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POSITION STATEMENT

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Environmental impact of inhaled medicines: A Thoracic Society of Australia and New Zealand position statement

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Abstract

Globally, more than 1.2 billion inhalers are purchased for asthma and chronic obstructive pulmonary disease (COPD) annually. In Australia and New Zealand, pressurized metered dose inhalers (pMDIs) are the leading delivery device prescribed and pMDI salbutamol can be purchased over the counter in Australia. These inhalers are a major contributor to healthcare related greenhouse gases. This is due to the propellants that they currently contain which have extremely high global warming potential (GWP). In this position paper, we report the findings of a Thoracic Society of Australia and New Zealand (TSANZ) working group on the environmental impact of inhaled respiratory medicines. We reviewed the use of inhaled medicines in Australia and New Zealand and their contribution to climate change and other environmental degradation. We propose strategies for health professionals and consumers to reduce

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environmental impact in the management of airway diseases. These include accurate diagnosis to avoid unnecessary treatment, better disease control to minimize the need for reliever therapy and actively choosing inhaler devices with lower environmental impacts when clinically appropriate. Inhaler selection should be tailored to the individual, aiming to achieve the best possible clinical outcome. Choosing an appropriate inhaler for an individual involves consideration of factors such as dexterity, inspiratory capacity and cost. In our current climate emergency and with the availability of lower carbon alternatives, health professionals should also consider environmental impact.

KEYWORDS
air pollution, asthma, climate change, clinical respiratory medicine, COPD

INTRODUCTION

Human contribution to environmental degradation and climate change and their subsequent effects on health are well recognized. We collectively face a huge challenge in addressing this.[1] Climate change has caused shifts in the frequency of extreme weather events.[2] In Australia and New Zealand alone, the last decade has brought significant droughts, heatwaves, flooding and bushfires.[3] Most notably, in Australia, climate change has driven a significant increase in forest fires in the last three decades leading to substantial losses (lives, livelihoods, property, ecology). The health impacts of major disasters, increases in communicable diseases, extreme temperatures, declining air and water quality and food insecurity are immeasurably large. Further, the full impact and breadth of climate change effects on global population health are likely to be under-estimated due to gaps in data from lower-income countries,[4] which are also the regions worst affected. Without considerable action, the impacts on the health of current and future generations will be devastating.[1,3] The effects of climate change will continue to worsen even if carbon emissions drop to zero, but drastic actions to reduce carbon emissions will reduce losses and damages to human health and ecosystems.[5] Healthcare practitioners are ideally placed to take leadership on this critical public health issue.

Globally, healthcare is responsible for an estimated 4.4%[6] of greenhouse gas emissions; however this figure is much higher (7%) in Australia[7] and is likely to be similar in New Zealand. Whilst healthcare is a critical service, there is significant scope to reduce its environmental impact while still ensuring optimal patient outcomes. We urgently need to identify feasible interventions to achieve sustainablility in healthcare.[6,7]

Airway diseases such as asthma and chronic obstructive pulmonary disease (COPD) affect over 3 million Australians[8] and 700,000 New Zealanders.[9] Inhaled therapies are the mainstay of treatment for these conditions; however, these inhalers contribute approximately 13% of the total carbon footprint associated with healthcare delivery.[10,11]

Inhaled medicines are available in various dosages and combinations, and are delivered by different devices such as pressurized metered-dose inhalers (pMDIs), the most commonly used delivery devices in Australia and New Zealand; dry powder inhalers (DPIs) and soft-mist inhalers (SMIs). All of these devices have environmental impacts from manufacture, shipping, use and disposal. However, the propellant gases currently used in pMDIs are potent greenhouse gases. When released into the atmosphere, these gases trap heat to a much greater degree than other common greenhouse gases like carbon dioxide and methane.

This position paper outlines our current understanding and critical knowledge gaps in this field. It highlights more environmentally sustainable prescribing practices and management strategies with lower carbon footprint and comparable efficacy. This paper is intended to complement established guidelines on inhaler prescribing for people with asthma and chronic obstructive pulmonary disease (COPD) to assist healthcare practitioners to make greener choices whilst maintaining the highest quality patient care.

METHODS

The writing group was convened by the Thoracic Society of Australia and New Zealand (TSANZ) following an open call for participants. Applications were received through the standardized TSANZ process and multidisciplinary members were selected on the basis of their experience and complementary skills. Applications from suitably qualified non-members were reviewed to ensure adequate expertise and representation. Co-chairs were selected from within the group, and they presented a broad outline of the scope and format of the position paper which comprised a development of the idea first proposed to TSANZ for this document. Following input from the wider group and changes by consensus to this structure, working subgroups were established to gather information on allocated topics and to draft sections of the paper.

This document is a Position Statement and is not intended as a guideline. Given the diversity of contributory information and relative paucity of respiratory clinical research, a formal systematic review and meta-analysis was not undertaken. Targeted literature reviews were performed by members of the working group. Reference is made to key reviews, studies and guidelines. Perspectives from other healthcare professionals with an interest in this area were sought to ensure no major omissions and that the manuscript represents a comprehensive summary of currently available literature and knowledge on the subject. We are

grateful for the input of consumers during a consumer-engagement event and NZ consumer and prescriber study.[12]

All authors had the opportunity to comment on and/or revise all drafted sections through working group videoconferences and access to a shared document. The final draft was crafted by a core writing group, circulated and edited before final approval by the overall group. Peer review was conducted jointly by TSANZ and Respirology and the final position paper was approved by the TSANZ Board and Editor-in-chief of Respirology. Given the relatively recent changes in guidelines for asthma and COPD, and the planned changes in propellants by several manufacturers, a review of this document is planned 3 years from the date of publication.

Consumer engagement

Consumer engagement was sought through a community conversation which was advertised widely through the Western Australian Health Translation Network Consumer and Community Involvement. We invited consumers with lived experience of taking any inhaled medication to participate. The event was held in 2021 as an online event held over several hours and consumers were remunerated for out of pocket expenses. A note taker recorded key points of the conversation, which was led by a Western Australian Health Translation Network Consumer and Community Involvement Officer, guided by several "conversation starters" provided by the TSANZ researcher leading the engagement activity.

Although the conversation was guided, the facilitator also asked questions and open conversation was encouraged by the two consumers in attendance. Consumer engagement in Australia is not qualitative and does not require ethics approval, which limits the sharing of data from the conversation. However, notes were summarized and a key message taken from the conversation. Consumers were not aware that there was an environmental impact of their inhaler prior to the community conversation, however, would be happy to switch to greener alternatives if: (1) they were equally as effective (as their old inhaler), (2) they did not cost more and (3) the alternative options were presented by their pharmacist and/or general practitioner.

THE USE OF INHALED MEDICINES

The importance of inhaled medicines

Chronic obstructive airways diseases such as asthma and COPD are highly prevalent globally, affecting hundreds of millions of people.[13] Inhaled therapies are a cornerstone of medical care for these conditions and cause fewer adverse effects than systemic treatments such as oral corticosteroids.[14]

Prescribing of inhaler therapies by healthcare practitioners in Australia and New Zealand is guided by international consensus documents and national guidelines. For asthma, these are the Australian Asthma Handbook,[15] National Asthma Council Asthma and Respiratory Foundation of New Zealand (ARFNZ) asthma guidelines[16] and Global Initiative for Asthma (GINA).[17] For COPD, these include the Global Initiative for Chronic Obstructive Lung Disease GOLD guide,[18] COPD-X Plan[19] and ARFNZ COPD guidelines.[20] All guidelines advocate for a stepwise approach to inhaler therapies and highlight their benefits in improving symptoms, quality of life, reducing unscheduled healthcare visits and hospitalisations/deaths; and now include information on the environmental impact of inhalers, highlighting the lower carbon footprint of DPIs compared to pMDIs.

Inhaler types

Although there are many inhaler devices in use globally, this document focuses on three broad types (pMDIs, DPIs and SMIs) reflecting those most prescribed in clinical practice in Australia and New Zealand. We recognize that nebulised SABA therapy (alone) is commonly used as emergency therapy delivered via facemask with similar effect to pMDI and spacer, although pMDI with spacer is the preferred emergency treatment in the GINA asthma[21] and GOLD COPD guidelines.[18] For this reason, nebuliser therapy is not considered further in this paper. ICS-SABA and ICS-formoterol treatment was discussed by GINA in the 2024 report as a replacement for SABA alone however more studies are needed to determine efficacy in the emergency department setting.[21]

For a given class of drug, the selection of an inhaler device (when options exist) should be a shared decision with the patient/parent. This is often driven by patient factors, for example, age, dexterity, satisfaction with the device. Cost and environmental impact should be included in the discussion. When switching devices, patient level factors are particularly important to consider and loss of disease control from an inappropriate device can lead to exacerbations which can have a very large carbon footprint.[22] In this context, it is perhaps surprising that patterns of prescribing vary markedly between countries with similar populations.[23] Sales of pMDIs range from less than 10% of total usage in some countries in Europe to over 60% in others.[23] Percentage of inhaler doses delivered by pMDI exceeds 80% in Australia, United States and United Kingdom; and, together with Brazil, Puerto Rico and Russia, Australia is one of the highest users among the top 15 markets globally (accounting for 90% of the global spend on COPD and asthma medicines).[24] In contrast, Japan has significantly lower use of pMDI with <35% of inhaler doses delivered by pMDI.[24]

Inhaler usage in Australia and New Zealand

Tens of millions of inhalers are consumed annually in Australia and New Zealand with some products having sold over one million units per year[25,26] The most recent asthma

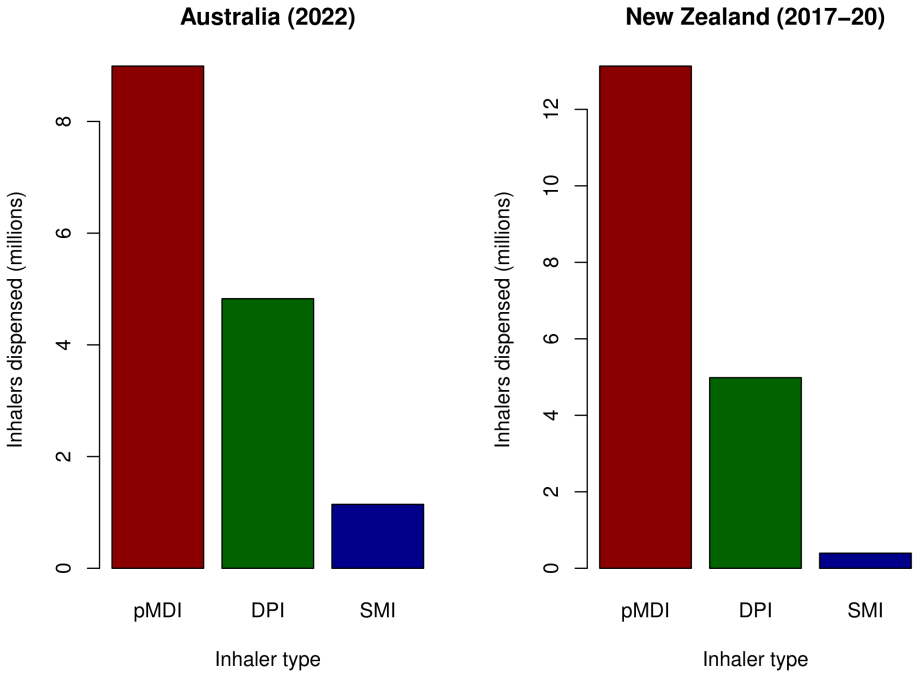

FIGURE 1 Relative dispensing frequency of inhaler types. NZ data shows Pharmac funded packs of inhalers 2017–2020 by type of inhaler dispensed. Australian data do not include SABAs sold over the counter, so significantly underestimates Australian pMDI sales, and slightly underestimates DPI sales. Private prescriptions are not included in either dataset. Australian data source: PBS 2022[28]; New Zealand data source Pharmac 2017–2020.[26]

guidelines strongly recommend a single combination inhaler (inhaled corticosteroid and long acting beta-agonist, ICS-LABA) as preventer and reliever for adolescents and adults.[17,27] Despite this recommendation, separate inhalers as reliever and preventer remain the most commonly used regimen (Figure 1A).

According to current GINA as well as Australian and New Zealand guidelines, SABA alone is *not* recommended for safety reasons. It should be noted that in Australia ICS-formoterol as budesonide/formoterol is not currently approved for children under the age of 12[29] and beclomethasone/formoterol is not approved for children under the age of 18.[29] Therefore, combination therapy will still include two inhalers for most children.

The primary drivers of pMDI use (over DPIs and SMIs) are often clinician comfort and familiarity and their availability over-the-counter. Preferential prescribing may also be driven by the Pharmaceutical Benefits Schedule (PBS). For example, subsidy for DPI terbutaline is only available when a patient is unable to use or has had an adverse reaction to a pMDI salbutamol formulation.[30] This is despite the absence of evidence that one device type is superior to the other at a population level.

THE ENVIRONMENTAL IMPACT OF INHALERS

There are many factors throughout the life cycle of an inhaler device that have detrimental impacts on the environment (Figure 2). These include the manufacture, distribution and disposal of single-use manufactured goods as well as the pharmaceuticals and non-active ingredients (excipients) used in these products.

The cause of global warming is the atmospheric release of greenhouse gases that reduce the amount of heat energy radiated into space. Some chemicals used in medical applications exert a disproportionate influence due to their greater per-molecule warming impact and their lifetime in the atmosphere. The hydrofluorocarbon (HFC) propellants in pMDIs are a major contributor. Indeed, pMDIs were estimated to contribute around 13% of the total carbon footprint associated with healthcare delivery in the British National Health System (NHS) in 2019.[10,11] The data on pMDIs are drawn from NHS modelling and confirm the substantial contribution to emissions from inhaler devices. This represents an opportunity for clinicians to reduce the environmental impact of prescribing through targeted change.

It is notable that almost all inhalers are made of single-use plastic or a combination of plastic and metal and are disposed of regularly (usually monthly). In Australia, the National Return and Disposal of Unwanted Medicines (NatRUM) program enables disposal of unwanted medications using high temperature incineration, thereby reducing the environmental impact.[31]

Re-useable devices are relatively uncommon however, in a welcome product development the SMIs have transitioned to a system where the medicine-containing canister is changed monthly whilst the plastic body of the device is retained for several months.[32] Re-useable device components can significantly reduce waste and environmental impact. Some inhalers have dose-counters so that patients know when their inhaler needs replacing. However, even fully used pMDIs contain residual propellant that will eventually leak into the environment. Overfill estimates from published and grey literature range from 5%[33] to 40%[34] a magnitude of difference with important implications for the impact of

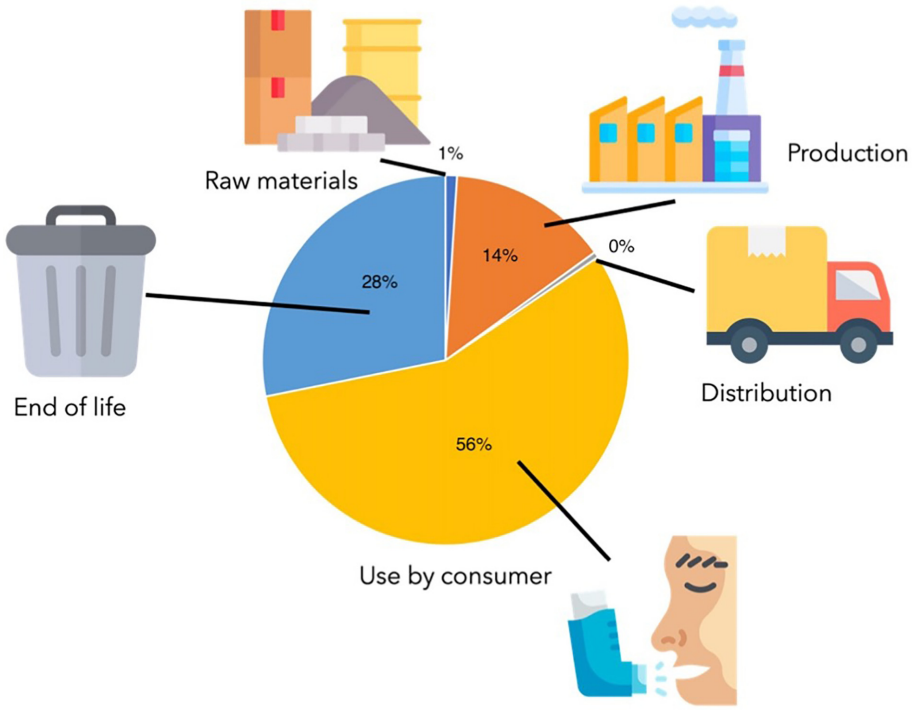

FIGURE 2 Relative contributions of stages of a pMDI life cycle to its total CO_2 equivalent carbon footprint with excipient propellant release representing the most substantial contributor, equivalent to 20 $kgCO_2e$ per 30-day treatment. 'End of life' and 'use by consumer' phases are almost entirely due to the propellant gas. Percentages rounded to nearest whole number in line with source report. *Data source*: The Carbon Trust GlaxoSmithKline PLC Product Carbon Footprint Certification Summary Report, 2014.

disposal in landfill as compared to recycling schemes such as NatRUM. Smart inhalers contain sensors and allow connectivity to mobile apps, so that patients know when their inhaler is empty. Smart (digital) inhalers are not readily available outside research settings in Australia and New Zealand, however, so are not discussed in this document.

The energy required to manufacture, transport and store inhalers is probably similar in absolute terms regardless of the inhaler design, although accurate and/or comparable data are difficult to acquire. However, the manufacture of pMDI devices creates 50%–100% greater carbon dioxide (CO_2) equivalent per unit than DPIs[35] (CO_2 equivalent is a metric used to compare emissions from greenhouse gases based on their global-warming potential (GWP): it is a measure of how much energy the emissions of a metric measure of a gas will absorb over a given period of time relative to the emissions from the same measure of CO_2).

Previously, pMDIs used chlorofluorocarbon (CFC) propellants, which were recognized to contribute substantially both to ozone layer depletion and global warming. The 1987 Montreal Protocol[36] led to the phasing out of ozone-depleting CFCs globally, including in inhalers. Unfortunately, the hydrofluorocarbons (HFCs) used as replacements for CFC propellants also have substantial global warming potential[37] because they are chemically stable (long-lasting) and very effective at trapping heat in the atmosphere. Their global warming potentials over 100 years (GWP-100) are thousands of times greater than CO_2. The Kigali Amendment to the Montreal Protocol, effective from 2019, commits to reductions in the production and consumption of hydrofluorocarbons (HFCs).[38] As of April 2024, the Kigali Amendment, which requires the phase-down of high global warming potential HFCs by more than 80% (in CO_2-equivalent) over the next 30 years, had been ratified, accepted or approved by 159 states, including Australia and New Zealand.[39] This has not yet led to changes to the HFC propellants contained in inhalers currently prescribed in clinical practice, however significant research and development are underway in this area.

All currently available pMDIs have a larger carbon footprint than DPIs or SMIs. Most of this larger carbon footprint is due to the HFC propellant released during its use and disposal at end-of-life. However, the carbon footprints of pMDIs vary depending on the amount and type of HFC propellant used (e.g., HFC-134a, GWP-100 1530; HFC-227ea, GWP-100 3600), and can range from 9900 to 36,500 grams of CO_2-equivalent (gCO_2e) per inhaler.[40] DPIs and SMIs are propellant-free and have much smaller carbon footprints ranging from 359 to 917 gCO_2e per inhaler.[36]

The working group used publicly available data to generate indicative estimates of the daily carbon footprint of commonly used inhalers (Appendix S1 in the Supporting Information). The following analysis illustrates the range of indicative carbon footprints from usage per day of the inhalers currently available on the Australian and New Zealand markets, using published carbon footprint data for equivalent or very similar inhalers on the UK market.[41–43] An estimated weighted average number of puffs per day was used to approximate average maximum daily SABA inhaler usage, based on an Australian study describing the maximum number of puffs per day (Figure 3).

The indicative carbon footprints of devices used in Australia and NZ range from 102 to 2293 gCO_2e per day for pMDIs; 3 to 68 gCO_2e per day for DPIs and 26 gCO_2e per

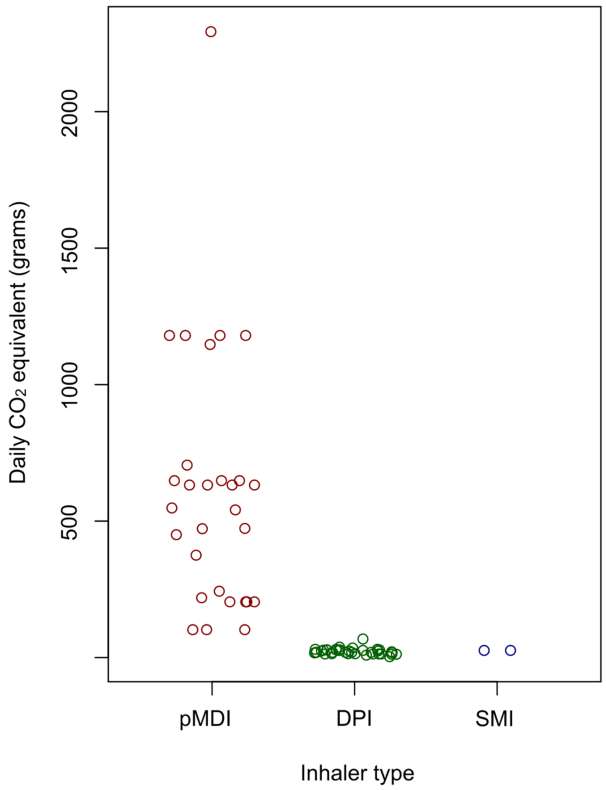

FIGURE 3 Daily CO_2e of inhalers by inhaler type. Range of indicative inhaler carbon footprints (gCO_2-equivalent) per day, by inhaler type, for inhalers used in Australia and New Zealand. *Source*: Data were taken from NAC and Pharmac for inhalers available on the Australian (Aus) and New Zealand (NZ) markets and compared against inhalers and their carbon footprints available from the United Kingdom (UK). Not all Australian and NZ inhalers are available in the United Kingdom and these have been omitted from this analysis: for Aus, ASMOL (Alphapharm), Fluticasone (Cipla) and Symbicort Rapihaler® 50 mcg/3 mcg budesonide/formoteral (AstraZeneca; other dosages included); and for NZ, Floair, Meterol, RexAir, SalAir (REX Medical), Duolin® (Cipla), Respigen® (Viatris; this inhaler was discontinued in October 2023) and Tilade® (Sanofi; this inhaler was discontinued in New Zealand during 2020). The carbon footprints of these products are likely similar to corresponding products already included in this analysis (see Appendix S1 in the Supporting Information).[41–43]

day for SMIs (Table A1 in the Supporting Information). For comparison, the estimated carbon footprint for the average emissions per day for a passenger vehicle in Australia is 4454 gCO_2e for 2020.[44,45] For further comparison, the reduction in a person's annual carbon footprint for a regular pMDI user changing from a pMDI to a DPI is similar to changing from a petrol to hybrid car or from a meat-eater to a vegetarian.[35,46]

Within this context, it is unsurprising that pMDIs are a major contributor to the overall carbon footprint of pharmaceuticals and a notable factor in the overall global impact of greenhouse gases. It is estimated that the contribution of inhalers to the overall annual greenhouse gas emissions of the United Kingdom is approximately 0.3%[11] and equivalent to the annual greenhouse gas emissions of approximately 610,000 diesel cars.[47] Published estimates for Australia and New Zealand are unavailable, however are likely to be of similar relative proportion. Published reviews have considered the impact of different device types with respect to their GWP.

The key findings as summarized in a recent review by *Woodcock* et al are as follow[48]:

- The carbon footprint of DPI and SMI devices can be 100–200-fold lower than those of pMDIs.
- Propellants in pMDIs contribute most of the carbon footprint of inhalers.
- There are large differences in the carbon footprint of pMDIs depending on the amount and type of propellant used, varying from 50 gCO_2e up to 300 gCO_2e per actuation, or 9900 to 36,500 gCO_2e per device.[36]
  - Not all propellants have the same GWP, for example, the high GWP propellant HFC-134a, used in most currently available pMDIs is about half the GWP of the very high GWP HFC-227ea propellant used in a few pMDIs.
  - The carbon footprint of different pMDI products can also vary substantially because they contain more or less propellant; for example, salbutamol pMDIs contain an estimated 6.68–19.8 g of HFC-134a depending on the brand.[48]
- The environmental impact should be considered in the decision-making algorithm regarding optimal inhaler use/combinations for an individual.

As noted above, under the Kigali Amendment to the Montreal Protocol, HFCs will be phased down. Pharmaceutical companies are increasingly establishing carbon reduction or carbon neutral corporate plans, the focus of which includes inhaler manufacture and downstream use. There are an increasing number of DPI and SMI choices available from major pharmaceutical companies. There are also HFC pMDIs available that contain less propellant (e.g., Airomir™ Autohaler™), and therefore have lower carbon footprints, than other HFC pMDIs (e.g., Ventolin). A small but growing number of pharmaceutical companies including Chiesi,[49] AstraZeneca[50] and GlaxoSmithKline[51] have announced plans to switch to lower-GWP propellants, with 10 or more companies globally reported to have active programs to develop pMDIs containing lower GWP propellants, HFC-152a (GWP-100 164) and HFO-1234ze (E) (GWP-100 1.37). In addition, recent agreements have been formed between the two major lower-GWP propellant manufacturers and contract development and manufacturing organizations to develop and manufacture pMDIs containing these propellants on behalf of other companies.[52] Based on company announcements, inhalers containing new propellants could launch from as early as 2025. Only one company so far has announced specific reformulation plans for salbutamol pMDI.[51,53] Based on modelling of a switch to pMDIs with HFC-152a propellant, with GWP almost 10 times smaller than HFC-134a propellant, studies suggest that the carbon footprint of pMDIs could be reduced by up to 92%, and the annual CO_2 equivalent emissions from inhalers could be halved by incorporating pMDIs with HFC-152a propellant into a strategy

alongside greater use of DPIs[54] and SMIs. A switch to HFO-1234ze(E) propellant in pMDIs would afford even greater carbon footprint reductions, given its GWP is more than 100 times smaller than HFC-152a. A range of technical and economic issues and potential challenges have been identified that could emerge in the transition away from high-GWP propellant pMDIs to inhalers with lower GWPs, for example, potential issues with the supply of high-GWP propellant, which could create future risks for inhaler markets unless carefully managed by governments and industry.[36,52]

In the real-world setting, preventer adherence is low for many individuals, resulting in less than optimal asthma control and consequently an unnecessarily high use of reliever medications contributing to their carbon footprint.[55] In fact, recent data from 20 European countries and Canada have shown that two-thirds of total greenhouse gas emissions associated with inhalers relates to high reliever use.[56]

Further to this, the working group recognize that inhaler choice is influenced by a number of factors, such as cost of inhalers, patient preferences,[57] clinician prescribing habits,[58] concerns about device switching[59] and the patient's ability to use the inhaler correctly[60] at all times aiming to achieve the best possible outcome for the patient.

POTENTIAL MEANS TO MITIGATE IMPACT

Prescribing strategies

Several strategies exist to improve prescribing practices which benefit the patient and reduce carbon footprint.[61] These include:

1. Ensure that the respiratory diagnosis is accurate, and that inhaled therapy is necessary. International evidence suggests that roughly a third of people labelled with asthma are incorrectly diagnosed[62] we expect this value to be similar in Australia and New Zealand. For COPD, the proportion of incorrect diagnoses ranges from 30% to 60%.[63] Improving access to lung function testing would assist in achieving this as spirometry is the gold-standard for asthma and COPD diagnosis. Regular re-assessment and de-prescribing, if appropriate, should be routinely performed.
2. Actively pursue better disease control. This has obvious benefits for patients and concurrently reduces use/overuse of short-acting beta-agonists (SABAs) or other reliever medications. Of people seeking SABA medication in Australian community pharmacies, most over-use SABAs and about a third of those with asthma are not prescribed inhaled corticosteroids (ICS),[64] despite current guidelines suggesting that most or all adolescents/adults with asthma should be prescribed preventative therapy as maintenance and/or as needed AIR (anti-inflammatory reliever) therapy.[16,17,65] This can lead to sub-optimal control and unnecessary use of SABAs. Evidence-based COPD guidelines outlining preventative strategies to optimize disease control using pharmaceutical and non-pharmaceutical measures should be adhered to.[66] Appropriate use of preventers, in line with current asthma and COPD guidelines, will mitigate against adverse asthma outcomes as well as global warming.
3. Prescribe inhalers with lower global warming potential (GWP). pMDIs with the current HFC propellants have the highest GWP. Although some pMDIs have higher GWP than others (Table A1 in the Supporting Information), a straightforward message for practice is that currently, preferential prescription of DPIs/SMIs for patients who can use them reduces unnecessary contribution to global warming with the current range of available devices.[67]
4. Create awareness among health professionals and healthcare students through education. Most patients are willing to consider changing to inhalers with lower GWP if they provide good symptom control and if their health practitioner recommends them.[12] The most environmentally sensitive choice is likely to be the inhaler that the patient can and will use and that reduces the risk of exacerbations.

It is important to note that pMDIs (with spacers ± face mask) are currently preferred in children under the age of six and in people with poor inspiratory capacity to maximize lung deposition.[65] However, consideration of DPIs or SMIs will be appropriate for most older people. Systematic reviews of clinical trial data have confirmed that DPIs and pMDIs have equivalent efficacy both for beta-agonists and ICS[68,69] and some real-world observational evidence suggests that DPIs are more effective.[70]

5. Clinicians should assess and reassess an individual patient's abilities when prescribing an inhaler device to ensure the most appropriate and effective delivery device (Figure 4) with consideration of common patient errors in their inhaler technique.[74,75] Whilst a proportion of patients (e.g., young children and elderly) may lack the inspiratory flow to use DPIs, two independent studies have found that a third of patients with asthma are unable to breathe in slowly and gently enough to achieve the correct inspiratory flow for a pMDI, even with training.[76,77] Minimizing plastic waste is also an important step towards reducing the environmental impact of inhalers.
6. Choose dosage regimens which use fewer devices, either by delivering the same cumulative dose from a smaller number of actuations or by choosing regimens with less total medicine use, is another potentially important step. An example of the former in asthma management is the robust evidence that a once-daily dose (such as 400 mcg) budesonide in adults is equally effective as a twice-daily dose of 200 mcg.[78] The once-daily option halves plastic waste and reduces cost.

Several of the above strategies can be achieved simultaneously with the use of "anti-inflammatory reliever" (AIR)

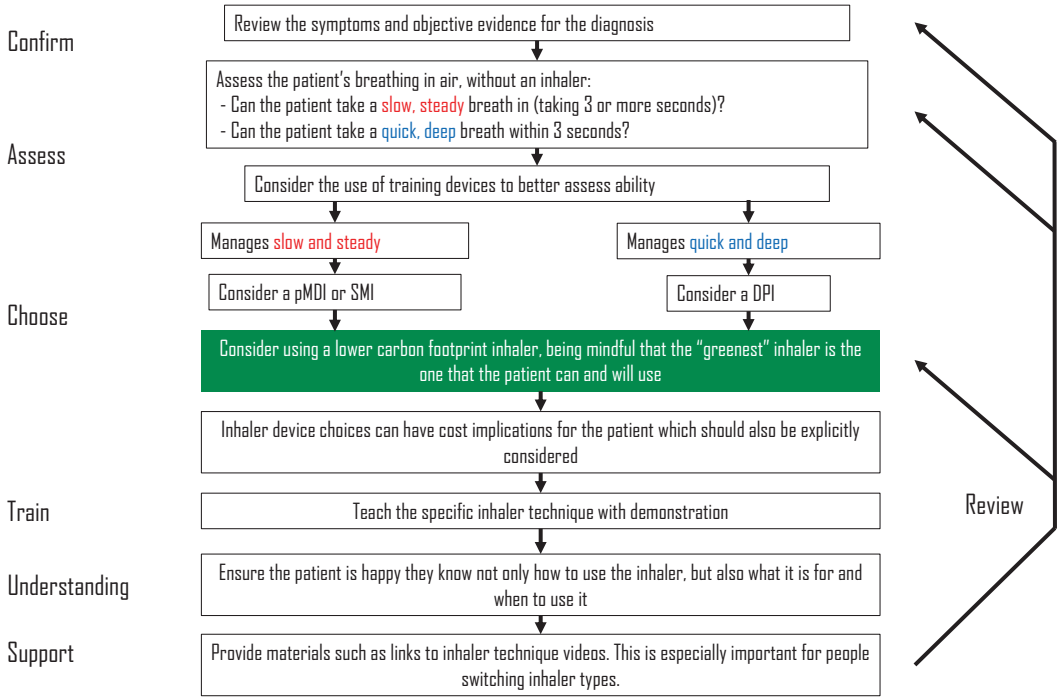

FIGURE 4 A stepwise, systematic approach to selecting an appropriate inhaler device for an individual patient.[71–73] This decision tree considers carbon footprint only and does not consider other environmental factors such as plastic waste and recycling. Reproduced with permission from The Royal Australian College of General Practitioners from: Montgomery BD, Blakey JD. Respiratory inhalers and the environment. Aust J Gen Pract 2022; 51 (12): 929–34. doi: 10.31128/AJGP-08-22-6536. Available at www1.racgp.org.au/ajgp/2022/december/respiratory-inhalers-and-the-environment.

therapy.[79,80] This involves the as-needed (prn) use of combination formoterol/ICS inhalers instead of SABA, with or without regular use of the same inhaler as maintenance. This is now the preferred strategy in New Zealand and international adult asthma guidelines[17,81] and is an option in Australian guidelines.[82] When formoterol/budesonide in a DPI is chosen for this purpose, over 90% of the carbon footprint can be saved due to a reduction in use of salbutamol pMDIs[83] (Figure 3), reflecting not just the use of less-polluting inhalers but also improved asthma control. Further, prn-only use in mild asthma likely modestly reduces plastic waste compared to regular ICS maintenance, due to using fewer doses, while achieving equivalent clinical outcomes.

Recycling and reuse

Many inhalers in Australia and New Zealand end up as landfill waste. The component parts (plastics and metals) are not recycled and any unused HFC propellant will eventually leak from the canisters.

A proportion of inhalers at their end-of-life are collected through National Return and Disposal of Australia's Return of Unwanted Medicines (NatRUM) program,[31] through which unwanted medications are returned by consumers to community pharmacies. These inhalers are collected by pharmaceutical wholesalers for incineration (which destroys the propellant) in accordance with regulations and environmental regulatory authority requirements.

Several pilot schemes have also been trialled internationally to responsibly recycle and/or dispose of inhalers at their useful end-of-life. Recent schemes have aimed to recycle plastic and metal components and recover HFCs for reuse in refrigeration and air conditioning. Recycling schemes have an important role alongside the above strategies. Whilst some initiatives have struggled with low participation and feasibility[84,85] a UK pilot postal scheme, Take AIR (Action for Inhaler Recycling) reduced an equivalent of an estimated 119.3 tonnes of carbon dioxide emissions over a 12-month period.

Modest reductions in plastic waste may be achievable by use of DPI or SMI devices with reusable inhaler components, such as the Handihaler and Respimat® devices used for some COPD medicines.[86]

DISCUSSION

The impact of human activity on the environment is a critical and urgent problem. We have described the scale of this issue and the relative global warming contributions of different types of inhalers in terms of their indicative carbon footprint and CO_2 equivalent, based on available information. Options for prescribing inhalers for mitigating this effect have been discussed. Broadly, these comprise steps to improve the efficiency of inhaler use which are considered good clinical practice (confirming the diagnosis and optimizing therapy, preventing breakthrough symptoms),

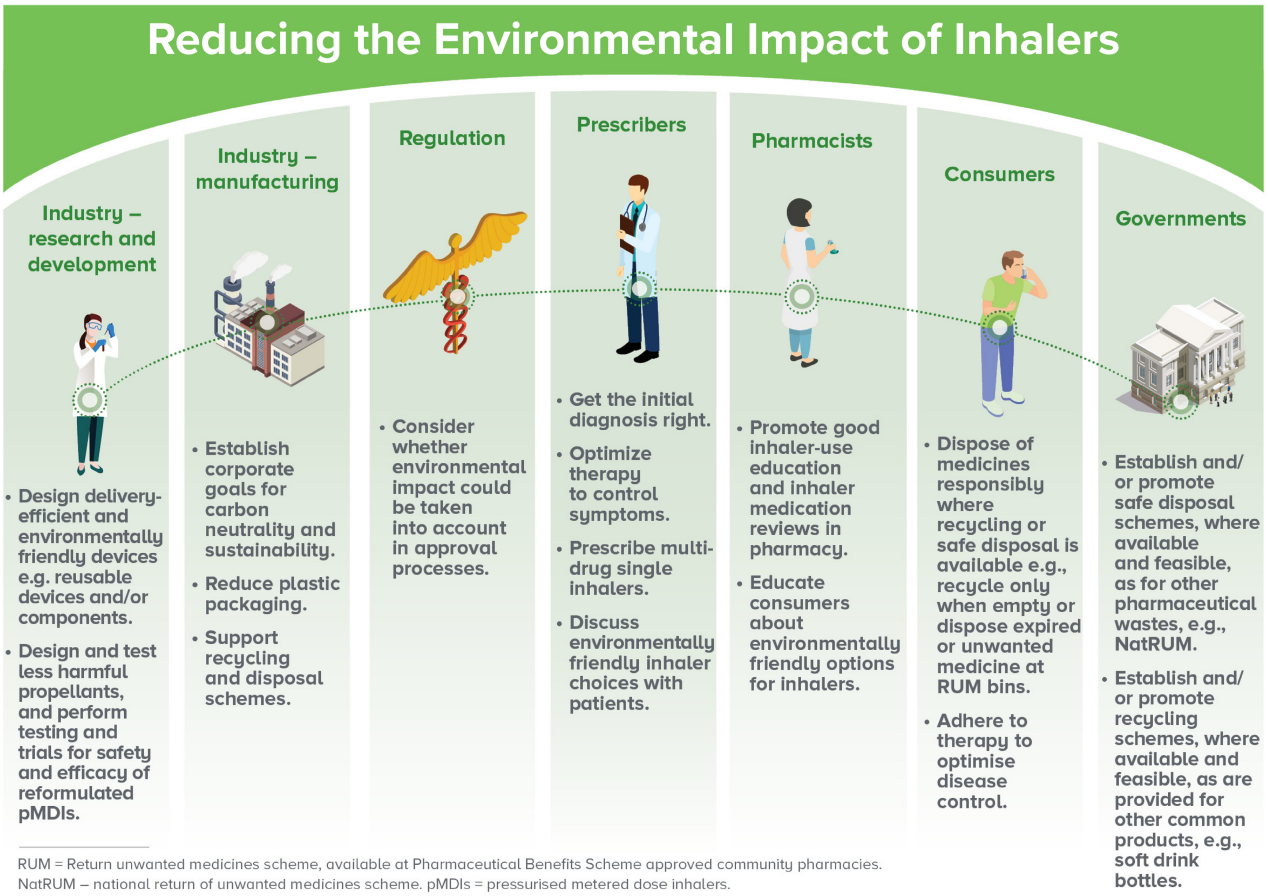

FIGURE 5 The many levels of responsibility for reducing the carbon footprint of inhalers.

alongside additional steps specifically aimed to reduce environmental impact where possible. These steps include preferentially recommending DPIs and SMIs instead of pMDIs for patients who are able to use them, and prescribing lower carbon footprint pMDIs (both those currently available and those under development when they become commercially available) (Figure 5).

Our understanding of the potential of inhaled medicines, and especially their propellants, to harm the environment is sound. However, we acknowledge that very precise estimates of the environmental influence are not currently available. This is due in part to uncertainty around energy consumption in production and distribution by manufacturers. There is also uncertainty and a lack of publicly available data in relation to prescribing and usage habits for many common inhalers making it difficult to estimate absolute climate impacts and the extent of waste from inhaler usage in Australia and New Zealand. However, these data limitations do not detract from the general principles and strategies outlined here to mitigate against the inherent environmental impacts from inhaler usage.

Some of the actions that clinicians may take now are described above, but there is also scope for further action by government, regulatory bodies and industry to facilitate the use of less environmentally impactful medicines. We also hope that those responsible for guidelines will include more practical information for prescribers in this crucial area.[87] In relation to prescribing/dispensing inhalers, our consumer group highlighted the importance of cost, clear communication between pharmacists and health practitioners, availability of inhaler recycling schemes and improving public awareness of greener inhaler choices.

The research currently underway into the use of less harmful propellants and reusable devices is welcome. However, we are not aware of large-scale research endeavours that look to understand how best to change the attitudes of prescribers to consider carbon footprint, or sustainability more broadly, in the prescription of inhalers in Australia and New Zealand.

CONCLUSION

The environmental impact of inhaled medicines is a critical global health issue that affects us all. It is one that is increasingly well delineated, internationally recognized, and, in the case of HFC propellants, subject to global environmental agreements supported through national legislation. This is driving change by inhaler manufacturers in Australia and New Zealand to incorporate lower carbon footprint alternatives. There are positive steps that prescribers can make *now*, by considering environmental impact in the decision-

making algorithm when prescribing, dispensing and recommending inhaler medications, with a focus on improving asthma control and reducing unnecessary pMDI use. It is everyone's responsibility to consider if and how they can take action to help mitigate the detrimental environmental impact of inhalers and we need to act now.

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CONFLICT OF INTEREST STATEMENT

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REFERENCES

1. Zhang Y, Beggs PJ, Bambrick H, Berry HL, Linnenluecke MK, Trueck S, et al. The MJA-lancet countdown on health and climate change: Australian policy inaction threatens lives. Med J Aust. 2018;209:474–5.
2. https://climate.nasa.gov/evidence/.
3. CSIRO. State of the climate 2020. Australian Government Bureau of Meteorology.
4. Callaghan M, Schleussner CF, Nath S, Lejeune Q, Knutson TR, Reichstein M, et al. Machine-learning-based evidence and attribution mapping of 100,000 climate impact studies. Nat Clim Change. 2021;11:966–72.
5. https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf.
6. Lenzen M, Malik A, Li M, Fry J, Weisz H, Pichler PP, et al. The environmental footprint of health care: a global assessment. Lancet Planet Health. 2020;4:e271–9.
7. Malik A, Lenzen M, McAlister S, McGain F. The carbon footprint of Australian health care. Lancet Planet Health. 2018;2:e27–35.
8. Australian Bureau of Statistics (2020–21), Health conditions prevalence, ABS Website, accessed 24 April 2023.
9. The impact of respiratory disease in New Zealand: 2020 update Dr Lucy Telfar Barnard, Jane Zhang.
10. Tennison I, Roschnik S, Ashby B, Boyd R, Hamilton I, Oreszczyn T, et al. Health care's response to climate change: a carbon footprint assessment of the NHS in England. Lancet Planet Health. 2021;5:e84–92.
11. Wilkinson A, Woodcock A. The environmental impact of inhalers for asthma: a green challenge and a golden opportunity. Br J Clin Pharmacol. 2022;88:3016–22.
12. Woodall MJ, Ma J, Emett K, Hamblin APE, Knowles K, Lee TH, et al. Investigating attitudes and insights into the global warming impact of inhalers. N Z Med J. 2023;136:94–105.
13. Diseases GBD, Injuries C. Global burden of 369 diseases and injuries in 204 countries and territories, 1990-2019: a systematic analysis for the global burden of disease study 2019. Lancet. 2020;396:1204–22.
14. Blakey J, Chung LP, McDonald VM, Ruane L, Gornall J, Barton C, et al. Oral corticosteroids stewardship for asthma in adults and adolescents: a position paper from the Thoracic Society of Australia and New Zealand. Respirology. 2021;26:1112–30.
15. https://www.nationalasthma.org.au/health-professionals/australian-asthma-handbook.
16. Beasley R, Beckert L, Fingleton J, Hancox RJ, Harwood M, Hurst M, et al. Asthma and respiratory foundation NZ adolescent and adult asthma guidelines 2020: a quick reference guide. N Z Med J. 2020;133:73–99.
17. Global Initiative for Asthma (GINA). Global Strategy for Asthma Management and Prevention. 2024 Available from: www.ginasthma.org
18. Global Initiative for Chronic Obstructive Lung Disease. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease 2023 report. Available from: https://goldcopd.org/2023-gold-report-2/#
19. Dabscheck E, George J, Hermann K, McDonald CF, McDonald VM, McNamara R, et al. COPD-X Australian guidelines for the diagnosis and management of chronic obstructive pulmonary disease: 2022 update. Med J Aust. 2022;217:415–23.
20. Hancox RJ, Jones S, Baggott C, Chen D, Corna N, Davies C, et al. New Zealand COPD guidelines: quick reference guide. N Z Med J. 2021;134:76–110.
21. https://ginasthma.org/wp-content/uploads/2024/05/GINA-2024-Strategy-Report-24_05_22_WMS.pdf.
22. Kponee-Shovein K, Marvel J, Ishikawa R, Choubey A, Kaur H, Thokala P, et al. Carbon footprint and associated costs of asthma exacerbation care among UK adults. J Med Econ. 2022;25:524–31.
23. Lavorini F, Corrigan CJ, Barnes PJ, Dekhuijzen PR, Levy ML, Pedersen S, et al. Aerosol drug management improvement T. Retail sales of inhalation devices in European countries: so much for a global policy. Respir Med. 2011;105:1099–103.
24. Pritchard JN. The climate is changing for metered-dose inhalers and action is needed. Drug Des Devel Ther. 2020;14:3043–55.
25. https://www.pbs.gov.au/info/statistics/expenditure-prescriptions/pb-expenditure-and-prescriptions-report-1-july-2019
26. https://pharmac.govt.nz/news-and-resources/official-information-act/official-information-act-responses/asthma-inhaler-devices-dispensed-from-2014-to-2020.

27. Reddel HK, FitzGerald JM, Bateman ED, Bacharier LB, Becker A, Brusselle G, et al. GINA 2019: a fundamental change in asthma management: treatment of asthma with short-acting bronchodilators alone is no longer recommended for adults and adolescents. Eur Respir J. 2019;53:1901046.
28. http://medicarestatistics.humanservices.gov.au/statistics/pbs_item.jsp.
29. https://www.tga.gov.au/resources/artg/373934.
30. https://www.pbs.gov.au/medicine/item/12267P accessed February 8th 2023.
31. https://returnmed.com.au/about-us/.
32. Hansel M, Bambach T, Wachtel H. Reduced environmental impact of the reusable Respimat((R)) soft mist inhaler compared with pressurised metered-dose inhalers. Adv Ther. 2019;36:2487–92.
33. Di Paolo ER, Spaggiari S, Pannatier A, Sadeghipour F, Rochat I, Hafen GM. Stop using the flotation technique and start weighing salbutamol pressurised metered-dose inhalers without dose counters. Swiss Med Wkly. 2015;145:w14162.
34. https://www.lskh.digital/article/trends-and-future-challenges-in-inhaled-drug-delivery.
35. Janson C, Henderson R, Lofdahl M, Hedberg M, Sharma R, Wilkinson AJK. Carbon footprint impact of the choice of inhalers for asthma and COPD. Thorax. 2020;75:82–4.
36. United Nations Environmental Program: Medical and Technical Options Committee. 2022 assessment report: Montreal protocol on substances that deplete the ozone layer. 2022. Retrieved from https://ozone.unep.org/system/files/documents/MCTOC-Assessment-Report-2022.pdf
37. https://www.epa.gov/ghgemissions/understanding-global-warming-potentials.
38. The Kigali Amendment. The amendment to the Montreal Protocol agreed by the Twenty-Eighth Meeting of the Parties (Kigali, 10–15 October 2016), (2016). 2016.
39. https://ozone.unep.org/all-ratifications.
40. Forster P, Storelvmo T, Armour K, Collins W, Dufresne J-L, Frame D, et al. The Earth's energy budget, climate feedbacks, and climate sensitivity. In: Masson-Delmotte V, Zhai P, Pirani A, Connors SL, Péan C, Berger S, et al., editors. Climate change 2021: the physical science basis. Contribution of working group I to the sixth assessment report of the intergovernmental panel on climate change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press; 2021. p. 923–1054. https://doi.org/10.1017/9781009157896.009 Chapter 7 Supplementary Material, Table 7.SM.7.
41. https://www.prescqipp.info/our-resources/bulletins/bulletin-295-inhaler-carbon-footprint/ (accessed 2022/2023).
42. https://www.nationalasthma.org.au/living-with-asthma/resources/health-professionals/charts/asthma-copd-medications-chart (August 2023).
43. Read R. OIA Response | Number and cost of metered dose and dry powder inhalers and devices dispensed each year from 2017 to 2020 - Pharmac | New Zealand Government 2021. Available from: https://pharmac.govt.nz/news-and-resources/official-information-act/official-information-act-responses/number-and-cost-of-metered-dose-and-dry-powder-inhalers-and-devices-dispensed-each-year-from-2017-to-2020/?keyword=inhaler&page=1 (accessed 26 Jun 2023)
44. https://www.ntc.gov.au/sites/default/files/assets/files/Carbon%20Dioxide%20Emissions%20Intensity%20for%20New%20Australian%20Light%20Vehicles%202021.pdf (https://www.google.com/url?q=https://www.ntc.gov.au/sites/default/files/assets/files/Carbon%2520Dioxide%2520Emissions%2520Intensity%2520for%2520New%2520Australian%2520Light%2520Vehicles%25202021.pdf&sa=D&source=docs&ust=1725955283083042&usg=AOvVaw1TgLyEPtiZO3hluLox2J24).
45. https://www.abs.gov.au/statistics/industry/tourism-and-transport/survey-motor-vehicle-use-australia/latest-release#kilometres-travelled (https://www.google.com/url?q=https://www.abs.gov.au/statistics/industry/tourism-and-transport/survey-motor-vehicle-use-australia/latest-release%23kilometres-travelled&sa=D&source=docs&ust=1725955283083148&usg=AOvVaw1AK2txL3hanxnrateTIBa2)
46. Scarborough P, Appleby PN, Mizdrak A, Briggs AD, Travis RC, Bradbury KE, et al. Dietary greenhouse gas emissions of meat-eaters, fish-eaters, vegetarians and vegans in the UK. Clim Change. 2014;125:179–92.
47. Jeswani HK, Azapagic A. Life cycle environmental impacts of inhalers. J Clean Prod. 2019;237:117733.
48. Woodcock A, Beeh KM, Sagara H, Aumonier S, Addo-Yobo E, Khan J, et al. The environmental impact of inhaled therapy: making informed treatment choices. Eur Respir J. 2022;60:2102106.
49. https://www.chiesi.com/en/koura-opens-worldrs-first-hfa-152a-medical-propellant-production-facility/. accessed 01/12/2022.
50. AstraZeneca Announcement, 2022: https://www.astrazeneca.com/media-centre/press-releases/2022/astrazeneca-progresses-ambition-zero-carbon-programme-with-honeywell-partnership-to-develop-next-generation-respiratory-inhalers.html
51. https://www.gsk.com/en-gb/media/press-releases/gsk-announces-major-renewable-energy-investment-and-low-carbon-inhaler-programme-alongside-life-sciences-sector-race-to-zero-breakthrough-at-nyc-climate-week/.
52. Reference UNEP. Report of the Technology and Economic Assessment Panel, Volume 1, Progress Report, May 2024. 2024 Available from: https://ozone.unep.org/system/files/documents/TEAP-May2024-Progress-Report.pdf
53. UNEP. Report of the technology and economic assessment panel, volume 1, Progress report, May 2024. 2024 Available from: https://ozone.unep.org/system/files/documents/TEAP-May2024-Progress-Report.pdf
54. Pernigotti D, Stonham C, Panigone S, Sandri F, Ferri R, Unal Y, et al. Reducing carbon footprint of inhalers: analysis of climate and clinical implications of different scenarios in five European countries. BMJ Open Respir Res. 2021;8:8.
55. Serhal S, Saini B, Bosnic-Anticevich S, Krass I, Wilson F, Armour C. Medication adherence in a community population with uncontrolled asthma. Pharmacy (Basel). 2020;8:8.
56. Janson C, Maslova E, Wilkinson A, Penz E, Papi A, Budgen N, et al. The carbon footprint of respiratory treatments in Europe and Canada: an observational study from the CARBON programme. Eur Respir J. 2022;60:2102760.
57. Price D, Keininger DL, Viswanad B, Gasser M, Walda S, Gutzwiller FS. Factors associated with appropriate inhaler use in patients with COPD - lessons from the REAL survey. Int J Chron Obstruct Pulmon Dis. 2018;13:695–702.
58. Starup-Hansen J, Dunne H, Sadler J, Jones A, Okorie M. Climate change in healthcare: exploring the potential role of inhaler prescribing. Pharmacol Res Perspect. 2020;8:e00675.
59. NHS England. NHS becomes the world's first national health system to commit to become 'carbon net zero', backed by clear deliverable and milestones. 2020.
60. Price D, Bosnic-Anticevich S, Briggs A, Chrystyn H, Rand C, Scheuch G, et al. Inhaler competence in asthma: common errors, barriers to use and recommended solutions. Respir Med. 2013;107(1):37–46.
61. Wilkinson AJK, Braggins R, Steinbach I, Smith J. Costs of switching to low global warming potential inhalers. An economic and carbon footprint analysis of NHS prescription data in England. BMJ Open. 2019;9:e028763.
62. Aaron SD, Boulet LP, Reddel HK, Gershon AS. Underdiagnosis and Overdiagnosis of asthma. Am J Respir Crit Care Med. 2018;198:1012–20.
63. Diab N, Gershon AS, Sin DD, Tan WC, Bourbeau J, Boulet LP, et al. Underdiagnosis and Overdiagnosis of chronic obstructive pulmonary disease. Am J Respir Crit Care Med. 2018;198:1130–9.
64. Azzi EA, Kritikos V, Peters MJ, Price DB, Srour P, Cvetkovski B, et al. Understanding reliever overuse in patients purchasing over-the-counter short-acting beta(2) agonists: an Australian community pharmacy-based survey. BMJ Open. 2019;9:e028995.
65. National Asthma Council Australia. Australian asthma handbook: choosing an inhaler device to suit the individual [Internet]. Available from: https://www.asthmahandbook.org.au/management/devices/device-choice
66. https://lungfoundation.com.au/resources/stepwise-management-of-stable-copd/.

67. Panigone S, Sandri F, Ferri R, Volpato A, Nudo E, Nicolini G. Environmental impact of inhalers for respiratory diseases: decreasing the carbon footprint while preserving patient-tailored treatment. BMJ Open Respir Res. 2020;7:7.
68. Ram FS, Brocklebank DM, White J, Wright JP, Jones PW. Pressurised metered dose inhalers versus all other hand-held inhaler devices to deliver beta-2 agonist bronchodilators for non-acute asthma. Cochrane Database Syst Rev. 2002;2002:CD002158.
69. Brocklebank D, Wright J, Cates C. Systematic review of clinical effectiveness of pressurised metered dose inhalers versus other hand held inhaler devices for delivering corticosteroids in asthma. BMJ. 2001; 323:896–900.
70. Price D, Haughney J, Sims E, Ali M, von Ziegenweidt J, Hillyer EV, et al. Effectiveness of inhaler types for real-world asthma management: retrospective observational study using the GPRD. J Asthma Allergy. 2011;4:37–47.
71. Montgomery BD, Blakey JD. Respiratory inhalers and the environment. Aust J Gen Pract. 2022;51:929–34.
72. https://www.medscape.co.uk/viewarticle/choosing-appropriate-inhaler-device-treatment-adults-asthma-2022a10025xw.
73. https://web.archive.org/web/20220703091634/https://www.guidelines.co.uk/respiratory/inhaler-choice-guideline/455503.article.
74. Sanchis J, Corrigan C, Levy ML, Viejo JL, Group A. Inhaler devices - from theory to practice. Respir Med. 2013;107:495–502.
75. Haughney J, Price D, Barnes NC, Virchow JC, Roche N, Chrystyn H. Choosing inhaler devices for people with asthma: current knowledge and outstanding research needs. Respir Med. 2010;104:1237–45.
76. Haughney J, Lee AJ, McKnight E, Pertsovskaya I, O'Driscoll M, Usmani OS. Peak inspiratory flow measured at different inhaler resistances in patients with asthma. J Allergy Clin Immunol Pract. 2021;9: 890–6.
77. Álvarez Gutiérrez F, Baynova K, Izquierdo Alonso J, Valero Santiago AL, Blanco Aparicio M, et al. P55 a training tool on inspiratory manoeuvre success in pMDIs and DPIs: the INSPIRE study. Thorax. 2023;78:A138–9.
78. Masoli M, Weatherall M, Holt S, Beasley R. Budesonide once versus twice-daily administration: meta-analysis. Respirology. 2004; 9:528–34.
79. https://bjgp.org/content/74/739/86.
80. Crossingham I, Turner S, Ramakrishnan S, Fries A, Gowell M, Yasmin F, et al. Combination fixed-dose beta agonist and steroid inhaler as required for adults or children with mild asthma: a Cochrane systematic review. BMJ Evid Based Med. 2022;27:178–84.
81. https://www.nzrespiratoryguidelines.co.nz/adultguidelines.html.
82. https://www.asthmahandbook.org.au/management/adults.
83. Hatter L, Holliday M, Eathorne A, Bruce P, Pavord ID, Reddel HK, et al. The carbon footprint of as-needed budesonide-formoterol in mild asthma: a post hoc analysis. Eur Respir J. 2024;64:2301705.
84. Clews G. Inhaler recycling scheme that cut carbon emissions equivalent to more than 8,500 cars is scrapped. Pharm J. Jul 2020;305:7939.
85. Robinson J. Only 62% of invited pharmacies sign up for Chiesi postal inhaler recycling scheme. Pharm J. 2021;305:7939.
86. Dahl R, Kaplan A. A systematic review of comparative studies of tiotropium Respimat(R) and tiotropium HandiHaler(R) in patients with chronic obstructive pulmonary disease: does inhaler choice matter? BMC Pulm Med. 2016;16:135.
87. https://www.nationalasthma.org.au/living-with-asthma/resources/health-professionals/information-paper/reducing-the-environmental-impact-of-asthma-treatment.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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