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Original research

Reducing scope 3 carbon emissions in gastrointestinal endoscopy: results of the prospective study of the 'Green Endoscopy Project Würzburg'

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ABSTRACT

Objective Carbon emissions generated by gastrointestinal endoscopy have been recognised as a critical issue. Scope 3 emissions are mainly caused by the manufacturing, packaging and transportation of purchased goods. However, to our knowledge, there are no prospective data on the efficacy of measurements aimed to reduce scope 3 emissions.

Design The study was performed in a medium-sized academic endoscopy unit. Manufacturers of endoscopic consumables were requested to answer a questionnaire on fabrication, origin, packaging and transport. Based on these data, alternative products were purchased whenever possible. In addition, staff was instructed on how to avoid waste. Thereafter, the carbon footprint of each item purchased was calculated from February to May 2023 (intervention period), and scope 3 emissions were compared with the same period of the previous year (control period).

Results 26 of 40 companies answered the questionnaire. 229 of 322 products were classified as unfavourable. A switch to alternative items was possible for 47/229 items (20.5%). 1666 endoscopies were performed during the intervention period compared with 1751 examinations during the control period (–4.1%). The number of instruments used decreased by 10.0% (3111 vs 3457). Using fewer and alternative products resulted in 11.5% less carbon emissions (7.09 vs 8.01 tons of carbon equivalent=tCO2 e). Separation of waste led to a reduction of 20.1% (26.55 vs 33.24 tCO2e). In total, carbon emissions could be reduced by 18.4%.

Conclusion Use of fewer instruments per procedure, recycling packaging material and switching to alternative products can reduce carbon emissions without impairing the endoscopic workflow.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Gastrointestinal endoscopy has been mentioned to be one of the largest contributors to carbon emission in endoscopy.

WHAT THIS STUDY ADDS

⇒ The impact of specific measures aimed to lower emissions was prospectively assessed. Compared with a control period, interventions lead to a reduction in emissions of about 20% without impairing the endoscopic workflow or harming patients.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Based on our results, lowering carbon emissions in endoscopy is possible and should be incorporated into clinical practice guidelines.

INTRODUCTION

Greenhouse emissions have been mentioned to be a major cause of global heating. Furthermore, medicine has been identified to cause about 1%–5% of such emissions.[1 2] This is related to direct emissions caused by heating (scope 1), emissions related to purchased energy (scope 2) or indirect emissions mainly caused by the manufacturing, packaging and transportation of purchased accessories and instruments (scope 3).[3]

To reduce the environmental footprint of gastrointestinal endoscopy, the '5 Rs' (Reduce, Reuse, Recycle, Research, Rethink) of greener endoscopy have been identified by the ESGE green endoscopy working group.[4] These guidelines certainly help to decrease carbon emissions in daily practice. Nevertheless, data on the precise impact of these measures are sparse. It is also unclear, which of the mentioned 'Rs' might have a comparably greater impact, and whether and how the endoscopic routine practice is influenced by these suggestions.

We have recently calculated the yearly carbon emissions of the endoscopy department at the University Hospital in Würzburg, Germany. As reported, a carbon dioxide-calculator tool has been developed to assess emissions of scopes 1, 2 and 3.[5] Thereby, we have been able to assess scope 3 emissions in gastrointestinal endoscopy for the first time. Having these data available, next steps were to take consequences out of these findings, to identify measurements leading to decrease emissions, and to prospectively evaluate the efficacy of those measures within a defined time frame. Here, we report on the prospective study of the Green Endoscopy Project Würzburg.

MATERIAL AND METHODS

Overall, three different scenarios were followed to potentially decrease carbon emissions: (1) search

Table 1 The parameters for grading respective items and distributing companies in more detail

	Item	Company
Very good	Complete response, measures initiated, intra-European production	Complete response, measures initiated
Good	Complete response, measures initiated, intra-European production	Complete response, certificates, planned measures
Satisfying	Only partially answered, measures initiated/certificates, intra-European production	Only partial response, measures planned
Sufficient	Only partially answered, measures initiated/certificates, non-European production	Only partial response, no measures/certificates
Inadequate	Not/only partially answered, no measures, intra-European production	Incomplete response, no measures
Inacceptable	Not/only partially answered, no measures, non-European production	No response

for alternative instruments, (2) staff education and documentation and (3) waste management.

Finally, a carbon calculator was applied to obtain reliably numbers of the effect of such a strategy.

Search for alternative instruments

At first, we identified all material, tools and accessories ordered by the endoscopy unit of the University Hospital Würzburg. Here, the focus was on potentially replaceable endoscopic instruments. Preprocedural materials, such as intravenous accesses, sedation or capital goods, such as endoscopes or computers were not considered. Thereafter, the distributing companies were contacted via mail. All companies were asked to participate in a web-based survey and to answer a 21-item questionnaire on the respective instrument but also on the company itself. Apart from details about the respective product (material, weight, packaging, location of manufacturing, transportation, …), we were also interested on general commitments of the companies on ecological manufacturing, and whether certain measurements have already been undertaken to reduce greenhouse emissions. The questionnaire is shown in detail in online supplemental file. All companies had 3 months to fill out the questionnaire (September 2022 to December 2022). After the first 2 months, reminders were sent out twice every fortnight. Thereafter, products and companies were evaluated based on defined criteria and graded as 'very good', 'good', 'satisfying', 'sufficient', 'inadequate' or 'unsatisfactory/inacceptable/lack of participation' (table 1).

If an item was graded 'inadequate' or 'inacceptable', we looked for alternatives whenever possible. For items graded 'sufficient', we searched for similar tools produced within Europe to decrease length of delivery route. With respect to companies, all those graded worse than 'sufficient' were banned as distributors if alternative products were available.

Staff education and assessment

Staff members (nurse assistants, endoscopists, personal from the hospital's purchase and facility departments) were instructed during several team meetings on the goals and methodology of the prospective study. In single sessions, the employees were informed about ways to avoid garbage, about recyclable garbage and waste separation. Furthermore, the staff was requested to limit number of examinations including devices as much as possible without changing the usual workflow and in-house requirements. Therefore, the staff was again reminded to critically review the examination indications.

After evaluation of the questionnaires, the staff was also involved in the search for alternative instruments or accessories. Endoscopists were additionally informed to note whenever problems with the chosen alternative products occurred, or they had to switch back to the conventional, previously used products.

In addition, the hospital's documentation system was used to assess numbers of endoscopies from 1 February 2022 to 1 May 2022 (control period), and during the same time frame 1 year later (intervention period). Capsule endoscopies, as well as enteroscopies, were excluded from the evaluation.

We also looked for severe complications during both evaluation periods. These included pancreatitis caused by endoscopic retrograde cholangiopancreaticography (ERCP) requiring a prolonged hospital stay of more than 3 days, procedure-related death (any type of endoscopy), and severe bleeding following endoscopic resections requiring transfusion red blood cell packages and/or surveillance on an intensive care unit.

With respect to the instruments used per procedure, the bar code of each item used was scanned and documented in the examination file. Thereby, each tool could by precisely assigned to the respective examination during both periods. Other articles, such as plastic tubes for suction, flushing, oxygen supply, valves, protection gowns and absorbent pads, were calculated with a predetermined number per examinations.

Waste management

From 1 February to 1 May 2023, waste was separated, and the daily amount (recyclable and standard hospital trash) was weighted. Thereafter, the mean weight per working day was compared with the mean daily weight of the usual, unseparated amount of trash as assessed during a 4-week period from mid-November to mid-December 2022.

Carbon calculator tool

For calculating the carbon footprint associated with consumables purchased by the endoscopy, we identified product categories based on the material composition. In detail, categories were as follows: balloons, bougies, wires, feeding tubes, tube/wire/plastic handle/metal head (eg, biopsy forceps, sphincterotome, …), metal stents, plastic stents, plastic consumables (eg, bite blocks, tubes), big plastic consumables (eg, pressure syringes), protection gowns, absorbent pads. For each group, we selected the most frequently used product as a reference. The reference products material composition was determined by disassembly and high-precision weighing. In addition, all items were weighed including packaging.

To account for the transportation from the manufacturing site to the endoscopy, we considered the three parameters product weight, transport distance and transport mode. For the latter two, information was acquired from the questionnaire (online supplemental file). Based on these data, we estimated a transport distance of 1000 km and the transport mode 'truck' for consumables produced in Europe. For goods produced overseas (Americas or Far East), we modelled a transport distance of 10 000 km and the transport modes 'ship' (90%) and 'plane' (10%). All the collected data were subsequently used to compute the respective emissions. The emission factors for the production and transport emissions for oil (0.34 kgCO2e/m^3), gas (0.70 kgCO2e/L) and externally generated electricity (0.05 kgCO2/kWh), were

derived from the Greenhouse Gas Protocol estimates as outlined in the UK Government's GHG Conversion Factors for Company Reporting.[3] Additionally, for emissions associated with waste burning (0.02 kgCO2e/kg), we referred to the same Greenhouse Gas Protocol estimates. The emission factor for each group was determined based on the reference products. The CO2 equivalents emitted during the production of these raw materials were subsequently obtained from the commercially available EcoInvent 3.8 database.[6]

The carbon emissions were calculated for each individual consumable and multiplied by the respective consumption figures. Finally, the individual numbers per item were added together with the amount of waste and energy-related activities to obtain the total amount of scope 3 emissions for the control and intervention period, respectively.

The carbon calculators source code is freely available (https://green-endoscopy.g-play.net/?).

RESULTS

Survey results and consequences

Overall, 40 companies were requested to fill-in the questionnaire. Among those, 4/40 were judged as 'very good', 3/40 as 'good', 5/40 as 'satisfying', 14/40 as 'sufficient' and 0/40 as 'inadequate'. Overall, 14/40 companies did not give any answers and were, therefore, graded as 'inacceptable'. Hence, only 12/40 reported to have taken measures to reduce carbon emission or are at least planning to do so. Of note, none of the responders could give a precise calculation of the respective company's carbon footprint.

With respect to the answers for instruments based on the grading system less than 30% of purchased products were made in European countries by companies that have taken measures to reduce carbon emissions, or at least are planning to do so.

Hence, we had to look for alternatives for 229/322 (71.1%) products. Table 2 lists the 11 product groups created based on their material composition. In addition, table 2 shows examples of products that needed to be replaced due to an insufficient, inadequate or inacceptable evaluation. However, several items were only available from companies graded 'inadequate/inacceptable' or were exclusively manufactured in distant, non-European countries. These items included all sort of protection material, absorbent-pads, plastic tubes, valves, gloves and biopsy forceps. A switch to alternative items was possible for only 47/332 (14.6%) consumables. These items were mainly EUS needles, metal stents, wires, balloons, snares and cleaning brushes.

Table 2 The product groups created with respective example products that needed to be exchanged for more ecological alternatives due to insufficient, inadequate or inacceptable evaluation

Product group	Examples of inadequate or inacceptable products
Consumable plastic big	Pressure syringe
Consumable plastic	Polyp trap, bite block
Plastic stents	Biliary stent
Metal stents	Oesophagus stent
Tube/wire/plastic handle/metal head	Biopsy forceps, Polypectomy snare
Feeding tube	Gastrotube
Wires	Guide wire
Bougies	Savary dilatator
Balloons	Extraction balloon
Absorbent pads	Single use absorbent pads
Protection gowns	Single use protection gowns

Examinations, complications, garbage

Table 3 shows the number of endoscopic examinations being performed from 1 February to 1 May in 2022 and 2023, respectively. As demonstrated, not only number of total examinations but also the number of used instruments per procedure could be decreased. Of note, using fewer and alternative instruments was not associated with a higher risk of procedure-related complication (1.4% for control vs 1.0% for intervention period). It should, however, also be noted, that for 18 examinations (1.1%) performed during the intervention period, examiners did not use the alternative product, and rather preferred the conventional item. In detail, this occurred during five EUS-guided drainages (EUS needle), seven ERCPs (wire) and six EGDs (1×clip, 1×grasper, 4×bougies).

The total amount of waste was 69.88 kg/day during the intervention period compared with 70.84 kg/day as before. Separation of garbage (recycling of packaging material) during the intervention period led to a further reduction of 4.38 kg/day. Hence, the reduction of was 7.5%.

Carbon emissions

Overall, for the intervention period, we were able to achieve a 11.5% decrease of scope 3 emission related to decreasing number of instruments/examinations and switching to alternative items (7.09 vs 8.01 tCO2e).

With regard to the effect of the applied waste separation, it must be considered whether the energy is reused through waste incineration. If this is not the case ('end-of-life model'), we were able to reduce carbon emissions by 20.1% by recycling packaging material. Combining scope 3 emissions and emissions if waste was separated, we were able to reduce carbon emissions from 41.25 tCO2 to 33.64 tCO2 (−18.4%). The impact of our measures on carbon emissions is summarised in figure 1.

Figure 2 shows remaining carbon emissions for the intervention period. As demonstrated, most of the emissions were caused by the categories 'protection gowns' and 'plastic consumables'. The factor 'transportation' still had an impact of 0.914 tCO2e (15.1%). Hence, if all accessories were produced within Europe (distance 1000 km, items delivered by truck), and protection gowns were completely omitted, scope 3 emissions could be theoretically further decreased by 38.0%.

DISCUSSION

To the best of our knowledge, this is the first study that prospectively assessed the efficacy of certain measures to reduce scope 3-related carbon emissions of a gastrointestinal endoscopy unit. We were able to show that a general environmental consciousness and switching to alternative accessories reduce carbon emissions without impairing the endoscopic workflow or harming patients. Although, the efficacy of such measurements is rather small (less than 20% reduction in emissions), our data suffice to give guidance for further steps taken under consideration the worldwide climate crisis (online supplemental visual abstract).

Most of the measures initiated and finally evaluated were based on a survey among companies that manufacture, distribute and sell endoscopic accessories. Of interest, less than one-third of participants appear to be aware of environmental issues. This stands in contrast to other industries, where it is usual that companies are publishing the results of their carbon footprints externally to manage risks associated with climate change. In

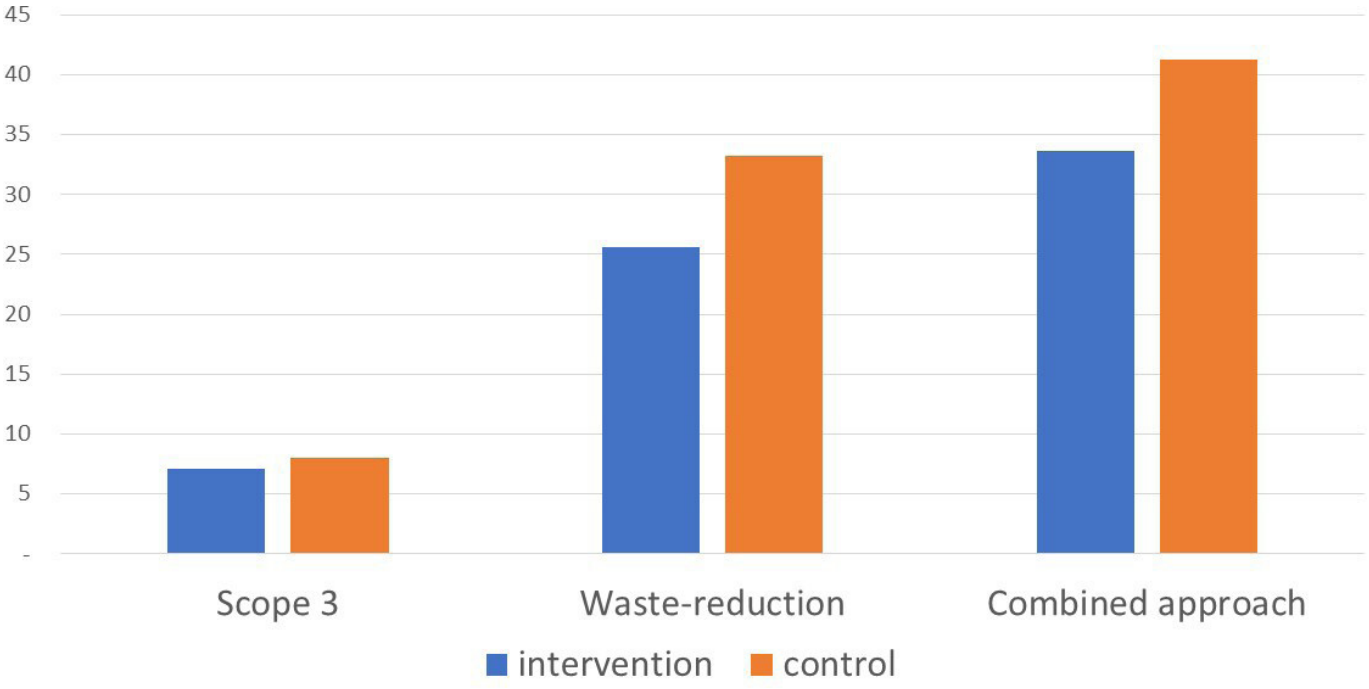
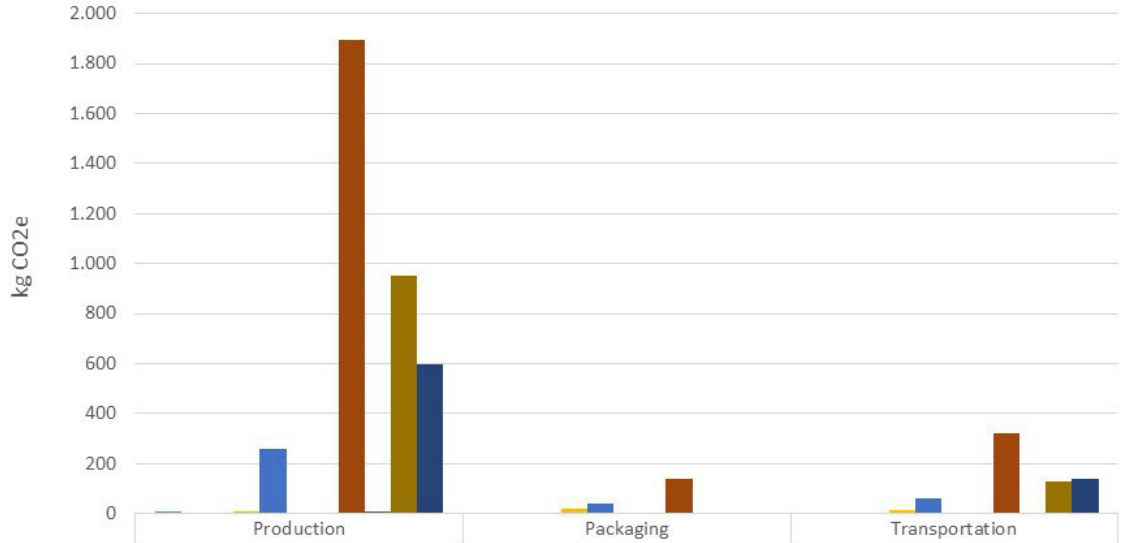


Figure 1 Reduction of carbon emission (in tCO2e) during the intervention period compared with the control period. 'Scope 3' summarises the effect of reducing number of examinations and instruments, as well as the use of alternative instruments (see text).



Product categories	Production	Packaging	Transportation
Balloons	10	3	4
Bougies	4	0	1
Wires	3	4	4
Feeding tubes	10	21	14
Tube /Wire/ Plastic Handle/ Metal Heads	256	42	58
Metall stents	4	1	2
Plastic stents	1	5	4
Consumable plastic	1.893	137	318
Consumable plastic big	9	3	3
Protection gowns	950	0	131
Absorbent pads	596	0	138

Figure 2 Carbon emission of the respective product groups during the intervention period in relation to production, packaging and transportation of goods.

Table 3 The number of examinations, instruments and side effects

	Control period (1 February 2022–1 May 2022)	Intervention period (1 February 2023–1 May 2023)	Change
All endoscopies	1738	1666	−4.1%
Gastroscopy	978	976	0.2%
Colonoscopy	419	369	11.9%
Endosonography	178	158	11.5%
ERCP	163	163	0%–0%
No of instruments*	3457	3111	−10.0%
Side effects†	25	17	−32.0%

*Only instruments used for intervention including biopsy forceps.
†Perforation, severe bleeding, post-ERCP-pacreatitis.
ERCP, endoscopic retrograde cholangiopancreaticography.

the automobile industry, green supply chains have become standards.[7] In addition, in February 2022, the European Commission has adopted a proposal on corporate sustainability due diligence. This proposal aims to foster sustainable behaviour throughout global value chains.[8] Hence, based on our survey, it may be concluded that many companies manufacturing endoscopic devices and accessories are not well prepared for such a directive.

We were also able to show that although 70% of all accessories have a rather unsatisfactory ecological footprint in the production and the delivery chain, no alternatives from other manufacturers could be found. This applies above all to all those items that are used in large quantities (eg, plastic tubes, biopsy forceps, protective materials). For European endoscopies, the transport route for these no-alternative-consumables is always more than 10 000 km (production sites are mainly located in the far-east). It can, therefore, be concluded that regardless of the ecological commitment of the respective company, production within 1000 km distance alone could lead to a significant reduction in carbon emissions (minus 15% at least according to our data).

Separation and avoidance of waste has also been reported a major factor potentially decreasing carbon emission.[9–11] For example, Cunha Neves *et al* showed that stricter indications for examinations and the introduction of waste separation can reduce the median total amount of waste generated by a Portuguese endoscopy by 12.9%, thus minimising the environmental footprint.[9] However, in our study, we experienced that with the introduction of a recycling system, only 7.5% of daily waste could be reduced. This is mainly related to the fact, that most of the waste is regarded as potentially infectious and therefore may not be recycled. However, it should be mentioned that hygiene measures and energy use from waste incineration may vary from institution to institution and from country to country, which can be considered as a limitation of generalisability of studies. Nevertheless, in accordance with our hospital's hygiene standards, only packaging material of accessories was allowed to be separated. Furthermore, at latest since the COVID-19 pandemic, all staff members are required to wear single-use protection gowns that must be changed after every examination.[12] Protection material alone accounts for a significant carbon emission (figure 2). Avoidance of protective single-use clothing after each intervention would reduce emissions by 30.4%. The necessity of these hygiene regulations or the switch to reusable protective articles should, therefore, also be reconsidered in view of the global climate crisis. These points, as well as the possibility of recycling other materials or instruments not contaminated or in direct contact with the endoscope, should be re-evaluated in hygiene committees and, if necessary, become the focus of further studies. Although reusable endoscopes and their reprocessing were not considered in this study, their role in reducing carbon emissions in endoscopy departments is a matter of debate.[13] Whether reusable or single-use endoscopes or their recycling lead to an improved carbon footprint, reduced waste or increased water consumption is the subject of current studies and should be considered in future calculations.

Despite our comprehensive analysis and documentation of relevant factors that influence the emissions of an endoscopy unit, this study also has some limitations. Some factors related to the endoscopic workflow such as reprocessing of endoscopes, propofol sedation, formalin fixation or biopsy tubes were not included in our scope 3 assessment. Also, capital goods such as endoscopes or computers were not considered in this study. Thus, our calculated amount of carbon emission is relatively small compared with other studies. For example, Lacroute *et al* showed that medical and non-medical equipment alone cause about 32% and consumables such as detergents or biopsy forceps only 7% of the total emissions.[14] However, it is important to note that, compared with previous studies, in this study, the amount of scope 3 emissions was calculated rather than estimated on databases. This approach should allow a more accurate calculation of a medical department's total amount of CO2, making it easier to identify CO2-intensive instruments. Nevertheless, as manufacturers did not provide information about their supply chain and manufacturing process, the endoscopic instruments emissions are based on their raw materials only. In addition, since manufacturers do not disclose the detailed material composition of their products,[15] we analysed one reference product per group in detail which may introduce an additional error.

With respect to transportation, it is also worth mentioning that the precise distance from fabrication to our department was not assessed. That 10% of all distantly produced items were delivered by plane was based on the results of the companies participating in the survey, rather than precisely assessed. In accordance to the Greenhouse Gas Protocol, scope 3 also includes business travel and employee commuting. Since this study was intended to evaluate endoscopy alone, these factors were not currently taken into account in the present calculation.

Nevertheless, in summary, we found out that certain measures as demonstrated indeed help to reduce scope 3-related emissions in gastrointestinal endoscopy without harming patients or disturbing standard endoscopic practice. However, based on our study, such measures can only be regarded as the first steps. We are convinced that a further carbon reduction of more than 50% is realistic. To achieve this, the majority of supplier companies should show greater environmental awareness in the manufacture and transport of their goods. In addition, consumers (hospitals, endoscopy units) should give preference to companies with an ecological commitment and focus also on the delivery routes when items are purchased (no long-distance routes). In addition, the manufacture of products from recycled material (eg, absorbent pads, protective films) should also be discussed together with industry and hygiene. Finally, current hygiene measures (use of single use protection gowns) should be reconsidered to reduce the amount of waste. In order to achieve these goals and reduce emission, sustainability should also be integrated into the training of physicians, nurses and hospital management, and so-called 'green pioneers' should be established in every hospital department.

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Contributors DH, TL and AM designed study, acquired and evaluated data, wrote manuscript and educated staff. MW: critical revision of data, developing the carbon calculator. MB, AW, KS and TK: data acquisition, assistant staff education. All: critical revision of the manuscript. AM: full responsibility for the work and/or the conduct of the study, had access to the data and controlled the decision to publish.

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Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval The study was designed as a cross-sectional prospective study. Since only waste and approved instruments were analysed, ethical approval was not deemed necessary.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request. The carbon calculator is freely avasilable onilne (as already mentioned in the manuscript)

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„Green Endoscopy“

Questionnaire

1. Product name: _____
2. Place of production:
    a. Germany
    b. Austria
    c. China
    d. Japan
    e. Others: _____
3. Are individual components produced by another company?
    ☐ yes ☐ no
4. What percentage of the product is produced by other companies: _____ %
5. In which country are the components produced?
    a. Germany
    b. Austria
    c. China
    d. Japan
    e. Others: _____
6. The transport to the completion site is carried out by:
    a. Train
    b. Ship
    c. Airplane
    d. Other: _____
7. What distance must be covered from the production site to the completion site?

    _____ km
8. How many parts does the product consist of?
    a. 1
    b. 2
    c. 3
    d. 4
    e. >5

9. How many parts are packed separatly?

    a. 1
    b. 2
    c. 3
    d. 4
    e. >5

10. What material are the individual parts made of?

    a. Plastic
    b. Metal
    c. Others: _____

11. How many grams the total product weighs?

    _____ g

12. What material is the product packaging made of?

    _____

    a. Does the packaging consist of recycled materials?

        ☐ yes ☐ no

    b. Does the packaging consist of recyclable material?

        ☐ yes ☐ no

13. How many grams of packaging material are needed for the product?

    _____ g

14. What are the dimensions of the packaging of the product?

    _____cm

15. What are the dimensions of the shipping box of the product?

    _____ cm

16. How heavy is the shipping box incl. product?

    _____ kg

17. How many products are in one shipping carton?

a. 1
b. 2
c. 3
d. 4
e. > 5

18. Do you know the carbon footprint of the product?

☐ yes ☐ no

a. If yes, how much is this? _____ tons/year

19. Do you know the Corporate carbon footprint of the product?

☐ yes ☐ no

a. If yes, how much is this? _____ tons/year

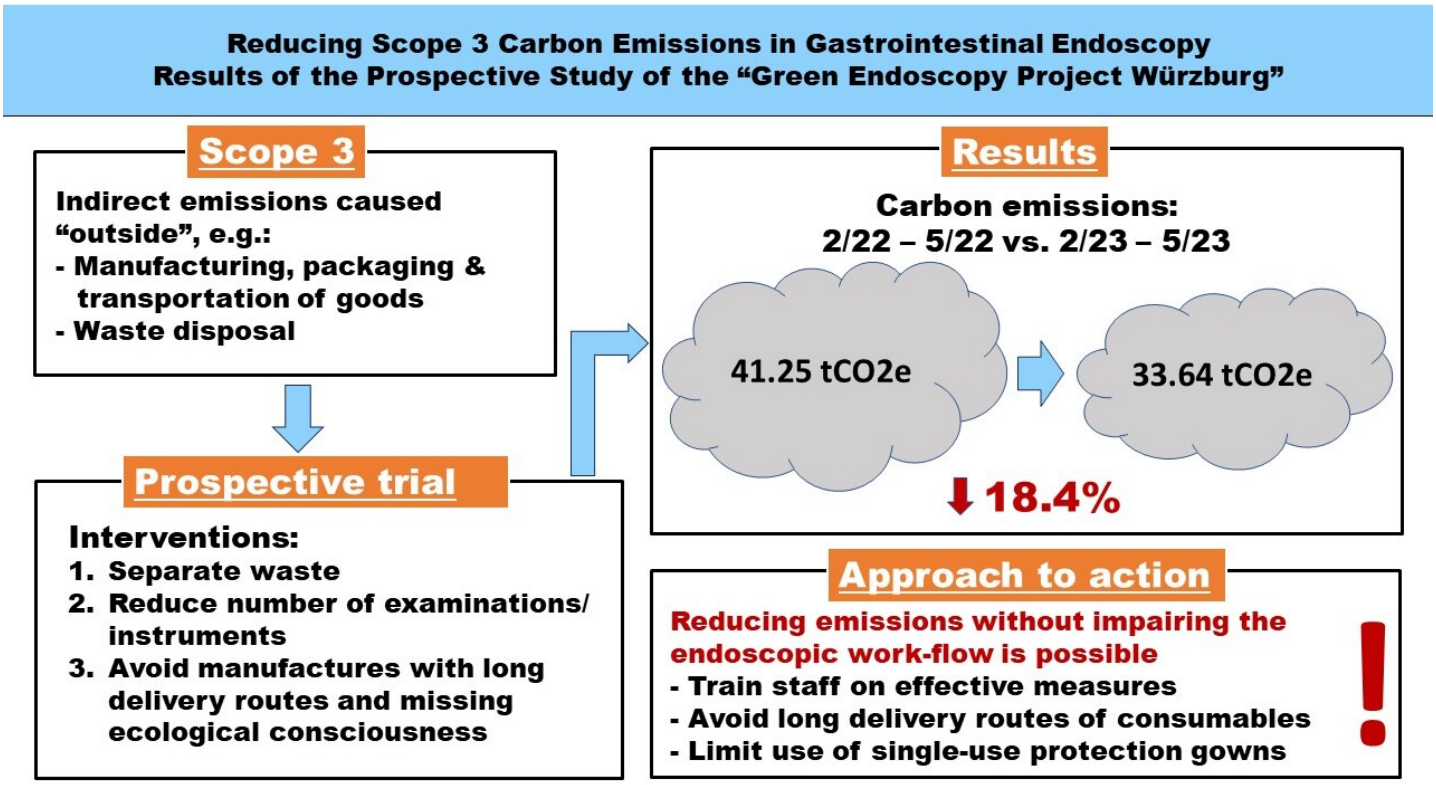
20. Is the product production CO2 neutral?

☐ yes ☐ no

21. Does your company have CO2 compensation?

☐ yes ☐ no

a. If yes, which one?
   i. CO2 certificate
   ii. Eco certificates
   iii. Others: _____


Reducing Scope 3 Carbon Emissions in Gastrointestinal Endoscopy
Results of the Prospective Study of the "Green Endoscopy Project Würzburg"
Scope 3
Indirect emissions caused "outside", e.g.:
- Manufacturing, packaging & transportation of goods
- Waste disposal
Prospective trial
Interventions:
1. Separate waste
2. Reduce number of examinations/ instruments
3. Avoid manufactures with long delivery routes and missing ecological consciousness
Results
Carbon emissions:
2/22 – 5/22 vs. 2/23 – 5/23
41.25 tCO2e
33.64 tCO2e
18.4%
Approach to action
Reducing emissions without impairing the endoscopic work-flow is possible
- Train staff on effective measures
- Avoid long delivery routes of consumables
- Limit use of single-use protection gowns