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REVIEW ARTICLE

An EAACI review: Go green in health care and research. Practical suggestions for sustainability in clinical practice, laboratories, and scientific meetings

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Abstract

Health care professionals (HCPs) and researchers in the health care sector dedicate their professional life to maintaining and optimizing the health of their patients. To achieve this, significant amounts of resources are used and currently it is estimated that the health care sector contributes to more than 4% of net greenhouse gas (GHG) emissions. GHG emissions adversely impact planetary health and consequently human health, as the two are intricately linked. There are many factors of health care that contribute to these emissions. Hospitals and research labs also use high amounts of consumables which require large amounts of raw materials and energy to produce. They are further responsible for polluting the environment via disposal of plastics, drug products, and other chemicals. To maintain and develop state-of-the-art best practices and treatments, medical experts exchange and update their knowledge on methods and technologies in the respective fields at highly specialized scientific meetings. These meetings necessitate thousands of attendants traveling around the globe. Therefore, while the goal of HCPs is to care for the individual, current practices have an enormous (indirect) impact on the health of the patients by their negative

Abbreviations: AIR, anti-inflammatory reliever; CO_2, carbon dioxide; CO_2e, carbon dioxide equivalent; COPD, chronic obstructive pulmonary disease; CUGH, Consortium of Universities for Global Health; DPIs, dry powder inhalers; GDP, gross domestic product; GHG, greenhouse gases; GWP, global warming potential; HCPs, healthcare professionals; HFA, hydrofluoroalkane; HFC, hydrofluorocarbons; ICS, inhaled corticosteroids; LABA, long-acting beta2 agonists; LAMA, long-acting anti-muscarinic agents; LMICs, low/middle income countries; MART, maintenance and reliever treatment; NHS, national health service; pMDIs, pressurized metered-dose inhalers; PPE, personal protective equipment; SABA, short-acting beta2 agonists; SDG, sustainable development goals; SMIs, soft mist inhalers.

environmental impacts. There is an urgent need for HCPs and researchers to mitigate these detrimental effects. The installation of a sustainability-manager at health care facilities and research organizations to implement sustainable practices while still providing quality health care is desirable. Increased use of telemedicine, virtual/hybrid conferences and green chemistry have recently been observed. The benefits of these practices need to be evaluated and implemented as appropriate. With this manuscript, we aim to increase the awareness about the negative impacts of the health care system (including health care research) on planetary and human health. We suggest some easy and highly impactful steps and encourage health care professionals and research scientists of all hierarchical levels to immediately implement them in their professional as well as private life to counteract the health care sector's detrimental effects on the environment.

KEYWORDS
asthma, education, environment, lung diseases, prevention, sustainability

1 | INTRODUCTION

The Anthropocene has recently been proposed as an independent geological epoch and is considered to be the period during which human beings have had a substantial (mainly negative) impact on the planet (planetary health), the environment/biosystems (eco health), and subsequently on the health of people and animals, all of which are tightly interconnected (One health).[1] These anthropogenic effects resulted in increased greenhouse gas (GHG) emission, loss of biodiversity, sealing of soil, and pollution of air, water and land, and have led to environmental destruction and climate change. The health consequences from climate change are broad and include injury, death, and displacement due to environmental disasters and extreme weather events, changes in the distribution of infectious and zoonotic diseases (thereby possibly even the rise of new pandemics as people interface with animal habitats), and food and water shortages.[2] Other adverse health effects include increases in non-communicable diseases such as asthma, allergies, and immunological disorders.

The health care sector plays a significant role in climate change and it is estimated that it contributes to around 4.4%–10% of net GHG emissions.[3] Research laboratories are also energy and resource intensive. A standard laboratory consumes five times the energy and water as a general office space of the same size. As a consequence, the actions which health care professionals (HCPs) and researchers take to maintain and improve the health of human and veterinary patients may directly or indirectly cause more harm than benefit. HCPs are, therefore, obligated to re-evaluate their existing processes and optimize them to mitigate climate change and pollution by improving resource management, increasing energy use efficiency, fostering greenness and biodiversity, and implementing sustainable processes, both in their private and professional lives.[4–8] Reducing emissions is key to climate change mitigation strategies. In addition to health benefits, health care facilities are discovering the potential for significant cost savings. For instance, Kaiser Permanente's (health maintenance organization) carbon neutrality goal since 2013 has led to cost savings by improving energy use efficiency and decreasing water use of over 20 million dollars—per year![9]

Education plays an important role in sustaining and expanding climate change mitigation efforts. Existing curricula should be updated at schools and universities so that forthcoming HCPs are educated in sustainable practices. Regular lectures about environmental aspects of their profession should be held.[10–14] Health care experts also need to educate and inform their patients about their medical management and treatment, the ecological footprint and environmental impact from production to disposal, as well as optimal alternatives. For example, in a fictional case,[4] a type 2-diabetic woman refrained from further increasing her medication and after consultation of her physician started to maneuver a part of the daily family-travel distances by foot instead of using a car, which had a number of (calculated) positive impacts on her health, the health of her children, and the health of the environment.

On a higher hierarchal level, city planners, politicians, and hospital directors have to implement sustainability in health care facilities[15] via sustainable energy supplies and transport for staff and patients, increased green indoor and outdoor areas, promotion of telemedicine, use of sustainable inhalers and anesthetics, reusable gowns, procuring sustainable products from suppliers, and reusing/recycling/reducing single-use disposable products in clinics and laboratories.

Other ideas have been collated by the Working Group of “One Health in Allergology” of the European Academy of Allergy and Clinical Immunology (EAACI) during 2022 in the “Go Green” webinar series (freely available[16]). The current review paper provides a summary of these webinars. It also aims to raise awareness in all health care professionals at every hierarchical level regarding the impact their daily professional life has on the environment, and consequently on planetary health. Some future perspectives and tasks, not discussed here in detail, also need to be considered (Box 1). We herewith call for action and encourage reducing the negative impacts (e.g., consumption of goods, water, energy; release of emissions, pollutants, detrimental substances/gases), increasing positive impacts (e.g., implementing education on sustainability; increasing green areas in private and professional environments; reducing travel and use of cars and planes; favoring virtual meetings), and motivating patients to do the same for both their own and environmental health.

2 | SUSTAINABILITY IN LABORATORIES

Scientists contribute knowledge and innovation and those in medicine and life sciences contribute to SDG 3[17] (human health and well-being) by developing vaccines and cures for diseases like cancer. However, they are also responsible for high levels of GHG and carbon dioxide equivalent (CO_2e) emissions (SDG 13[17]), hazardous lab waste production (SDG 12[17]), and excessive harvesting of red algae, which are the basis for the production of agarose (SDG 14[17]).

Lab buildings alone consume on average 3–5 times more energy[18] and water[19] than normal office buildings of the same area. Lab instruments[20] like fume cupboards, −80°C freezers, autoclaves, or incubators are often running 24/7 and consume on average equal or greater energy as a single-family house (Table 1). Single-use plastic is used especially in microbiology, molecular biology, and clinical labs, constituting an enormous amount of plastic waste. A study by the University of Exeter estimated that life science labs around the world together generate about 5.5 million tons of plastic per year.[21] This accounts for 1.8% of global plastic waste. One single microbiology lab produced 97 kg of plastic waste in 1 month.[22] The "plastic problem" is raising awareness within the scientific community and under #Labwasteday, scientists post the waste that they have generated: in 2019 about 300–400 g was generated in 1 day/person.[23] In 2018, the University of Manchester[24] and the University of Leeds[25] pledged to become plastic-free in 2022 and 2023, respectively. Even mainstream media like Guardian[26] and Süddeutsche Zeitung[27] picked up this topic and reported on the huge plastic waste generated in labs. Finally, data storage, simulations, or data evaluation can have a big carbon footprint. Grealey et al. calculated the carbon footprint of bioinformatics[28] and estimated that a simulation of the molecular dynamics of the tobacco mosaic virus for 100 ns releases between 17.8 and 95 kg CO_2e, depending on the software used.

Ways to lower the environmental impact of a lab include precise analysis of processes and routines to identify improvements, a switch to sustainable methods wherever possible and the establishment of a sustainable procurement process (Figure 1). Freezer management, for example, can have a big impact in reduction of energy consumption. Effective freezer management[29] includes regular defrosting, discarding samples which are not needed anymore, and regular removal of dust from filters and condensers to allow generated heat to dissipate. Short freezer door opening times contribute[30] to energy saving and reduce the formation of ice crystals, which can damage sealings. A significant step to lower energy consumption includes rising the temperature of freezers from −80°C to −70°C, which can decrease energy use by 20%–34%, and also increases the temperature consistency (−70°C ± 1°C vs. ±4.5°C at −80°C).[31,32] Several studies show evidence that some samples can be stored at −70°C without compromising their quality. Yeast strains and molds, for example, can be stored at −70°C for up to 8 years[33] and samples of

BOX 1 Future research and perspectives.

Task in clinical care and research	Example
Confirm via studies sustainability of measures from first to last step (i.e., from production to disposal or recycling) for alternative and new drugs, remedies, clinical treatments, or diagnostic processes	Asthma inhalers, anesthetics incl. dental medicine; reduction of drug application/instructing patients to a healthier lifestyle for themselves and the environment (e.g., type 2-diabetic patients switch to walking or driving by bicycle instead of using car)
Substitute substances and processes, which are dangerous or toxic not only for people or animals but also for the environment, by less harmful ones	Switch to green (analytical) chemistry
Identify and control effective recycling strategies for medical devices and drugs, and control the process	By "waste watchers"; Financial punishment if remnants from drugs or chemical substances are not collected and/or recycled properly
Label medical processes and remedies with ecological footprint from production until disposal	Pharmaceutical and chemical industry needs to provide numbers for ecological footprint of their respective products/drugs/chemicals
Educate health care professionals and patients about sustainable medical treatments (e.g., alternative asthma inhaler types; substitute type 2-diabetic drugs by more physical activity)	Education in sustainability for medical experts and allied health care professionals need to be updated/expanded; physicians need to be prepared to instruct their patients about the benefits of a life-style that is healthy for themselves and the environment (One Health approach)

TABLE 1 Energy consumption of typical instruments used in a laboratory.[20]

Device	Energy consumption (kWh/y)	Assumptions informing energy consumption of device
Lab freezer (undercounter −20°C)	1548	Based on values published by ENERGY STAR
Lab freezer (full sized upright/chest −20°C)	4876	Based on values published by ENERGY STAR
Lab freezer (full sized upright /chest −80°C)	7720	Based on measured values from Stanford and Labs21
Autoclave (countertop)	1170	25 cycles per week
Autoclave (floor mounted)	11,700	15 cycles per week
Centrifuge (mini)	14	Based on values from Stanford labs
Centrifuge (countertop)	91	Based on values from other campuses
Centrifuge (floor-mounted)	1007	Based on values from other campuses
Lab refrigerator (Under-counter)	1004	Based on values published by ENERGY STAR
Lab refrigerator (full-sized)	2686	Based on values published by ENERGY STAR
Microscope	350	On 8 h per day, standby rest of day
Incubator (Countertop, shaking)	2245	Based on values from Stanford
Incubator (Countertop, not shaking)	262	Based on values from Labs21
Incubator (Floor-mounted, shaking)	6570	Based on values from other campuses
Incubator (Countertop, not shaking)	3723	Based on values from other campuses
Grow lamps/plug lighting	210	Based on 32-W bulb, on 18 h per day, off rest of day
Vortex mixer	24	On 1 h per day, standby rest of day
Shake table (Countertop)	231	Based on VWR models, on 8 h per day, standby rest of day
Shake table (floor-mounted)	2184	Based on values from other campuses
Hot plate	243	Based on values from other campuses
Water bath (shaking)	4561	Based on values for SHEL LAB 17- and 27-liter models, on 12 h per day, off rest or day
Water bath (not shaking)	3850	Based on values from Stanford

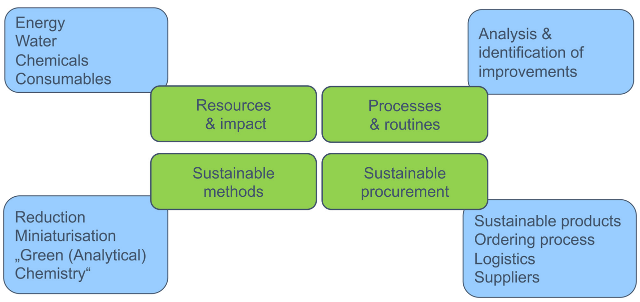

FIGURE 1 A sustainable lab has to focus on four topics (green), each comprising several detailed aspects (blue).

Staphylococcus aureus from clinical samples for up to 91 days without change of quality.[34] HIV Pr55gag virus-like particles stored in 15% trehalose at −70°C retained their original appearance over a period of 1 year.[35] In a publicly accessible google document,[36] researchers share which samples were successfully stored at −70°C. Lastly, DNA can also be stored at room temperature[37] under specific conditions. Already in 2009, the university of Stanford estimated that 20%–25% of all its samples could be stored at room temperature, which would save 2.8 million kWh/year.[38] Switching off instruments can also have a significant impact. A clinical lab analyzed the energy needs of each device used for a specific method.[39] By adopting the usage time, the lab saved 30% of energy and carbon emissions without changing the method itself.

Addressing the reduction of single-use plastic is challenging, especially in life science labs, but feasible. The “plastic-free” pledge from the University of Manchester prompted two employees from the School of Biological Sciences to run a project to reduce plastic waste in the undergraduate labs.[40] They identified measures like re-using plastic cuvettes, or replacing plastic loops with a wooden stirrer. Other items which are used frequently, like beakers or pipettes, can also be replaced by glass alternatives. Alves et al. established a reuse and replace scheme in a microbiology lab.[22] Single-use items like plastic serological pipettes, weighing boats, Petri dishes, or cuvettes were washed and re-used, whereas other items like plastic inoculation loops were replaced by metal alternatives. Autoclavable single-use tubes were decontaminated, washed, autoclaved, and re-used. Such re-use of tubes produces 11 times less CO_2e emission compared to single-use plastic.[41] Certainly, some products with a high risk of cross-contamination and sample interference such as pipette tips generally cannot be reused. On the other hand, groups successfully implemented recycling schemes for pipette tip boxes, pipette trays, and cell culture flasks.

The principles of green chemistry[42] and green analytical chemistry[43] can guide in the search for more sustainable methods. Miniaturization, reduction of resources and waste, use of renewable resources as well as safe and monitored, automated processes are key points. Green solvent guides can help to choose more environmental-friendly solvents and some, like ethanol, are already made of renewable resources.[44] Another example is the replacement of formamide with ethylene carbonate for in situ hybridization.[45]

Last but not least, labs should introduce sustainable procurement. This includes the setup of an efficient ordering process, proper inventory management to avoid unnecessary transport and CO_2e emissions, as well as searching for more sustainable products. Certificates like Energy Star,[46] EGNATON CERT[47] or the ACT label[48] can serve as guidance. It remains to be seen what influence political requirements, such as the revision of the Ecodesign Directive[49] and the digital product passport,[50] which rate products based on their respective sustainability performance, will have on the development of sustainable laboratory products in the future.

The aforementioned examples can serve as guiding principles for individual laboratories, however, it is clear that each lab has to develop its own action plan according to individualized criteria.

3 | SUSTAINABILITY IN CLINICAL CARE

Health care industries are among the top carbon utilizers. From 2000 through 2015, GHGs from the health sector have risen by 29%. The US health system is responsible for a quarter of global healthcare emissions, which have been rising domestically over the past decade[51,52] (Figure 2). According to a 2018 estimate, health care waste is associated with the loss of 388,000 to 405,000 disability-adjusted life years.[54,55] The ethos of the medical profession demands that these tangible and escalating harms to patients and communities be addressed. However, beyond ethical obligations, there are unequivocal benefits of integrating sustainability into clinical care; in addition to health benefits, reducing emissions has the potential for substantial cost savings in health facilities.[9]

Calculating the amount of waste generated by health systems involves accounting for direct emissions by health care facilities, and indirect emissions through the purchase of electricity and the manufacture and movement of goods and services through supply chains. Although healthcare facilities are incredibly energy-intensive facilities through the use of space heating, cooling, and ventilation systems, the majority of emissions are generated through the supply chain.[54] Approaches to reduce waste in health care are many, varied, and extensive. Examples include energy efficient building design; retrofitting existing health facilities to improve insulation and ventilation[53,54]; avoiding the use of certain anesthetic gases like desflurane in energy-intensive areas of hospitals like the operating room[56]; transportation infrastructure investments that incentivize employees and patients to use public transportation, ride-sharing or bicycles, and alternative fuels for ambulances; and properly sorting and disposing of medical waste as well as purchasing eco-friendly materials.

Obstacles to these actions include the perception that environmental-friendly measures like reducing fossil-fuel dependence increase costs. As demonstrated by examples such as Kaiser Permanente, taking steps toward sustainability can be cost-effective although it is important to acknowledge the possible upfront costs. In 2017, part of Boston Medical Center's transition to a more energy efficient and self-sustaining system involved a 15 million dollar investment into a natural gas-driven, onsite power plant.[57] This step is saving the institution over a million dollars per year and will render the facility resilient to climate-related disruptions to the power grid, but the initial investment can be prohibitive for some health systems. This issue can be addressed on a state or federal level by funding health systems that invest in sustainable energy and infrastructure.

Not only can measures like decarbonization directly reduce costs, other indirect expenses associated with climate-related disruptions must also be considered. An analysis of 10 natural disasters in the United States caused or exacerbated by climate change found that healthcare costs incurred due to emergency department visits and hospitalizations were in the realm of several billion dollars.[58] A 2021 report issued by the National Resources Defense Council stated that the physical and mental health burden of climate change and the use of fossil fuels is costing the United States over 800 billion dollars per year.[59]

The COVID-19 pandemic introduced challenges such as a steep rise in waste through the use of single-use personal protective equipment (PPE).[60] Health systems that have implemented reusable PPE found significant reductions in waste and cost savings relative to single-use PPE[60]; the reusable PPE did not have worse performance and, in fact, offered superior protection to single-use counterparts.[61]

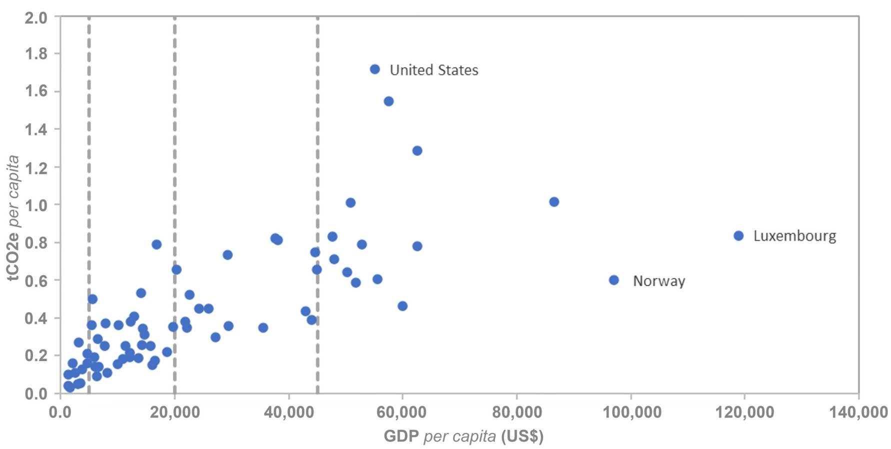

FIGURE 2 Emission per capita compared to the GDP for the nations covered in this study according to their typology and threshold used to allocate the four trajectories to nations (dashed gray line). The United States has the highest carbon dioxide emissions per capita worldwide. tCO2e, tonnes of carbon dioxide equivalents; GDP, gross domestic product. Reprinted with kind permission from Health Care Without Harm.[53]

Some may also wonder if fundamental structural changes like decarbonization will adversely affect patient outcomes. An analysis of health care-related GHG emissions across states and health system performance metrics did not find a statistically significant relationship between these variables.[54]

An environmentally sustainable transformation of the United States health system promises health benefits and significant cost savings. Central to this effort is systemic decarbonization. In 2022, the United States Department of Health and Human Services launched a voluntary pledge signed by over 100 healthcare organizations in pursuit of three goals: reducing emissions by 50% by 2030 and entirely by 2050, providing an inventory of supply chain emissions, and devising climate resilience plans.[62] While an important step, progress toward a net-zero health system will be limited if it relies on voluntary participation and with no legislative emissions targets or a formal system for tracking GHG emissions from facilities.[63] At the United Nations Climate Change Conference in Glasgow in 2022, 14 nations established GHG emissions targets. Of these, England went farthest by embedding their goals into legislation.[64] The Health and Care Act 2022 has set the National Health Service *en route* to reach net zero emissions by 2045 with an interim target of 80% emissions reduction by 2028 to 2032.[65]

Advocating for legislative mandates to track and reduce emissions is critical to mitigating the worst of climate change impacts. However, there are also other opportunities to help shape a greener health sector. A key area of intervention is the education of medical trainees and health professionals. While more medical schools are integrating climate change and health material into their curricula, many states still do not have institutions that offer this necessary training and those that do are often lacking various curricular competencies (Figure 3).[67,68] Some do not clearly outline the climate change and health content they offer, which makes it impossible to discern if the institution provides any instruction about sustainability in clinical care.

From the point of clinical practice and sustainability in addition to transportation, heating expenditures, and waste production, hospital care requires a range of economical inputs, including wages, prescription drugs, food, medical equipment, utilities, and professional insurance. Rapid increases in these input costs, as well as rapidly rising drug prices, can undermine hospitals' efforts to reduce care costs, resulting in reduced sustainability, medical care and thus, in the end, higher expenditures.[69]

Ultimately, a sustainable reformation of the health system in the United States and other industrialized countries will require a systemic and systematic approach with state and federal legislative support that aims to curb emissions both from health facilities and the supply chain, and incentivizes green construction, retro-fitting, and purchases. It will also require investments in educating future generations of medical trainees on the role of the health system in climate change and how to implement sustainability in their professional and personal lives (Box 1).

4 | SUSTAINABILITY BY INHALERS FOR ASTHMA AND COPD

Climate change continues to demand global improvements in health education on sustainability and access to mitigation, economy, and

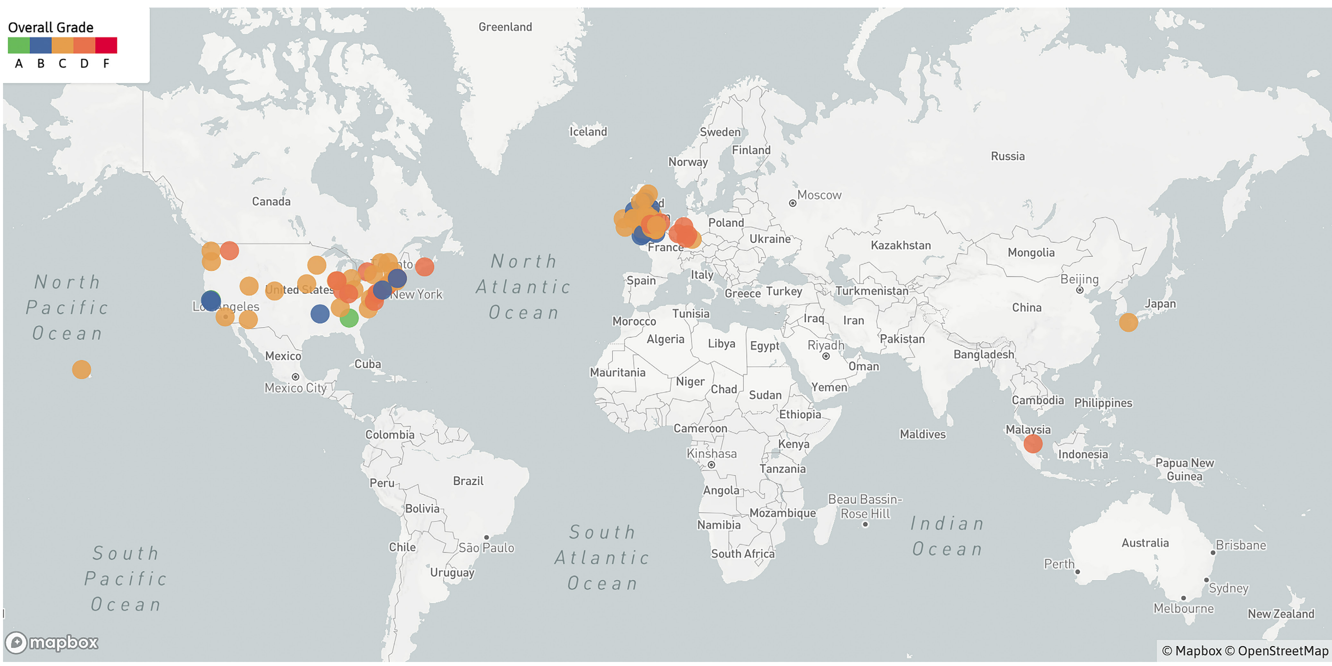

FIGURE 3 An overview of medical schools that provide climate change and health education, graded on a scale of F to A based on their amount and quality of curricular competencies. These rankings, entitled the Planetary Health Report Card, are issued annually. Reprinted with kind permission.[66]

adaptation plans for all patients.[70] The challenge brought by chronic respiratory disease like asthma and chronic obstructive pulmonary disease (COPD) is fourfold:

1. Asthma and COPD are among the most common chronic diseases worldwide: according to the World Health Organization, asthma affected an estimated 262 million people in 2019.[71] Using the GOLD definition, almost 400 million people aged 30–79 years had COPD worldwide in 2019, with 80.5% of COPD patients living in low/middle income countries (LMICs).[72]
2. Inhaled therapies are the major way of treatment for asthma and COPD patients. The three principal types of inhalers are: (a) pressurized metered-dose inhalers (pMDIs) used with or without holding chambers or spacers, (b) dry-powder inhalers (DPIs), and (c) soft mist inhalers (SMIs). The most common inhalers, the pMDIs, use hydrofluorocarbon propellants (HFC-134a and HFC-227ea), which are powerful GHGs; MDIs are associated with a 10–40 times higher CO_2-footprint than GHG-free DPIs. The major drug classes delivered by inhalation are short-acting beta2 agonists (SABA), still the most widely used reliever medication; long-acting beta2 agonists (LABA); long acting anti-muscarinic agents (LAMA); and inhaled corticosteroids (ICS).
3. There is insufficient control of asthma and COPD, and this is frequently associated with over-reliance on the reliever (usually an MDI) and with poor inhaler technique, increasing the emissions instead of proper delivery of medication to the lungs.
4. HCPs lack awareness of the inhalers' carbon footprint, while on the regulatory side only the active pharmaceutical ingredients are evaluated for their environmental impact instead of the "whole package" (e.g., hydrofluorocarbons contained in MDIs, carbon footprint of continuous production of new devices instead of recycling).

The carbon footprint of inhalers should be evaluated through the whole life cycle of the product (raw material extraction, production, packaging, distribution and storage, usage, and end-of-life disposal) and not just by the amount of emissions (Box 1). Discussed here in more detail are the usage and the disposal, as for the other steps there are no published data.

The environmental impact of inhalers can be evaluated through their global warming potential (GWP) or by the CO_2e (Table 2).

In the United Kingdom almost 70% of market share belong to pMDIs; in France, Germany, and Spain there is an equal share between pMDIs and DPIs/SMIs; in Italy there is a 62.7% market share for DPIs/SMIs. This is reflected in inhalers CO_2e of 1300, 520, 450, 330, and 190 kilo tons in the United Kingdom, France, Germany and Spain, and Italy, respectively.[73] Two thirds of all emissions were associated with SABA use as relievers in patients with poorly controlled disease. It is estimated that in the United Kingdom MDIs account for approximately 13% of the national health system carbon footprint related to the delivery of care.

The end of life of inhalers occurs through domestic disposal (up to 70% in the United Kingdom Germany and Spain), return to

TABLE 2 Emissions of different inhalers in CO_2 equivalents.[73,74]

Inhaler type	Propellant (drug class)	CO_2e kg/inhaler
pMDIs	HFC-227ea (ICS/LABA)	36,500
pMDIs	Large SABA	25,260
pMDIs	Small volume SABA	9870
pMDIs	HFC-227ea	3350
pMDIs	HFC-134a	1300
DPIs	Accuhaler discus	0.6
SMIs	Propellant-free	0.8

Abbreviations: DPIs, dry-powder inhalers; HFC, hydrofluorocarbons; ICS, inhaled corticosteroids; LABA, long-acting beta2-agonists; pMDIs, pressurized metered-dose inhalers; SABA, short-acting beta2-agonists; SMIs, soft mist inhalers.

pharmacies (56% in France and 40% in Italy) or recycling. Most of the domestic disposal goes to landfills, with a very limited proportion being incinerated or even less incinerated with energy recovery.[73] This is in contrast with pharmacy disposal where devices are incinerated with or without energy disposal. Landfill disposal of pMDI devices with unused doses continue to release GHG, which persist in the atmosphere for up to 50 years. Unfortunately, <1% of inhaler devices are recycled every year worldwide.

Uncontrolled asthma and COPD has major contributions to the carbon footprint of inhalers. Asthma and COPD exacerbations drive emissions due to medical services, including patient-travel, and quick-relief inhalers. GHG emissions from asthma exacerbation management were the highest for severe/life-threatening events, followed by moderate exacerbations.[75] HCPs treating patients with asthma and COPD should strive to optimize disease control, decrease moderate and severe exacerbations, and pay special attention to patients who are currently using high amounts of salbutamol MDIs.

Strategies that replace overuse of reliever MDIs with regimes emphasizing ICS have the potential to improve asthma control alongside significant reductions in GHG emissions. Maintenance and reliever therapy (MART), which uses combination reliever and ICS in one device (usually a DPI), can simplify therapy, improve asthma control, and reduce GHG emissions. The anti-inflammatory reliever (AIR) approach with ICS-formoterol is associated with significant reductions in severe asthma exacerbations, across the spectrum of asthma severity. In mild asthma, budesonide-formoterol DPI resulted in a 60% reduction in severe exacerbations, with half the number of actuations from the DPI that has less than 5% the carbon footprint of the salbutamol pMDI per actuation.[76] In children aged 4–11 years with moderate-to-severe asthma, AIR significantly reduced the risk of a severe asthma exacerbation, which required medical intervention, by 75%.[77]

The feasibility and relevance of prescription conversion from pMDIs to DPIs were investigated in a pulmonology outpatient clinic regarding the CO_2-footprint and the economic costs under real-world conditions. The proportion of DPIs prescribed increased from

49% to 78% of total inhaler prescriptions with a particularly striking increase in the prescriptions for single-agent ICS from 19.8% to 74.1%. This change in prescription pattern came with no increase in costs compared to nationwide costs. The conversion from MDIs to DPIs saved between 115 and 480 kg CO_2e per year and patient, depending on intensity of therapy and GHG used. The authors conclude that if all ambulant pulmonologists in Germany would prescribe 75% DPI, CO_2-emissions could be reduced by 11,650 tonnes CO_2e per quarter, and 46,600 tonnes CO_2e per year, respectively.[78] The inhaler's remaining carbon footprint can be reduced by transitioning to lower carbon footprint rescue inhalers or by pharmacy disposal instead of landfills. Improving inhaler technique and spacer use, better matching of patients' devices to inhaler technique rather than defaulting to MDIs, and minimizing propellant release by using smaller volume MDIs and simpler dosing regimens are all excellent tools for an environmentally conscious HCP.

Pernigotti et al. evaluated four scenario analyses using asthma and COPD inhaler usage data from 2019 to model CO_2e emissions reduction over a 10-year period (2020–2030) in the UK, Italy, France, Germany, and Spain.[73] Scenario #1 focused on switching from propellant-driven pMDIs to propellant-free DPIs/SMIs with 3 pathways: (i) forced (80% switch until 2030); (ii) forced accelerated (50% switch until 2025); (iii) clinically driven (balanced with patient preferences and personal profile for an inhaler). In scenario #2, transitioning of both maintenance and SABA inhalers to low GWP propellant (hydrofluoroalkane (HFA)-152a) pMDIs achieved the greatest emission reduction (82%–89%). In scenario #3, only by reducing short-acting β_2-agonist (SABA) use through better disease control, CO_2 emissions drop by 17%–48%. Scenario #4, checking the impact of inhaler recycling, showed a significant impact but only with transition to low GWP propellant.

Patients care deeply about the environmental consequences of their treatments, and thus are a trustworthy partner of the HCPs striving to implement a low carbon footprint management of their diseases. A questionnaire study of asthma and COPD patients identified "environmentally friendly" as one of the most important inhaler characteristics, while another survey of asthma patients in the United Kingdom found that over four out of five inhaler users "would" or "might" change their device for environmental reasons.[79,80] Patients' education is an essential step to reduce exacerbations of symptoms, use of health care and medications, and hospital admission. On the one hand, this can comprise education on management of COPD and asthma[81] in parallel with support in smoking cessation[82] or, even better, prevention, and on the other hand education on efficient treatment, for example, correct inhalation technique.[83]

On the industry side, conception of inhalers with dose counters to prevent waste, integrating whistles to optimize inhalation technique, making inhalers refillable, or optimizing materials for recycling and investment into new, lower GWP propellants are valuable tools for optimizing the carbon footprint of the inhalers.[84–86]

The pathway to an eco-friendly approach in asthma and COPD treatment is, however, not without its hurdles. Significant funds are needed to successfully manage targeted inhaler transitions, together with counseling and follow-up appointments with an appropriately skilled clinician to assess the patient's inhaler technique and ensure disease control.[87] The very young, very old, and those undergoing an acute exacerbation still require pMDIs. The increase in the use and availability for more formulations delivered through SMIs might be a potential solution for these special populations. Until new propellants with lower GWP like HFC-152a are available on the market, the abrupt implementation of the Kigali Amendment to the Montreal Protocol stipulating that 11 HFC-134a, HFC-227ea, and HFC-152a are expected to be phased out between 2020 and 2050, will lead to a significant shortage in pMDIs availability especially in LMIC, with a significant impact on asthma and COPD care. In addition, the reduction of propellants in non-medical uses is likely to give rise to a fivefold cost increase for pMDIs use and is likely to hit the Western world in 2025. This may lead to a price increase in reliever medication that will make it unaffordable for the poorer communities in some markets. There are opportunities to save money by developing new formulations using propellants with lower GWP, such as HFC-152a or HFO-1234ze(E), and two companies have made this commitment, but neither currently has a strong presence in reliever medication.

5 | SUSTAINABILITY VIA TELEMEDICINE

Telemedicine, "the use of electronic information and communications technologies to provide and support health care when distance separates the participants",[88] has its historical roots in the early 19th century[89] and evolved constantly, gaining particular momentum for clinical allergy care during the SARS-CoV-2 pandemic. In the light of mitigation measures and contact restrictions, healthcare professionals searched for alternative ways of delivering care, especially for patients with chronic diseases needing regular check-ups.[90] This need led to an increase in remote healthcare utilization, particularly for synchronous video consultations (Figure 4).[91] Even before 2020, telemedicine has been under evaluation as a useful tool to provide health care for rural and underserved areas.[92–94] While several studies focused on the quality of remote visits and their economic benefits,[92,95–97] new opportunities arose in the light of the climate crisis. In a recent report on carbon emissions of the National Health Service (NHS, United Kingdom), patient and visitor travels accounted for approximately 6% of the system's CO_2 emissions (Figure 5).[98] These can be reduced by identifying suitable settings to replace face-to-face visits by remote consultations. However, the choice of adequate scenarios is important not only to ensure quality of care but also potential of savings, as determined by a recent systematic review evaluating 14 studies on the carbon saving potential of telemedicine.[99] The calculated carbon footprint savings varied significantly (between 0.70 and 372 kg CO_2 per consultation) according to the geographic and clinical scenario of the studies. Yet, the authors state that the emissions produced by the use of telemedicine systems were in all cases very low compared to those of traveling patients.

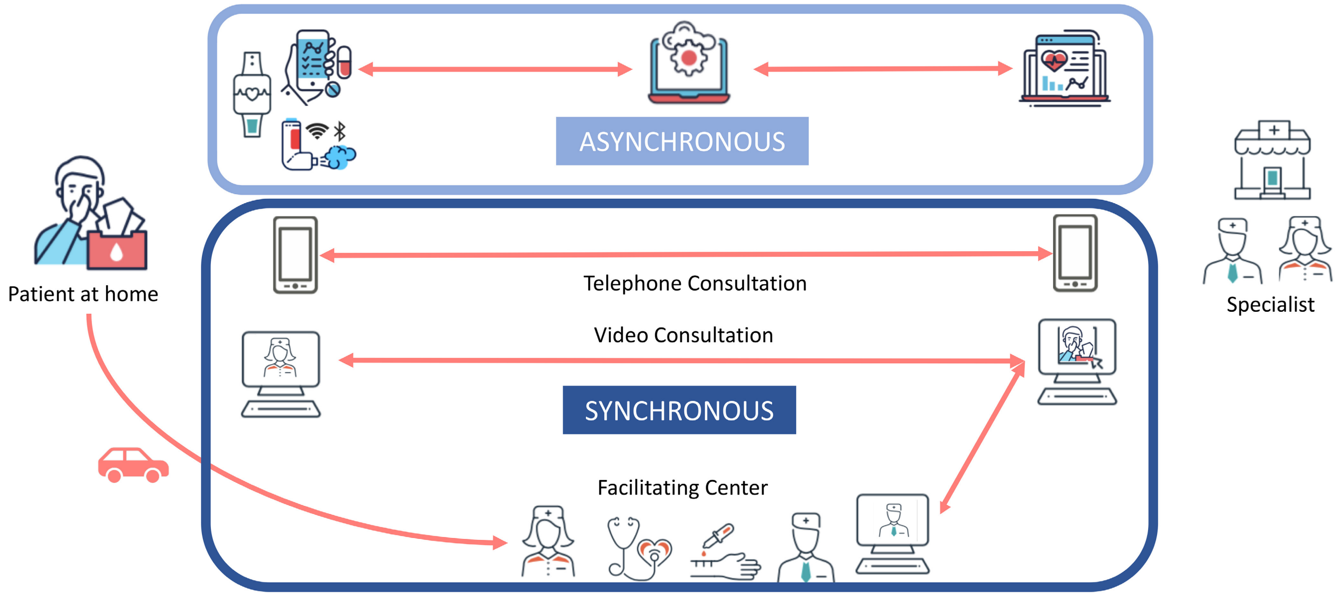

FIGURE 4 Different forms of direct and indirect remote care via telemedicine. Consultations can be implemented synchronously (i.e., both communicators connect with each other at the same time) or data can be exchanged asynchronously. Especially synchronous telemedicine service may be facilitated by a local service provider collecting test results and supporting remote communication with adequate technological equipment. Reprinted with kind permission.[91]

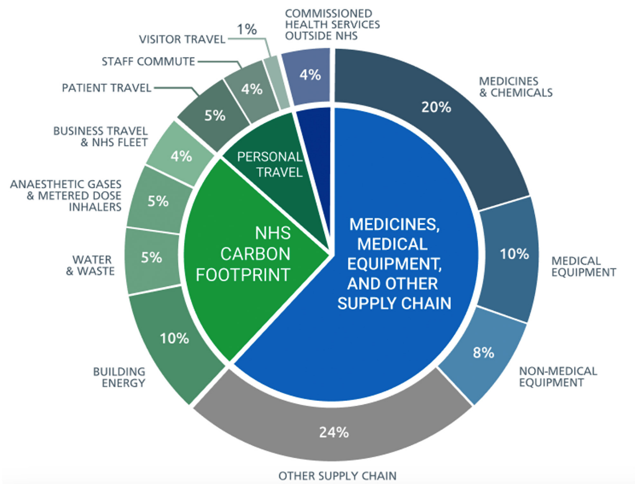

FIGURE 5 Sources of carbon emissions by proportion of NHS Carbon Footprint Plus. NHS: National Health Service.[98]

When considering the implementation of remote visits, it is important to acknowledge that the benefits of healthcare at a distance go beyond CO_2 savings. Telemedicine (i) increases the accessibility of medical care, especially in remote and underserved areas; (ii) improves the practical integration of healthcare appointments in daily activities and therefore may decrease the number of missed visits; (iii) allows a higher frequency of short check-ups to potentially increase adherence to and safety of treatments; (iv) reduces the amount of patient and visitor traffic in healthcare institutions.

Given the variety of benefits, a healthcare provider may decide to implement routine remote clinical consultations.[91,100] To this end, some conceptional considerations are needed. As mentioned above, the suitability of settings and patients for remote visits should be evaluated. Criteria to be considered could be: (i) the patient's interest in a remote visit; (ii) disease phenotype and control (e.g., acute vs. chronic conditions); (iii) individual (dis-)abilities of the patient (e.g., physical flexibility and technical understanding); (iv) travel distance to the clinic; (v) self-management skills and reliability of the patient; (vi) family and work situation (e.g., a remote visit may be preferred by families with young children).

Before starting remote visits, some infrastructural arrangements need to be implemented. To date, many communication technology providers offer individual calls free of charge. For a more sustainable integration in daily clinical care, there are both, subscription models and individual call charges. The choice of the most cost-efficient solution depends primarily on the frequency of use and needed functions within the software. While for some settings a simple and safe video channel is sufficient, other consultations may need a more complex infrastructure including scheduling, chat, or encrypted file sharing functions. In case of doubt, it is recommendable to start with an easy but certified video tool focusing on high practicability for both patients and healthcare professionals. Over time, both parties will be able to evaluate whether more functions are needed.[91]

Once the technological aspects are covered, some general requirements should be checked:

- The room for remote consultations should secure the same amount of privacy as in-person visits
- Light should be placed behind the screen adequately illuminating the face of the healthcare professional
- Staff should be instructed not to interrupt during hours of remote consultations
- Instructional material (e.g., organ models) can be prepared live and/or via a shared screen

Finally, some "website manners" should be respected during the video consultation.[101] The clinical history should be collected just as carefully and sensitively as during a face-to-face visit. To ensure consistent eye contact, the camera should be placed closely to the screen edge where the video image appears. Also, patients may initially need a little bit of time to adapt to the online setting, which should be respected when requesting answers. Of course, all collected information should be carefully documented in patients' files.

Once all requirements for remote visits are covered, it is also important to check who is going to pay for the virtual care. Many health insurers acknowledge the benefits of telemedicine and are implementing reimbursement procedures in their payment structures. In case the health insurance does not cover remote visits, other stakeholders may have a specific interest of doing so. These could be, for example, the patients themselves, their employers, or industry partners.[102] Of course, the coverage of costs should be clearly and transparently addressed before scheduling a first visit in order to avoid negative experiences on both sides. As part of telemedical care, as well as education of patients and medical students, emerging metaverse technologies like hologram techniques can be envisaged.[103–105]

In summary, remote consultations as a part of telemedicine are a useful tool to reduce the carbon footprint of healthcare systems and increase the accessibility to care.

6 | SUSTAINABILITY IN HEALTH AND SCIENCE CONFERENCES

Conferences drive collaboration and allow exchange of the latest innovations in the field. In most cases, a society or academy organizes these conferences and these events also hold meetings for the general assembly, executive board, and other groups. Typically, societies organize meetings annually and all members are invited. Hence, the size of the event is usually determined by the number of members within the organizing body. For example, the European Academy of Allergy and Clinical Immunology (EAACI) has over 135,000 members and its meeting attendance is around 50%. As an add-on, commercial exhibitors present their latest technological products. Companies have a great interest to be represented at conferences for several reasons: (i) demonstration of their power and magnitude in the market, (ii) direct comparison with competitors, (iii) cultivation of customer loyalty and access to new customers.

The COVID-19 pandemic forced the community into pure virtual meetings in 2020. The unescapable need for alternative options catalyzed the fast development and acceptance of a new generation of conferences taking advantage of virtual platforms and communication tools.[106] The pandemic, therefore, was a true game changer, pushing health professionals, scientists, and exhibitors into a completely new framework with new challenges.

From the pure virtual meetings in 2020, hybrid conferences quickly emerged, which offer both, in-person meetings as well as the opportunity for people unable to attend to take part virtually. Virtual and hybrid meetings provide a chance for assembling international delegates in difficult times, even though there is consensus that online meetings cannot match the level of networking provided by real meetings. To solve the "coffee break problem", virtual relaxation rooms have been introduced aside the main sessions. For instance, the Climate Action Task Force of the American Association of Geographers (AAG) designed a conference program offering numerous virtual spaces.[107] This resulted in high delegate satisfaction, even though the conference ran across 15 time zones. Also, in EAACI meetings, virtual coffee break rooms have been introduced with great success, for instance the 2021 virtual Winter School of Immunology was decorated virtually with a pleasantly crackling fireplace in a cozy mountain hut.

The shift toward virtual or hybrid meetings is being scientifically analyzed. We provide here a few examples illustrating how virtual meetings offer a great chance to successfully deliver the contents and attract more attendants than live events.

The annual Bethune Round Table (BRT) academic conference of Canadian medical societies (Canadian Network for International Surgery and the Centre for Global Surgery at the McGill University Health Centre) reported that their virtual meeting in 2021 enabled a doubling of attendees and facilitated participation from 50 countries.[108] Half of the speakers were live streamed, half offered prerecordings of their talks, and the recorded sessions were still being listened to 1 month after the meeting. The success of the BRT meeting was, thus, largely dependent on the virtual platform (X-CD), enabling attendance from many different countries worldwide.

A similarly positive evaluation was achieved for the student-run Interactive Global Health Conference[109]: when comparing the 2020 physical with the 2021 virtual event, the latter attracted more registrants at lower costs to deliver the conference content. Instead of full-day physical meetings of international health professionals, virtual meeting platforms were successfully exploited combined with online survey tools like Qualtrics.[110] This allowed effective gathering of inputs and comments from all attendants, who were widely dispersed geographically.

Remarkably, converting the American Society of Nutrition's Conference "Nutrition" to virtual increased its attendance by a factor of 10. In 2019, Nutrition hosted 3157 attendants from 59 countries, in 2020 over 30,000 from 164 countries attended the virtual conference.[111]

Other disciplines also report dramatically increasing numbers of virtual attendance, the European Society of Cardiology (ESC) recorded a 177% increase at the 2020 conference with 77,350 virtual attendees[112]; the European Respiratory Society (ERS) reported a 50% increase in 2020.

The International Society of Computational Biology—Student Council (ISCB-SC) organized a virtual global meeting in 2021 using the platform Airmeet.[113] Despite the global presence of ISCB-SC, in the pre-pandemic era usually only few board members attended the conferences due to high travel costs, while the whole board attended in 2021. The organizers highlighted the importance of social media accompanying the virtual event to make it lively and connecting. Still, participation was 70% from high-income countries as compared to 30% from others, potentially due to limitations in internet bandwidth and difference in time zones.

Overall, there seem to be more benefits than handicaps in virtual conferences, particularly with hybrid events. The shift in meeting culture and in the event industry is constantly monitored in platforms like Skift Meetings[114] (previously EventMB). While in 2019, 39% of event planners still agreed that "engaging attendees" is pivotal, in 2020 57% of them considered that online meetings are a real good alternative and 34% of event planners acknowledge increased attendance and lower overhead costs. This is good news for the industry supporting EAACI, too.

It is accepted that virtual conferences work technically and easily bring together international delegates from all places around the world. Therefore, many attendants avoid expensive travel costs, which is an advantage for the individual. A same trend can also be seen for the well-attended annual congresses of EAACI (Table 3).

In addition, and even more importantly, virtual conferences also avoid transporting hundreds to sometimes thousands of attendants around the globe for only a few days. In the USA, the (physical) attendance numbers at the 2015 medical meetings ranged between 11,000–51,000, according to Statista.[115] Some keynote speakers fly in only for the talks they are presenting and immediately return afterward. This is unacceptable today in terms of climate threats.

There have been efforts to quantify climate benefits when holding conferences virtually,[116] taking the 2021 Consortium of Universities for Global Health (CUGH) conference as an example. This conference, originally planned in Houston, was transformed into an all-virtual format. Based on the 1909 registrations, the authors calculated the flight distance and driving distance (for attendants living closer than 300 km from Houston), and therefrom the travel-related carbon emissions to 1436 metrics tons CO_2. Thus, transforming the CUGH meeting into virtual format was "equivalent to conservation of 2994 acres of forest for a year", the authors say. In line, when the well-attended annual congresses of

TABLE 3 EAACI annual congress attendance since 2014, with currently more than 15,000 members overall (numbers kindly provided by EAACI).

		Number of delegates		
Year	Venue (format)	Total	Onsite	Remote
2014	Copenhagen (onsite)	7403	7403	
2015	Barcelona (onsite)	7681	7681	
2016	Vienna (onsite)	7823	7823	
2017	Helsinki (onsite)	8144	8144	
2018	Munich (onsite)	7607	7607	
2019	Lisbon (onsite)	8733	8733	
2020	London (digital)	8567		8567
2021	Krakow (hybrid)	7100	1100	6000
2022	Prague (hybrid)	7200	4300	2900
2023	Hamburg (hybrid)	7082	5994	1088

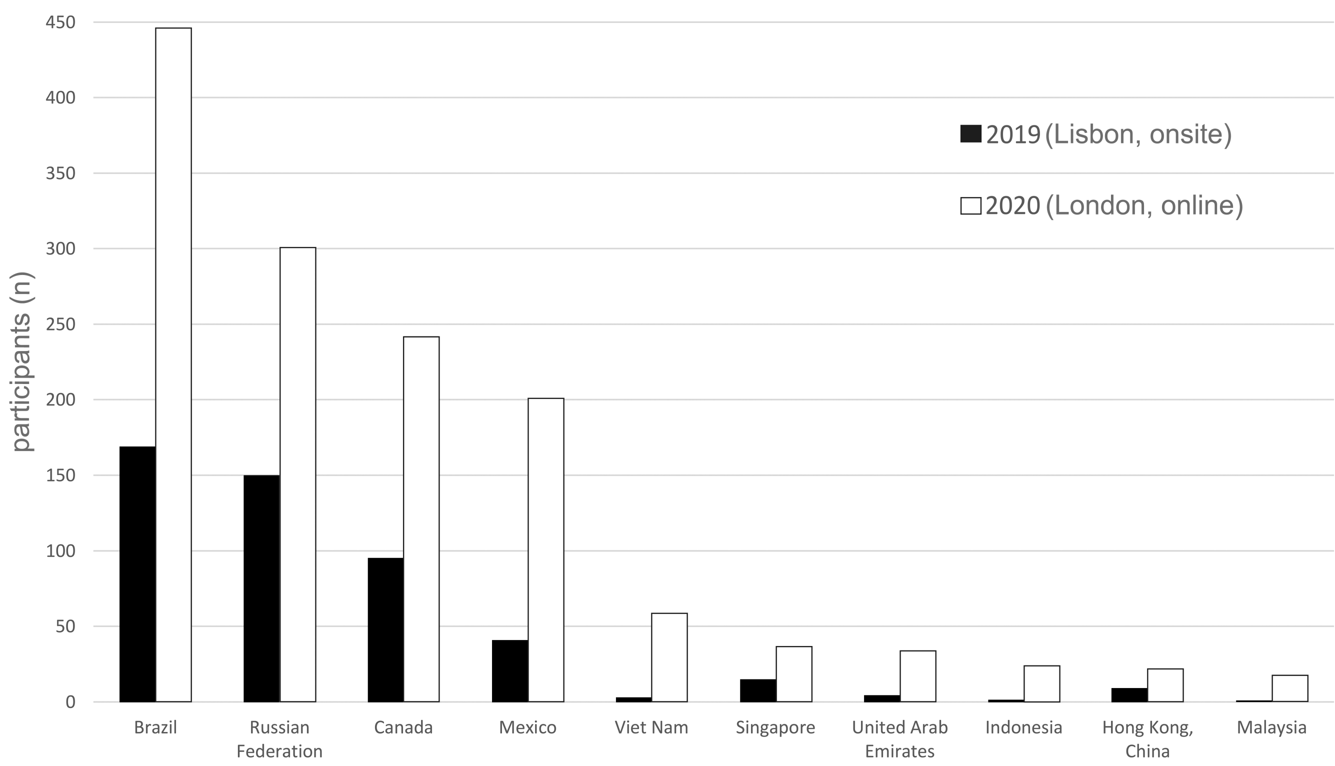

FIGURE 6 The change of the annual congress of EAACI into online format (2020) resulted in participation of many more attendees from faraway countries outside Europe compared to onsite meeting in Lisbon (2019). Data and diagram kindly provided by EAACI.

EAACI were turned into digital (2020) or hybrid format (2021, 2022 and 2023), this only slightly affected the overall number of attendees (Table 3). Furthermore, digital formats facilitated participation of relatively more delegates from faraway countries outside Europe than previous onsite-only congresses (Figure 6). Most importantly, the digital—in contrast to onsite—attendance of the international faculty saved roughly 2909 metric tons of CO_2 (Table 4).

TABLE 4 Calculation of metric tons CO_2 saved by international delegates by participating online in the digital EAACI annual congress 2020 (originally planned onsite for London/LON, United Kingdom/UK).

Theoretical embarking airports of international delegates	Airport code	Metric tons CO_2 (Roundtrip from embarkation airport to LON)	International delegates taking part online (*n*)	Total CO_2 saved via online participation (metric tons)
Brazil (Rio de Janeiro)	RIO	2.75	446	1226.50
Russia (Moscow)	MOW	0.76	300	228.00
Canada (Montreal)	YMQ	1.37	249	341.13
Mexico (Mexico City)	NLU	2.65	200	530
Viet Nam (Kon Tum)	KON	2.95	60	177.00
Singapore (Changi)	SIN	3.21	40	128
United Arab Emirates (Dubai)	DXB	1.62	39	63.18
Indonesia (Sam Ratulangi)	MDC	3.61	25	90.25
China (Hong Kong)	HKG	2.84	22	62.48
Malaysia (Kuala Lumpur)	KUL	3.13	20	62.60
Total		24.89	1401	2909.54

Note: Calculations were performed with online carbon footprint calculator (https://www.carbonfootprint.com/calculator.aspx, acc. to Lewy et al.[116]), using the main airports from the country as starting point.

FIGURE 7 Health care professionals, researchers, and organizers of scientific meetings have multiple possibilities to lessen the impact on environment and climate in their daily life, with a high potential in saving energy, and reducing consumption of resources and water, as well as production of waste and emission of GHG in health care facilities, laboratories, and congress places.

7 | SUMMARY

Medical experts and researchers enjoy the trust of people for important and objective information transfer,[117] and with this trust comes the responsibility to immediately act in a One Health approach to preserve the health of people/patients, animals, and environment.

Fortunately, sustainability is now a focus in labs and if researchers work together on this common goal, science can contribute to better health and to research about the climate crisis, best case ultimately preventing the latter.

There is high potential for saving energy, and reducing consumption of resources and water, as well as production of waste and emission of GHG in laboratories, health care,[98] and scientific meetings (Figure 7).

Besides building management, also prescription of medicine can decisively affect emissions: for asthma treatment, randomized control trials and real-world evidence shows that once-daily long-acting combination dry-powder inhalers (DPIs) can improve compliance and asthma control, and reduce the carbon footprint of care. HCPs should prioritize ICS or ICS/LABA/LAMA combinations via DPIs or SMIs and switch to DPIs/SMIs for rescue medication whenever possible. Patients who switched from pMDI-based maintenance therapy to DPI-based maintenance therapy reduced their inhaler carbon footprint by more than 50% with no loss of asthma control.[118]

Implementation of virtual visits and remote health care are promising and easy tools to reduce the carbon footprint of healthcare systems, especially for patients living at great distances from the next healthcare provider.

For scientific meetings, statistics in selected case studies clearly underpin the impact of remote conferences in saving 98% of the emissions as compared to hub & spoke meetings (for the latter, a single event site broadcasts out to additional participants who could participate from home, or in a local venue with others).[119] This can be directly translated into saving thousands of barrels of oil. Depending on the impact of the conference scenario, pollution by one participant could be equal to burning the equivalent of half a gallon of gasoline, and in a high-impact meeting up to 50 gallons of gasoline.

Many more aspects—not discussed in the present paper—should be considered to increase the sustainability of the health care sector,[120] among those are the application of machine learning and artificial intelligence (a critical review also including ethical considerations was published by Richie C. in 2020[121]), the analysis of existing resources like biobanks and big-data,[120] the application of high-throughput screening and diagnosis while reducing sample volumes, and the avoidance of overdiagnosis.[122]

Clearly, there is a need to establish a global action plan and to create a flexible road-map, which adapts to the respective country/world region.[53] The transition to net-zero-emission health care systems (by 2050) may require that developed countries lend support to developing regions.[53]

We call for action on an individual level, as health care professionals and researchers have multiple avenues to lessen their impact on the environment and the climate in their daily life (Box 2)—and as every single step counts, everybody can pick the lowest-hanging fruit and implement these easy measures immediately.

BOX 2 Key messages/major milestone discoveries.

- Research and health care contribute immensely to environmental damage, pollution of air and water, usage of energy and resources, but can also take a lot of actions for counter-balance
- Health care professionals from every discipline and on every level need to be educated for sustainability in their respective area (e.g., implement lectures in curricula of schools and universities)
- On a basic level, every individual from physician to patient is responsible to increase sustainability in their professional and private life;

Examples include
  - Switch to sustainable transport of staff and patients to work and conference places (e.g., commuting by subway, bicycle, tram, foot; avoid flights and cars)
  - Use of sustainable travel mode for (scientific) conferences or for long-distance trips switch to remote participation
  - Reduction of temperature from −80°C to −70°C for deep-freezer where samples tolerate
  - Unplugging of unused charging devices, turning off electric devices not needed (instead of stand-by)
- At bigger institutions like hospitals or large research institutes, the campus management, clinical leadership, or laboratory managers can install/hire a sustainability manager on a short-term or continuous contract to help find appropriate and effective measures for sustainability without any disadvantages for the medical or scientific outcomes
- Companies and providers shall be asked for the specific footprint of products and also for a proper recycling system for their products
- Policy makers need to force-implement regulations for labs and clinics, and control for keeping with rules and suggest improvement where necessary
- Industry needs to replace harmful products and production processes
- Healthcare practitioners/clinicians and researchers can pick their lowest hanging fruit (i.e., implement what is easiest in their daily work practice) and thereby can participate in innovation, adoption, and embedding of low carbon practices.[4]

Glossary

- Anthropocene: geologic time unit, referring to the most recent period in the history of Earth, when human activity started to have a huge impact on climate and ecosystems of the planet.[123]
- Planetary health: the achievement of the highest attainable standard of health, wellbeing, and equity worldwide through judicious attention to the human systems—political, economic, and social—that shape the future of humanity and the Earth's natural systems that define the safe environmental limits within which humanity can flourish.[124]
- Eco health: "Eco health is a field of research, education, and practice that adopts systems approaches to promote the health of people, animals, and ecosystems in the context of social and ecological interactions."[125]

- One Health: "integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems, while recognizing that the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent."[126]
- Global warming potential: GWP of gases indicates the warming induced by a gas over a given period (typically 100 years) in comparison with carbon dioxide (CO_2), which is defined as GWP = 1.
- Carbon dioxide equivalent: CO_2e describes the number of metric tons of CO_2 emissions with the same global warming potential as one metric ton of another GHG.

AUTHORS CONTRIBUTIONS

Isabella Pali-Schöll: conceptualization, MS writing, figure drafting; Kerstin Hermuth-Kleinschmidt: MS writing (laboratories); Stephanie Dramburg: MS writing (telemedicine); Ioana Agache: MS writing (inhalers); Erika Jensen-Jarolim and Hanna Mayerhofer: MS writing (scientific meetings), figure drafting; Anna Goshua and Kari C. Nadeau: MS writing (clinical care). All authors have read and approved the final version of this paper.

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CONFLICT OF INTEREST STATEMENT

IPS, SD, HM, IA, and AG declare no conflict of interest in relation to the present article. EJJ is a shareholder in Biomedical International R+D GmbH, Vienna, and co-inventor on patent EP 2894478 A1 (Method and means for diagnosing and treating allergy) of Biomedical Int. R+D GmbH. KHK is auditor for EGNATON-CERT. KN reports grants from National Institute of Allergy and Infectious Diseases (NIAID), National Heart, Lung, and Blood Institute (NHLBI), National Institute of Environmental Health Sciences (NIEHS), and Food Allergy Research & Education (FARE); Stock options from IgGenix, Seed Health, ClostraBio, Cour, Alladapt, Clostrabio, and ImmuneID; Director of the World Allergy Organization Center of Excellence for Stanford; Advisor at Cour Pharma; Consultant for Excellergy, Red tree ventures, Before Brands, Alladapt, Cour, Latitude, Regeneron, and IgGenix; Co-founder of Before Brands, Alladapt, Latitude, and IgGenix; National Scientific Committee member at Immune Tolerance Network (ITN), and National Institutes of Health (NIH) clinical research centers; patents include, "Mixed allergen composition and methods for using the same," "Granulocyte-based methods for detecting and monitoring immune system disorders," and "Methods and Assays for Detecting and Quantifying Pure Subpopulations of White Blood Cells in Immune System Disorders."

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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BIBLIOGRAPHICAL ANNOTATION/HIGHLIGHT

8. Stancliffe et al., 2022: This article summarizes practical measure in a One Health approach for health care systems, hospitals, and practitioners to reach the goal of net-zero sustainable health care, including a fictional case of a diabetic patient to visualize the possible measure that patients and health care professionals can implement.

14. Stanford et al., 2023: This article deals with the implementation of core knowledge and skills of sustainable health care in education of health care experts, giving examples for educational activity and introducing the pioneering framework of sustainability in quality improvement (SusQI), where the outcome for patient and population is set in relation to the environmental, social, and financial impact.

26. Alves et al., 2021: This case study reports the effect of plastic reduction by re-use and reduction in one microbiology laboratory, reporting the exact pipeline to decontaminate and sterilize plastic tubes for reuse and guidelines to reduce plastic waste, by which they reduced their laboratory waste equal to 516 kg of waste per year for one laboratory with seven co-workers. This study could serve as pilot and example for all laboratories of its kind.

75. Pernigotti et al., 2021: The authors assessed four different scenarios for switching to more sustainable asthma control inhalers, and calculated (i) switch from pMDIs to DPI/SMIs; (ii) transition to low-GWP propellant; (iii) clinical optimization of asthma maintenance therapy to reduce SABA use; and (iv) inhaler end-of-life treatment (implementation of inhaler recycling), showing that transition to low GWP propellant (hydrofluoroalkane (HFA)-152a) pMDIs achieved the greatest emission reductions (82%–89%).

94. Purohit et al., 2021: This systematic review has included 14 studies and analyzed them for carbon emission savings due to telemedicine, showing that telemedicine does reduce the carbon footprint of healthcare context-specifically, primarily by reduction in transport-associated emissions, with savings ranging between 0.70–372 kg CO_2e per consultation.

108. Lewy et al., 2022: The authors calculated the carbon footprint of each registrant's round-trip, exemplarily for an international conference planned to be held in Houston then turned in all-online version, resulting in estimated savings of 2443.82 MtCO_2 emissions.

110. Woodcock et al., 2022: The authors investigated the effects of switching from a pressurized metered dose inhaler (pMDI)-based to a dry powder inhaler (DPI)-based maintenance therapy versus continued usual care on greenhouse gas emissions (carbon dioxide equivalents) and asthma control, calculating that patients who switched from a pMDI-based to a DPI-based maintenance therapy more than halved their inhaler carbon footprint without loss of asthma control.

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