajectories of an overweight and obese population ($25\ kg/m^2 < BMI < 60\ kg/m^2$) were investigated using multilevel modelling of repeated measures of BMI, with age as the timescale. Only linear trajectories were modelled. Using this evidence, the model assumes that up to an age of 65, the BMI is increased at a rate of 0.175 $kg/m^2$ per year for women and 0.145 $kg/m^2$ per year for men. From ages 65 to 85, the increase in BMI per year decreases linearly from 0.175 $kg/m^2$ (for women), or 0.145 $kg/m^2$ (for men), until a BMI increase of 0 is reached at age 85. The BMI is assumed to remain constant at ages above 85.

30. For the treatment scenario, the BMI reduction based on the calorie reduction (calculation discussed in *Excess Calorie Calculations*) is subtracted from the control scenario for each year following implementation of the model. As previously mentioned, an input to the model is how many years it takes to achieve the target calorie reduction, and so this is factored into consideration when necessary. The model assumes that the reduction in calories would not cause a reduction in weight instantaneously: instead the weight change is 0% of what you would expect in year 1, 33% of what you would expect in year 2, 66% of what you would expect in year 3, and then 100% of the expected reduction in BMI is seen in year 4 onwards. The literature [3] does suggest that weight loss occurs in a non-linear fashion, with 50% of weight lost by the end of year 1, and 95% lost by the end of year 3. Given the relative unimportance of this transition period to the overall benefits, a simple linear trend is assumed for the purpose of this model.

## 3.7. Number Deaths Avoided

31. With the starting populations and BMI defined for each population group, the model now looks at the impact of the calorie reduction implementation on 5 diseases associated with obesity: diabetes, coronary heart disease, stroke, colorectal cancer, and breast cancer.

32. A baseline mortality rate for each year is assumed using data from ONS [8] which is dependent on the age and gender of the group. Given this is a baseline mortality (i.e. the number of general deaths that will occur), the same baseline mortality rate is used in the control and treatment scenarios. This is multiplied by the starting population of that year to give the baseline number of deaths for each group throughout the implementation of the policy. Although it is not unreasonable to assume age-specific mortality rates would fall in future years, it is not possible to make a robust forecast of this over a 25 year period. Hence, age-specific mortality rates are held constant over time.

33. The model then calculates incidence (number of new cases) and prevalence (total number of cases) for each of the diseases considered. Data from the World Obesity Federation [2] provide the relative incidence rates: these values provide the percentage increase in disease incidence per unit BMI above a BMI of 22 kg/m$^2$. Given the model includes only adult populations with a BMI over 25, all individuals in the model have a heightened risk unless they lose sufficient weight to get down to a BMI of 22. This would require a decrease in average daily calories of *c*. 320 kcal per day, which is far greater than any of the proposed policies. Hence the relative incidence rates are justified throughout the model. These relative risks can be multiplied by the disease incidence rates of a standard population [9, 10, 11, 12, 13] to give the incidence of all population groups. The prevalence is found by adding the incidence of that year by the number alive with the disease at the end of the previous year (to be discussed in *Cost to the NHS*). The treatment group has a reduced BMI, and hence reduced relative risks. This leads to a reduction in the overall incidence and prevalence of disease in the treatment group.

34. The model then finds the excess mortality from the disease. In this sense, the term “excess” refers to additional mortalities from the disease caused by being overweight. In other words, there would be no excess mortality from the disease if the population had a BMI below 22. This was found by multiplying the number of people with the disease alive at the end of the previous year (to be discussed in the *Cost to the NHS*) by the baseline mortality rate [8], by the excess mortality rate of that disease [14, 15, 16, 17, 18, 19, 20]. As with the baseline mortality rate, it may be expected that the excess mortality rates would reduce over time as healthcare and treatments improve. Again, due to it not being possible to make a robust forecast of this over a 25 year period, the excess mortality rates

are held constant over time. Lower incidence/prevalence of the disease leads to a smaller number of excess mortalities in the treatment group compared to the control group.

35. The total number of excess deaths each year is found by summing the excess deaths for each disease, and adding this to the baseline number of deaths.

## 3.8. NHS Cost Savings

36. The number of people with the disease alive at the end of the year is calculated by taking the disease prevalence (see *Number Deaths Avoided*) and subtracting the: number of excess mortalities (see *Number Deaths Avoided*), the baseline mortality (see *Number Deaths Avoided*), and the number of excess mortalities from the other diseases multiplied by the likelihood of having the disease of interest (the prevalence divided by the population alive). The last term accounts for people who have multiple diseases, and hence would have died from one of the other diseases.

37. The model uses the national programme budgeting data [21] to estimate the annual NHS cost per case associated with each disease. The total NHS secondary and primary care spending in England on each of the diseases is divided by the estimated prevalence of each disease, derived from the NHS Clinical and Health Outcomes Knowledge Base compendium indicators [22] or cancer registry data [23] to estimate the cost per patient per year for each disease. The average cost is increased using the hospital and community health services (HCHS) index [24]. The HCHS index is a pay and price inflation, and is calculated as a weighted average of two separate inflation indices: the pay cost index (PCI) and health service cost index (HSCI). The PCI accounts for inflation in the HCHS, and is a weighted average of increases in staff costs. The HSCI accounts for price change of goods and services purchased by the HCHS. Increasing the average cost gives an uplifted cost per patient per year for each disease.

38. The number of people with the disease alive at the end of each year is multiplied by the uplifted cost per patient per year to give a total cost to the NHS. Lower prevalence in the treatment group means there are fewer people with the disease alive at the end of each year, and hence results in a lower treatment cost to the NHS. The model does not net off any NHS costs that individuals incur through living longer because of these conditions being prevented. This is consistent with the approach taken in NICE cost effectiveness appraisals.

## 3.9. Wider Economic Benefits

39. The model also considers the productivity gain that would be achieved by having a larger population alive in the treatment group.

40. The median wages for men and women in various age categories are taken from ONS data [25]. In order to obtain a wage for each individual age, the model assigns the median salary to the middle of that age group. For example, the median salary for men aged 30-39 is £28,528, and so this salary would be assigned to a male aged 35. The model then assumes the median wage will increase linearly until the median salary is reached in the middle of the next age group. Continuing with our example, the next age bracket is 40-49 which has a median salary of £31,391. Hence, the median salary will continue to increase by £286 ((£31,391-£28,528)/10) from the age of 35 to 45. Once this age is reached, the process is repeated using the new median salaries. It is assumed nobody over the age of 66 is earning a salary.

41. The same process as described above is also used on data from ONS [26] to give the percentage of individuals in employment depending on their age and gender.

42. The model then considers the proportions of death in a year caused by each age. This is calculated by multiplying the mortality rate at that age by the ratio of the population at that age to the sum product of all mortality rates and all populations. This starts at age 19, and is repeated for every year of the policy, with youngest age removed on each year of the policy. For example in year 2, there are no 19 year olds because the 19 year olds are now 20 year olds.

43. These proportions are then multiplied by the percentage of individuals in employment at each age, in order to obtain a weighting for each age of the salary earned. An output wage per life-year is calculated for each year of the policy using a sum product of the weighting for each age, and the salary at that age.

44. To summarise, a modelled salary is achieved for each year of the policy by considering how much the population would earn in total if each individual earned the median wage for his or her age.

45. We also predict that the fulfilment of the calorie reductions modelled would result in a healthier workforce. Therefore, a further increase to economic output would be gained by healthier workers in the labour market. However, this impact is not estimated quantitatively in the analysis.

## 3.10. Social Care

46. The probability of a population needing local authority (LA) community based social care is based upon their age, gender, and BMI. The model assumes that the probability of needed social care remains at zero up until an age of 50 years.

Once this age is reached, probabilities are calculated using data from HSE [27, 28, 29].

47. The cost per year of an LA home care worker is calculated by multiplying the percentage of needs met by formal LA care [4], by the average hours of formal LA help received per week based on given needs [27, 28, 29], by the cost per hour of an average home care week [24], by the number of weeks in a year.

48. This cost per year of an LA home care worker can be multiplied by the probability of needing social care, to give a total cost for all groups, and hence a difference between the control and treatment scenarios can be calculated. Lower BMIs in the treatment scenario result in smaller probabilities of needing social care, meaning a reduced overall cost.

49. It is important to note that these costs are for community based social care and do not extend to costs in the care home population.

## 3.11. QALY

50. One final output of the model is the quality-adjusted life years (QALYs). QALY is a measure of disease burden, and factors in both the quality and quantity of life lived. One QALY can be thought of as one year of perfect health, and this number drops below one if an individual's health is less than perfect.

51. The calculation of the QALY is dependent upon mean EQ-5D values. EQ-5D is a standardised instrument developed by the EuroQol Group [30] as a measure of health-related quality of life that can be used in a wide range of health conditions and treatments.

52. A tobit regression model was constructed using HSE data from 2011-2013 [27, 28, 29] to describe the association between mean EQ-5D score and: age, sex, BMI, and disease status for each of the diseases. This results in a mean EQ-5D score for each disease. This mean value is used as the health-related quality of life (HRQOL) reduction value within the calorie model (see Table 1). A death is given an HRQOL reduction of 1. Hence, more deaths in the control scenario will cause a bigger reduction in QALYs.

53. The model is then able to find the increase in QALYs caused by implementation of the policy. The HRQOL reduction value for each disease is multiplied by the difference in the number alive with the disease at the end of the year between the control and treatment scenario. The death HRQOL is multiplied by the difference in the total population alive. These are summed together to give a total increase in QALYs caused by the policy.

54. This increase in QALYs can be converted into monetised QALY using a conversion of how much society values a QALY. This model assumes the monetary value for a QALY to be £60,000 [31]. Hence, the increase in QALYs is multiplied by £60,000 in order to obtain the monetised QALY from the implementation of the policy.

**Table 1: HRQOL reductions used for each disease**

| Disease | HRQOL reduction |
|---|---|
| Diabetes | 0.11 |
| CHD | 0.16 |
| Stroke | 0.18 |
| Colorectal Cancer | 0.16 |
| Breast Cancer | 0.16 |
| Death | 1.00 |

## 3.12. Discount Rates

55. There remains a technical issue for all aspects discussed within this model, which concerns the costs and benefits that arise at different points in time. Discounting allows costs and benefits which occur in the future to be compared on a common "present value" basis. It is based on the concept of time preference, that generally people prefer to receive goods and services now rather than later.

56. Monetary values occurring in the future need to be discounted in order to reflect both pure time preference (a preference for something to come at one point in time rather than another merely because of when it occurs in time), and the diminished marginal utility of income (the change in human satisfaction resulting from an increase or decrease in an individual's income). These are combined with the assumption that real incomes rise over time.

57. In practice, the only reason to discount quantities of health is the existence of pure time preference, which equates to a health discount rate of 1.5% [31] used throughout this model. All other monetary values should be discounted at the general discount rate of 3.5% [31] set out in the HM Treasury Green Book. Discount rates were applied as a cumulative multiplier to the outputs shown in Figure 2.

## 3.13. Final Outputs

58. This write-up has generally described the savings/reductions in deaths at the end of each year caused by a reduction in calorie intake. The final step of the model

is to sum the aspects considered across all groups during the 25 years of implementation.

59. Hence the final outputs of the model are the reduction in the number of deaths, the healthcare costs saved by the NHS, the social care costs saved, the increase in economic output, and the monetised QALY.

# 4. Quality Assurance

60. The model has been quality assured in line with the principles set out in the government Aqua book [32].

61. The model methodology is based on the PHE Economic Assessment Tool which has been peer-reviewed. This DHSC model was developed alongside PHE analysts to provide external challenge and ensure our model was of high standard. We have tested the model outputs against figures produced by PHE using their model, such as the calorie reduction programme [33] and found good agreement.

62. As part of the QA process, we performed an internal peer review, consisting of analysts involved in the development of the model, and analysts with no prior knowledge of the model. Following the approach set out in the Aqua book, this included:
    a. validation of the structure of the model
    b. inspection of input data
    c. inspection of equations within the model
    d. ensuring input data were correctly sourced
    e. validation of the model assumptions
    f. ensuring the general flow of the model is logical and working.

## 4.1. Sensitivity Analysis

63. We performed sensitivity analysis to ensure that outputs vary smoothly when the inputs are varied. This was done at several stages of the model, to minimise the likelihood of any errors propagating through to the final version.

64. We examined input variables to the model and rated them Red, Amber, or Green (RAG) in terms of how *certain* we are of their value, and how large an *impact* a change in that variable has on the model outputs. This gives us a RAG table with two dimensions.

65. For impact, we gave each variable a range of percentage increases and decreases. For all, except one, the output varied linearly with the change in the variable. The RAG ratings below show the impact on outputs relative to an illustrative 1% change in the input:
    - Green: low impact – a 1% change changed economic benefits by less than 0.2%.
    - Amber: intermediate impact – a 1% change caused a change between 0.25 and 0.5%.
    - Red: high impact – a 1% change causes a change of at least 0.5%.

While a parameter was being investigated, all other variables were fixed. The non-linear parameter was observed over a range of percentage changes, and rated according to these guidelines.

66. For certainty, we have given each of the identified variables a high, medium or low rating depending on the quality and relevance of the source:
    - Green: high certainty – e.g. official statistics with a large sample size, or strong peer-reviewed research.
    - Amber: intermediate certainty – e.g. slightly older peer-reviewed research.
    - Red: low certainty – Weaker evidence than Amber. This rating does not apply to any of our variables.

67. Although there are a large number of parameters in the model, they were grouped according to where they impact within the model structure, allowing for a more manageable number of parameters to be analysed. The results are shown in Table 2 rounded to 1 decimal place.

**Table 2: RAG table for the 11 parameters showing the effect of a 1% change for each parameter.**

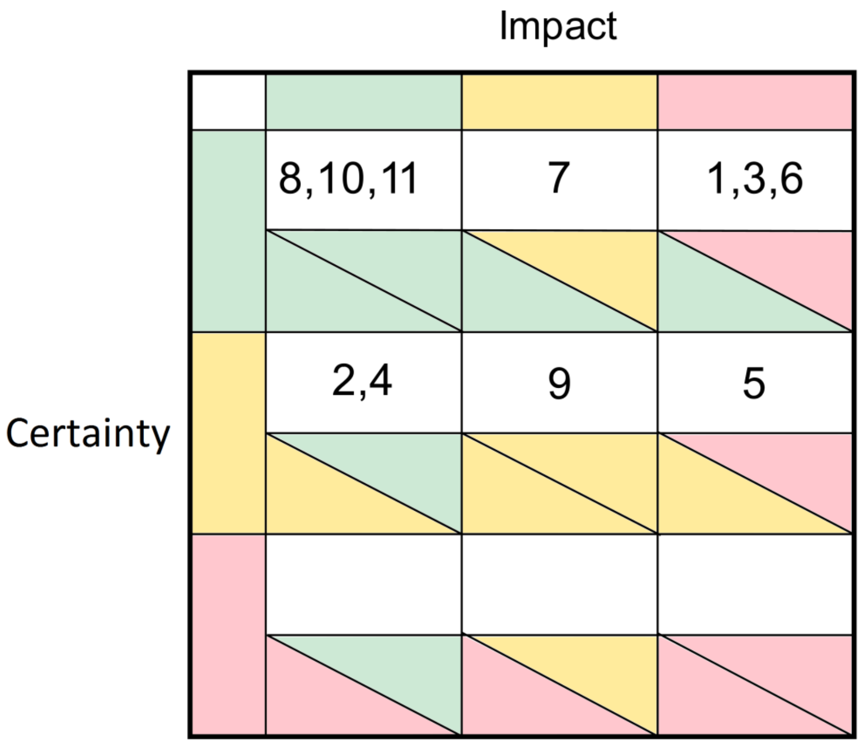
| | Parameter | Certainty | Impact | Given a 1% change in this parameter, total output changes by: |
|---|---|---|---|---|
| 1 | kg lost per Calorie change | Highly Certain | High Impact | 1.0% |
| 2 | Baseline BMI | Intermediate Certainty | Low Impact | 0.1% |
| 3 | Obesity rates | Highly Certain | High Impact | 1.0% |
| 4 | Adult BMI increases | Intermediate Certainty | Low Impact | 0.0% |
| 5 | Increased risk of disease | Intermediate Certainty | High Impact | 0.9% |
| 6 | Population incidence | Highly Certain | High Impact | 0.8% |
| 7 | Mortality uplifts | Highly Certain | Intermediate Impact | 0.2% |
| 8 | NHS costs of treatment | Highly Certain | Low Impact | 0.1% |
| 9 | HRQOL detriment | Intermediate Certainty | Intermediate Impact | 0.4% |
| 10 | Employment rates | Highly Certain | Low Impact | 0.0% |
| 11 | Median wage | Highly Certain | Low Impact | 0.0% |

*The baseline BMI is the BMI above which an individual is more likely to get one of the diseases because of excess weight. Increased risk of disease is per unit of BMI above baseline. Population incidence is the observed incidence of each disease, and this changed the modelled benefits nonlinearly.*

68. We have chosen to focus on those variables where we have low-to medium confidence and medium to high impact, as variables with a high certainty or a low impact have little ability to significantly change the modelled economic benefits.

69. Displaying this same information in a grid (see Figure 3) shows that all the parameters, except for 5 & 9, have high certainty, or low impact. We have therefore focussed on parameters 5 & 9.

**Figure 3: The 11 variables displayed in a 2-dimensional RAG table.**



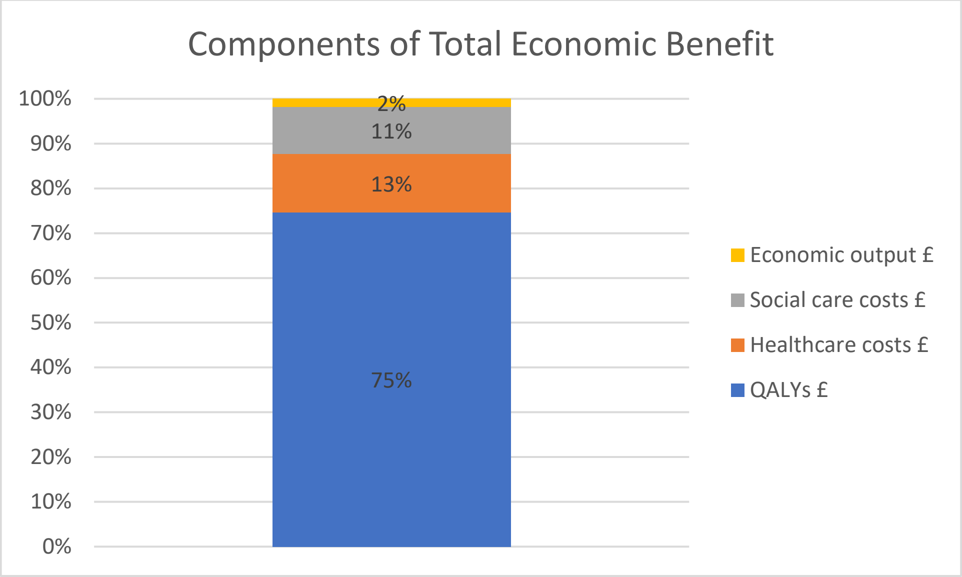
| | 🟩 | 🟨 | 🟥 |
|---|---|---|---|
| 🟩 | 8,10,11 | 7 | 1,3,6 |
| 🟨 | 2,4 | 9 | 5 |
| 🟥 | | | |

70. We have tested parameters 5 and 9 with ‘high’ and ‘low’ scenarios that are 33% higher or lower than the values used in the model. This range is broadly consistent with the extreme higher and lower values for these parameters found in the literature. In these scenarios, the modelled economic benefits would increase or decrease by up to 40%.

71. To go into more detail on the impact of these parameters, we looked at how different components of the model contribute to the total economic benefits. The model has 4 components that sum to give the total economic benefits of a policy: QALYs (from reduced morbidity and mortality), reduced NHS costs (from reduced incidence of the diseases), reduced social care costs (from a reduction in excess

BMI), and increased economic output (from increased employment due to reduced disease). See Figure 4 for results.

**Figure 4: Percentage contribution to total economic benefit by section of model.**



72. As can be seen above, by far the largest component of the economic benefits are the monetised QALY gains resulting from lower levels of obesity related morbidity and mortality. Together, the QALY gains make up around three quarters of the benefits estimated by the model. This clearly shows why variables that affect these calculations are more sensitive than those relating to other outputs from the model.

# 5. Results

73. Example results from running the model are shown below in Table 3 for hypothetical policies that result in a population-wide average reduction of 5 kcal, 10 kcal, and 20 kcal per day. The results are over a 25 year period and show the number of fewer deaths, the savings regarding healthcare costs, social care costs, and economic outputs, as well as the QALYs saved (both absolute QALYs and monetised QALYs). The model does not calculate confidence intervals and only provides a central estimate for each value. Instead, sensitivity analyses are performed when these results are reported on, specific to the policy under discussion. Results are shown here to 3 significant figures.

**Table 3: Example results for a given reduction in kcal per day**

| kcal reduction per day | Number of reduced deaths | NHS costs saved (£M) | Social care costs saved (£M) | Increased economic output (£M) | QALYs saved (total) | QALYs saved (mortality) | QALYs saved (morbidity) | Monetised QALYs saved (£M) (total) | Monetised QALYs saved (£M) (mortality) | Monetised QALYs saved (£M) (morbidity) |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 2,630 | 350 | 280 | 48 | 43,600 | 22,100 | 21,500 | 1,990 | 1,000 | 990 |
| 10 | 5,250 | 700 | 560 | 96 | 87,200 | 44,200 | 42,900 | 3,990 | 2,000 | 1,990 |
| 20 | 10,500 | 1,400 | 1,120 | 191 | 174,000 | 88,500 | 85,900 | 7,980 | 3,990 | 3,990 |

# 6. Limitations of the Model

74. There are a number of limitations to this model which should be noted. The causes of obesity are complex, but in order to quantify the benefits we had to simplify the problem by only considering calorie imbalances. However, as mentioned previously, this simplified approach allows the model to be applied to various policies given a simple input of calorie reduction from each policy.

75. This model also works on the assumption that a calorie is a calorie: in other words it does not matter what food group or type the calorie comes from, it will still cause the same reduction in weight. This is an area of active research [3], so for reasons of simplicity we have not considered the composition of diet, but only total calories.

76. The model only considers a relatively small number of diseases and does not take into consideration the effects of socioeconomic status or ethnic origin. Given risks are altered amongst socioeconomic status and ethnic origin, this could have an influence on the final outputs.

# 7. Future Developments

77. This model looks at the effect of a calorie imbalance reduction on an adult population. The long-term effects on children have not yet been modelled as it is far more difficult to accurately predict how a child’s body weight trajectory will change in response to an intervention. This is due to the dynamic energy partitioning between fat and lean tissue during various phases of growth [34, 35]. There are also various other factors that need to be assumed for a child’s population, making the modelling approach more difficult. Future versions of the model will aim to include these effects, and consider the benefits on a child’s population.

78. It has been mentioned that the average age of a population was used throughout the model. However, given the groups cover a wide age band, this assumption is likely to lead to some inaccuracies in the timing of benefits. Hence, this issue will be addressed in a future version of the model.

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