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The carbon footprint of ambulatory gastrointestinal endoscopy

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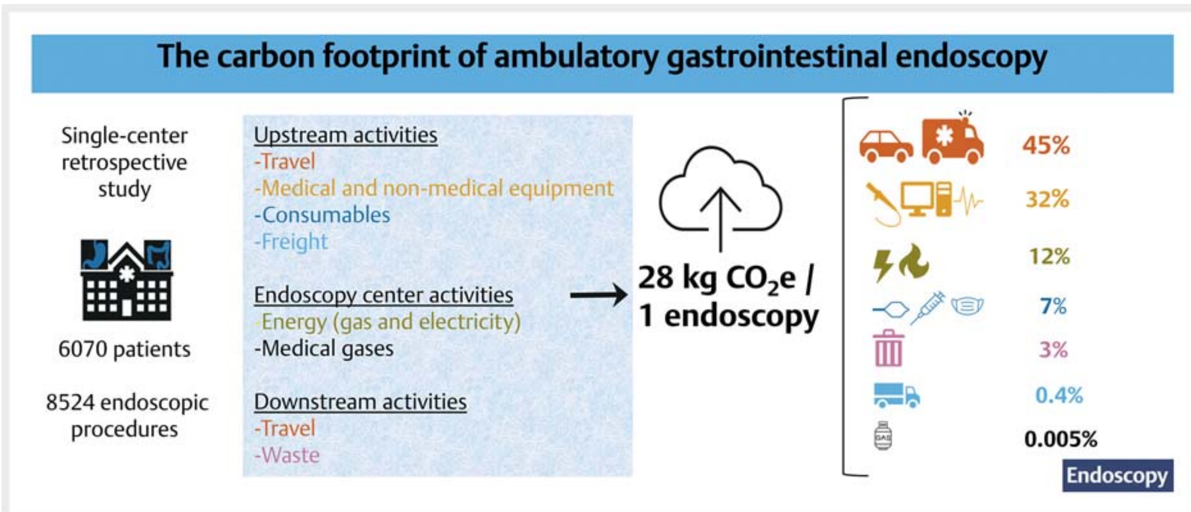
GRAPHICAL ABSTRACT



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ABSTRACT

Background Endoscopy is considered the third highest generator of waste within healthcare. This is of public importance as approximately 18 million endoscopy procedures are performed yearly in the USA and 2 million in France. However, a precise measure of the carbon footprint of gastrointestinal endoscopy (GIE) is lacking.

Methods This retrospective study for 2021 was conducted in an ambulatory GIE center in France where 8524 procedures were performed on 6070 patients. The annual carbon footprint of GIE was calculated using "Bilan Carbone" of the French Environment and Energy Management Agency. This multi-criteria method accounts for direct and indirect greenhouse gas (GHG) emissions from energy consumption (gas and electricity), medical gases, medical and non-medical equipment, consumables, freight, travel, and waste.

Results GHG emissions in 2021 were estimated to be 241.4 tonnes CO_2 equivalent (CO_2e) at the center, giving a carbon footprint for one GIE procedure of 28.4 kg CO_2e. The main GHG emission, 45 % of total emissions, was from travel by patients and center staff to and from the center. Other emission sources, in rank order, were medical and non-medical equipment (32 %), energy consumption (12 %), consumables (7 %), waste (3 %), freight (0.4 %), and medical gases (0.005 %).

Conclusions This is the first multi-criteria analysis assessing the carbon footprint of GIE. It highlights that travel, medical equipment, and energy are major sources of impact, with waste being a minor contributor. This study provides an opportunity to raise awareness among gastroenterologists of the carbon footprint of GIE procedures.

Introduction

Climate change represents a major threat to public health over the coming decades [1]. It is well established that rising greenhouse gas (GHG) emission levels contribute to air pollution, threaten adequate food supplies, limit access to clean water, and increase microbial disease incidence [1–4]. By increasing the frequency of extreme weather events, climate change will also cause indirect health problems [1].

A carbon footprint is defined by the Carbon Trust as "the total set of GHG emissions caused directly and indirectly by an individual, event, organization or product, expressed as carbon dioxide equivalent (CO_2e)" [5]. Healthcare is a significant contributor of carbon emissions, accounting for approximately 8 % of the global carbon footprint in France [6]. Within healthcare, gastrointestinal endoscopy (GIE) is considered the third highest generator of waste [7]. This is of public importance as approximately 18 million endoscopy procedures are performed each year in the USA [5] and approximately 2 million in France [8]. However, a precise measure of the carbon footprint of GIE is unknown. A few studies have been conducted on endoscopy waste but none of them included direct and indirect sources of carbon emissions.

We conducted an analysis of our digestive ambulatory center to evaluate the carbon footprint of GIE procedures.

Methods

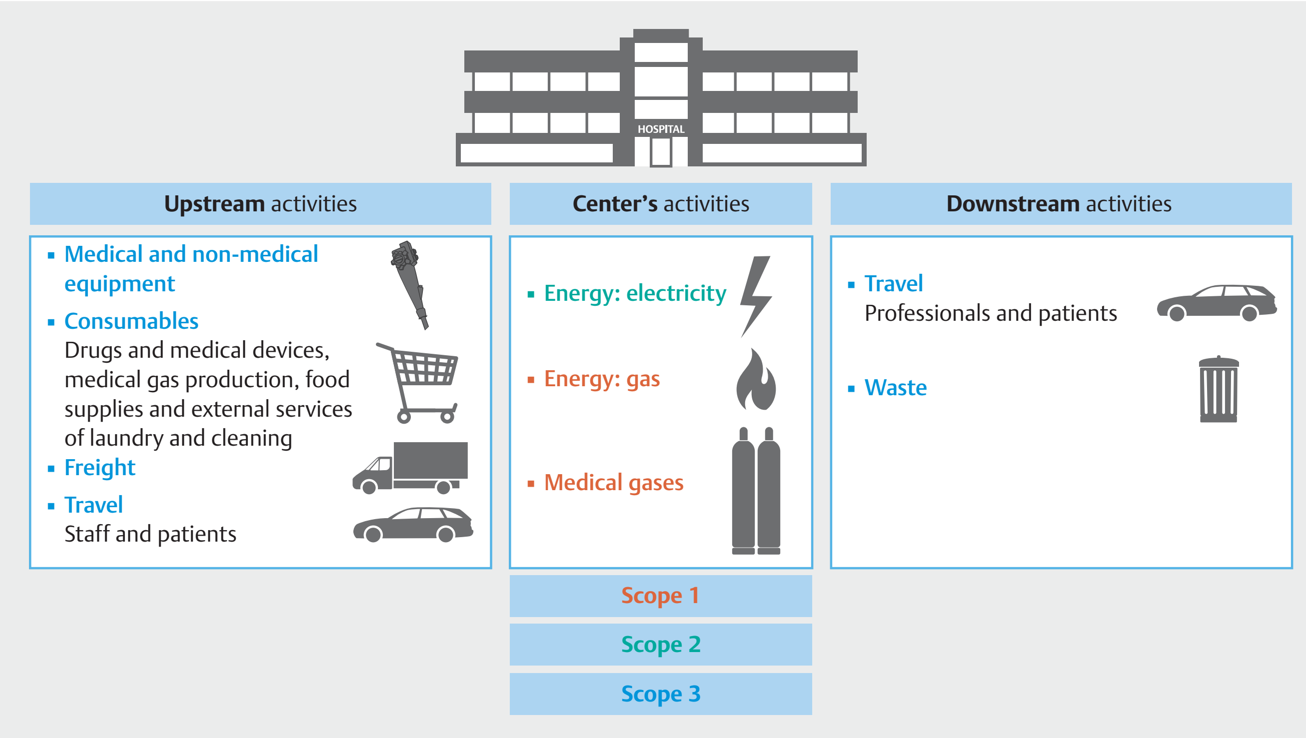
Study design

This retrospective study was conducted at the Centre d'Endoscopie et de Médecine Ambulatoire (hereafter "the center"), Strasbourg, France, which is an ambulatory endoscopic digestive center. The center has authorization for GIE procedures (mainly gastroscopy, colonoscopy with or without polypectomy, and endoscopic ultrasound), minor activities involving

▶ **Table 1** Procedures performed at the center in 2021.

	Under general anesthesia	Without general anesthesia	Total
Gastroscopy	3446	520	3966
Rectosigmoidoscopy	0	231	231
Colonoscopy	2522	10	2532
Colonoscopy with polypectomy	1612	0	1612
Ultrasound endoscopy	173	0	173
Ultrasound endoscopy with biopsy	10	0	10
Total	7763	761	8524 procedures for 6070 patients

The global colonoscopy adenoma rate at the center was 28 % in 2021.



▶ **Fig. 1** Direct and indirect greenhouse gas emission classes included in this study. The Environment and Energy Management Agency, France (ADEME) method evaluates direct emissions resulting from activities that an organization controls (scope 1), emissions from energy usage (scope 2), and indirect emissions from products and services an organization does not directly control (scope 3).

therapeutic infusion (such as iron infusion or intravenous biological therapies, mainly for inflammatory bowel diseases), functional digestive explorations, capsule endoscopy, and therapeutic education. A total of 35 center staff (medical, paramedical, and administrative staff) work at the center. The surface area of the center is 800 m^2, divided into two rooms for endoscopy under general anesthesia with propofol (but without endotracheal intubation), one cleaning room, one recovery room, two patient resting rooms, two waiting rooms, and nine medical consultation rooms. In 2021, 6070 patients underwent investigation at the center (open 220 days) and 8524 endoscopic procedures were performed (▶ **Table 1**).

The carbon footprint of the center was calculated by Alternative Carbone, a company specializing in such analysis. Alternative Carbone works with the "Bilan Carbone" tool (version 8.7.1), which was developed for the Environment and Energy Management Agency, France (ADEME). We first studied the entire carbon footprint of the center. Then we focused on digestive endoscopy, excluding the carbon footprint of minor activities (i. e. consumables for these activities, energy necessary for the specific center superficy devoted to minor activities, and nitrogen oxide consumption, as it is used in our center only for cryogenic hemorrhoid ligation).

Method of carbon footprint calculation

The Bilan Carbone method evaluates direct GHG emissions resulting from activities that an organization controls (scope 1), emissions from energy use (scope 2), and indirect emissions from products and services an organization does not directly control (scope 3; ▶ **Fig. 1**). Direct and indirect emissions are classed as follows: energy (electricity and gas); medical gases; medical and non-medical equipment (technical platforms); consumables (drugs, medical devices, endoscopy-related single-use products, food, and office supplies) and related freight emissions (kilometers traveled and mode of transport); external services included in consumables (laundry, cleaning); travel (staff and patients); and direct waste from healthcare activities. This method considers GHGs, defined by the Intergovernmental Panel on Climate Change (IPCC). The term carbon dioxide equivalent (CO_2e) enables different GHGs to be quantified, using a common standardized unit to measure the equivalent global warming impact.

Carbon emission is calculated based on total activity data (*AD*, expressed in units presented in ▶ **Table 2**) multiplied by the corresponding emission factors (*EFs*), leading to a GHG emission output, expressed in gram (g), kilogram (kg), or metric tonne (t) of CO_2 equivalent (CO_2e). Emission factors are coefficients that relate a quantity of an emission released to the atmosphere to a particular activity datum. In our study we used emission factors from the ADEME Carbon Base [9], Ecoinvent database [11], the guide AGRIBALYSE [12], and the Guide Sectoriel BEGES Santé [13]. The latter is written by health professionals to estimate regulatory GHG assessments with sector-specific emission factors. When no specific emission factor was available for a product, we used a monetary ratio, where a car-

▶ **Table 2** Activity data collected for the study according to the different greenhouse gas emission classes used.

GHG emission class **Activity data collected (with unit)**	**Emission factor or monetary ratio**	**Data collection means**	**Method used to assess carbon footprint *(with reference)***
Energy			
▪ Electricity consumption (kWh)	0.06 kg CO_2e/kWh	Annual invoices	Emission factor *(ADEME Carbon Base)* [9]
▪ Gas consumption (kWh)	0.227 kg CO_2e/kWh		
Medical and non-medical equipment			
▪ Endoscopes (€) Endoscopic columns (€) Electrical scalpels (€)	315 kg CO_2e/k€	Annual invoices	Monetary ratios *(ADEME Carbon base* [9], *NHS England Carbon Emissions Carbon Footprinting Report, May 2008* [10]*)*
▪ Monitoring scopes (€)	700 kg CO_2e/k€		Monetary ratios *(ADEME Carbon Base 2021, Machines and equipment* [9]*)*
▪ Respirator (€)	700 kg CO_2e/k€		
▪ Endoscope washers disinfectors (€)	700 kg CO_2e/k€		
▪ Drying and storage machine for endoscope (€)	700 kg CO_2e/k€		
▪ IT equipment (€)	295 kg CO_2e/computer 197 kg CO_2e/printer		Monetary ratios *(ADEME Carbon base* [9]*)*
Consumables			
▪ Electronic devices (€)	315 kg CO_2e/k€	Annual invoices	Monetary ratios (*ADEME Carbon Base* [9])
▪ Single-use products (€)	0.00448 kg CO_2e/glove 0.0189 kg CO_2e/needle		Emission factor (*Guide sectorial BEGES Santé* [13] and *Ecoinvent* [11])
▪ Laundry (€)	170 kg CO_2e/k€		Monetary ratios (*ADEME Carbon Base* [9])
▪ Packaging	5 500 kg CO_2e/t plastic		Emission factor (*ADEME Carbon Base* [9])
▪ Food	1.0 kg CO_2e/kg orange juice		Emission factor *(AGRIBALYSE* [12]*)*
Medical gases			
▪ kg CO_2	1 kg CO_2e/kg CO_2	Annual Invoices	Emission Factor *(Ecoinvent database* [11]*)*
Travel			
▪ km/mode of transport	0.218 kg CO_2e/km by car 0.152 kg CO_2e/km by bus 0.03 kg CO_2e/km by train	Online survey (center staff) Questionnaire (969 patients)	Emission factor *(ADEME Carbon Base* [9]*)*
Waste			
▪ Hazardous by weight (kg)	943 kg CO_2e/t	Over 2 days	Emission factor *(ADEME Carbon Base* [9]*)* Monetary ratios
▪ Non-hazardous by weight (kg)	374 kg CO_2e/t	Over 2 days	
▪ Cardboard by volume (m^3)	992 kg CO2e/t	Over 1 week	
▪ Wastewater (m^3)	0.262 kg CO_2e/m^3	Annual invoices	
Freight			
▪ km (road transport)	0.13 kg CO_2e/t/km by truck	Estimation	Emission factor *(ADEME Carbon Base* [9]*)*

bon footprint of an item is ascribed according to its purchase cost in Euros (€) [9].

Activity data and emission factors are provided with a degree of uncertainty (*U*): U_{AD} was set by Alternative Carbone based on the quality of the data (invoice = low uncertainty, extrapolated value = high uncertainty). Uncertainties in activity data range from 5 % to 50 %. U_{EF} was set by ADEME Carbon Base, based on life cycle assessment, from which the emission factors are derived. U_{EF} can vary from 20 % to 100 %.

The total uncertainty U_{total} resulting from the combination of an emission factor and an activity datum was calculated according to the following formula of the Bilan Carbone method:

$$U_{total} = \sqrt{U^2{}_{AD} + U^2{}_{EF}}$$

This approach is coherent with the IPCC Good Practice Guidance and uncertainty management for national inventories.

We first estimated the carbon footprint related to the entire work process at the endoscopy center. We then used the total number of endoscopies performed in 2021 to estimate a carbon footprint per procedure.

Study outcomes

The primary outcome was the carbon footprint of GIE at our center in 2021 expressed in t CO_2e. Secondary outcomes were the estimates of the respective weighting of each emission class as a percentage of the total.

Data collection

Data collected for the study are summarized in ▶ **Table 2**. Most of the data originated from the administrative unit of the center. Electricity consumption in kWh over the year was based on the supplier's invoices. The work was led by two medical doctors (a gastroenterologist and an anesthesiologist), who were tasked with liaising with data analysts at Alternative Carbone, methodological support, and facilitating the data collection phase. The nursing team participated in waste weighing and in listing products specific to endoscopy procedures.

Data analysis

Data were analyzed by Alternative Carbone analysts and included consideration of the uncertainties specific to each item.

We considered all energy needed to heat the building (gas) and to operate medical devices, lighting, and computer stations (electricity). The emission factor used for electricity was that of the French electricity network for year 2020: 0.06 kg CO_2e/kWh. Electricity network losses (8.93 % of consumption) were also included. The emission factor used for gas was 0.227 kg CO_2e/kWh. As the area given to minor activities represented 2.5 % of the total superficies of the center, it was removed from the total energy needs.

Medical gases include GHG emissions related to release of oxygen, carbon dioxide, and nitrogen oxide into the atmosphere following their use on the technical platform. The emission factors used were those of the Carbon Base, carbon dioxide being the reference unit and nitrogen oxide having a global warming power 265 times that of carbon dioxide [9].

For medical and non-medical equipment, the only method available was derived from monetary ratios. We could not use specific emission factors as no data concerning life cycle assessment of endoscopic and non-endoscopic equipment are available. We used two different monetary ratios for this emission class (▶ **Table 2**): one quite old value based on UK National Health Service (NHS) Carbon Emissions Carbon Footprinting Report, 2008 (315 kg CO_2e/k€) [10], and a second one from the ADEME Carbon Base 2021 that was specific to machines and equipment (700 kg CO2e/k€) [9]. Data were amortized over the useful life of products, which, by convention, is generally admitted to equal the duration of accounting amortization. The most important medical equipment at the center was considered, including two endoscopy columns, three endoscope washer disinfectors, seven gastroscopes, seven colonoscopes, two echoendoscopes, two electrical scalpels, one drying and storage machine for endoscopes, seven monitoring scopes, and one respirator, all of which were fully depreciated over 7 years.

Consumables included single-use products and instruments or, less frequently, reusable devices playing a role in the patient's stay at the center: disposable garments, syringes, needles, and small products for endoscopy such as biopsy forceps and hemoclips. When a specific emission factor was known in the database (e. g. gloves), we used it to determine the relevant carbon footprint. When there was no emission factor for a product in the databases, the product was weighed and analyzed, to identify its main components to define the most relevant emission factor (see **Table 1 s** in the online-only Supplementary material). Evidently, in this case, the emission factor associated with manufacture of a product could not be taken into account. Packaging associated with these specific medical products was weighed and analyzed (carboard, plastic, glass), and the packaging manufacture was taken into account using the relevant emission factor. The manufacture of medical gases was included in consumables. Emission factors for food products consumed by patients on site were also included in consumables. Laundry services and cleaning were estimated through their monetary ratios.

Emission factors associated with travel were calculated based on answers to two questionnaires provided to center staff (100 % response rate) and to 1861 patients (968 responses, 52 % response rate). The questionnaire was exhaustively distributed to different patients when they arrived for an appointment with the gastroenterologist, anesthesiologist, and for the endoscopic procedure in January and April. The 968 questionnaires returned constituted the non-probabilistic sample used to extrapolate for 6070 patients who made 18 210 return journeys to the center (6070 patients multiplied by 3) over 220 days of activity. The emission factors were those of the modes of transport identified.

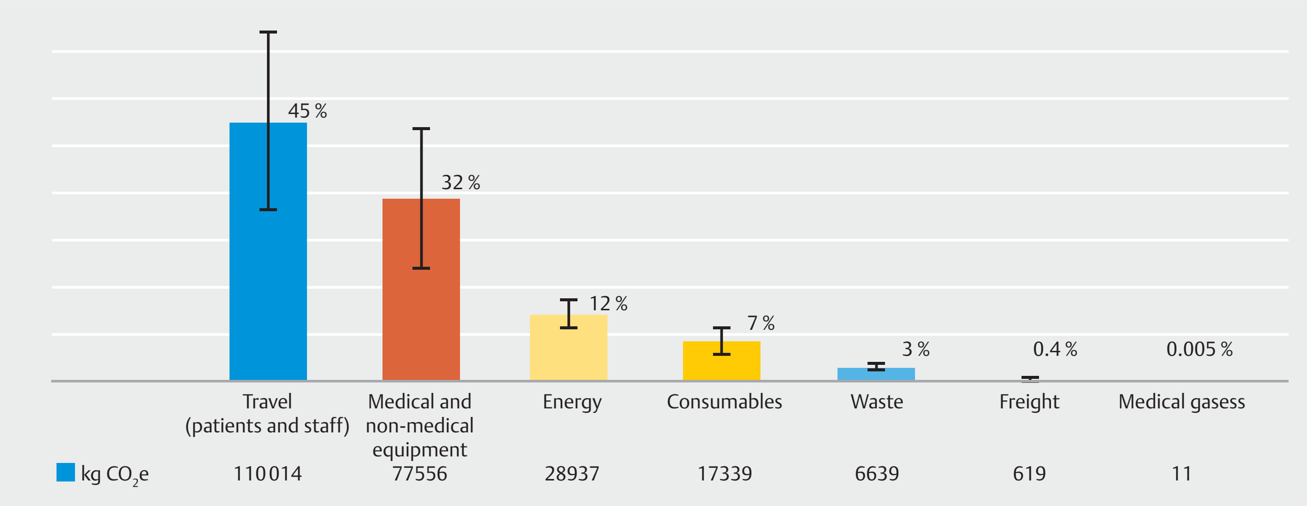
In this study, waste included pre- and post-procedure care, sedation-related waste, and reprocessing of endoscopes. Waste was incinerated and cardboard was recycled. The latest ADEME estimate for the carbon impact of nonhazardous waste incineration was 374 kg CO_2e/t in 2014 [10]. For hazardous waste, the emission factor was 943 kg CO_2e/t in 2021 [9].

For freight, in the absence of more precise information, all transport was considered as made by road with an emission factor of 0.13 kg CO_2e/km [9]. When we could not readily determine the location of the supplier, the distance considered was between the port at Rotterdam and the center in Strasbourg, making the assumption that a majority of consumables came from outside Europe.

Results

Main outcome

Emissions at the GIE center for year 2021 were estimated to total 282 t CO_2e. The data has an uncertainty of ± 56 t CO_2e (i. e. 20 % of the total). The uncertainty associated with the outcome of this study can be read from the vertical lines on ▶ **Fig. 2**. By

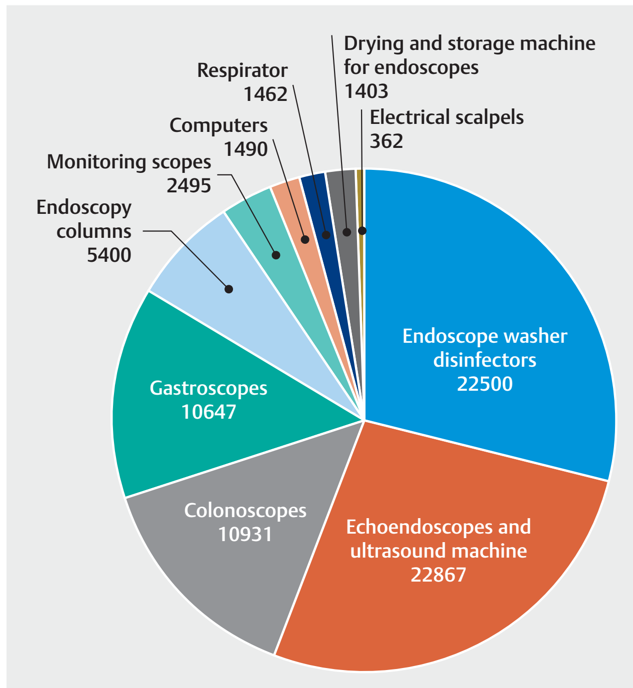


► **Fig. 2** Contribution of different greenhouse gas emission classes to emissions at the center in 2021 in kg of carbon dioxide equivalent (kg CO_2e). The vertical lines represent % uncertainty (see Methods).

excluding consumables for minor activities, the estimated global emissions for the center were reduced to 241.4 t CO_2e. The carbon footprint of a single GIE procedure was 28.4 kg CO_2e (i. e. 241 t CO_2e divided by 8524, the number of endoscopy procedures performed at the center in 2021).

Other outcomes

Taking all emission classes combined, the main emission source was travel by patients and center staff, representing 45 % of the total (► **Fig. 2**). As emissions associated with travel were calculated from a non-probabilistic sample, we cannot quantify uncertainty. However, the population sampled was homogeneous, as evidenced by the similarity in the mean distance traveled per patient and the means of transport used by patients in the two sampling periods of January and April (**Table 2 s**). In addition, all patients were aged between 18 and 85 years and were scheduled for ambulatory endoscopy. The other classes, in descending order of emissions, were medical and non-medical equipment (32 %), energy consumption (12 %), consumables (7 %), waste (3 %), freight (0.4 %), and medical gases (0.005 %) (► **Fig. 2**). The GHG emission estimation for travel, at 110 t CO_2e (16.5 t CO_2e for center staff and 93.5 t CO_2e for patients), was driven by the fact that motorcars represented the principal means of transport for both patients and center staff (**Fig. 1 s, Fig. 2 s**). Moreover, for all travel in our study, motorcars had the highest emission factor due to high levels of GHGs generated in car manufacture and internal combustion. Cars constituted 74 % of the travel means by patients, representing 84 % of patient GHG emissions for travel (including carpooling). Overall, 32 % of center staff traveled by car, generating 60 % of travel-related emissions by staff. The second highest travel emissions were for buses, which were considerably greater than emissions from trains. No GHG emissions were generated by the 26 % of center staff who walked or cycled to work (the carbon footprint for bicycle manufacture was not included for this mode of transport).



► **Fig. 3** Greenhouse gas emissions by medical and non-medical equipment at the center in 2021 in kg of carbon dioxide equivalent (kg CO2e). Endoscopy-specific materials accounted for 98 % of emissions, whereas computers and printers accounted for only 2 %.

Medical and non-medical equipment represented the second highest class of emissions, at 78 t CO_2e (► **Fig. 2**, ► **Fig. 3**). The ADEME Carbon Base monetary ratio was used to estimate emissions for the informatic infrastructure at the center, consisting of 24 computers and 17 printers, for which GHG emissions totaled 1.5 t CO_2e. For endoscopic and anesthetic material, there are currently no data on their life cycle assessment and therefore no specific emission factor is known. Thus, monetary ratio was used to estimate emissions by endoscopic and anesthetic material, explaining the high uncertainty for this estimation (38 %). The endoscopy-specific materials (▶ **Table 2**) (i. e. not including the computing equipment) contributed 98 % of GHG emissions generated by this class.

Energy consumption accounted for 28.9 t CO_2e at the center (▶ **Fig. 2**). Gas consumption to heat the center in 2021 was 126 350 kWh. Gas combustion gave rise to 19 t CO_2e and its production generated 4.5 t CO_2e. In 2021, 57 840 kWh of electricity was consumed, generating 3 t CO_2e. The energetic performance of the center building is in category E for energy and in C for GHG emissions, according to the French regulatory method for calculating building performance.

Consumables constituted the fourth highest GHG emission class, at 17.3 t CO_2e (▶ **Table 3**). Single-use products accounted for 7.9 t CO_2e, with patient clothing, single-use sheets for patients, biopsy forceps, gloves, detergents, and disinfectants for endoscopes having the highest carbon footprints (▶ **Table 3, Table 1 s**). The carbon footprint of medical gas manufacture, at 1.8 t CO_2e, was mainly due to oxygen. The carbon footprint of laundry, at 2.9 t CO_2e, was due to reusable sheets and professional garments. The carbon footprint for food, estimated at 2.2 t CO_2e, was generated by the snack (light food and beverages) served to patients after endoscopy. Emissions from packaging of consumables were estimated at 2.5 t CO_2e (▶ **Table 3**).

Waste accounted for 6.6 t CO_2e (▶ **Fig. 2**). The weight of solid waste arising from one GIE procedure was 1.5 kg. The amount of waste generated ranked, in decreasing order, from household waste, cardboard, wastewater to hazardous waste. Cardboard ranked highest in the amount of GHG emissions, followed by hazardous waste, household waste, and water.

GHG emissions due to freight was 0.9 t CO_2e (▶ **Fig. 2**). The analysis showed that a high proportion of consumables (except for food and laundry) came from outside Europe.

Medical gas emissions (related to release of carbon dioxide) accounted for 11 kg CO_2e.

▶ **Table 3** Greenhouse gas emissions for consumables by category and product type used at the center in 2021.

Consumables	**Carbon footprint in kg CO_2e**	**Carbon footprint per unit of consumable (g CO_2e/unit)**
Total for single-use products	7504[1]	
▪ Detergents	1055	4180 /kg
▪ Chemicals for decontamination	1195	1290 /kg
▪ Sheet protectors	843	131
▪ Biopsy forceps[2]	527	145
▪ Gloves	250	4.5
▪ Swab kits	282	38
▪ Patient shirts	219	28
▪ Cold snares[2]	29	41
▪ Diathermic snares[2]	44	111
▪ Hemoclips[2]	49	115
▪ Other items[3]	3011	See **Table 1 s**
Medical gases (production)	1804	
▪ Oxygen	1796	
▪ Carbon dioxide	8	
Laundry[4]	2944	
Packaging	2451	
Food	2202	
Total consumables	**17 339**	

[1] Totals multiplied by 1.0582 for extrapolation to 100 % for single-use products where only the most expensive items, accounting for 94.5 % of the total, were considered.
[2] For biopsy forceps, snares, and hemoclips composed of more than one material, the product was weighed and analyzed to identify its main material, which was used to estimate the carbon footprint; see also **Table 1 s**.
[3] Other items: masks, needles, compresses, oxygen tubing, polyp traps, syringes, disposable underpads, suction jars, hand towels, toilet paper, garbage bags.
[4] All emission factors used for consumables were based on life cycle assessment, except for laundry where the monetary ratio was used (see Methods).

Discussion

This is the first study to estimate the carbon footprint of GIE based on a multi-criteria analysis. The carbon footprint was estimated to be 28.4 kg CO_2e per endoscopic procedure. In France, some 2 413 244 GIE procedures are performed each year [8]. Extrapolating from our data, we estimate annual French GIE activity generates 68 536 t CO_2e. This is equivalent to the annual carbon footprint of 8000 French inhabitants. Previous studies have attempted to estimate the environmental impact of GIE. Siau et al. estimated that one endoscopy generated a carbon footprint of 4.8 kg CO_2e related to waste and energy in the USA [5]. Considering only the energy (12 %) and waste (3 %) estimations of our study, we obtained a similar carbon footprint at 4.2 kg CO_2e. Another US study [14] estimated that a single endoscopic procedure generated 1.5 kg of waste, which our study confirmed. However, these studies only considered waste and energy. Such an analysis is incomplete for an evaluation of the carbon footprint as defined by ADEME. Our study involved a level of uncertainty that is inherent to every environmental multi-criteria assessment. The uncertainty of 20 % for our main outcome is considered quite low in this field of work. Nevertheless, this study calculated and ranked the GHG emissions associated with GIE, which allowed priority areas to be identified and targeted for actions to decrease the environmental impact of such procedures.

We did not expect travel to emerge as the highest emission class. Overall, travel by patients and center staff represented 45 % of the center's carbon footprint. The Shift Project – a French think tank advocating energy transition to a post-carbon economy [6] – reported that emissions linked to transport of patients and visitors represent only 11 % of total health sector GHG emissions. This discrepancy with our study is probably due to the fact that our center is a highly specialized center, thus improving its overall efficiency, and that other emission classes are low and cost effective. For example, the center's small superficies enables low energy consumption. Shift Project data also showed that staff travel represents 5 % of the total healthcare emissions, close to the 6 % recorded in the current study (as a proportion of the total carbon footprint for the center). UK NHS data showed that, in 2019, GHG emissions linked to healthcare travel were 10 % [15]. Our results led us to raise patient and staff awareness concerning the carbon footprint of their mode of transport by displaying our findings in waiting rooms and on our website. In addition, we decided to develop a teleconsultation service for both anesthesia and gastroenterology consultations [16, 17].

Owing to the technical nature of GIE, it is not surprising that medical and non-medical equipment emerged as second in terms of emission levels, at 32 %. This class represents just 9 % of total emissions in the Shift Project assessment of the health sector carbon footprint [6]. Our study can be improved on in future studies, as we used monetary ratios with high uncertainty for estimating the carbon footprint of endoscopy materials. An advance in assessing the true carbon footprint of GIE would be to oblige endoscope manufacturers to provide clients with an "eco score," such as a life cycle assessment of a medical device or equipment. Such an eco score could certainly become an important criterion at purchase if the technical performance of a device is otherwise equivalent between manufacturers [18]. Equipment is critical in GIE owing to the amount of precision and electronic tools required. Indeed, GIE has reached a very high level of technicality, a trend that is likely to continue through innovations such as artificial intelligence. It would theoretically be possible to reduce equipment needs through single-use gastrointestinal endoscopes but this would probably increase freight, packaging, and waste emissions [19, 20].

Consumables ranked fourth in terms of GHG emissions at the center and waste had a relatively low carbon footprint in our study. One explanation could be that our center uses few single-use instruments, as we mostly perform diagnostic or common therapeutic endoscopy and no advance procedures that require a high number of accessories. Another explanation could be related to use by the center of many reusable medical devices such as mouth guards and anesthesia trays, counter to the current trend for use of disposable devices in many hospitals and clinics. In addition, disposable garments for staff are not used at the center as they are known to emit three times more GHGs than those made from cloth [21, 22]. Moreover, anesthesiologists do not routinely use infusion (tubing, stopcock, and crystalloid solution) at our center, but only in cases of clinical signs of hypovolemia. It is a paradox that while waste management is a subject of growing interest among health professionals concerned with sustainable development, the carbon footprint of waste is in fact quite low. This questions the priority of actions to be taken.

Energy represented 12 % of the center's GHG emissions, quite close to the previous estimates published by the Shift Project [6] and others. However, comparison with other studies is limited by the fact that the main source of electricity varies between countries. In France, nuclear energy represented 70.6 % of electricity production in 2019, far ahead of the 10.1 % estimated for worldwide electricity production [23]. This French specificity explains the less significant contribution of energy to the estimated carbon footprint. The emission factor for electricity by means of production in France expressed in g CO_2e/kWh is 6 for a nuclear power plant compared with 1058 for a coal-fired power plant [11].

The present study has certain limitations. For example, we evaluated ambulatory endoscopic activity in a relatively small, specialized center. While this has the advantage of direct access to data on the different classes of products contributing to GHG emissions, the carbon footprint is probably much higher when GIE is performed within a bigger technical platform, such as in an operating theater, with its significantly higher energy demands for ventilation, air conditioning, and lighting. Moreover, we did not consider other sources of GHG emissions that form part of the GIE process such as histological analysis [24] and maintenance of endoscopes that occurs outside of the center. As we had no reliable data on the carbon footprint of certain consumables, we made an approximation of their footprint based on the emission factor of the main material of such an item. In addition, the calculation of the emission factor for freight assumed that single-use products were delivered from a European country. Identifying the exact place of manufacture of each medical device is complicated and very time consuming. Accordingly, there may well be an underestimation of the emission factor related to freight. Finally, we did not consider other potential ecological footprints of GIE, such as rare mineral extraction for electronic components and water pollution.

This study provides an opportunity to raise awareness among gastroenterologists of the carbon footprint of GIE procedures. Endoscopy is undoubtably a very efficient tool and a pillar in the prevention and treatment of digestive diseases, particularly bowel cancer. However, studies suggest that as much as 30 % of endoscopic procedures are avoidable or unnecessary [25–29]. As suggested recently by Bjørsum-Meyer et al. [27], "reducing [the carbon footprint] from superfluous colonoscopies could be one of the potentialities to scale down our impact" [28]. It is possible to reduce unnecessary procedures and improve endoscopic efficiency through new US, European, and French recommendations on post-polypectomy procedures [30–32], through use of noninvasive techniques such as fecal immunochemical or calprotectin testing, and with radiological alternatives. Moreover, development of optical diagnosis and the growing use of artificial intelligence systems in the resect and discard strategy will probably serve to decrease unnecessary histopathological examinations [33].

This study highlights the importance of global assessment of the carbon footprint of GIE. There are many ways of reducing the carbon footprint and acting responsibly with future generations in mind. While peering through the small lens-bearing end of the endoscope, gastroenterologists need to bear in mind their public health responsibility, inseparable from ecological awareness. For the gastroenterology community, the challenge is to develop sustainable/green endoscopy as recommended by the recent guideline of the European Society of Gastrointestinal Endoscopy [33].

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Competing Interest

The authors declare that they have no conflict of interest.

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