

Reducing the environmental footprint of gastrointestinal endoscopy: European Society of Gastrointestinal Endoscopy (ESGE) and European Society of Gastroenterology and Endoscopy Nurses and Associates (ESGENA) Position Statement



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ABSTRACT

Climate change and the destruction of ecosystems by human activities are among the greatest challenges of the 21st century and require urgent action. Health care activities significantly contribute to the emission of greenhouse gases and waste production, with gastrointestinal (GI) endoscopy being one of the largest contributors. This Position Statement aims to raise awareness of the ecological footprint of GI endoscopy and provides guidance to reduce its environmental impact. The European Society of Gastrointestinal Endoscopy (ESGE) and the European Society of Gastroenterology and Endoscopy Nurses and Associates (ESGENA) outline suggestions and recommendations for health care providers, patients, governments, and industry.

Main statements **1** GI endoscopy is a resource-intensive activity with a significant yet poorly assessed environmental impact. **2** ESGE-ESGENA recommend adopting immediate actions to reduce the environmental impact of GI endoscopy. **3** ESGE-ESGENA recommend adherence to guidelines and implementation of audit strategies on the appropriateness of GI endoscopy to avoid the environmental impact of unnecessary procedures. **4** ESGE-ESGENA recommend the embedding of reduce, reuse, and recycle programs in the GI endoscopy unit. **5** ESGE-ESGENA suggest that there is an urgent need to reassess and reduce the environmental and economic impact of single-use GI endoscopic devices. **6** ESGE-ESGENA suggest against routine use of single-use GI endoscopes. However, their use could be considered in highly selected patients on a case-by-case basis. **7** ESGE-ESGENA recommend inclusion of sustainability in the training curricula of GI endoscopy and as a quality domain. **8** ESGE-ESGENA recommend conducting high quality research to quantify and minimize the environmental impact of GI endoscopy. **9** ESGE-ESGENA recommend that GI endoscopy companies assess, disclose, and audit the environmental impact of their value chain. **10** ESGE-ESGENA recommend that GI endoscopy should become a net-zero greenhouse gas emissions practice by 2050.

ABBREVIATIONS

AI	artificial intelligence
ASGE	American Society of Gastrointestinal Endoscopy
EMR	endoscopic mucosal resection
ERCP	endoscopic retrograde cholangio-pancreatography
ESD	endoscopic submucosal dissection
ESGE	European Society of Gastrointestinal Endoscopy
ESGENA	European Society of Gastroenterology and Endoscopy Nurses and Associates
EU	European Union
GI	gastrointestinal
GHG	greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
KPM	key performance measure
PICO	population/problem, intervention, comparison, outcome
PVC	polyvinyl chloride
RCT	randomized controlled trial

SOURCE AND SCOPE

This Position Statement from the European Society of Gastrointestinal Endoscopy (ESGE) and the European Society of Gastroenterology and Endoscopy Nurses and Associates (ESGENA) reviews the available data on the environmental impact of gastrointestinal endoscopy. It aims to raise awareness of this growing problem that demands urgent action and to outline strategies to achieve sustainable endoscopy practice ("green endoscopy").

1 Introduction

Climate change driven by human activities is an undeniable reality that already has visible effects on the environment and human health. We are witnessing an increasing frequency of extreme weather events such as hurricanes, droughts, heatwaves, floods, and an unprecedented extinction of species and loss of biodiversity. Due to human activities, the global temperature has risen by about 1.2 degrees Celsius (C) since the late 19th century, the Arctic Sea ice is steadily declining and has reached its minimum for at least the last 1000 years, and glaciers are retreating worldwide [1]. The years 2016 and 2020 were the warmest since temperatures have been recorded [1]. The Intergovernmental Panel on Climate Change (IPCC) of the United Nations, which comprises more than 1300 scientists, claims that global temperatures will rise during this century by up to 4–5 degrees C unless immediate action is taken, primarily due to the increase in human-driven greenhouse gas (GHG) production and the destruction of ecosystems [2].

Climate change has an insidious but relentless and significant adverse effect on health. Notably, high temperatures and

air pollution have a synergistic negative impact on physical and psychological health [3]. An increase in morbidity and mortality from heatstroke, infectious disease, and exacerbations of cardiovascular and respiratory disease is expected due to global warming [3,4]. Considering all the above, there is an urgent need for change. Governments, industries, institutions, individuals, and scientific societies can and must do more to face the environmental crisis.

Health care systems contribute significantly to the emission of GHGs [5]. Preliminary studies suggest that gastrointestinal (GI) endoscopy is one of the largest polluters and waste generators [6]. Currently, there is little awareness, assessment, or guidance from medical societies about the environmental impact of clinical practice. This Position Statement emphasizes the commitment of the European Society of Gastrointestinal Endoscopy (ESGE) and the European Society of Gastroenterology and Endoscopy Nurses and Associates (ESGENA) to combating climate change. Therefore, the main aims of this document are to raise awareness of the ecological footprint of GI endoscopy and to provide guidance to reduce its environmental impact in clinical practice, education, and research.

2 Methods

This document has been developed in accordance with the current ESGE Publications Policy [7]. A Position Statement was considered appropriate given the anticipated lack of high quality evidence and the strategic relevance of the topic.

In August 2021, the project leaders (E.R. de S. and M.D.R.) proposed a preliminary list of questions and topics to all panelists and formed nine working groups. A virtual online meeting was held on 4 September, 2021, and a final list comprising 20 questions was approved. A structured template was developed to standardize the literature search and methods. Subsequently, we conducted a systematic literature search in a minimum of two databases from inception to January 2022, using several PICO (population/problem, intervention, comparison, outcome) questions (see **Supplementary material**, available online-only). When framing a PICO question was not considered feasible, questions were answered through an expert-based review to elucidate the ESGE-ESGENA position. Subsequently, each working group appraised the available literature and drafted an initial list of statements.

The consensus among panelists for statements was assessed through an anonymous and iterative Delphi process. A maximum of three voting rounds to reach consensus was set beforehand. Statements were graded with a 5-point Likert scale (1 Strongly disagree, 2 Disagree, 3 Neither agree nor disagree, 4 Agree, 5 Strongly agree) via a web-based platform. Panelists could make open suggestions for each statement using a text box. Before voting, panelists received a preliminary manuscript draft that included the evidence supporting each statement. Panelists were asked to consider clinical benefits and harms for patients and health care systems, costs, quality of the evidence, and the environmental impact. Consensus was defined as $\geq 80\%$ agreement (the sum of Agree and Strongly agree) on each statement. Statements were deleted or reformulated by the

► **Table 1** Reducing the environmental footprint of gastrointestinal (GI) endoscopy.

Background: the environmental impact of GI endoscopy

- GI endoscopy is a resource-intensive activity with a significant yet poorly assessed environmental impact. GI endoscopy is estimated to be the third highest generator of hazardous waste in health care facilities.
- GI endoscopic instruments and supplies are composed of thermoplastic polymers, metals, rubber composites, optical glass, and semiconductor materials. Packaging material typically includes paper, cardboard, and plastic.
- GI endoscopy predominantly uses reusable endoscopes and requires a considerable amount of single-use, plastic-predominant, consumable instruments and supplies.
- There is a need to understand and publicly disclose the exact material composition of GI endoscopic instruments and supplies to estimate their environmental impact.

Statements: the path towards sustainable GI endoscopy

Clinical and endoscopic management

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|---|---|
| 1 | ESGE-ESGENA recommend adopting immediate actions to reduce the environmental impact of GI endoscopy. |
| 2 | ESGE-ESGENA recommend adherence to guidelines and implementation of audit strategies on the appropriateness of GI endoscopy, to avoid the environmental impact of unnecessary procedures. |
| 3 | ESGE-ESGENA recommend a rational use of periprocedural and intraprocedural medication to reduce the environmental impact of GI endoscopy. |
| 4 | ESGE-ESGENA recommend using low-waste, less invasive alternatives to endoscopy (e. g., fecal calprotectin, urea breath test, etc.) within the bounds endorsed by evidence-based clinical guidelines. |
| 5 | ESGE-ESGENA suggest that digitalization, telemedicine, and efficient clinical pathways may reduce the environmental impact of pre- and post-procedural GI endoscopy-related health care. |
| 6 | ESGE-ESGENA suggest that diagnostic strategies that safely reduce the number of samples sent for histological analysis can reduce the environmental impact. This can be achieved via optical diagnosis and adherence to guidelines on the indications for endoscopic tissue sampling. |
| 7 | ESGE-ESGENA recommend considering the environmental impact when selecting the appropriate endoscopic technique. The less resource-intensive technique should be favored, provided efficacy and safety are maintained. |
| 8 | ESGE-ESGENA recommend a rational use of endoscopic accessories during the procedure. |
| 9 | ESGE-ESGENA suggest performing most elective endoscopic procedures on an outpatient basis to avoid overnight hospital stays and hence reduce the environmental impact. |

Endoscopy logistics

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| 10 | ESGE-ESGENA recommend applying the principles of sustainable architecture to the design and construction of GI endoscopy units. |
| 11 | ESGE-ESGENA suggest implementing an accreditation process for GI endoscopy units that embraces sustainability. |
| 12 | ESGE-ESGENA recommend favoring the use of renewable energy at GI endoscopy units. This goal should be achieved in the context of local and national policies. |
| 13 | ESGE-ESGENA recommend the embedding of reduce, reuse, and recycle programs in the GI endoscopy unit. |
| 14 | ESGE-ESGENA recommend revisiting waste management in the GI endoscopy unit to ensure adequate segregation and processing policies. The 3 R (Reduce-Reuse-Recycle) and circular economy principles should be the core of these policies. |
| 15 | ESGE-ESGENA recommend the digitalization of the GI endoscopy unit (including electronic reporting), minimizing paper printing, and using energy-efficient endoscopy and electronic devices. |
| 16 | ESGE-ESGENA recommend establishing local protocols and environmental educational programs for personnel to practice in an environmentally friendly and sustainable way. |

Single-use accessories

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|----|--|
| 17 | ESGE-ESGENA recommend that future clinical guidelines and regulations on GI endoscopy reprocessing/disinfection should consider the environmental impact of these practices and that of single-use devices. |
| 18 | ESGE-ESGENA suggest that there is an urgent need to reassess and reduce the environmental and economic impact of single-use GI endoscopic devices. GI and endoscopy societies should collaborate with industry to minimize the environmental burden of single-use devices. |
| 19 | ESGE-ESGENA suggest using GI endoscopy devices that have an environmentally sustainable design (e. g., reloadable clips or band ligators). |

<i>Single-use endoscopes</i>	
20	ESGE-ESGENA suggest against routine use of single-use GI endoscopes. However, their use could be considered in highly selected patients, on a case-by-case basis.
<i>Education and training</i>	
21	ESGE-ESGENA recommend embedding sustainability into the curricula of GI endoscopy.
22	ESGE-ESGENA recommend conducting research into the environmental impact of GI endoscopy training. Waste reduction and awareness of the environmental costs during training are ethically linked to the notion of high quality GI endoscopy.
23	ESGE-ESGENA recommend that GI endoscopy training should be undertaken in structured, auditable programs and take into account local availability of endoscopy simulators and on-site/off-site teaching modules. Adoption of teaching strategies that shorten the learning curve and ensure safe and efficient procedures is essential to reduce unnecessary waste during training.
24	ESGE-ESGENA suggest that virtual training and online educational modalities can reduce the environmental impact of GI endoscopy.
<i>Green quality</i>	
25	ESGE-ESGENA suggest that the implementation of and adherence to quality measures for GI endoscopy can reduce its environmental impact.
26	ESGE-ESGENA recommend including sustainability as a quality domain for GI endoscopy.
<i>Green research and guidelines</i>	
27	ESGE-ESGENA should encourage and fund research into “green and sustainable” GI endoscopy.
28	ESGE-ESGENA recommend conducting high quality research to quantify and minimize the environmental impact of GI endoscopy.
29	ESGE-ESGENA recommend incorporating the principles of sustainability into every GI endoscopy research project. The study design should consider the environmental impact of the research.
30	ESGE-ESGENA recommend taking into account environmental impact when grading the strength of recommendations in GI endoscopy guidelines.
31	ESGE-ESGENA suggest defining specific PICO (population/problem, intervention, comparison, outcome) questions to evaluate the environmental impact of guideline recommendations. In the absence of evidence, ESGE-ESGENA recommend highlighting the need for research to examine the environmental impact of the GI endoscopy guideline.
<i>Industry, health insurers, and health care providers</i>	
32	ESGE-ESGENA recommend that GI endoscopy companies assess, disclose, and audit the environmental impact of their value chain.
33	ESGE-ESGENA recommend that GI endoscopy companies manufacture environmentally friendly materials and devices.
34	ESGE-ESGENA recommend against planned obsolescence of GI endoscopy materials and devices.
35	ESGE-ESGENA recommend that governments, health insurers, and health care providers align with environmentally preferable purchasing strategies (“green purchasing”), including choosing materials and supplies with a low carbon footprint.
<i>Policymakers, governments, and patients</i>	
36	ESGE-ESGENA recommend that policymakers and governments take immediate action in the path towards environmentally sustainable GI endoscopy.
37	ESGE-ESGENA recommend development of “Choosing Wisely” campaigns for GI endoscopy, discouraging overuse and overtreatment, and thus contributing to lower waste related to GI endoscopy, together with patients and patient organizations.
38	ESGE-ESGENA suggest that patient empowerment programs and a healthy lifestyle can reduce the need for GI endoscopy procedures in the long term.
<i>Conclusion</i>	
39	ESGE-ESGENA recommend that GI endoscopy should become a net-zero greenhouse gas emissions practice by 2050.
ESGE, European Society of Gastrointestinal Endoscopy; ESGENA: European Society of Gastroenterology and Endoscopy Nurses and Associates; GI, gastrointestinal; PICO, population/problem, intervention, comparison, and outcome.	

project leaders for the subsequent voting round if the agreement was <80%, and considering the suggestions made by the panelists. The results of each voting round are detailed in **Supplementary material**.

After two voting rounds, the final statements (► **Table 1**) and manuscript were discussed and approved during a second

virtual meeting held on 1 April, 2022. This draft was then sent for modifications and final approval to the ESGE Governing Board. Further details on the methodology of ESGE position statements can be obtained elsewhere [7].

A glossary with ten core terms adapted from the IPCC [2] and other sources [8–16] is provided in ► **Table 2**.

► **Table 2** “Green” glossary of core terms.

3 R principle (Reduce–Reuse–Recycle)	Sequence of steps on how to manage waste and materials properly. The top priority is Reduce waste and products generation, then Reuse, and then Recycle [8].
carbon footprint	The total set of greenhouse gas emissions caused directly and indirectly by an individual, event, organization, or product [9].
circular economy	A model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing, and recycling existing materials and products for as long as possible. In this way, the life cycle of products is extended. In practice, it implies reducing waste to a minimum. When a product reaches the end of its life, its materials are kept within the economy wherever possible. This differs from the traditional, linear economic model, which is based on a take-make-consume-throw away pattern [10].
climate change	A variation in the state of the weather and temperatures that persists for an extended period. It may be due to natural internal processes or external forces such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use [11]. The scientific community agrees that the current climate change is driven by human activities [2].
energy efficiency	The ratio of output of useful energy or energy services or other useful physical outputs obtained, from a system, conversion process, transmission or storage activity, to the input of energy [11].
“green endoscopy”	Term initially used by Maurice et al. [12] that refers to the practice of gastrointestinal endoscopy that aims to raise awareness, assess and reduce endoscopy’s environmental impact. “Green Endoscopy” also refers to an international network of health care professionals that advocates for sustainable practice in endoscopy and related specialties [13].
greenhouse gases (GHGs)	Those gaseous constituents of the atmosphere that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth’s surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapor, carbon dioxide, nitrous oxide, methane, and ozone are the primary greenhouse gases [11].
life cycle assessment	Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product or service throughout its life cycle. A full life cycle includes all phases from development of a product, manufacturing, and use, to disposal (“cradle to grave”). This definition builds from International Organization for Standardization (ISO) (2018) [11].
net zero emissions	These are achieved when anthropogenic emissions of greenhouse gases are balanced by anthropogenic removals over a specified period. Based on the Greenhouse Gas Protocol to measure and standardize greenhouse gas emissions [14], three areas (“scopes”) contribute to emissions and need to reach net zero to reach full carbon neutrality. Scope 1 represents emissions directly emanating from health care facilities (e. g. anesthetic gases or burning of fossil fuel). Scope 2 represents indirect emissions purchased for electricity or heating/cooling from nonrenewable energy sources. Scope 3 represents emissions originating from the health care supply chain. Within the health care sector, scopes 1, 2, and 3 make up 17 %, 12 %, and 71 % of emissions, respectively [15].
sustainability	A dynamic process that guarantees the persistence of natural and human systems in an equitable manner. Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs, and balances social, economic and environmental concerns [11]. Principles of sustainable health care include patient empowerment, prevention, lean services, and low carbon alternatives [16].

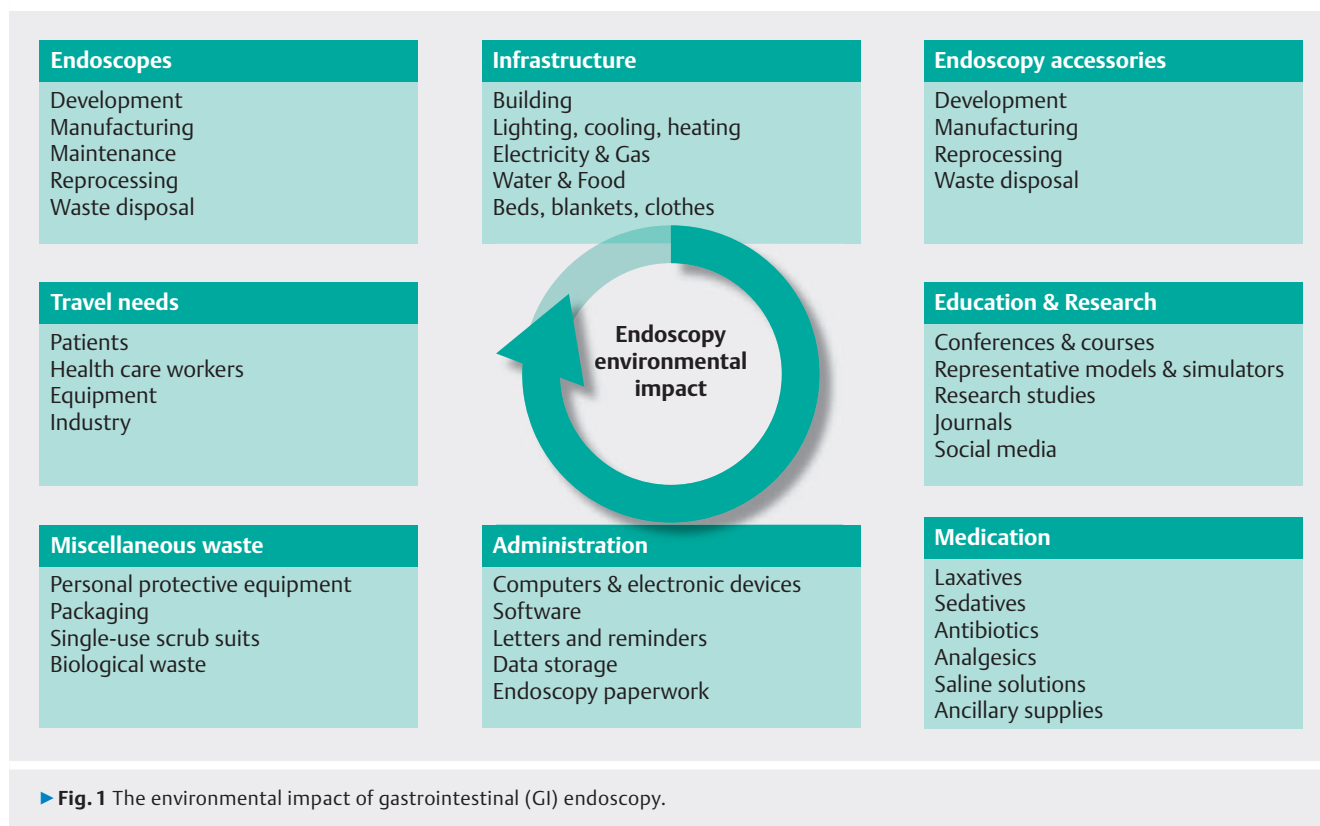
3 The environmental impact of GI endoscopy

3.1 The carbon footprint of GI endoscopy

Health care activities have a substantial carbon footprint, accounting for about 1 % to 5 % of human environmental impact and about 4.4 % of GHG emissions worldwide [5]. The major contributors are generation and distribution of energy, including gas and heat or cooling (40 %), and emissions directly from health care institutions (13 %). Transport (7 %), pharmaceutical and chemical products (5 %) and waste management (3 %) also have a considerable environmental burden [15]. The United States, China, and the European Union (EU) account for more than half of all emissions. If the health care sector were a country, it would be the fifth-largest emitter worldwide [15]. Trend analyses show that health care GHG emissions have increased by nearly a third over the last two decades [5], both in low and

high income countries [17]. Notably, several reports indicate that this carbon footprint is largely avoidable and could be reduced without compromising quality [5, 15, 18, 19].

GI endoscopy has direct and indirect ecological harms (► **Fig. 1**) and is estimated to be the third highest generator of hazardous waste in health care facilities (3.09 kg/day/bed) [19]. Specific data addressing its environmental impact are very scarce. Furthermore, available data are based on indirect estimates, heterogeneous assumptions, and calculators not designed explicitly for GI endoscopy. The reason for this lack of data is multifactorial and includes a lack of interest from manufacturers, health care providers, and researchers, as well as difficulties in conducting comprehensive life cycle assessment (i. e., lack of methodological consensus and limited data about the origin, manufacturing, and waste disposal of GI endoscopy products) [20]. A summary of available data with current estimates is provided in ► **Table 3** [6, 21–24].



BACKGROUND

- GI endoscopy is a resource-intensive activity with a significant yet poorly assessed environmental impact. GI endoscopy is estimated to be the third highest generator of hazardous waste in health care facilities.
- GI endoscopic instruments and supplies are composed of thermoplastic polymers, metals, rubber composites, optical glass, and semiconductor materials. Packaging material typically includes paper, cardboard, and plastic.
- GI endoscopy predominantly uses reusable endoscopes and requires a considerable amount of single-use, plastic-predominant, consumable instruments and supplies.
- There is a need to understand and publicly disclose the exact material composition of GI endoscopic instruments and supplies to estimate their environmental impact.

3.2 Materials used in GI endoscopes and accessories

The literature search revealed that only very limited information is available on the type and amount of materials used in GI endoscopy. Available information includes personal reviews of instruments and supplies and discussion with engineering departments and company representatives [25,26]. Based on different aspects (structure, properties, processing, and per-

formance), materials used in medical device manufacturing can be classified into polymers, metals, ceramics, composites, and biomaterials. Polymers are large molecules made by chemical linking of repeating units (forming thermoplastics, thermosets, and elastomers), to provide various forms of rubber and plastics. Metals are commonly used because of their strength, toughness, durability, and high electrical and thermal conductivity. These include stainless steel, aluminum, brass, copper, nickel, and titanium. Ceramics are robust inorganic and non-metallic materials, including glass and other crystalline structures with piezoelectric properties. Composite materials combine two or more of the aforementioned groups [27]. For example, the alloy nitinol (nickel and titanium) is used in self-expandable metal stents. Finally, biomaterials are nonvital materials intended to interact with biological systems to replace or restore functions [27, 28]. In addition, packaging contributes considerably to total materials used, and typically includes plastic, paper, and cardboard.

Details of the material composition of reusable or single-use GI endoscopic instruments are not publicly available. The major components of GI reusable endoscopes are metal (approximately 70% of total mass) and plastic (25%–30%), with a remaining small proportion of electronic components. In contrast, single-use GI endoscopes consist primarily of plastic and a lesser proportion of metal. Accessory devices (e.g., water bottles, irrigation tubes, polyp snares, etc.) are generally plastic-predominant [6]. Plastics used in GI endoscopy include some with potential carcinogenic and adverse effects on health such as polyvinyl chloride (PVC) and phthalates, and hence

► **Table 3** Estimates of the environmental impact of gastrointestinal (GI) endoscopy.

First author	Methodology and topic	Estimates
Gayam [21]	Cross-sectional study on endoscopy waste and carbon footprint using online calculators. See Supplementary material for methodology. It does not include pre- and post-procedure care. Carbon footprint does not include manufacturing, distribution, disposal, heating, or facility energy needs.	<ul style="list-style-type: none"> One endoscopic procedure: 1.5 kg of waste (0.3 % kg recyclable). 1-year endoscopy activity in the United States (18 million procedures): <ul style="list-style-type: none"> 13 500 tons of plastic waste, of which 10 800 tons are non-recyclable. CO₂ emissions equivalent to more than 3 995 448 gallons of gasoline consumed. Energy consumption per day in a GI endoscopy unit located in the United States that averages 40 procedures per day: <ul style="list-style-type: none"> Wash machines 24.67 kWh Endoscopy machines 27.00 kWh Anesthesia machine 12.00 kWh Room lighting 47.88 kWh Total 111.55 kWh.
Namburar [22]	Cross-sectional study of endoscopy waste at 2 academic centers in the United States, including pre- and post-procedure care.	<ul style="list-style-type: none"> One endoscopic procedure: 2.1 kg of disposable waste (46 L); 64 % of waste went to landfill, 28 % was biohazard waste, and 9 % was recycled. Personal protective equipment accounted for 8 % of waste. 1-year endoscopy activity in the United States: 38 000 metric tons of waste (equivalent to 25 000 passenger cars). Universal single-use endoscopes would increase the net waste mass by 40 %.
Siau [6]	Narrative review on endoscopic procedure and transport	<ul style="list-style-type: none"> 1-year endoscopy activity in the United States (18 million procedures): 85 768 tonnes of CO₂ → 4.8 kg of CO₂ per endoscopy. This calculation includes CO₂ related to waste and basic energy needs. The carbon footprint of a GI scientist using an electric vehicle and accounting for conference travel has been estimated at equivalent to 20.8 tonnes of CO₂ per year.
Gordon [23]	Life cycle assessment of pathology specimen	<ul style="list-style-type: none"> Equivalent to 0.28 kg CO₂ per GI biopsy when 1 jar is used and 0.79 kg CO₂ when 3 jars are used; emissions equivalent to driving a typical passenger vehicle 0.7 mile and 2.0 miles, respectively. Production of supplies was the largest contributor to greenhouse gas emissions.
Hernández [24]	Life cycle assessment of single-use duodenoscope Only presented as a conference abstract	<ul style="list-style-type: none"> Single-use duodenoscope consumes 467 MJ and releases 29.3 kg of CO₂ Reusable duodenoscope 26.8 MJ and 1.55 kg CO₂; 20 times less than single-use model. Duodenoscope with disposable end caps 23.4 MJ and 1.37 kg CO₂.
Vaccari [19]	Data on per capita health care spent at the national level, as well as a case study of a hospital in Italy	<ul style="list-style-type: none"> Departments with highest generation of hazardous waste per daily occupied bed were: 1 anesthetics, 2 pediatric and intensive care, and 3 gastroenterology–digestive endoscopy (3.09 kg/day/bed). Departments with the highest average monthly waste generation rates per clinical procedure were 1 radiology (0.67 kg/procedure), 2 gastroenterology–digestive endoscopy (0.50 kg/procedure), and 3 plastic surgery.

some companies are moving towards a PVC-free policy [29]. A shift towards recyclable and environmentally friendly GI endoscopy materials is of paramount importance.

Regarding the nature of materials, there is minimal information from manufacturers. Unfortunately, current EU regulations on medical devices do not force companies to publicly detail the composition and sources of materials used in GI endoscopy devices, and this information is rarely provided to users [30]. Knowing the type of material used is key to estimating the environmental impact of GI endoscopes and devices. A life cycle assessment requires data on how materials were resourced and used in the manufacturing process. In addition, material type determines its potential for reuse, for recycling (for in-

stance, thermoplastics can be recycled, but thermoset plastics cannot), or for incineration and determines the time to decomposition in a landfill [6].

4 The path towards environmentally sustainable GI endoscopy ► Fig. 2

STATEMENT

1 ESGE-ESGENA recommend adopting immediate actions to reduce the environmental impact of GI endoscopy.

4.1 Reducing the carbon footprint before, during, and after GI endoscopy

In our systematic search, we did not find any study that directly evaluated the impact on environmental outcomes of GI endoscopy or related clinical management (see **Supplementary material**).

4.1.1 Clinical management

STATEMENT

2 ESGE-ESGENA recommend adherence to guidelines and implementation of audit strategies on the appropriateness of GI endoscopy, to avoid the environmental impact of unnecessary procedures.

STATEMENT

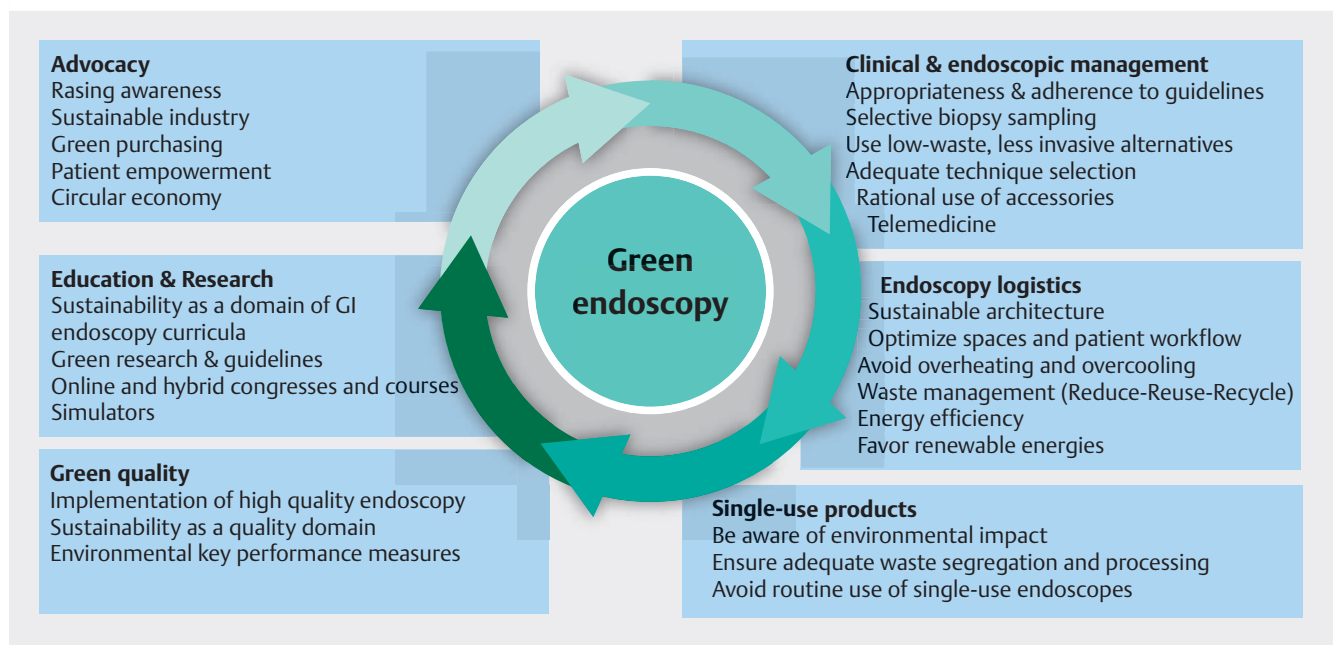
3 ESGE-ESGENA recommend a rational use of periprocedural and intraprocedural medication to reduce the environmental impact of GI endoscopy.

Several actions beyond the endoscopic procedure itself are of paramount importance to reduce the carbon footprint.

ESGE-ESGENA consider that reducing the current rate of unnecessary GI endoscopic procedures is key to that end and should be prioritized by GI endoscopy services and health care systems. This is probably the most effective action to mitigate the GHG emissions of GI endoscopy.

Adherence to guidelines ensuring the appropriateness of the indication for GI endoscopy is vital to optimizing patient care and use of resources [31,32]. Triage of waiting lists and cancellation of unnecessary procedures have proven useful during the COVID-19 pandemic and deserve to be evaluated in the long term [33–35]. Two recent meta-analyses indicate that the rate of inappropriate upper GI endoscopies and colonoscopies is 20%–30% [36,37]. Limiting endoscopic procedures to only those that are appropriate has been shown to be cost-effective, reduces procedure-related risks, and significantly increases the probability of diagnosing relevant findings, including malignancy [36]. Nevertheless, appropriateness criteria are not perfect and should always be combined with clinical judgment [31,32].

Oversurveillance is also common and has been extensively documented in several conditions such as Barrett's esophagus [38] or colonic polyps [39]. In this regard, ESGE has published a document to summarize when endoscopic follow-up is not recommended [32]. Recent guidelines are expected to reduce surveillance colonoscopies by over 80%, with notable cost savings and capacity improvements [40]. Endoscopy services are encouraged to assess the appropriateness of endoscopy and to take action when endoscopy has been performed inappropriately [41]. Avoiding routine pre-endoscopy testing (e.g., blood tests, electrocardiography, or chest radiography) can additionally reduce the carbon footprint [42].



► Fig. 2 The path towards sustainable endoscopy.

Medications before endoscopy (e.g. bowel preparation and laxatives for colonoscopy, or mucolytic solutions before esophagogastroduodenoscopy), during (e.g. sedatives, antibiotics, or analgesics), and after the procedure also have also an environmental burden that has not been formally quantified [43]. It has recently been estimated that 1 g medication has a CO₂ footprint of somewhere between 10 g and 1000 g, compared to 1 g of oil, which has a 3-g CO₂ footprint [44]. Thus, the use of medication only when strictly indicated is a simple and ethical green measure (e.g. avoiding routine saline fluid intravenous solution during sedation, inadequate antibiotic prophylaxis, etc.) [43].

Direct environmental impact comparisons between nitrous oxide and intravenous sedation strategies specifically in the context of endoscopy have not been published. Nonetheless, nitrous oxide has a global warming potential of nearly 300 times that of CO₂ [45], and its negative environmental impact is well recognized in the anesthesiology community, where significant efforts to minimize its use are underway [46]. Moderate versus deep sedation versus endotracheal intubation, and selective versus universal involvement of an anesthesiologist, are factors that may influence the GI endoscopy carbon footprint and deserve future assessment.

STATEMENT

4 ESGE-ESGENA recommend using low-waste, less invasive alternatives to endoscopy (e.g. fecal calprotectin, urea breath test, etc.) within the bounds endorsed by evidence-based clinical guidelines.

Intuitively, using low-waste less invasive alternatives to GI endoscopy is another sensible approach to limit environmental impact [47]. However, manufacturers do not disclose the ecological footprint of less invasive tests and we lack comparative life cycle assessment studies between these alternative tests and GI endoscopy. Thus, the benefits of this strategy in all scenarios should not be entirely assumed, especially for high-tech less invasive tests that require intense manufacturing and processing. Until further data are available, ESGE-ESGENA encourage less invasive tests for the indications endorsed by evidence-based clinical guidelines (► **Table 4** [48–56]).

STATEMENT

5 ESGE-ESGENA suggest that digitalization, telemedicine, and efficient clinical pathways may reduce the environmental impact of pre- and post-procedural GI endoscopy-related health care.

The current COVID-19 crisis has placed telemedicine as a necessary alternative to face-to-face medical consultations with promising results [57], thereby decreasing direct and indirect contributions to the environmental footprint of health care [58]. Although there is no direct evidence, reasonable esti-

mations from a systematic review suggest that telemedicine reduces the carbon footprint of health care, mainly by lowering transport-associated GHG emissions [59]. The environmental cost of telemedicine equipment was also assessed and was comparatively low.

Telemedicine has great potential to reduce in-person visits related to low-risk procedures or visits intended to communicate GI endoscopy results that do not substantially impact clinical management. However, the efficiency of telemedicine is context-dependent and some patients express an unwillingness to abandon face-to-face medical consultations [57].

Similarly to the strategies explored in GI endoscopy workflow improvement, specific local situations (including infrastructure and patient preferences) should be analyzed to identify actionable factors. The benefits and applicability of telemedicine require more study to assuage fears of misdiagnosis or of uncertainty, leading to the risk of double consultations.

4.1.2 Endoscopic intraprocedural management

The specific intraprocedural factors that determine GI endoscopy's environmental impact include the use of a high volume of single-use consumables, energy and water usage, medications, and tissue sampling requiring histological analysis (► **Fig. 3**).

STATEMENT

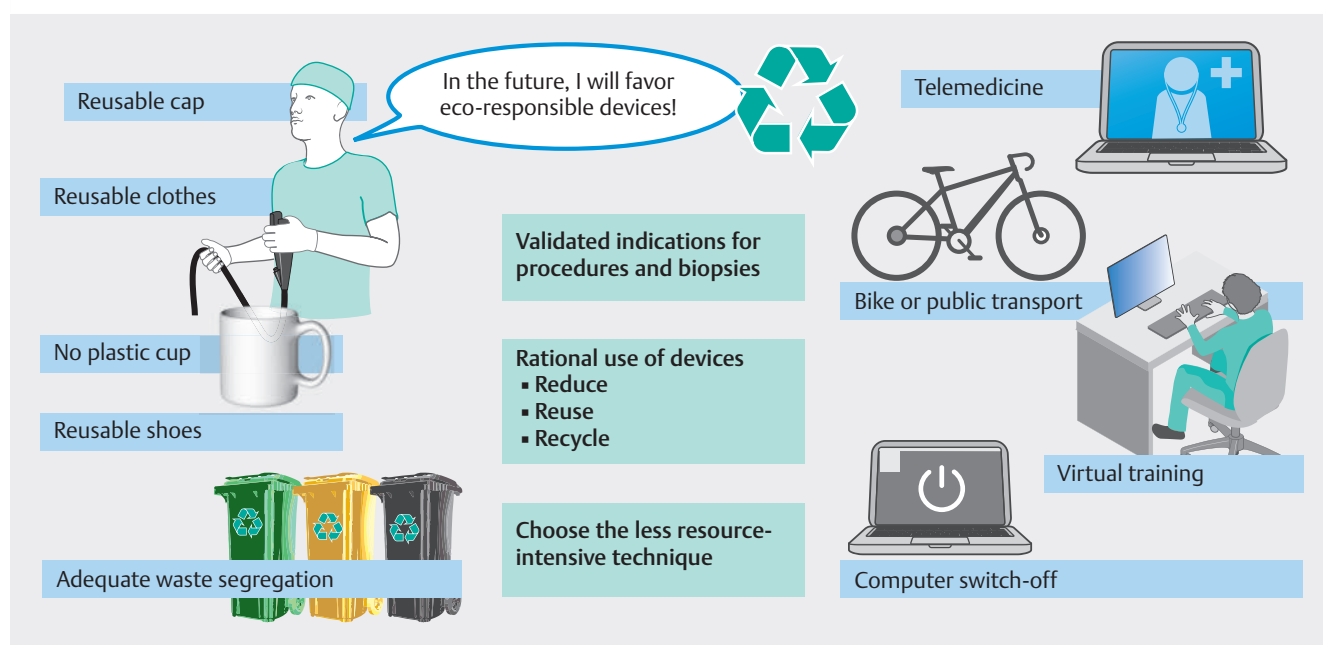
6 ESGE-ESGENA suggest that diagnostic strategies that safely reduce the number of samples sent for histological analysis can reduce the environmental impact. This can be achieved via optical diagnosis and adherence to guidelines on the indications for endoscopic tissue sampling.

The processing of biopsies entails an added energy requirement, generates hazardous waste and is responsible for a significant carbon footprint which increases roughly proportionally to the number of biopsy specimen bottles sent for histological analysis [23]. Endoscopy's histopathological output can be reduced without altering the management of most patients by ensuring that only appropriate biopsies are undertaken [60, 61]. Adherence to such guidelines, along with strategies that safely avoid the need for histological analysis, would likely reduce endoscopy's carbon footprint.

Optical diagnosis is used for mucosal lesions throughout the GI tract, and is integral to diagnose-and-leave and resect-and-discard strategies for managing diminutive colorectal polyps [62]. Both these strategies reduce the number of tissue samples sent for analysis and thereby endoscopy's carbon footprint. ESGE has endorsed the use of optical diagnosis in place of histopathology for diminutive colorectal polyps, under strictly controlled conditions [63], and has subsequently published a curriculum to develop and maintain these relevant skills [64]. While a resect-and-discard strategy is referenced in British guidelines [65], and the findings of a meta-analysis [66] confirm fulfillment of American Society of Gastrointestinal Endoscopy (ASGE) minimum performance thresholds for imaging technologies [67], the practice of these strategies has yet to

► **Table 4** Less invasive tests approved by regulatory agencies as alternatives to gastrointestinal endoscopy.

Less invasive test	Indication endorsed by guidelines	Research
Fecal immunohistochemical testing [48]	Colorectal cancer screening Triage of symptomatic patients in primary health care	Postpolypectomy surveillance in high risk individuals Iron-deficiency anemia Colorectal cancer prognosis Endoscopy waiting list triage
Multitarget DNA stool test	Colorectal cancer screening	Postpolypectomy surveillance
Fecal calprotectin [49, 50]	Chronic diarrhea Monitoring patients with inflammatory bowel disease	Biomarker in other inflammatory diseases Protein-losing enteropathy
Urea breath test [51] Stool antigen test [51]	Diagnosis and eradication of <i>Helicobacter pylori</i>	
Cytosponge [52]	None	Barrett's esophagus Eosinophilic esophagitis
Elastography and platelet count [53]	Screening of esophageal varices in cirrhosis Monitoring liver disease	Noninvasive diagnosis and prognosis of liver disease
Small-bowel capsule [54]	Obscure gastrointestinal bleeding Iron-deficiency anemia Inflammatory bowel disease workup Refractory celiac disease	Monitoring mucosal healing in Crohn's disease
Esophageal and colon capsules [55]	None	Upper gastrointestinal symptoms and bleeding Detection of esophagitis and varices Colorectal cancer screening Postpolypectomy surveillance Incomplete colonoscopy
Transnasal unsedated endoscopy [56]	None	Barrett's esophagus Eosinophilic esophagitis Variceal screening Gastric cancer



► **Fig. 3** The “eco-endoscopist.”

be widely implemented in those countries. Medicolegal concerns, lack of awareness, financial incentives, and patient acceptability are some of the hurdles to their widespread implementation. Substitutes for histopathological analysis will likely expand further with both the evolving indications for endoscopic optical diagnosis, such as in the diagnosis of celiac disease [68], and the growing use of artificial intelligence (AI) systems.

STATEMENT

7 ESGE-ESGENA recommend considering the environmental impact when selecting the appropriate endoscopic technique. The less resource-intensive technique should be favored, provided efficacy and safety are maintained.

STATEMENT

8 ESGE-ESGENA recommend a rational use of endoscopic accessories during the procedure.

STATEMENT

9 ESGE-ESGENA suggest performing most elective endoscopic procedures on an outpatient basis to avoid overnight hospital stays and hence reduce the environmental impact.

Judicious and rational use of GI endoscopic techniques and accessories is also crucial to achieving sustainable practice. In this context, less resource-intensive techniques should be favored, provided efficacy and safety are maintained and their use is supported by current evidence-based clinical guidelines. Thus, ESGE-ESGENA encourage appropriate technique selection to avoid the overuse of procedures that may involve a greater consumption of resources, such as cholangioscopy, endoscopic suturing, full-thickness resection, or endoscopic submucosal dissection (ESD). This strategy should be balanced with the GIRFT (“getting it right first time”) principle that aims to reduce the number of therapeutic procedures that are unnecessarily repeated because a definitive outcome is not achieved in the initial intervention. These concepts extend not only to GI endoscopists but to the whole health care chain, including well-informed patients.

Regarding accessories, in clinical practice prophylactic clipping of polyp resection defects does not always adhere to current recommendations and its overuse should be discouraged [69]. In this sense, determining the average need of accessories per procedure and periodically revisiting the number of accessories used could help to reduce waste and gain efficiency. Favoring cold snare polypectomy and underwater endoscopic mucosal resection (EMR) in validated indications could reduce the procedural carbon footprint. Cold snare polypectomy

avoids the use of an electrosurgical unit and a disposable electrode pad. Underwater EMR avoids the use of an injection needle, a syringe, and submucosal solution, as well as the packaging of all these accessories. There is currently little published experience on the reuse of GI endoscopy accessories (e.g., injection needle, biopsy forceps, polypectomy snare, etc.) within the same or combined procedures (e.g., gastroscopy followed by colonoscopy). In the absence of safety or efficacy concerns, prioritizing the reuse of GI endoscopy accessories within a single procedure should be encouraged (e.g., using the same polyp snare for the resection of small polyps or the same biopsy forceps for duodenal and gastric biopsies).

The use of sterile or potable tap water in irrigation bottles is a matter of ongoing debate and has environmental and financial relevance. The rationale for the use of sterile water is that the concentration of pathogenic microorganisms in tap water may exceed the infectious dose and thus cause disease. A recent multisociety guideline and ESGE-ESGENA guidelines recommend using sterile water following manufacturers' instructions, based on low quality evidence [70,71]. In the absence of a manufacturer's recommendation, the endoscopy unit should perform an independent risk assessment for using sterile versus clean tap water for standard endoscopic procedures in which mucosal penetration would be unusual [70]. Given the concern regarding infection in selected patients, this multisociety guideline suggests that sterile water should be the primary water source, especially for those procedures with anticipated traversing of GI mucosa [70]. Conversely, some authors advocate using potable tap water because most microorganisms in tap water are nonpathogenic and do not cause disease except in unusual circumstances [72]. Outside endoscopy practice, randomized controlled trials (RCTs) have shown no difference between the use of tap water and saline in the rates of infection and healing in the cleansing of wounds [73]. In addition, the exposure of the nonsterile GI lumen to potential pathogens would theoretically be the same when water is ingested before or after the GI endoscopic procedure. Furthermore, two studies support the idea that using tap water is safe and found that the rate of positive water cultures was similar to that of sterile water [74,75]. The only published reports on transmission of infection by water identified unsterilized irrigation water bottles as a source of infection [72]. Underwater EMR and water-exchange colonoscopy have been performed using clean tap water without any safety concerns [76,77], although the type of water has not been formally compared in any study and was overlooked in a recent international consensus study [78]. Finally, there are no direct data showing that the use of potable tap water increases the risk of infection for patients. Thus, the idea of a universal need for sterile water deserves to be revisited and future guidelines should weigh clinically relevant infection risks, costs, and environmental concerns.

Finally, most elective GI endoscopic procedures should be performed on an outpatient basis, as hospitalization for a procedure incurs more resource consumption and CO₂ emissions [79]. Several reports support that well-selected high risk procedures, including ESD [80], peroral endoscopic myotomy [81], or endoscopic retrograde cholangiopancreatography (ERCP) [82]

can be performed safely without hospitalization. Comorbidity, risks of the procedure, and accessibility to health care in case of an adverse event should be considered when deciding the need for admission.

4.2 Endoscopy logistics: a sustainable structure and functioning of the GI endoscopy unit

STATEMENT

10 ESGE-ESGENA recommend applying the principles of sustainable architecture to the design and construction of GI endoscopy units.

STATEMENT

11 ESGE-ESGENA suggest implementing an accreditation process for GI endoscopy units that embraces sustainability.

STATEMENT

12 ESGE-ESGENA recommend favoring the use of renewable energy at GI endoscopy units. This goal should be achieved in the context of local and national policies.

No studies have assessed the most efficient and sustainable structure of a GI endoscopy unit. However, some data are available from studies on carbon footprint reduction in the operating room [83–85]. The design and the functioning of the endoscopy unit as proposed by current guidelines do not consider the issue of sustainability [71, 86, 87]. ESGE-ESGENA advocate incorporating the principles of sustainable architecture and efficient energy management at every step of this process and suggest implementing an accreditation process for GI endoscopy units that includes sustainability [88–91]:

- **Location.** There are no studies comparing the environmental impact of hospital-based versus out-of-hospital GI endoscopy units. Location should take into account local needs (e.g., low risk versus high risk procedures, number of procedures, etc.) and legislation, population density, costs, adaptability to changing climate conditions, and local biodiversity. The endoscopy unit should be easily accessible by public transportation and located in proximity to patients to minimize travel needs.
- **Use of sustainable, long-life, and nontoxic building materials.**
- **Heating, cooling, and ventilation.** Overcooling and overheating are responsible for billions of tons of CO₂ emissions worldwide [92]. The optimal temperature and humidity of the endoscopy room have not been established [93]. Local protocols and use of sensors should aim at maintaining a temperature that takes into account infection control, patient and provider comfort, and energy demands.
- **Use of renewable energy sources.** It has been estimated that 10%–30% of the environmental impact related to an

operating room-based surgery comes from electricity consumption [94]. Promoting renewable energy at an institutional level should be prioritized.

- **Efficient workflow and use of space.** This concept includes a structure that assures an optimal flow of patients, endoscopy unit personnel, and supplies; and avoids empty, unused, spaces. Endoscopy rooms that are not in use should be put into a “sleep” mode to conserve energy, and a plan for better use of this space implemented. An optimal workflow is crucial for optimizing the efficiency of the endoscopy unit. The following measures can improve efficiency: having dedicated staff for performing intravenous access and for obtaining informed consent before the patient enters the endoscopy room; utilization of block scheduling; minimizing room turnover times; fluent communication among staff; and consideration before scheduling of the types of sedation to be administered [95]. Instead of morning-only activity, morning and evening shifts have been adopted by several GI endoscopy units, and this seems to be a reasonable strategy to cope with the growing demand for GI endoscopy without increasing the number of endoscopy rooms [96]. A meta-analysis suggests that colonoscopy quality is not affected by the time of the day, provided that endoscopists do not perform full-day shifts [97].
- **Efficient use of natural resources.** The unit should incorporate natural light in most rooms as much as possible. Water efficiency is paramount and can be achieved via low water consumption equipment for disinfection and reprocessing, efficient laundry, and low-flow toilets in patient spaces [91].

STATEMENT

13 ESGE-ESGENA recommend the embedding of reduce, reuse, and recycle programs in the GI endoscopy unit.

STATEMENT

14 ESGE-ESGENA recommend revisiting waste management in the GI endoscopy unit to ensure adequate segregation and processing policies. The 3R (Reduce-Reuse-Recycle) and circular economy principles should be the core of these policies.

STATEMENT

15 ESGE-ESGENA recommend the digitalization of the GI endoscopy unit (including electronic reporting), minimizing paper printing, and using energy-efficient endoscopy and electronic devices.

STATEMENT

16 ESGE-ESGENA recommend establishing local protocols and environmental educational programs for personnel to practice in an environmentally friendly and sustainable way.

- **Waste management.** The majority of health care waste (approximately 85%) is nonhazardous and similar to domestic waste, which means that much of it could be recycled [98, 99]. Poor medical waste management has a deleterious economic and ecological impact [19, 22, 100]. GI endoscopy waste is often handled inappropriately [101], and materials and packaging are rarely recycled [19, 22, 100]. Placing labels on waste containers to facilitate segregation and incorporating recycling bins in the GI endoscopy unit are actions that can be easily implemented.

In a survey of 783 GI endoscopy staff members, only 0.6% understood waste disposal costs, over a third disposed waste inappropriately, and 98% felt that medical personnel should be better informed about medical waste management [101]. Consequently, adequate waste segregation and revisiting institutional waste management policies are integral to the concept of green GI endoscopy.

The guiding principles for future sustainable health care waste management include: application of the 3Rs (Reduce–Reuse–Recycle) (► **Table 2**); phasing down incineration; ensuring toxicity-free waste; ensuring worker protection; implementing circular economy principles; and ultimately achieving zero waste (► **Fig. 2**) [98, 99]. Further details on sustainable health care waste management can be found elsewhere [98, 99].

- **Disinfection and reprocessing.** There is a need to examine the environmental impact of our reprocessing processes and to implement sustainable practice. This includes efficient energy and water use in washer-disinfectors and using process chemicals that have an environmentally friendly value [71].
- **Digitalization.** The digitalization of GI endoscopy-related health care data, reports, and patient letters can benefit the environment [102]. ESGE-ESGENA recommend minimizing use of paper, printing double-sided if printing is needed, and using paper products that are made from recycled material and nonbleached (chlorine bleach releases toxic dioxins into water). Use of 100% recycled paper is claimed to reduce GHG emissions by 37% and water use by 50% [103].
- **Energy efficiency of electronic devices.** This includes GI endoscopy systems and all electronic devices in the unit (computers, monitors, endoscope reprocessors, etc.). Room lighting can consume more energy than endoscopy itself [21]. Thus, LED lighting or energy-saving light bulbs should be preferred. Energy consumption is lessened by switching lights off, and turning off computers (or placing them in “sleep” mode) and also printers, coffee machines, etc., during extended breaks and at the end of the day [21, 104].

Units should consider installing motion sensors to switch off lights. Automatic control of lighting using daylight-dimming and occupancy sensors leads to major energy savings [105].

- **Staff education.** Implementation of sustainable endoscopy practice requires GI endoscopy team members to re-examine their habits, modify them if needed, and become educated about the abovementioned aspects. Members of the endoscopy team can further contribute outside the endoscopy unit by using public transportation to get to work. Making a public commitment towards environmentally sustainable practice in the endoscopy unit in the form of a guidance document sends a clear message to staff, patients, and visitors that the unit cares about the climate crisis, and that all the agents involved in the health care chain can do something about it [90].

4.3 Single-use products

4.3.1 Single-use accessories

STATEMENT

17 ESGE-ESGENA recommend that future clinical guidelines and regulations on GI endoscopy reprocessing/disinfection should consider the environmental impact of these practices and that of single-use devices.

STATEMENT

18 ESGE-ESGENA suggest that there is an urgent need to reassess and reduce the environmental and economic impact of single-use GI endoscopic devices. GI and endoscopy societies should collaborate with industry to minimize the environmental burden of single-use devices.

A “single-use” device is defined as a medical device intended to be used on one individual during a single procedure. The “single-use” label is solely based on the decision of manufacturers [106]. The following GI endoscopy accessories have been marketed as reusable and are still available in some places:

- bougie dilators [107–109]
- biopsy forceps [110–112]
- band ligation devices [113]
- sphincterotomes [114–118]
- baskets for stone retrieval [118, 119]
- reloadable clip applicators [120]
- suction and air valves [121]
- snares, guidewires, and balloon expanders [121]
- personal protective equipment [122].

There has been a shift towards the increasing use of single-use accessories in the last two decades. The environmental impact of this transition in GI endoscopy has not been formally addressed and lacks solid scientific background. Data from the anesthesia community indicate that the widespread use of single-

use medical devices in the operating theatre does not significantly reduce patients' risk of infection but has a greater financial, environmental, and social impact than use of reusable devices [123].

Despite the strong recommendation of ESGE-ESGENA guidelines for using single-use endoscopic accessories whenever possible [71], and particularly when the epithelial barrier is penetrated [121], the real risk of infection transmission due to reusable accessories remains controversial [114]. The 2010 ASGE Technology Committee guideline on ERCP cannulation and sphincterotomy devices [124], claims that reprocessed reusable devices offer potential cost savings when available and adequately reprocessed [118]. Several studies support the idea that reusable devices are safe when adequately reprocessed [112, 114–118]. Worldwide, although several infection outbreaks have occurred that were related to duodenoscope reprocessing [125–128], this has never been described with reusable devices. Furthermore, the reuse of surgical instruments has demonstrated a reduction of 10% of GHG in a surgical study [129].

On the other hand, other studies suggest that the risk of infection is not null [110, 111, 113, 130]. Consideration should also be given to the loss of function of devices after the reprocessing procedure [121]. Also, reprocessing has itself an environmental burden that should be acknowledged.

Reprocessing of single-use devices is forbidden in some but not all EU countries [131]. Current EU legislation mentions that reprocessing of devices should only take place where permitted by national law and mostly with reusable devices. "Reusable" here means tested by the manufacturer with the demonstration that the device ensures an equivalent level of safety and performance to the corresponding initial single-use device [30]. Nevertheless, Regulation (EU) 2017/745 allows member states not to apply all of the rules relating to manufacturers' obligations laid down in that Regulation. One of the conditions for such reprocessing is that it is performed under common specifications. In particular, the reprocessing cycle should be based on the characteristics of the single-use device and the results of a technical assessment.

Recommendations on single-use GI endoscopy reprocessing are beyond the scope of this document. Yet, current clinical guidelines fail to consider sustainability [70, 71, 132]. ESGE-ESGENA recommend that future guidelines and legislation on GI endoscopy reprocessing/disinfection should take this domain into account.

The environmental and economic impact of waste generated by single-use devices is high. Proactive collaboration between endoscopy societies and manufacturers to provide single-use devices more responsibly is needed. For instance, the weight and dimensions of packaging and the amount of material used should be examined. Extensive printed user instructions are no longer justifiable; instructions for use and guarantee documents represent around 30% of the total weight for some devices, mainly in paper which is not always recycled. A QR code instead of a printed manual for each device is preferable. Creation of an environmental score for each GI endoscopy device based on its life cycle (similar to the Nutri-

Score for the nutritional value of food) could be of value in helping to choose the most ecologically desirable devices.

STATEMENT

19 ESGE-ESGENA suggest using GI endoscopy devices that have an environmentally sustainable design (e.g. reloadable clips or band ligators).

The concept of reuse is an integral part of sustainability. Some single-use devices can be reloaded so that the whole device is not entirely disposed of with each use [120]. This is the case with clips that are available in a single-use but reloadable version. The same handle (<80 g) can be used to reload clips during the same procedure (waste weight between 5 g and 10 g) instead of using a single-use device with a measured waste weight of more than 80 g for each clip. The same principle applies to reloadable esophageal variceal band ligators [120, 133].

4.3.2 Single-use endoscopes

STATEMENT

20 ESGE-ESGENA suggest against routine use of single-use endoscopes. However, their use could be considered in highly selected patients, on a case-by-case basis.

The main arguments in favor of single-use rather than reusable endoscopes have been reduction in the risk of infection and greater cost-effectiveness, from a hospital viewpoint. We reviewed the literature to determine the risk of infection with reusable endoscopes and appraised the available data on single-use endoscopes. Data are limited, heterogeneous, and with potential for both overestimation and underestimation:

1 Endoscopy-related infection. There is no consensus on what constitutes an endoscopy-related infection [126, 134]. The estimated risk ranges from 1 in 20 000 to 1 in 1.8 million procedures [135, 136]. However, some cost-effectiveness analyses of single-use endoscopes have used a much higher figure for risk, which may have led to overestimates of the true cost-effectiveness [137–139]. The risk of a clinically relevant infection is probably very low since multiple steps are needed (i.e., high enough infectious load leading to bacteremia and bypassing the immune system). This is further complicated because some of these conditions may already be present in the patient or inherent to the ERCP and might not impact clinically relevant outcomes. For instance, in an RCT that evaluated the need for antibiotic prophylaxis for endocarditis, the authors reported bacteremia in 23% of patients after brushing teeth and 60% after tooth extraction, suggesting that bacteremia is mostly inconsequential [140].

2 Endoscope contamination and infection risk. Using contamination of the endoscope as a surrogate marker for infection risk to patients is fraught with inaccuracies and variability. Most studies have centered around duodenoscopes because of their complex tip design and difficulty in cleaning. Between 2008 and 2018, there were 24 reported clusters of duodenoscope-associated multidrug resistant microorganisms, including 490 infected patients and 32 deaths worldwide [141]. In a subsequent systematic review, the calculated minimum estimated duodenoscope-associated infection risk was 0.01% and the minimum estimated duodenoscope-associated colonization was 0.023%–0.029% [142]. However, a potential risk of infection is inherent with all endoscopies. Ofstead et al. assessed endoscope reprocessing at three hospitals and detected contamination in 71% of endoscopes [143]. They examined 45 endoscopes, of which only 5 were duodenoscopes. This study suggests that contamination of the endoscope rarely translates into clinical infection.

3 Basis of cost-effectiveness analyses. Available cost-effectiveness analyses are written from a hospital perspective when considering costs related to capital equipment, reprocessing, maintenance, and potential post-endoscopic infections [144]. These analyses assume a high rate of endoscope-related infection (~1%) and high costs of infection treatment in the intensive care unit [137, 138]. The convenience and low cost of using single-use endoscopes for a hospital should not be conflated with a possible reduction of endoscope-associated infections since the beneficiaries are different.

4 Infection risk and human error. Infection risk is, to a large extent, due to human error during reprocessing. Inadequate reprocessing and nonadherence to protocols have been reported with endoscope-related infections [126]. An international survey identified a large variation in endoscope-reprocessing practices [145]. While infection risk cannot be eliminated entirely with adequate reprocessing, it can be substantially reduced [126]. Standardized education and training programs that include a competency assessment, as well as periodic auditing, and researching more effective methods of endoscope reprocessing have the potential to reduce infection rates even further. Reinforcing the importance of hand hygiene and other basic hygiene measures is crucial, whether or not single-use or reusable endoscopes are employed. These interventions are often overlooked in routine clinical practice and impact the risk of infection [146].

5 Societal impact of single-use endoscopes. It is essential to review the consequences of adopting single-use endoscopes from a societal perspective (economy, environment, and social justice). For example, the cost of a single-use duodenoscope ranges from 1900 to 4000 USD (approximately 1700–3600 EUR) [139, 147], and for all the ERCPs performed, the total additional cost load to health care systems would be billions of euros. This might lead to difficult decisions related to the reallocation of already limited resources, paring of certain medical services, or more financial burden on patients. From an

environmental perspective, it is estimated that switching to single-use endoscopes would increase waste by 40% [22]. The carbon footprint of single-use endoscopes remains to be determined, but it is probably substantial. A recent preliminary study estimated that a single-use duodenoscope consumes 467 MJ and releases 29.3 kg of CO₂, 20 times more than a reusable one or a duodenoscope with disposable end caps (23.4 MJ and 1.37 kg CO₂) [24]. Disposable end caps and sheaths are available for some marketed duodenoscopes and could reduce infection risk, but more data are still needed [148].

6 Benefit for selected patients. It has been proposed that immunocompromised patients or those with multidrug-resistant bacteria are likely to benefit from single-use endoscopes, but the theoretical advantages of this strategy remain to be proven in comparative studies [149]. Available data on single-use endoscopes, mainly duodenoscopes (► Table 5, ► Table 6), comprise cost-effectiveness analyses based on heterogeneous assumptions [137–139] and studies limited to reports of technical feasibility and procedural safety [152, 154, 157–161].

Summary. Thus, the available data indicate that clinically relevant endoscope-related infection risk after adequate endoscope reprocessing is probably minimal, although not zero. The approach to endoscope-related infections needs to follow the principle of ALARP (“as low as reasonably practicable”) [162] so that the economic, environmental, and social costs in trying to reduce the risk to zero do not outweigh the benefit gained. A more robust and consensus-driven definition of endoscope-related infection is needed. Data based on life cycle assessments of single-use endoscopes and comparative studies focused on clinically relevant outcomes are mandatory before formal recommendations can be made about their routine use. At present, the employment of single-use endoscopes in highly selected cases might be considered individually. Nevertheless, evidence showing a net benefit is lacking and insufficient to make recommendations.

4.4 Education and training

4.4.1 Incorporating the environmental dimension into curricula and training for GI endoscopy

STATEMENT

21 ESGE-ESGENA recommend embedding sustainability into the curricula of GI endoscopy.

STATEMENT

22 ESGE-ESGENA recommend conducting research into the environmental impact of GI endoscopy training. Waste reduction and awareness of the environmental costs during training are ethically linked to the notion of high quality GI endoscopy.

► **Table 5** Studies on single-use duodenoscopes: Cost–effectiveness analyses.

First author	Methodology	Assumptions	Results	Conflict of interest (COI), or funded by manufacturer of single-use endoscopes
Barakat [137]	Cost–utility analysis from facility viewpoint Outcomes: costs of different strategies (disposable cap, single or double high level disinfection [HLD], ethylene oxide, culture and hold, disposable duodenoscope) at different infection rates	<ul style="list-style-type: none"> Residual contamination after reprocessing not given Transmission risk from infected endoscope: 30 % Infection risk after transmission: 50 % Treatment of infection (cholangitis): \$375 000 Cost of single reprocessing: \$131 Cost of disposable endoscope: \$2991 Post ERCP lifespan: 7 years QALY value: \$100K 	At infection rate of <1 %, disposable cap had the best cost–utility Disposable endoscopes preferred over single or double HLD at all infection rates Results not robust across sensitivity analyses Assumptions based on single studies or expert opinion. Results may change significantly with changes in these assumptions.	Not mentioned in journal pre-proof article. In other articles authors have disclosed research support from companies that manufacture single-use scopes.
Das [139]	Cost–effectiveness analysis from patient viewpoint Outcomes: Compare cost and QALYs of methods of reprocessing (single HLD, ethylene oxide, culture and hold) to reduce contamination risk of duodenoscope	<ul style="list-style-type: none"> Residual contamination after reprocessing: 6 % Transmission risk from infected endoscope: 40 % Infection risk after transmission: 30 % Treatment of infection (cholangitis): \$40 000 (additional probability ICU costs) Cost of single reprocessing: \$200 Cost of disposable endoscope: \$3000 Risk of long-term colonization: 40 % Willingness to pay: \$100 000 	HLD was least costly and disposable duodenoscope was the costliest. Incremental cost–effectiveness ratio for disposable duodenoscope was \$62 185	Yes
Travis [138]	Microcosting analysis to determine cost of ERCP using reusable duodenoscopes. Data from 7 endoscopy units under one health care system in the United States	<ul style="list-style-type: none"> Cost of reusable duodenoscope: \$45 000 Cost of reprocessor (AER): \$35 400 Annual AER maintenance: \$5000 Annual endoscope repair cost: \$2500 Risk of infection from using reprocessed endoscope: 1 %–1.2 % Treatment of infection: \$47 181 	Total per procedure cost: <ul style="list-style-type: none"> 50 procedures/year, \$2729 > 750 procedures/year, \$1292 	Yes
Sahu [150]	Cost–minimization model to determine procedure cost with reusable endoscope and disposable sheath systems vs. single-use endoscopes. Only presented as conference abstract.	<ul style="list-style-type: none"> Cost of reusable duodenoscope (average): \$56 135 Annual cost of reprocessor (AER): \$8166 Annual cost of maintenance: \$140 337 Life of endoscope: 3 years Total cost/procedure: \$687 Cost of disposable endoscope: \$3500 	Total per procedure cost: <ul style="list-style-type: none"> reusable endoscope, \$687 single-use endoscope \$426 Infection risk not considered	COI or funding not detailed in the abstract.

HLD, high level disinfection; QALY, quality-adjusted life-year; ERCP, endoscopic retrograde cholangiopancreatography; ICU, intensive care unit; AER, automated endoscope reprocessor.

► **Table 6** Studies on single-use duodenoscopes: Clinical studies.

First author	Study design	Sample size	Results	Infection risk compared with reusable endoscopes	COI or funded by manufacturer of single-use duodenoscopes
Napoléon [151]	Prospective case series Outcomes: completion rate, safety, operators' satisfaction	60	Completion rate: 95 % High operators' satisfaction Adverse events: 5 %	No	Yes
Lisotti [152]	Meta-analysis Outcomes: Technical success and adverse events	4 studies [151, 153, 155, 156] 381 patients	Technical success: 92.9 % Adverse events: 6.4 % Serious adverse events: 5.9 %	No	Yes
Muthusamy [153]	Case series Outcomes: feasibility, preliminary safety, performance	73	Procedure completion rate: 96.7 % Adverse events: 6.8 % Median overall satisfaction: 9/10	No	Yes
Ross [154]	Bench simulation study Outcomes: ability to complete tasks, subjective ratings, image quality, maneuverability	Preclinical study 3 reusable duodenoscopes vs. 1 single-use duodenoscope	Similar task completion times, tip control, and overall performance rating. Navigation was worse for the single-use duodenoscope.	No	Yes
Bang [155]	Randomized controlled trial Outcomes: number of attempts to achieve successful cannulation, crossover rate, maneuverability, adverse events	98	Single-use endoscopes required fewer attempts for successful cannulation. Ease of passage into stomach, image quality and stability, and air–water button functionality were significantly worse for single-use scopes Similar safety profile	No	Yes
Slivka [156]	Prospective case series Outcomes: completion of the procedure, crossover rate to another endoscope, device performance ratings, and serious adverse events.	200	Crossover rate: 9.5 % Adverse events: 6.5 % Similar results for experts and nonexperts High device performance ratings	No	Yes

COI, conflict of interest.

Several organizations and institutions already advocate integrating consideration of planetary health into medical and clinical education [4,163]. Recently, the Association for Medical Education in Europe has developed a consensus statement to promote and outline the structural changes required [164]. While there are no data on the specific impact of training and educational activities of GI endoscopy, it is evident that it is associated with considerable environmental costs. The lack of research and awareness of this dimension of endoscopic practice argues for action by dedicated professional societies. Incorporating sustainability in endoscopy training is likely to influence the everyday practice of current and future GI endoscopists by optimizing resource utilization [19]. Raising awareness has been shown to be effective in other disciplines such as laparoscopic pediatric surgery, where giving individual surgeons a monthly report card that detailed the utilization and cost of disposable, high cost surgical supplies reduced the use of disposable trocars by 56% [165]. Recommendations on

environmentally friendly training alternatives, correct use and disposal of GI endoscopy devices [101], and overall attention to environmental issues can contribute to the ethical mindset of developing endoscopists. The incorporation of sustainability into the curricula of GI endoscopy requires the allocation of dedicated material, human, and time resources for trainers and trainees.

4.4.2 Reducing the carbon footprint during training and educational activities

STATEMENT

23 ESGE-ESGENA recommend that GI endoscopy training should be undertaken in structured, auditable programs and take into account local availability of endoscopy simulators and on-site/off-site teaching modules. Adoption of teaching strategies that shorten the learning curve and ensure safe and efficient procedures is essential to reduce unnecessary waste during training.

STATEMENT

24 ESGE-ESGENA suggest that virtual training and online educational modalities can reduce the environmental impact of GI endoscopy.

High quality training programs for fellows are an essential part of health care systems but incur significant material costs, due to potential prolongation of procedure time and hospitalization [166,167], use of additional materials and instruments, or the need for dedicated spaces and equipment such as simulators [168]. While the structure and objectives of GI endoscopy training programs are highly variable across health care systems, strategies that reduce skill acquisition time and accelerate the learning curve are most likely to reduce the carbon footprint associated with training activities. Simulator training has been shown to be beneficial, especially in early skill acquisition, and may reduce procedure time and costs when trainees transition to procedures involving patients [169]. There is no consensus on the optimal type of simulator, and existing models offer different advantages and disadvantages from an ecological standpoint (e.g., reusability, need for explanted organs or live animals, electricity usage, etc.) [169].

Educational activities such as courses, congresses, and workshops contribute to the environmental footprint mainly due to transport-associated CO₂ emissions, redundant paper-based documentation, and avoidable items (e.g., leaflets, programs, advertisements, bags, cards, etc.) [170]. A recent life cycle assessment study concluded that the environmental impact of a virtual conference would be significantly less (4 tons CO₂ equivalent) than that of a traditional international face-to-face conference (192 tons CO₂ equivalent) [171]. In this sense, live endoscopy events are valuable educational activities that show a real-time approach to a clinical case by experts and minimize travel needs [172]. Adopting virtual/hybrid formats and electronic documentation where possible can contribute to the reduction of the carbon footprint.

Finally, responsibility in the choice of trainers for educational events could also reduce travel by encouraging the participation of local rather than foreign experts when local competence is available.

4.5 Green quality

4.5.1 Reducing the environmental impact of GI endoscopy by adherence to quality guidelines

STATEMENT

25 ESGE-ESGENA suggest that the implementation of and adherence to quality measures for GI endoscopy can reduce its environmental impact.

Our search did not find any study that directly assessed the impact of adhering to endoscopy quality guidelines on environmental outcomes. ESGE has been promoting quality in GI endoscopy since 2013 [173], and it is conceivable that adherence to key performance measures (KPMs) does not only improve patient outcomes [173], but also has a beneficial effect on the environment. Many of the ESGE KPMs focus on *doing less yet doing it better*. Thus, compliance with the following endoscopy service [41] and individual KPMs is expected to translate into a reduction in environmental impact:

- Appropriateness, as previously mentioned, increases the yield of endoscopy and reduces the number of unnecessary procedures [36,37].
- Adequate fulfillment of KPMs for pre-endoscopy (i.e., rate of adequate bowel preparation >90% [174] and correct instructions for fasting >95% [175]) and for completeness of procedures (i.e., cecal intubation rate >90% [174], bile duct cannulation >90% [176], etc.), followed by proper management and identification of pathology, reduces the number of repeated procedures and allows adequate follow-up intervals. Standardized photo and video documentation facilitates referral and planning of therapeutic intervention, and potentially avoids repeated diagnostic procedures. The use of artificial intelligence (AI) during routine colonoscopy has the potential to improve the quality of endoscopy, particularly to assure a procedure's completeness [177]. Recent technological developments indeed enable automated assessment of bowel preparation and blind spots during endoscopy [178]. This is an additional effect that needs to be considered when calculating the cost-effectiveness of AI implementation in daily practice.
- Adequate endoscopist and staff training. Adherence to guidelines only translates into patient benefits if the endoscopist KPMs are met. These criteria include a high polyp detection rate and ability to remove polyps with regard to screening colonoscopies, or sufficient inspection time and appropriate biopsy sampling for specific conditions.
- Systematic electronic reporting. The first publication of the ESGE Quality Improvement Committee was on the prerequisites of electronic reporting systems and the need to develop these for measuring quality [179]. To facilitate quality assurance and, as a secondary effect, reduce endoscopy's carbon footprint, it is pivotal that quality assurance and automated guideline recommendations are incorporated into GI endoscopy reporting systems.

- Periodic inspection, calibration, and maintenance of facilities and equipment, especially decontamination and reprocessing circuits, are mandatory for energy-efficient service [41].

4.5.2 Sustainability as a new domain of high quality GI endoscopy

STATEMENT

26 ESGE-ESGENA recommend including sustainability as a quality domain for GI endoscopy.

Sustainability can be considered a part of quality health care [13]. Indeed, several health care organizations have already included sustainability as a critical domain of their conceptual quality framework [13]. Recently, the implementation of quality improvement in gastroenterology has been proposed to obtain a more environmentally sustainable delivery of endoscopy by the National Health Service in the United Kingdom [13, 46]. The process of developing environmental KPMs in endoscopy is beyond the scope of this document. Nonetheless, ESGE-ESGENA acknowledge that this is an unmet need that should be addressed in the coming years. Potential KPMs to be considered in the future are CO₂ emissions; waste; energy and water expended per endoscopy procedure [22]; mass of recycled and of total waste; renewable energy as a percentage of total energy used in the GI endoscopy unit, etc.

4.6 Green research and guidelines

4.6.1 Defining the roadmap for sustainable research in GI endoscopy

STATEMENT

27 ESGE-ESGENA should encourage and fund research into “green and sustainable” GI endoscopy.

STATEMENT

28 ESGE-ESGENA recommend conducting high quality research to quantify and minimize the environmental impact of GI endoscopy.

STATEMENT

29 ESGE-ESGENA recommend incorporating the principles of sustainability into every GI endoscopy research project. The study design should consider the environmental impact of the research.

► **Table 7** Actions for reducing the environmental impact of GI endoscopy research [164, 166–168].

Research phase	Action
Conception and rationale	<ol style="list-style-type: none"> 1. Acknowledge sustainability as a core element of every research project. 2. Review the evidence systematically and check public study registries to avoid overlapping research. 3. Balance the pertinence and strategic relevance of the project within a multidisciplinary team. Involve patients and clinicians to define outcomes.
Design	<ol style="list-style-type: none"> 1. Estimate an “efficient” sample size. 2. Design a statistical analysis plan before the study outset. 3. Involve methodologists. 4. Consider including environmental parameters as primary or secondary outcomes. 5. Take into account the environmental impact of the project. 6. Carefully consider the requirement for human and material resources. 7. Minimize travel requirement of the research team and the study population. Encourage public transport. 8. Restrict visits and complementary tests to what is strictly necessary for study purposes. 9. Consider replacing on-site visits with phone or virtual visits. 10. Consider the pertinence of answering more than one research question (e. g., factorial design or including an observational phase after a randomized controlled trial). 11. Reduce bureaucracy where possible.
Data collection, recruitment, and monitoring	<ol style="list-style-type: none"> 1. Avoid unnecessary data collection. 2. Use paperless web-based case report forms and databases. 3. Use systematic, electronic, and centralized systems for auditing and monitoring the study. 4. Avoid unnecessary monitoring visits. 5. Consider conducting a carbon audit. 6. Transfer eco-friendly attitudes (Reduce-Reuse-Recycle) from home to the research project.
Reporting	<ol style="list-style-type: none"> 1. Discuss the potential environmental impact of the results and raise awareness when possible. 2. Disseminate the results rapidly to avoid overlapping research. 3. Ensure that the information provided is reproducible and usable to other researchers. 4. Limit the number of on-site congresses where research is presented.

The task of minimizing the environmental impact of GI endoscopy starts with improving our understanding of the ecological impact of all its practices, procedures and devices. Research addressing these questions with regard to GI endoscopy is currently anecdotal [47]. Moreover, it is frequently overlooked that research activities themselves have a substantial carbon footprint. The Sustainable Clinical Trials Group has shown that RCTs generate hundreds of tonnes of CO₂ [180]. As

an example, ClinicalTrials.gov has about 350 000 registered trials, which would generate CO₂ emissions of an estimated 27.5 million tonnes, almost equal to the total CO₂ emission of Switzerland (8.7 million population) in 2020 [181,182]. Many of these emissions come from travel and are probably preventable [180]. A pertinent and thorough study design increases scientific validity and may also reduce the carbon footprint by increasing research efficiency [181].

ESGE-ESGENA should actively promote and support research that will allow us to understand the carbon footprint of GI endoscopy and help identify ways in which this impact can be minimized. To achieve this goal, ESGE-ESGENA favor not only including the concept of sustainability into every GI endoscopy research project (► **Table 7**) [181,183–185], but also the performance of research specifically focused on environmental outcomes. While medico-economic dimensions may now be incorporated into research protocols, medico-ecological ones are not currently considered [186]. However, ecological impact should become a criterion [11,186–188] in the choice of research strategy [85,188–190]. A research agenda focused on the most urgent topics is proposed in ► **Table 8**.

4.6.2 Incorporating sustainability when grading the strength of recommendations

STATEMENT

30 ESGE-ESGENA recommend taking into account environmental impact when grading the strength of recommendations in GI endoscopy guidelines.

STATEMENT

31 ESGE-ESGENA suggest defining specific PICO (population/problem, intervention, comparison, outcome) questions to evaluate the environmental impact of guideline recommendations. In the absence of evidence, ESGE-ESGENA recommend highlighting the need for research to examine the environmental impact of the GI endoscopy guideline.

Many guidelines in all fields of medicine fail to consider resource utilization and the potential clinical and environmental harms that can derive from their recommendations [191]. The Grading of Recommendations Assessment, Development and Evaluation (GRADE) system, which is currently used by most GI endoscopy guidelines, does not directly cite sustainability. However, it places resource use as a binding domain that contributes to the strength of recommendation (the more resource consumed, the less likely a strong recommendation is made) [192]. The recently established Cochrane Sustainable Health care group aims to reduce medical excess and underpin a needed shift towards an evidence-based synthesis process that weighs and prioritizes the environmental impact of medical actions [191]. Increased attention to all steps of the evidence chain is required to adequately balance the multifaceted effects of an

► **Table 8** Environmental research priorities in gastrointestinal (GI) endoscopy.

1	Strategies to reduce unnecessary GI endoscopic procedures and interventions and to lengthen follow-up intervals.
2	Define environmental outcomes related to the field of GI endoscopy.
3	Quantify the environmental impact of reusable GI endoscopes and accessories and identify strategies to reduce their carbon footprint.
4	Quantify the environmental impact of single-use GI endoscopes, and single-use accessories, and identify strategies to reduce their carbon footprint.
5	Quantify the environmental impact of GI endoscope reprocessing and identify strategies to minimize its carbon footprint.
6	Identify the carbon footprint of all types of GI endoscopic procedures at a per-procedure level.
7	Develop strategies for effectively reducing, reusing, and recycling all GI endoscopy-related equipment and waste.
8	Environmental impact of activities and practices related to training in GI endoscopy.
9	Define environmental key performance measures for green quality.
10	Telemedicine in GI endoscopy.

intervention. While acknowledging that there is minimal evidence on how to introduce the environmental impact of endoscopy into GI endoscopy guidelines, ESGE-ESGENA support that a change in mindset is required during the guideline development process in order to achieve sustainable health care.

4.7 Industry, health insurers, and health care providers

4.7.1 Encouraging companies to declare the environmental impact of their GI endoscopy products and to manufacture environmentally friendly devices

STATEMENT

32 ESGE-ESGENA recommend that GI endoscopy companies assess, disclose, and audit the environmental impact of their value chain.

STATEMENT

33 ESGE-ESGENA recommend that GI endoscopy companies manufacture environmentally friendly materials and devices.

STATEMENT

34 ESGE-ESGENA recommend against planned obsolescence of GI endoscopy materials and devices.

Currently, most GI endoscopy companies do not provide transparent, audited, and easy accessible information about the potential environmental impact of their products and practices. ESGE-ESGENA encourage GI endoscopy companies and manufacturers to adhere to the conceptual and legal frameworks developed by the EU and the United Nations [193, 194]. The European Green Deal, launched by the European Commission, includes a set of policies aimed at developing a more sustainable and environmentally friendly industrial model [193]. This strategy seeks to achieve a resource-efficient and competitive economy and advocates low-emission technologies, sustainable products, and services with no net GHG emission by 2050. Likewise, the United Nations Global Compact calls upon companies to align financial strategies and operations with universal principles on human rights, labor, anticorruption, and the environment; and to take actions to advance societal goals [195]. The United Nations code declares that companies should support a precautionary approach to environmental challenges, undertake initiatives to promote greater environmental responsibility, and encourage the development and diffusion of environmentally friendly technologies [194].

Ecological standards must apply to a product's total life cycle, from research and innovation to the extraction of raw materials, material formulation, manufacturing, packaging (often unnecessarily bulky and environmentally harmful [196]), distribution, usage, and waste disposal. ESGE-ESGENA encourage GI endoscopy companies to implement carbon offsetting programs, which enable companies to compensate for the carbon footprint secondary to their activities by supporting projects that reduce emissions elsewhere [197].

Planned obsolescence (i.e., designing and producing a product with an artificially limited lifespan) occurs in the health care industry and conflicts with sustainability, ethical principles, and the concept of a circular economy [198]. The optimal lifespan of high-tech devices, such as GI endoscopes, video processors, or electrosurgical units, depends on several factors such as national and local regulations, manufacturers' policies and amenability to technical maintenance. A minimum lifespan of 7–10 years is expected for endoscopes and devices of similar complexity [199]. Thus, replacing newer-generation devices before this timeframe seems only justified if new technologies impact clinically relevant outcomes or for research purposes. Finally, expiry dates of GI endoscopy accessories should be based on transparent and audited scientific evidence and not driven by commercial interests.

4.7.2 Advocating environmentally preferable purchasing

STATEMENT

35 ESGE-ESGENA recommend that governments, health insurers, and health care providers align with environmentally preferable purchasing strategies ("green purchasing"), including choosing materials and supplies with a low carbon footprint.

Governments, health insurers, and health care providers may also contribute to a more sustainable future by instituting environmentally preferable purchasing programs (i.e., purchasing products or services whose environmental impact has been assessed and found to be less damaging to the environment and human health when compared to competing alternatives). This has been termed "green public procurement" or "green purchasing" by the EU and promotes the policy that Europe's public authorities, including hospitals, use their purchasing power to choose environmentally friendly goods and services. This initiative demands the inclusion of transparent and verifiable environmental criteria for medical products in the public procurement process. Several European countries have already developed national guidelines to achieve this goal [193].

4.8 Policymakers, governments, and patients

4.8.1 Engaging policymakers and governments

STATEMENT

36 ESGE-ESGENA recommend that policymakers and governments take immediate action in the path towards environmentally sustainable GI endoscopy.

Policymakers, funding bodies, and governments play a crucial role in facilitating the transition towards green endoscopy. Areas of future regulation and policymaker engagement include:

- Mandating assessments of environmental impact as part of the EU medical device regulation approval and evaluation process.
- Encouragement of environmentally friendly GI endoscopy device alternatives by reimbursement incentives and penalties for less advantageous options.
- Promoting research grant initiatives for green endoscopy research projects by the EU, national or regional public funders, and policymakers.
- Inclusion of green endoscopy initiatives as part of local, regional, or national quality improvement programs in GI endoscopy.

- Policymaker-sponsored training programs for endoscopy managers, endoscopists, and patient organizations, to educate about green endoscopy alternatives and incentives.
- Educational programs for patients and citizens focused on promoting health, environmental sustainability, and rational use of health care resources.

4.8.2 Raising patient awareness and promoting patient empowerment

STATEMENT

37 ESGE-ESGENA recommend development of “Choosing Wisely” campaigns for GI endoscopy, discouraging over-use and overtreatment, and thus contributing to lower waste related to GI endoscopy, together with patients and patient organizations.

STATEMENT

38 ESGE-ESGENA suggest that patient empowerment programs and a healthy lifestyle can reduce the need for GI endoscopy procedures in the long term.

Data from the United Kingdom indicate that most patients (82%) are concerned about climate change. Nevertheless, only a quarter think that the health care system significantly contributes to climate change and do not identify health care environmental sustainability as a priority [200]. Patients and individuals undergoing GI endoscopy for disease prevention purposes are to be encouraged to reduce waste and take environmentally conscious action in the following ways:

- Choose public over private transport. Favoring public transport can dramatically impact GHG emissions [201] and is feasible for most patients undergoing GI endoscopy, except for fragile or unfit patients who may require individual vehicles.
- Choose non-fossil fuel transport.
- Request “green endoscopy” information from GI endoscopy providers and choose those who provide such a service.
- Be aware of patient empowerment, defined by the World Health Organization as “a process through which people gain greater control over decisions and actions affecting their health” [202]. Patient empowerment is promoted by the EU and positively impacts health [203, 204]. Patients should be conscious about the usage of GI endoscopy services related to medical needs, pay attention to, and engage in “Choosing Wisely” campaigns against overusage of endoscopy.
- Primary prevention can also reduce the need for GI endoscopy in the long run. Compelling evidence indicates that a healthy lifestyle reduces the risk of several GI diseases that often demand endoscopy, such as gastroesophageal reflux disease, functional dyspepsia, colorectal cancer, and metabolic-associated fatty liver disease.

- Be conscious of absolute benefits and harms of GI endoscopy services related to single-use or reusable equipment.

5 Conclusions

STATEMENT

39 ESGE-ESGENA recommend that GI endoscopy should become a net-zero GHG emissions practice by 2050.

Global warming and the destruction of ecosystems are among the greatest and most complex threats to humanity. GI endoscopy is a resource-demanding activity and a probable major contributor to the environmental impact of health care. The scientific community has unanimously called for emergency action to limit global temperature increases, restore biodiversity, and protect health. Through this Position Statement, ESGE-ESGENA encourage health care providers, patients, companies, policymakers, and governments to act proactively against the climate challenge. The current climate crisis demands not only a green mindset for nurses and physicians but that all stakeholders involved in GI endoscopy work together for a more sustainable future.

Herein, we provide short- and long-term actionable strategies for more sustainable GI endoscopy (► Fig. 2 and ► Fig. 3). It is crucial to take into account GI endoscopy’s environmental and social impact while keeping patients’ clinical outcomes as the priority. The most immediate actions are to reduce the rate of unnecessary procedures and to embed circular economy principles into GI endoscopy practice. Single-use devices can reduce infection risk and have become increasingly popular, but studies including life cycle assessment are urgently needed to better assess their environmental viability. In line with the EU climate goals [205], GI endoscopy net-zero GHG emissions by 2050, or ideally even before, should become a firm and common goal.

Disclaimer

The legal disclaimer for ESGE Guidelines as described in the 2020 Publications Policy update [206] applies to this Position Statement.

Competing interests

M. Arvanitakis is providing consultancy to Ambu (September 2021 to September 2022). E. Bak is Chair of the Polish Society of Endoscopic Nurses and Assistants (from 2019, ongoing). M. Dinis-Ribeiro has provided consultancy to Medtronic (from 2021 and Roche (from 2022); his department has received a research grant (loan) from Fujifilm (2021–2022); he is Co-Editor-in-Chief of *Endoscopy* journal. A. Eickhoff has provided consultancy to Ambu Medical (2012–2020). L. Donnelly is an elected member of the British Society of Gastroenterology – Nurses Association (2022, ongoing). C. Hassan has provided consultancy to and/or received research grants from Alfasigma, Fujifilm, Medtronic, Norgine, Olympus, and Pentax. B.H. Hayee is receiving

ing grant support for sustainability research from Boston Scientific (from April 2022 for 24 months). M.F. Kaminski has provided consultancy to Olympus and Erbe (from 2021), and lectured for Boston Scientific (from 2016) and Recordati (from 2020). H. Messmann has received consultation fees from Ambu, Boston Scientific, and Olympus (in the past 3 years); his department has received financial support from Olympus and Satisfai. M. Pellisé has provided consultancy to Norgine Iberia (2015–2019), CI Supply (2019), and Fujifilm Europe (from 2021, ongoing); her department has received research support from Fujifilm Spain (2019), Fujifilm Europe (from 2020, ongoing), Casen Recordati (2020), ZiuZ (2021), and 3D-Matrix (2022); she is Chair of the ESGE Diversity and Equity Working Group (2021–2022) and a Councillor for SEED (Sociedad Española de Endoscopia Digestiva) (2016–2022). H. Pohl is Co-Editor-in-Chief of *Endoscopy* journal. E. Rodríguez de Santiago receives support for academic and educational activities with Olympus (from 2021, ongoing); his department receives support for academic and educational activities with Olympus, Boston Scientific, Casen Recordati, and Norgine (from 2016, ongoing). P.D. Siersema receives research support from Pentax, Japan (from 2019), The E-Nose Company, Netherlands (from 2018), Lucid Diagnostics, US (from 2021), MicroTech, China (from 2019), and Magentiq Eye, Israel (from 2021); he receives research support from and advises Motus GI, US (from 2018), and support from Endo Tools Therapeutics, Belgium (2022); he is Editor-in-Chief of *Endoscopy* journal. A. Veitch has received speaker's fees from Olympus (March 2022). G.J. Webster has received honoraria for teaching from Boston Scientific (2010–2022). D. Agrawal, R. Baddeley, U. Beilenhoff, P. Bhandari, R. Bisschops, M. Bretthauer, P. Burga, I.M. Gralnek, K. Karlović, V. Lorenzo-Zuniga, M. Pioche, K. Siau, W. Stableforth, T.C. Tham, K. Triantafyllou, A. Tringali, A. Vienne, and A. Voiosu have no competing interests.

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Supplementary material

ESGE-ESGENA Position Statement: Reducing the environmental footprint of gastrointestinal endoscopy

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Supplementary material

Search methods

The following databases and sources were used:

- Pubmed.
- Embase
- Google Scholar
- Web of Science
- Institutional webpages.
- Abstract conference from DDW and ESGE days.

Searches were completed through manual review of references of included articles and expert-based literature review.

Supplementary material

1. Taskforces, PICO questions and search strategies

1.1 The environmental impact of GI endoscopy

1.1.1 Taskforce 1: The environmental impact of GI endoscopy

1.1.1.1 Definitions

Based on intergovernmental Panel on Climate Change [1] and other sources [2–4].

1.1.1.2 Question 1: What is the current environmental impact of GI endoscopy?

PICO question

- **Problem:** Environmental impact
- **Intervention:** GI endoscopy.
- **Comparison:** Not a requisite. If information is available, compare the impact of GI endoscopy with non-invasive tests and surgery.
- **Outcomes:** energy and water consumption, CO₂, kg of waste (specifically plastic and non-recyclable waste).

Search in Pubmed:

("endoscopie"[All Fields] OR "endoscopy"[MeSH Terms] OR "endoscopy"[All Fields] OR "endoscopies"[All Fields] OR "endoscopy s"[All Fields]) AND ("greenhouse"[All Fields] OR "greenhouses"[All Fields] OR ("carbon footprint"[MeSH Terms] OR ("carbon"[All Fields] AND "footprint"[All Fields]) OR "carbon footprint"[All Fields]) OR "climate change"[All Fields] OR ("waste"[All Fields] OR "waste s"[All Fields] OR "wasted"[All Fields] OR "wasteful"[All Fields] OR "wastes"[All Fields]))

Results: 169

1.1.1.3 Question 2: Which materials do we use in devices and endoscopes?

PICO question

- **Problem:** Environmental impact of the production of endoscopy material.
- **Intervention:** GI endoscopy.
- **Comparison:** biodegradable vs non-biodegradable, plastic vs others, recyclable vs non-recyclable
- **Outcomes:** energy and water consumption, CO₂, kg of waste, % of environmentally friendly materials.

Search:

Expert-based review + personal review of instruments and supplies + personal discussion with engineering departments and company representatives

Supplementary material

1.2 The path towards environmentally sustainable GI endoscopy

1.2.1 Taskforce 2: Clinical and endoscopic management.

1.2.1.1 Question 3: How can we reduce the carbon footprint before endoscopy?

PICO question

- **P**roblem: Environmental impact
- **I**ntervention: management **before** GI endoscopy.
- **C**omparison: adherence to guidelines regarding indication & non-adherence, non-invasive tests, combining endoscopy procedures.
- **O**utcomes: energy and water consumption, CO₂ & other GHG, kg of waste, cost.

Search in Pubmed:

#1 "endoscopy, digestive system"[MeSH Terms] OR "GI endoscopy"[Text Word] OR "digestive endoscopy"[Text Word] OR "gastrointestinal endoscopy"[Text Word] OR "endoscopie"[All Fields] OR "endoscopy"[MeSH Terms] OR "endoscopy"[All Fields] OR "endoscopies"[All Fields] OR "endoscopy s"[All Fields]. Results: 422,438

#2 "greenhouse effect"[MeSH Terms] OR ("greenhouse"[All Fields] AND "effect"[All Fields]) OR "greenhouse effect"[All Fields] OR "carbon footprint"[MeSH Terms] OR ("carbon"[All Fields] AND "footprint"[All Fields]) OR "carbon footprint"[All Fields] OR "environment*" [All Fields] OR "biodegradation, environmental"[MeSH Terms] OR "pollution"[Text Word] OR "waste"[Text Word] OR "green"[Text Word] OR "sustainability"[All Fields] OR "climate change"[All Fields]. Results: 2,224,744

#3 "ambulatory care facilities"[MeSH Terms] OR " organization and administration"[MeSH Terms] OR ("disease"[All Fields] AND "management"[All Fields]) OR "disease management"[All Fields] OR " clinical management"[All Fields] OR "postprocedur*" [All Fields] OR "preendoscopy"[All Fields] OR "pre-operative"[All Fields] OR "indication"[All Fields] OR "appropriateness"[All Fields] OR "noninvasive"[All Fields] OR "adherence"[All fields] OR "simultaneous"[All Fields] OR "combination"[All Fields]. Results: 3,660,776

#1 AND #2 AND #3. Results: 1,017, 0 relevant articles

Supplementary material

1.2.1.2 Question 4: How can we reduce the carbon footprint during endoscopy?**PICO question**

- **Problem:** Environmental impact
- **Intervention:** **intraprocedural** GI endoscopy.
- **Comparison:** resect & discard strategy vs histopathology for all polyps, biopsy policy based on guidelines vs endoscopist-based policy, optical diagnosis vs taking biopsies of all lesions, reuse accessories in the same patient (e.g., same polypectomy snare or biopsy forceps), nitrous oxide for sedation vs other sedative drugs.
- **Outcomes:** energy and water consumption, CO₂ & other GHG, kg of waste, cost.

Supplementary material

Search:

#	Database	Search term	Results
1	Medline	exp ENVIRONMENT/ OR exp "CARBON FOOTPRINT"/ OR exp "GREENHOUSE EFFECT"/	1970139
2	Medline	(greenhouse effect OR Lu2 OR waste management OR environment OR sustainability OR footprint OR climate change OR water consumption).ti,ab	754344
3	Medline	""CLIMATE CHANGE"/ OR ""GLOBAL WARMING"/	14311
4	Medline	(1 OR 2 OR 3)	2558554
5	Medline	(gastrointestinal endoscopy OR GI).ti,ab	63209
6	Medline	*ESOPHAGOSCOPY/ OR ""ENDOSCOPY, GASTROINTESTINAL"/ OR ""ENDOSCOPY, DIGESTIVE SYSTEM"/	20715
7	Medline	(intraprocedural).ti,ab	2295
8	Medline	(procedure).ti,ab	737800
10	Medline	(resect AND (discard strategy OR histopathology)).ti,ab	118
11	Medline	(optical diagnosis OR taking biopsies).ti,ab	12727
12	Medline	(polypectomy snare OR biopsy forceps).ti,ab	2644
13	Medline	(nitrous oxide OR sedation drug*).ti,ab	25071
14	Medline	""NITROGEN OXIDES"/ OR ""NITROUS OXIDE"/	11886
15	Medline	(5 OR 6)	79749
16	Medline	(endoscopy ADJ4 procedure*).ti,ab	1099
17	Medline	(endoscopy ADJ4 intraprocedural*).ti,ab	5
18	Medline	(carbon footprint ADJ3 endoscopy).ti,ab	0
19	Medline	(7 OR 8)	739266
20	Medline	(4 AND 15 AND 19)	309
22	Medline	("sustainable GI endoscopy" OR health care sustainability OR carbon footprint OR greenhouse effect).ti,ab	10107
23	Medline	(1 AND 6)	658
24	Medline	(19 AND 23)	114
25	HMIC	"CLINICAL WASTE"/	181
26	HMIC	"CLIMATE CHANGE"/ OR "GLOBAL WARMING"/ OR "ENVIRONMENTAL DETERIORATION"/ OR CLIMATE/	372
27	HMIC	SUSTAINABILITY/ OR "SUSTAINABLE DEVELOPMENT"/	1192
28	HMIC	"GREENHOUSE GASES"/	42
29	HMIC	(25 OR 26 OR 27 OR 28)	1675
30	HMIC	(endoscopy OR GI endoscop* OR digestive system).ti,ab	222
31	HMIC	(gastrointestinal endoscopy).ti,ab	34
32	HMIC	"DIGESTIVE SYSTEM DISEASES"/ OR "GASTROINTESTINAL DISEASES"/	149
33	HMIC	(30 OR 31 OR 32)	355
34	HMIC	(intraprocedural OR procedure).ti,ab	2954
35	HMIC	"CLINICAL PROCEDURES"/	58
36	HMIC	(34 OR 35)	3000
37	HMIC	(29 AND 33)	0
38	HMIC	(29 AND 31)	0
39	HMIC	(29 AND 30)	0
40	HMIC	(endoscopy AND footprint).ti,ab	0
41	Medline	(carbon footprint).ti,ab	1469
42	Medline	(siau, keith).au	91
43	Medline	(41 AND 42)	0
44	HMIC	(carbon footprint).ti,ab	45
45	HMIC	(siau, keith).au	0
46	HMIC	(carbon footprint).ti,ab	45
47	HMIC	(siau, keith).au	0
48	HMIC	(46 AND 47)	0

Supplementary material

49	PubMed	(green endoscopy).ti,ab	492
50	PubMed	(green endoscopy OR sustainable endoscopy).ti,ab	526
51	PubMed	(endoscopy carbon footprint).ti,ab	4
55	EMBASE	exp ENVIRONMENT/ OR exp "CARBON FOOTPRINT"/ OR exp "GREENHOUSE EFFECT"/	8060058
56	EMBASE	(greenhouse effect OR co2 OR waste management OR environment OR sustainability OR footprint OR climate change OR water consumption).ti,ab	869603
57	EMBASE	**CLIMATE CHANGE"/ OR **GLOBAL WARMING"/	23749
58	EMBASE	(55 OR 56 OR 57)	8485507
61	EMBASE	(intraprocedural).ti,ab	4060
63	EMBASE	(resect AND (discard strategy OR histopathology)).ti,ab	302
64	EMBASE	(optical diagnosis OR taking biopsies).ti,ab	736
65	EMBASE	(polypectomy snare OR biopsy forceps).ti,ab	2333
66	EMBASE	(nitrous oxide OR sedation drug*).ti,ab	18114
67	EMBASE	**NITROGEN OXIDES"/ OR **NITROUS OXIDE"/	21224
68	EMBASE	(gastrointestinal endoscopy OR GI).ti,ab	102551
69	EMBASE	*ESOPHAGOSCOPY/ OR **ENDOSCOPY, GASTROINTESTINAL/ OR **ENDOSCOPY, DIGESTIVE SYSTEM"/	12987
70	EMBASE	(68 OR 69)	111866
71	EMBASE	(endoscopy ADJ4 procedure*).ti,ab	2955
72	EMBASE	(endoscopy ADJ4 intraprocedural*).ti,ab	7
73	EMBASE	(carbon footprint ADJ3 endoscopy).ti,ab	0
74	EMBASE	(intraprocedural).ti,ab	4060
75	EMBASE	(procedure).ti,ab	1032810
76	EMBASE	(74 OR 75)	1034945
77	EMBASE	exp ENVIRONMENT/ OR exp "CARBON FOOTPRINT"/ OR exp "GREENHOUSE EFFECT"/	8060058
78	EMBASE	(greenhouse effect OR co2 OR waste management OR environment OR sustainability OR footprint OR climate change OR water consumption).ti,ab	869603
79	EMBASE	**CLIMATE CHANGE"/ OR **GLOBAL WARMING"/	23749
80	EMBASE	(77 OR 78 OR 79)	8487542
81	EMBASE	(70 AND 80)	33189
82	EMBASE	(74 AND 81)	48
83	EMBASE	(74 AND 80)	1436
84	PubMed	(carbon footprint OR climate change OR climate warming OR sustainability).ti,ab	75150
85	PubMed	(gastrointestinal endoscopy).ti,ab	8017
86	PubMed	(intraprocedural gastrointestinal endoscopy).ti,ab	10
87	PubMed	(84 AND 86)	0
88	PubMed	(84 AND 85)	1
89	PubMed	(gastroenterology AND climate change).ti,ab	5
91	PubMed	(endoscopy's current carbon footprint).ti,ab	0
92	PubMed	(green endoscopy AND sustainability).ti,ab	1
93	PubMed	(84 AND 85)	1
94	PubMed	(environmental impact of endoscopy).ti,ab	0
95	PubMed	(84 AND 86)	0

4 relevant articles.

Supplementary material

1.2.1.3 Question 5: How can we reduce the carbon footprint after endoscopy?

PICO question

- **Problem:** Environmental impact
- **Intervention:** clinical management after GI endoscopy.
- **Comparison:** adherence to guidelines vs no adherence for surveillance, telemedicine vs consultation in person
- **Outcomes:** energy and water consumption, CO₂ & other GHG, kg of waste, cost.

Search in Pubmed:

#1 "endoscopy, digestive system"[MeSH Terms] OR "GI endoscopy"[Text Word] OR "digestive endoscopy"[Text Word] OR "gastrointestinal endoscopy"[Text Word] OR "endoscopie"[All Fields] OR "endoscopy"[MeSH Terms] OR "endoscopy"[All Fields] OR "endoscopies"[All Fields] OR "endoscopy s"[All Fields]

#2 "environment*"[Text Word] OR "biodegradation, environmental"[MeSH Terms] OR "pollution"[Text Word] OR "waste"[Text Word] OR "green"[Text Word] OR "sustainability"[All Fields] OR "climate change"[All Fields] OR "greenhouse effect"[MeSH Terms] OR ("greenhouse"[All Fields] AND "effect"[All Fields]) OR "greenhouse effect"[All Fields] OR "carbon footprint"[MeSH Terms] OR ("carbon"[All Fields] AND "footprint"[All Fields]) OR "carbon footprint"[All Fields]

#3 "postprocedur*"[Text Word] OR "postendoscopy"[Text Word] OR "post-operative"[Text Word] OR "patient care"[MeSH Terms] OR "ambulatory care facilities"[MeSH Terms] OR "organization and administration"[MeSH Terms] OR ("disease"[All Fields] AND "management"[All Fields]) OR "disease management"[All Fields] OR "clinical management"[All Fields]

Initial search #1 AND #2 AND #3: 788 records on PubMed (1968-2021), 5 relevant articles (read in extenso), further 4 relevant discovered through references

Search strategy Web of science:

((ALL=("environment" OR "biodegradation" OR "pollution" OR "waste" OR "green" OR "sustainability" OR "climate change" OR "greenhouse effect" OR ("greenhouse" AND "effect")) OR "carbon footprint" OR ("carbon" AND "footprint")) AND ALL=("postprocedure" OR "postendoscopy" OR "post-operative" OR "patient care" OR "ambulatory care facilities" OR "organization and administration" OR ("disease" AND "management") OR "disease management" OR "clinical management")) AND ALL=("GI endoscopy" OR "digestive endoscopy" OR "gastrointestinal endoscopy" OR "endoscopie" OR "endoscopy" OR "endoscopy" OR "endoscopies" OR "endoscopy s")

145 cords on Web of science (1992-2021), 0 relevant articles

Supplementary material

1.2.2 Taskforce 3: Endoscopy logistics

1.2.2.1 Question 6: What should be the structure of the endoscopy unit?

PICO question

- **Problem:** Structure of the Endoscopy Unit
- **Intervention:** Location, size of endoscopy rooms and climatization.
- **Comparison:** separated GI clinic vs Endoscopy unit inside hospital; optimum m2 per room; centralized climatization vs natural ventilation.
- **Outcomes:** energy and water consumption, CO2 & other GHG, kg of waste, cost, benefits & risks for patients.

Search strategy:

Expert-based review

1.2.2.2 Question 7: Regarding the functioning of the endoscopy unit, what can be done to reduce the carbon footprint?

PICO question

- **Problem:** Functioning of the Endoscopy Unit
- **Intervention:** Shifts, digitalisation
- **Comparison:** morning activity vs all-day activity; full digitalisation vs paper documentation (including endoscopy report for patients).
- **Outcomes:** energy and water consumption, CO2 & other GHG, kg of waste, cost, benefits & risks for patients.

Search strategy:

Expert-based review

Supplementary material

1.2.3 Taskforce 4: Single-use products

1.2.3.1 Question 8: What endoscopy accessories can be reused? Is there good evidence for the current universal single-use policy?**PICO question**

- **P**opulation: Endoscopy accessories.
- **I**ntervention: Disinfection and reprocessing.
- **C**omparison: reusable vs single-use.
- **O**utcomes: energy and water consumption, CO₂ & other GHG, kg of waste, cost, benefits & risks for patients (mainly infection risk).

Search in Pubmed:

- Reprocessing endoscopic devices: 544 articles
- Duodenoscope infection: 227 results
- Reloadable clips: 1 result
- Sustainability endoscopy

1.2.3.2 Question 9: Single-use vs re-usable endoscopes?**PICO question**

- **P**opulation: Endoscopes
- **I**ntervention: Disinfection and reprocessing.
- **C**omparison: reusable vs single-use.
- **O**utcomes: energy and water consumption, CO₂ & other GHG, kg of waste, cost, benefits & risks for patients (mainly infection risk).

Search in Pubmed:

"single-use"[All Fields] AND ("endoscope s"[All Fields] OR "endoscoped"[All Fields] OR "endoscopes"[MeSH Terms] OR "endoscopes"[All Fields] OR "endoscope"[All Fields] OR "endoscopical"[All Fields] OR "endoscopically"[All Fields] OR "endoscopy"[MeSH Terms] OR "endoscopy"[All Fields] OR "endoscopic"[All Fields] OR ("duodenoscopes"[MeSH Terms] OR "duodenoscopes"[All Fields] OR "duodenoscope"[All Fields] OR "duodenoscopic"[All Fields]) OR ("endoscopie"[All Fields] OR "endoscopy"[MeSH Terms] OR "endoscopy"[All Fields] OR "endoscopies"[All Fields] OR "endoscopy s"[All Fields]) OR ("scope"[All Fields] OR "scopes"[All Fields] OR "scoping"[All Fields]))

Results: 454

Supplementary material

1.2.4 Taskforce 5: Education and training

1.2.4.1 Question 10: Should ESGE add the environmental dimension to the curriculum and training of endoscopy?

A PICO format was not deemed suitable for this question.

Search:

Expert-based review.

1.2.4.2 Question 11: How can the carbon footprint be reduced during training and educational activities?**PICO question**

- **Problem:** Environmental impact
- **Intervention:** Educational (including courses and congresses) and training activities related to GI endoscopy. If there is indirect evidence from other medical areas, please discuss.
- **Comparison:** online/e-learning vs presential meetings, animal training vs simulator,
- **Outcomes:** energy and water consumption, CO₂ & other GHG, kg of waste, cost, learning curve/competence.

Search strategy Pubmed:

a) Systematic search:

#1 "train*" [MeSH Terms] OR "train*" [Text Word] OR "education*" [MeSH Terms] OR "education" [Text Word] OR "skill" [Text Word] OR "training" [All Fields] OR "performance" [Text Word] OR "competence" [All Fields] OR "educational measurement" [MeSH Terms] OR "teaching" [MeSH Terms] OR "congresses as topic" [MeSH Terms] OR "congress" [Text Word] OR "conference" [Text Word] OR "group processes" [MeSH Terms] OR "meeting" [Text Word]

#2 "environment*" [Text Word] OR "biodegradation, environmental" [MeSH Terms] OR "pollution" [Text Word] OR "waste" [Text Word] OR "green" [Text Word] OR "sustainability" [All Fields] OR "climate change" [All Fields] OR "greenhouse effect" [MeSH Terms] OR ("greenhouse" [All Fields] AND "effect" [All Fields]) OR "greenhouse effect" [All Fields] OR "carbon footprint" [MeSH Terms] OR ("carbon" [All Fields] AND "footprint" [All Fields]) OR "carbon footprint" [All Fields]

#3 "endoscopy, digestive system" [MeSH Terms] OR "GI endoscopy" [Text Word] OR "digestive endoscopy" [Text Word] OR "gastrointestinal endoscopy" [Text Word] OR "endoscopie" [All Fields] OR "endoscopy" [MeSH Terms] OR "endoscopy" [All Fields] OR "endoscopies" [All Fields] OR "endoscopy s" [All Fields]

#1 AND #2 AND #3: 1077 records on PubMed (1968-2021), 7 of interest

b) Search strategy Web of science:

("train" OR "education" OR "skill" OR "training" OR "performance" OR "competence" OR "educational measurement" OR "teaching" OR "congress" OR "conference" OR "meeting") AND ("environment" OR "biodegradation" OR "pollution" OR "waste" OR "green" OR "sustainability" OR "climate change" OR "greenhouse effect" OR ("greenhouse" AND "effect") OR "carbon footprint" OR ("carbon" AND "footprint")) AND ("GI endoscopy" OR "digestive endoscopy" OR "gastrointestinal endoscopy" OR "endoscopie" OR "endoscopy" OR "endoscopies" OR "endoscopy s")

Supplementary material

1036 records on Web of science, of interest

#	Article (Medline)	Type	Main ideas
1	Vanella et al, Therap Adv Gastroenterol. 2020 Oct 8;13:1756284820965070.	Review	"In a scenario of PPE sparing and exposure risk reduction, Fellows have been usually withdrawn from endoscopy suites."
2	Vaccari et al, Waste Manag Res. 2018 Jan;36(1):39-47	Original article	"The departments with the highest average monthly waste generation rates per clinical procedure were radiology (0.67kgprocedure-1), gastroenterology–digestive endoscopy (0.50kgprocedure-1)"
3	Washke et al, Gastrointest Endosc. 2019 Jul;90(1):1-12.	ASGE White paper	Important principles of training in endoscopy
4	Goodman et al, Endoscopic simulators, (Gastrointest Endosc 2019;:-1-11.)	ASGE Technological status report	<p>"Mechanical simulators [...] are usually made of plastic molds and various hoses and wire end sleeves". – reusable, no PPE required, low-maintenance</p> <p>"Live animal models" and "Composite simulators combine a plastic housing or mold with explanted animal organs" – livestock special facilities or organ procurement issues, organic matter disposal, PPE (i.e. gloves, covers) & disinfectants used, separate "animal-only" endoscopes</p> <p>Virtual simulators are typically trolley-mounted, computerized devices that come with replica endoscopes and an insertion tool" – complicated components (production footprint), use of electricity and maintenance requirements; no PPE required, limitless sessions. No statement on environmental issues.</p>
5	Agrawal et al, Gastroenterol Nurs. 2017 Jan/Feb;40(1):13-18.	Original article (survey based)	<p>736 nurses and 163 gastroenterologists (48% fellows) answered the survey ("how they discarded polypectomy snares, dilating balloons, ERCP sphincterotomes, and wires, focusing on disposal as regular trash, red bag, or sharps".)</p> <p>"Less than one third of endoscopy staff disposed of accessories appropriately in regular trash."</p> <p>"There were no differences in the practice of fellows and faculty gastroenterologists"</p> <p>"The results of our survey lead us to question whether endoscopy staff and/or gastroenterologists are simply unaware of (which is concerning) or indifferent to proper disposal methods"</p>
6	Blackburn et al, World J Gastrointest Endosc. 2014 Jun 16; 6(6): 234–239.	Review	"the use of a portable space for simulation as a simulation environment has the potential to avoid both the problem of simulation being inaccessible to trainees located away from central clinical skills centres and simulation sessions disturbing the normal function of the clinical environment." (ref: Med Teach. 2010;32:65–70.)
7	Depew et al, Can J Gastroenterol. 2010 Dec;24(12):733-8	Original article (retrospective study)	<p>"Resident training prolonged procedure times for ambulatory colonoscopy by 50%." – e.g. prolonged use of CO2 insufflation, utilities, etc.</p> <p>"The current study demonstrated significant opportunity costs associated with endoscopic instruction, both for throughput and financial compensation." – increased procedure time is associated with direct and indirect increase in environmental footprint of endoscopy</p>
8	Balcombe et al, Altern Lab Anim. 2004 Jun;32 Suppl 1B:553-60.	Review	<p>"Prevalent opinion is that animals serve as an intermediate between models/simulators and clinical training with human patients. This thinking is based on the belief that simulators cannot yet provide either the realism or the range of scenarios that animals can."</p> <p>"in a 2002 survey by the European Research Centre for Alternatives (EURCA), ten out of ten responding institutions reported using animals (pigs and rabbits) in their laparoscopic/endoscopic training curricula."</p> <p>The article argues for a transition from animal models to VR (in 2004!)</p>
9	Valenti et al, Industrial Health 2021, 59, 334 – 339	Review	SWOT analysis on the use of virtual conferences in the era of the COVID-19 pandemic: environment sustainability because of less air travel
10	Duane et al, Cardiology in the Young, 2021. doi: 10.1017/S1047951121000718	Original article	<p>Life Cycle Analysis calculation of a webinar event compared to a simulation of the same event in a in-person setting</p> <p>Conclusion: Webinars reduce the environmental footprint of pediatric cardiology conferences:</p> <p>The authors showed that the theoretical environmental impact of a virtual conference is significantly less (4 tons CO2 equivalent) than the traditional international face-to-face conference (192 tons CO2 equivalent). The life cycle assessment methodology showed that resource use for a face-to-face conference lasting 2.5 days for 1374 attendees is equivalent to 400 times what an average person would use in one year, the climate change and photochemical ozone formation approximately 250 times and the eutrophication terrestrial equivalent to 225 times.</p>
11	Park et al, Reducing cost and waste in pediatric laparoscopic procedures, Journal of Pediatric Surgery 2020	Original article (prospective)	<p>Prospective study to assess if we could reduce the cost and waste in pediatric laparoscopic procedures without affecting clinical outcomes by using monthly report card detailing the utilization and cost of disposable, high-cost surgical supplies for individual surgeons.</p> <p>The authors reduced the median supply cost per case by</p>

Supplementary material

			43% after the intervention with total cost savings of \$71,035 for the first four quarters. The authors also reduced the use of disposable trocars by 56% and the use of disposable harmonics and staplers by 33%.
#	Article (WoS)	-	-
Further literature search			
s.1	Gastrointest Endosc. 2020 Dec;92(6):1228-1235	Original article (RCT)	Screening colonoscopy involving trainees vs. no trainees: "The adenoma detection rate in the intervention group was 44.8% versus 37.1% in the control arm (P = .02). The mean number of adenomas per colonoscopy was significantly higher in the intervention group (0.65 ± 0.3 vs 0.53 ± 0.2 in the control arm, P < .001)." Little or no improvement when attending ADR is already high
s.2	MacCashland et al Am J Gastroenterol. 2000 Nov;95(11):3129-32	Original article (retrospective database analysis)	"Fellow involvement prolonged procedure time by 10–37%." "Efficient simulation would speed up the learning process before moving to apprenticeship training with patients."

c) Further relevant topic-oriented search:

- 1. Does simulator training increase or decrease material waste and environmental costs? – trainee involvement increases procedural time and overall costs (see paper); simulator training may reduce material waste, hidden costs, etc. Reusable simulator models (e.g. virtual or artificial as compared to explants)?
- 2. PPE for live/ animal training vs virtual simulators
- 3. Issue is not addressed by papers on endoscopic training (ASGE,ESGE)
- 4. Paper-based documentation and leaflets at congresses and conferences

Supplementary material

1.2.5 Taskforce 6: Green quality

1.2.5.1 Question 12: Does the adherence to Quality guidelines reduce the environmental impact of endoscopy activity?**PICO question**

- **Problem:** Environmental impact of GI endoscopy
- **Intervention:** Quality in GI endoscopy.
- **Comparison:** adherence to quality guidelines vs no adherence. If there is indirect evidence from other medical areas, please discuss.
- **Outcomes:** energy and water consumption, CO₂ & other GHG, kg of waste, cost, benefits & risks for patients.

Search strategy in Pubmed:

#1 "greenhouse effect"[MeSH Terms] OR ("greenhouse"[All Fields] AND "effect"[All Fields]) OR "greenhouse effect"[All Fields] OR "carbon footprint"[MeSH Terms] OR ("carbon"[All Fields] AND "footprint"[All Fields]) OR "carbon footprint"[All Fields] OR "environment*" [All Fields] OR "biodegradation, environmental"[MeSH Terms] OR "pollution"[Text Word] OR "waste"[Text Word] OR "green"[Text Word] OR "sustainability"[All Fields] OR "climate change"[All Fields]. Results: 2,285,694

#2 "endoscopy, digestive system"[MeSH Terms] OR "GI endoscopy"[Text Word] OR "digestive endoscopy"[Text Word] OR "gastrointestinal endoscopy"[Text Word] OR "endoscopie"[All Fields] OR "endoscopy"[MeSH Terms] OR "endoscopy"[All Fields] OR "endoscopies"[All Fields] OR "endoscopy s"[All Fields] . Results: 430,270

#3 "qualities"[All Fields] OR "quality"[All Fields] OR "quality s"[All Fields] OR "excellence"[All Fields] OR "excellence s"[All Fields] OR "excellences"[All Fields] OR "high-quality"[All Fields]. Results: 1,557,655

#1 AND #2 AND 3#. Results: 508, 2 included.

1.2.5.2 Question 13: Should ESGE and ESGENA in the future consider the carbon footprint of endoscopist/endoscopy units as a quality performance measure?

A PICO format is not suitable here.

Supplementary material

1.2.6 Taskforce 7: Green research and guidelines

1.2.6.1 Question 14: Should ESGE promote research about the environmental impact of GI endoscopy and how to reduce the carbon footprint?**PICO question**

- **Problem:** Environmental impact of GI endoscopy
- **Intervention:** Research in GI endoscopy.
- **Comparison:** Research about and/or considering the environmental impact of GI endoscopy vs not considering the environmental impact.
- **Outcomes:** energy and water consumption, CO₂ & other GHG, kg of waste, cost, benefits & risks for patients.

Search strategy: expert-based review + Cochrane sustainable healthcare webpage

1.2.6.2 Question 15: Should the environmental impact be considered when grading the strength of recommendations in GI endoscopy guidelines?**PICO question**

- **Problem:** Environmental impact of GI endoscopy
- **Intervention:** Guidelines in GI endoscopy.
- **Comparison:** Grading GI endoscopy guidelines recommendations considering the environmental impact vs no considering the environmental impact.
- **Outcomes:** energy and water consumption, CO₂ & other GHG, kg of waste, cost, benefits & risks for patients.

Search strategy: expert-based review + Cochrane sustainable healthcare webpage

Supplementary material

1.2.7 Taskforce 8: Industry and healthcare providers

1.2.7.1 Question 16: Should ESGE encourage that companies and manufacturers declare the environmental impact of their GI endoscopy-related products?

1.2.7.2 Question 17: Should ESGE encourage companies to produce environmentally friendly products and materials?

1.2.7.3 Question 18: Should ESGE recommend against planned obsolescence of GI endoscopy equipment? Define planned obsolescence and briefly discuss current EU regulations.

Search:

Due to the nature of this Taskforce and its strategic relevance, we did not perform a systematic literature search using PICO, but chose an expert-based literature review. This taskforce aims to state the strategic positioning of ESGE and ESGENA

Supplementary material

1.2.8 Taskforce 9: Policymakers and patients

1.2.8.1 Question 19: How can policymakers and governments be involved in the path to environmentally sustainable endoscopy? Should ESGE promote and provide guidance for sustainable legislation in this field?

A PICO format was not deemed appropriate

1.2.8.2 Question 20: How can patients who undergo endoscopy reduce their carbon footprint and environmental impact?**PICO question:**

- **P**opulation: Patients who undergo endoscopy.
- **I**ntervention: Gastrointestinal endoscopy
- **C**omparison: Primary disease prevention vs no prevention; public transport vs petrol private vehicle vs zero emission vehicle; patient empowerment vs paternalistic medicine.
- **O**utcomes: energy and water consumption, CO₂ & other GHG, kg of waste, cost, benefits & risks for patients.

Search:

Due to the nature of this Taskforce, we did not perform a systematic literature search using PICO, but chose an expert-based literature review by searching Pubmed and Google Scholar for topic matters and applied searches of references in articles found at initial searches.

Webpages consulted

1. <https://www.ema.europa.eu/en/human-regulatory/overview/medical-devices#medical-devices-legislation-section>
2. <https://www.choosingwisely.org/>
3. <https://digestivecancers.eu/>

Supplementary material

2. Voting results

1st voting round

Nº of Panellists	32
Answered	29
Skipped	3
% of panelist that responded the survey (mimumum required 80%)	90,63
Nº of statements First round	41
Nº of statements with agreement < 80%	3
Nº of deleted statements for the second round	6
Nº of statements with major changes based on suggestions	8
Nº of new statements for 2nd round	3
Nº of statements for 2nd round	39

2nd voting round

Nº of panellists	32
Answered	24
Skipped	8
% of panelist that responded the survey	75
Nº of statements for 2nd round	39
Nº of statements with agreement > 90%	35
Nº of statements with agreement 80-90%	3
Nº of statements with agreement < 80%	1
Nº of statements approved after modifications during the virtual meeting	1
Nº of final statements	39

Supplementary material

3. References

- [1] Glossary — Global Warming of 1.5 °C. . Im Internet: <https://www.ipcc.ch/sr15/chapter/glossary/>; Stand: 24.01.2022
- [2] Bahraini A. Waste4Change Supports 3R (Reduce-Reuse-Recycle) Green Concept! Waste4Change 2019; Im Internet: <https://waste4change.com/blog/waste4change-supports-3r-reduce-reuse-recycle-green-concept/>; Stand: 24.01.2022
- [3] Circular economy: definition, importance and benefits | News | European Parliament. 2015; Im Internet: <https://www.europarl.europa.eu/news/en/headlines/economy/20151201STO05603/circular-economy-definition-importance-and-benefits>; Stand: 24.01.2022
- [4] 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: 636–638. doi:10.1016/S2468-1253(20)30157-6