Investing in breath:

Measuring the economic cost of asthma and COPD in the UK and identifying ways to reduce it through better diagnosis and care

Technical Report (2023)

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Executive summary

This technical report was supported by PwC analysis and aims to estimate the economic cost of asthma and COPD in the UK for 2023 as well as the impact of specific interventions into improved diagnosis and better care for those individuals.

Asthma and COPD are lung conditions that represent a significant cost to the UK economy. The UK is one of the worst performing developed countries for asthma deaths in the 5-to-34-year age range, ranking 35th out of 37. Furthermore, the UK is in the top 20 developed countries for COPD deaths and admissions with COPD being responsible for 30,000 deaths a year in England.[1]

In their Long Term Plan[2], the NHS has outlined its aims to reduce the cost of lung conditions by supporting earlier and more accurate diagnosis, optimisation of medical treatment and supporting patient self-management. It has also begun the transition to integrated care through the establishment of Integrated Care Systems (ICSs) which are partnerships of organisations to plan and deliver joined up health care services meaning effective and timely treatment is available to all.

Integrated care is a key recommendation of the National Institute of Health and Care Excellence (NICE) and they have developed specific care pathways for asthma and COPD encapsulating the whole range of treatments that should be available to patients. Within the care pathways a specific focus is placed on the need for early and accurate diagnosis as well as optimal long-term management and treatment of the lung conditions. They outline numerous treatment recommendations that can help to reduce the cost of disease on individuals as well as the NHS and the economy overall.

This report captures the potential benefits of improved diagnosis and better care of asthma and COPD by firstly, estimating the annual economic cost of the two lung conditions and secondly, estimating the impacts of specific interventions into improved diagnosis and better care.

This report estimates the current 2023 economic costs of asthma and COPD: direct costs to the NHS, environmental costs, productivity costs and the costs to quality of life for those affected by asthma and COPD. **The total economic cost of asthma in the UK is estimated to be £6 billion and the cost of COPD to be £9 billion in 2023.**

To estimate the impact of improved diagnosis and better care, specific interventions were chosen based on data availability, relevance and causal linkage between the interventions and the subsequent impacts. Notably, this report does not capture the costs of these interventions but looks at the likely impacts of the interventions relative to the as-is scenarios (what is currently happening today) to a range of stakeholders.

The chosen interventions to model were the use of FeNO testing and improved patient treatment adherence for asthma and an uptake in spirometry testing for the undiagnosed COPD population and greater referral and completion rates of pulmonary rehabilitation for COPD. The analysis estimates that effective FeNO usage could lead to total savings of £147 million in 2023 and improved patient adherence results in £292 million savings.[3] The use of greater spirometry testing for COPD is estimated to generate economic benefits worth £137 million in 2023 and an increase in pulmonary referral and completion rate could lead to £267 million in annual economic benefits to the UK.

[1] NHS England, Respiratory disease, 2023
[2] NHS England, NHS Long Term Plan, 2019
[3] Inclusive of direct, indirect, emissions and patient travel.

As asthma and COPD represent a large component to the NHS during the winter period through non-elective admissions, the impacts of earlier diagnosis and better care on winter bed days was modelled and estimated to lead to a reduction in 18,000 bed days during the winter for asthma and 100,000 bed days for COPD for 2023.

Finally, to highlight the impacts at the ICB level, impacts were distributed across England at the ICB level accounting for the effects of deprivation. The analysis indicated that not only are the costs of asthma and COPD greater in areas of higher deprivation but the potential impact savings from effective interventions are also greater.

Based on the analysis, this report concludes that asthma and COPD represent a significant economic cost across the UK for the year of 2023. The analysis indicates that effective implementation of FeNO testing and improved patient adherence training for asthma patients leads to a significant reduction in direct costs to the NHS as well as indirect costs to the economy. Furthermore, an uptake in spirometry testing and an increase in the referral and completion rate of pulmonary rehabilitation results in substantial reductions in the annual economic cost of COPD. The analysis highlights the need to improve the quality of care of asthma and COPD. By ensuring accurate diagnosis and effective treatments of patients, costs to the NHS, individuals and the economy can be significantly reduced.

1. Introduction

Context:

Asthma and COPD represent a significant cost to individuals, the NHS and the economy and are likely to grow in the coming years. The National Institute of Health and Care Excellence (NICE) is an institute with the purpose of helping practitioners and clinicians deliver the highest quality care to patients whilst ensuring cost effectiveness. They have developed optimal care pathways for both asthma and COPD focusing on early and accurate diagnosis and better care.[4] To reduce the current cost of asthma and COPD as well as prevent it increasing in the future, early and accurate diagnosis of the asthma and COPD population and optimal long-term treatment and management of individuals has the potential to offer vast benefits. This report demonstrates the positive impacts from interventions in better diagnosis and better care.

What this report does:

This report estimates the current 2023 economic costs of asthma and COPD, considering direct costs to the NHS, environmental costs, productivity costs and most importantly the impact of asthma and COPD on the day to day lives of patients suffering from the lung conditions. This report also explores the impacts of specific interventions focused on improving care and earlier as well more accurate diagnosis for the diseases. Specifically, the benefits of use of FeNO testing and improved patient treatment adherence for asthma and an uptake in spirometry testing and greater referral and completion rates of pulmonary rehabilitation for COPD are modelled.

This report only measures the benefits of better care and/or better diagnosis for both asthma and COPD. It does not consider the costs or policy changes required to implement the interventions and to realise the benefits identified. The costs would need to be considered in greater detail for implementation, with value for money assessments on a case-by-case basis.

Purpose of this report:

The purpose of this report is to assess the total economic cost of asthma and COPD and demonstrate the impact of better care and earlier diagnosis. We also model impacts at the ICB level for England accounting for the effects of deprivation as well as estimating the reduction in bed days due to asthma and COPD in the winter period in the UK.

[4] NICE, 2023

2. The cost of asthma in the UK

2.1 Context

This chapter explains the cost of asthma in the UK by:

- Defining the clinical symptoms of asthma and grouping them to determine the cost of asthma in the UK;
- Outlining the stages of an asthma patient pathway such as the diagnosis, maintenance and uncontrolled symptoms stage;
- Defining the costs that are measured within the report. They are direct NHS costs, GHG emissions costs, patient travel costs, indirect health related quality of life costs and productivity costs;
- Explaining how the methodology for the report is structured;
- Presenting the findings for the cost of asthma in the UK in 2023.

Definitions and symptoms

Asthma is a chronic long term condition that is caused by inflammation affecting the airways that carry air in and out of one's lungs.[5] Asthmatics have symptoms such as coughing, wheezing, feeling breathless or a tight chest.[6] These symptoms vary in individuals and can be triggered by factors such as exercise, allergens, changes in the weather or through viral respiratory illnesses.[7] These symptoms are not specific to asthma which leads to the risk of people not getting a respiratory diagnosis, or being misdiagnosed.

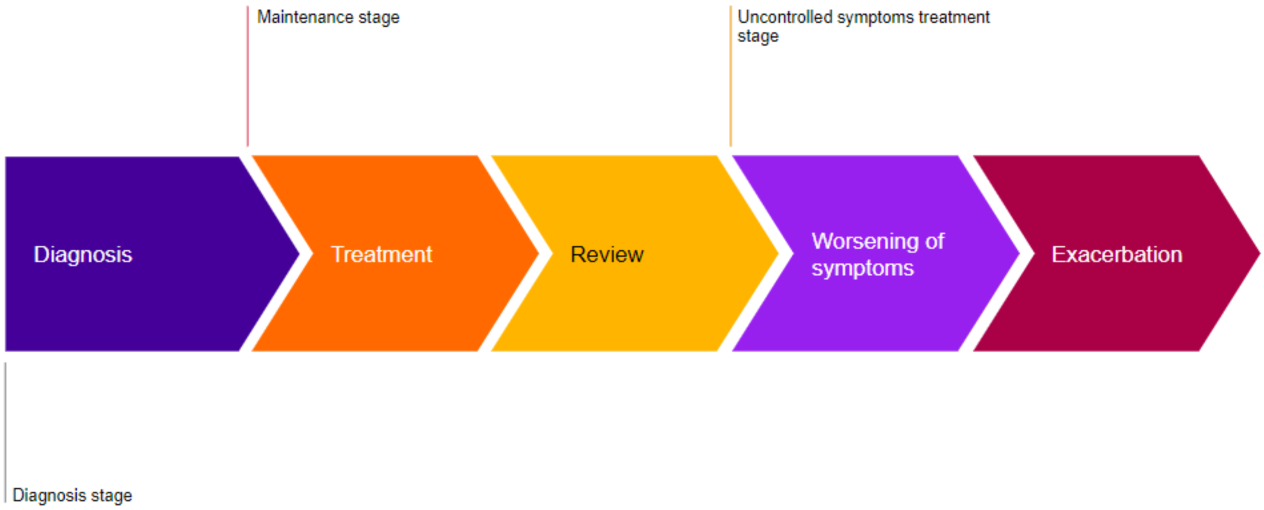
Asthma is a heterogeneous condition which can present with different patterns of symptoms, pathophysiology, triggers, and response to medication. Some are harder to treat or require higher levels of controller medication and are termed severe asthma. The Global Initiative for Asthma (GINA) is an organisation that provides medical guidelines on asthma. The GINA guidelines present definitions on populations within asthma that are used for the analysis. They are:

- **Non-severe asthma:** Non-severe asthma is used to distinguish patients from severe asthma patients. They include uncontrolled asthma patients as well. The definition of non-severe asthma includes both controlled and uncontrolled asthma:
    - **Controlled asthma:** Asthma does not affect controlled asthma patients in a meaningful way.
    - **Uncontrolled asthma:** Asthma patients who are uncontrolled have poor control of symptoms. This includes frequent reliever use, activity limited by asthma, and night waking due to asthma. It also includes exacerbations requiring oral corticosteroids and serious exacerbations requiring hospitalisation. For the purposes of the analysis, the term non-severe uncontrolled asthma will be used to distinguish it from severe asthma.[8]
- **Severe asthma:** Severe asthma is defined as uncontrolled asthma despite a patient's adherence to maximal optimised high dose medication.[9]

Five stages of asthma were modelled for non-severe and severe asthma patients in the UK. This is an aggregated approach where the care pathways for asthma have been simplified for this report.

[5] Asthma and Lung UK, What is asthma?, 2021
[6] Global Initiative of Asthma, Global strategy for asthma management and prevention, 2022
[7] Global Initiative of Asthma, Global strategy for asthma management and prevention, 2022
[8] Global Initiative of Asthma, Global strategy for asthma management and prevention, 2022
[9] Global Initiative of Asthma, Global strategy for asthma management and prevention, 2022

Figure 1: Five stages of asthma patient pathway



As shown in Figure 1, the five stages of asthma have been identified. These stages are based on previously completed analyses for Asthma and Lung UK.[10] They are broken down into the diagnosis, maintenance, and uncontrolled symptoms stages.

The **diagnosis stage** applies to all people with asthma. This most commonly involves initial appointments in primary care to assess the person's history and examination. On its own this is neither sensitive nor specific for asthma so objective diagnostic tests should be performed to assess for reversible or variable airflow obstruction with spirometry, reversibility, and airflow inflammation with FeNO.[11] A recent report by Asthma and Lung UK highlighted the inadequate utilisation of diagnostic tests in asthma.

The **maintenance stage** is to control symptoms for diagnosed asthma patients. Using a treatment plan, the patient will be prescribed medicine usually in the form of inhalers. Patients will adhere to their medication regime at different levels. They should receive at least one annual review of their asthma to see if their treatment plan needs updating based on how well controlled their symptoms are and whether they have had any exacerbations.

Some patients have uncontrolled asthma and enter the **uncontrolled symptoms stage**. This can manifest itself as either persistent symptoms or as an exacerbation of asthma. In both cases, the underlying severity of their asthma, the level of treatment they are prescribed, adequate adherence and inhaler technique and the person's exposure to their personal triggers all contribute towards whether someone experiences uncontrolled asthma. Having persistent symptoms increases the risk of developing an exacerbation.

For the purposes of this analysis the population has been divided in two:

- **Population 1:** Some patients experiencing an exacerbation are able to self-manage their symptoms;
- **Population 2:** Other patients will require the use of GPs, or secondary care such as ambulances or admission into hospitals.

The distribution of these two populations is unequal and is based on evidence which suggests adherence to treatment reduces the risk of uncontrolled symptoms. In some cases, an exacerbation can be fatal. The National Review of Asthma Deaths found that approximately 50% of asthma deaths were preventable.

[10] Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022
[11] NICE, Asthma: diagnosis, monitoring and chronic asthma management

The asthma patient pathway is not linear in terms of asthma symptoms, treatment adherence and exacerbations. Patients who may have good symptom control and treatment adherence could experience an exacerbation at any time. The next sections in this chapter explain the stages of asthma in greater detail.

Diagnosis stage[12]

At the diagnosis stage, patients will present with respiratory symptoms such as a cough, shortness of breath or wheezing. As these symptoms are not specific to asthma the relevance of asthma-like symptoms may be overlooked or attributed to another cause. A healthcare professional, usually a GP will perform a series of diagnostic tests as well as examine a patient's history of respiratory symptoms. According to GINA, there are two steps.[13]

1. The first step is to verify whether the patient's symptoms and the time the symptoms occur are typical of an asthma patient;
2. The second step is to run diagnostic tests to confirm or exclude asthma.

Guidelines recommend that a patient should complete a spirometry test to measure for evidence of airflow obstruction, then a bronchodilator reversibility test. The bronchodilator reversibility test is used for lung responsiveness. Fractional Exhaled Nitric Oxide (FeNO) tests should also be used to test for inflammation in the lungs. These tests can be carried out by a range of different healthcare professionals with appropriate training in performing the test, and then interpreted by a healthcare professional with appropriate training. These tests are readily available in primary and secondary care, and recently in diagnostic hubs.[14]

Many children are unable to perform spirometry, and some may not be able to perform FeNO testing. Most asthma initially presents in children. It is important that a presumed diagnosis in childhood does not translate into a lifelong label for patients, with its associated costs on the patient and the NHS, without confirming the diagnosis with objective measures once they are able to perform appropriate tests.[15]

Treatment stage

Asthma is primarily self-managed by patients. The provision of medication is not enough to maintain control of asthma as patients still need to administer their treatment independently in between contacts with healthcare professionals. It is important to recognise the relationships between patients and their doctors play a role in adherence to asthma treatment, and by extension the control of asthma.

There are no routinely used ways of monitoring people with asthma between appointments. Digital inhalers are an expensive option and digital aids/apps are poorly adhered to in their current form. Primary care has access to data which could be used to monitor the ordering of both preventer and reliever inhaler use, and to monitor NHS visits with exacerbations. However, this data is not routinely used to identify poor asthma control.

Unlike other long-term conditions there is no formalised education for people with asthma about their disease and treatments. Informal education may be offered by healthcare professionals in existing appointment time, or by signposting to organisations such as Asthma and Lung UK.

Asthma reviews occur regularly to check on a patient's asthma control and how they are responding to their medicines and treatment plan. This occurs around once a year but can be held more frequently.[16] Asthma patients have varying levels of adherence to treatment.[17] While asthma can be exacerbated by external factors, one of the most important aspects of asthma control is adherence to medication. A review found that adherence is

[12] The costs of diagnosis in the report are adjusted for incidence.
[13] Global Initiative of Asthma, Global strategy for asthma management and prevention, 2022
[14] Asthma and Lung UK, Diagnosing asthma, 2021
[15] This report only considers asthma in adults.
[16] Asthma and Lung UK, How to get the best from your asthma review, 2021
[17] Global Initiative of Asthma, Global strategy for asthma management and prevention, 2022

defined by several pieces of literature as 80% or above prescription filling, and that 65% of asthma patients are sub-optimally adhering.[18]

Patients can miss doses of medication or adopt poor inhaler techniques. This means they do not receive adequate doses of their prescribed medication. This increases the chance of untreated inflammation in the airways and increases the risk of asthma symptoms and asthma exacerbations. There are various definitions on the level of doses missed, but it is generally accepted that poor or a lack of usage of inhalers can influence the occurrence of symptoms and exacerbations. This is defined as suboptimal adherence to treatment, an important categorisation in our methodology.[19]

Uncontrolled symptoms stage

All asthma patients are at risk of developing uncontrolled symptoms due to the unpredictable nature of asthma triggers especially for those with untreated inflammation. Some uncontrolled symptoms can be self-managed with occasional doses of reliever inhaler. When a flare up of symptoms is particularly severe or prolonged it is termed an exacerbation. In this case, a patient might see a GP, or access secondary care. Examples of secondary care that are included in the analysis include:

- Calling 111;
- Calling 999 for an ambulance;
- Presenting at the emergency department (A&E);
- Becoming admitted into hospital after presenting at A&E.[20]

In an exacerbation, oral corticosteroids and higher dose reliever medication are usually administered. Some exacerbations can also be fatal.[21] This report considers two factors that influence the frequency of exacerbations:

1. **Factor 1:** Asthma severity. A previous literature review found that severe asthmatics are more likely to experience an exacerbation;[22]
2. **Factor 2:** Treatment adherence. The same literature review found a link between asthma control and adherence to treatment.[23]

2.2 Costs of asthma framework

This report uses previously developed frameworks, including those developed by Frontier Economics, to estimate the costs of asthma on the environment, society, and the economy.[24] This report examines direct and indirect impacts.

Direct costs

Direct costs refer to the expenses incurred in providing treatment to patients. Direct costs are broken down into three components:

- NHS costs incurred by the NHS;
- GHG emissions costs incurred by society;
- Patient travel costs incurred by patients.

NHS costs

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[18] Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022
[19] George and Bender, New insights to improve treatment adherence in asthma and COPD, 2019
[20] Patients can also present to urgent care centres / walk in centres.
[21] Krishnan et al, Mortality in Patients Hospitalised for Asthma Exacerbations in the United States, 2006
[22] Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022
[23] Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022
[24] Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022

Direct impacts occur directly as a result of treatment either to the NHS, to the patient or to society. In this report, the direct costs to the NHS quantified in the model are:

- Healthcare professional's time to diagnose, to annually review asthma, and to follow up on exacerbations during unplanned patient visits;
- The cost of diagnostic tests;
- The cost of medications prescribed;
- The use of secondary care.[25]

GHG emissions costs

This report also quantifies the generation of GHG emissions as a direct cost to society for:

- Healthcare facilities open for patients;
- Patient travel to and from healthcare facilities;
- Transportation of patients during exacerbation emergencies;
- Hospitalisation of patients following a serious exacerbation;
- Patient use of inhalers.[26]

Patient travel costs

This report quantifies the direct cost of different modes of transport that patients use to attend medical appointments for asthma. It is assumed that patients directly incur travel costs.

Patients can also incur out of pocket prescription charges for their medication, but this is not included in the analysis to avoid accounting for transfers of cost.

Indirect costs

Indirect costs account for the cessation or reduction of work productivity due to the morbidity and mortality of a disease. The indirect costs modelled for asthma patients include:

- Health related quality of life incurred by patients;
- Productivity losses incurred to employers.

Caregiving is also considered an indirect cost but has not been captured in this report. Potential Limited estimated that in 2018-2019, at least 600,000 school days were lost in the UK due to asthma.[27] Employees would be expected to take paid time off work to care for their children, resulting in lost output in the economy.

Health related quality of life

Asthma can result in a lower quality of life for asthma patients, especially if they have an exacerbation and this is quantified in the model.[28] For the purpose of this report, a loss in health-related quality of life applies only to uncontrolled asthma patients as per the definitions of controlled and uncontrolled asthma. Controlled asthma patients do not see an impact of asthma on their lives.

Productivity

[25] Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022
[26] Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022
[27] Potential Limited, The economic cost of uncontrolled asthma, 2021
[28] Barnes et al, Estimating loss in quality of life associated with asthma-related crisis events (ESQUARE): a cohort, observational study, 2019

Asthma affects the productivity of the working population. Uncontrolled asthma affects the participation rate of individuals in the labour market, as patients experiencing asthma symptoms may not be able to work.[29] Furthermore, employed asthma patients may be less present at work due to the number of sick days they need to take. Finally, research suggests that employees who have asthma have median wages lower than the rest of the population.[30] These aspects are all quantified in this report.

2.3 Quantitative model

Introduction to the model

This section introduces the quantitative model. The purpose of the model is to:

- quantitatively estimate the impact of environmental, societal and economic impact of asthma;
- and explore the impacts of what would happen if the UK was able to provide either more accurate diagnoses for asthma and/or provide better care.

Firstly, the base of the model represents the counterfactual. The counterfactual is a status quo scenario to assess the total costs without any intervention (as things are today). The counterfactual aspect of the model draws on the existing literature and assumptions that are used in the previous body of work.[31] However, it has been updated to account for inflation.

Secondly, as shown in Figure 2, this report adds to the existing base by assessing the impacts of what would happen if the UK was able to provide either more accurate diagnoses for asthma and/or provide better care. The impacts are then quantified in terms of monetary costs saved, bed days avoided and winter pressures. Finally, the impacts are distributed across health boards, then adjusted for levels of deprivation in the UK.

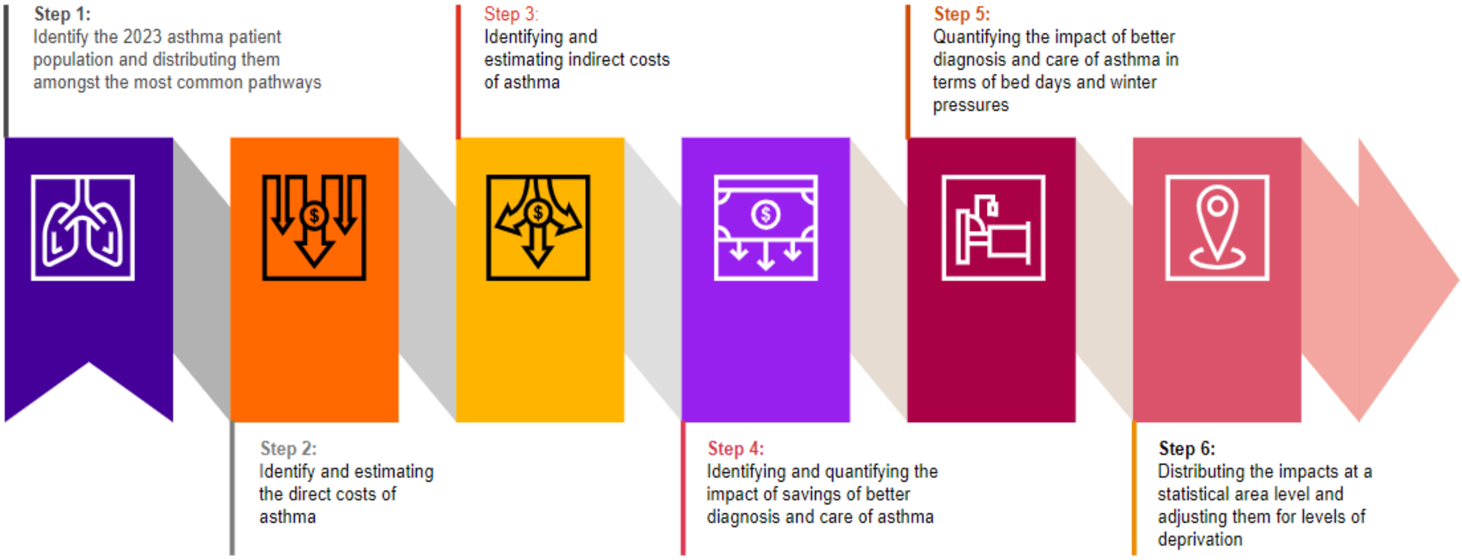
Where additional information was required, publicly available quantitative data and academic literature was used. The assumptions used in the report were validated with our clinicians. As part of the literature review, data was collected for possible assumptions and inputs to be used in the analysis. While not all impacts such as GHG emissions and health related quality of life are initially in monetary values, they have been converted to commonly agreed monetary values so that they can be compared.

This model assesses the total cost of asthma in the year 2023 and this is reflected within the model's assumptions. This model only assesses the total cost of asthma for one year. Costs would change in the years after based on inflation of the cost of items and wages, as well as the prevalence of the asthma population.

The next section describes at a high level how the costs of asthma were calculated. Additional detail on the calculation methodology is provided in the Technical Appendix.

[29] Potential Limited, The economic cost of uncontrolled asthma, 2021
[30] Potential Limited, The economic cost of uncontrolled asthma, 2021
[31] Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022

Figure 2: Cost modelling process



Modelling the asthma population

Existing analyses of asthma have already identified a non-exhaustive set of patient pathways for modelling. This was done by identifying the most common patient journeys and aggregating them where possible. This is reflected in the analysis of this report.

The total population of asthma in the UK was first adjusted to 2023 levels of prevalence using a calculated historical growth rate from 2011 - 2012. The prevalence was then split by the sub-categories across the devolved nations. The total proportions of these sub-population splits are in the Technical Appendix 1.

As shown in Figure 3, the asthma population in the UK was split into the following subcategories:

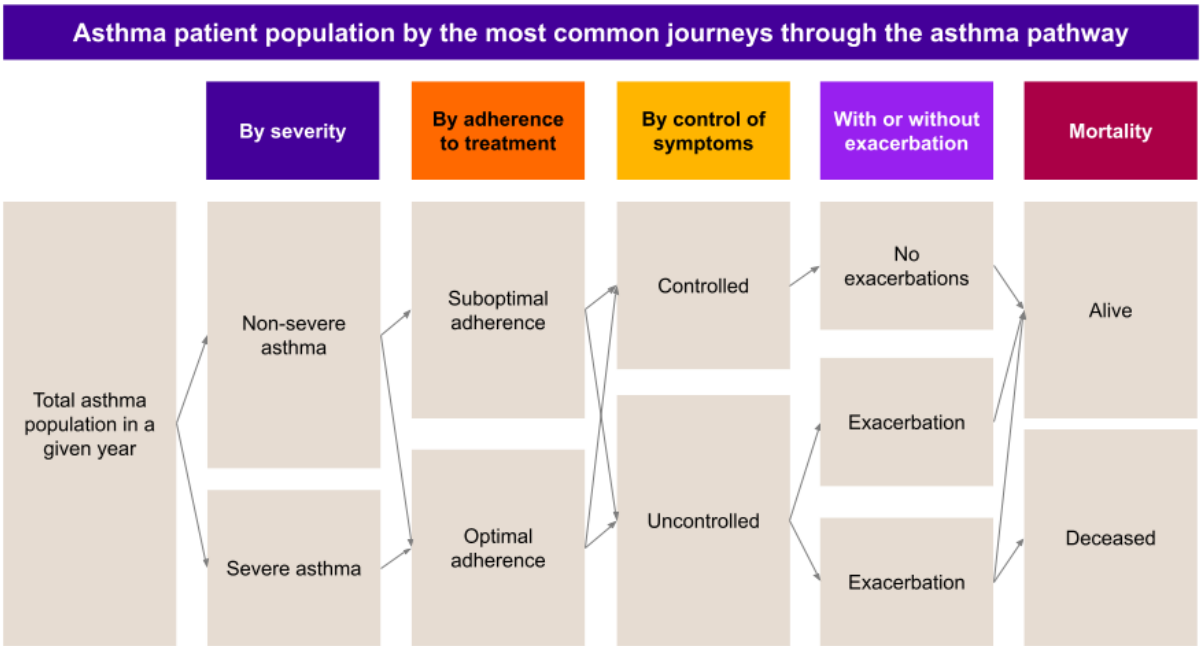
Severity: The population is first split into non-severe and severe asthma patients. Severe asthma is defined as uncontrolled asthma despite a patient's adherence to maximal optimised high dose medication.[32] Non-severe asthma is used to distinguish patients from severe asthma patients. Both severe and non-severe asthma may be poorly controlled.

1. **Adherence to treatment:** Similarly, the extent of which patients adhere to their treatment plan is split. Optimal adherence is defined as at least 80% adherence to a treatment plan, and sub-optimal adherence is defined as less than 80% adherence.[33]
2. **Control of asthma:** Patients are split into two categories of asthma control. Well-controlled asthma patients who are not significantly disabled by symptoms and uncontrolled asthma patients who experience a worsening of symptoms called an exacerbation that will usually necessitate medical intervention.
3. **Exacerbations:** Uncontrolled asthma is also then split into three different categories of exacerbation.
    a. Firstly, asthma patients who only experience a mild worsening of symptoms meaning they don't have an exacerbation.
    b. Secondly, patients who self-manage an exacerbation through a reliever inhaler.
    c. Thirdly, patients who experience an exacerbation requiring secondary care usage such as a hospital or an ambulance.

[32] Global Initiative of Asthma, Global strategy for asthma management and prevention, 2022
[33] For the purposes of this analysis, severe asthmatics are adherent to treatment plans in line with GINA guidelines. However, it is highlighted that

4. **Mortality:** A proportion of asthma patients experiencing an exacerbation do not survive.

Figure 3: Split of the asthma population in the model[34]



The existing literature that split the total UK asthma population into these sub-categories considered several intersectional factors. In many cases, they needed to consider the likelihood of one sub-categories affecting the downstream sub-categories. Some examples include:

- Non-severe asthma patients more often have suboptimal adherence to treatment than not;[35]
- Sub optimally adhering patients are more likely to have uncontrolled asthma;[36]
- Severe asthma patients are more likely to experience exacerbations than non-severe asthma patients.

[34] Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022
[35] Murphy et al. Identifying non-adherence with asthma medication and the relationship to clinical outcomes amongst adults with difficult-to-control asthma. (2009)
[36] Starobin et al. Asthma control and compliance in a cohort of adult asthmatics: first survey in Israel. (2007)

2.4 Assessing current costs of asthma in 2023

This section presents the current costs of asthma in the UK for the year 2023, without considering any intervention of changes. The results presented are estimated through calculations that have been done within the quantitative model. 2023 has been chosen as it is the most current year. The costs presented in order are direct costs, then indirect costs.

Direct costs

As Figure 4 shows, NHS costs, the direct impacts of GHG emissions (from patient travel, inhaler use and operation of healthcare facilities) and patient travel costs were modelled for the total asthma population.

Figure 4: Components of direct costs of asthma

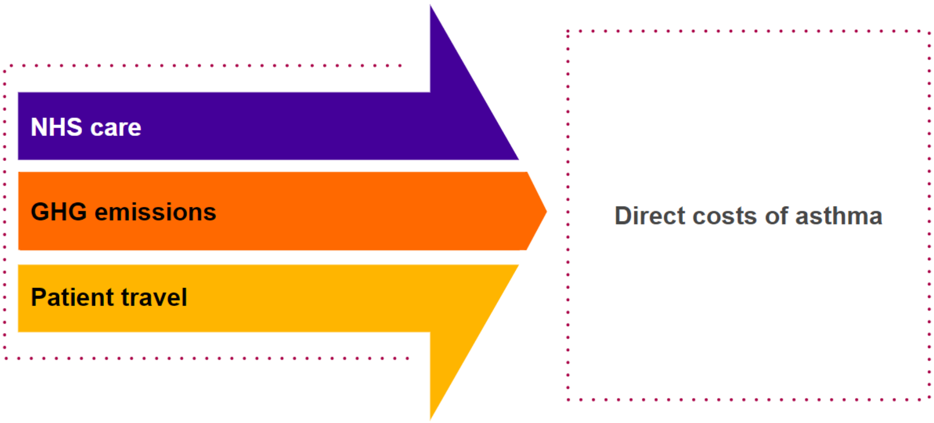
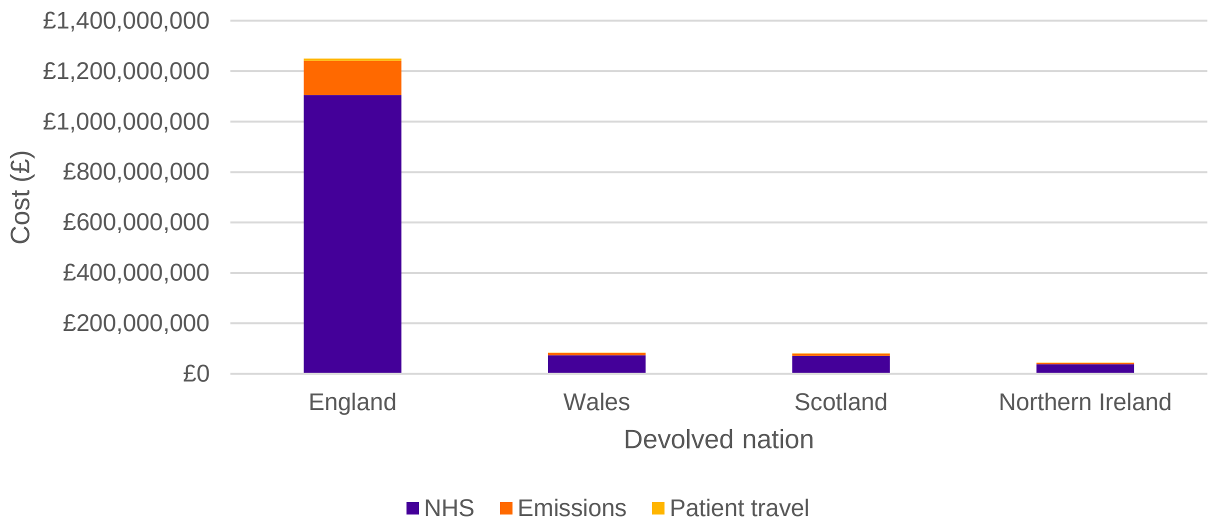


Figure 5 shows the estimated cost expressed in monetary values for the year 2023 for UK adults with asthma. The majority of the direct costs associated with asthma are NHS costs. These NHS costs include the cost of primary care and medication during the diagnosis and maintenance stages, as well as secondary care during select exacerbations.[37] The total direct cost of asthma in the UK for 2023 is £1.5 billion. NHS costs account for approximately £1.3 billion of total direct costs.

The estimated total direct cost of asthma in the UK in 2023 is £1.5 billion.

[37] Only the cost of new asthma diagnoses in 2023 are considered

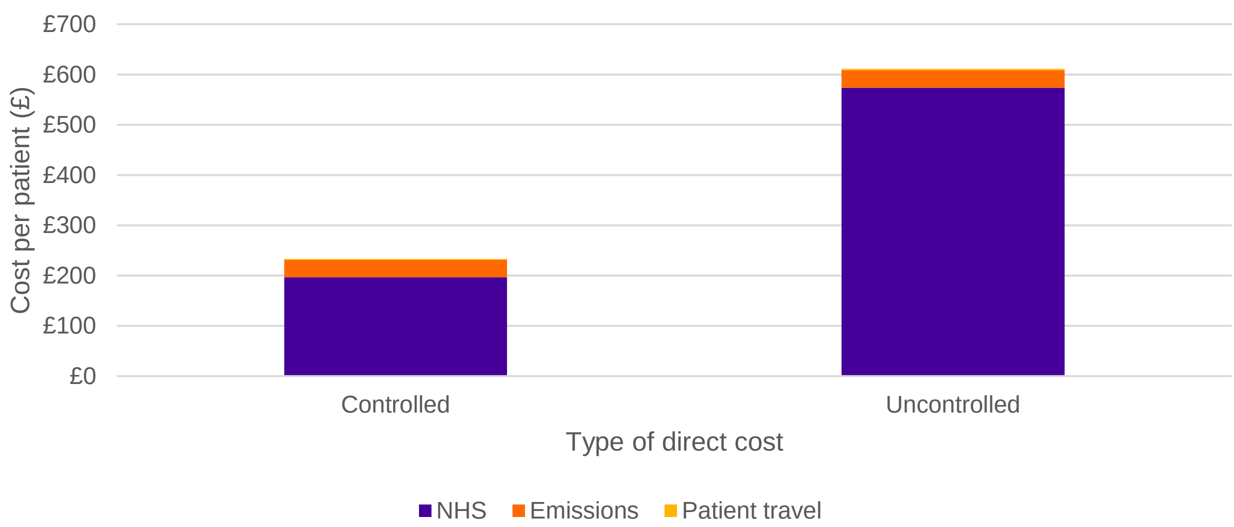
Figure 5: Estimated direct costs of the UK asthma population in 2023 (£) by devolved nation



As shown in Figure 5, England accounts for the most direct costs at £1.2 billion. The same patient costs have been applied across the devolved nations without accounting for differences that may occur in actual costs across the different regions.

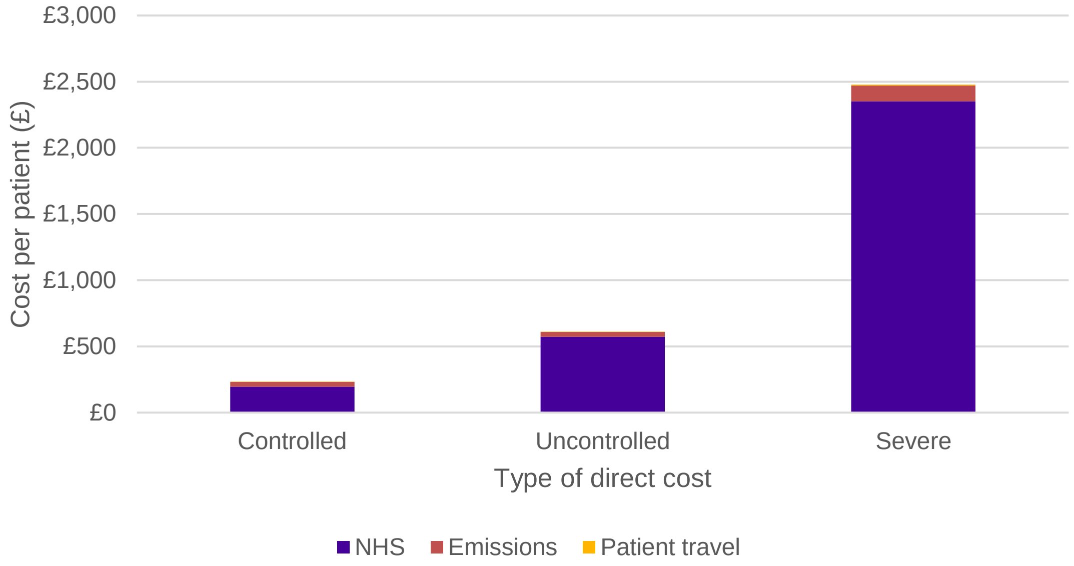
As part of the direct costs analysis, the impact of all patient travel and inhaler emissions across all stages of asthma as well as the emissions emitted by healthcare sites during appointments. The total impact of GHG emissions in 2023 for our analysis is estimated to be £158 million when monetised.

Figure 6: Average non-severe patient direct costs by level of asthma control in 2023 (£)



As shown in Figure 6, the differences between the costs incurred by uncontrolled and controlled UK non-severe asthma patients in 2023 were considered. Patients with non-severe uncontrolled asthma on average cost 62% or £378 more per patient when converted to monetary values than those with controlled asthma. Uncontrolled non-severe asthma patients incur more costs than controlled asthma patients because they are more likely to have exacerbations, have unplanned GP visits, and use secondary care as well.

Figure 7: Total per patient direct costs by controlled and uncontrolled non-severe asthma and severe asthma in 2023 (£)



As shown in Figure 7, per patient direct costs for severe asthma patients are £2477 compared to £611 for uncontrolled non-severe asthma patients.[38] Severe asthma patients incur the greatest per patient costs because they are expected to use secondary care the most, meaning they are more likely to incur costs associated with GHG emissions from ambulances, unexpected GP visits and hospital care as well. During the maintenance stage, they also require additional medication to manage their symptoms compared to the non-severe asthma population.

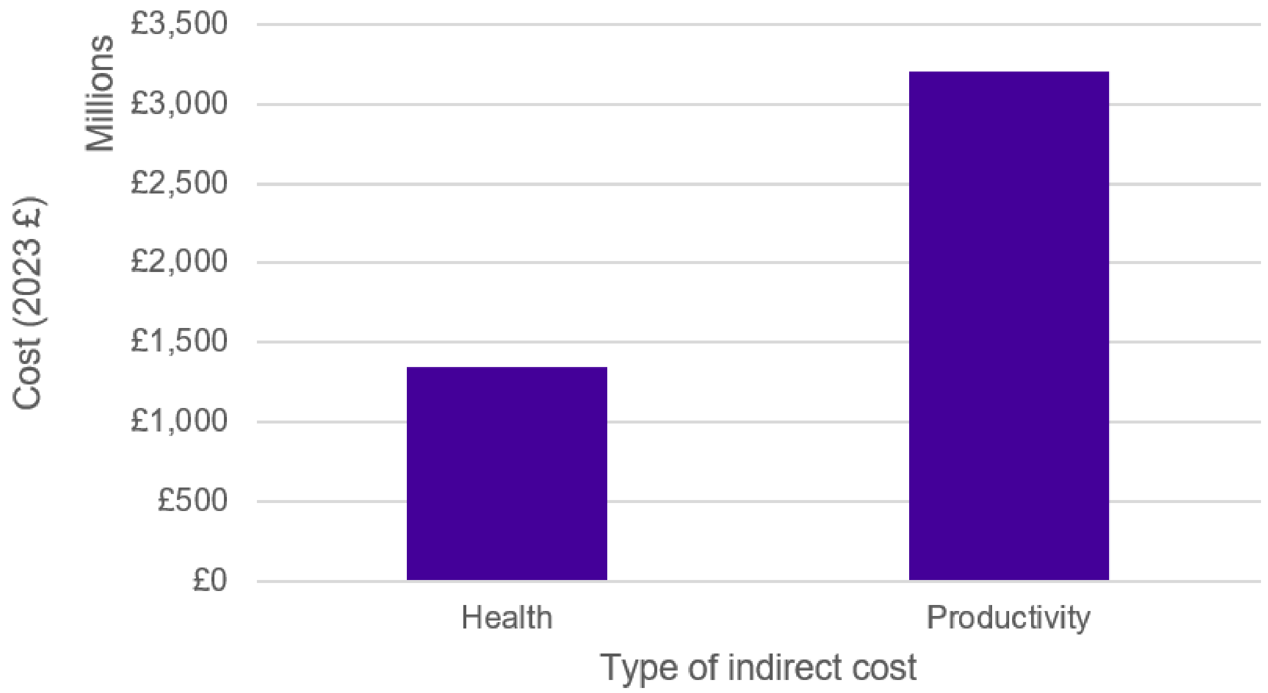
Indirect costs

Two indirect costs were modelled for this report: health quality of life costs and productivity losses. These occur only to the uncontrolled asthma population. As explained earlier in this report, controlled asthma patients are not impacted on a day-to-day basis by their symptoms. As a result, indirect costs for non-severe controlled asthma patients have not been considered.

The estimated total indirect cost of asthma in the UK in 2023 is £4.5 billion.

[38] This is on a per-patient basis and is not adjusted for the prevalence.

Figure 8: Total indirect costs of uncontrolled adult asthma patients in the UK in 2023



The indirect cost of the uncontrolled asthma when converted into monetary terms, was £4.5 billion. As shown in Figure 8, productivity costs incurred to employers are greater in monetary value than health related quality of life costs incurred to patients. Productivity costs accounted for 70% or almost £3.2 billion of the total indirect costs in 2023.

The monetary costs of exacerbations are high when accounting for health-related quality of life losses to asthma patients. Not all uncontrolled asthma patients experience an exacerbation. Not all patients who experience exacerbations survive. An asthma related death results in 2.55 years of life lost on average, which in monetary terms is equal to £47,819 lost in 2023 values.[39] [40]

On productivity, it is estimated that reduced working hours may cost UK employers £833 million in 2023 due to sick days taken from asthma symptoms or to attend a HCP appointment.[41] The median UK hourly rate of those living with asthma is lower than that of the median population. In 2023, this has a £716 million impact in terms of lower wages and fewer working hours relative to the non-asthma population.

Uncontrolled asthma patients who may also fall under a disability code have a lower probability of being employed. This leads to higher unemployment within the uncontrolled asthma population than compared to the average person in the UK. These losses are estimated to be around £783 million.

Overall, the productivity loss of the uncontrolled asthma population to employers in 2023 is £3.2 billion.

[39] Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022
[40] This paper calculates YLL using NHS methodology by comparing the average age of asthma mortality and the age of 75. The EQ-5D scores of those aged 65+ was used to reflect older patient mortality from asthma as evidenced in ONS data, which was used in the monetary calculations.
[41] This includes the assumed sick days taken during hospitalisation to avoid double counting.

Severe asthma patients have higher per patient monetary impacts compared to non-severe asthma patients, with £5298 per patient compared to £1611 on average.[42] Severe patients impact the UK economy almost £1 billion through productivity loss.

Summary

The total environmental, economic and societal impacts of the UK is estimated in 2023 to total £6 billion. They include NHS costs, patient travel costs, greenhouse gas (GHG) emissions, quality of life and productivity losses. The main driver of these total costs are uncontrolled non-severe asthma patients and their indirect costs to productivity and health related quality of life.

[42] This is on a per-patient basis and is not adjusted for the prevalence.

3.Estimating the impacts of better diagnosis and care for the asthma population in the UK

3.1 Impact analysis

Introduction to impact assessment

The economic cost of asthma can be reduced through the adoption strategies throughout the asthma patient pathway at the diagnosis and maintenance stages which reduce the usage of secondary care. Patients suffering from severe asthma have a greatly diminished quality of life, not only is their ability to carry out daily activities significantly reduced but exacerbations requiring hospitalisation are extremely disruptive and distressing for the individual.

There are significant costs associated with patient maintenance and exacerbations in asthma, so reducing the likelihood of exacerbations and use of secondary care greatly diminishes the cost of asthma on the NHS. Primary prevention is also key to reducing costs to the NHS. However, that has not been included as part of this analysis.

There are a number of interventions where evidence is strongest for chronic respiratory diseases, including asthma.[43] These intervention areas have been identified by NHS England as part of their major conditions strategy. Not all possible interventions have been modelled, but there has been focus on two aspects of the asthma patient pathway. The first area of focus was around diagnosis, and the other area of focus was around care/maintenance.

The long list of possible interventions was narrowed to model based on several criteria:

- The evidence base, and availability of data to support the modelling analysis;
- The materiality of the impacts in terms of real world feasibility;
- The causality of the intervention leading to positive impacts.

To quantify these select impacts, impact pathways are used. Impact pathways are conceptual frameworks that link the causal impacts between an activity and their intended outcomes beyond what is being delivered. They are commonly used to quantify the impacts of programs and interventions in public policy, and to structure and illustrate how certain interventions could lead to a change.

Choosing the impacts to model

The two interventions being modelled are:

- The increase in availability and usage of FeNO during asthma diagnosis to reduce false positive diagnoses, and reduce maintenance costs;
- The usage of patient medication refill data by doctors to check on and improve patient adherence - reducing the number of uncontrolled asthma patients.

To quantify the impacts of earlier diagnosis and better of asthma, the chosen impacts modelled were:

[43] NHSE, Major Conditions Strategy – Respiratory Interventions and Evidence

- Avoided NHS costs, patient travel and emissions, and treatment costs for non-severe controlled asthmatics;
- Reduced maintenance costs for the entire asthma population after adjusting for removal of non-severe controlled asthma patients.

Only the benefits have been calculated (the reduction in the costs of asthma), not the costs that would be required to implement these activities. Draft impact pathways were modelled from the long list of interventions using high level data inputs and assumptions.

Considerations

A determining factor of successful health outcomes lies directly with patient behaviours. Furthermore, these interventions would not work alone. For the impacts described to occur, there needs to be a series of integrated care touch points with the health system, a degree of patient self-management and lifestyle choices that do not actively worsen asthma symptoms.

Approaches towards area level impacts, deprivation and winter bed days

Breaking down impacts by area

There are also additional modelling components when accounting for impacts. Impacts have been apportioned to the most granular statistical areas where possible by the prevalence data. For example, in England data is aggregated from the ICB level and used with the proportion of prevalence within the UK to divide up the costs. Additional information on this approach can be found in the Appendix.

Link between cost impacts and deprivation levels

A high-level analysis of secondary care costs based on deprivation for England only was performed. Evidence suggests that quintiles of the highest level of deprivation incur greater costs than when compared to the lowest level of deprivation, and other levels of deprivation.[44] This change is observed at a secondary level and for indirect costs caused by symptoms/uncontrolled asthma. The prevalence-based impacts are then adjusted by deprivation. Impacts are adjusted on how deprived the ICBs in England are. This was estimated by ranking the ICBs by the average level of deprivation of the statistical areas that sit within them.

Winter bed days

Other components of the impact analysis are the inclusion of bed days and winter impacts. An average inpatient stay of an asthma patient who has an exacerbation that requires secondary care and admission was used to estimate the number of bed days potentially avoided in 2023.

The bed days analysis informs the impact of winter and the pressures that it puts on the health system.[45] The impact on bed days and total costs overall provides a focus on delivering the interventions effectively during the winter months to save on the bulk of costs.

3.2 Impacts of more accurate diagnosis

Increasing the availability and usage of FeNO

In this section, the impacts of more accurate diagnosis by expanding the availability of FeNO to clinicians to support the diagnosis of asthma are assessed. Despite guidelines, there is no standardised way to diagnose asthma in primary care in the NHS. NICE guidelines recommend a measure of airflow obstruction with variability

[44] Gupta et al, Persistent variations in national asthma mortality, hospital admissions and prevalence by socioeconomic status and region in England, 2018
[45] Winter bed day, Asthma and Lung UK analysis

or reversibility using a spirometry test, and a FeNO test to measure eosinophilic inflammation in the airway. However, not all spirometry is quality assured and some clinicians will use peak flow in place of spirometry.[46]

The diagnosis of asthma also leans heavily on the experience of the clinician, not just the results of the tests themselves. A clinician should ask about a patient's symptoms such as wheezing and coughing, as well as any familial history of allergies or asthma. While many tests can be used to support a positive diagnosis of asthma, no single tool can diagnose asthma reliably on its own.

A study found that 33% of asthma patients are incorrectly diagnosed as false positives following a re-evaluation of their diagnosis. The study found this proportion of patients did not exhibit any evidence of acute worsening of their asthma symptoms, reversible airflow obstruction or bronchial hyperresponsiveness after tapering the patients off their medication.

To reduce the number of false positives for asthma diagnoses, the diagnostic test must have a high specificity. The specificity of a test is its ability to designate an individual who does not have a disease as negative. This means it can tell patients who don't have asthma that they don't have asthma. A highly specific test means that there are few false positive results.[47] Sensitivity refers to a test's ability to designate an individual with disease as positive.

According to NICE, FeNO is increasingly used as a diagnostic tool in clinical practice to support diagnosis and it has a high specificity for asthma. This test measures fractional exhaled nitric oxide. This means that it measures the amount of nitric oxide gas a patient breathes out during the test. A high level of nitric oxide gas indicates that there is inflammation in the patient's airways and can indicate that an individual has asthma.

The FeNO test should not be used in isolation, and multiple guidelines indicate the importance of leaning on other diagnostic tests as part of asthma diagnosis such as spirometry, physical examination and clinical history.[48] Currently FeNO is available to 53% of GPs across the UK.[49]

Methodology

To model the impacts of improved diagnosis it required developing an impact pathway which establishes the evidence and causal link between an intervention and eventual impact, as a result the impact pathway is broken down into four stages:

1. **Activity**

As shown in Figure 9, the impacts of more accurate diagnosis by expanding the availability and usage of FeNO to clinicians to support the diagnosis of asthma are assessed. Usually, a patient will complete an expiratory airflow or spirometry test, then a bronchodilator reversibility test. There is no standard way to diagnose asthma, and a FeNO result can be used to support a positive bronchodilator reversibility, positive peak flow variability or bronchial hyperactivity test result.[50]

Currently FeNO is available to 53% of GPs across the UK, and the impacts have been modelled if this activity were to be increased across the UK to 100%.[51] It is also assumed that within the 53%, not all usage is correct. It is assumed that there is 75% correct usage within the existing availability. It is also assumed that each diagnosed asthma patient will undergo at least one FeNO test during the year 2023, in conjunction with the other usual asthma diagnostic tests. This is important as FeNO on its own does not have high sensitivity.[52] Therefore, it is

[46] NICE, Asthma: diagnosis, monitoring and chronic asthma management, 2021
[47] Health New York, Disease Screening - Statistics Teaching Tools, N/A
[48] NIOX, An introduction to international guidelines for FeNO testing
[49] Aaron et al. Reevaluation of Diagnosis in Adults With Physician-Diagnosed Asthma, 2017
[50] NICE, Asthma: diagnosis, monitoring and chronic asthma management, 2021
[51] Aaron et al. Reevaluation of Diagnosis in Adults With Physician-Diagnosed Asthma, 2017
[52] Schneider et al. Diagnostic accuracy of FeNO in asthma and predictive value for inhaled corticosteroid responsiveness: A prospective, multicentre study, 2022

assumed that FeNO is used on top of the standard diagnostic tests such as spirometry followed by a bronchodilator reversibility test.

This means that while FeNO may not directly contribute towards a positive test, it will minimise the risk of a false positive. As Schneider et al writes, FeNO measurement allows a valid ruling-in of an asthma diagnosis, whereas ruling-out of asthma is not possible.[53] This causality is considered in the analysis and is explained further in the impact results section.

2. Output

As a result of increased GP accessibility to FeNO testing, the first output is an increased number of asthma patients having a FeNO test.

3. Outcome

This leads to two outcomes that have been modelled. They are:

1. *A reduction in misdiagnosed false positives*: It is estimated that using FeNO in this manner would reduce the proportion of false positive diagnoses by 100%. This reduction also relies on adequate training and access to a full history and examination and access to quality assured spirometry.[54]
2. *A reduction in maintenance costs*: For the entire asthma population after adjusting for removal of non-severe controlled asthma patients, there would be reduced asthma maintenance costs.

4. Impacts

The impacts estimated are:

Reduction in direct costs

The reduction in misdiagnosed false positive asthma patients leads to a reduction in direct costs. Patients who are assessed to not have asthma after completing FeNO testing would no longer incur inappropriate treatment costs (including ICS usage), as well as additional reviews for asthma. They would also avoid additional travel costs associated with the respective asthma reviews. All savings would be received by the NHS, apart from patient travel, which is received by the patient directly.

Reducing maintenance costs for asthma patients

Adjusting for the asthma population after accounting for misdiagnosed false positive asthma patients, patients who undergo FeNO are estimated to incur lower maintenance costs from more tailored treatment prescriptions. All savings would be received by the NHS.

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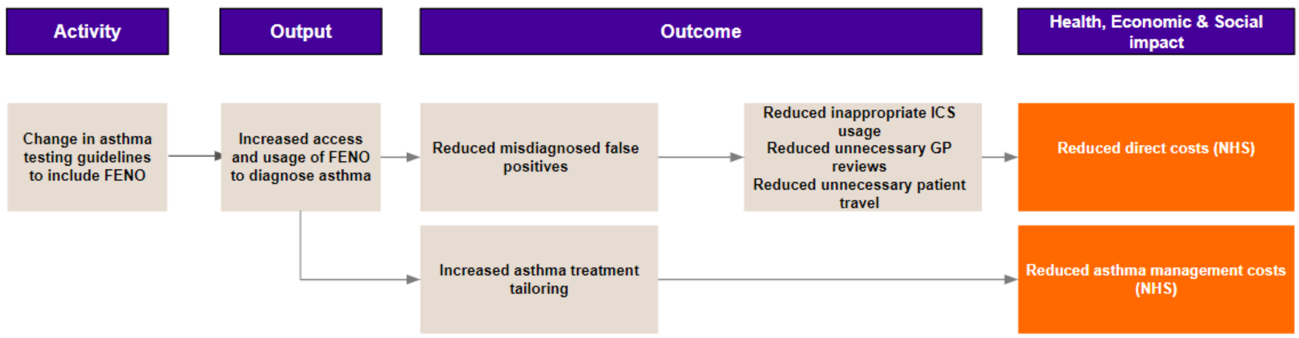
[53] Schneider et al. Diagnostic accuracy of FeNO in asthma and predictive value for inhaled corticosteroid responsiveness: A prospective, multicentre study, 2022
[54] Asthma and Lung UK assumption

Figure 9: Impact pathway of expanding FeNO usage during diagnosis and maintenance



Impact results

Reduction in direct costs

To model the counterfactual, this proportion of incorrectly diagnosed false positive asthma patients was multiplied by the prevalence of asthma across the devolved nations to obtain the number of asthma patients misdiagnosed as false positive by the devolved nations. This is shown in Table 1.

Using the asthma cohorts that were established earlier in the report, false positive asthma misdiagnosis has been assumed to only apply to controlled asthma patients who are otherwise healthy and would not have any other respiratory conditions. Patients who may otherwise have COPD or a severe form of a different respiratory disease are not considered because it is assumed that they do not have good control of their respiratory symptoms and would still continue to incur maintenance costs that are providing no benefit, and potential harm.

Figure 10: The number of false positive asthma diagnoses in the UK in 2023 by devolved nation

	England	Wales	Scotland	Northern Ireland
Number of optimal controlled patients misdiagnosed as false positive by devolved nation	296,969	19,898	19,076	10,254
Number of suboptimal controlled patients misdiagnosed as false positive by devolved nation	460,671	30,867	29,591	15,907

The counterfactuals are broken down by the cohorts and by the devolved nations for this analysis to find the total number of optimal controlled patients and suboptimal controlled patients misdiagnosed as false positives by the devolved nations.

Figure 11: The cost of false positive asthma diagnoses in the UK in 2023 by stage of asthma

	Maintenance costs	Emissions cost	Travel cost
Cost of optimal controlled asthma patient misdiagnosed as false positive	£219	£41	£1.92
Cost of suboptimal controlled asthma patient misdiagnosed as false positive	£146	£28	£1.92

Assuming that diagnostic costs have already been incurred by misdiagnosed false positive asthma patients, the maintenance costs of optimal controlled patients and suboptimal controlled patients are shown in Figure 11. They are £219 and £146 per patient respectively. As shown in Figure 12, multiplying this together provides the total costs of false positive diagnoses.

Figure 12: The cost of false positive asthma diagnoses in the UK in 2023 by devolved nation

Cost	England	Wales	Scotland	Northern Ireland
Total cost of optimal controlled patients misdiagnosed as false positive by devolved nation	£65,065,921	£4,359,735	£4,179,544	£2,246,735
Total cost of suboptimal controlled patients misdiagnosed as false positive by devolved nation	£67,288,784	£4,508,677	£4,322,331	£2,323,490

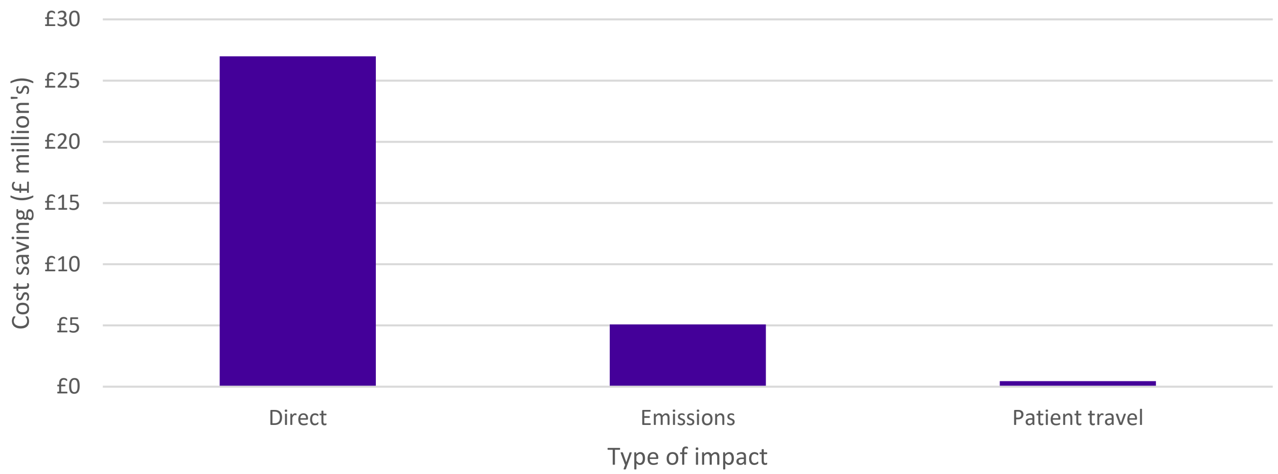
Applying an assumption from the Primary Care Respiratory Society that 75% of FeNO consumables are actually used (i.e. 25% optimism bias) is combined with the data from the FeNO PTF reports suggesting that FeNO actively supported diagnosis in 36% of diagnostic test applications.[55] The latter data point is an assumption that accounts for causality of FeNO during diagnosis.[56] It is estimated that 53% of GPs in England currently have access to FeNO testing in 2023 but that proper use is only currently 75%.[57] For the purposes of this analysis, this has also been applied across the other devolved nations of the UK in lieu of other available data.

Optimal controlled patients account for more costs per patient during maintenance. This is because of their optimal adherence to treatment, which means they are taking their treatment and medication options more often and will need to replace them more often. Taking into account the costs and adjustments, the total savings of avoiding false positive asthma diagnoses through FeNO total £32 million in 2023 in the UK as shown in Figure 13.

Avoiding false positive asthma diagnoses through FeNO could save £32 million in 2023

[55] This causality is also attributed to lower maintenance costs in addition to diagnostic applications in lieu of an appropriate proxy.
[56] Primary Care Respiratory Society, FeNO National Programme Impact Report, 2023
[57] Primary Care Respiratory Society, FeNO National Programme Impact Report, 2023

Figure 13: Total impact savings of avoiding false positive asthma diagnoses through FeNO in the UK in 2023



Reducing maintenance costs for asthma patients

Evidence on the cost effectiveness of FeNO testing for asthma diagnosis and maintenance has found a reduction in maintenance costs for diagnosed asthma patients.[58] In practice, FeNO may lead to an increase or decrease in medication costs but ultimately maintenance costs will be reduced by less follow up and better control of asthma symptoms as well as more constructive dialogue about the role of controller/preventer medication in suppressing eosinophilic inflammation and controlling symptoms/preventing exacerbations.

The management model as described by Price et al evaluated the cost-effectiveness of NIOX MINO, a FeNO tool compared with standard guidelines for the management of asthma. Patients in their model were assumed to visit their GP four times a year.[59] The model used for this analysis assumes at least one visit in the year of 2023 to realise the impacts.

For the purposes of this analysis, the Price et al. model results found costs savings of £341 and £553 for the management of non-severe and severe asthma over one year. The original cost savings from Price et al. have been converted into a percentage saving to transfer the cost reductions.

The reduced asthma management costs are then multiplied within this report's model against the asthma population in the UK to determine the maintenance cost savings for asthma as shown in Figure 14.

Optimising asthma treatment using FeNO could save £114m in 2023

[58] Price et al, Measurement of exhaled nitric oxide concentration in asthma: a systematic review and economic evaluation of NIOX MINO, NIOX VERO and NObreath, 2008
[59] As indicated in the costs section, patients are assumed to attend asthma reviews once a year in this model instead.

Figure 14: Total cost savings of reduced maintenance costs from FeNO monitoring

	England	Wales	Scotland	Northern Ireland
Total	£97,903,257	£6,559,997	£6,288,867	£3,380,612
Total saving	**£114,132,734**			

3.3 Impacts of better care

Increasing the usage of patient refill data to influence patient adherence to treatment

Research has shown that the majority of patients with asthma with treatment failure have an associated lack of inhaler adherence. Furthermore, studies have shown that in children referred to tertiary care with severe asthma, adherence with prescription collection was below 80% in over half of the cohort.[60] This can lead to increased unplanned secondary care, use of the provision of oral corticosteroids, and in some cases, death. Furthermore, exacerbations can reduce lung function and increase time off school/work.[61]

Effective asthma management is also reliant on patient behaviour as much as it is on clinical activities and guidelines. However, there is strong evidence to show that patients who have optimal adherence to treatment have a higher likelihood of asthma control.[62] Better control of asthma is associated with fewer exacerbations and by extension, usage of secondary care services.[63]

For the purposes of this analysis, it is assumed that during reviews, clinicians assess patient adherence. While clinicians can assess this based on their clinical judgement of patient symptoms, or through verbal assessment, this can be inconsistent because patients may not be truthful about their adherence to treatment. Routine assessment of a patient's adherence remains a primary option in assessing their asthma maintenance of symptoms. This model presents the case as to why using patient refill data as a measure of adherence would be better than relying on patient's telling clinicians of their usage.

Methodology

To model the impacts of increasing the usage of patient refill data to influence patient adherence to treatment, an impact pathway was developed. It is explained in the four stages below.

1. **Activity**

The activity defined is a change in guideline which encourages the access of detailed patient refill data to be used routinely for patient adherence monitoring.

2. **Output**

As a result of the change in guideline, more GPs will routinely use refill data to influence patient treatment adherence.

3. **Outcome**

[60] Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022
[61] Potential Limited, The economic cost of uncontrolled asthma, 2021
[62] Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022
[63] Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022

The increased number of GPs accessing refill data routinely and in a meaningful manner will increase patient treatment adherence. As shown in Figure 15, clinicians could review pharmacy refill data to make judgements on an asthma patient's adherence to treatment. These records could indicate their maximum level of treatment adherence in patients, a proxy for their ingestion and daily usage.[64] Evidence shows that clinicians who elect to view a patient's detailed adherence information was linked with 35.7% higher adherence in that patient.[65] Greater clinical usage of patient refill data to influence treatment adherence in turn reduces the number of uncontrolled asthma patients within the asthma population.

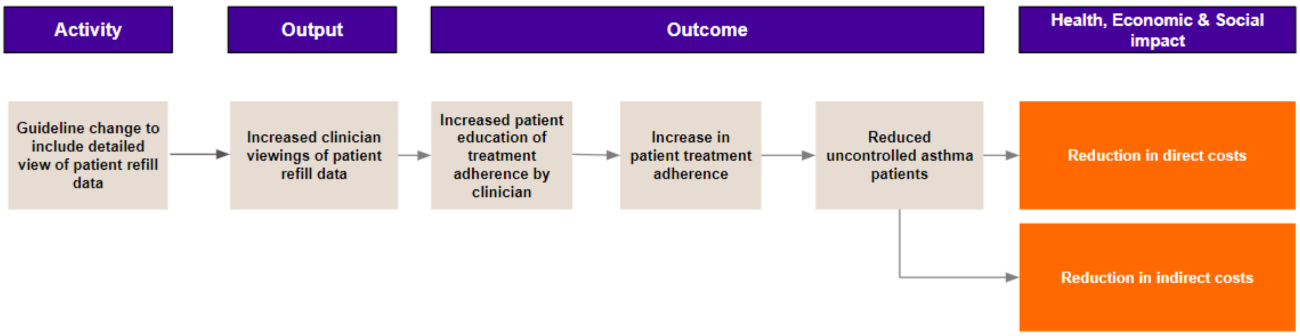
4. Impact

Switching over uncontrolled asthma patients to optimally adhering patients increases the chances of them being controlled. As shown in Figure 15, the outcomes result in direct, and indirect cost savings. These include all direct and indirect costs that were modelled in the cost section of the analysis at all diagnosis, maintenance and secondary stages of asthma, as well as patient travel and emissions costs.

By switching populations from suboptimally adhering non-severe asthma population to optimally adhering non-severe asthma, there will be fewer deaths from uncontrolled asthma and also lower maintenance costs as it was established earlier that better control of asthma leads to a lower risk of exacerbation, and by extension asthma associated deaths.

Because optimally adhering asthma patients are less likely to be uncontrolled, there are fewer indirect impacts. There are also reduced emissions costs avoided from secondary care and reliever inhalers as well as reduced patient travel costs.

Figure 15: Impact pathway of using patient refill data to increase patient treatment adherence



Impact results

As shown in Figure 16, the total number of non-severe asthma patients was calculated, after being adjusted for the removal of false positive asthma patients.[66]

Figure 16: Calculating the number of asthma patients by adherence adjusted for reduced false positive

	England	Wales	Scotland	Northern Ireland
Number of current optimal patients non-severe asthma patients	1219607	81720	78342	42113

[64] Eakin et al, Improving Patient Adherence with Asthma Self-Management Practices: What Works?, 2012
[65] Eakin et al, Improving Patient Adherence with Asthma Self-Management Practices: What Works?, 2012
[66] This analysis is not adjusted for the number of false negatives.

Number of current sub-optimal patients non-severe asthma patients	2285879	153165	146835	78932
Total number of non-severe asthma patients	3505486	234885	225177	121045

As shown in Figure 17, this total number of non-severe asthma patients is adjusted for after the introduction of patient refills. This results in a revised asthma population with more optimally adhering non-severe asthma patients than before.

Figure 17: Calculating the number of asthma patients by adherence after introducing patient refills

	England	Wales	Scotland	Northern Ireland
New number of optimal patients non-severe asthma patients	1,747,694	117,104	112,264	60,348
New number of sub-optimal patients non-severe asthma patients	1,932,049	129,457	124,106	66,714

As a result, Figure 18 shows the savings by switching the populations from sub-optimally adhering to optimally adhering. In terms of patient refills, it is assumed that 4% of GPs are proactively using this data in detail even though it is available to all clinicians. However, in 2023 if there had been a revision to treatment guidelines it is assumed that of the remaining GPs not using this already, 75% would use this feature to account for uptake.[67]

Figure 18: Total UK cost savings in 2023 from patient refills by types of impacts[68]

	England	Wales	Scotland	Northern Ireland
Direct	£7,082,938	£474,591	£454,976	£244,575
Indirect	£243,643,345	£16,325,295	£15,650,559	£8,413,036
Emissions	-£893,447	-£59,865	-£57,391	-£30,851
Patient travel	£370,568	£24,830	£23,804	£12,796
Total	£250,203,403	£16,764,851	£16,071,948	£8,639,556

3.4 Total impacts of both interventions

As shown in Figure 19, adding together the impacts of the interventions (FeNO and patient refills) estimates the total amount saved by the UK by the devolved nations.

[67] Asthma and Lung UK assumption and in line with FeNO uptake assumptions
[68] There are minor impacts to emissions due to more optimally adhering patients

Figure 19: Total impact savings from the two asthma interventions in 2023

	England	Wales	Scotland	Northern Ireland
Total FeNO	£125,793,421	£8,428,774	£8,080,407	£4,343,663
Total refills	£250,203,403	£16,764,851	£16,071,948	£8,639,556
Total	**£375,996,824**	**£25,193,625**	**£24,152,355**	**£12,983,218**

As shown in Figure 19, England accounts for over £375 million of the total impact savings due to the size of their prevalence. Similarly, the direct impacts are also the largest in England. Direct impacts make up the majority of savings, accounting for £149 million of the total £438 million that could be saved in 2023.

Better care and diagnosis could save £438 million in 2023 in England

Figure 20: Total impact savings from the two asthma interventions by devolved nation and by type of saving in 2023

	England	Wales	Scotland	Northern Ireland
Direct	£128,125,106	£8,585,008	£8,230,184	£4,424,176
Indirect	£243,643,345	£16,325,295	£15,650,559	£8,413,036
Emissions	£3,464,510	£232,139	£222,545	£119,630
Patient travel	£763,862	£51,183	£49,067	£26,376

3.5 Bed days and winter impacts analysis

As part of this analysis, the impact of the patient refills on bed days in the NHS, and how this might occur over winter were modelled. To calculate the baseline level of bed days, it was assumed all the hospitalisations within the model had an average length of stay of three days.[69] Multiplying these together gives us the total number of bed days expected in 2023. The usage of FeNO during reviews of asthma lowers the risk of hospitalisation but this has not been modelled this in detail.[70]

Increasing patient adherence was modelled to switch the population of suboptimal adhering asthma patients into the adhering population. Adhering patients are more likely to be controlled. As controlled asthma patients are

[69] Soyiri et al. Asthma Length of Stay in Hospitals in London 2001–2006: Demographic, Diagnostic and Temporal Factors, 2011

[70] Price et al, Measurement of exhaled nitric oxide concentration in asthma: a systematic review and economic evaluation of NIOX MINO, NIOX VERO and NObreath, 2008

less likely to have exacerbations and require secondary care, this achieves savings of bed days on its own. The revised lower number of bed days is indicative of the bed days avoided in the UK in 2023 as shown in Figure 21.

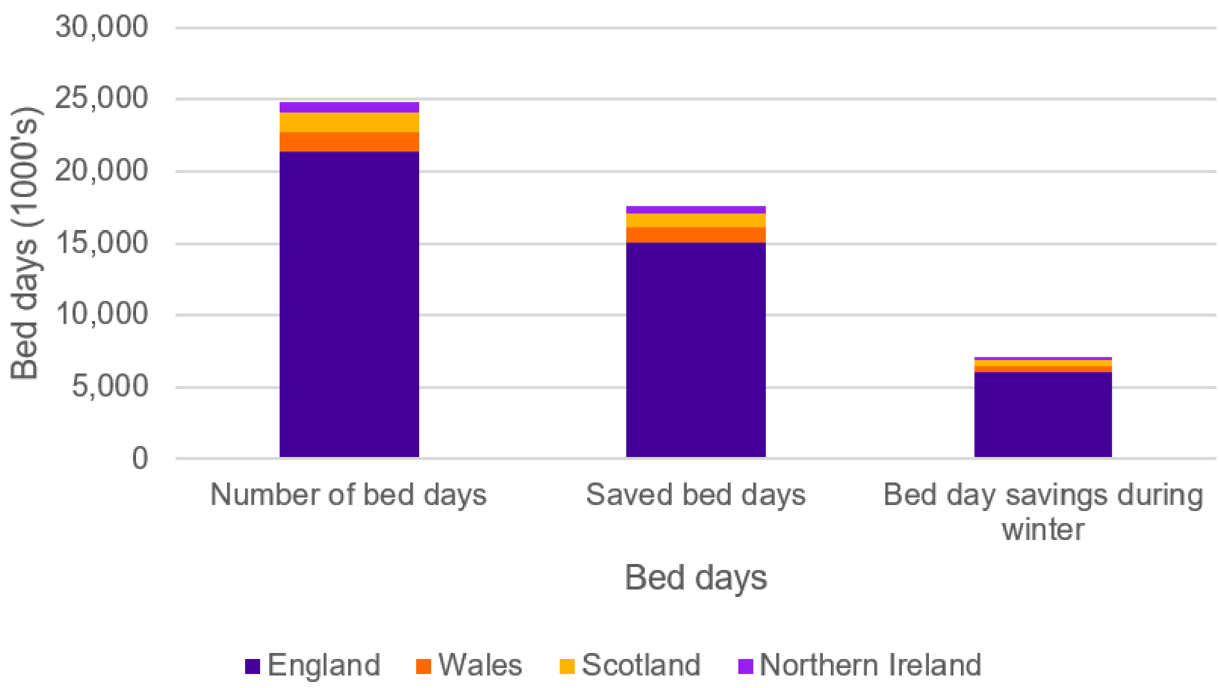
Figure 21: Expected number of total bed days avoided and during winter in 2023

Bed days	England	Wales	Scotland	Northern Ireland
Current number of bed days	21,316	1,428	1,369	736
Revised number of bed days	6,225	417	400	215
Bed days avoided	15,091	1,011	969	521
Bed day avoided during winter	6,036	404	388	208

Asthma and Lung UK data and analysis on hospital admissions during the year show that 40% of bed day savings would occur during winter.[71] This is shown below in Figure 22.

[71] Asthma and Lung UK analysis

Figure 22: Current and revised number of hospital bed days after intervention in the UK in 2023



3.6 Breaking down the impacts by areas and deprivation

A method was also developed to distribute the impact savings across the different regions of the UK, as well to adjust for areas of deprivation.

Dividing out impact savings by statistical areas

Prevalence data for asthma in the UK exists with varying levels of disaggregated statistical areas. The cost savings are firstly distributed based on the prevalence of the most granular statistical area available. For example, in England the impact savings are distributed by Integrated Care Board areas based on the prevalence. Only direct NHS impact savings have been distributed.

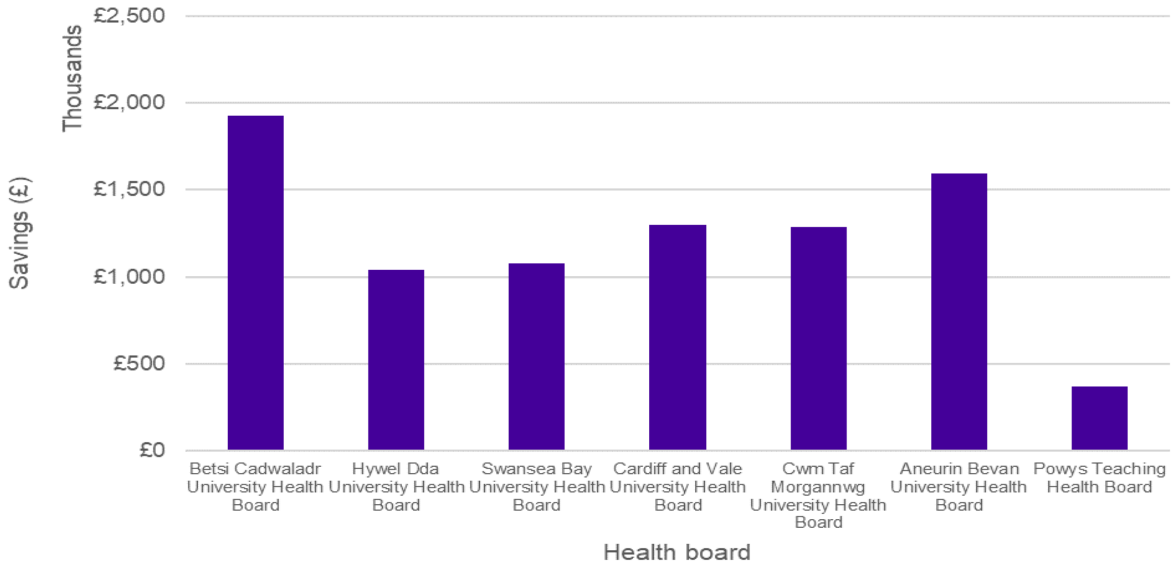
Figure 23: UK population of asthma and disaggregated statistical area used by devolved nation (2023)

Devolved nation	Prevalence	Disaggregated statistical area used
England	3,745,077	Integrated Care Board
Wales	241,031	Health Board
Scotland	240,567	NHS Regional Board
Northern Ireland	131,949	Local Commissioning Groups

NHS North East and North Cumbria Integrated Care Board, NHS Greater Manchester Integrated Care Board and NHS Cheshire and Merseyside Integrated Care Board are where the three areas of greatest savings in England could be achieved. These results are further explored in the deprivation sub-chapter below.

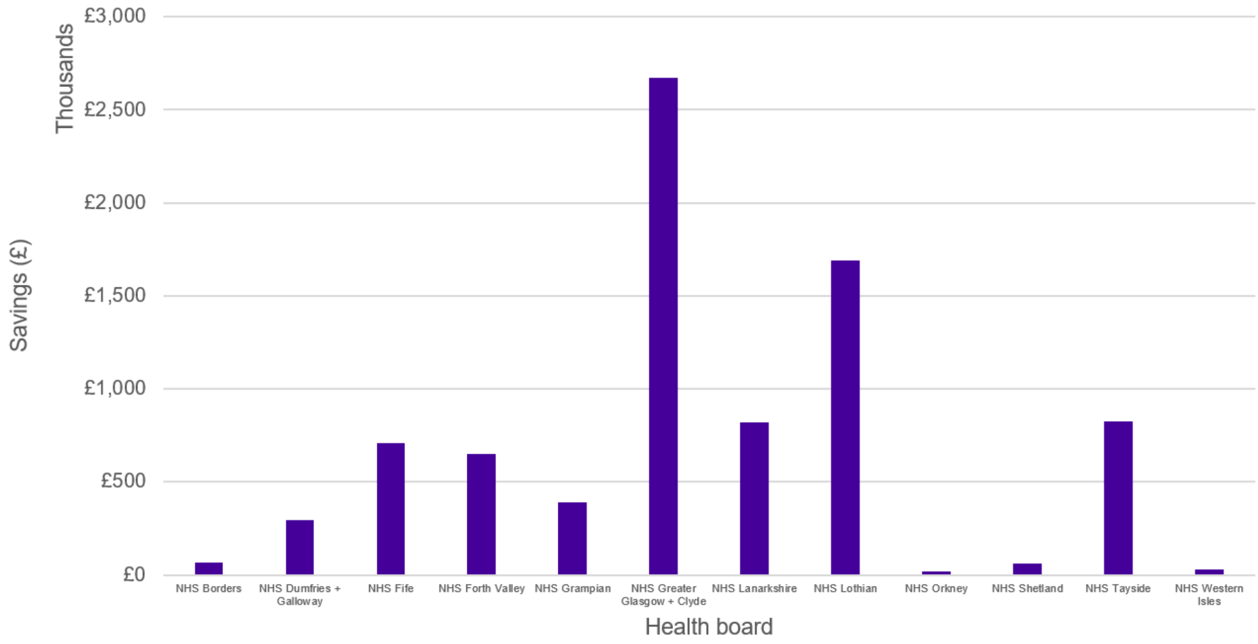
As shown in Figure 24 below, Betsi Cadwaladr University Health Board, Aneurin Bevan University Health Board and Cwm Taf Morgannwg University Health Board are the three areas of greatest savings in Wales could be achieved. Potential direct NHS savings in these areas could be £1.9 million, £1.6 million and £1.3 million respectively.

Figure 24: Direct Wales NHS impact savings by Health Board (2023)



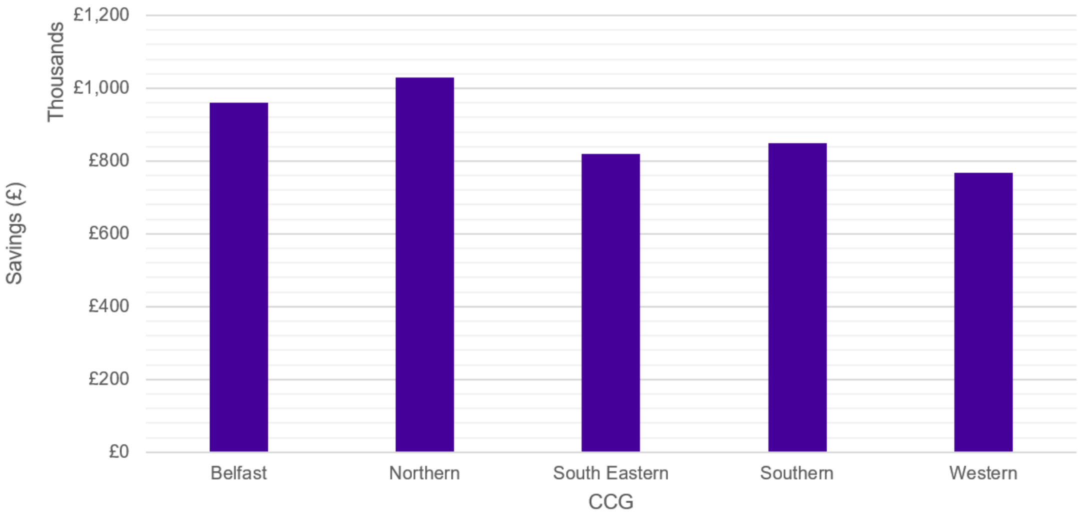
As shown in Figure 25 below, NHS Greater Glasgow + Clyde, NHS Lothian and NHS Tayside are the three areas of greatest savings in Scotland that could be achieved. Potential direct NHS savings in these areas could be £2.7 million, £1.7 million and £0.8 million respectively.

Figure 25: Direct Scotland NHS impact savings by Regional Board (2023)



As shown in Figure 26 below, Northern, Belfast and Southern are the three areas of greatest savings in Northern Ireland that could be achieved. Potential direct NHS savings in these areas could be £1 million, £0.9 million and £0.8 million respectively.

Figure 26: Direct Northern Ireland NHS impact savings by Local Commissioning Groups (2023)



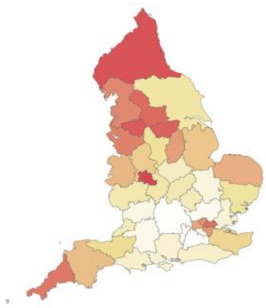
3.7 Using deprivation to distribute cost impacts in England

Deprivation is a driving factor of health inequality. Health inequality refers not only to the differences in care that people receive but the outcomes in health due to a range of determinants.[72] The UK has seven areas of deprivation in order to calculate their overall deprivation factor. These are:

- Income;
- Employment;
- Crime;
- Barriers to housing;
- Living environment;
- Health;
- Education.[73]

To reflect this in the analysis, a deprivation adjustment for secondary care within NHS impacts and for indirect impacts was done. To caveat this, the model does not account for higher prevalence in areas that are more deprived due to these deprivation factors. This analysis is an attempt to further highlight this disparity. There is evidence to suggest that the areas with the most deprivation have more asthma related hospital admissions, and are more likely to receive severe asthma symptoms.[74] Severe symptoms have been used as a proxy for uncontrolled asthma based on the questionnaire used in the source. England was the only devolved nation that had a deprivation assessment due to the availability of data.

Figure 27: Map of England by ICB deprivation (2023)

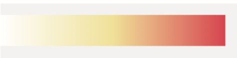


As shown in Figure 27, deprivation is more concentrated in the north of England.[75] The darker colours indicate a higher level of deprivation in that area. It is important to note that ICBs differ in the size of their populations and they all function differently. The colours indicate that some ICBs have a higher concentration of deprivation than others, reflecting previous analysis in this area.[76]

Less than 1% of neighbourhoods in Surrey Heartlands are in the most deprived fifth of the neighbourhoods nationally, compared with nearly 50% in Birmingham and Solihull as shown in Figure 28.[77]

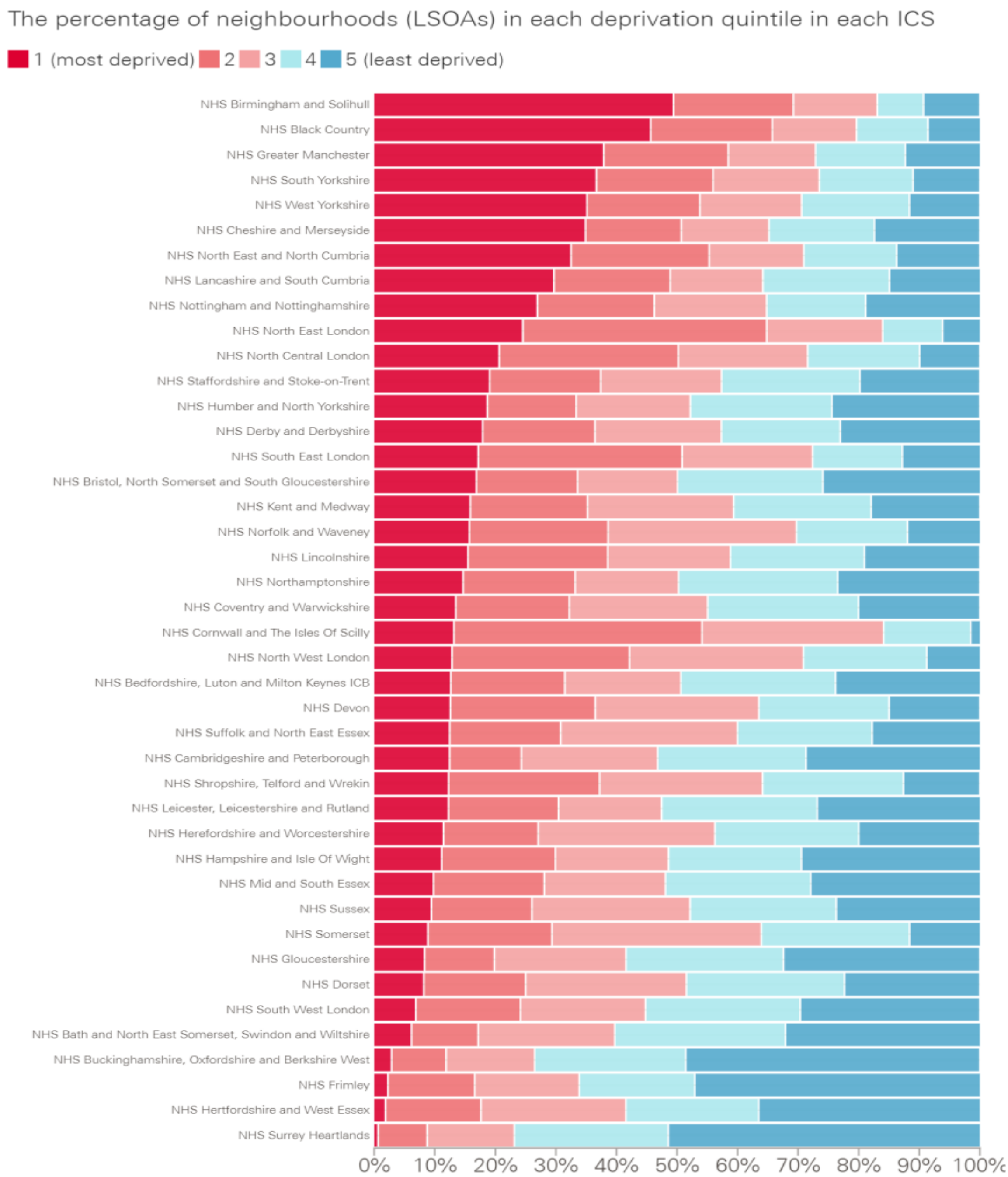
(Asthma and Lung UK analysis, 2023)

Gradient of least to most deprived (left to right)



[72] NHS England, Deprivation
[73] NHS England, Deprivation
[74] Gupta et al, Persistent variations in national asthma mortality, hospital admissions and prevalence by socioeconomic status and region in England, 2018
[75] The most deprived areas are shown in red. The least deprived areas are shown in white. This figure uses a colour gradient.
[76] Dunn et al, Integrated care systems: what do they look like?, 2022
[77] Dunn et al, Integrated care systems: what do they look like?, 2022

Figure 28: Example of a deprivation chart of ICS by their Lower Layer Super Output Area (LSOAs)[78]



Deprivation analysis approach

1. To reflect this in the model for England, each area of deprivation in England was ranked, with 1 being the most deprived.
2. The areas (LSOAs) were aggregated to an ICB level, then the ICBs were ranked based on the average ranking of the underlying areas of deprivation within them.
3. There is evidence in England to suggest that people with asthma living in areas of greater deprivation are more likely to be admitted into hospital, or suffer more severe symptoms.[79]

[78] Dunn et al. [Integrated care systems: what do they look like?](), 2022
[79] Gupta et al. [Persistent variations in national asthma mortality, hospital admissions and prevalence by socioeconomic status and region in England](), 2018

4. Each ICB was assigned a quintile, and this was used to convert the portion of secondary care and indirect impacts. Each ICB represented a multiplier that increased or decreased impacts depending on the level of deprivation.
5. For example, ICBs in the most deprived quintiles would expect to see larger impacts. Table 12 shows two examples of this adjustment which is then fed into the direct NHS costs.

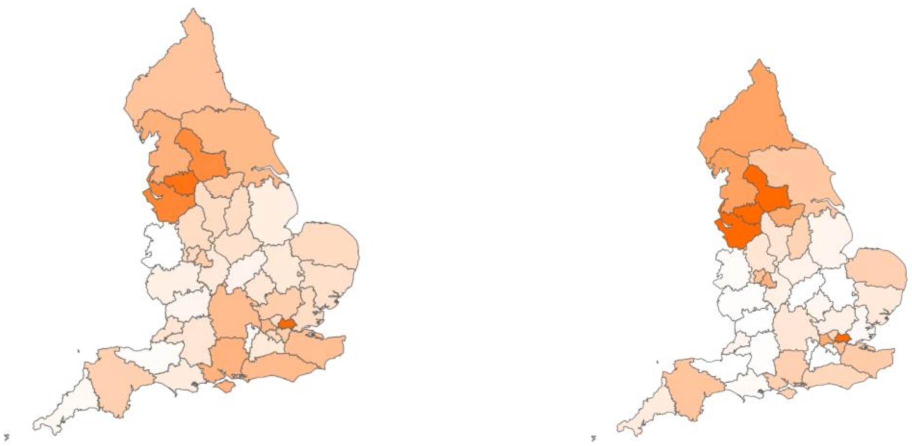
This deprivation analysis applies firstly to secondary care costs which are considered as part of the overall direct cost of asthma to the UK in 2023 and are incurred after non-self-managed exacerbations. It secondly applies to indirect costs to account for symptom control in terms of health quality and productivity.

Figure 29: Example of deprivation distribution adjustment to secondary care NHS costs in England (2023)

ICB	Deprivation quintile	Secondary care impact before deprivation adjustment	Secondary care impact after deprivation adjustment
NHS Birmingham and Solihull Integrated Care Board	Most deprived quintile	£23,821	£36,053
NHS Surrey Heartlands Integrated Care Board	Least deprived quintile	£15,528	£8,366

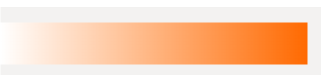
Figure 30 below shows the ICBs in England adjusted before and after deprivation for indirect impacts. The darker the colour, the larger the potential impact. The analysis suggests that the UK would expect to see the largest potential savings to the economy through a targeted focus in areas of deprivation. These areas which already have a high prevalence, are likely also to incur avoidable indirect productivity and health related quality of life impacts.

Figure 30: Comparison of indirect impacts before (left) and after (right) deprivation adjustment in England (2023)



(Asthma and Lung UK analysis, 2023)

Gradient of potential impacts before and after deprivation (left to right)



It is hoped that current integrated care pathways would effectively support the realisation of the potential impacts outlined in this report. These interventions will need to be closely monitored to effectively manage uncontrolled asthma to avoid the use of secondary care.

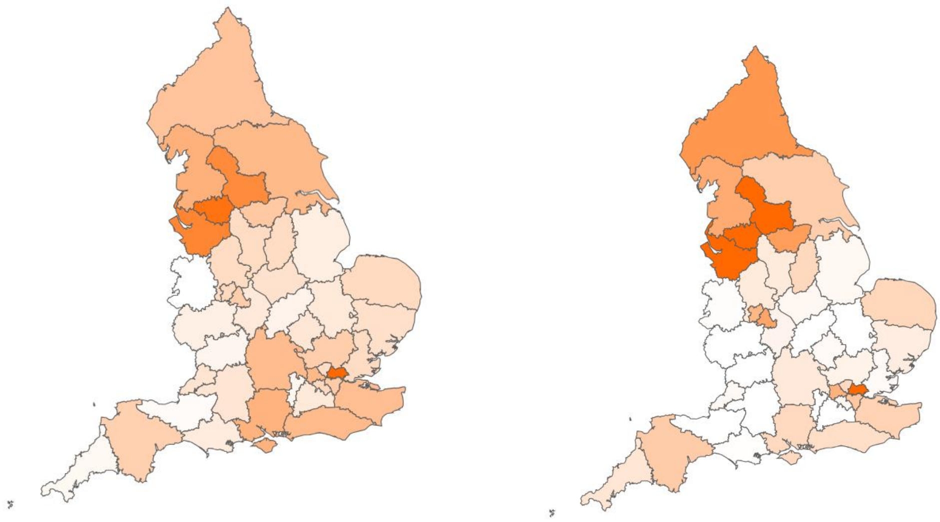
Looking at deprivation across ICBs does not provide the full picture. Even ICBs that do not appear deprived in Figure 30 above contain LSOAs (within an ICB) that rank amongst the bottom in England. ICBs will need to understand how their respective LSOAs fare in terms of deprivation to design effective and targeted ways to integrate care, and by extension introduce the interventions for asthma from this report. There are other factors not considered as part of this analysis such as workforce capacity distribution within more rural areas not shown in these figures.

Accounting for deprivation, NHS North East and North Cumbria Integrated Care Board could have £21 million in indirect cost savings in 2023

The three highest areas of indirect cost potential savings are:

- NHS North East and North Cumbria Integrated Care Board with a potential saving of £21 million;
- NHS Greater Manchester Integrated Care Board with a potential saving of £18 million;
- NHS Cheshire and Merseyside Integrated Care Board with a potential saving of £17 million.[80]

Figure 31: Comparison of secondary care impacts before (left) and after (right) deprivation adjustment in England (2023)



(Asthma and Lung UK analysis, 2023)

[80] Rounded to the nearest million

Gradient of potential impacts before and after deprivation (left to right)

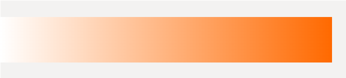


Figure 31 above shows that the three areas of highest potential secondary care savings after adjusting for deprivation are:

- NHS North East and North Cumbria Integrated Care Board with a potential saving of £82,853;
- NHS Greater Manchester Integrated Care Board with a potential saving of £78,031;
- NHS Cheshire and Merseyside Integrated Care Board with a potential saving of £68,814.[81]

Conclusion

Overall, the analysis found:

- There are significant cost savings to the NHS and the economy through better care and better diagnosis for asthma patients in the UK in 2023. There are also patient travel savings and greenhouse gas reductions as well. The total impacts (including indirect) are in excess of £430 million.
- The secondary care cost and bed day savings as part of this are likely to occur during the winter months;
- Deprivation analysis for England shows that the greatest cost saving opportunities are located in the poorest areas where patients live.

[81] Rounded to the nearest 1000

4. The cost of COPD in the UK

4.1 Context

This chapter explains the current cost of COPD in the UK by:

- Defining the clinical symptoms of COPD and grouping them in a way to be used in determining the cost of COPD in the UK;
- Outlining the stages of the COPD patient pathway that will be used within the analysis such as treatment, maintenance and exacerbation stage;
- Defining the costs that are measured within the model. They are direct NHS costs, productivity loss and QALYs;
- Explaining how the analysis model is structured and presenting the findings for the cost of COPD in the UK.

Method:

To do this a cost of illness model was built that captures the impacts of COPD on the NHS, productivity loss and Quality Adjusted Life Year (QALY) loss. To quantify the impact of non-monetary QALY values, NICE recommendations on the monetised value of QALYs were used. The estimated costs are for the year 2023 based on COPD prevalence data obtained from NHS Integrated Care Boards (ICBs), Imperial College London and Task Force for Lung Health. To ensure the model reflects the reality of COPD in the UK, information was gathered from secondary research as well as expert advice from our respiratory clinicians.

Results and conclusions:

The estimated annual economic cost of COPD in the UK is £9 billion in 2023

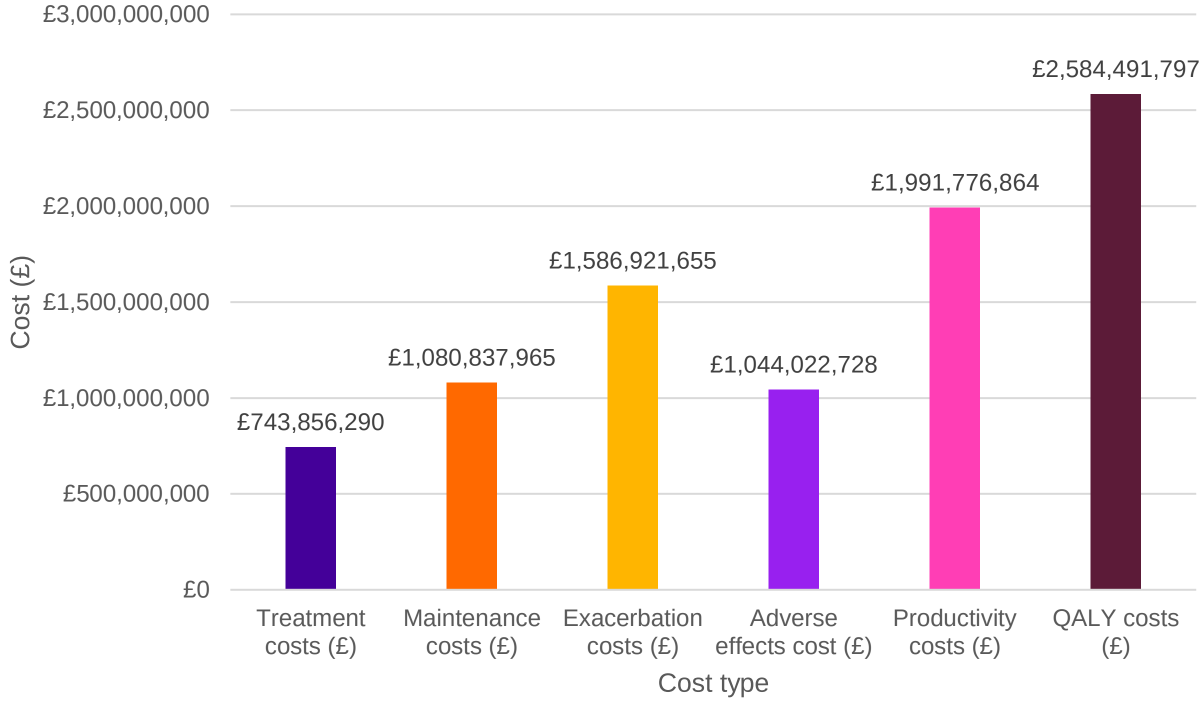
The total economic cost of COPD in the UK was estimated to be £9 billion in 2023 with England making up the majority of costs. COPD costs to the NHS account for £4.5 billion of total costs, whilst productivity costs account for £2 billion and the costs associated with quality of life is £2.6 billion. Furthermore, COPD is estimated to account for over 1.8 million annual hospital bed days with 620,000 occurring during the winter period. The total cost of COPD in England is £7.9 billion which is more than seven times the combined COPD cost of Wales, Scotland and Northern Ireland which is equal to £1.1 billion pounds.

Figure 32: Total economic cost of COPD in the UK (2023)

Country	Treatment costs (£)	Maintenance costs (£)	Exacerbation costs (£)	Adverse effects cost (£)	Productivity costs (£)	QALY costs (£)	Total cost by country (£)
England	£650,819,703	£945,653,955	£1,388,440,070	£913,443,323	£1,742,658,688	£2,261,240,788	**£7,902,256,527**
Wales	£35,179,968	£51,117,192	£75,051,934	£49,376,051	£94,199,172	£122,231,054	**£427,155,371**
Scotland	£39,569,413	£57,495,143	£84,416,250	£55,536,758	£105,952,510	£137,481,963	**£480,452,037**

Northern Ireland	£18,287,206	£26,571,674	£39,013,401	£25,666,596	£48,966,494	£63,537,992	**£222,043,364**
Total	**£743,856,290**	**£1,080,837,965**	**£1,586,921,655**	**£1,044,022,728**	**£1,991,776,864**	**£2,584,491,797**	**£9,031,907,299**

Figure 33: Total economic cost of COPD in the UK by cost type (2023)



Definition and symptoms

COPD is the name for a group of lung conditions that cause breathing difficulties such as emphysema and chronic bronchitis and can significantly limit the day-to-day activities of individuals. COPD mainly affects middle age or older adults who smoke, resulting in symptoms such as shortness of breath, a persistent cough, frequent chest infections and persistent wheezing. Breathing problems tend to grow worse over time and without appropriate treatment can result in flare ups known as exacerbations which can lead to hospitalisation.

The severity of COPD can differ significantly amongst patients, typically depending on age and their level of smoking. As a result, the Global Initiative for Chronic Obstructive Lung Disease (GOLD) has developed a ranking system to categorise COPD severity based on exacerbation frequency, exacerbation severity, level of breathlessness and the impact COPD has on the daily life of an individual resulting in a ranking from A - D outlined below:

- A: 0 - 1 exacerbations (not leading to hospitalisation), mMRC 0 - 1 or CAT < 10;
- B: 0 - 1 exacerbations (not leading to hospitalisation), mMRC ≥ 2 or CAT ≥ 10;
- C: ≥ 2 exacerbations (not leading to hospitalisation) or ≥ 1 exacerbation leading to hospitalisation, mMRC 0 - 1 or CAT < 10;
- D: ≥ 2 exacerbations (not leading to hospitalisation) or ≥ 1 exacerbation leading to hospitalisation, mMRC ≥ 2 or CAT ≥ 10.[82]

[82] GOLD, Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: 2020 report. (2020)

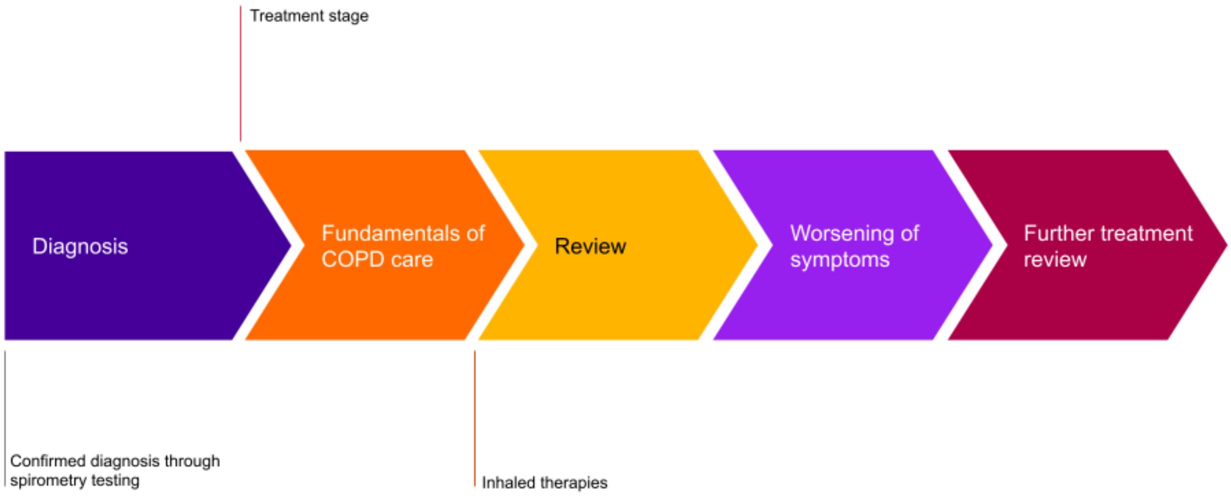
The mMRC (Modified Medical Research Council) is a scale used to measure the severity of patient dyspnea, the sensation of running out of air and of not being able to breathe as fast or deep enough.[83]

The CAT score is derived from a questionnaire offered to COPD patients to measure the impact COPD has on their day to day lives.

COPD care pathway

To model the cost of COPD, it was necessary to outline the care pathway a COPD patient should receive. By breaking down the stages of the care pathway it is possible to develop a framework to effectively cost the component that makes it up. NICE has outlined the optimal treatment pathway for an individual with a confirmed diagnosis of COPD offering a broad range of treatments which should be offered to patients along the patient pathway dependent upon severity of COPD and response to treatment:

Figure 34: COPD care pathway



Stage 1: Treatment stage

After confirmed diagnosis, the following fundamentals of COPD care should be offered to patients involving:

- Treatment and support in smoking cessation;
- Offer pneumococcal and influenza vaccinations;
- Offer pulmonary rehabilitation if indicated;
- Co-develop a personalised self-management plan;
- Optimise treatment for comorbidities.

Stage 2: Review

Inhaled therapies are then offered if:

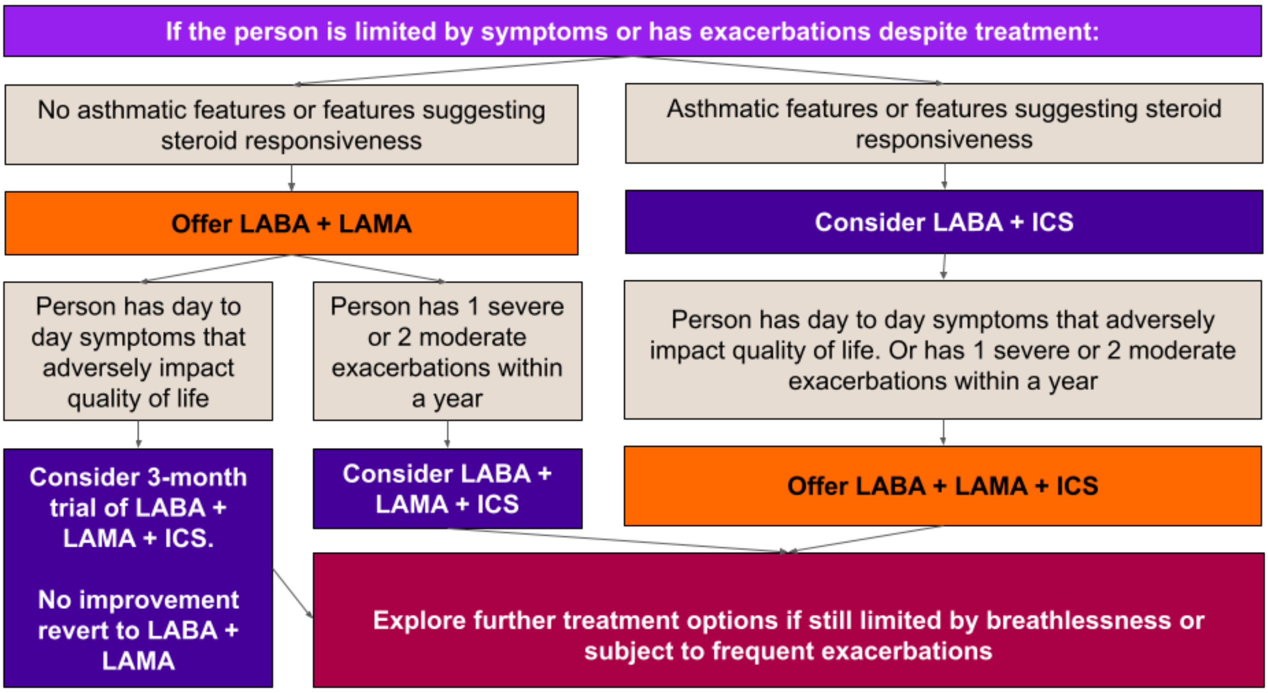
- Above interventions have been offered;
- They are required to relieve breathlessness and exercise limitation;
- Patients have been trained to use inhalers and can demonstrate appropriate technique.

Stage 3: Worsening of symptoms or nonresponsive to treatment

[83] Muhammad F. Hashmi; Pranav Modi; Hajira Basit; Sandeep Sharma, Dyspnea. (2023)

Response to treatment varies amongst individuals suffering from COPD and the health of COPD patients can deteriorate at different rates. Therefore there are a number of different treatment plans that can be offered to patients. For example, patients with no asthmatic features or features suggesting steroid responsiveness are offered a treatment combination of LABA + LAMA whilst patients with asthmatic features or features suggesting steroid responsiveness are recommended to be offered a treatment combination of LABA + ICS. Outlining the different treatment combination pathways of COPD patients is necessary to effectively model the cost of COPD treatment. Therefore, the NICE treatment recommendation framework is used, as shown below in Figure 35. Using NICE's framework it is possible to model the cost of different treatment combinations for COPD patients.

Figure 35: NICE treatment recommendation



Having identified the different stages within the COPD patient care pathway and the cost components within them it is then possible to begin modelling the costs of COPD.

4.2 Costs of COPD framework

Having outlined the COPD patient pathways, economic costs were defined as direct costs (costs to the NHS) and indirect costs (cost to productivity and quality of life).

Direct costs

NHS costs:

- Costs of medication treatment by GOLD category;
- Cost of maintenance by GOLD category;
- Cost of exacerbation through primary and secondary care;
- Cost of adverse events through primary and secondary care.

Indirect costs

Productivity

Productivity costs were defined as the lost productivity due to absence from work and the reduction in productivity whilst at work as a result of suffering from COPD.

Quality of life

Quality of life costs were defined as the Quality adjusted life years (QALYs) lost from COPD exacerbations and adverse events. A QALY is used to measure disease burden, accounting for quality and quantity of life.

4.3 Quantitative model

This section introduces the model used to estimate the economic cost of COPD as well as establishing the counterfactual to model the impacts of interventions. The structure of the model is as follows:

1. COPD diagnosed and undiagnosed population;
2. Treatment costs;
3. Maintenance costs;
4. Exacerbation costs;
5. Adverse events costs;
6. Productivity costs;
7. QALYs costs;
8. Bed days.

Modelling the COPD population

To model the COPD population, the population was broken down into three components

1. Diagnosed and undiagnosed;
2. GOLD category;
3. Moderate and severe exacerbation frequency.

To estimate the costs and subsequent interventions of COPD, the population of diagnosed and undiagnosed COPD was established. Research conducted by Imperial College London estimated the diagnosed COPD population of individuals over 40 in 2019 to be 1.4 million with the number of people undiagnosed being 500,000.[84] To obtain the COPD population of Wales, Scotland and Northern Ireland, health board and LCG level data of COPD patients were used.[85,86,87] As the undiagnosed population of Wales, Scotland and Northern Ireland was unknown, it is assumed that the proportion of undiagnosed to the diagnosed population was equal to England's. This ratio was applied to the respective devolved nation diagnosed population to obtain the undiagnosed population. To obtain 2023 costs, a yearly growth rate of 2.1% was applied which was estimated from the forecasted growth of COPD in England and Scotland from 2011 to 2030.[88]

To determine the distribution of GOLD categories across nations the findings of Haughney et al. were applied. They investigated the distribution of COPD categories across the UK through primary care databases. These

[84] Task Force for Lung Health, Prevalence of Chronic Obstructive Pulmonary Disease in England from 2000 to 2019, 2023
[85] NHS, Quality and Outcomes Framework, 2021-22, 2022
[86] StatsWales, Quality Assurance and Improvement Framework (QAIF) disease registers by local health board, 2022
[87] Public Health Scotland, General practice - disease prevalence data visualisation, 2022
[88] NI Department for Health, 2022/23 raw disease prevalence trend data for Northern Ireland, 2023

proportions were applied across only the diagnosed COPD populations across devolved nations, which are shown below:[89]

Figure 36: GOLD category prevalence in the UK

GOLD Category	Prevalence
A	34.6%
B	17.5%
C	21.1%
D	26.8%

To obtain the GOLD categorization of the undiagnosed population, it was assumed that the undiagnosed population was only made up of GOLD A and GOLD B patients. This is assumed because more severe COPD would likely result in a diagnosis. It was then assumed that half of the undiagnosed population are classified as GOLD A and half are classified as GOLD B.

Having established the distribution of GOLD categories, it was necessary to obtain annual exacerbations by GOLD category. There are two types of exacerbations; moderate (requires a visit to a GP) and severe (requires hospitalisation). Estimates of annual exacerbations by NICE were used. NICE estimated the annual number of exacerbations by severity as well as the GOLD category. As the report measured exacerbation per cycle, with a cycle being three months, estimated exacerbation rates were multiplied by four to obtain annual exacerbation rates as shown below:

Figure 37: Diagnosed exacerbation rate by GOLD category

GOLD Category	Moderate exacerbation rate	Severe exacerbation rate
A	1.52	0.116
B	1.56	0.096
C	2.00	0.208
D	2.40	0.328

It is more difficult to obtain estimates for the exacerbation rates of the undiagnosed population. However, it is reasonable to assume that the undiagnosed population would likely experience more exacerbations in a year due to not being on a patient pathway and receiving appropriate treatment. Therefore the findings of Kostikas et al. were used. They found that the annual exacerbation rate of individuals who were diagnosed earlier compared to later was almost 50% less.[90] Therefore it is assumed that the undiagnosed population experiences approximately double the number of exacerbations compared to the diagnosed population. As the undiagnosed population is assumed to only consist of GOLD A and B patients, exacerbation rates were only increased for those categories as shown below:

[89] John Haughney, Kevin Gruffydd-Jones, June Roberts, Amanda J Lee, Alison Hardwell, Lorcan McGarvey, The distribution of COPD in UK general practice using the new GOLD classification, 2014
[90] Kostikas K, Price D, Gutzwiller FS, Jones B, Loefroth E, Clemens A, Fogel R, Jones R, Cao H. Clinical Impact and Healthcare Resource Utilisation Associated with Early versus Late COPD Diagnosis in Patients from UK CPRD Database, 2020

Figure 38: Undiagnosed exacerbation rate by GOLD category

GOLD Category	Moderate exacerbation rate	Severe exacerbation rate
A	2.98	0.23
B	3.06	0.19

4.4 Assessing current costs of COPD in 2023

Treatment costs

Treatment costs are defined as the costs that arise from day to day medicinal treatment in order to manage stable COPD. To estimate treatment costs several inputs were needed; the type of treatment used, the distribution of treatment use across GOLD categories and annual unit cost of treatment costs. Gayle et al. investigated the impact of GOLD recommended treatment on patients in the UK. They broke down the proportions of different treatment combinations used by COPD patients within each GOLD category and their findings were used to assume the combination and distribution of treatment.[91] A detailed breakdown of this can be found in the appendix.

The cost of drug combinations was obtained from the 2018 NICE resource impact economic model report, where they calculated the annual cost of drug combinations weighted to account for non adherence.[92] All the NHS costs are inflated using the CPI for health. However, as annual estimates are only available up to the year 2022, NHS costs are adjusted to 2022 values.

Figure 39: Annual cost of COPD treatment combinations (2022)

COPD treatment combination	Annual unit cost (£)
LAMA	£315
LABA	£324
LAMA + LABA	£333
LABA + ICS	£368
LAMA + LABA + ICS	£635

Having obtained annual maintenance costs per patient, GOLD categories were broken down by the proportions of treatment combination to calculate the weighted diagnosed population; undiagnosed patients are excluded under the assumption that they receive no treatment. This was then multiplied by the sum of annual treatment combinations. Total treatment costs in the UK amounted to £750 million as shown below. A more detailed breakdown of costs by treatment combination can be found in the Appendix.

[91] Gayle A, Dickinson S, Morris K, Poole C, Mathioudakis AG, Vestbo J. What is the impact of GOLD 2017 recommendations in primary care? - a descriptive study of patient classifications, treatment burden and costs. Int J Chron Obstruct Pulmon Dis, 2018
[92] NICE, Resource impact report: Chronic obstructive pulmonary disease in over 16s: diagnosis and management, 2018

Figure 40: Annual treatment costs in the UK (2022)

Country	Annual treatment costs (£)
England	£650,819,703
Wales	£35,179,968
Scotland	£39,569,413
Northern Ireland	£18,287,206
Total	**£743,856,290**

Maintenance costs

Maintenance costs are defined as routine healthcare resources used for each GOLD severity stage and were obtained from the 2018 NICE economic model report.[93] Resources included were:

- GP visits;
- Respiratory team visits;
- Outpatient visits;
- Spirometry;
- Pulmonary rehabilitation;
- Home oxygen therapy;
- Influenza vaccine;
- SAMA;
- SABA;
- Theophylline;
- Mucolytics;
- Oral corticosteroids;
- CT scan.

The report estimates the costs per cycle, which is three months. Therefore, costs were multiplied by four to obtain per annum costs. Cost per annum by GOLD category are shown below:

Figure 41: Annual maintenance costs of COPD by GOLD category (2022)

GOLD category	Maintenance cost per annum (2022)
A	£109
B	£118
C	£796
D	£1,474

Having obtained maintenance costs for each GOLD category they were applied to the COPD diagnosed population, resulting in an approximate total cost of £1.1 billion as shown below:

[93] NICE, Economic model report, 2018

Figure 42: Annual maintenance cost in the UK (2023)

Country	Annual maintenance costs (£)
England	£ 945,653,955
Wales	£ 51,117,192
Scotland	£ 57,495,143
Northern Ireland	£ 26,571,674
Total	**£ 1,080,837,965**

Exacerbation costs

To estimate the annual cost of exacerbations it was assumed that exacerbations were split between moderate (exacerbations where a visit to a GP is required) and severe (where hospitalisation is required). To obtain annual exacerbation rates per GOLD category, annual exacerbations estimates of NICE were used.

The cost of a moderate exacerbation and severe exacerbations were obtained from the 2018 NICE economic model report which estimated the cost of a moderate exacerbation to be £86 and severe exacerbation to cost £2632 when adjusted to 2022 values.[94] This cost is a weighted average cost based on prices from National Tariff 2018/19 and activity data from NHS reference costs 2015-2016 for HRG codes DZ65A-J Chronic Obstructive Pulmonary Disease or Bronchitis and includes cost from A&E services.

Having obtained the annual number of moderate and severe exacerbations, costs were applied, resulting in total annual exacerbation costs equally approximately £1.6 billion as shown below in Figure 43.

Figure 43: Annual exacerbation costs in the UK (2023)

Country	Total moderate exacerbations	Total severe exacerbations	Annual exacerbations costs (£)
England	4476940	400291	£1,388,440,070
Wales	242000	21638	£75,051,934
Scotland	272195	24337	£84,416,250
Northern Ireland	125796	11248	£39,013,401
Total	**5105849**	**456751**	**£ 1,586,921,655**

A detailed breakdown of costs can be found in the Appendix.

Adverse event costs

To capture the whole cost of COPD the cost of adverse events must be estimated, in this context they are the costs of negative health events associated with COPD patients. To estimate this, the list of adverse events was obtained from NICE in their economic report consisting of:

- Cardiac arrest;
- Syncope;
- Ventricular tachycardia;

[94] NICE, Resource impact report: Chronic obstructive pulmonary disease in over 16s: diagnosis and management, 2022

- Myocardial infarction;
- Atrial fibrillation/flutter;
- Angina;
- Stroke;
- Heart failure;
- Pneumonia;
- Constipation;
- Diarrhoea;
- Dry mouth;
- Urinary retention;
- Glaucoma.

NICE also estimated the annual frequency of the adverse effects as well as the annual costs, which are shown below:

Figure 44: Annual frequency and cost of COPD adverse events (2022)

Adverse effect	Annual frequency	Annual cost (£)	Average annual cost (£)
Cardiac arrest	0.0017	£1,647	£3.35
Syncope	0.0153	£118	£2.16
Ventricular tachycardia	0.0004	£169	£0.07
Myocardial infarction	0.01	£1,755	£20.99
Atrial flutter	0.335	£429	£171.92
Angina	0.0167	£6,656	£27.86
Stroke	0.0122	£17,024	£62.12
Heart failure	0.0464	£6,656	£92.36
Pneumonia	0.0148	£1,909	£28.31
Constipation	0.0551	£27	£1.71
Diarrhoea	0.0266	£18	£0.59
Dry mouth	0.003	£18	£0.07
Urinary retention	0.0109	£2,756	£30.08
Glaucoma	0.0015	£1,904	£0.72

Having obtained annual frequency and cost, the weighted cost of adverse events was summed to estimate the total cost of adverse events to be £442 per COPD patient. As the frequency and costs of events are for the average COPD patients, the total per patient cost was applied to the whole diagnosed and undiagnosed population, resulting in a total adverse events cost of approximately £1 billion in 2023 as shown below in Figure 45. It is important to note that estimations for the frequency of adverse events were obtained exclusively from COPD patients only on LABA treatment. As this treatment course is more common amongst the lower COPD severity population, adverse event costs are likely underestimated.

Figure 45: Annual cost of COPD adverse events (2023)

Country	Cost (£)
England	£913,443,323
Wales	£49,376,051
Scotland	£55,536,758
Northern Ireland	£25,666,596
Total	**£1,044,022,728**

Productivity costs

Total estimated annual productivity costs of COPD to the UK are £2 billion

Productivity costs were obtained using the findings of Fletch et al. who estimated the annual cost of reduced working hours of individuals with COPD when adjusted to 2023 to be £2236.[95] To estimate the impact of COPD on work productivity they obtained values for the average hours of work lost due to COPD through a survey on UK COPD patients and then used the average UK income to calculate annual productivity costs.

To obtain the proportion of the working age COPD population who were currently employed, the Government estimation of the UK working age proportion of 62.9% was applied to the COPD diagnosed and undiagnosed population.[96] To obtain the employed COPD population, NHS Scotland estimated the proportion of the employed COPD Scottish population to be 60%. This was then applied to the COPD working age population.[97]

The weighted annual productivity cost was then calculated to be approximately £844 pounds. This was then applied to the COPD population to obtain total productivity costs which was estimated as approximately £2 billion, as shown below:

Figure 46: Annual productivity costs in the UK (2023)

Country	Annual productivity costs (£) (2023)
England	£1,742,658,688

[95] Fletcher, M.J., Upton, J., Taylor-Fishwick, J. et al. COPD uncovered: an international survey on the impact of chronic obstructive pulmonary disease [COPD] on a working age population, 2011
[96] Gov.UK, Working Age Population, 2030
[97] NHS, Employment in people with COPD, 2013

Wales	£94,199,172
Scotland	£105,952,510
Northern Ireland	£48,966,494
Total	**£1,991,776,864**

Quality of life costs

Total estimated annual QALY costs of COPD to the UK are £2.6 billion

To estimate the costs to quality of life from COPD it was chosen to estimate the QALY loss derived from moderate and severe exacerbations as well as the QALY loss of adverse events. According to NICE in their 2018 COPD economic model report, a moderate exacerbation leads to a loss in QALY of 0.01 and a severe exacerbation leads to a loss of 0.04 A list of QALY costs associated with adverse events can be found in the Appendix.[98] It is important to note that the QALY cost associated with angina, strokes, heart failure and glaucoma are excluded as NICE did not have QALY costs for said events. Having obtained the annual number of moderate and severe exacerbations by devolved nations, the values are applied to the diagnosed and undiagnosed COPD population to calculate the total annual QALY loss due to exacerbations. Using the annual frequency of adverse events, the total average annual QALY cost of adverse events per patient is estimated to be 0.025.

In order to monetise the value of QALY loss the NICE QALY value of £20,000 was used, using this, it is possible to obtain the total intangible cost of COPD due to exacerbations and adverse events which is estimated to be £2.6 billion, the results are shown below**:**

Figure 47: Annual QALY costs in the UK (2023)

Country	**Annual QALY costs (£) (2023)**
England	£2,261,240,788
Wales	£122,231,054
Scotland	£137,481,963
Northern Ireland	£63,537,992
Total	**£2,584,491,797**

Bed days

To estimate the current number of bed days due to COPD, it was assumed that the annual number of bed days due to a severe exacerbation was four days as assumed by NACAP in their secondary care audit report. It assumed that moderate exacerbation causes no bed days as patients are not hospitalised. Therefore, the average number of bed days was applied to the total number of annual exacerbations. The estimates indicated that COPD is responsible for approximately 1.8 million bed days per year. Although there is a cost attached to bed days, it was excluded from cost estimations to avoid double counting due to the cost of bed days being already included within exacerbation costs.

[98] NICE, Chronic obstructive disease in over 16s: diagnosis and Management, Economic model report, 2018

Figure 48: Annual number of bed days in the UK (2023)

Country	Annual number of bed days
England	1,601,163
Wales	86,551
Scotland	97,350
Northern Ireland	44,991
Total	**1,830,054**

Cost summary

In conclusion, COPD is responsible for significant costs to the NHS, the quality of life of individuals and as well UK wide productivity. Total annual economic cost for 2023 is estimated to amount to £9 billion and COPD is responsible for 1.8 million bed days a year. Total NHS costs amount to nearly half of all costs equalling approximately £4.5 billion. Productivity costs due to reduced working hours is approximately £2 billion and costs to quality of life are equal to £2.6 billion

5. Estimating the impacts of better diagnosis and care to the COPD population in the UK

5.1 Impacts analysis

This section outlines the methodology and results of the impact assessment of interventions into better diagnose and better care of COPD, this is done by:

- Defining the interventions into COPD
- Developing impacts pathways for defined intervention
- Defining the monetizable impacts of interventions
- Estimating impacts at the country and ICB level

Choosing the impacts to model

The impact assessment focuses on the start of the COPD care pathway, focusing on diagnosis and the fundamentals of COPD care. The following interventions were chosen to model after consideration of data availability, materiality of impacts and causal linkage to develop impacts pathways:

Reduced exacerbations from earlier diagnosis resulting in beginning the COPD care pathway;

- Reduced exacerbations from pulmonary rehabilitation completion.

To quantify impacts of earlier diagnosis and better care, the chosen impacts modelled were:

- Reduced NHS costs from reduced exacerbations costs;
- Productivity savings from reduced working hours caused by exacerbations;
- QALY savings from reduced exacerbations;
- Bed days saved from reduced exacerbations.

To highlight the impacts of early diagnosis and better care during the winter the reduction of bed days during the winter period are calculated. Using English ICB prevalence data impacts are distributed across ICBs accounting for deprivation effects to highlight impacts at a more granular level.

Approaches towards ICB level impacts, deprivation and winter bed days

Breaking cost impacts by ICBs

To break down impacts at the ICB level the same approach used for asthma was applied. Obtaining prevalence data for COPD at the ICB level for England, health board level for Wales and Scotland and LCG level for Northern Ireland**,** costs were distributed proportionally to the number of registered COPD patients in an ICB. The methodology of this can be found in the appendix

Link between cost impacts and deprivation levels

Following the approach used to account for deprivation effects of asthma, it was found that hospital admissions for COPD increases with deprivation quintile.[99] ICB impacts at the ICB level were then adjusted to account for the level of deprivation. For example a multiple of 1.17 was applied to ICB impacts within the most deprived areas and 0.86 to ICBs within the least deprived areas. A breakdown of the deprivation costs can be found in the Appendix.

Winter bed days

To obtain the impact of the interventions on winter bed days for COPD, assumptions on the average length of stay of an exacerbation were made. Using data provided by Asthma and Lung UK on the proportion of bed days attributable to COPD during the winter period, it was possible to estimate the reduction in winter bed days from reduced exacerbations.[100]

5.2 Impacts of increased diagnosis

Increasing spirometry testing of the undiagnosed COPD population

Increasing spirometry testing for COPD could result in £137 million of annual economic savings

Diagnosis of COPD is the crucial first step in effective management of the disease. However, the journey to diagnosis is obstructed by numerous barriers. For example, in a survey conducted by Asthma and Lung UK in 2022 of 6500 respondents, 35.6% stated a significant barrier to obtaining a diagnosis was difficulty in getting an appointment whilst 34% said they did not know what the signs of potential COPD were.[101] While 58.1% had waited a year or less for a diagnosis, one in eight people with COPD had waited ten years for a diagnosis after first noticing symptoms. The prevalence and severity of COPD increases with age and the earlier a diagnosis the better the long term health outcomes are, despite this most people are not diagnosed until they are in their fifties.

Current levels of treatment for COPD are already far below the recommended levels of care and that issue is severely exacerbated by current levels of diagnosis. There are several interventions that can lead to earlier and more accurate diagnosis. However upon consideration it was chosen to model the intervention of an increase in quality assured spirometry testing to receive a confirmed diagnosis of COPD.

Methodology

To model the impacts of increased diagnosis it required developing an impact pathway which establishes the evidence and causal link between an intervention and eventual impact. As a result the impact pathway is broken down into four stages:

1. **Activity**

The activity in the impact pathway is defined as an increase in confirmed diagnosis of the undiagnosed COPD population through an increase in quality assured spirometry testing. According to NACAP, in the years of

[99] Asaria M, Foran T, Cookson. The costs of inequality: whole-population modelling study of lifetime inpatient hospital costs in the English National Health Service by level of neighbourhood deprivation, 2016
[100] Asthma and Lung UK analysis
[101] Asthma and Lung UK, COPD in the UK: Delayed diagnosis and unequal care, 2023

2018/2020 11.5% of registered COPD patients received spirometry testing in primary care.[102] It is then assumed that in the current year 11.5% of the undiagnosed COPD population will receive a confirmed diagnosis from a quality assured spirometry test. To model the impacts of an uptake in spirometry testing, it assumed that there is an uptake in spirometry testing of 40% in primary care in line with NACAP recommendation of having 40% of COPD patients receiving a diagnosis by April 2023.

2. **Output**

As result, increased levels of spirometry testing lead to the output of an increase in the number of the undiagnosed COPD population receiving a confirmed diagnosis.

3. **Outcome**

There are numerous outcomes from receiving a confirmed diagnosis, the first being that the patient will then begin on the COPD patient pathway and begin receiving appropriate treatment. In a study conducted by Kostikas et al. on health care utilisation associated with early diagnosis versus late diagnosis in COPD patients in the UK, they found the rate of exacerbations for individuals diagnosed earlier was nearly half compared to individuals diagnosed late when observed over the course of a year.[103] They attribute the significant reduction to the earlier implementation of appropriate treatment. It is therefore assumed that the undiagnosed population has approximately double the number of exacerbations of the diagnosed population. The intervention of confirmed diagnosis results in the undiagnosed population's exacerbation rate being reduced to the same level of a diagnosed individual. A reduction in annual exacerbations then results in three further outcomes:

1. A reduction in visits to the GPs or hospital due to a moderate or severe exacerbation;
2. A reduction in the cost to quality of life due to exacerbations;
3. A reduction in absence from work due to bed days spent at a hospital from a severe exacerbation.

Establishing the outcomes, it was then necessary to monetise these outcomes in order to estimate the impacts.

4. **Impacts**

The impacts estimated are therefore:

Reduction in NHS costs:

The reduction in annual exacerbations leads to a reduction in costs for the NHS from treating moderate exacerbations in primary care and severe exacerbations in secondary care. As outlined in the costs section of the report the cost of a moderate exacerbation is estimated to be £84 and severe exacerbation costs £2525 when adjusted to 2022 values. Therefore, the impact of reduced NHS is estimated through saved exacerbations costs from reduced annual exacerbations.

Reduction in productivity costs:

The reduction in annual severe exacerbations leads to a reduction in bed days at the hospital. As a result, this leads to a reduction in absence from work. Productivity savings were estimated by estimating the total number of work days lost due to a severe exacerbation multiplied by the weighted daily median wage of the COPD population. To account for weekends the median wage was multiplied by 5/7. According to NACAP programme the average stay of a COPD hospital exacerbation was 4 days and the weighted daily median wage of COPD patients was £25.[104] Therefore the average productivity loss from a severe exacerbation was £100. Whilst

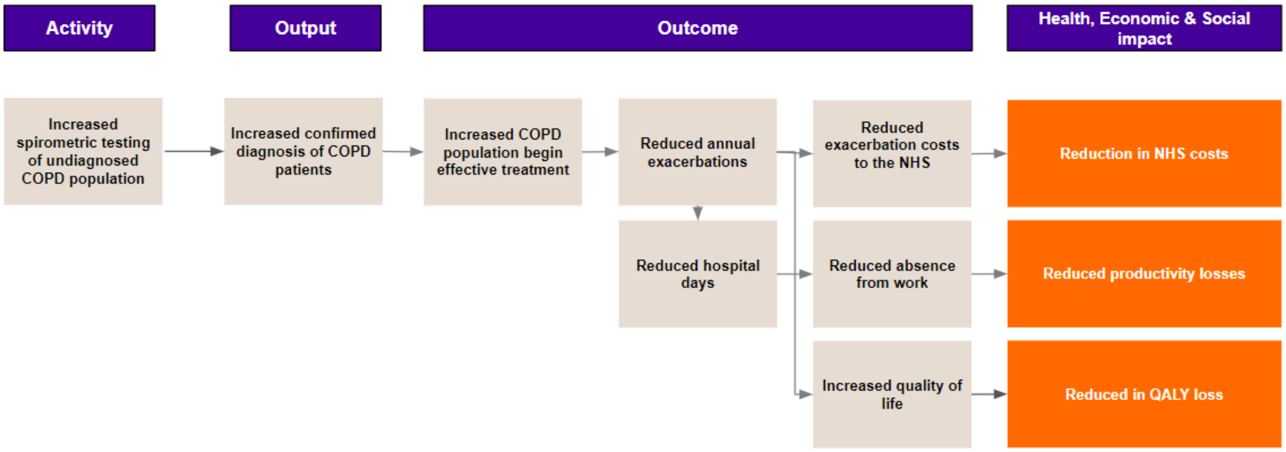
[102] Royal College of Physicians, Wales primary care clinical audit report 2021, 2022
[103] Kostikas K, Price D, Gutzwiller FS, Jones B, Loefroth E, Clemens A, Fogel R, Jones R, Cao H. Clinical Impact and Healthcare Resource Utilisation Associated with Early versus Late COPD Diagnosis in Patients from UK CPRD Database, 2020
[104] NACAP, Drawing Breath, 2023

moderate exacerbation also led to significant productivity costs to individuals, they were excluded from the impact analysis due to limitations on data availability on productivity costs of moderate exacerbations. Therefore productivity cost impacts are likely underestimated.

Reduction in QALY costs:

As outlined in the cost section, there is a quality of life cost associated with exacerbations. A moderate exacerbation leads to a loss in QALYs of 0.01 and a severe exacerbation leads to a loss of 0.03. Assuming that a QALY equates to the value of £20,000 In line with NICE guidelines, it's estimated that the cost of a moderate exacerbation is £200 and the QALY cost of a severe exacerbation is £600. Therefore the impact of a reduction in QALY loss is estimated as the reduced QALY cost from the reduced number of annual exacerbations.

Figure 49: Impact of increased spirometry of undiagnosed population



Impact results

Having developed the impact pathway and established the monetised impacts, it is then possible to model the overall impact of an increase in spirometry testing.

To do this, it is assumed that there is an uptake in spirometry testing of 40% in primary care in line with NACAP recommendation of having 40% of COPD patients receiving a diagnosis by April 2023. The assumed reduction in annual exacerbations of 51% to the undiagnosed exacerbation rates was then applied to the now diagnosed population. The difference was taken between current and reduced exacerbation rates.

With the assumed new level of diagnosed COPD patients calculated, the net reduction in exacerbations in each GOLD category for the devolved nations is calculated. With the cost of moderate and severe exacerbations known, and cost gains from QALY as well as reduced productivity costs from reduced bed days it is then possible to calculate the net benefit of increased spirometry testing.

Having obtained the reduction in exacerbation rates due to early diagnosis, the associated reduction in costs are calculated which are shown below, total annual reduction in NHS costs are calculated to be approximately £68 million, savings to productivity are £1.8 million, annual QALY cost savings is £67 million and reduced bed days per year is approximately 72,000 with 25,000 reduced bed days during the winter period. Notably this analysis does not consider the costs of these interventions, including the costs to the NHS.

Figure 50: Impact of an uptake in spirometry testing by devolved nation (2023)

Country	Exacerbation savings	Productivity savings	QALY savings	Bed days saved	Winter bed days saved
England	£59,328,134	£1,559,465	£58,617,239	63,273	21,513
Wales	£3,206,974	£84,297	£3,168,547	3,420	1,163
Scotland	£3,607,112	£94,814	£3,563,890	3,847	1,308
Northern Ireland	£1,667,045	£43,819	£1,647,070	1,778	604
Total	**£67,809,265**	**£1,782,395**	**£ 66,996,746**	**72,318**	**24,588**

5.3 Impacts of better care

Increasing the referral and completion rate of pulmonary rehabilitation

An increase in pulmonary rehabilitation referral and completion rates could result in total savings of £267 million for 2023

Pulmonary rehabilitation (PR) is an exercise and education programme designed for people with lung disease who experience symptoms of breathlessness. It focuses on tailored physical exercises and information that help people to better understand and manage their conditions and symptoms such as feeling short of breath. The course typically lasts six to eight weeks and is offered to individuals with long term lung conditions such as bronchiectasis and pulmonary fibrosis. However the majority of people attending are those with COPD.

Evidence has shown that PR supports better self management, reduction in moderate exacerbations and a reduction in severe exacerbations leading to hospitalisations. However, despite being included as a key intervention in the NHS Long Term plan the proportion of the COPD population in England referred to PR is only 13.8% and the completion rate of the COPD population is 4.3%.[105, 106] Furthermore, individuals are typically referred to PR if they have an mMRC over three or after having a severe exacerbation which is costly to the NHS as well as being extremely distressing for the patient. With exacerbations making up the majority of COPD costs in the UK, treatment needs to be proactive rather than reactive to effectively reduce the economic cost of the disease. This could occur by preventing exacerbations from occurring in the first place instead of reducing the chance of the next one.

This is the view held by NICE in their quality statement of pulmonary rehabilitation for COPD patients who state that pulmonary rehabilitation should be offered to individuals with stable COPD and exercise limitation rather than on an mMRC over 3 or only after a severe exacerbation.[107] Therefore, the net impacts of an increase in the referral rate and increase in the completion rate of pulmonary rehabilitation across the whole COPD diagnosed population was modelled.

[105] NHS, Long Term Plan, 2023
[106] Taskforce for Lung Health, Prevalence of Chronic Obstructive Pulmonary Disease in England from 2000 to 2019, 2023
[107] NICE, Chronic obstructive pulmonary disease in adults, 2016

Methodology

To model the impacts of increased referral and completion rates the same methodology of developing an impact pathway is employed as shown in Figure 51. The impact pathway is again broken down into the follow components:

1. **Activity**

The activity in the impact pathway is defined as an increase in the referral and completion rate of PR for the UK diagnosed UK COPD population. Current referral rates to PR is assumed to be 13.8% and completion rates are assumed to be 4.3%. Therefore the completion rate of the referral population is 31%. It is then assumed that an increase in referral rates of 80% and completion rates of the referral population is 50%.

2. **Output**

As a result of the increased referral and completion, it leads to the output of a greater number of the COPD population completing PR.

3. **Outcomes**

The completion of PR results in similar outcomes to those found in the early diagnosis impact pathway. Completion of PR results in a reduction in annual exacerbations which leads to the outcomes of:

1. A reduction in visits to hospital or the GP due to a moderate or severe exacerbation;
2. A reduction in the cost to quality of life due to exacerbations;
3. A reduction in absence from work due to bed days spent at a hospital due to a severe exacerbation.

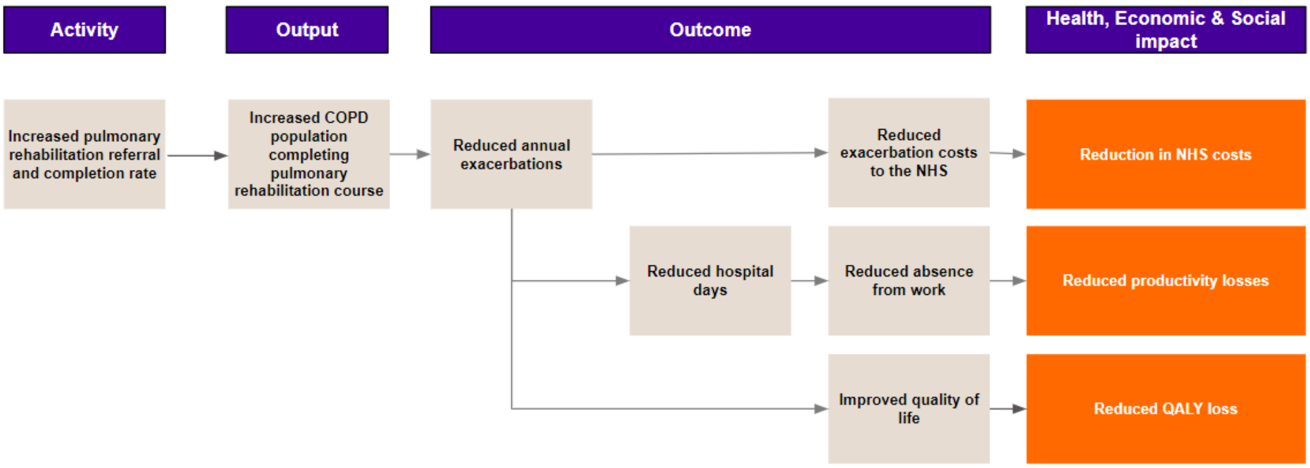
4. **Impacts**

To monetise the outcomes to estimate impacts the same methodology used for modelling the impact of spirometry testing is used resulting in the impacts of:

1. Reduction in NHS costs;
2. Reduction in productivity costs;
3. Reduction in QALY costs.

Having developed the impact pathway for an uptake in pulmonary rehabilitation referral and completion it is then possible to model total impacts of the intervention in the UK.

Figure 51: Impact pathway of increase referral and completion rate of pulmonary rehabilitation



Impact results

Having developed the impact pathway for an uptake in pulmonary rehabilitation referral and completion it is then possible to model total impacts of the intervention in the UK.

To model the impacts of increased pulmonary rehabilitation referral and completion rate, only the diagnosed COPD population is included as it is assumed that the undiagnosed individuals are not on a care pathway. Using the population distributions of the GOLD category calculated in the COPD cost methodology the population was then broken down into the proportion of those who receive PR referral and again into those who complete it.

According to a report by Task Force for Lung Health PR is only offered to individuals who have a severe exacerbation or have an mMRC ranking greater than three.[108] Therefore, it is assumed that the GOLD A population receive no PR due to the classification of non severe exacerbations and a mMRC being less than two. As it is not possible to disaggregate the GOLD B population by mMRC scores it was assumed half of the moderate exacerbation population would be referred to PR. Having established the current population of referred COPD patients it is possible to calculate the proportion of the population who complete PR.

To model the impacts of the intervention, it is assumed that 80% of individuals diagnosed with COPD are referred to PR and 50% of them complete it. An assumption of 80% referral rate is used to align with NICE's recommendation that all patients with stable COPD and exercise limitation and patients who have experienced a severe exacerbation should be referred to PR 90 days after, however in the future 100% of patients should be referred to PR. A conservative estimate of a 50% completion rate is assumed due to numerous factors that affect rates of PR completion such as:

- Low awareness by health professionals on how to refer patients;
- Not communicated well to patients;
- Drop out rates;
- Travel difficulties of COPD patients;
- Geographical spread of available clinics.

The reality of effective increases in PR referral and completion would be through the standardisation of referral process, increased information made available to health professionals on treatment options, improving infrastructure to support pulmonary rehabilitation and increased education of pulmonary rehabilitation benefits to COPD patients.

In a study conducted by van Ranst et al. they found that completion of PR led to 22.5% reduction in moderation exacerbation per year and a 46% reduction in severe exacerbations in a year.[109] Therefore it is assumed that completion of PR leads to a reduction in 22.5% of annual moderate exacerbations and a 46% reduction in annual severe exacerbations.

Calculating the baseline population of current PR referral and completion population, the new population of referred and completed PR population is calculated. To calculate the net impacts, the difference in current completion population to new completion population was calculated. The net impacts are then calculated by applying PR benefits to the net increase in the PR completion population.

With the assumed new level of PR calculated, the net reduction in exacerbations in each GOLD category for the devolved nations is calculated. With the cost of moderate and severe exacerbations known, and cost gain from QALY as well as reduced productivity costs from reduced bed days it is possible to calculate the net benefit of increased PR referral rates and completion rates in the UK.

[108] Task Force for Lung Health, Prevalence of Chronic Obstructive Pulmonary Disease in England from 2000 to 2019, 2023
[109] van Ranst D, Stoop WA, Meijer JW, Otten HJ, van de Port IG. Reduction of exacerbation frequency in patients with COPD after participation in a comprehensive pulmonary rehabilitation program, 2014

As shown in Figure 52, our model calculated that an increase in PR referral rates to 80% and an increase in completion rate to 50% could result in approximately £163 million of annual reduction in NHS costs through a reduction in exacerbations, £5.5 million in annual productivity, QALY savings of £99 million and a reduction in bed days of approximately 222,000 of which there is reduction of 75,000 bed days during the winter period. Notably this analysis does not consider the costs of these interventions, including the costs to the NHS.

Figure 52: Impact of an uptake in pulmonary rehabilitation by devolved nation (2023)

Country	Exacerbation savings	Productivity savings	QALY savings	Bed days saved	Winter bed days saved
England	£142,639,923	£4,787,808	£86,273,440	194,259	66,048
Wales	£7,710,381	£258,804	£4,663,499	10,501	3,570
Scotland	£8,672,414	£291,096	£5,245,369	11,811	4,016
Northern Ireland	£4,008,001	£134,531	£2,424,174	5,458	1,856
Total	**£163,030,719**	**£5,472,239**	**£98,606,482**	**222,029**	**75,490**

5.4 Breaking down the impacts by areas and deprivation

Accounting for deprivation, NHS North East and North Cumbria could save £17.2 million on primary and secondary care costs annually

To estimate the impacts at the ICB level, the approach used to estimate asthma ICB costs is followed. Having obtained total NHS reduction in costs from greater levels of spirometry and PR, costs are distributed across ICBs, with the proportion of savings for each ICB being weighted according to disease prevalence. A detailed breakdown of cost at the ICB level can be found in the appendix.

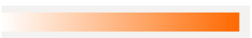
To account for the effects of deprivation, estimations were based on the findings of Asari et Al. who found that the annual secondary care admissions rate for COPD patients increased with the level of deprivation.[110] Secondary care savings were then isolated at the ICB level and deprivation effects were applied. Accounting for deprivation, the analysis indicated that the ICB which would save the most in annual costs is NHS North East and North Cumbria, potentially saving a total of £17.2 million.

[110] Asaria M, Foran T, Cookson. The costs of inequality: whole-population modelling study of lifetime inpatient hospital costs in the English National Health Service by level of neighbourhood deprivation, 2016

Figure 53: Side by side comparison of secondary care impacts before (left) and after (right) deprivation adjustment in England (2023)

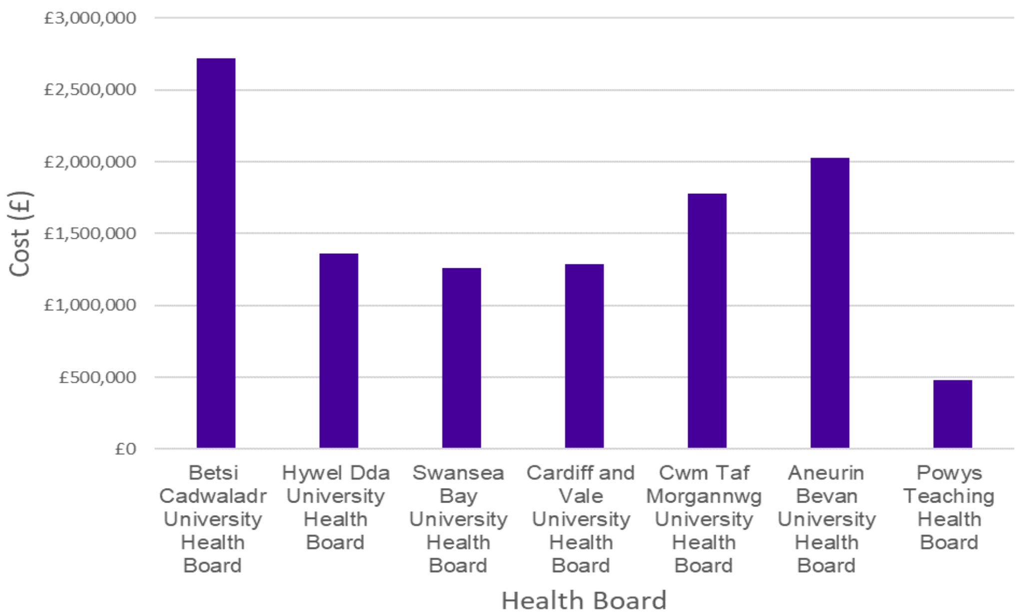
(Asthma and Lung UK analysis, 2023)

Gradient of potential impacts before and after deprivation (left to right)



As shown below in Figure 54 the greatest amount of savings would be found within the Betsi Cadwaladr University health board with potential annual savings of £2.7 million.

Figure 54: Total savings by health board in Wales (2023)



As shown below in Figure 55 the greatest amount of savings is found in the Greater Glasgow and Clyde health board. According to the analysis, effective uptake in spirometry testing and an increase in the referral and completion rate of PR could result in savings of £4.4 million.

Figure 55: Total savings by health board in Scotland (2023)

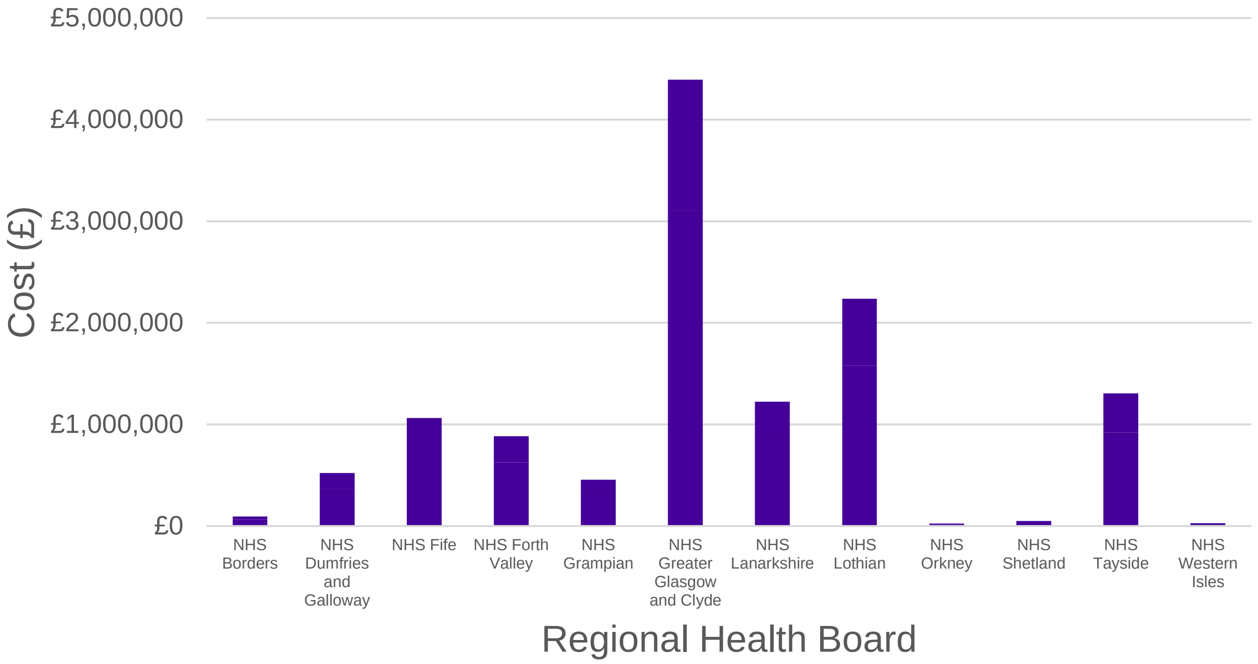
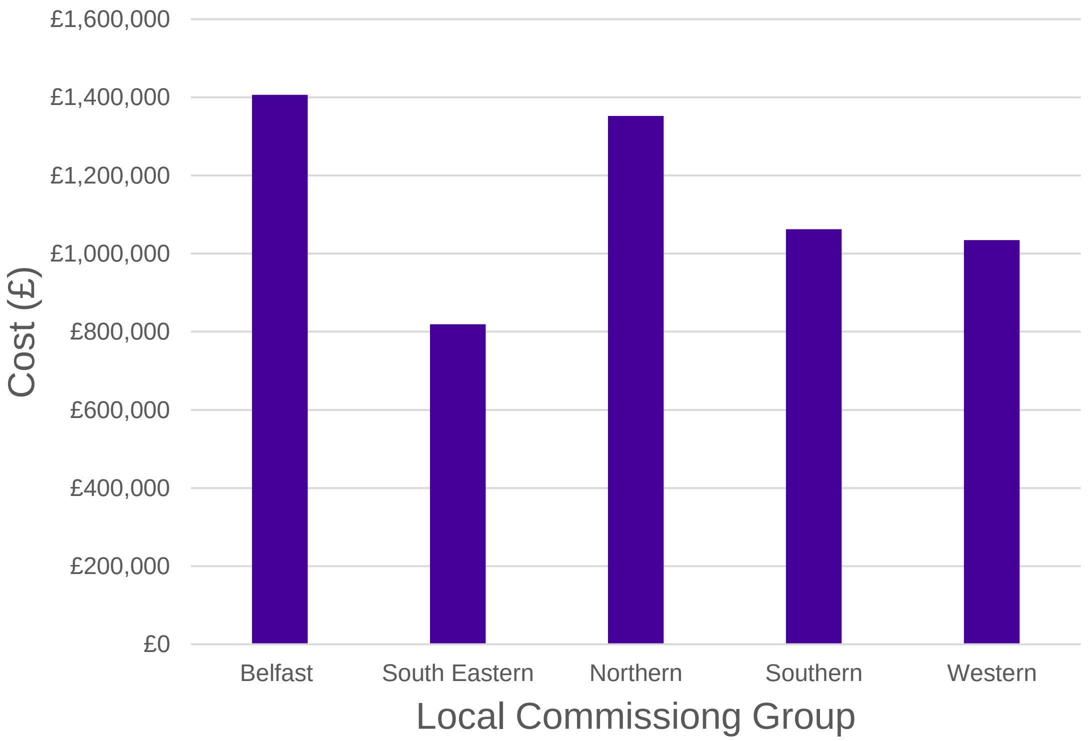


Figure 56 shows that the most amount of savings from COD interventions would be found in the Belfast CCG with annual savings of just over £1.4 million.

Figure 56: Total savings by LCG in Northern Ireland (2023)



Summary

In conclusion, effective implementation of increased quality assured spirometry testing and increases in PR referral and completion results in significant positive impacts for the UK. Combined total impacts could result in:

- **Annual savings of £231 million to the NHS;**
- **Annual productivity savings of £7 million;**
- **Annual QALY savings of £166 million;**
- **Reduced annual bed days of 294,000 with a reduction of 100,000 during the winter period.**

Notably this analysis does not consider the costs of the intervention, and who these costs may accrue to.

The analysis also demonstrated the effect of impacts based on levels of deprivation indicating that intervention can result in greater impacts in areas of higher deprivation. The analysis demonstrates the case to improve diagnosis and care for COPD in the UK.

6. Conclusion

The economic cost of asthma and COPD in the UK is substantial. Asthma has an estimated annual economic cost of £6 billion and COPD has a cost of £9 billion in 2023. The increased usage of FeNO tests and improved patient treatment adherence could lead to reduced costs of £148 million. Increasing spirometry testing, could lead to annual economic benefits of £137 million and a reduction of 25,000 bed days occupied per year. Similarly, improved referral and completion rates for pulmonary rehabilitation show even greater potential impacts, amounting to £267 million in economic benefits and 75,000 fewer winter bed days occupied annually.

Furthermore, this report highlights the increased impacts better diagnosis and better care would have in higher areas of deprivation. Overall, the findings of this report underscore the importance of prioritising asthma and COPD care and implementing measures to improve early detection and comprehensive management.

Appendix

Appendix 1: Asthma methodology

Introduction to asthma methodology appendix:

This report uses previously developed frameworks, including those developed by Frontier Economics, to estimate the costs of asthma on the environment, society and the economy.[111] This report examines direct and indirect impacts.

Direct costs

Direct costs refer to the expenses incurred in providing treatment to patients. Direct costs are broken down into three components:

- NHS costs incurred by the NHS;
- GHG emissions costs incurred by society;
- Patient travel costs incurred by patients.

NHS costs

Direct impacts occur directly as a result of treatment either to the NHS, to the patient or to society. In this report, the direct costs to the NHS quantified in the model are:

- Healthcare professional's time to diagnose, to annually review asthma, and to follow up on exacerbations during unplanned patient visits;
- The cost of diagnostic tests;
- The cost of medications prescribed;
- The use of secondary care.[112]

GHG emissions costs

This report also quantifies the generation of GHG emissions as a direct cost to society for:

- Healthcare facilities open for patients;
- Patient travel to and from healthcare facilities;
- Transportation of patients during exacerbation emergencies;
- Hospitalisation of patients following a serious exacerbation;
- Patient use of inhalers.[113]

Patient travel costs

This report quantifies the direct cost of different modes of transport that patients use to attend medical appointments for asthma. It is assumed that patients directly incur travel costs.

Patients can also incur out of pocket prescription charges for their medication, but this is not included in the analysis to avoid accounting for transfers of cost.

Indirect costs

[111] Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022
[112] Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022
[113] Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022

Indirect costs account for the cessation or reduction of work productivity due to the morbidity and mortality of a disease. The indirect costs modelled for asthma patients include:

- health related quality of life incurred by patients
- productivity losses incurred to employers.

Caregiving is also considered an indirect cost, but has not been captured in this report. Potential Limited estimated that in 2018-2019, at least 600,000 school days were lost in the UK due to asthma.[114] Employees would be expected to take paid time off work to care for their children, resulting in lost output in the economy.

Health related quality of life

Asthma can result in a lower quality of life for asthma patients, especially if they have an exacerbation and this is quantified in the model.[115] For the purpose of this report, a loss in health related quality of life applies only to uncontrolled asthma patients as per the definitions of controlled and uncontrolled asthma. Controlled asthma patients do not see an impact of asthma on their lives.

Productivity

Asthma affects productivity of the working population. Uncontrolled asthma affects the participation rate, as patients experiencing asthma symptoms may not be able to work.[116] Employed asthma patients may be more absent at work due to the number of sick days they need to take. Employees who have asthma have median wages lower than the rest of the population.[117] These aspects are all quantified in this report.

Table 1: General assumptions

Within the asthma model, we have made some general assumptions and we provide the rationale for them below.

General assumption	Explanation
Inflation	All monetary values have been adjusted to take account of inflation where this is reasonable. Some examples of where we have inflated costs in lieu of available data include the costs of medical appointments, and the costs of medicines.
Apportioning impacts across the devolved nations and their more granular statistical areas	Impacts for the devolved nations are calculated independently based on their prevalence. These impacts have been split based on their prevalence, then by deprivation in England.
Time period of analysis	The time period of this analysis is for the current year, 2023. This has been chosen because it is the current year of writing this report.

Total number of asthma patients by devolved nation

The prevalence data for the UK is first broken down by the devolved nations of England, Wales, Scotland and Northern Ireland. It is then further disaggregated by health level statistical areas. These are outlined below.

Table 2: Distribution of current adult asthma population across the devolved nations

[114] Potential Limited, The economic cost of uncontrolled asthma, 2021
[115] Barnes et al, Estimating loss in quality of life associated with asthma-related crisis events (ESQUARE): a cohort, observational study, 2019
[116] Potential Limited, The economic cost of uncontrolled asthma, 2021
[117] Potential Limited, The economic cost of uncontrolled asthma, 2021

Devolved nation	Prevalence	Year	Disaggregated statistical area used	Source
England	3,821,272	2022	Integrated Care Board	Asthma and Lung UK
Wales	256,044	2020	Health Board	Asthma and Lung UK
Scotland	245,461	2022	NHS Regional Board	Asthma and Lung UK
Northern Ireland	131,949	2023	Local Commissioning Groups	Asthma and Lung UK

A growth rate to increase the prevalence to the current year was applied to the populations.

Table 3: Asthma UK prevalence to calculate growth rate

	Estimated number of those diagnosed (2011)	Estimated number of those diagnosed (2012)	Growth rate
Asthma	7,868,651	8,028,741	2.03%

Breaking down the asthma population into different clinical cohorts

Table 4 contains the original distribution of the UK adult asthma population in 2021 found in the Frontier report

Table 4: Original distribution of 2021 UK adult asthma population

Asthma severity	Treatment adherence	Control of symptoms	Level of uncontrolled symptoms	Need for secondary care intervention	Mortality	Number of patients	Proportion of total
Non-severe Asthma	Optimal	Controlled				844,748	23.48%
Non-severe Asthma	Optimal	Uncontrolled	Worsening of symptoms			308,710	8.58%
Non-severe Asthma	Optimal	Uncontrolled	At least one exacerbation	Self managed		49,101	1.36%
Non-severe Asthma	Optimal	Uncontrolled	At least one exacerbation	Needing secondary care	Non fatal	9,788	0.27%
Non-severe Asthma	Optimal	Uncontrolled	At least one exacerbation	Needing secondary care	Fatal	288	0.01%
Non-	Sub-	Controlled				1,310,411	36.42%

severe Asthma	optimal						
Non-severe Asthma	Sub-optimal	Uncontrolled	Worsening of symptoms			724,163	20.13%
Non-severe Asthma	Sub-optimal	Uncontrolled	At least one exacerbation	Self managed		180,435	5.01%
Non-severe Asthma	Sub-optimal	Uncontrolled	At least one exacerbation	Needing secondary care	Non fatal	35,969	1.00%
Non-severe Asthma	Sub-optimal	Uncontrolled	At least one exacerbation	Needing secondary care	Fatal	1,059	0.03%
Severe Asthma	Optimal	Uncontrolled	Worsening of symptoms			107,671	2.99%
Severe Asthma	Optimal	Uncontrolled	At least one exacerbation	Self managed		21,229	0.59%
Severe Asthma	Optimal	Uncontrolled	At least one exacerbation	Needing secondary care	Non fatal	4,232	0.12%
Severe Asthma	Optimal	Uncontrolled	At least one exacerbation	Needing secondary care	Fatal	125	0.00%
					Total	3597929	

Table 5 outlines how the proportions of the sub-population are then applied to the current asthma population in 2023.

Table 5: Current distribution of UK adult asthma population

Asthma severity	Treatment adherence	Control of symptoms	Level of uncontrolled symptoms	Need for secondary care intervention	Mortality	Proportion of total	Current total England	Current total Wales	Current total Scotland	Current total Northern Ireland
Non-severe Asthma	Optimal	Controlled				23.48%	897,186	60,116	57,631	30,980
Non-severe Asthma	Optimal	Uncontrolled	Worsening of symptoms			8.58%	327,873	21,969	21,061	11,322
Non-severe Asthma	Optimal	Uncontrolled	At least one exacerbation	Self managed		1.36%	52,149	3,494	3,350	1,801
Non-severe Asthma	Optimal	Uncontrolled	At least one exacerbation	Needing secondary care	Non fatal	0.27%	10,396	697	668	359
Non-severe Asthma	Optimal	Uncontrolled	At least one exacerbation	Needing secondary care	Fatal	0.01%	306	20	20	11
Non-severe Asthma	Sub-optimal	Controlled				36.42%	1,391,755	93,254	89,400	48,057
Non-severe Asthma	Sub-optimal	Uncontrolled	Worsening of symptoms			20.13%	769,116	51,535	49,405	26,558
Non-severe Asthma	Sub-optimal	Uncontrolled	At least one exacerbation	Self managed		5.01%	191,636	12,841	12,310	6,617
Non-	Sub-optimal	Uncontrolled	At least one	Needing	Non fatal	1.00%	38,202	2,560	2,454	1,319

severe Asthma			exacerbation	secondary care						
Non-severe Asthma	Sub-optimal	Uncontrolled	At least one exacerbation	Needing secondary care	Fatal	0.03%	1,125	75	72	39
Severe Asthma	Optimal	Uncontrolled	Worsening of symptoms			2.99%	114,355	7,662	7,346	3,949
Severe Asthma	Optimal	Uncontrolled	At least one exacerbation	Self managed		0.59%	22,547	1,511	1,448	779
Severe Asthma	Optimal	Uncontrolled	At least one exacerbation	Needing secondary care	Non fatal	0.12%	4,495	301	289	155
Severe Asthma	Optimal	Uncontrolled	At least one exacerbation	Needing secondary care	Fatal	0.00%	133	9	9	5

Modelling the cost of asthma diagnosis

For this analysis, the direct costs of asthma diagnosis are made up of:

- The cost of a healthcare appointment
- The cost of the tests that are used to diagnose asthma
- The cost of patient travel
- The cost of GHG emissions

NHS costs for asthma diagnosis from the previous report are updated to 2023 values using a calculated growth rate derived from costs between 2021 and 2022. The previous report considers several health care professionals that a patient would interact with over the course of their diagnosis. They are included below. The costs for 2021/2022 appointments are sourced from the Personal Social Services Research Unit Report.

Table 6: Cost of a diagnosis appointment

Health care professional	Cost for on appointment (2021£/hour)	Cost for on appointment (2022£/hour)	Growth rate	Cost for an appointment (2023£/hour)
GP	£255[118]	£271[119]	6.27%	£288.00
Practice nurse	£44	£52	18.18%	£61.45
Lung specialist	£319[120]	£339[121]	6.27%	£288.00

During a diagnosis appointment, the previous report also assumes the percentage of patients that would be tested through various means. These include forced expiratory volume (FEV) spirometry test, peak flow test and bronchodilator reversibility test. These tests are referenced by NICE.

Table 7: Cost of a diagnosis test

Asthma diagnosis test	Cost for on appointment (20£/hour)[122]	Cost for on appointment (2023£/hour)	Proportion of appointments with test: non-severe (%)	Proportion of appointments with test: severe (%)
Forced expiratory volume (FEV) spirometry test	£2.44	£2.48	50%	50%
Peak flow test	£16.18	£16.48	50%	50%

118 PSSRU, Unit Costs of Health and Social Care
119 PSSRU, Unit Costs of Health and Social Care
120 Asthma and Lung UK
121 Asthma and Lung UK
122 Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022

Bronchodilator reversibility test	£12.85	£13.09	100%	30%

The cost of healthcare activities during the diagnosis stage are estimated.

- A patient will see a range care of health care professionals;
- A patient will undergo several diagnostic tests .

Some assumptions are made based on how many appointments are required and what mix of healthcare specialists a patient sees depending on their severity. These assumptions are based from the previous report, which has been informed by a clinical expert panel.

Table 8: Appointment assumptions by asthma severity

Item	Non-severe	Severe	Source
Duration (hours)	0.33	0.5	Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022
Number of appointments	2.5	7.5	Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022
HCPs performing diagnosis: GP	47.50%	0.00%	Asthma and Lung UK
HCP performing diagnosis: Practice nurse	47.50%	0.00%	Asthma and Lung UK
HCP performing diagnosis: Asthma specialist	5%	100%	Asthma and Lung UK
In person appointments	90%	90%	Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022

- These assumptions are used to calculate the cost to the NHS of primary care usage through access to primary care services and the costs of tests.
- The assumptions of the probability of each health care professional are combined with the hourly cost and duration of an appointment.
- This is multiplied with the expected number of appointments per patient, which is derived from the number of appointments multiplied by the proportion of HCPs performing the diagnosis.
- Together this provides a per patient NHS cost by each health care professional.
- The sum each per patient NHS cost by HCP combines to give the per patient NHS cost of diagnosis related appointments.
- These costs are different between those who have non-severe and severe asthma, though the approach remains the same.

Table 9: Per-patient NHS cost of an HCP appointment at the diagnosis stage for non-severe asthma

HCP	Number of	Number of	Per-patient NHS cost by HCP non-	Per-patient NHS cost by	HCP	Number of appointments per

	appointments per patient non-severe (#)	appointments per patient severe (#)	severe (£)	HCP severe (£)		patient non-severe (#)
GP	1.1875	0	£114.00	£0.00	GP	1.1875
Practice nurse	1.1875	0	£24.33	£0.00	Practice nurse	1.1875

Table 10: Per-patient NHS cost of an HCP appointment at the diagnosis stage for severe asthma

Item	Number of tests per patient non-severe (#)	Number of tests per patient severe (#)	Cost per patient non-severe (2023£)	Cost per patient severe (2023£)	Item	Number of tests per patient non-severe (#)
Forced expiratory volume (FEV) spirometry test	1.25	3.75	£3.11	£9.32	Forced expiratory volume (FEV) spirometry test	1.25
Peak flow test	1.25	3.75	£20.60	£61.79	Peak flow test	1.25

- The number of appointments and the likelihood of running each test during an appointment is used in order to generate a weighted number of appointments.
- They are then summed together to generate a per-patient testing cost.
- The number of tests per patient is derived by multiplying the expected number of appointments by the likelihood of each test being used during these appointments.
- The same approach is used for both non-severe and severe asthma.

Table 11: Total per patient NHS costs for diagnosis

Patient by severity	Cost
Per-patient non-severe cost (2023£)	£209.74
Per-patient severe cost (2023£)	£1,450.57

- The cost of diagnosis is adjusted so that it only applies to the proportion of incidence of asthma in the UK.
- This cost is then adjusted for a total diagnosis cost

Table 12: Total per patient NHS costs for diagnosis after adjusting for incidence

Patient by severity	Cost
Per-patient non-severe cost (2023£)	£7.53
Per-patient severe cost (2023£)	£52.10

Modelling the cost of asthma maintenance

- After diagnosis, the costs of primary care at maintenance are modelled. There are two components to the costs that are:
    - Cost of an annual visit to review symptoms;
    - medication.
- We have made assumptions that there are differences in these presentations based on the severity of asthma but also the treatment adherence. As mentioned above, we assume that all severe asthma patients are optimally adhering.
- We also assume severe asthma patients will need more reviews within an annual period based on their symptoms.
- We have leveraged assumptions on how the percentage of reviews are attended by optimally adhering and sub optimally adhering asthma patients.
- The clinical expert panel in this report also assumed that asthma review appointments are shorter in duration than diagnosis appointments, and that a portion of these appointments are completed in person. They also provided the assumptions of the proportion of appointments that require additional testing.

Table 13: Number of asthma reviews in a year

Activity	Non-severe	Severe	Source	Notes
Number of appointments (#)	1	3	Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022	
Optimally adhering (%)	90%	90%	Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022	
Suboptimally adhering (%)	60%	90%	Frontier Economics,	All severe asthma

			Environmental Societal and Economic Impact of Asthma in the UK, 2022	patients are optimally adhering
Duration (hrs)	0.25	0.42	Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022	
Proportion of asthma reviews done in person	60.30%	60.30%	Asthma and Lung UK	
% of reviews with FEV1	10%	20%	Asthma and Lung UK	
% of reviews with PEF	10%	20%	Asthma and Lung UK	
% of reviews with BDR	20%	40%	Asthma and Lung UK	

- These assumptions are used to generate per patient HCP costs using the breakdown of appointment attendance.
- These are calculated by combining the probability of attending a review appointment by the cost of the appointment. This is calculated for Optimally adhering non-severe, Sub-optimally adhering non-severe and severe asthma patients.

Table 14: Per-patient HCP costs from HCP appointments at the maintenance stage

Item	Number of appointments
Optimally adhering non-severe	0.9
Sub-optimally adhering non-severe	0.6
Severe	2.7

- This is calculated by the cost of each test multiplied by the number of patients it is expected to attend, multiplied by the level of adherence of attendance and the proportion of appointments that have these tests.

Table 15: Per-patient NHS cost of testing at the maintenance stage

Item	Per patient cost optimally adhering non-severe	Per patient cost Sub-optimally adhering non-	Per patient cost severe

		severe	
Forced expiratory volume (FEV) spirometry test	£0.22	£0.15	£1.34
Peak flow test	£1.48	£0.99	£8.90
Bronchodilator reversibility test	£2.36	£1.57	£14.13

Table 16: Per-patient NHS cost of testing at the maintenance stage

Severity	£
Optimally adhering non-severe	**£4.06**
Sub-optimally adhering non-severe	**£2.71**
Severe	**£24.37**

There are three categories of asthma medications that are referenced in this analysis. Similar types of medications have been grouped together. A longer list of the medications used in the analysis can be found in the Technical Appendix. The medications in the analysis are:

- **Controller medications:** These inhalers contain inhaled corticosteroids either alone or in combination with other preventer medication and are used regularly to maintain control of symptoms and to reduce the risk of exacerbations and decline in lung health.[123]
- **Reliever medications:** These are used when asthma patients have symptoms or exacerbations. Delivered through inhalers, reliever medications include Short Acting Beta Agonists (SABAs).[124] All patients with asthma should be prescribed a controller inhaler and an inhaler that they can use when they get symptoms or are experiencing an exacerbation. There are some inhalers which can be used for both controller and reliever.
- **Add on medications:** Add on medications are used when initial (ICS)controller medication is not fully controlling the person's asthma. In this report, these will be used for patients with persistent symptoms. These include Long Acting Muscarinic Antagonists (LAMAs) and Leukotriene receptor antagonists.[125] This report also considers the use of biologics for severe asthma.

There are two different types of inhalers that have been considered when calculating the costs and emissions of inhalers:

- The first type of inhaler is a pressurised metered-dose inhaler (pMDI) where propellants administer the medication into the lungs with a gentle slow inhalation, ideally with a spacer device.

[123] Global Initiative of Asthma, Global strategy for asthma management and prevention, 2022
[124] Global Initiative of Asthma, Global strategy for asthma management and prevention, 2022
[125] Global Initiative of Asthma, Global strategy for asthma management and prevention, 2022

- The second type of inhaler is a dry powdered inhaler (DPI) uses a metered and powdered dose, but this is dependent on the patient's ability to inhale with a deep forceful breath. We also consider inhaler costs as part of maintenance for all asthma patients, both severe and nonsevere.
- These are split into several types of controller inhalers, reliever inhalers and additional medication for severe asthmatics.
- Costs provided by Chiesi to Frontier on inhaler costs are inflated to 2023 values before taking the average between DPI and pMDI.

Table 17: Average costs per inhaler

Class	DPI (2021£)	pMDI (2021£)	DPI (2023£)	pMDI (2023£)	Average cost (2023£)
Controller					
ICS	£17.63	£9.69	£17.95	£9.87	£13.91
ICS+/LABA	£26.83	£20.14	£27.32	£20.51	£23.92
ICS+/LABA+/LAMA	£29.23	£22.01	£29.77	£22.41	£26.09
Reliever					
SABA	£4.48	£1.78	£4.56	£1.81	£3.19

- To calculate the costs per patient, how many controller inhalers are prescribed per month are then converted to an annual basis.
- The number of inhalers that are prescribed per month, and by extension year is dependent on their severity.

Table 18: Controller inhaler therapeutic class prescribed per month by asthma severity

Asthma severity	Controller inhaler therapeutic class prescribed per month (#)	Source
Non-severe asthma	1	Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022
Severe asthma	2	Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022

- Adherence to treatment rates are applied to the patients in order to determine the number of controller inhalers used in a year.

Table 19: Annual usage of controller inhalers by type of patient

Asthma severity	Number of controller inhalers used in a year (#)
Optimally adhering non-severe	10.8
Sub-optimally adhering non-severe	7.2
Severe	21.6

- The 2023 average cost of different inhalers is multiplied by the number of controller inhalers used in a year based on the severity of the asthma patient.

Table 20: Per-patient NHS cost of controller inhalers at the maintenance treatment stage

Asthma severity	Controller class	Number of controller inhalers used in a year (#)	Per-patient cost (2023£)
Optimally adhering non-severe	ICS	10.8	£150.24
Sub-optimally adhering non-severe	ICS	7.2	£100.16
Severe	ICS+/LABA	21.6	£516.59
Severe	ICS+/LABA+/LAMA	21.6	£563.56

- Summing this together brings us to a total cost for asthma patients and their controller inhalers.

Optimally adhering non-severe	£150.24
Sub-optimally adhering non-severe	£100.16
Severe	£1,080.15

- The number of reliever inhalers that are prescribed per year are different depending on the severity of asthma, as well as the adherence to treatment.
- These costs are then applied to their respective populations.

Table 21: Reliever inhalers prescribed annually

Severity	Number of reliever inhalers per year	Unit cost (2023£)	Per-patient cost (2023£)
Optimally adhering non-severe controlled	2	£3.19	£6.37
Optimally adhering non-severe uncontrolled	7	£3.19	£22.31
Sub-optimally adhering non-severe controlled	2	£3.19	£6.37
Sub-optimally adhering non-severe uncontrolled	8	£3.19	£25.50
Severe uncontrolled	15	£3.19	£47.81

- Also considered are add on medications that are prescribed to asthma patients.
- These are presented on an annual basis in order to capture annual costs.
- It is assumed that non-severe asthma patients do not require any add on medication.
- Firstly, the list of potential add on medications is listed below.
- The costs are shown in 2023 terms following the application of inflation.

Table 22: Add on medication type

Add on medication type	Brand name	Unit cost (2021£)	Unit cost (2023£)
LTRA	ZAFIRLUKAST	£4.56	£4.64
LTRA	Montelukast	£3.07	£3.13
Theophylline	THEOPHYLLINE	£3.85	£3.92
Theophylline	AMINOPHYLLINE	£2.80	£2.85
Beta-2 adrenergic agonist	BAMBUTEROL	£30.26	£30.82
Beta-2 adrenergic agonist	TERBUTALINE	£14.06	£14.32
Beta-2 adrenergic agonist	ISOPRENALINE	£0.01	£0.01
Allergy	KETOTIFEN	£8.99	£9.16
Biological treatment	OMALIZUMAB	£249.29	£253.87

Nebuliser	Salbutamol	£33.93	£34.55
Allergy injection	MEPOLIZUMAB	£840	£855.43
Allergy injection	BENRALIZUMAB	£1,955	£1,990.90
Oral Corticosteroid	PREDNISOLONE	£79	£80.45
Antibiotic	Azithromycin	£108	£109.98
Bronchial Thermoplasty	Bronchial Thermoplasty	£1,996	£2,032.66

- These values are adjusted based on the level of adherence for severe asthma, then converted into a total add on medication cost for severe asthma patients.

Table 23: Add-on medications prescribed to severe asthma patients

Add on medication	Number of packs a year	Proportion of patients prescribed	Level of adherence	Unit cost (2023£)	Per-patient cost (2023£)
LTRA	12	10%	90%	£3.89	£4.20
Theophylline	12	10%	90%	£3.39	£3.66
Oral Corticosteroid	12	5%	90%	£80.45	£43.44
Biological treatment	12	10%	90%	£253.87	£274.18
Antibiotic	12	10%	90%	£109.98	£118.78
Bronchial Thermoplasty	1	1%	90%	£2,032.66	£18.29

- The sum of all the per patient costs for severe asthma patients add on medication is calculated below.

Table 24: Total Add-on medications prescribed to severe asthma patients

Add-on medications prescribed to severe asthma patients	**£462.55**

Modelling the cost of uncontrolled asthma

- It is assumed that a patient who has uncontrolled symptoms and an exacerbation will see a GP.
- The previous assumptions on duration of appointments and percentage of appointments done in person are maintained

Table 25: Inputs for primary care usage when a patient has uncontrolled symptoms

Activity	Input	Source	Notes
Proportion of exacerbations followed by a GP appointment (%)	74%	Bloom et al, Exacerbation risk and characterisation of the UK's asthma population from infants to old age, 2017	18 - 54 GP only level of care divided by total exacerbations
Duration of the appointment (hours)	0.25	Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022	

- From this, the additional costs to the NHS following an exacerbation are calculated
- This cost is derived from the proportion of exacerbations followed by a GP appointment multiplied by the duration.

Table 26: NHS cost per exacerbation related to GP appointments when a patient has uncontrolled symptoms

Activity	Per-exacerbation unplanned GP appointment NHS cost (2023£)
Per exacerbation unplanned GP appointment cost	£52.98

Modelling the cost of asthma related secondary care

- In the population, a portion of asthma patients who suffer from an exacerbation will require secondary care including the use of reliever inhalers during secondary care

Table 27: Relievers used in secondary care during an exacerbation

Secondary care stage	Number of inhalers used	Per-exacerbation cost (£2023)
In the hospital	2	£6.37
In the ambulance	2	£6.37

- Together, the sum provides a total cost of reliever used during secondary care.

Table 28: Relievers used in secondary care during an exacerbation

Relievers used in secondary care during an exacerbation	£14.55

- This also extends to oral corticosteroid medication that is prescribed following an exacerbation

Table 29: OCS used in secondary care during an exacerbation

Activity	Add-on medication	Data	Unit cost (2023£)
Number of packs prescribed	Oral Corticosteroid	1.5	£80.45
Portion of exacerbations that are treated with rescue medication	Oral Corticosteroid	90%	

- Multiplying the number of packs prescribed by the unit cost of a pack brings us to the total cost of OCS used.

Oral corticosteroids	£108.61

- The cost of using secondary services is measured. These services are provided in 2023 terms.
- This includes the costs of calling 999, and ambulance, using A&E and for some inpatient stays of less than or more than one day
- For the purposes of the bed day analysis, the mean stay for inpatient asthma patients is 3 days.
- This is all combined based on usage into a weighted cost.

Table 30: Cost of secondary care services

Secondary care service	Unit cost (£2021)	Unit cost (£2023)	Usage	Per-exacerbation cost (2023£)
Call to 999	£89.59	£91.24	72%	£64.50

Ambulance	£357.40	£363.96	28%	£100.07
A&E	£296.87	£302.32	28%	£83.12
Inpatient <1 day	£497.11	£506.24	14%	£69.60
Inpatient > 1 day (2009)	£1,342.20	£1,366.85	13%	£174.49

- The total is applied to all patients within the population who have an exacerbation that requires secondary care.

Total	£491.78

Calculating indirect costs

- The indirect impacts for uncontrolled asthma patients are modelled. This is because uncontrolled asthma is assumed to have a significant health impact as well as one for those who would otherwise be healthy and working.

Transferring burden of disease into monetary terms

- A change in QALYs demonstrates the morbidity and mortality of asthma outcomes.
- One QALY equates to one year of good health and this is used for appraisals for health interventions as per the Green Book guidance by HM Treasury.
- The expected QALYs lost by asthma patients are monetised

Measuring quality of life loss due to uncontrolled asthma

- The health of asthma patients against the general population are examined
- Males and females are examined separately. However, the rest of the model does not do this, so they are combined together to have a weighted impact
- The difference in EQ-5D is measured from uncontrolled asthma patients to the general population, and then apply a monetary value of £20,000 for QALYs.

Table 31: HRQoL impact of uncontrolled asthma

HRQoL impact of uncontrolled asthma	Input	Source
Female % in population	58.51%	Asthma and Lung UK
EQ-5D differences from the general population in female uncontrolled patients	-0.18	Hernandez et al, Impact of asthma on women and men:

		Comparison with the general population using the EQ-5D-5L questionnaire , 2018
EQ-5D differences from the general population in male uncontrolled patients	-0.15	Link
Weighted average	-0.167553	
EQ-5D for the general population (65+)	£20,000.00	NICE

- This estimates the monetary value of impact to the health of an uncontrolled asthma patient that experiences an exacerbation.

The monetary value of health reduction of health reduction for one uncontrolled patient with an exacerbation	£3,351.06

Years of life lost to asthma death

To estimate the years of life lost to asthma death:

- Find the average age of death for an asthma related death
- Take the average life expectancy from the NHS, then we find the difference between this to find the impact of asthma.
- Frontier uses an adjusted EQ-5D that is lower to adjust for two factors
    - The first factor is that older patients die from asthma, so the EQ-5D score reflects this, and to remain in line with NHS YLL calculation methodology.
    - The monetary value of the exacerbation that causes the death is subtracted to isolate the monetary value of the death
- The monetary value of QALYs lost due to one year of premature asthma death is multiplied number of years of premature death compared to the average UK life expectancy, capped at 75

Table 32: YLL due to asthma death

Item	Input	Source
Average age of asthma death	72.45	NHS England
Average UK life expectancy for YLL calculations	75	NHS England
YLL due to premature death	2.55	

EQ-5D of the general population	0.73	
Monetary value for QALY lost	£20,000	NICE
Monetary value of a QALY for 65 and above	£14,600	NICE
The monetary value of health reduction of health reduction for one uncontrolled patient with an exacerbation	£3,351.06	
Monetary value of QALY lost due to one year lost due to asthma death	£11,248.94	
NPV value of QALY lost due to asthma death	£44,467.89	

Modelling productivity impacts

- Several impacts to productivity based on uncontrolled asthma are measured. They are:
    - Unemployment
    - Lower hourly earnings
    - Reduced working hours due to illness
- This only applies to uncontrolled asthma patients who are not fatal based on the population profile.
- The first thing modelled is annual wages, and the additional impact having asthma has on it.
- The median hourly wage of an asthma patient and the median hourly wage of the general population is compared to calculate the percentage difference in hourly wage.
- These values are inflated to 2023
- It is assumed for these calculations of 37 working hours per week and 48 working weeks per year to general an annual working hours total of the general population.
- We leverage evidence that finds asthma patients work fewer hours also on average compared to the general population.
- So, we model a lower hourly wage, and fewer hours worked to generate the average wage for asthma - which is lower.

Table 33: Modelling productivity impacts

Item	Value	Source
Median hourly wage of asthma patient	£10.26	Potential Limited, The economic cost of uncontrolled asthma , 2021
Median hourly wage of the general population	£11.82	Potential Limited, The

		economic cost of uncontrolled asthma , 2021
% difference in hourly wage	-15.20%	
Median hourly wage of the general population (2023)	£17.03	ONS, Average Weekly Earnings
Median hourly wage of asthma patient (2023)	£14.44	
Annual working hours of the general population	1776	
Assumed lower hours worked per asthma patient	3.50%	Jones et al, Asthma impacts on workplace productivity in employed patients who are symptomatic despite background therapy: a multinational survey , 2019
Annual working hours average per asthma patient	1713.84	
Average wage per asthma patient	£24,744.63	

- The second thing that we model is unemployment
- We then model the per patient loss due to higher unemployment of uncontrolled asthma patients by multiplying the average wage per asthma patient by the difference in the unemployment rate due to asthma

Difference in unemployment rate due to asthma	10.20%	Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022
Per-patient loss due to unemployment of patients with uncontrolled asthma	£2,523.95	

- The source the report uses finds that the difference in unemployment rate relates only to uncontrolled asthma patients with a specific disability category.
- We have not modelled this.
- Therefore, we adjust the impact to our population within the model.
- We list the assumptions that have been made in the Frontier model
    - They assume all severe patients fall under the disability category in 2018
    - We then apply population growth from 2018 to 2023 to find the current number of patients that fall within this disability profile
    - We subtract our severe population to get the remainder of patients who fall in the disability model that are uncontrolled.
    - We then take our total number of uncontrolled asthma patients in our model that are alive
    - We calculate % of patients that uncontrolled in our model that fall under the disability category
    - We then multiply that % with the per patient loss due to higher unemployment calculated above.
    - This gets us an adjusted per patient loss due to higher unemployment of patients with non-severe uncontrolled asthma.

Table 34: Modelling unemployment impacts

Item	Value
Number of patients disability unable to breathe	661279
Population growth between 2018 and 2021	1.96%
Number of patients disability unable to breathe (2023)	674257.2127
Number of severe asthma patients	133257
Number of uncontrolled patients	541000.2127
Total uncontrolled	1530767

% of uncontrolled patients within the uncontrolled patients that fall under the disability model	28.51%
Adjusted per-patient loss due to higher unemployment of patients with non-severe uncontrolled asthma	£719.55

Lower wages

- We calculate lower wages for asthma patients that the population, which indirectly affects the economy through reduced purchasing power
- This hourly wage was calculated above and is adjusted for a yearly loss, then only to include the employed adult population and the reduced working hours of asthma patients.
- We assume this is the lower wage cost for severe asthma
- For non-severe asthma, we adjust using the number of non-severe uncontrolled asthma patients that fit into the disability category as a ratio.

Table 35: Annual wage lost

Item	Value	Source
Hourly wage difference	£2.59	
Total loss from lower hourly wage	£4,436.97	
Adjustment to include only the impact for the employed population	52%	Potential Limited, The economic cost of uncontrolled asthma , 2021
Per-patient monetary value from lower hourly wage - severe asthma	£2,307.22	
Per-patient monetary value from lower hourly wage - non-severe uncontrolled asthma	£815.41	

- Lastly we calculate the impacts of reduced working hours due to illness
- We use the assumptions that we have presented above to calculate the number of hours that are lost due to uncontrolled asthma.
- This is estimated by multiplying the annual working hours for an average population by the percentage of hours that are lost due to uncontrolled asthma.
- This gives us a number of annual working hours lost which we multiply against the median hourly wage that we calculated, and adjust this to only include the employed population.

Table 36: Lost productivity due to reduced working hours (2023)

Item	Value	Source
Annual working hours lost - asthma patients with uncontrolled asthma	62.16	
Median hourly wage of asthma patient (2023)	£14.44	
Monetary value lost due to reduced working hours per uncontrolled patient	£897.47	
Total loss from lower hourly wage adjusted for employed asthma patients	£466.69	

- The sum of this provides the indirect cost to the UK economy by multiplying our UK asthma population
- The total monetary values are independent for each nation, as we have used their individual prevalence data for each population profile.

Cost of emissions and patient travel costs

- We leverage the existing methodology to model the impact of GHG emissions.
- These include emissions from diagnosis, maintenance and exacerbations.
- These emissions come from inhalers, patient travel and secondary care usage.
- They also differ depending on asthma severity and adherence to treatment.
- We then monetise the impact of these emissions based on Green Book guidance from HM Treasury.
- First we take the assumption of GHG emissions that are generated within 9.22 minutes of contact at a GP facility.
- We also model patient travel costs.

Table 37: Emissions generated by the facility where the appointment takes place

Item	GHG Emissions (g CO2e)	Source
GHG emissions generated by 9.22 minutes of contact in a GP facility	6000	PSSRU, Unit Costs of Health & Social Care 2020 , 2020

- This is combined with the weighted proportion of journeys that patients travel to have their diagnosis appointments.
- This is calculated by taking the sum of journeys to and journeys from and dividing it by the total number of journeys.

Table 38: Proportion of journeys travelling to an HCP facility

Mode of travel	Journeys to (#)	Journeys from (#)	Proportion of journeys (%)	Source
Car	179	168	56.70%	Andrews et al. Carbon footprint of patient journeys through primary care: a mixed methods

				approach, 2013
Taxi	29	30	9.64%	Andrews et al. Carbon footprint of patient journeys through primary care: a mixed methods approach, 2013
Bus	16	11	4.41%	Andrews et al. Carbon footprint of patient journeys through primary care: a mixed methods approach, 2013
Walk	76	91	27.29%	Andrews et al. Carbon footprint of patient journeys through primary care: a mixed methods approach, 2013
Other (Train)	6	6	1.96%	Andrews et al. Carbon footprint of patient journeys through primary care: a mixed methods approach, 2013

- Take the annualised distance travel per year and the number of appointments per year to estimate the average distance travelled one way to get to an appointment.
- Take the GHG emissions for one round trip by multiplying the one way emissions by two, then weight them against the proportion of journeys from the table above

Table 39: Weighted average of journey distance travelling to an HCP facility

Mode of travel	Annualised distance (km)	Appointments per year (#)	Number of journeys (#)	Average distance one way trip (km)	GHG emissions conversion (g CO2e/km)	GHG emissions for one round trip (g CO2e)	Weighted GHG emissions against proportion of journeys (g CO2e)
Car	21920	50	347	1.263400576	199.7	504.6021902	286.1061438

Taxi	21920	50	59	7.430508475	199.7	2967.745085	286.1061438
Bus	38526	50	27	28.53777778	147.5	8418.644444	371.4107843
Walk	62327	50	167	7.464311377	0	0	0
Other (Train)	6066	50	12	10.11	50.1	1013.022	19.86317647

- Taking the sum of this generates an average weighted GHG emission per patient per trip.

Average GHG emissions generated by patient travelling to an HCP facility (g CO2e)	1195.595078

- Estimate the cost of patient travel
- For travel by car, take the approved mileage rates and multiply it by the cost of a round trip.
- All costs are weighted by the proportion of trips by their respective mode of transport.

Table 40: Average patient travel cost to an HCP facility[126]

Mode of travel	Approved mileage rates (£/1.6 km)	Approved mileage rates (£/km)	Cost of round trip (£)	Weighted cost (£)	Source	Notes
Car	0.45	0.28125	£0.71	£0.40	GOV UK, Travel — mileage and fuel rates and allowances, 2023	
Taxi	N/A	N/A	£22.00	£2.12	Taxi Insurer, HOW MUCH DOES A TAXI COST PER MILE IN THE UK	AVERAGE(Monday to Friday 8pm - 10pm, Saturday and Sunday - 5am - 10pm, 4 miles)
Bus	N/A	N/A	£3.50	£0.15	TFL, Bus and tram fares	18+ Pay as you go

[126] This is adjusted for incidence in asthma patients only during the diagnosis phase

Walk	N/A	N/A	£0.00	£0.00	N/A	
Other (Train)	N/A	N/A	£6.80	£0.13	London Toolkit, London Underground - 2023 fares and how to use them	Zone 1 + 2 Peak

- Taking the sum of this generates an average weighted patient travel cost to an HCP facility

Average patient travel cost to an HCP facility (2023£)	£2.81

Emissions during diagnostic testing[127]

- Estimate the Per-patient GHG emissions generated by HCP appointments at the diagnosis stage
- Take the number of appointments per patient and adjust them between the length of appointment and the emissions per 9.22 appointment.
- Take the number of emissions per appointment, and multiply by the number of appointments.
- These values differ asthma severity
- Sum the emissions up by asthma severity to find a total of emissions per asthma patient

Non severe per patient emission	2,690.09
Severe per patient emission	8,070.27

- We do the same for patient travel cost

Table 41: Average patient travel cost to an HCP facility

Per-patient travel cost at the diagnosis stage	Number of appointments per patient (#)	In person appointments (%)	Average patient travel cost to an HCP facility (2023£)	Total patient cost (2023£)
Non-severe	2.5	90%	£2.81	£6.33
Severe	7.5	90%	£2.81	£18.98

Patient cost and emissions during maintenance

- Emissions for asthma patients are modelled based on severity and treatment adherence
  - Specifically, they relate to these sub populations
    - Optimally adhering non-severe controlled

[127] This is adjusted for incidence of asthma patients only

    - Optimally adhering non-severe uncontrolled
    - Sub-optimally adhering non-severe controlled
    - Sub-optimally adhering non-severe uncontrolled
    - Severe uncontrolled
- This is used to estimate emissions generation during review appointments

Table 42: Per-patient HCP costs from HCP appointments at the maintenance stage

Item	Level of adherence (%)	Number of appointments (#)	Duration (hrs)	Number of appointments
Optimally adhering non-severe	90%	1	0.25	0.9
Sub-optimally adhering non-severe	60%	1	0.25	0.6
Severe	90%	3	0.416666667	2.7

- Per-patient GHG emissions generated by HCP appointments are calculated by taking the per patient GHG emissions of an appointment, and adjusting that value based on the level of adherence and the number of appointments.
- They are also adjusted for the length of expected appointments, given that longer appointments will generate more emissions.

Table 43: Per-patient GHG emission generated by HCP appointments

Per-patient GHG emissions	**Per-patient GHG emissions (g CO2e)**
Optimally adhering non-severe	8785.249458
Sub-optimally adhering non-severe	5856.832972
Severe	43926.24729

- Per-patient GHG emission generated by patient travel is also estimated
- This is done by adjusting the level of emissions generated by patient travel during diagnosis using the number of appointments, the level of adherence and the proportion of asthma reviews that are done in person.

Table 44: Per-patient GHG emission generated by patient travel

Per-patient GHG emission generated by patient travel	**Per-patient GHG emissions (g CO2e)**
Optimally adhering non-severe	522.883987
Sub-optimally adhering non-severe	348.5893247

Severe	1568.651961

- The same is done to adjust for patient travel costs for asthma reviews

Table 45: Per-patient GHG emission generated by patient travel

Per-patient travel costs during the maintenance stage	Average patient travel cost to an HCP facility (2023£)
Optimally adhering non-severe	£1.70
Sub-optimally adhering non-severe	£1.70
Severe	£5.09

Emissions during exacerbation

- From the above, we assume a certain portion of patients will see their GP following an exacerbation
- We adjust for this portion and the length of appointments that occur following an exacerbation

Table 46: Per-exacerbation GHG emissions generated by HCP appointments when a patient has uncontrolled symptoms

Activity	Per-exacerbation unplanned GP appointment emissions (2023£)
GP appointment	7182.581478

- We replicate this also for patient travel to generate Per-exacerbation GHG emissions generated by patient travel when a patient has uncontrolled symptoms

Table 47: Per-exacerbation GHG emissions generated by patient travel when a patient has uncontrolled symptoms

Activity	Per-exacerbation unplanned GP appointment emissions (2023£)
GP appointment	427.4957539

- We replicate this also for patient travel costs

Table 48: Per-patient travel costs when a patient has uncontrolled symptoms

Activity	Per-exacerbation unplanned GP appointment travel cost (2023£)

GP appointment	£1.25

- Below we present a weighted average of different inhaler combinations

Table 49: Average CO2e per inhaler by product

Class	DPI (g CO2e)	pMDI (g CO2e)	Weighted average (g CO2e)	Source
ICS	2154	155327	14282	Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022
ICS+/LABA	981	15757	10924	Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022
ICS+/LABA+/LAMA	820	14761	8807	Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022
SABA	527	20907	18252	Frontier Economics, Environmental Societal and Economic Impact of Asthma in the UK, 2022

- We calculate the Per-patient emissions generated by controlled inhalers at the maintenance treatment stage by multiplying the Average CO2e per inhaler by product by the number of controller inhalers used per year.

Table 50: Per-patient emissions generated by controlled inhalers at the maintenance treatment stage

Severity	Emissions (g CO2e in 2021)	Per-patient emissions (g CO2e in 2021)
Optimally adhering non-severe	14282	154245.6
Sub-optimally adhering non-severe	14282	102830.4
Severe	10924	235958.4
Severe	8807	190231.2

- We repeat this for reliever inhalers as well.

Table 51: Reliever inhalers prescribed annually

Severity	Number of reliever inhalers per year	Emissions (g CO2e)	Per-patient emissions (g CO2e)
Optimally adhering non-severe controlled	2	18252	36504
Optimally adhering non-severe uncontrolled	7	18252	127764
Sub-optimally adhering non-severe controlled	2	18252	36504
Sub-optimally adhering non-severe uncontrolled	8	18252	146016
Severe uncontrolled	15	18252	273780

Patient emissions during secondary care

- During secondary care, we have assumed reliever care usage to generate per patient emissions.

Table 52: Relievers used in secondary care during an exacerbation

Secondary care stage	Number of inhalers used	Emissions (g CO2e)	Per-patient emissions (g CO2e)
In the hospital	2	18252	36504
In the ambulance	2	18252	36504

- This extends also to the range of secondary care services a patient is expected to use.

- We calculate the Emissions per exacerbation (g CO2e) by adjusting the emissions per unit of secondary care service by the expected usage.

Table 53: Unit cost of secondary care services

Secondary care service	Emissions per unit (g CO2e)	Usage	Emissions per exacerbation (g CO2e)
Call to 999	2967.745085	72%	0
Ambulance	75000	28%	21000
A&E	76000	28%	21280
Inpatient <1 day	125000	14%	17500
Inpatient > 1 day (2009)	375000	13%	48750

- Adding together the total emissions per exacerbation column gets us the expected total emissions per exacerbation per patient.

Total	108,530.00

Assessing the potential impacts of better diagnosis and care for asthma in the UK

FeNO false positive impact

1. Calculate the number of patients misdiagnosed as false positive
2. Break down the proportion of false positive asthma patients by optimal adherence
3. Apply the proportions to the original population of false positive asthma patients
4. Calculate the total cost of false positive asthma patients
5. Calculate the reduced number of patients misdiagnosed as false positive
6. Calculate the reduced total cost of false positive asthma patients.

FeNO maintenance impact

1. The asthma population is adjusted after removing for false positives
2. This is multiplied by the reduced maintenance cost to calculate the impact savings.

Refill impact

1. Calculate the number of asthma patients by adherence adjusted for reduced false positive
2. Calculate the number of asthma patients by adherence after introducing patient refills
3. This generates a revised total cost, and savings.

Total impacts

1. The total impacts are calculated by adding the impacts of FeNO and patient refills together
2. They are then adjusted for current availability, appropriate use and take up rate.

Appendix 2: COPD methodology

Introduction to COPD methodology appendix:

This appendix illustrates the methodology, assumptions, and sources that we have used to develop our model that estimates the costs of COPD across the UK, as well as the impact of better diagnosis and care. Where possible, we have used assumptions from primary data sources, and through stakeholder workshops. We have also drawn on previous work that has been completed on calculating the total economic cost of asthma in the UK.

A2.1 COPD population

Population growth:

1. Forecasted growth prevalence in Scotland and England was obtained from 2011 - 2030
2. Average annual growth rate was calculated

Table 1: COPD prevalence average annual growth rate

Year	COPD Prevalence (%)
2011	1.79
2030	2.19
Growth rate	2.1%
McLean S, Hoogendoorn M, Hoogenveen RT, Feenstra TL, Wild S, Simpson CR, Mölken MR, Sheikh A. Projecting the COPD population and costs in England and Scotland: 2011 to 2030, (2016)	

COPD diagnosed population:

1. Population of COPD patients were obtained and updated to 2023 by applying prevalence growth

Table 2: COPD diagnosed population by devolved nations (2023)

Country	Population	Forecasted population (2023)	Source
England	1400000 (2019)	1521670	Task Force for Lung Health, Prevalence of Chronic Obstructive Pulmonary Disease in England from 2000 to 2019, 2023
Wales	77,270 (2020)	82254	StatsWales, Quality Assurance and Improvement Framework (QAIF) disease registers by local health board, 2022
Scotland	90,609 (2022)	92517	Public Health Scotland, General practice - disease prevalence data visualisation, 2022
Northern Ireland	-	42,757	NI Department for Health, 2022/23 raw disease prevalence trend data for Northern Ireland, 2023

COPD undiagnosed population:

1. Undiagnosed incidence of COPD estimated to be in 500,000 in England
2. Percentage of undiagnosed as proportion of diagnosed estimated to be 36%
3. Assume 36% of diagnosed population equals undiagnosed incidence in devolved nations

Table 3: COPD Undiagnosed population by devolved nations (2023)

Country	Population
England	543454

Wales	29376
Scotland	33042
Northern Ireland	15270

COPD population by GOLD category:

1. Estimates for GOLD category proportions were obtained and applied to devolved nations

Table 4: GOLD category prevalence

GOLD Category	Prevalence
A	34.6%
B	17.5%
C	21.1%
D	26.8%

Source: John Haughney, Kevin Gruffydd-Jones, June Roberts, Amanda J Lee, Alison Hardwell, Lorcan McGarvey, The distribution of COPD in UK general practice using the new GOLD classification, 2014

Table 5: England COPD population by GOLD category

England GOLD Category	Prevalence	Diagnosed	Undiagnosed
A	34.6%	526498	188035
B	17.5%	266292	95104
C	21.1%	321072	114669
D	26.8%	407808	145646

Table 6: Wales COPD population by GOLD category

GOLD Category	Prevalence	Diagnosed	Undiagnosed
A	34.6%	28460	10164
B	17.5%	14394	5141
C	21.1%	17356	6198

D	26.8%	22044	7873

Table 7: Scotland COPD population by GOLD category

GOLD Category	Prevalence	Diagnosed	Undiagnosed
A	34.6%	32011	11432
B	17.5%	16190	5663
C	21.1%	19521	6828
D	26.8%	24794	8673

Table 8: Northern Ireland COPD population by GOLD category

GOLD Category	Prevalence	Diagnosed	Undiagnosed
A	34.6%	14794	5284
B	17.5%	7482	2672
C	21.1%	9022	3222
D	26.8%	11459	4092

COPD diagnosed population by exacerbation classification:

1. Exacerbations per cycle (3 months) were obtained
2. Multiplied by four to obtain annual exacerbations

Table 9: COPD exacerbation rate

GOLD category	Moderate exacerbation per cycle	Severe exacerbation per cycle	Moderate exacerbation per year	Severe exacerbation per year
A	0.38	0.029	1.52	0.116
B	0.39	0.024	1.56	0.096
C	0.499	0.052	1.996	0.208
D	0.599	0.082	2.396	0.328
Source: NICE, Chronic obstructive disease in over 16s: diagnosis and management 2018. (2018)				

COPD undiagnosed population by exacerbation classification:

1. Obtained difference in exacerbation of early vs late diagnosis
2. Difference in exacerbation rate applied to diagnosed exacerbation to obtain annual undiagnosed rate

Table 10: Exacerbation rate of early vs late diagnosis

Undiagnosed population	Exacerbation rate per year per 100 person years
Late COPD diagnose	94.11
Early COPD diagnosis	47.93
Exacerbation rate difference	51%
Source: Kostikas K, Price D, Gutzwiller FS, Jones B, Loefroth E, Clemens A, Fogel R, Jones R, Cao H. Clinical Impact and Healthcare Resource Utilization Associated with Early versus Late COPD Diagnosis in Patients from UK CPRD Database. (2020)	

Table 11: Undiagnosed exacerbation rate

GOLD Category	Moderate exacerbation rate	Severe exacerbation rate
A	2.98	0.23
B	3.06	0.19

NHS costs:

Treatment costs:

1. Treatment combination proportions were obtained for each GOLD category

Table 12: Treatment combination proportion by GOLD category

	GOLD category			
	A	B	C	D
Treatment combination	Proportion			
LAMA	16%	15%	11%	10%
LABA	2%	2%	1%	1%
LAMA + LABA	3%	4%	2%	3%
LABA + ICS	20%	16%	21%	15%
LAMA + LABA + ICS	22%	43%	45%	62%
ICS Only	3%	1%	2%	1%
ICS LAMA	1%	1%	2%	1%
SAMA SABA	10%	8%	7%	5%
None	23%	10%	9%	3%
Source: Gayle A, Dickinson S, Morris K, Poole C, Mathioudakis AG, Vestbo J. What is the impact of GOLD 2017 recommendations in primary care? - a descriptive study of patient classifications, treatment burden and costs. Int J Chron Obstruct Pulmon Dis. (2018)				

2. NICE only consider LAMA, LABA, LAMA + LABA, LABA + ICS and LAMA + LABA + ICS and None, therefore all other treatment combinations are excluded and the proportion of NICE combinations are calculated

Table 13: NICE Treatment combination proportion by GOLD category

	GOLD category			
	A	B	C	D
Treatment combination	Proportion			
LAMA	19%	17%	12%	11%
LABA	2%	2%	1%	1%
LAMA + LABA	3%	4%	2%	3%
LABA + ICS	23%	18%	24%	16%
LAMA + LABA + ICS	26%	48%	51%	66%
None	27%	11%	10%	3%

3. Treatment combination costs were obtained from the NICE economic report for each treatment combination

Table 14: Annual treatment combination cost (2022)

COPD treatment combination	Annual unit cost (£)
LAMA	£315
LABA	£324
LAMA + LABA	£333
LABA + ICS	£368
LAMA + LABA + ICS	£635
Source: NICE, Resource impact report: Chronic obstructive pulmonary disease in over 16s: diagnosis and management. (2018)	

4. Proportion of treatment was applied to total diagnosed population for each GOLD category

Table 15: England treatment costs (2022)

GOLD category	Treatment combination	Unit cost per annum (£)	Usage proportion (%)	Weighted cost per annum (£)	Population	Total cost of diagnosed (£)
A	LAMA	£314.99	19%	£58.60	526498	£30,854,511.83
A	LABA	£323.96	2%	£7.53	526498	£3,966,640.37
A	LAMA + LABA	£333.27	3%	£11.63	526498	£6,120,887.53
A	LABA + ICS	£368.43	23%	£85.68	526498	£45,111,317.52
A	LAMA + LABA + ICS	£634.87	26%	£162.41	526498	£85,507,834.63
A	None	£0.00	27%	£0.00	526498	£-
B	LAMA	£314.99	17%	£52.50	266292	£13,980,021.77
B	LABA	£323.96	2%	£7.20	266292	£1,917,082.13
B	LAMA + LABA	£333.27	4%	£14.81	266292	£3,944,309.89
B	LABA + ICS	£368.43	18%	£65.50	266292	£17,441,883.85
B	LAMA + LABA + ICS	£634.87	48%	£303.33	266292	£80,773,625.25
B	None	£0.00	11%	£0.00	266292	£0
C	LAMA	£314.99	12%	£38.93	321072	£12,499,889.77
C	LABA	£323.96	1%	£3.64	321072	£1,168,712.35
C	LAMA + LABA	£333.27	2%	£7.49	321072	£2,404,572.86

C	LABA + ICS	£368.43	24%	£86.93	321072	£27,911,913.56
C	LAMA + LABA + ICS	£634.87	51%	£321.00	321072	£103,064,842.22
C	None	£0.00	10%	£0.00	321072	£-
D	LAMA	£314.99	11%	£33.51	407808	£13,665,577.51
D	LABA	£323.96	1%	£3.45	407808	£1,405,471.76
D	LAMA + LABA	£333.27	3%	£10.64	407808	£4,337,542.00
D	LABA + ICS	£368.43	16%	£58.79	407808	£23,975,963.43
D	LAMA + LABA + ICS	£634.87	66%	£418.74	407808	£170,767,102.76
D	None	£0.00	3%	£0.00	407808	£0
	Total					£650,819,702.98

Table 16: Wales treatment costs (2023)

GOLD category	Treatment combination	Unit cost per annum (£)	Usage proportion (%)	Weighted cost per annum (£)	Population	Total cost of diagnosed (£)
A	LAMA	£319.59	19%	£59.46	28460	£1,667,836
A	LABA	£328.69	2%	£7.64	28460	£214,416
A	LAMA + LABA	£338.14	3%	£11.80	28460	£330,864
A	LABA + ICS	£373.81	23%	£86.93	28460	£2,438,486
A	LAMA + LABA + ICS	£644.14	26%	£164.78	28460	£4,622,114
A	None	£0.00	27%	£-	28460	£0
B	LAMA	£319.59	17%	£53.27	14394	£755,688
B	LABA	£328.69	2%	£7.30	14394	£103,628
B	LAMA + LABA	£338.14	4%	£15.03	14394	£213,209
B	LABA + ICS	£373.81	18%	£66.46	14394	£942,819
B	LAMA + LABA + ICS	£644.14	48%	£307.76	14394	£4,366,207
B	None	£0.00	11%	£-	14394	£0
C	LAMA	£319.59	12%	£39.50	17356	£675,680
C	LABA	£328.69	1%	£3.69	17356	£63,175
C	LAMA + LABA	£338.14	2%	£7.60	17356	£129,979

C	LABA + ICS	£373.81	24%	£88.20	17356	£1,508,775
C	LAMA + LABA + ICS	£644.14	51%	£325.69	17356	£5,571,156
C	None	£0.00	10%	£-	17356	£0
D	LAMA	£319.59	11%	£34.00	22044	£738,691
D	LABA	£328.69	1%	£3.50	22044	£75,973
D	LAMA + LABA	£338.14	3%	£10.79	22044	£234,465
D	LABA + ICS	£373.81	16%	£59.65	22044	£1,296,017
D	LAMA + LABA + ICS	£644.14	66%	£424.86	22044	£9,230,792
D	None	£0.00	3%	£-	22044	£0
	Total					£35,179,968

Table 17: Scotland treatment costs (2023)

GOLD category	Treatment combination	Unit cost per annum (£)	Usage proportion %	Weighted cost per annum (£)	Population	Total cost of diagnosed (£)
A	LAMA	£314.99	19%	£59.46	32011	£1,875,934
A	LABA	£323.96	2%	£7.64	32011	£241,169
A	LAMA + LABA	£333.27	3%	£11.80	32011	£372,146
A	LABA + ICS	£368.43	23%	£86.93	32011	£2,742,739
A	LAMA + LABA + ICS	£634.87	26%	£164.78	32011	£5,198,821
A	None	£0.00	27%	£0.00	32011	£0
B	LAMA	£314.99	17%	£53.27	16190	£849,976
B	LABA	£323.96	2%	£7.30	16190	£116,557
B	LAMA + LABA	£333.27	4%	£15.03	16190	£239,811
B	LABA + ICS	£368.43	18%	£66.46	16190	£1,060,455
B	LAMA + LABA + ICS	£634.87	48%	£307.76	16190	£4,910,984
B	None	£0.00	11%	£0.00	16190	£0
C	LAMA	£314.99	12%	£39.50	19521	£759,985
C	LABA	£323.96	1%	£3.69	19521	£71,057
C	LAMA + LABA	£333.27	2%	£7.60	19521	£146,196

C	LABA + ICS	£368.43	24%	£88.20	19521	£1,697,026
C	LAMA + LABA + ICS	£634.87	51%	£325.69	19521	£6,266,275
C	None	£0.00	10%	£0.00	19521	£0
D	LAMA	£314.99	11%	£34.00	24794	£830,858
D	LABA	£323.96	1%	£3.50	24794	£85,452
D	LAMA + LABA	£333.27	3%	£10.79	24794	£263,720
D	LABA + ICS	£368.43	16%	£59.65	24794	£1,457,723
D	LAMA + LABA + ICS	£634.87	66%	£424.86	24794	£10,382,528
D	None	£0.00	3%	£0.00	24794	£0
	Total					£39,569,413

Table 18: Northern Ireland treatment costs (2023)

GOLD category	Treatment combination	Unit cost per annum (£)	Usage proportion %	Weighted cost per annum (£)	Population	Total cost of diagnosed (£)
A	LAMA	£314.99	19%	£59.46	14794	£866,973
A	LABA	£323.96	2%	£7.64	14794	£111,458
A	LAMA + LABA	£333.27	3%	£11.80	14794	£171,989
A	LABA + ICS	£368.43	23%	£86.93	14794	£1,267,571
A	LAMA + LABA + ICS	£634.87	26%	£164.78	14794	£2,402,661
A	None	£0.00	27%	£0.00	14794	£0
B	LAMA	£314.99	17%	£53.27	7482	£392,821
B	LABA	£323.96	2%	£7.30	7482	£53,868
B	LAMA + LABA	£333.27	4%	£15.03	7482	£110,830
B	LABA + ICS	£368.43	18%	£66.46	7482	£490,095
B	LAMA + LABA + ICS	£634.87	48%	£307.76	7482	£2,269,636
B	None	£0.00	11%	£0.00	7482	£0
C	LAMA	£314.99	12%	£39.50	9022	£351,231
C	LABA	£323.96	1%	£3.69	9022	£32,839
C	LAMA + LABA	£333.27	2%	£7.60	9022	£67,565

C	LABA + ICS	£368.43	24%	£88.20	9022	£784,289
C	LAMA + LABA + ICS	£634.87	51%	£325.69	9022	£2,895,991
C	None	£0.00	10%	£0.00	9022	£0
D	LAMA	£314.99	11%	£34.00	11459	£383,985
D	LABA	£323.96	1%	£3.50	11459	£39,492
D	LAMA + LABA	£333.27	3%	£10.79	11459	£121,879
D	LABA + ICS	£368.43	16%	£59.65	11459	£673,694
D	LAMA + LABA + ICS	£634.87	66%	£424.86	11459	£4,798,339
D	None	£0.00	3%	£0.00	11459	£0
	Total					£18,287,206

Maintenance costs:

1. Maintenance costs were calculated using the estimated maintenance cost of COPD for each GOLD category as estimated by NICE[128].

Costs included were:

- GP visits
- Respiratory team visits
- Outpatient visits
- Spirometry
- Pulmonary rehabilitation
- Home oxygen therapy
- Influenza vaccine
- SAMA
- SABA
- Theophylline
- Mucolytics
- Oral corticosteroids
- CT scan

2. Costs were estimated in the time span of a ‘cycle’ which was three months. Therefore, to obtain annual costs of treatment we multiplied the value by four and inflated it to 2022 values.

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Table 19: Maintenance costs (2022)

GOLD Category	Cost per cycle (2018) (£)	Cost per year (2018) (£)	Cost per year (2022) (£)
A	£26	£104	£109
B	£28	£112	£118
C	£189	£756	£796
D	£350	£1,400	£1,474
NICE, Economic model report, 2018			

3. GOLD category costs were then multiplied by the COPD diagnosed population.

Table 20: Annual maintenance costs in the UK (2022)

Country	England	Wales	Scotland	Northern Ireland
GOLD Category	Costs (£)			
A	£57,645,963	£3,116,044	£3,504,837	£1,619,778
B	£31,398,979	£1,697,267	£1,909,037	£882,271
C	£255,542,836	£13,813,332	£15,536,838	£7,180,429
D	£601,066,177	£32,490,548	£36,544,431	£16,889,196

Total	£945,653,955	£51,117,192	£57,495,143	£26,571,674

Exacerbation costs:

1. Moderate and severe exacerbation costs from the NICE economic model report were used and updated to 2022 values

Moderate exacerbation costs (2018) (£)	Cost (2022) (£)
£78	£84
Severe exacerbation cost (£)	**Cost (2022) (£)**
£2111	£2525
Source: NICE, Economic model report, 2018	

2. Estimations for annual exacerbations were obtained

Table 21: Diagnosed annual exacerbations in the UK

GOLD Category	Moderate exacerbation per year	Severe exacerbation per year
A	1.52	0.116
B	1.56	0.096
C	1.996	0.208
D	2.396	0.328
Source: Merinopoulou E, Raluy-Callado M, Ramagopalan S, MacLachlan S, Khalid JM. COPD exacerbations by disease severity in England, 2016		

Table 22: Undiagnosed annual exacerbations in the UK

GOLD Category	Moderate exacerbation per year	Severe exacerbation per year
A	2.98	0.23
B	3.06	0.19

3. Having established the proportion of moderate and severe exacerbations per year, exacerbations were broken up between moderate and severe exacerbation population
4. The cost of exacerbations was then applied to the annual number of exacerbations for each exacerbation severity

Table 23: England total exacerbation costs and bed days (2023)

England	Gold stage	Population	Moderate exacerbation rate	Severe exacerbation rate	Total moderate exacerbations	Total severe exacerbations	Exacerbation cost per person (£)	Total exacerbation cost (£)	Bed days
	A	526498	1.5	0.116	800277	61074	£436	£221,724,427	244,295
	B	266292	1.6	0.096	415416	25564	£387	£99,592,483	102,256
	C	321072	2.0	0.208	640861	66783	£720	£222,698,153	267,132
	D	407808	2.4	0.328	977107	133761	£1,070	£420,198,627	535,044
England undiagnosed									
	A	271727	3.0	0.228	810969	61890	£857	£224,686,904	247,559
	B	271727	3.1	0.188	832311	51219	£760	£199,539,477	204,876
Total		2065124			4476940	113109		£1,388,440,070	1,601,163

Table 24: Wales total exacerbation costs and bed days (2023)

Wales	Gold stage	Population	Moderate exacerbation rate	Severe exacerbation rate	Total moderate exacerbations	Total severe exacerbations	Exacerbation cost per person (£)	Total exacerbation cost (£)	Bed days
	A	28460	1.5	0.116	43259	3301	£436	£11,985,283	13,205
	B	14394	1.6	0.096	22455	1382	£387	£5,383,458	5,527

	C	17356	2.0	0.208	34642	3610	£720	£12,037,917	14,440
	D	22044	2.4	0.328	52817	7230	£1,070	£22,713,778	28,922
Wales undiagnosed									**-**
	A	14688	3.0	0.228	43837	3345	£857	£12,145,419	13,382
	B	14688	3.1	0.188	44990	2769	£760	£10,786,079	11,075
Total		111630			242000	6114		£75,051,934	86,551

Table 25: Scotland total exacerbation costs and bed days (2023)

Scotland	Gold stage	Population	Moderate exacerbation rate	Severe exacerbation rate	Total moderate exacerbations	Total severe exacerbations	Exacerbation cost per person (£)	Total exacerbation cost (£)	Bed days
	A	32011	1.5	0.116	48656	3713	£436	£13,480,700	14,853
	B	16190	1.6	0.096	25257	1554	£387	£6,055,158	6,217
	C	19521	2.0	0.208	38964	4060	£720	£13,539,902	16,241
	D	24794	2.4	0.328	59407	8133	£1,070	£25,547,802	32,530
Scotland undiagnosed									
	A	16521	3.0	0.228	49306	3763	£857	£13,660,817	15,051
	B	16521	3.1	0.188	50604	3114	£760	£12,131,870	12,456

Total		125558			272195	24337		£84,416,250	97,350

Table 26: Northern Ireland total exacerbation costs and bed days (2023)

Northern Ireland	Gold stage	Population	Moderate exacerbation rate	Severe exacerbation rate	Total moderate exacerbations	Total severe exacerbations	Exacerbation cost per person (£)	Total exacerbation cost (£)	Bed days
	A	14794	1.5	0.116	22487	1716	£436	£6,230,175	6,864
	B	7482	1.6	0.096	11673	718	£387	£2,798,422	2,873
	C	9022	2.0	0.208	18007	1877	£720	£6,257,535	7,506
	D	11459	2.4	0.328	27455	3759	£1,070	£11,807,047	15,034
Northern Ireland undiagnosed									
	A	7635	3.0	0.228	22787	1739	£857	£6,313,416	6,956
	B	7635	3.1	0.188	23387	1439	£760	£5,606,806	5,757
Total		58027			125796	11248		£39,013,401	44,991

A3.3 Adverse events costs

1. Obtained the cost and annual frequency and of adverse events per patient
2. Calculated average annual cost per patient of each adverse event
3. Calculated the total average annual costs of adverse events per patient
4. Applied costs to the COPD diagnosed and undiagnosed population

Table 27: Annual average cost of adverse events per patient (2022)

Adverse effect	Annual rate	Cost per patient (£)	Annual average cost per patient (£)
Cardiac arrest	0.002	£1,970.28	£3.35
Syncope	0.015	£141.16	£2.16
Ventricular tachycardia	0.000	£173.08	£0.07
Myocardial infarction	0.010	£2,099.48	£20.99
Artial flutter	0.335	£513.21	£171.92
Angina	0.017	£1,668.08	£27.86
Stroke	0.012	£5,091.40	£62.12
Heart failure	0.046	£1,990.62	£92.36
Pneumonia	0.015	£1,913.08	£28.31
Constipation	0.055	£31.08	£1.71
Diarrhoea	0.027	£22.08	£0.59

Dry mouth	0.003	£22.08	£0.07
Urinary retention	0.011	£2,760.08	£30.08
Glaucoma	0.002	£480.08	£0.72

Table 28: Total annual average cost of adverse events (2023)

Total annual average cost of adverse events (£)	**£442.32**

Table 29: Total cost of adverse events in the UK (2023)

Country	**Cost (£)**
England	£913,443,323
Wales	£49,376,051
Scotland	£55,536,758
Northern Ireland	£25,666,596
Total	**£1,044,022,728**

A3.4 Indirect costs

1. Productivity loss from an employed individual COPD patient was found to be £2284 when adjusted for 2023
2. To estimate productivity loss from the working COPD population, the proportion of COPD patients in employment had to be obtained
    a. Applied ONS population of working age to total COPD population
    b. Applied COPD proportion who are employed to COPD population of working age
    c. Calculated the weighted productivity loss from having COPD

Productivity	Value	Source
Loss of income due to COPD (2023)	£2,236	Fletcher, M.J., Upton, J., Taylor-Fishwick, J. et al. COPD uncovered: an international survey on the impact of chronic obstructive pulmonary disease [COPD] on a working age population, 2011
Population of working age	0.629	Gov, Working Age Population, 2023
COPD population of working age who are employed	0.6	NHS, Employment in people with COPD, 2013
Average productivity loss	£843.85	

3. Applied weighted productivity loss to total COPD population of devolved nations

Table 30: England productivity costs (2023)

England	Gold stage	Population	Productivity costs (£)
	A	526498	£444,286,247
	B	266292	£224,711,252
	C	321072	£270,937,567
	D	407808	£344,129,231
England undiagnosed			
	A	271727	£229,297,196
	B	271727	£229,297,196
Total		2065124	£1,742,658,688

Table 31: Wales productivity costs (2023)

Wales	Gold stage	Population	Productivity costs (£)
	A	28460	£24,015,831
	B	14394	£12,146,735
	C	17356	£14,645,492
	D	22044	£18,601,857
Wales undiagnosed			

	A	14688	£12,394,628
	B	14688	£12,394,628
Total		111630	£94,199,172

Table 32: Scotland productivity costs (2023)

Scotland	Gold stage	Population	Productivity costs (£)
	A	32011	£27,012,314
	B	16190	£13,662,297
	C	19521	£16,472,827
	D	24794	£20,922,833
Scotland undiagnosed			
	A	16521	£13,941,120
	B	16521	£13,941,120
Total		125558	£105,952,510

Table 33: Northern Ireland productivity costs (2023)

Northern Ireland	Gold stage	Population	Productivity costs (£)
	A	14794	£12,483,879
	B	7482	£6,314,101

	C	9022	£7,613,001
	D	11459	£9,669,594
Northern Ireland undiagnosed			
	A	7635	£6,442,960
	B	7635	£6,442,960
Total		58027	£48,966,494

A3.5 Intangible costs:

Exacerbation QALY costs

1. QALY loss estimates from a moderate and severe exacerbation were found to 0.01 QALYS for a severe exacerbation and 0.04 for a moderate exacerbations
2. QALY value is £20,000
3. Applied QALY loss to current number of annual moderate and severe exacerbations

Table 34: England QALY cost (2023)

England	Gold stage	Population	Moderate exacerbation rate	Severe exacerbation rate	Total moderate exacerbations	Total severe exacerbations	Moderate QALYs	Severe QALYs	Total QALY cost (£)
	A	526498	1.5	0.1	800277	61074	8003	2443	£208,914,370.13
	B	266292	1.6	0.1	415416	25564	4154	1023	£103,534,444.22
	C	321072	2.0	0.2	640861	66783	6409	2671	£181,598,563.03
	D	407808	2.4	0.3	977107	133761	9771	5350	£302,430,137.39
England undiagnosed									
	A	271727	3.0	0.2	810969	61890	8110	2476	£211,705,690.88
	B	271727	3.1	0.2	832311	51219	8323	2049	£207,437,430.98
Total		2065124	13.5	1.2	4476940	400291	44769	16012	£1,215,620,636.64

Table 35: Wales QALY cost (2023)

Wales	Gold stage	Population	Moderate exacerbation rate	Severe exacerbation rate	Total moderate exacerbations	Total severe exacerbations	Moderate QALYs	Severe QALYs	Total QALY cost (£)
	A	28460	1.5	0.1	43259	3301	433	132	£11,292,837.05

	B	14394	1.6	0.1	22455	1382	225	55	£5,596,539.90
	C	17356	2.0	0.2	34642	3610	346	144	£9,816,284.92
	D	22044	2.4	0.3	52817	7230	528	289	£16,347,818.76
Wales undiagnosed									
	A	14688	3.0	0.2	43837	3345	438	134	£11,443,721.50
	B	14688	3.1	0.2	44990	2769	450	111	£11,213,001.31
Total		111630					2420	866	£65,710,203.43

Table 36: Scotland QALY cost (2023)

Scotland	Gold stage	Population	Moderate exacerbation rate	Severe exacerbation rate	Total moderate exacerbations	Total severe exacerbations	Moderate QALYs	Severe QALYs	Total QALY cost (£)
	A	32011	1.5	0.1	48656	3713	487	149	£12,701,857.28
	B	16190	1.6	0.1	25257	1554	253	62	£6,294,826.60
	C	19521	2.0	0.2	38964	4060	390	162	£11,041,074.05
	D	24794	2.4	0.3	59407	8133	594	325	£18,387,554.86
Scotland undiagnosed									

	A	16521	3.0	0.228	49306	3763	493	151	£12,871,567.76
	B	16521	3.1	0.188	50604	3114	506	125	£12,612,060.34
Total		125558			272195	24337	£2,722	£973	£73,908,940.89

Table 37: Northern Ireland QALY cost (2023)

Northern Ireland diagnosed	Gold stage	Population	Moderate exacerbation rate	Severe exacerbation rate	Total moderate exacerbations	Total severe exacerbations	Moderate QALYs	Severe QALYs	Total QALY cost (£)
	A	14794	1.52	0.116	22486.76	1716.09	225	69	£5,870,228.25
	B	7482	1.56	0.096	11672.66	718.32	117	29	£2,909,186.28
	C	9022	1.996	0.208	18007.37	1876.52	180	75	£5,102,688.79
	D	11459	2.396	0.328	27455.47	3758.51	275	150	£8,497,902.44
Northern Ireland undiagnosed									
	A	7635	2.984502399	0.227764657	22787.21	1739.02	228	70	£5,948,660.81
	B	7635	3.063041	0.188494888	23386.87	1439.19	234	58	£5,828,728.1

			936						4
Total		58027					1258	450	£34,157,394.71

Adverse effects QALY costs

1. Obtained QALY costs of adverse effects (angina, stroke and heart failure excluded)
2. Obtained annual frequency of adverse events
3. Calculated average annual QALY cost of each adverse event per patient
4. Calculated total average annual QALY cost of adverse events per patient
5. Applied QALY value of £20,000 to obtain average annual QALY financial cost per patient
6. Applied QALY financial cost to diagnosed and undiagnosed population

Table 38: Annual frequency and QALY cost of adverse events per patient

Adverse effect	Annual rate	QALY	Annual average QALY per patient
Cardiac arrest	0.002	0.13	0.00022
Syncope	0.015	0.0014	0.00002
Ventricular tachycardia	0.000	0.032	0.00001
Myocardial infarction	0.010	0.13	0.00130
Atrial flutter	0.335	0.032	0.01072
Angina	0.017	0	0

Stroke	0.012	0	0
Heart failure	0.046	0	0
Pneumonia	0.015	0.13	0.00192
Constipation	0.055	0.0014	0.00008
Diarrhoea	0.027	0.41	0.01091
Dry mouth	0.003	0.001	0.00000
Urinary retention	0.011	0.012	0.00013
Glaucoma	0.002	0	0

Table 39

Total average annual QALYs of adverse events per patient	**0.025**

Table 40: Total QALY financial cost of adverse events in the UK (2023)

Country	QALYs	QALY costs (£)
England	52281	£1,045,620,151.03

Wales	2826	£56,520,850.97
Scotland	3179	£63,573,022.38
Northern Ireland	1469	£29,380,597.16
Total	**59755**	**£1,195,094,621.54**

Impacts of early diagnosis and better care

A4.1 Productivity loss

1. To obtain productivity loss we assumed a severe exacerbation lead to to 4 days in hospital estimated by in the Nation Audit COPD report: 2017
2. ONS daily medina wage was found to be £91.42
3. Wage was weighted estimated to working age employed COPD population to be £34.51
4. Accounting for week days productivity loss is £24.65

Productivity from lost bed days	Value	Source
Daily median wage	£91.43	ONS, Earnings and working hours, 2023
COPD population of working age	0.629	Gov, Working Age Population, 2030
COPD population of working age who are employed	0.6	NHS, Employment in people with COPD, 2013
Weighted productivity loss from reduced working hours per patient bed day	£34.51	

Weighted productivity loss from reduced working hours per patient bed day accounting for weekends	£24.65	

A4.2 Interventions

Early diagnosis

Diagnosis assumptions:

Current spirometry level in primary care	Proposed spirometry level in primary care
11.5%	40%

1. Apply exacerbation reduction to net increase undiagnosed spirometry testing
2. Calculated net reduction in annual exacerbations
3. Calculate net reduction in exacerbations, net QALY gains, net reduction in bed days

Table 42: England diagnosis impacts (2023)

England	Gold stage	Moderate exacerbation reduction	Severe exacerbation reduction	Net increased diagnosed	Moderate exacerbation reduction	Severe exacerbation reduction	Exacerbation savings (£)	Bed days saved	Productivity savings (£)	QALY savings (£)
	A	1.46	0.11	77442	113414	8655	£31,422,502.86	34621	£853,291.97	£29,607,077.99
	B	1.50	0.09	77442	116399	7163	£27,905,630.85	28652	£706,172.67	£29,010,161.09
Total		-	-	154884	229813	15818	£59,328,133.71	63273	£1,559,464.64	£58,617,239.08

Table 43: Wales diagnosis impacts (2023)

Wales	Gold stage	Moderate exacerbation reduction	Severe exacerbation reduction	Net increased diagnosed	Moderate exacerbation reduction	Severe exacerbation reduction	Exacerbation savings (£)	Bed days saved	Productivity savings (£)	QALY savings (£)
	A	1.46	0.11	4186	6131	468	£1,698,539.00	1871	£46,124.58	£1,600,406.46
	B	1.50	0.09	4186	6292	387	£1,508,434.97	1549	£38,172.06	£1,568,140.20
Total		-	-	8372	12423	855	£3,206,973.97	3420	£84,296.64	£3,168,546.66

Table 44: Scotland diagnosis impacts (2023)

Scotland	Gold stage	Moderate exacerbation reduction	Severe exacerbation reduction	Net increased diagnosed	Moderate exacerbation reduction	Severe exacerbation reduction	Exacerbation savings (£)	Bed days saved	Productivity savings (£)	QALY savings (£)
	A	1.46	0.11	4708	6896	526	£1,910,467.65	2105	£51,879.59	£1,800,091.01
	B	1.50	0.09	4708	7077	436	£1,696,644.13	1742	£42,934.84	£1,763,798.85
Total		-	-	9417	13972	962	£3,607,111.79	3847	£94,814.43	£3,563,889.86

Table 45: Northern Ireland diagnosis impacts (2023)

Northern Ireland	Gold stage	Moderate exacerbation reduction	Severe exacerbation reduction	Net increased diagnosed	Moderate exacerbation reduction	Severe exacerbation reduction	Exacerbation savings (£)	Bed days saved	Productivity savings (£)	QALY savings (£)
	A	1.46	0.11	2176	3186.795141	243	£882,932.39	973	£23,976.42	£831,921.26
	B	1.50	0.09	2176	3270.658171	201	£784,112.76	805	£19,842.55	£815,148.65

Total		-	-	4352	6457.453312	444	£1,667,045.15	1778	£43,818.97	£1,647,069.91

Pulmonary rehabilitation

Table 46: referral and completion rate

Current referral OF COPD population	Current completion of COPD population	Proposed referral	Proposed completion	Moderate exacerbation reduction	Severe exacerbation reduction
13.8% (GOLD A excluded, 50% of GOLD B excluded) (Taskforce for Lung Health)	4.3% (Taskforce for Lung Health)	80%	50%	23%	46%
Recommendation					
• All COPD patients should be referred for PR therefore we recommend a referral rate of 80% • The difficulty in ensuring people complete PR means we have to be conservative with our estimates, therefore we recommend a proposed completion rate of 50%					

1. Apply exacerbation reduction to net increase in PR completion rate
2. Calculated net reduction in annual exacerbations
3. Calculate net reduction in exacerbation costs, net QALY gains, net reduction in bed days

Table 47: England PR impacts (2023)

England	Gold stage	Moderate exacerbation rate reduction	Severe exacerbation rate reduction	Net completion	Moderate exacerbation reduction	Severe exacerbation reduction	Exacerbation savings	Bed days saved	Productivity savings (£)	QALY savings (£)

				increase			(£)			
	A	0.34	0.05	210599	71947	11224	£34,413,182.76	44897	£1,106,566.74	£23,368,835.17
	B	0.35	0.04	100792	35339	4446	£14,207,411.92	17783	£438,287.11	£10,624,472.80
	C	0.45	0.10	114623	51421	10954	£31,999,973.51	43817	£1,079,934.81	£19,047,628.32
	D	0.54	0.15	145587	78401	21940	£62,019,354.81	87762	£2,163,019.27	£33,232,504.03
Total				571601	237108	48565	£142,639,923.00	194259	£4,787,807.93	£86,273,440.33

Table 48: Wales PR impacts (2023)

Wales	Gold stage	Moderate exacerbation rate reduction	Severe exacerbation rate reduction	Net completion increase	Moderate exacerbation reduction	Severe exacerbation reduction	Exacerbation savings (£)	Bed days saved	Productivity savings (£)	QALY savings (£)
	A	0.34	0.05	11384	3889	607	£1,860,199.78	2427	£59,815.31	£1,263,199.12
	B	0.35	0.04	5448	1910	240	£767,979.66	961	£23,691.55	£574,304.39
	C	0.45	0.10	6196	2780	592	£1,729,754.09	2369	£58,375.73	£1,029,616.88

	D	0.54	0.15	7870	4238	1186	£3,352,447.55	4744	£116,921.70	£1,796,378.36
Total				30898	12817	2625	£7,710,381.08	10501	£258,804.29	£4,663,498.75

Table 49: Scotland PR impacts (2023)

Scotland	Gold stage	Moderate exacerbation rate reduction	Severe exacerbation rate reduction	Net completion increase	Moderate exacerbation reduction	Severe exacerbation reduction	Exacerbation savings (£)	Bed days saved	Productivity savings (£)	QALY savings (£)
	A	0.34	0.05	12804	4374	682	£2,092,299.04	2730	£67,278.54	£1,420,809.92
	B	0.35	0.04	6128	2149	270	£863,801.37	1081	£26,647.57	£645,961.01
	C	0.45	0.10	6969	3126	666	£1,945,577.49	2664	£65,659.33	£1,158,083.36
	D	0.54	0.15	8852	4767	1334	£3,770,736.27	5336	£131,510.16	£2,020,514.54
Total				34753	14416	2953	£8,672,414.17	11811	£291,095.60	£5,245,368.83

Table 50: Northern Ireland PR impacts (2023)

Northern	Gold stage	Moderate exacerbation rate reduction	Severe exacerbation rate	Net completion	Moderate exacerbation reduction	Severe exacerbation reduction	Exacerbation savings	Bed days saved	Productivity savings (£)	QALY savings (£)

Ireland			reduction	increase			(£)			
	A	0.34	0.05	5918	2022	315	£966,966.69	1262	£31,093.12	£656,634.56
	B	0.35	0.04	2832	993	125	£399,210.22	500	£12,315.31	£298,534.18
	C	0.45	0.10	3221	1445	308	£899,158.58	1231	£30,344.80	£535,214.14
	D	0.54	0.15	4091	2203	616	£1,742,665.04	2466	£60,778.09	£933,791.12
Total				16061	6662	1365	£4,008,000.53	5458	£134,531.32	£2,424,174.01

A4.3 Impacts by health board

1. To model the impacts of interventions across health boards, prevalence data was used, and total impact savings were split between ICB based on prevalence

Table 51: England ICB savings (2023)

Country	Total savings (£)
England	£201,968,057
ICB	
NHS Bath and North East Somerset, Swindon and Wiltshire Integrated Care Board	£2,513,754
NHS Bedfordshire, Luton and Milton Keynes Integrated Care	£2,643,475

Board	
NHS Birmingham and Solihull Integrated Care Board	£4,549,774
NHS Black Country Integrated Care Board	£5,168,674
NHS Bristol, North Somerset and South Gloucestershire Integrated Care Board	£3,001,446
NHS Buckinghamshire, Oxfordshire and Berkshire West Integrated Care Board	£3,773,665
NHS Cambridgeshire and Peterborough Integrated Care Board	£2,615,524
NHS Cheshire and Merseyside Integrated Care Board	£13,346,755
NHS Cornwall and the Isles of Scilly Integrated Care Board	£2,692,300
NHS Coventry and Warwickshire Integrated Care Board	£2,829,542
NHS Derby and Derbyshire Integrated Care Board	£4,126,520
NHS Devon Integrated Care Board	£5,099,004
NHS Dorset Integrated Care Board	£2,834,296
NHS Frimley Integrated Care Board	£1,550,659
NHS Gloucestershire Integrated Care Board	£1,863,400
NHS Greater Manchester Integrated Care Board	£13,647,773
NHS Hampshire and Isle of Wight Integrated Care Board	£6,016,901
NHS Herefordshire and Worcestershire Integrated Care Board	£2,742,992
NHS Hertfordshire and West Essex Integrated Care Board	£3,630,945

NHS Humber and North Yorkshire Integrated Care Board	£6,979,100
NHS Kent and Medway Integrated Care Board	£6,628,497
NHS Lancashire and South Cumbria Integrated Care Board	£7,814,250
NHS Leicester, Leicestershire and Rutland Integrated Care Board	£3,072,782
NHS Lincolnshire Integrated Care Board	£3,108,175
NHS Mid and South Essex Integrated Care Board	£3,559,812
NHS Norfolk and Waveney Integrated Care Board	£4,298,260
NHS North Central London Integrated Care Board	£3,289,192
NHS North East London Integrated Care Board	£4,758,142
NHS North East and North Cumbria Integrated Care Board	£17,233,049
NHS North West London Integrated Care Board	£4,398,023
NHS Northamptonshire Integrated Care Board	£2,493,878
NHS Nottingham and Nottinghamshire Integrated Care Board	£4,430,222
NHS Shropshire, Telford and Wrekin Integrated Care Board	£1,757,027
NHS Somerset Integrated Care Board	£2,235,619
NHS South East London Integrated Care Board	£4,584,177
NHS South West London Integrated Care Board	£2,783,573
NHS South Yorkshire Integrated Care Board	£7,375,818

NHS Staffordshire and Stoke-on-Trent Integrated Care Board	£4,436,094
NHS Suffolk and North East Essex Integrated Care Board	£3,585,734
NHS Surrey Heartlands Integrated Care Board	£2,164,765
NHS Sussex Integrated Care Board	£5,536,387
NHS West Yorkshire Integrated Care Board	£10,798,082

Table 52: Wales Health Board savings (2023)

Country	Total savings
Wales	£10,917,355
ICB	
Betsi Cadwaladr University Health Board	£2,723,051
Hywel Dda University Health Board	£1,361,738
Swansea Bay University Health Board	£1,261,140
Cardiff and Vale University Health Board	£1,289,115
Cwm Taf Morgannwg University Health Board	£1,780,375
Aneurin Bevan University Health Board	£2,024,663
Powys Teaching Health Board	£477,272

Table 53: Scotland NHS Regional Board savings (2023)

Country	Total savings
Scotland	£12,279,526
ICB	
NHS Borders	£93,917
NHS Dumfries and Galloway	£522,980
NHS Fife	£1,063,442
NHS Forth Valley	£884,960
NHS Grampian	£457,116
NHS Greater Glasgow and Clyde	£4,393,492
NHS Lanarkshire	£1,223,629
NHS Lothian	£2,235,980
NHS Orkney	£23,716
NHS Shetland	£48,652
NHS Tayside	£1,305,078
NHS Western Isles	£26,562

Table 54: Northern Ireland Local Commissioning Group savings (2023)

Country	Total savings
Northern Ireland	£5,675,046
ICB	
Belfast	£1,406,650
South Eastern	£819,196
Northern	£1,352,630
Southern	£1,062,088
Western	£1,034,481

Deprivation effects:

Table 55: Deprivation effect in England

Description	Quintile	Hospital admission rate per 100,000	Portion of costs	Ratio multiplier compared to expected
Least deprived	0.2	31928	17%	86%
	0.4	34472	19%	93%
	0.6	36408	20%	99%
	0.8	38526	21%	104%
Most deprived	1	43385	23%	117%
Source: Asaria M, Foran T, Cookson. The costs of inequality: whole-population modelling study of lifetime inpatient hospital costs in the English National Health				

Service by level of neighbourhood deprivation. (2016)

Table 56: Deprivation costs at the ICB level (2023)

Country	Total savings	New total savings accounting for deprivation
England	£201,968,057	£201,968,057
ICB		
NHS Bath and North East Somerset, Swindon and Wiltshire Integrated Care Board	£2,905,059	£2,513,754
NHS Bedfordshire, Luton and Milton Keynes Integrated Care Board	£2,877,365	£2,643,475
NHS Birmingham and Solihull Integrated Care Board	£4,114,303	£4,549,774
NHS Black Country Integrated Care Board	£4,673,966	£5,168,674
NHS Bristol, North Somerset and South Gloucestershire Integrated Care Board	£3,267,009	£3,001,446
NHS Buckinghamshire, Oxfordshire and Berkshire West Integrated Care Board	£4,361,095	£3,773,665
NHS Cambridgeshire and Peterborough Integrated Care Board	£3,022,671	£2,615,524
NHS Cheshire and Merseyside Integrated Care	£12,069,300	£13,346,755

Board		
NHS Cornwall and the Isles of Scilly Integrated Care Board	£2,434,613	£2,692,300
NHS Coventry and Warwickshire Integrated Care Board	£2,949,405	£2,829,542
NHS Derby and Derbyshire Integrated Care Board	£4,301,325	£4,126,520
NHS Devon Integrated Care Board	£5,079,560	£5,099,004
NHS Dorset Integrated Care Board	£3,085,070	£2,834,296
NHS Frimley Integrated Care Board	£1,792,043	£1,550,659
NHS Gloucestershire Integrated Care Board	£2,153,467	£1,863,400
NHS Greater Manchester Integrated Care Board	£12,341,507	£13,647,773
NHS Hampshire and Isle of Wight Integrated Care Board	£6,549,267	£6,016,901
NHS Herefordshire and Worcestershire Integrated Care Board	£2,985,687	£2,742,992
NHS Hertfordshire and West Essex Integrated Care Board	£4,196,158	£3,630,945
NHS Humber and North Yorkshire Integrated Care Board	£7,274,743	£6,979,100
NHS Kent and Medway Integrated Care Board	£6,909,288	£6,628,497
NHS Lancashire and South Cumbria Integrated Care Board	£7,784,451	£7,814,250

NHS Leicester, Leicestershire and Rutland Integrated Care Board	£3,344,657	£3,072,782
NHS Lincolnshire Integrated Care Board	£3,239,841	£3,108,175
NHS Mid and South Essex Integrated Care Board	£4,113,952	£3,559,812
NHS Norfolk and Waveney Integrated Care Board	£4,281,869	£4,298,260
NHS North Central London Integrated Care Board	£3,276,649	£3,289,192
NHS North East London Integrated Care Board	£4,302,727	£4,758,142
NHS North East and North Cumbria Integrated Care Board	£15,583,626	£17,233,049
NHS North West London Integrated Care Board	£4,381,252	£4,398,023
NHS Northamptonshire Integrated Care Board	£2,714,532	£2,493,878
NHS Nottingham and Nottinghamshire Integrated Care Board	£4,413,327	£4,430,222
NHS Shropshire, Telford and Wrekin Integrated Care Board	£1,750,327	£1,757,027
NHS Somerset Integrated Care Board	£2,330,322	£2,235,619
NHS South East London Integrated Care Board	£4,566,696	£4,584,177
NHS South West London Integrated Care Board	£3,216,879	£2,783,573
NHS South Yorkshire Integrated Care Board	£6,669,858	£7,375,818
NHS Staffordshire and Stoke-on-Trent Integrated Care Board	£4,624,012	£4,436,094

NHS Suffolk and North East Essex Integrated Care Board	£3,737,630	£3,585,734
NHS Surrey Heartlands Integrated Care Board	£2,501,744	£2,164,765
NHS Sussex Integrated Care Board	£6,026,237	£5,536,387
NHS West Yorkshire Integrated Care Board	£9,764,568	£10,798,082