

## Research article

## Climate change, sustainability and anesthesiology practice: A national survey among anesthesiologists and nurse anesthetists in Norway

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## ABSTRACT

**Background:** In the face of climate change the health sector will need to tackle both the increasing consequences for health worldwide and to reduce its own carbon footprint, which is estimated at 4.4% of global emissions. Raising the voice of health professionals has been identified as paramount to achieving the wide-scale and urgent response required to limit the consequences of climate change for health. Among health professionals, anesthetic practitioners are ideally placed to lead the way given that they make daily decisions regarding anesthetic gasses with a considerable footprint on climate and the environment.

**Methods:** Here, we describe a cross-sectional nationwide survey among 3,300 anesthesiologists and nurse anesthetists in Norway, focusing on climate change, health, and sustainable anesthetic care. Responses were tabulated and characterized using descriptive statistics.

**Results:** A large majority of the responding anesthesiologists and nurse anesthetists ( $n = 697$ , response rate 21.1%) agreed or strongly agreed that the world is facing a climate crisis; that nurses and doctors have a particular responsibility to warn about health threats; and that health organizations should limit their impact on climate and the environment. We found that desflurane is still widely used in Norway, despite its high climate footprint. We also identified several barriers to development of sustainable anesthetic care, including a lack of easy access to waste management systems, an absence of guidelines which promote sustainable care, and inadequate means for disposal of drug residues.

**Conclusions:** Alongside other surveys, the present survey identifies safe and feasible adjustments to anesthetic practice which can give substantial emission reductions, pave the way for a wider health sector response, and yield considerable benefits to planetary health.

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## 1. Introduction

The World Health Organization (WHO) considers global warming to be the single biggest health threat facing humanity [1]. The Intergovernmental Panel on Climate Change (IPCC) states that the scientific evidence is unequivocal: Any delay in global action on adaptation and mitigation will miss a brief and rapidly closing window of opportunity to secure a livable and sustainable future for all

[2]. All IPCC modelled pathways that limit global warming to 1.5 °C, involve rapid, deep, and in most cases immediate, greenhouse gas emission reductions in *all* sectors [3]. The health sector, therefore, will need not only to tackle the increasing health effects of climate change, but also to reduce its own carbon footprint, which is estimated at 4.4% of global emissions [4]. At the Climate Change Conference of the Parties (COP26) in Glasgow, 2021, health was designated as a scientific priority area for the first time, and more than 50 countries committed to building health systems which are able to withstand the impacts of climate change, and which are low carbon and sustainable [5]. Under this COP26 Health Programme, another core initiative was raising the voice of health professionals as advocates for stronger ambition on climate change [5].

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Anesthetic practitioners can play a pivotal role in the transition to climate resilient, low-carbon health care. As front-line health professionals who may witness the acute health effects of climate change worldwide, anesthetic practitioners also make day-to-day decisions with considerable implications for health sector emissions [6]. First, the Sustainable Development Unit of the National Health Service (NHS) in the UK estimated that 5% of the CO<sub>2</sub> from acute health organizations is attributable to anesthetic gasses [7]. Second, drug waste and urinary excretion of drugs and metabolites causes pollution in soil and ground water [8]. Third, anesthetic and surgical procedures and their associated single-use equipment lead to substantial amounts of waste [9,10]. In the UK, it was estimated that each operating theatre on average left behind 2300 kg of waste annually, and that only 10% of this was recycled [7]. Limited research has been undertaken on anesthetic practitioners' knowledge and views relating to sustainable anesthetic practice. Previous studies among anesthesiologists indicate a lack of sustainable practice and a large potential for improvement [11–13].

By driving a transformation towards low-emission anesthetic practice, anesthetic health personnel can both provide a key contribution towards mitigating climate change and its' wide-ranging consequences for global health, as well as set the example that will bring a step-change in how other areas of medicine work towards reaching low carbon, sustainable operations. To our knowledge, no studies focusing on climate awareness and sustainability in relation to clinical anesthetic practice have been conducted in the Nordic countries. Hence, we designed a nationwide survey among anesthesiologists and nurse anesthetists in Norway, aiming to explore their knowledge, views, and practice in relation to climate change, health, and sustainable anesthetic care.

## 2. Materials and methods

### 2.1. Study design

The study had a national, cross-sectional design, using a purpose-designed questionnaire among anesthesiologists and nurse anesthetists in Norway. The study is reported in-line with the Consensus-Based Checklist for Reporting of Survey Studies (See [online supplement 1: Checklist for reporting of survey studies \(CROSS\)](#)) [14].

### 2.2. Data collection methods

The questionnaire was developed by the team of authors, which include a medical student who is a registered nurse, a nurse anesthetist, an anesthesiologist/researcher, a nurse anesthetist/professor well experienced with development of questionnaires, and a medical doctor/associate professor specialized in public health. To identify previous questionnaires, a literature search was performed using the search terms «anesthetists», «anesthesia», «inhalation», «anesthesiology», «anesthetic gasses», «general anesthesia», «conservation of natural resources», «climate change», «greenhouse effect», «sustainable practice», «global warming», «pollution», «greenhouse gas emissions», and «surveys and questionnaires» in different combinations in MEDLINE. Relevant literature was selected if there were surveys about clinical practice from a climate and sustainability perspective, conducted among anesthesiologists, and/or nurse anesthetists. All other types of studies, for example literature studies, analyses of purchasing data, indoor environment issues, surveys which did not involve outdoor climate topics were excluded. Furthermore, surveys conducted among patients, or among healthcare personnel outside the anesthesia profession were excluded. We identified relevant questionnaires [11–13,15], and extracted questions from these to an excel spread sheet. The authors then jointly identified and formulated relevant questions, which were translated and adjusted to the Norwegian context as applicable. Then, the

questions were backtranslated to English, and the English versions were compared to ensure consistency. The final questionnaire was piloted among the board members of the Norwegian Society of Anesthesiologists ( $n = 3$ ) and the Norwegian Association of Nurse Anesthetists ( $n = 7$ ), followed by minor adjustments to improve the questionnaire's face and content validity.

The final questionnaire consisted of ten questions on demographics, 11 questions on participants' views relating to climate change and health, and 12 questions on anesthetic practice. Modalities included a five-point Likert scale where 1=strongly disagree, and 5=strongly agree, and for some questions the option of giving free text answers (see [Online supplement 2: Survey about sustainability and anesthesia](#)).

### 2.3. Study population

The survey was undertaken among all members of The Norwegian Society of Anesthesiologists ( $n = 1500$ ) and the Norwegian Association of Nurse Anesthetists ( $n = 1800$ ). No further inclusion or exclusion criteria for participation were used. Since we used a total population approach, we did not perform any sample size calculations.

### 2.4. Survey administration

An invitation to participate in the survey was sent by e-mail to all members of the two professional organizations. The questionnaire was made available using a secure online platform for data capture and storage (Nettskjema) provided by the University of Oslo, also ensuring single participation. The invitation email included a link to the online questionnaire and an attached information letter. The invitation was sent 31 August 2022 and a reminder email was sent two weeks later. The online survey closed four weeks after the last email had been sent.

### 2.5. Ethical considerations

The study was approved by the Norwegian centre for Research Data (NSD, 434,740). According to Norwegian legislations no ethical approvals are necessary when the research does not include patients. The invitation letter stated that responding and submitting the questionnaire was considered as consent to participate. All responses were anonymous, i.e. we did not collect ip addresses, dates of birth or other personal identifiable information. The Norwegian Society of Anesthesiologists board and the Norwegian Association of Nurse Anesthetists board reviewed the final version of the questionnaire and information letter, and approved distribution among their members.

### 2.6. Statistical analysis

Descriptive statistics were generated as proportions of respondents' responses (n,%) using Microsoft Excel for Mac version 16.65. No method for calculation of missing data was used. Data on reasons for non-response were not collected and no adjustment was made for non-representativeness of the sample.

## 3. Results

### 3.1. Characteristics of respondents

The survey was sent to 3300 eligible participants, and we received 697 responses (response rate of 21.1%). Among respondents, there were slightly more nurse anesthetists (56%) than anesthesiologists (44%). Similar proportions of respondents worked in university hospitals and in non-university hospitals (both 47%). Answers regarding

**Table 1**  
Characteristics of respondents in a nationwide survey of anesthetic nurses and doctors, Norway, 2021 ( $n = 697$ ).

	n (%)
<b>Age, years (<math>n = 696</math>)</b>	
< 30	20 (2.9)
30–45	321 (46.1)
46–60	246 (35.3)
> 60	109 (15.7)
<b>Gender (<math>n = 696</math>)</b>	
Female	384 (55.2)
<b>Occupation (<math>n = 689</math>)</b>	
Nurse anesthetist	390 (56.6)
Anesthesiologist	299 (43.4)
<b>Position (<math>n = 694</math>)*</b>	
Clinical	636 (91.6)
Professional development	84 (12.1)
Manager	59 (8.5)
Research	45 (6.5)
Teaching	56 (8.1)
Other	29 (4.2)
<b>Anesthesia practice, years (<math>n = 696</math>)</b>	
>5	156 (22.4)
5–9	116 (16.7)
10–14	119 (17.1)
15–19	90 (12.9)
20–24	90 (12.9)
> 25	125 (18.0)
<b>Proportion of work related to anesthetic practice, percent (<math>n = 694</math>)</b>	
0–24	64 (9.2)
25–49	57 (8.2)
50–74	108 (15.6)
75–99	189 (27.2)
100	276 (39.8)
<b>Region (<math>n = 695</math>)</b>	
South-Eastern	402 (57.8)
Western	124 (17.9)
Middle	96 (13.8)
Northern	73 (10.5)
<b>Main place of work (<math>n = 696</math>)*</b>	
University hospital	327 (47.0)
Non-university hospital	329 (47.3)
Private hospital	30 (4.3)
Other	23 (3.3)
<b>Type of surgery in hospital (<math>n = 696</math>)*</b>	
Acute	586 (84.2)
Elective	657 (94.5)
Not relevant	30 (4.3)

\* Multiple responses were allowed.

the number of operating theatres at workplaces were as follows ( $n = 687$ ): "under 5" = 8%, "5–9" = 24%, "10–14" = 31%, "15–19" = 9%, "20–24" = 7%, and "25 or more" = 17%; this was "not relevant" in 4%. Among respondents 56% had 14 years of experience or less. About two-thirds (67%) worked in the operating theatre more than 74% of their daily work. Respondents' characteristics are summarized in Table 1.

### 3.2. Views relating to climate change and health

The respondents were asked to indicate to which extent they agreed to 11 statements regarding climate, health, and the health sector. A large majority of the respondents (91%) agreed or strongly agreed with the statement "The world is facing a climate crisis". A large majority of respondents (92%) agreed with the statement that "Businesses in the health sector should limit their impact on climate and the environment". Similarly, a large majority of respondents (93%) agreed or strongly agreed that the health sector has an important role in the response to crises with significance for health. Furthermore, a large majority (90%) of respondents agreed or strongly agreed that nurses and doctors have a particular responsibility to warn about health threats. Only 56.7% agreed or strongly agreed that reducing climate footprint is the responsibility of the individual

health professional, while 84.2% agreed or strongly agreed that reducing climate footprint is the responsibility of the health institution. The responses to statements on climate change health, and the health sector are given in Table 2.

### 3.3. Responses relating to anesthetic practice

The respondents' answers regarding the use of anesthetic agents are given in Tables 3 and 4, respectively. Among respondents, sevoflurane was by far the most used volatile anesthetic, with 72.0% of the respondents indicating they used sevoflurane often or always. Most respondents reported using a circle system for administering volatile anesthetics, but 13.4% reported not always using such a system. During general anesthesia with volatile anesthetics, desflurane was administered often or always by 30.1% of respondents.

We also asked whether the respondents' use of inhalation anesthetics had changed in the last ten years. The majority responded that they use less desflurane. However, 13 respondents answered that they use more desflurane.

Of the 341 who answered in free text on whether the use of volatile anesthetics had changed in the last ten years, 73 (21.4%) respondents highlighted environmental and climate impact as direct reason for changing clinical practice. It was also highlighted that changing workplace could lead to changed practice due to, for example, cultural differences or different procedures in different departments.

The participants were also asked about disposal of drug residues, recycling possibilities and measures for sustainable practice. Approximately half of the respondents (47.3%) answered in-line with Norwegian national guidelines from hospital pharmacies, that drug residues were discarded into a separate container for medicinal residues and returned to the pharmacy. An overview of responses is illustrated in Fig. 1.

#### Number of answers (% of respondents), $n = 691$

Regarding the extent of measures taken by their workplace for a more sustainable clinical practice (i.e., training, information documents, local guidelines, less use of disposable equipment or similar), a minority of the respondents answered "to a moderate extent" 217 (32.0%), or "to a very large extent" 37 (5.5%). Furthermore, 405 (59.0%) out of 687 respondents answered that the workplace only to a small or very small extent facilitated possibilities for recycling of single-use equipment and packaging. In free text responses, the most frequent comment was that no sorting systems were available in the operating theatres. It was highlighted that equipment is often single use and wrapped in plastic packaging, and that sorting waste takes time away from other work. Responders also suggested that attitudes and lack of knowledge were barriers against sustainable practice.

The participants were asked about what kind of waste they recycled at their hospital. Answers are shown in Fig. 2.

#### Number of answer (% of respondents), $n = 644$

Of 665 respondents, 245 (36.8%) stated that they used the available recycling systems to a large or very large extent, 257 (38.7%) to a medium extent, and 163 (24.5%) to a small or very small extent.

Finally, the respondents were asked what they thought was needed to reduce the amount of waste and increase recycling in the operating theatres, whereas 591 (84.8%) answered that they believed that increased recycling could be achieved through more easily accessible systems for recycling. Additionally, 477 (69.4%) answered that distinct and precise local guidelines and procedures would increase recycling, and 387 (56.3%) stated that the lowest possible climate footprint should be a criterion when choosing an equipment supplier. Furthermore, it was pointed out that the equipment packaging should consist of just one material (as opposed to both paper and plastic), and that more support staff should be used to limit the time spent to recycling procedures by anesthetic personnel.

**Table 2**  
Responses to statements on climate change and health in a nationwide survey of anesthetic nurses and doctors, Norway, 2021 (n = 696) \*.

Statements	Responses n (%)				
	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
The world is facing a climate crisis (n=696)	9 (1.3)	10 (1.4)	45 (6.5)	268 (38.5)	364 (52.3)
I am worried about the consequences of climate change on public health (n=695)	6 (0.9)	25 (3.6)	74 (10.6)	288 (41.4)	302 (43.5)
Businesses in the health sector should limit their impact on climate and the environment (n=696)	6 (0.9)	7 (1.0)	44 (6.3)	272 (39.1)	367 (52.7)
The health sector has such a low climate footprint that climate friendly changes will not be of importance (n=694)	245 (35.3)	294 (42.3)	118 (17.0)	31 (4.5)	6 (0.9)
Reducing climate footprint is the responsibility of the health institution (n=695)	12 (1.7)	27 (3.9)	71 (10.2)	335 (48.2)	250 (36.0)
Reducing climate footprint is the responsibility of the individual health professional (n=696)	27 (3.9)	115 (16.5)	159 (22.9)	319 (45.8)	76 (10.9)
The health sector has an important role in the response to crises with importance for health (n=695)	3 (0.4)	1 (0.1)	45 (6.5)	305 (43.9)	341 (49.1)
Nurses and doctors have a particular responsibility to warn about threats against health (n=693)	2 (0.3)	10 (1.4)	59 (8.5)	358 (51.7)	264 (38.1)
A «green» health sector is a more attractive place to work (n=696)	8 (1.1)	17 (2.4)	196 (28.2)	253 (36.4)	222 (31.9)
The health sector should lead by example in the prevention of health loss owing to impact on climate and the environment (n=694)	4 (0.6)	9 (1.3)	80 (11.5)	335 (48.3)	266 (38.3)
The health sector has too many other concerns to also be able to emphasize the environment (n=695)	161 (23.2)	333 (47.9)	117 (16.8)	55 (7.9)	29 (4.2)

\* Deeper color intensity indicates a higher proportion of respondents.

#### 4. Discussion

This is the first study focusing on knowledge, views, and practice in relation to climate change, health, and sustainable anesthetic care among anesthesiologists and nurse anesthetists in Norway. We found that a large majority of the responding anesthesiologists and nurse anesthetists agreed or strongly agreed that the world is facing a climate crisis, that they were concerned about the consequences for public health, that nurses and doctors have a particular responsibility to warn about health threats, and that health institutions should limit their own impact on climate and the environment. Furthermore, we identified that desflurane is still widely used in Norway, despite its high climate footprint, and several barriers exist which limit sustainable anesthetic care.

Some studies have been conducted on sustainable approaches in anesthetic practice that correspond to our findings. For example, a 2014 study among anesthesiologists (n = 184) in Delhi found that 98% were aware of the greenhouse effect [11]. Even though 90% of our respondents indicated that health personnel have a particular responsibility to warn about health threats, only 56.7% acknowledged that reducing climate footprint is the responsibility of the individual health professional, whilst 84.2% agreed or strongly agreed that reducing climate footprint is the responsibility of the health institution. Nevertheless, the results indicate an absence of local procedures and guidelines for sustainable practice at operating theatres. Furthermore, 62.5% of respondents answered that measures to promote sustainable practice in the workplace had only been taken to a small or very small extent. This is in line with findings in other surveys [12,15].

**Table 3**  
Responses to questions regarding the use of anesthetics in a nationwide survey of anesthetic nurses and doctors, Norway, 2021 (n = 696) \*.

Questions	Responses n (%)				
	Never	Rarely	Sometimes	Often	Always
How often do you use volatile anesthetics during general anesthesia? (n=690)	9 (1.3)	125 (18.1)	190 (27.6)	366 (53.0)	0 (0.0)
When you use volatile anesthetics, how often do you use...					
a circle system? (n=686)	7 (1.0)	5 (0.7)	3 (0.4)	77 (11.3)	594 (86.6)
sevoflurane? (n=687)	11 (1.6)	63 (9.2)	118 (17.2)	352 (51.2)	143 (20.8)
desflurane? (n=687)	202 (29.4)	159 (23.2)	119 (17.3)	202 (29.4)	5 (0.7)
isoflurane? (n=687)	563 (81.9)	70 (10.2)	24 (3.5)	28 (4.1)	2 (0.3)
nitrous oxide? (n=688)	181 (26.3)	355 (51.6)	125 (18.2)	26 (3.8)	1 (0.1)
When you use intravenous anesthesia, how often do you use propofol? (n=689)	4 (0.6)	0 (0.0)	2 (0.3)	431 (62.5)	252 (36.6)

\* Deeper color intensity indicates a higher proportion of respondents.

**Table 4**  
Responses to questions regarding the preference of anesthetics administration and use, and disposal of pharmaceutical waste.

	n (%)
<b>What flow do you usually use when administrating volatile anesthetics, (L/min)? (n = 677)</b>	
< 0.5	76 (11.2)
0.5–0.9	331 (48.8)
1.0–1.4	161 (23.8)
1.5–1.9	43 (6.4)
> 2.00	12 (1.8)
Varying	54 (8.0)
<b>What is the normal procedure for disposal of pharmaceutical waste? (n = 691) *</b>	
Throw in separate container for pharmaceutical waste and returned to pharmacy	372 (53.8)
Throw in general waste bin	194 (28.1)
Rinsed into the sink	56 (8.1)
I don't know	119 (17.2)
Other, comment:	101 (14.6)
<b>What do you emphasize when you choose your anesthetic drug? (n = 688) *</b>	
Time to onset and awakening	558 (81.1)
Cost	105 (15.3)
Side effects (e.g., airway irritability or postoperative nausea and vomiting)	604 (87.8)
Availability	216 (31.4)
The patient's comorbidity	594 (86.3)
Additional effects	139 (20.2)
Environmental considerations	126 (18.3)
<b>Has your use of volatile anesthetics changed in the last ten years? (n = 687)</b>	
Yes	385 (56.0)
No	199 (29.0)
I don't know	103 (15.0)

\* Multiple responses were allowed.

Our survey indicates that a typical general anesthesia in Norway with volatile anesthetics will often be based on sevoflurane with a fresh gas flow 0.5–0.9 liter/minute using a circle system without nitrous oxide. The reasons for choosing an anesthetic agent were to a small extent based on environmental considerations. This was also observed by McGain et al. [13] who found that only 10% of Australia and New Zealand's anesthesiologists emphasized environmental reasons when choosing an anesthetic agent. Instead, side effects, comorbidity, and pharmacodynamics were highlighted as more important factors. This may explain why desflurane was administered by as much as one-third of the respondents using volatile anesthesia in our survey.

In our survey, about 30% of respondents used desflurane often or always during daily anesthetic procedures, a higher proportion than observed in other surveys in USA, Australia and New Zealand [12,13]. Data from public hospitals in Norway shows that overall desflurane use decreased by more than 50% from 2019 to 2022. In a recent landmark decision in the UK, NHS England announced the decommissioning of desflurane by early 2024, which also has the support of the Royal College of Anesthetists and the Association of Anesthetists [16]. Nitrous oxide has an impact of approximately 10% of desflurane's GWP100 [17]. In our survey, nitrous oxide was administered to a low extent, and 78% reported seldom or never using. This is similar to findings in Australia, New Zealand and Scandinavia [13,18].

Even if the majority of respondents in our survey responded that they used less desflurane than before, 13 respondents answered that they used more desflurane. Desflurane has by far the highest global warming potential of the halogenated gasses due to long atmospheric persistence of 9–21 years, with a 100-year global warming potential (GWP100) 2540 times that of an equal mass of CO2 [19–21]. Isoflurane and sevoflurane have carbon footprints of around one fourth and 5% of desflurane, respectively [19,22]. Accordingly, it has been

### Disposal of drug residues

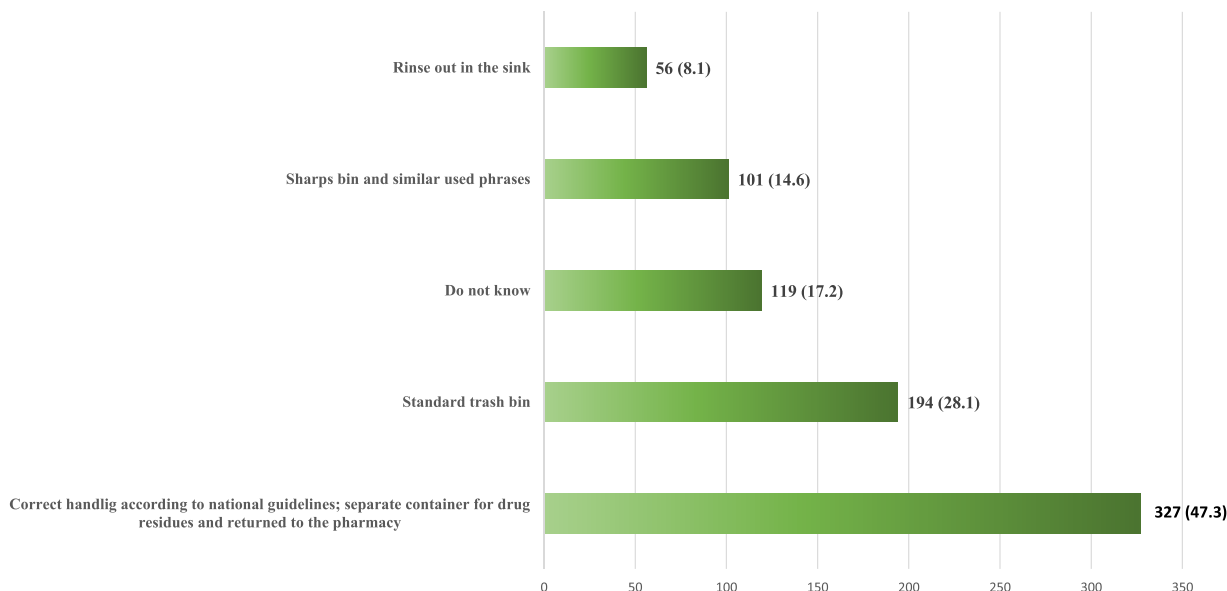


Fig. 1. Responses to questions regarding the disposal of pharmaceutical residues. Multiple responses were allowed.

### Kind of waste recycled at the respondents hospital

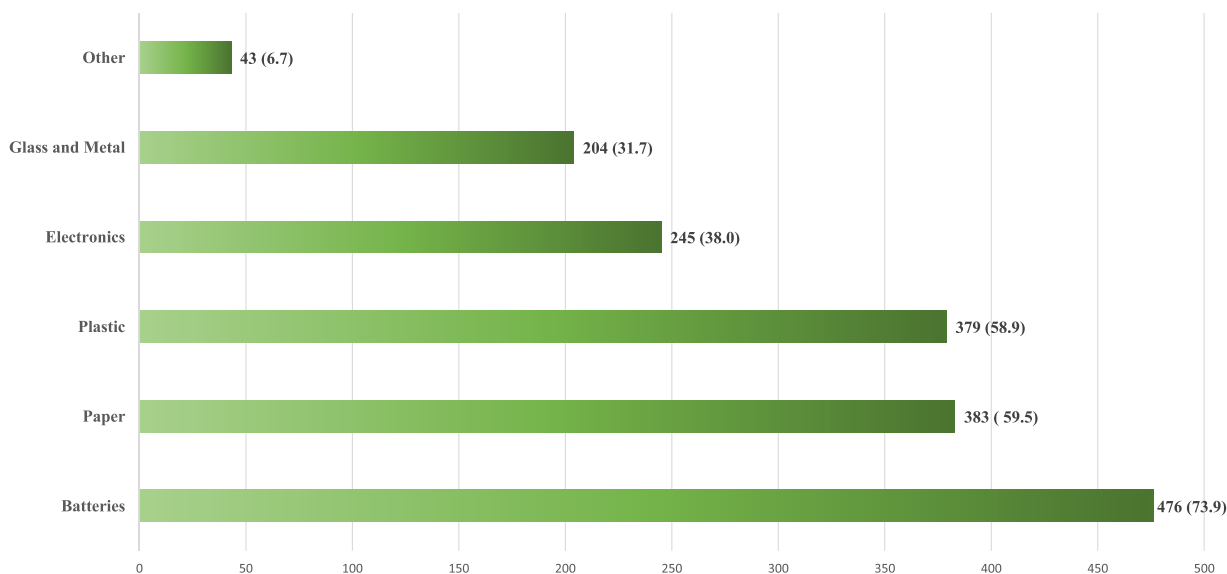


Fig. 2. Responses to questions regarding type of waste recycled at the respondents' hospitals. Multiple responses were allowed.

suggested that the use of desflurane should be abolished in routine operations with general anesthesia as the putative clinical benefits have a limited knowledge base, which do not justify the larger environmental footprint [16].

Almost one out of three (32%) respondents in our survey used a higher flow than 1.0 liter/minute, whilst half of respondents used a flow between 0.5 and one liter. This contrasts the fact that low fresh gas flow is shown to reduce the environmental impact of volatile anesthetics [18,23]. With modern anesthesia ventilators and use of circle systems, lower fresh gas flows can be used without additional risks for patient safety, which would also be cost saving and limit environmental side effects [24,25]. This is also an important point globally, as several reports describe higher fresh gas flow than seen in our survey [26,27]. Unfortunately, we did not differentiate

between fresh gas flow during induction, maintenance and emergence of anesthesia. By doing this, we could have detected whether the respondents consciously adjusted the fresh gas flow down during maintenance. Wyssusek et al. [19] explored the impact of sustainability interventions on the environmental and financial cost of inhaled anesthetic gas use, using global warming potential and carbon dioxide equivalents (CO<sub>2</sub>e) to estimate the environmental impact of volatile agents. Through staff education of desflurane-sparing practices, distribution of posters and progressive removal of desflurane from operating theatres, they achieved a significant reduction in desflurane and sevoflurane emissions and costs.

Only 12% of the respondents in our survey answered that the hospitals facilitated recycling of equipment and packaging in the operating theatres, which is in line with findings among anesthesiologists

in Australia and New Zealand [13]. Where recycling systems were available for the respondents, only 37% answered that they used this system to a large or very large extent. This moderate uptake could be due to difficult-to-access systems in a busy clinical practice, or a lack of awareness about detrimental effects on the environment. These findings correspond to those of Azouz et al. [28], who found that 39% of hospital staff reported they 'only sometimes' or 'never' recycled in the operating theatre. Here, 56.7% of 524 participants reported being unclear which items were recyclable, and 47.7% thought the greatest barrier to recycling was lack of knowledge. In 2016, the American Society of Anesthesiologists conducted a survey of American anesthesiologists ( $n = 2189$ ) regarding environmental sustainability [11]. Of the respondents, 80.1% were interested in recycling, however only 27.7% reported to do so. Reasons were lack of information on how to recycle (67%), or lack of a mandate from hospital leadership to promote sustainability programs (12.6%). A 2019 study in anesthetic practitioners in New Zealand and Australia ( $n = 359$ ), found that sevoflurane was the preferred gas by 72%, at low fresh-gas flow rates (93%) [12]. A reason for this preference was 'low-risk clinical profile'. Petre et al. [15] found that only 30.2% of Canadian anesthesiologists ( $n = 426$ ) recycled at work, despite a willingness to do so. However, sustainable practice was shown through donating unused medical equipment to medical missions (49.5%) and turning down anesthesia machines when not in use (46.3%). Only 31.4% of the anesthesiologists were aware of any efforts to promote sustainable practices at their institution.

We identified several barriers to a sustainable anesthesia practice, for example that no sorting systems or local guidelines for recycling were available, large amounts of equipment were wrapped in plastic packaging, sorting waste took time away at the expense of other work tasks. Additionally, respondents urge for more easily accessible systems for recycling. This is in-line with the findings in several other studies from e.g. USA, India, Canada and Germany [10,11,13,29,30].

Both our survey and other reports [12,15] show that feasible and safe adjustments to clinical practice which can give substantial environmental benefit have a substantial potential for better implementation. Examples of this are using less volatile anesthetics, less desflurane, low flow technique, or using a circle system [18]. In other areas of anesthesia, the tools for a more sustainable practice need to be further developed and refined. The consensus statement 'Principles of environmentally-sustainable anesthesia' from the World Federation of Societies of Anesthesiologists, underlines that hospitals and international bodies should develop and recommend meaningful, measurable standards for healthcare systems, which should aim to mandate them to reduce their contribution to global warming [31]. Moreover, the working group acknowledges that 'while anesthesia providers may be able to influence 'top down' mandate in some countries, 'grassroots' environmental sustainability strategies may be more successful in others'. Notably, the World Federation of Societies of Anesthesiologists has developed seven fundamental principles to guide anesthesia providers to environmentally sustainable practice, including: choice of medications and equipment; minimizing waste and overuse of resources; and addressing environmental sustainability in anesthesiologists' education, research, quality improvement and local healthcare leadership activities [31].

Other international studies we identified have included anesthesiologists only (Online supplement 3). In Norway nurse anesthetists have an important role in choosing anesthetics, recycling and ensuring sustainable anesthesia practice as they are trained to independently provide anesthesia to selected patients when an anesthesiologist has passed the patient as fit for anesthesia [32].

This survey has some limitations. Firstly, we used a self-developed questionnaire. However, the questionnaire was developed based on previous questionnaires [11–13,15] by a cross-disciplinary team of experts, and was piloted among both anesthesiologists and nurse anesthetists, presumably increasing the validity of the survey.

Secondly, although in Norway the proportion of nurses and medical doctors who are members of their professional organization is generally very high (e.g., 96% of certified specialists are members of the Norwegian Medical Association), which suggests those receiving the questionnaire were representative of the target population, the response rate was low and this means we cannot know if the findings accurately represent the views of all anesthetic practitioners in Norway. Nevertheless, the respondents represent both anesthesiologists and nurse anesthetists from different parts of Norway, including both university and non-university hospital contexts, potentially supporting the transferability of our findings. The response rate of 21.1% is in line with other survey studies [11,15,30].

## 5. Conclusion

To conclude, our study shows that even though anesthesia practitioners both have knowledge and positive views towards a sustainable anesthesia practice, there is a large potential for improvement. Barriers for achieving sustainability include a lack of access to systems and guidelines for use of 'safe anesthetics', use of fresh-gas flow, recycling, reusable equipment, and optimal disposal of residues. This is supported by several international studies throughout the last decade, even though the efforts are easy and low-cost. Initiatives must be taken now, to ensure a sustainable anesthesia practice for the future. There is an opportunity for employers and governing agencies to tap into this potential through awareness raising, normative guidance, and practical support.

## Contributors

EL was responsible for study conceptualization, study design, and original draft writing and editing. JH was responsible for study conceptualization, data collection and database creation, as well as reviewing and editing the manuscript. ACLL was responsible for study conceptualization, study design, as well as reviewing and editing the manuscript. CS was responsible for study conceptualization as well as reviewing and editing the manuscript. ETA was responsible for conceptualization and study design, as well as reviewing and editing the manuscript. JH and ETA accessed and verified the data. All authors had access to the data used in the study.

## Author agreement

I certify that all authors have seen and approved the final version of the manuscript being submitted. This article is the authors original work, hasn't received prior publication and isn't under consideration for publication elsewhere.

## Data sharing

Anonymized data will be made available by the corresponding author upon reasonable request.

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## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

## Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.joclim.2023.100259.

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