Adherence to NICE guidelines for chronic obstructive pulmonary disease can improve patient outcomes and reduce carbon footprint when compared with current clinical practice

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01 BACKGROUND

- Chronic obstructive pulmonary disease (COPD) has an increasing global burden, with prevalence projected to reach 600 million cases by 2050, an increase of 23% from the number of individuals in 2020.[1]
- Pharmacological therapy is the cornerstone of disease management, reducing patient symptoms and the frequency/severity of COPD exacerbations as well as associated pneumonia episodes. COPD exacerbations are defined as a period of acute worsening of respiratory symptoms, requiring increased healthcare resource use such as hospitalisations.[2]
- Long-acting muscarinic antagonists (LAMA), long-acting β-agonists (LABA), and inhaled corticosteroids (ICS) are commonly used alone or in combination. LAMA, LABA, and ICS inhaled treatments are available in different forms which include pressurised metered-dose inhalers (pMDIs), dry powder inhalers (DPIs), and soft-mist inhalers (SMIs).[1]
- Each inhaler type has different greenhouse gas (GHG) emissions, with pMDIs having a higher environmental impact due to the hydrofluorocarbon propellants used.[3]
- National recommendations often differ from real-world prescribing practices which can influence patient outcomes.
- Globally, healthcare decision makers are making a commitment to reduce their GHG emissions, with the National Health Service in the UK looking to reach net zero emissions by 2045.[5] Optimising patient care will not only improve clinical outcomes, but also potentially environmental impact.

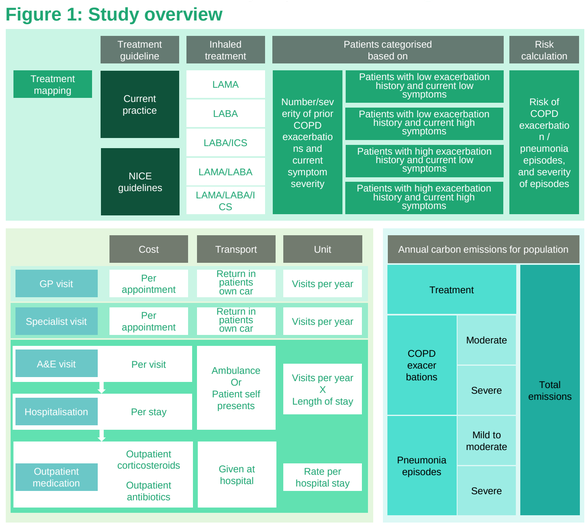
02 OBJECTIVE

- This study aimed to model the environmental impact of COPD treatment pathways in the UK, comparing National Institute for Health and Care Excellence (NICE) guidelines to current clinical practice.

03 METHODS

- An overview of the study is presented in **Figure 1**.

Figure 1: Study overview



A&E, accident and emergency; GP, general practitioner; LABA, long-acting β-agonists; LAMA, Long-acting

- COPD treatment was mapped over one year (2018) using published prescribing patterns[6] or NICE recommendations (NG115)[7] for the UK COPD population (N=1,067,531, of which 886,051 use inhalers) (**Table 1**).

Table 1: Details of clinical inputs used for model, as published elsewhere[2]

Population details

	Total population	Prevalence (%)	Using inhalers	Percentage
COPD population	1,067,531	0.019	886,051	0.83
Prior exacerbations vs symptoms	**Proportion**	**Absolute number**	**Proportion with high eosinophil count**	**Absolute number**
High/high	11.64	103,136	19.17	19,771
High/low	6.92	61,315	20.26	12,422
Low/High	38.23	338,737	20.67	70,017
Low/Low	43.21	382,863	19.47	74,543
Total		***886,051***		***176,754***

Exacerbation risk

	COPD exacerbation risk	%	
Absolute risk with no prior exacerbations for LAMA/LABA	Moderate	7.13	
	Severe	2.41	
	Inhaler type	**No prior exacerbations**	**Prior exacerbations**
Relative risk	LAMA	1.11	4.63
	LABA	1.28	5.34
	LAMA/LABA	1	4.17
	LABA/ICS	1.15	4.79
	LAMA/LABA/ICS	0.87	3.62

Pneumonia risk

Inhaler type	Pneumonia risk	%	
Absolute risk with no prior exacerbations for LAMA/LABA	Moderate	1.67	
	Severe	3.08	
	Inhaler type	**No prior exacerbations**	**Prior exacerbations**
Relative risk	LAMA	1	1
	LABA	1	1
	LAMA/LABA	1	1
	LABA/ICS	1.31	1.7
	LAMA/LABA/ICS	1.31	1.7

LABA, long-acting β-agonists; LAMA, Long-acting muscarinic antagonists; ICS, inhaled corticosteroids

- Patients were categorised based on the number/severity of prior COPD exacerbations and current symptom severity, following the GOLD 'ABCD' classification (2020):[2]
  - (A) Patients with low exacerbation history and current low symptoms
  - (B) Patients with low exacerbation history and current high symptoms
  - (C) Patients with high exacerbation history and current low symptoms
  - (D) Patients with high exacerbation history and current high symptoms
- Treatment mapping also considered treatment requirements for patients with high eosinophil counts, with NICE guidance suggesting these patients have a higher likelihood of benefit with treatment containing ICS.[7]
- Treatment covered maintenance therapy with LAMA, LABA, and ICS inhaled treatments.
- Exacerbation and pneumonia risks associated with each inhaler class and patient categorisation were taken from published information (**Table 1**).[6]

Calculating greenhouse gas emissions

- Greenhouse gas (GHG) emissions for healthcare resource use and travel were sourced from shcoalition.org.[8] Three and five days of hospitalisation was used for modelling COPD exacerbations, and pneumonia episodes, respectively.[9]
- GHG emissions for each inhaler class were calculated as an average of the different inhaler types: breath-actuated metered dose inhalers (BAI), DPIs, pMDIs, and SMIs (**Table 2**).[10]

Table 2: Annual carbon cost per patient for each inhaler class modelled

	DPI/SMI		pMDI/BAI		All	
Inhaler type	Annual inhaler use	Carbon emissions (kg CO_2e)	Annual inhaler use	Carbon emissions (kg CO_2e)	Annual inhaler use	Carbon emissions (kg CO_2e)
LAMA	4	7.36	0	0.00	4	7.36
LABA	4	5.86	2	142.35	6	51.35
LABA/ICS	10	8.01	3	174.32	13	46.39
LAMA/LABA	3	8.34	0	0.00	3	8.34
LAMA/LABA/ICS	2	10.16	1	172.81	3	64.37
ICS	5	15.82	4	195.50	9	95.68

DPI, dry powder inhaler; LABA, long-acting β-agonists; LAMA, Long-acting muscarinic antagonists; ICS, inhaled corticosteroids; SMI, soft mist inhaler; pMDI, pressurised metered-dose inhaler; BAI, breath-actuated metered dose inhaler

- GHG emissions for outpatient administration of corticosteroids and antibiotics were estimated by applying NICE guidelines for prescribing practices (NG115)[7] to GHG emissions given by the Medicine Carbon Footprint formulary (MCF) (**Table 3**).[11]
- The environmental cost of treatment was estimated using published clinical outcomes, including changes in rates of moderate and severe COPD exacerbations and mild/moderate and severe pneumonia episodes (**Table 3**).[6]

Table 3: Model input parameters - Carbon emissions associated with moderate/severe COPD exacerbations and mild/moderate/severe pneumonia episodes

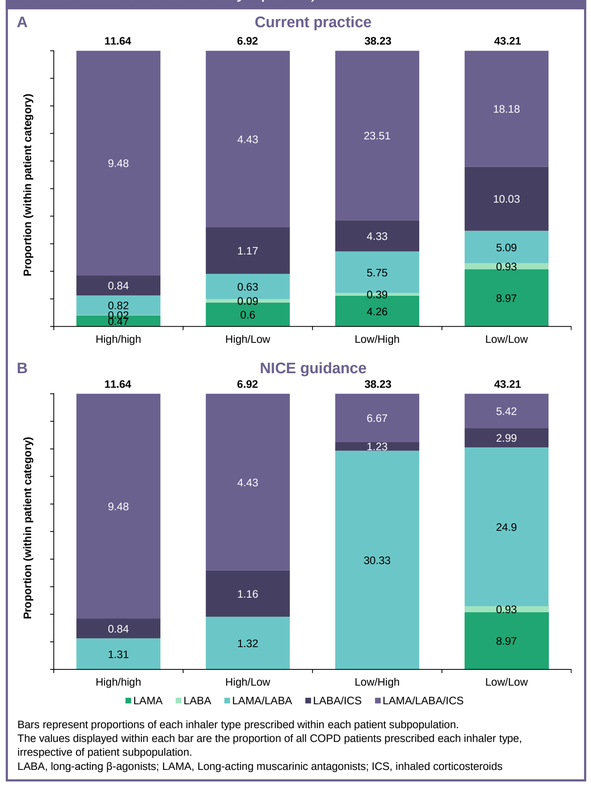
Module	Carbon emission (kg CO_2e)	Moderate exacerbation		Severe exacerbation		Mild/moderate pneumonia		Severe pneumonia	
		Use rate	Carbon emissions (kg CO_2e)	Use rate	Carbon emissions (kg CO_2e)	Use rate	Carbon emissions (kg CO_2e)	Use rate	Carbon emission (kg CO_2e)
GP visit *(inc. patient transport)*	2.26	0.6	1.35	0	0.00	0	0.00	0	0.00
Respiratory team visit *(inc. patient transport)*	6.94	0.1	0.69	0	0.00	0	0.00	0	0.00
A&E visit *(no transport)*	13.77	0.3	4.13	0.3	4.13	1	13.77	0.3	4.13
Hospitalisation (COPD exacerbation)*(no transport)*	113.71	0	0.00	1	113.71	0	0.00	0	0.00
Hospitalisation (Pneumonia)*(no transport)*	189.52	0	0.00	0	0.00	0	0.00	1	189.52
Hospital transport - Ambulance	38.99	0	0.00	0.7	27.30	0	0.00	0.7	27.30
Hospital transport - Patient self-presents	5.80	0.3	1.74	0.3	1.74	1	5.80	0.3	1.74
Outpatient corticosteroids	0.28	1	0.28	0	0.00	0	0.00	0	0.00
Outpatient antibiotics	22.18	2	44.36	0	0.00	1	22.18	0	0.00
Total			***52.55***		***146.88***		***41.75***		***222.68***

A&E, accident and emergency; GP, general practitioner

04 RESULTS

- **Figure 2** shows the adoption of NICE recommendations and using guideline-directed medical therapy compared with current clinical practice.

Figure 2: Proportions of each inhaler type prescribed according to current practice (A) or NICE guidance (B), with prescription pattern determined by patient GOLD classification (prior number of COPD exacerbations vs current symptoms)



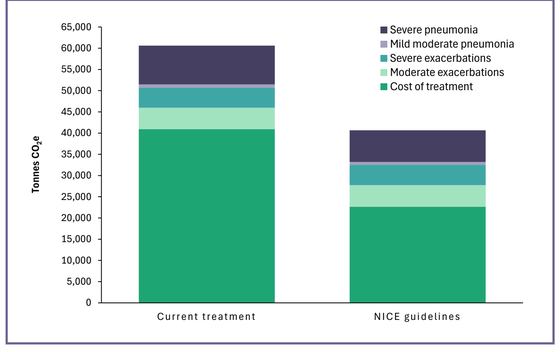
Bars represent proportions of each inhaler type prescribed within each patient subpopulation.
The values displayed within each bar are the proportion of all COPD patients prescribed each inhaler type, irrespective of patient subpopulation.
LABA, long-acting β-agonists; LAMA, Long-acting muscarinic antagonists; ICS, inhaled corticosteroids

- Treating COPD according to clinical practice was estimated as 60,612 tonnes CO_2e, using guideline-directed medical therapy was estimated as 40,653 tonnes CO_2e (**Table 4, Figure 3**).
- Treating COPD as per NICE recommendations could potentially save ~19,959 tonnes of carbon dioxide equivalents (CO_2e) when compared with current clinical practice (**Table 4, Figure 3**).

Table 4: Treatment of COPD according to NICE guidelines could potentially result in a reduction of carbon emissions (tonnes CO_2e) when compared with current treatment patterns

	Cost of treatment *(tonnes CO_2e)*	Cost of COPD exacerbations (tonnes CO_2e)		Cost of pneumonia episodes (tonnes CO_2e)		*Total cost (tonnes CO_2e)*
		Moderate exacerbations	Severe exacerbations	Mild moderate pneumonia	Severe pneumonia	
Current treatment	40,932.5	5,032.3	4,753.8	755.6	9,138.0	60,612.1
NICE guidelines	22,671.4	5,068.2	4,787.6	679.4	7,446.5	40,653.1
Impact (tonnes CO2e)	-18,261.1	35.9	33.9	-76.2	-1,691.6	-19,959.1
Impact (%)	-44.6	0.7	0.7	-10.1	-18.5	-32.9

Figure 3: Carbon cost of treatment and associated outcomes



- Medication-associated GHG emissions (18,261 tonnes CO_2e) are associated with 91.5% of savings (**Table 4, Figure 3**), attributable to increased usage of LAMA/LABA inhalers (**Figure 2**).
- Reducing severe pneumonia episodes saves 1,692 tonnes CO_2e, with fewer hospitalisations (**Table 4, Figure 3).**
- Environmental impact associated with COPD exacerbations remain similar with both treatment practices (9,786 vs 9,856 tonnes CO_2e) (**Table 4, Figure 3**).

Scenario analysis

- Prescribing practices for the different inhaler types (DPIs, SMIs, pMDIs, BAIs) within each of the inhaler classes was not available. For the main analysis, to estimate the GHG emissions for each inhaler treatment class an average was taken based on what inhaler types are available.
- pMDI/BAI have much higher GHG emissions than DPI/SMI. pMDIs made up 70% of the market share of GHG emissions for inhaled products in 2019 in the UK,[12] but make up 26% of the available inhaled products in our study. To assess this variability, a scenario analysis was conducted where a weighted average was instead used to estimate the GHG emissions associated with each inhaler class. Weighted averages were calculated using a range of 70:30 pMDI/BAI to DPI/SMI, down to 0:100 (**Table 5**)

Table 5: Annual carbon cost per patient for each inhaler class modelled, where a weighted average has been applied to the ratio of pMDI/BAI to DPI/SMI inhalers

Inhaler type	Carbon emissions (kg CO_2e) for each weighted average (ratio of pMDI/BAI vs DPI/SMI)							
	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
LAMA*	*7.36*	*7.36*	*7.36*	*7.36*	*7.36*	*7.36*	*7.36*	*7.36*
LABA	101.40	87.75	74.10	60.45	46.80	33.15	19.50	5.86
LABA/ICS	124.42	107.79	91.16	74.53	57.90	41.27	24.64	8.01
LAMA/LABA*	*8.34*	*8.34*	*8.34*	*8.34*	*8.34*	*8.34*	*8.34*	*8.34*
LAMA/LABA/ICS	124.01	107.75	91.48	75.22	58.95	42.69	26.42	10.16

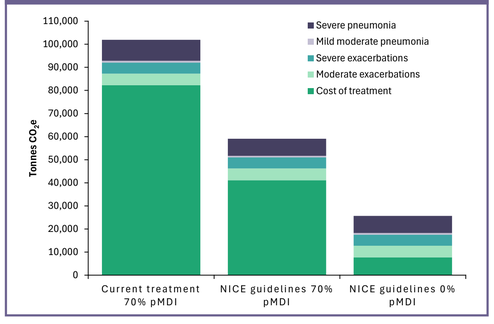
* No pMDI/BAI inhalers available in source material for these inhaler classes, so values are 100% DPI/SMI
DPI, dry powder inhaler; LABA, long-acting β-agonists; LAMA, Long-acting muscarinic antagonists; ICS, inhaled corticosteroids; SMI, soft mist inhaler; pMDI, pressurised metered-dose inhaler; BAI, breath-actuated metered dose inhaler

- Comparing current practice (with 70% pMDI/BAI use) to NICE recommendations (with 0% pMDI/BAI use), shows the potential to reduce emissions associated with COPD treatment in England by 75%, from 101,947 to 25,673 tonnes CO_2e (**Table 6, Figure 4**).

Table 6: Treatment of COPD with DPI/SMI inhaler types instead of pMDI/BAI could reduce emissions associated with the COPD pathway

	GHG emissions (tonnes CO_2e) for each weighted average (ratio of pMDI/BAI vs DPI/SMI)							
	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
Current treatment								
Treatment costs	82267.2	71668.9	61070.6	50472.3	39873.9	29275.6	18677.3	8079.0
Moderate exacerbations	5032.3	5032.3	5032.3	5032.3	5032.3	5032.3	5032.3	5032.3
Severe exacerbations	4753.8	4753.8	4753.8	4753.8	4753.8	4753.8	4753.8	4753.8
Mild moderate pneumonia	755.6	755.6	755.6	755.6	755.6	755.6	755.6	755.6
Total	101946.8	91348.5	80750.2	70151.9	59553.6	48955.3	38357.0	27758.7
NICE guidelines								
Treatment costs	41124.3	36348.1	31572.0	26795.8	22019.6	17243.4	12467.2	7691.1
Moderate exacerbations	5068.2	5068.2	5068.2	5068.2	5068.2	5068.2	5068.2	5068.2
Severe exacerbations	4787.6	4787.6	4787.6	4787.6	4787.6	4787.6	4787.6	4787.6
Mild moderate pneumonia	679.4	679.4	679.4	679.4	679.4	679.4	679.4	679.4
Severe pneumonia	7446.5	7446.5	7446.5	7446.5	7446.5	7446.5	7446.5	7446.5
Total	59106.0	54329.8	49553.6	44777.5	40001.3	35225.1	30448.9	25672.7

Figure 6: Scenario analysis



05 DISCUSSION AND CONCLUSIONS

- **Following the latest evidence-based NICE-recommended prescribing practices could reduce environmental impact for patients with COPD due to decreased medication emissions and fewer pneumonia hospitalisation episodes. Where patient outcomes are not affected, switching from pMDI/BAI to DPI/SMI inhalers could further decrease COPD-associated GHG emissions in England.**
- **There is a growing global focus on reducing health-related GHG emissions, with countries like the UK aiming for net-zero emissions targets in their healthcare systems. A patient-centred approach enhances both clinical outcomes and supports healthcare systems in achieving their net-zero goals. As the incidence of COPD rises worldwide over the next 25 years, the environmental impact will also increase unless mitigation measures are implemented.**

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