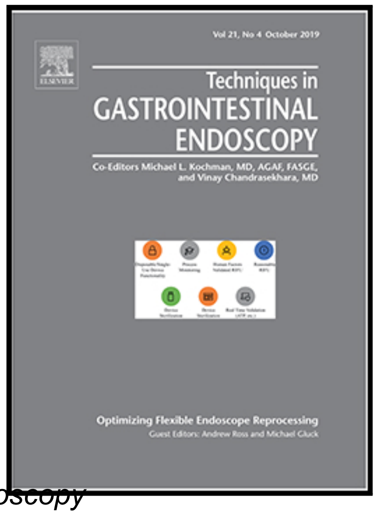
Journal Pre-proof



Endoscopy's Current Carbon Footprint

Keith SIAU , Bu'Hussain HAYEE , Swapna GAYAM

PII: S2590-0307(21)00043-X
DOI: https://doi.org/10.1016/j.tige.2021.06.005
Reference: TIGE 150727

To appear in: *Techniques and Innovations in Gastrointestinal Endoscopy*

Received date: 15 March 2021
Revised date: 7 June 2021
Accepted date: 16 June 2021

Please cite this article as: Keith SIAU , Bu'Hussain HAYEE , Swapna GAYAM , Endoscopy's Current Carbon Footprint, *Techniques and Innovations in Gastrointestinal Endoscopy* (2021), doi: https://doi.org/10.1016/j.tige.2021.06.005

Endoscopy's Current Carbon Footprint

Keith **SIAU**[1], Bu'Hussain **HAYEE**[2], Swapna **GAYAM**[3]

Affiliations:

1. Department of Gastroenterology, Dudley Group Hospitals NHS Foundation Trust, Dudley, UK
2. King's Health Partners Institute for Therapeutic Endoscopy, King's College Hospital, London, UK
3. Section of Gastroenterology and Hepatology, West Virginia University Medicine, Morgantown, West Virginia, USA

Corresponding author: Dr Keith Siau, keithsiau@nhs.net

Contributions: All authors contributed equally

Word Count: 3913**; Abstract:** 228

ABSTRACT

Each year, over 18 million endoscopy procedures are performed in the United States (US) alone. Endoscopy is the third highest generator of waste in healthcare, a sector with significant contributions to carbon emissions worldwide. Endoscopy carries a substantial carbon footprint owing to its resource-heavy decontamination processes, complex waste streams, high throughput caseloads and its heavy reliance on single-use, non-recyclable consumables. In this review, we aim to identify sources of waste within endoscopy, provide a framework approach for measuring the carbon footprint, and propose actionable steps that can be delivered to mitigate endoscopy's carbon footprint. Based on operational energy usage and plastic waste from endoscopic procedures alone, we estimate the carbon footprint of endoscopy in the US at 85,768 metric tonnes of CO2 emissions annually, equivalent to more than 9 million gallons of gasoline consumed, 94 million pounds of coal burned and 212 million miles driven in average non-electric car. Sequestering these CO2 emissions would require an additional 112,000 acres of new forests per year. Urgent action is therefore needed within endoscopy units. Units should start by embracing the 3R's of sustainability - "Reduce, Re-use, Recycle". Patient and administrative pathways in endoscopy should be process mapped to identify opportunities for sustainability interventions at each step. Finally, we propose a taxonomy of sustainability interventions where a pragmatic "Review, Research and Reinvent" approach can be applied at all levels, ranging from the individual to international societies, to minimise the carbon footprint of endoscopy.

Keywords
Carbon footprint; Endoscopy; Sustainability

INTRODUCTION

Healthcare is a significant contributor to carbon emissions, accounting for approximately 4.4% of the global carbon footprint.[1] The United States (US) spends 18% of its gross domestic product on healthcare ($4 trillion USD in 2020), estimated to generate 8-10% of national greenhouse gas (GHG) emissions.[2,3] In the United Kingdom (UK), the implementation of the 2008 Climate Change Act has led to a 62% reduction in the carbon footprint of the National Health Service (NHS) from 16.2 million metric tons of CO2 equivalents (MtCO2e) in 1990 to 6.1 MtCO2e in 2020, amounting to its current share of 4% of the country's emissions. Healthcare emissions from the US, UK, Canada and Australia are estimated to total 748 MtCO2e annually.[4] If healthcare systems around the world were regarded as a country, it would rank as the fifth largest emitter worldwide.

Within healthcare, endoscopy is thought to be the third highest generator of waste.[5] In the US, more than 18 million endoscopy procedures are performed each year,[6] the bulk of which comprise colonoscopy (11million/yr) and upper GI endoscopy (6million/yr). Each procedure requires administrative processing, travel, decontamination and single-use consumables. Endoscopy is a high-intensity specialty often involving high throughput caseloads, resource-heavy decontamination processes, numerous procedures and hospital visits.[7] Although the specialty is one that is well-suited for quality improvement interventions in sustainability, the published literature on sustainable endoscopy remains sparse.

This review aims to identify sources of waste within endoscopy, provide a framework approach for measuring the carbon footprint and propose actionable steps that may be undertaken to mitigate endoscopy's carbon footprint.

THE SCALE OF THE PROBLEM

Endoscopy is a field with one of the highest procedure volumes. Globally, the endoscopy market size was valued at 10.8 billion USD in 2020 with an expected compound annual growth of 8% in the next few years.[8] In the US alone, there are approximately 18 million procedures performed annually. A census of UK endoscopy units reported a total of 2.1 million endoscopy procedures performed in 2019.[9] Over the last two decades, renewed commitments to reduce preventable deaths from colorectal and esophagogastric cancers have led to a surge in screening endoscopies amongst the asymptomatic population. Colorectal cancer screening in the US will soon be expanded to also include those between

45-49.[10] Emphasis on quality improvement in endoscopy has also led to increasing lesion detection, more specimens being processed, and a higher burden of surveillance procedures.

Despite initial reductions in procedure volumes associated with the coronavirus disease 2019 (COVID-19) pandemic, usage of personal protective equipment, enhanced decontamination measures, and the compensatory increase in workload have eked out the transient reductions in emissions.[11] Pre-COVID, it was estimated that endoscopy incurs the third highest burden of hospital waste (3.1kg per bed day) after anaesthetics and intensive care.[5] However, these estimates now need to be revisited in light of COVID-19.

WHAT IS A CARBON FOOTPRINT?

The carbon footprint is defined by the Carbon Trust as "the total set of greenhouse gas emissions caused directly and indirectly by an individual, event, organisation or product, expressed as CO2e." A greenhouse gas (GHG) refers to any gas which accumulates in the atmosphere, absorbs and re-emits heat, thereby carrying the potential for global warming. In addition to carbon dioxide (CO2) which makes up 85%, GHGs mainly comprise methane (CH4), nitrous oxide (N2O) and ozone. Each GHG has global warming potential (GWP), often expressed relative to CO2 (**Table 1**). The term carbon dioxide equivalent (CO2e) enables different GHGs to be quantified using a common standardised unit in order to measure the equivalent global warming impact, e.g. 1kg of nitrous oxide emissions would be equivalent to 300kg CO2e. Based on the Greenhouse Gas Protocol, GHGs may be classified according to three main types: 1) direct emissions which result from activities that an organisation controls, 2) emissions from electricity usage, 3) indirect emissions from products and services that an organisation does not directly control. This classification can help to measure the carbon footprint and identify opportunities for improvement.

CALCULATING THE CARBON FOOTPRINT

Basic carbon emission calculations consist of two parts which can then be summed up to estimate total CO2 equivalents: a) Carbon emissions from energy consumption; b) Carbon emissions from waste disposal.

a) *Carbon emissions from energy consumption*

Energy consumption of equipment can be calculated using the manufacturer's energy usage data in watts (W) and equipment operational times. The total energy consumed can be obtained by multiplying the energy used in watts per hour and the number of operational hours per day (**Table 2**). This is expressed in kilowatt hours (Kwh) per day. This can then be converted into Kwh/year based on the number of operational days per year for that endoscopy unit (assuming five working days per week). This data can then be converted into carbon emission numbers and equivalents by using the environmental protection agency (EPA) online GHG equivalencies calculator.[12] At West Virginia University Medicine's (WVUM) Endoscopy Unit, for example-which performs approximately 40 procedures per day, the average energy consumption can be estimated at approximately 120.5 kWh (0.085 tCO2e) per day or 31330kWh (22.1 tCO2) per year.

This does not include the energy consumption from heating and cooling of the building which would include an additional burden to the unit's carbon footprint.

b) *Carbon emissions from waste disposal*

Waste can be categorized into hazardous, infectious, recyclable and municipal solid waste. These can be weighed separately and the values in tons per day can be plugged into an online calculator, e.g. the Mazzetti M+ WasteCare online calculator.[13] The distance from the nearest waste management center or the waste disposal technique (incineration / landfill etc) for each type of waste would be required for calculations. The carbon emissions thus calculated can be plugged into the above mentioned EPA calculator to obtain GHG equivalencies. On average, a single endoscopy generates about 1.5 kg of plastic waste. Based on this, the carbon footprint based on plastic waste disposal alone measures 0.066 tons/d (in a unit performing 40 procedures per day), or 37.4 metric tCO2e annually.

Considering eighteen million endoscopic procedures annually in the United States of America(US), previous calculations estimate a carbon footprint of 35,492 tCO2e.[14] Adding computer usage and emissions from plastic landfill waste to this, the annual carbon footprint of endoscopy in the US is approximately 85,768 tCO2e which is equivalent to 9,650,951 gallons of gasoline consumed, 94,504,569 lbs of coal burned or 212 million miles driven in an average non-electric car (**Figure 1**). To sequester the CO2 produced by these procedures would take 112,009 acres of US forests over one year. The carbon footprint of data storage is an increasing contributor to global CO2 emissions, but has not been included in the calculations presented above. Of note, these basic calculations do not take into account incinerated waste (e.g. from sharps containers) or the carbon footprint from the manufacturing process of endoscopy consumables.

On a planetary scale, it is also possible to crudely estimate CO2e using statistical models centred on healthcare expenditure.[15] Conversely, it is also possible to estimate the impact of increasing carbon footprint on healthcare expenditure, with a 1% increase in carbon footprint projected to cause a 2.04% rise in healthcare expenditure in the USA.[16]

SOURCES OF CARBON EMISSIONS IN ENDOSCOPY

In order to estimate the carbon footprint for each procedure, the sources of energy and waste should be considered for each process mapped within a patient's journey (**Figure 2**), and sustainability embraced at every step. This schematic also provides a framework for individual departments to consider their approach to footprint reduction. Within endoscopy, the main sources of carbon include the following:

a) Single use consumables

Endoscopy has a significant requirement for single-use consumables. These are dependent on the specifics of the procedure, but are generally plastic-predominant, individually wrapped, and are not recycled. Each patient may require oxygen tubing, mouthguards, privacy gowns, bags and pots (to store personal belongings), mouthguards (upper GI procedures), intravenous cannulas and dressings. In addition, diagnostic procedures often require suction tubing, endoscope buttons and bungs, plastic caps/hoods, +/- biopsy forceps. Capsule endoscopy, promoted as an alternative to conventional diagnostic endoscopy during COVID-19, relies on wireless video capsules which are non-reusable. In recent years, concerns regarding endoscopy-associated infections,[17,18] along with the emphasis on convenience and avoidance of endoscope reprocessing have led to increasing commercial interest in single-use, disposable endoscopes.[19] In the gastrointestinal sector, the concept has expanded from duodenoscopes to include gastroscopes and colonoscopes. For therapeutic procedures, most accessories are also single-use and non-recyclable, e.g. snares, diathermy pads and adaptors, polyp traps, histology pots, and purpose-specific devices. In some units, surgical accessories, e.g. forceps and laryngoscopes used during nasojejunal tube placement may also be disposable.

The majority of products are not recyclable and are disposed of via incineration or landfill. At present, it is not possible to estimate the carbon footprint of single-use consumables unless declared by manufacturers.

b) Equipment reprocessing

Equipment reprocessing is a critical step for reusable endoscopes where effective cleaning and sterilization is required to prevent transmissible infection. The process is often resource heavy, involves multiple cycles requiring large volumes of water (80-100L per wash), electricity, heat, disinfectants and detergents. Reprocessing may be broken down to include: precleaning, cleaning, disinfection, rinsing, drying, cleaning of reusable components.[20] Each endoscopy wash machine incurs approximately 24.67 kWh/d equating to 0.017 tCO_2e/d.

c) Operational resource utilization

Hospitals are typically energy intrinsic. Endoscopy requires the use of electricity to maintain processors, endoscopy, monitors, computers, lights within the room and the endoscopy unit. Energy consumption from electricity accounts for 10-30% of the environmental impact of individuals and healthcare systems.[21,22] Heating and air conditioning may be necessary to maintain a comfortable ambient temperature. In relation to heat retention, endoscopy units will vary in their energy efficiency depending on their structural design, operational resource utilization and user habits.

In addition to reprocessing, water is often used during endoscopic procedures. Despite the lack of supporting evidence, sterile bottled water is often used, even during water-assisted colonoscopy, which uses approximately 700ml per procedure.[23] In endoscopy, CO2 is often used during insufflation due to its rapid absorption from the GI tract to reduce procedural discomfort. Nitrous oxide (e.g. Entonox) is used in some countries for unsedated colonoscopy to reduce turnaround times,[24] but it should be emphasised as a GHG which is 300 times more potent than CO2.

The cleaning of the endoscopy room is also another mark on the carbon footprint, especially in patients with potentially transmissible infections. This may be mitigated through sensible cohorting and list management.

Accurate carbon footprinting data is not available for many aspects of endoscopy. Future studies and consensus to accurately estimate carbon footprinting of various procedures, to include cleaning, reprocessing, and waste audits from procedures are required.

d) Administration

Each procedure incurs a significant administrative burden. Pre-endoscopy, this may include printed letters, reminders, postage of bowel preparation, and even COVID-19 screening tests. Following the procedure, multiple copies of endoscopy reports (and colour photodocumentation) are often printed and stored in paper records, and mailed out to the referrer and the general practitioner. Histology requests are often accompanied with a paper request form, and require results to be mailed to all parties. Although a switch towards digitisation seems to be beneficial, this is not always the case and can inadvertently lead to increases. For instance, printing an endoscopy report on recycled paper stock and posting it to a recipient could incur around 5-10g CO2e while sending an email with a large data attachment (such as multiple digital images or a large PDF) could incur as much as 50g.[25] Worldwide, it is estimated that data storage will account for 14% of the global carbon footprint by 2040,[26,27] but at present, this is a necessary and unavoidable part of healthcare. The same applies to appointments and pre-procedure instructions - sending them via electronic means would reduce the carbon footprint from paper and postage. As a discipline, endoscopy must balance the need for storage to facilitate governance and direct healthcare delivery with storage-intensive media (especially video).

e) Travel

Travel to and from the unit is an obvious source of GHG emissions and adds to the overall carbon footprint. This applies to both patients and staff. While types of travel cannot be dictated, and will be affected by the use of sedation or anaesthesia, promoting awareness around this issue may encourage different choices to be made. Relaxation of 'escort' policies to allow patients to merely be met at home by a trusted carer would incur less travel from accompanying individuals. Initiatives such as pre-assessment by video-conferencing, electronic consent, and capsule endoscopy alternatives that mitigate the need for travel are being explored.

f) Outside the Endoscopy Unit

External sources of emissions relevant to endoscopy include food, conferencing activities, endoscopy journals, social media, etc. At an individual level, the carbon footprint of a GI scientist using an electric vehicle and accounting for conference travel has been estimated at 20.8 tCO_2e/yr, which is higher than the US average of 17.5 tCO_2e/yr.[22]

MITIGATING ENDOSCOPY'S CARBON FOOTPRINT: REDUCE, REUSE, RECYCLE

Reducing carbon footprint in endoscopy is multifaceted. A pathway-oriented approach (**Figure 2**) helps to identify specific areas for action, while the 'three R's' (reduce, reuse, recycle) that govern the principles of reducing any carbon footprint can be applied to endoscopy as an action-oriented approach (**Figure 3**). These interventions can be applied at all levels, ranging from the individual to international levels (**Figure 4**).

a) Reduce

The greatest waste is a procedure that did not need to be done. Indeed, the most effective method for reducing the endoscopy carbon footprint is by reducing the number of unnecessary procedures. This occurs in up to 56% of referrals for upper GI endoscopies and between 23-52% for colonoscopies,[28,29]. Minimising unnecessary procedures can be achieved by following evidence and guidelines, better training and education, as well as implementing stricter triaging/vetting processes.[30] Some of these processes will have been tightened during COVID-19. For instance, some units implement Baveno criteria to limit variceal surveillance gastroscopies to cirrhotic patients who fulfil high-risk criteria for clinically significant varices.[31] Coeliac disease can also be diagnosed and monitored based on clinical and serological grounds to minimise endoscopy burden.[32,33] Similarly, recently published British and European post-polypectomy surveillance guidelines are expected to reduce colonoscopy surveillance burden by over 80% by discharging patients to national colorectal cancer screening,[34–36] which involves stool-based testing as follow-up. Other non-invasive measures, e.g. faecal calprotectin,[37] can be used to avoid procedures in patients with low likelihood of pathology, whereas radiological alternatives such as CT colonography can be considered as a sustainable first-line alternative in selected individuals.[38] Improving optical diagnosis of diminutive colorectal polyps, either via training or artificial intelligence technology, may enable a “resect and discard” strategy to reduce the need for histological analysis.

Within hospitals, lighting and heating are amongst the biggest contributors to energy consumption.[39] Sources of energy waste from lighting include the usage of energy inefficient bulbs (eg. incandescent and halide bulbs) and the lack of attention to whether lights are switched off. For example, at the WVUM endoscopy Unit, one third of the bulbs in each room are incandescent and another third are LED bulbs. By switching all of the incandescent to energy efficient light emitting diode bulbs (LED), energy consumption can be reduced by more than 60%, with the added benefit of cost savings to the facility annually. Hospitals are wasteful as they are often “always on” - this applies for heating, lighting, computers, etc. In countries where the endoscopy unit is generally not used out of hours (and emergencies are performed in theatres), energy consumption should be rationalized to minimize waste. For example, timer-controlled electronic thermostats and motion-sensing light switches which automatically turn off after 3-5 minutes of inactivity can also be installed to reduce energy waste.

The most visible menace is plastic. In 2015, only 20% of global plastic waste was recycled and 55% disposed of.[40] In the US alone, 13,500 tons of plastic waste is generated annually from the endoscopy sector, of which 10,800 tons is non-recyclable.[14] This draws attention to the importance of reducing plastic use. Plastic water bottles have an ubiquitous presence, and endoscopy is no exception. An average endoscopy unit uses about 100 water bottles per day, the demand for which will be boosted by the switch towards water-assisted colonoscopy. This can be offset by installing tap water filtration systems in endoscopy rooms which will minimize or even eliminate the use of water bottles. A good example of this is the infra-red taps used in the United Kingdom.

Infection prevention and control (IPC) policies are of primary concern and will ultimately dictate potential for recycling and re-use. However, these policies must be revisited in light of the current crisis. Decisions are often put in place for expediency rather than being based on specific guidance. Investing in biodegradable components would not only reduce plastic waste but would help drive carbon back into the soil. It is also important to consider comparing the energy efficiency of endoscopy and wash machines and switch to the most energy efficient models. An example of this when buying wash machines is that using double basin models with both basins running simultaneously uses 25% less energy.

Electronic medical records (EMR) has been healthcare’s biggest positive change in the US in the last decade. Paperless communication of electronic reports/letters to referring doctors and patients and encouraging patients to sign up to view their results online would save both paper and gas mileage for patients. The era of telemedicine, webinars and virtual conferences has also significantly reduced road travel for post-endoscopic consultations and air miles for conference travel, thereby reducing the carbon footprint of the specialty outside the endoscopy room.

Above all, clean energy sources powering the facility would be the greatest contributor to GHG reduction. These should be considered in future hospital designs, e.g. installation of solar panels.

b) Reuse

Endoscope re-use is currently a source of major debate.[41] There is a tremendous push from industry to use single-use endoscopes, especially duodenoscopes, to offset the risk of infection. However, this has the potential to add a significant burden to the endoscopy carbon footprint. Endoscope accessories such as the use of disposable elevator caps might be a more sustainable alternative to disposable endoscopes. Personal protective equipment (PPE; including face-masks, gowns, aprons, gloves) has become highly topical through the COVID-19 pandemic. PPE-related waste may be minimized by cohorting COVID positive patients during endoscopy lists. There are a number of innovative ways in which a sustainability agenda can be served in this sphere, without impacting the safety of patients and staff. Minimising single-use equipment and the reuse of endoscopic accessories will require a progressive dialogue with industry.

c) Recycle

Up to 40% of all hospital waste is potentially recyclable,[42] but ends up incinerated or disposed in landfill. Within the endoscopy unit, recyclable materials include plastic, paper, cardboard and glass. Incineration of potentially recyclable waste leads to pollution and carbon emissions. Measures to increase recycling may include staff education and empowerment initiatives, improving segregation of waste, increasing availability of recycling bins, and targeting ergonomic layouts of recycling bins to promote their use. It is worth exploring newer options with industry. For example, technologies such as Sterimelt provide novel solutions to recycling plastic within PPE, such as blue drapes, gowns, gloves, masks etc.[43] Water can be recycled too. Water from wash machines can be processed and directed to toilets in the facility.

AGENDAS FOR CHANGE

Climate change requires a joint commitment by healthcare economies across the world. The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 to provide policymakers with scientific assessments on climate change and solutions for adaptation and mitigation. The IPCC projected the potentially cataclysmic impact of a 2°C increase in global temperatures by 2050 and 2100, and recommended limiting the rise to 1.5°C. In 2016, the Paris agreement was signed by 196 state parties as part of the United Nations Framework Convention on Climate Change with the aim to limit global warming to <2°C above pre-industrial levels, with the aspirational target of <1.5°C. To achieve this target, developed nations will need to reduce the carbon footprint by 50% by 2030. The Lancet Countdown on health and climate change provides annual reports on the international progress towards the goals of the Paris agreement.[44] Other international non-profit organisations have also joined this call to action to drive transformations in healthcare.

In the UK, 'net zero' targets set within the NHS Carbon Footprint Plus framework aim for an 80% reduction in CO_2 emissions from the 1990 baseline by 2036. This has seen a reduction in carbon footprint by 19% since 2007 despite a 27% increase in activity. Between 2010 and 2017, NHS water consumption also reduced by 21%, equivalent to around 243,000 Olympic swimming pools.

PRIORITIES FOR FUTURE RESEARCH

The current knowledge gap in sustainable endoscopy and the urgency to reduce carbon emissions in this sector requires urgent attention through research and quality improvement. In order to deliver a transformation in sustainable endoscopy, we recommend a "Review, Research and Reinvent" approach (**Figure 5**), delivered at all levels of the sustainability taxonomy (**Figure 4**). Endoscopy units should start by reviewing existing practice to identify areas for sustainability intervention. A systematic step-by-step process map of endoscopy workstreams (to include the patient, endoscope and staff) will identify interventions where carbon reduction can be embraced. Local policies should be reviewed to facilitate "Reduce, Reuse and Recycle". Research should focus on exploring the burden of endoscopy processes on carbon emissions, methods of mitigating emissions, and identifying impactful and upscalable interventions that can be shared to benefit the carbon footprint. A life-cycle assessment of endoscopes and accessories, from construction to disposal, is desperately warranted for benchmarking purposes, to refine carbon footprint calculations, and to enable comparisons between reusable and disposable endoscopes. The impact of COVID-19 on additional PPE requirements and on endoscopy waste generation should be quantified, in addition to the carbon footprint of non-endoscopic modalities, e.g. FIT testing or CT colonography in place of colonoscopy. Quality standards and guidelines for sustainable endoscopy practice should be developed. The research sector itself could proactively champion sustainable endoscopy through conferences, societies, provision of research funding and working with universities and non-government organisations to develop research fellowship positions. Endoscopy and GI societies should reflect on the successes of digital / virtual conferences, delivered in light of COVID-19, on the reduction in travel-related emissions, of which air travel contribute nearly 37% of a GI delegate's annual carbon footprint.[22] Finally, a reinvention of endoscopy practice is required to incorporate principles of sustainable healthcare at all levels, ranging from individuals to international societies, with the use of quality frameworks to promote the culture of audit and quality improvement cycles in sustainable endoscopy.

CONCLUSION

The COVID-19 pandemic has been an extraordinary global challenge, but the planet is facing a larger existential crisis - a climate emergency. The effects of climate change with global warming, rising sea levels and air pollution are undeniable and inflict far-reaching damage to planetary ecosystems and human health. There is a clear need for urgent action to minimise our ecological footprint to preserve our planet for future generations. At first glance, efforts to reduce carbon footprint can seem cumbersome with no immediate reward. Incentivizing and rewarding green initiatives on an individual and departmental level would help motivate the workforce to adopt best green practices. Everyone contributes to climate change and bears responsibility to reduce their carbon footprint. As physicians and promoters of health, with a focus on endoscopy as an exemplar, we are a well-placed demographic, both at an individual and organizational level, to set an example for our community.

Competing Interests: None declared

REFERENCES

1 Healthcare's climate footprint. https://www.arup.com/perspectives/publications/research/section/healthcares-climate-footprint (accessed 1 Mar 2021).

2 Chung JW, Meltzer DO. Estimate of the carbon footprint of the US health care sector. *JAMA* 2009;**302**:1970–2.

3 Eckelman MJ, Sherman J. Environmental Impacts of the U.S. Health Care System and Effects on Public Health. *PLoS One* 2016;**11**:e0157014.

4 Sherman JD, MacNeill A, Thiel C. Reducing Pollution From the Health Care Industry. *JAMA* Published Online First: 2 August 2019. doi:10.1001/jama.2019.10823

5 Vaccari M, Tudor T, Perteghella A. Costs associated with the management of waste from healthcare facilities: An analysis at national and site level. *Waste Manag Res* 2018;**36**:39–47.

6 Peery AF, Crockett SD, Murphy CC, *et al.* Burden and Cost of Gastrointestinal, Liver, and Pancreatic Diseases in the United States: Update 2018. *Gastroenterology* 2019;**156**:254–72.e11.

7 Maurice JB, Siau K, Sebastian S, *et al.* Green endoscopy: a call for sustainability in the midst of COVID-19. *Lancet Gastroenterol Hepatol* 2020;**5**:636–8.

8 Endoscopes market share & growth report, 2021-2028. https://www.grandviewresearch.com/industry-analysis/endoscopes-market (accessed 15 Mar 2021).

9 Ravindran S, Bassett P, Shaw T, *et al.* National census of UK endoscopy services in 2019. *Frontline Gastroenterol* Published Online First: 24 June 2020. doi:10.1136/flgastro-2020-101538

10 The Lancet Gastroenterology Hepatology. USPSTF recommends expansion of colorectal cancer

screening. *Lancet Gastroenterol Hepatol* 2021;**6**:1.

11 Morris EJA, Goldacre R, Spata E, *et al.* Impact of the COVID-19 pandemic on the detection and management of colorectal cancer in England: a population-based study. *Lancet Gastroenterol Hepatol* 2021;**6**:199–208.

12 Epa US, OAR. Greenhouse gas equivalencies calculator. Published Online First: 28 August 2015.https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator (accessed 15 Mar 2021).

13 M+WasteCare - Mazzetti. https://wastecare.mazzetti.com/calculator (accessed 15 Mar 2021).

14 Gayam S. Environmental Impact of Endoscopy: 'Scope' of the Problem. *Official journal of the American College of Gastroenterology | ACG* 2020;**115**:1931.

15 Lenzen M, Malik A, Li M, *et al.* The environmental footprint of health care: a global assessment. *Lancet Planet Health* 2020;**4**:e271–9.

16 Gündüz M. Healthcare expenditure and carbon footprint in the USA: evidence from hidden cointegration approach. *Eur J Health Econ* 2020;**21**:801–11.

17 Wang P, Xu T, Ngamruengphong S, *et al.* Rates of infection after colonoscopy and osophagogastroduodenoscopy in ambulatory surgery centres in the USA. *Gut* 2018;**67**:1626–36.

18 Larsen S, Russell RV, Ockert LK, *et al.* Rate and impact of duodenoscope contamination: A systematic review and meta-analysis. *EClinicalMedicine* 2020;**25**:100451.

19 Eqbal A, Wickremeratne T, Turner S, *et al.* One-stop shop for variceal surveillance: integration of unsedated ultrathin endoscopy into the routine clinic visit. *Frontline Gastroenterol* Published Online First: 12 January 2021. doi:10.1136/flgastro-2020-101680

20 Lee YK, Park JB. Steps of reprocessing and equipments. *Clin Endosc* 2013;**46**:274–9.

21 Thiel CL, Woods NC, Bilec MM. Strategies to Reduce Greenhouse Gas Emissions from Laparoscopic Surgery. *Am J Public Health* 2018;**108**:S158–64.

22 Williams JA, Kao JY, Omary MB. How Can Individuals and the GI Community Reduce Climate Change? *Gastroenterology* 2020;**158**:14–7.

23 Siau K, Beintaris I. My approach to water-assisted colonoscopy. *Frontline Gastroenterol* 2019;**10**:194–7.

24 Welchman S, Cochrane S, Minto G, *et al.* Systematic review: the use of nitrous oxide gas for lower gastrointestinal endoscopy. *Aliment Pharmacol Ther* 2010;**32**:324–33.

25 The carbon cost of an email - the carbon literacy project. 2018.https://carbonliteracy.com/the-carbon-cost-of-an-email/ (accessed 6 Jun 2021).

26 Posani L, Paccoia A, Moschettini M. The carbon footprint of distributed cloud storage. arXiv [cs.DC]. 2018.http://arxiv.org/abs/1803.06973

27 Andrae ASG, Edler T. On Global Electricity Usage of Communication Technology: Trends to 2030. *Challenges* 2015;**6**:117–57.

28 Sheffield KM, Han Y, Kuo Y-F, *et al.* Potentially inappropriate screening colonoscopy in Medicare patients: variation by physician and geographic region. *JAMA Intern Med* 2013;**173**:542–50.

29 de Jong JJ, Lantinga MA, Drenth JP. Prevention of overuse: A view on upper gastrointestinal endoscopy. *World J Gastroenterol* 2019;**25**:178–89.

30 Rodríguez-de-Santiago E, Frazzoni L, Fuccio L, *et al.* Digestive findings that do not require endoscopic surveillance - Reducing the burden of care: European Society of Gastrointestinal Endoscopy (ESGE) Position Statement. *Endoscopy* 2020;**52**:491–7.

31 Stafylidou M, Paschos P, Katsoula A, *et al.* Performance of Baveno VI and Expanded Baveno VI Criteria for Excluding High-Risk Varices in Patients With Chronic Liver Diseases: A Systematic Review and Meta-analysis. *Clin Gastroenterol Hepatol* 2019;**17**:1744–55.e11.

32 Penny HA, Raju SA, Lau MS, *et al.* Accuracy of a no-biopsy approach for the diagnosis of coeliac disease across different adult cohorts. *Gut* Published Online First: 2 November 2020. doi:10.1136/gutjnl-2020-320913

33 Al-Toma A, Volta U, Auricchio R, *et al.* European Society for the Study of Coeliac Disease (ESsCD) guideline for coeliac disease and other gluten-related disorders. *United European Gastroenterol J* 2019;**7**:583–613.

34 Rutter MD, East J, Rees CJ, *et al.* British Society of Gastroenterology/Association of Coloproctology of Great Britain and Ireland/Public Health England post-polypectomy and post-colorectal cancer resection surveillance guidelines. *Gut* 2020;**69**:201–23.

35 Shandro B, Chang V, Mathur J, *et al.* Real-life cost savings and capacity improvements on implementation of the new BSG post-polypectomy surveillance guideline. *Clin Med* 2020;**20**:116–7.

36 Hassan C, Antonelli G, Dumonceau J-M, *et al.* Post-polypectomy colonoscopy surveillance: European Society of Gastrointestinal Endoscopy (ESGE) Guideline – Update 2020. Endoscopy. 2020;**52**:687–700. doi:10.1055/a-1185-3109

37 Turvill J, Turnock D. Audit of the impact of the York faecal calprotectin care pathway on colonoscopy activity. *Frontline Gastroenterol* 2020;**11**:285–9.

38 Spada C, Hassan C, Bellini D, *et al.* Imaging alternatives to colonoscopy: CT colonography and colon capsule. European Society of Gastrointestinal Endoscopy (ESGE) and European Society of Gastrointestinal and Abdominal Radiology (ESGAR) Guideline – Update 2020. Endoscopy. 2020;**52**:1127–41. doi:10.1055/a-1258-4819

39 Bawaneh K, Nezami FG, Rasheduzzaman M, *et al.* Energy Consumption Analysis and Characterization of Healthcare Facilities in the United States. Energies. 2019;**12**:3775. doi:10.3390/en12193775

40 Ritchie H, Roser M. Plastic Pollution. *Our World in Data* Published Online First: 1 September 2018.https://ourworldindata.org/plastic-pollution (accessed 3 Mar 2021).

41 Elta GH, Law RJ. Great haste makes great waste: Do available data support the widespread adoption of disposable endoscopes? Gastrointest. Endosc. 2020;**91**:404–5.

42 Hutchins DCJ, White SM. Coming round to recycling. *BMJ* 2009;**338**:b609.

43 Hignett K. Covid-19 Plastic Waste: U.K. Hospitals Are Recycling Disposable PPE. *Forbes Magazine* 2021.https://www.forbes.com/sites/katherinehignett/2021/01/18/covid-19-plastic-waste-uk-hospitals-are-recycling-disposable-ppe/ (accessed 7 Jun 2021).

44 Watts N, Amann M, Arnell N, *et al.* The 2018 report of the Lancet Countdown on health and climate change: shaping the health of nations for centuries to come. *Lancet* 2018;**392**:2479–514.

FIGURE CAPTIONS

Figure 1: The annual carbon footprint of endoscopy in the USA. *Estimates are based on energy use and plastic waste disposal calculations (over 18 million procedures per year) but do not account for incinerated waste and emissions involved in the manufacturing of endoscopy consumables.*

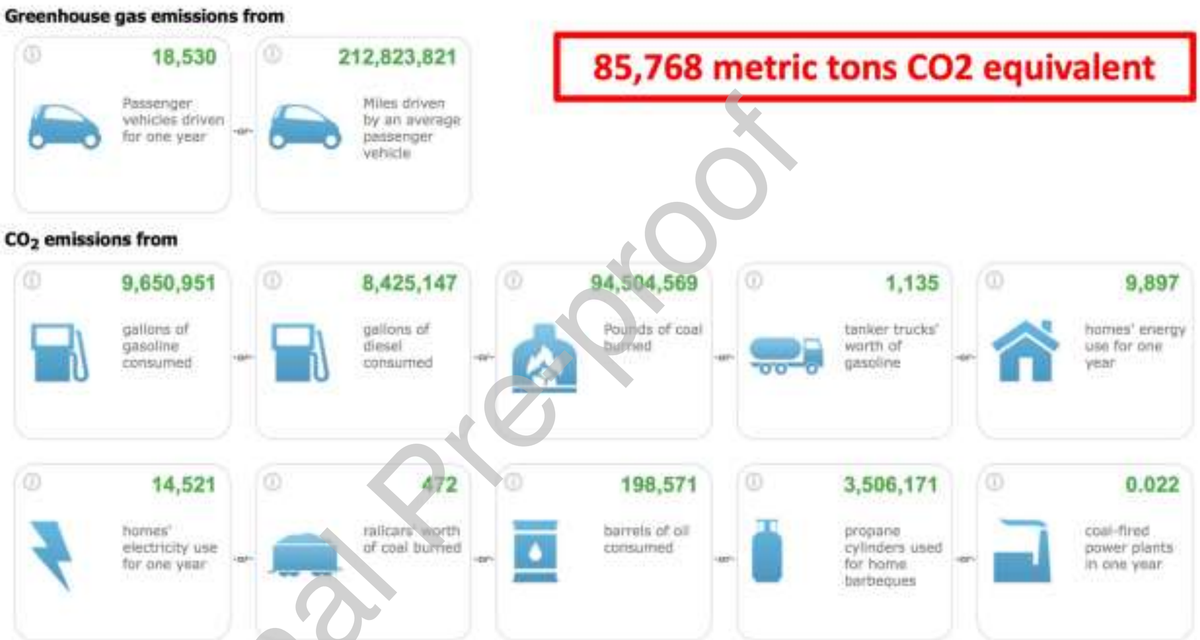


Figure 2: An example of process mapping of the patient journey in endoscopy and the opportunities for sustainability-based interventions.

Figure 3: Opportunities to Reduce, Reuse and Recycle in endoscopy.

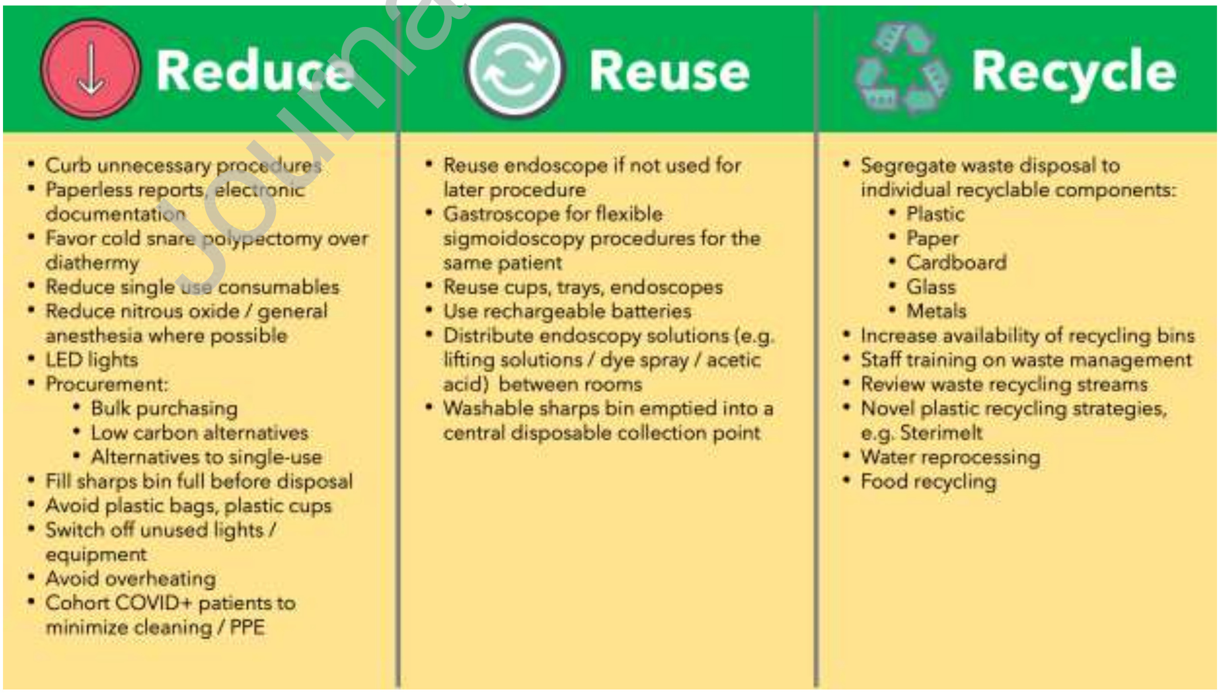


Figure 4: Taxonomy of sustainability interventions in endoscopy.

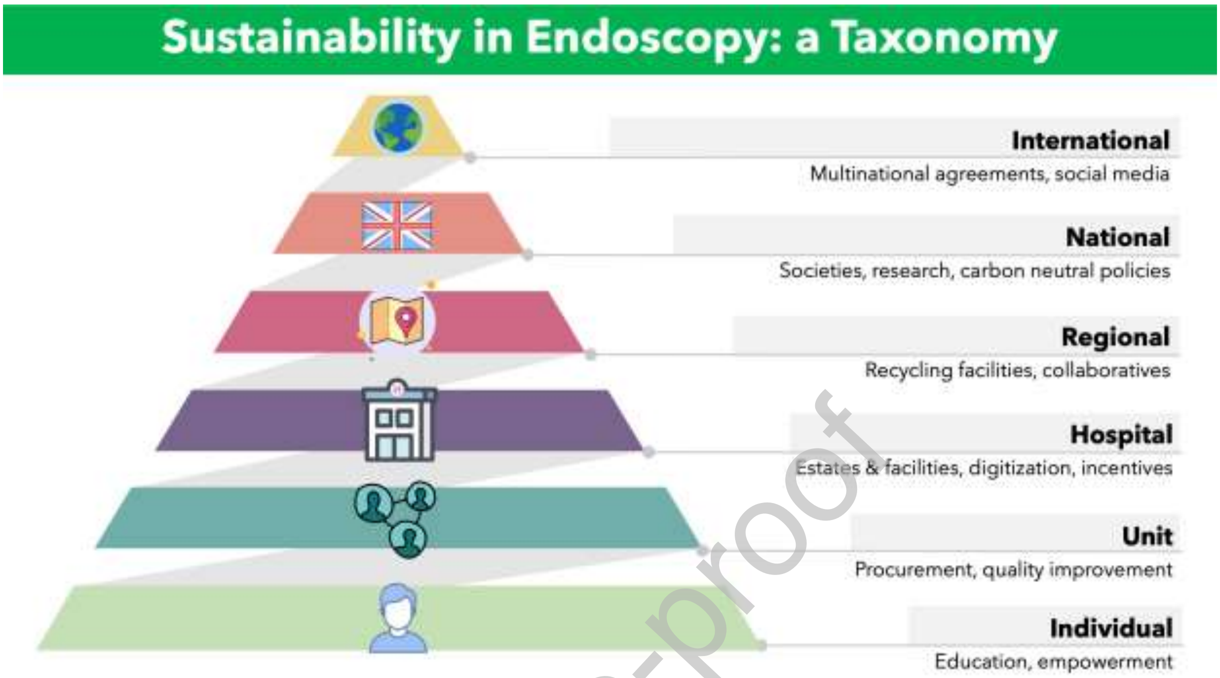
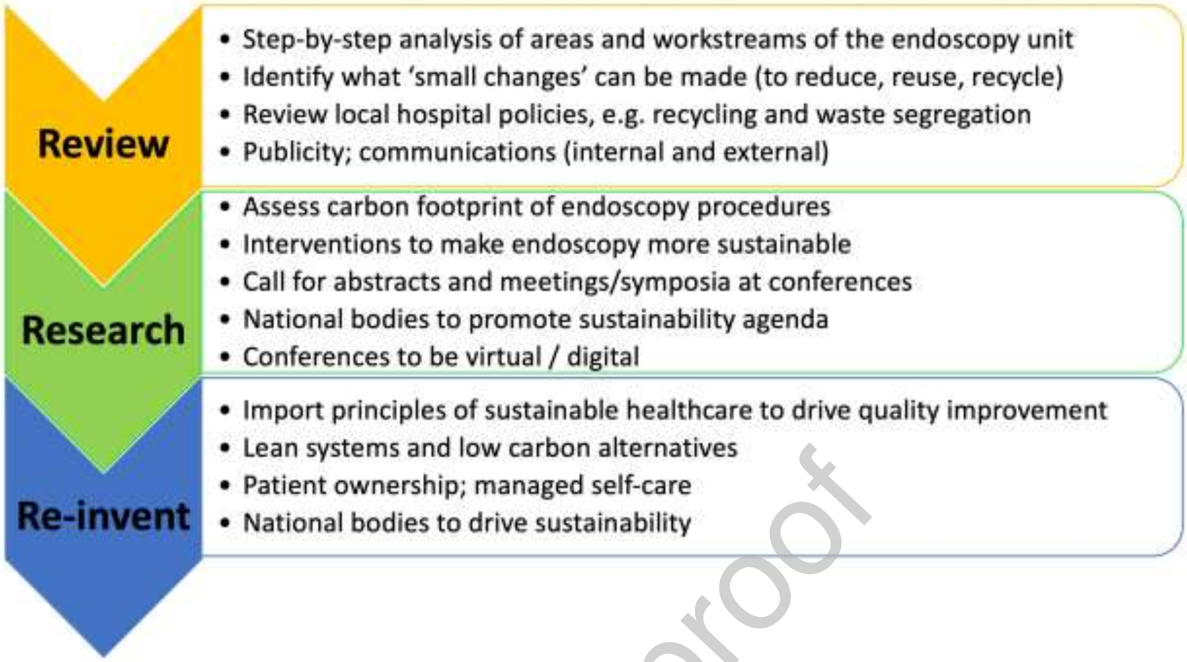


Figure 5: Review, Research and Re-invent: a pragmatic action plan to address sustainability in endoscopy.



Review
• Step-by-step analysis of areas and workstreams of the endoscopy unit
• Identify what 'small changes' can be made (to reduce, reuse, recycle)
• Review local hospital policies, e.g. recycling and waste segregation
• Publicity; communications (internal and external)
Research
• Assess carbon footprint of endoscopy procedures
• Interventions to make endoscopy more sustainable
• Call for abstracts and meetings/symposia at conferences
• National bodies to promote sustainability agenda
• Conferences to be virtual / digital
Re-invent
• Import principles of sustainable healthcare to drive quality improvement
• Lean systems and low carbon alternatives
• Patient ownership; managed self-care
• National bodies to drive sustainability

TABLES

Greenhouse Gas	**Global Warming Potential (CO2 equivalents)**
Carbon dioxide (CO_2)	**1**
Methane (CH_4)	**25**
Nitrous oxide (N_2O)	**298**
Hydrofluorocarbons (HFCs)	**124-14800**
Perfluorocarbons (PFCs)	**7390-12200**
Sulfur hexafluoride (SF_6)	**22800**
Nitrogen trifluoride (NF_3)	**17200**

Table 1: Greenhouse gases and their global warming potential in carbon dioxide equivalents (CO_2e).

Unit	Energy consumption (kWh) per day	Energy consumption (kWh) per year	Carbon emissions (metric tCO_2e) per day	Carbon emissions (metric tCO_2e) per year
Computers	8.96	2336	0.006	1.56
Anesthesia machines	12	3129	0.008	2.09
Wash machines	24.67	6431	0.017	4.43
Scope processors	27	7039	0.019	4.95
Lighting	47.88	12483	0.034	8.86
Total	120.5	31416	0.085	22.2

Table 2: Energy consumption at WVUM Endoscopy Unit (excluding heating and cooling). With permission from Wolters Kluwer.[14]