

# Increasing the environmental sustainability of operating rooms in Canada: an evidence-informed guideline for policy

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## Abstract

**Background:** Canada's health care systems contribute about 4.6% of Canada's greenhouse gas emissions and 200 000 tonnes of other pollutants, with operating rooms (ORs) having a substantial environmental impact. In this guideline, we provide actionable recommendations to increase the environmental sustainability of ORs.

**Methods:** This guideline was developed by the Best Practice in Surgery Group from the University of Toronto, with national representation. We followed the Appraisal of Guidelines for Research and Evaluation (AGREE) Health Services tool, ADAPTE, and Guidelines International Network principles. Given the nature of the evidence, we created a

unique grading matrix based on the triple bottom line (people, profit, planet) and did not assess quality of studies. Twenty-four rapid reviews informed the guideline, and we used a modified Delphi approach to reach consensus. We conducted external reviews with various hospitals across Canada.

**Recommendations:** We outline 21 recommendations to improve the environmental sustainability of ORs, grouped into 4 categories: reduce, reuse, recycle, and rethink. The "reduce" category focuses on decreasing unnecessary waste by way of appropriate waste segregation, decreasing pharmaceutical waste, reducing instruments in surgical trays and custom packs, and lowering unnecessary energy

use. We also provide recommendations for reducing emissions from inhalational anesthesia. "Reuse" emphasizes replacing disposable items — such as medical devices, textiles, and sharps containers — with reusable alternatives. "Recycle" includes recommendations for traditional and specialized recycling programs. "Rethink" includes strategies with limited direct evidence but considered essential to long-term sustainability, such as donations, alcohol hand rub, and environmentally preferable purchasing policies.

**Interpretation:** Operating rooms greatly contribute to the environmental burden of the Canadian health care system and these recommendations can help to reduce this impact.

Canada's health care systems are responsible for 4.6% of the country's greenhouse gas emissions and 200 000 tonnes of other pollutants.<sup>1</sup> Within hospitals, operating rooms (ORs) have a particularly negative environmental impact<sup>2,3</sup> as they are extremely energy intensive, consuming 6 times more energy per square metre than the rest of the hospital.<sup>4</sup> They also generate as much as a third of total hospital waste.<sup>2,5,6</sup> Given the substantial environmental footprint of ORs, they present opportune sites for interventions to support environmental sustainability. Numerous opportunities exist for sustainable practices in the OR that can save time and money while maintaining high-quality care and patient safety.

This is an update of a guideline released in 2020, which was originally developed by Best Practice in Surgery, a quality improvement program within the Department of Surgery at the University of Toronto.<sup>7</sup> Since 2020, several systematic reviews and guidance documents have further evaluated the evidence for "green" interventions in the OR.<sup>2,8-13</sup> This update includes broader input from experts, feedback from a broad range of potential end-users from across Canada, and endorsements from relevant national organizations. The objective of this guideline is to provide actionable, evidence-informed recommendations to increase the environmental sustainability of ORs. This article is a synopsis of the full guideline, which is

available in Appendix 1, available at [www.cmaj.ca/lookup/doi/10.1503/cmaj.251192/tab-related-content](http://www.cmaj.ca/lookup/doi/10.1503/cmaj.251192/tab-related-content).

## Scope

The scope of this guideline is limited to interventions related directly to the OR. The end-users include, but are not limited to, people working in ORs (e.g., surgeons, anesthesiologists, nurses, OR managers, trainees, assistants), housekeeping and patient service staff (e.g., laundry and waste services), medical device-reprocessing departments, and administrators (e.g., environmental and quality improvement managers, procurement teams). It will also be of use to hospital executives and policy-makers (e.g., provincial hospital associations or health authorities).

## Recommendations

We developed 21 recommendations (Table 1), which we present by way of the 4Rs (reduce, reuse, recycle, and rethink), commonly used categories for sustainability efforts in health care.<sup>10,41,42</sup>

“Reduce” refers to interventions that decrease waste of resources (e.g., energy use) or physical waste. “Reuse” entails substituting reusable items for disposable ones, or reusing or remanufacturing single-use items. “Recycle” relates to converting waste into reusable materials. “Rethink” refers to interventions that require more research or consideration for change.<sup>41,42</sup>

We developed a unique grading matrix adapted from the traditional hierarchy of evidence and assigned a grade for each component of the triple bottom line (people, planet, profits)<sup>43,44</sup>

**Table 1 (part 1 of 2): Summary of recommendations**

| Recommendation                                                                                                                           | Strength of recommendation | Grade of evidence by triple-bottom-line component* |        |        | Reported implementation strategies                                                                                                                                                                                                                           |
|------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|----------------------------------------------------|--------|--------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                          |                            | Planet                                             | Profit | People |                                                                                                                                                                                                                                                              |
| 1. Reduce                                                                                                                                |                            |                                                    |        |        |                                                                                                                                                                                                                                                              |
| 1.1. Reduce energy use by turning off lights and equipment at the end of the day, using set-back systems or occupancy sensors            | Strong                     | ✓✓✓                                                | ✓✓     | ✓✓     | <ul style="list-style-type: none"><li>• Staff education<sup>14,15</sup></li><li>• Audit (energy)<sup>14,15</sup></li><li>• Visual reminders<sup>12,16,17</sup></li><li>• Checklists<sup>12,16,17</sup></li></ul>                                             |
| 1.2. Reduce unnecessary waste by ensuring appropriate waste segregation                                                                  | Strong                     | ✓✓✓                                                | ✓✓     | ✓✓     | <ul style="list-style-type: none"><li>• Staff education<sup>8,18–22</sup></li><li>• Multidisciplinary teams<sup>23</sup></li><li>• Visual reminders<sup>2</sup></li></ul>                                                                                    |
| 1.3. Reduce pharmaceutical drug waste (e.g., use prefilled syringes, refrigerate unused drugs, use drugs that are close to expiry first) | Strong                     | ✓✓                                                 | ✓✓     | ✓✓     | <ul style="list-style-type: none"><li>• Multidisciplinary teams<sup>24</sup></li><li>• Using prefilled syringes, splitting vials, avoiding drawing up medications that may not be used<sup>24</sup></li></ul>                                                |
| 1.4. Reduce redundant items on surgical trays                                                                                            | Strong                     | ✓✓                                                 | ✓✓     | ✓✓     | <ul style="list-style-type: none"><li>• Practice Greenhealth’s step-by-step guide<sup>25</sup></li><li>• Multidisciplinary teams<sup>17</sup></li></ul>                                                                                                      |
| 1.5. Reduce redundant items in custom packs                                                                                              | Strong                     | ✓✓✓                                                | ✓✓     | ✓      | <ul style="list-style-type: none"><li>• Protocols<sup>26</sup></li><li>• Multidisciplinary teams<sup>26</sup></li><li>• Audit (waste)<sup>27</sup></li></ul>                                                                                                 |
| 1.6. Reduce the use of blue wrap                                                                                                         | Strong                     | ✓✓✓                                                | ✓✓     | ✓✓✓    | <ul style="list-style-type: none"><li>• Use of rigid sterilized containers or cotton wrap or linens<sup>28</sup></li><li>• Practice Greenhealth’s step-by-step guide<sup>29</sup></li><li>• Specialized recycling program (see Recommendation 3.2)</li></ul> |
| 1.7. Reduce greenhouse gas emissions from inhalational anesthesia                                                                        |                            |                                                    |        |        | <ul style="list-style-type: none"><li>• ASA<sup>30</sup> and CASCADES<sup>31</sup> websites for implementation support</li></ul>                                                                                                                             |
| 1.7.1. Do not use desflurane                                                                                                             | Strong                     | ✓✓✓                                                | NR     | NR     |                                                                                                                                                                                                                                                              |
| 1.7.2. Avoid the use of nitrous oxide if possible                                                                                        | Strong                     | ✓✓✓                                                | NR     | NR     |                                                                                                                                                                                                                                                              |
| 1.7.3. Decommission the use of nitrous oxide through central piping systems and use portable canisters instead                           | Strong                     | ✓✓                                                 | NR     | NR     |                                                                                                                                                                                                                                                              |
| 1.7.4. Minimize fresh gas flows (≤ 1 L/min)                                                                                              | Strong                     | ✓✓                                                 | NR     | NR     |                                                                                                                                                                                                                                                              |

(Box 1). The triple bottom line is a conceptual framework, originating from business literature, that assesses the social, environmental, and financial impacts of an activity.<sup>44</sup> In this guideline, we use the terms “people,” “planet,” and “profits” to indicate the social, environmental, and financial impact of each recommendation. We modified the traditional hierarchy of evidence to include studies relevant to environmental sustainability.<sup>43,45</sup> We provide a visual snapshot of the type of studies informing each

aspect of the triple bottom line, so that end-users can better understand the impact of each intervention and to assist with implementation (e.g., “profit” information for administrators, “planet” information to increase user buy-in, “people” information to understand potential barriers).

The strength of each recommendation (strong, conditional, or for consideration) is provided for each recommendation (Box 2). We determined these based on our synthesis of evidence using

**Table 1 (part 2 of 2): Summary of recommendations**

| Recommendation                                                                                                                                                                                                                             | Strength of recommendation | Grade of evidence by triple-bottom-line component* |        |        | Reported implementation strategies                                                                                                                                                                                                                               |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|----------------------------------------------------|--------|--------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                                                                                            |                            | Planet                                             | Profit | People |                                                                                                                                                                                                                                                                  |
| 2. Reuse                                                                                                                                                                                                                                   |                            |                                                    |        |        |                                                                                                                                                                                                                                                                  |
| 2.1. Use reusable medical devices                                                                                                                                                                                                          | Strong                     | ✓✓✓                                                | ✓✓✓    | ✓✓✓    | <ul style="list-style-type: none"><li>• Staff education<sup>32</sup></li><li>• Liaising with manufacturers</li></ul>                                                                                                                                             |
| 2.2. Use reusable textiles (e.g., surgical gowns)                                                                                                                                                                                          | Strong                     | ✓✓✓                                                | ✓✓     | ✓✓✓    | <ul style="list-style-type: none"><li>• Administrative buy-in<sup>33</sup></li><li>• Multidisciplinary teams<sup>33</sup></li><li>• Liaising with manufacturers<sup>33</sup></li><li>• Staff education<sup>33,34</sup></li><li>• Audit<sup>33-35</sup></li></ul> |
| 2.3. Use reusable sharps containers                                                                                                                                                                                                        | Strong                     | ✓✓✓                                                | ✓      | ✓✓✓    | <ul style="list-style-type: none"><li>• Audit (visual)†</li><li>• Liaising with manufacturers†</li></ul>                                                                                                                                                         |
| 2.4. Collect single-use medical devices for remanufacturing and reuse whenever possible                                                                                                                                                    | Strong                     | ✓✓✓                                                | ✓✓✓    | ✓✓✓    | <ul style="list-style-type: none"><li>• Liaising with manufacturers†</li><li>• Allowing surgeons to trial remanufactured devices†</li><li>• Multidisciplinary teams†</li></ul>                                                                                   |
| 3. Recycle                                                                                                                                                                                                                                 |                            |                                                    |        |        |                                                                                                                                                                                                                                                                  |
| 3.1. Develop and implement an effective recycling program in the operating room. To ensure effectiveness, assess recycling procedures at your hospital (e.g., downstream processes and recycling hauler regulations) before implementation | Weak                       | ✓✓                                                 | ✓      | ✓✓✓    | <ul style="list-style-type: none"><li>• Audit†</li><li>• Liaising with recycling haulers†</li><li>• Staff education<sup>6</sup></li></ul>                                                                                                                        |
| 3.2. Develop and implement specialized recycling programs if feasible (i.e., plastics, blue wrap, batteries, copper)                                                                                                                       | Weak                       | ✓                                                  | ✓      | ✓      | <ul style="list-style-type: none"><li>• Practice Greenhealth’s step-by-step guide<sup>36</sup></li><li>• Assessing jurisdictional regulations</li><li>• Staff education<sup>8</sup></li><li>• Engaging hospital administrators<sup>5</sup></li></ul>             |
| 4. Rethink                                                                                                                                                                                                                                 |                            |                                                    |        |        |                                                                                                                                                                                                                                                                  |
| 4.1. Rethink disposal of unused supplies and older machines and devices, and consider donation where appropriate                                                                                                                           | For consideration          | NR                                                 | NR     | NR     | <ul style="list-style-type: none"><li>• World Health Organization guidelines for donations<sup>37,38</sup></li></ul>                                                                                                                                             |
| 4.2. Rethink all procurement decisions by implementing an environmentally preferable purchasing policy                                                                                                                                     | For consideration          | NR                                                 | NR     | NR     | <ul style="list-style-type: none"><li>• Practice Greenhealth’s step-by-step guide<sup>39</sup></li><li>• CASCADES playbook<sup>40</sup></li></ul>                                                                                                                |
| 4.3. Rethink traditional hand scrub and consider the use of alcohol hand rub                                                                                                                                                               | For consideration          | ✓✓✓                                                | NR     | ✓✓     |                                                                                                                                                                                                                                                                  |
| 4.4. Rethink anesthetic techniques other than inhalational anesthesia                                                                                                                                                                      | For consideration          | NR                                                 | NR     | NR     |                                                                                                                                                                                                                                                                  |
| Note: ASA = American Society of Anesthesiologists, NR = not reported.<br>*See Box 1.<br>†Feedback from end-user survey and guideline development team in 2024 (see Methods).                                                               |                            |                                                    |        |        |                                                                                                                                                                                                                                                                  |

**Box 1: Grading matrix based on the hierarchy of evidence using study designs<sup>44,45</sup>**

- High (✓✓✓): Supporting evidence comes from systematic reviews, meta-analyses, randomized controlled trials, life-cycle analyses, or carbon footprint analyses.
- Moderate (✓✓): Supporting evidence comes from comparative studies, waste audits, literature reviews, narrative reviews, scoping reviews, cost analyses, quality-improvement studies, or guidelines.
- Low (✓): Supporting evidence comes from survey studies, review articles (unspecified), grey literature, or expert opinion.

**Box 2: Grading of recommendations<sup>47</sup>**

- **Strong recommendation:** The recommendation can be adapted as policy in most situations. Adherence to this recommendation could be used as a quality indicator for the environmental impact of operating rooms.
- **Conditional recommendation:** Policy-making will require substantial debate and involvement of various partners. An appropriately documented decision-making process could be used as a quality indicator for the environmental impact of this recommendation.
- **For consideration:** Insufficient evidence exists to support a decision for or against a recommendation. However, the intervention is considered to have the potential to increase the environmental sustainability of operating rooms.

standard guideline development tools,<sup>46–48</sup> while considering factors appropriate to each triple-bottom-line component. For example, we considered resource use, cost–benefit, cost savings, and upfront costs reported for “profit”; desirable and undesirable consequences, such as health care team preferences, feasibility, implementability, and safety of the intervention for “people”; and reported environmental impact for “planet.”

A visual summary of the guideline is available in Figure 1.

**Reduce**

The 11 “reduce” recommendations focus on minimizing unnecessary waste in ORs. Several quality-improvement studies and audits have consistently shown the environmental and financial benefit of reducing unnecessary waste by way of lowering energy use, segregating waste appropriately, reducing instruments in surgical trays and custom packs (“leaning”), decreasing the use of blue wrap (polypropylene wrapping used for sterilization), and minimizing pharmaceutical waste.<sup>4,6,12,42,49</sup> Additionally, several guidelines highlight strategies to reduce the greenhouse gas emissions of inhalational anesthesia.<sup>10–12,49–52</sup>

In terms of energy use, ORs are among the most energy-intensive hospital areas, with heating, ventilation, and air conditioning (HVAC) systems accounting for 90% to 99% of the ORs’ energy use,<sup>12</sup> despite only about 60% occupancy time.<sup>42</sup> Several energy audits have shown that reducing energy use during OR off-hours can have positive environmental and financial effects, without affecting patient care or staff resources (financial or time).<sup>6,12,17,42</sup>

At 3 academic hospitals, a carbon footprint audit showed that HVAC energy consumption was reduced by 50% when an HVAC set-back system was used that reduced air-flow rates in 19 of 22 theatres overnight and on weekends, while leaving 3 theatres online for emergencies.<sup>4</sup>

Several waste audits show that as much as 90% of OR waste is misclassified, with much of it treated as biohazardous, resulting in unnecessary costs and harmful environmental effects from incineration or autoclaving.<sup>5,6,8,21,42,53</sup> Educational interventions have been shown to increase proper waste segregation and reduce unnecessary costs by 75%.<sup>6</sup>

Ample evidence from quality-improvement studies and waste audits indicates that leaning surgical trays and custom packs reduces waste and saves money, without affecting patient safety.<sup>54–58</sup> For example, a quality-improvement study at a Canadian community hospital resulted in 1-year cost savings of more than Can\$9000 and 10-year cost savings of Can\$69576, after the authors observed 238 otolaryngology procedures and implemented a reduction of unnecessary instruments by 26%.<sup>58</sup> Fu and colleagues also found time savings in tray set-up (2.5 min) and no impact on patient safety.<sup>58</sup> Lastly, they noted a 92% satisfaction rating with users of the optimized trays.<sup>58</sup>

Blue wrap comprises about 19% of OR waste, is non-biodegradable, and contributes more than 255 million pounds of waste annually.<sup>59</sup> A life-cycle analysis showed that switching to rigid, reusable sterilization containers can reduce emissions by as much as 82% and substantially cut costs.<sup>60</sup> Although switching to reusable containers has upfront costs, quality-improvement studies have noted cost savings in 1 to 2 years.<sup>61</sup>

Multiple quality-improvement studies and guidelines document the environmental and financial impacts of pharmaceutical drug waste, noting that 20% to 50% of drugs drawn during surgery are wasted.<sup>11,12,49,50,62–64</sup> A Canadian quality-improvement study found meaningful environmental and financial impacts when the switch was made to prefilled syringes, including saving more than 4900 kg of annual preventable waste and daily drug losses exceeding Can\$1000.<sup>64</sup> In terms of the social impact, inadequate drug disposal may pose a risk to ecosystems and public health.<sup>11,12,50,64</sup>

Lastly, several recent guidelines have highlighted strategies to reduce the negative impact of inhalational anesthesia.<sup>10–12,49–52</sup> This guideline mirrors those recommendations in advising against the use of desflurane and nitrous oxide because of their high global-warming potential.<sup>10–12,49–52</sup> It is well known that desflurane has a global warming potential 20 times that of sevoflurane, 5 times that of isoflurane, and 10 times that of nitrous oxide.<sup>10,13</sup> Additionally, studies have shown that the atmospheric lifetime of desflurane is about 14 years, isoflurane is 3 years, and sevoflurane is 1 to 2 years, with nitrous oxide having the greatest impact of 114 years.<sup>11,50</sup> If nitrous oxide must be used, guidelines recommend decommissioning pipelines because of frequent leaks and using portable canisters instead.<sup>9,11,50</sup> A fresh gas flow of 1 L per minute or less is also advised, to minimize emissions without compromising patient safety.<sup>11,50</sup>

# Recommendations for increasing the environmental sustainability of operating rooms in Canada



**Figure 1:** Summary of the guideline recommendations. See Related Content tab for accessible version.

## Reuse

The 4 “reuse” interventions prioritize selecting items that can be safely and effectively reused in the OR rather than relying on disposable or single-use products. A growing body of evidence, including a systematic review and life-cycle analyses, demonstrates clear environmental benefits.<sup>65–71</sup>

With regard to reusable versus disposable devices, a systematic review found a 47% reduction in greenhouse gas emissions for reusable medical devices.<sup>65</sup> Similarly, a life-cycle analysis reported that switching to reusable anesthesia equipment in the United States could cut carbon dioxide emissions by 50%.<sup>66</sup> Financially, less available information exists for reusing equipment; however, some evidence has indicated cost reductions. For example, Boberg and colleagues found that use of single-use trocars was twice as expensive as reusable options.<sup>68</sup> In terms of patient safety, 3 reviews reported no notable differences between reusable and disposable instruments in preventing surgical-site infections.<sup>32,72,73</sup>

Extensive evidence from life-cycle analyses indicates that using reusable textiles has a lower environmental impact than disposable textiles, while also yielding cost savings.<sup>74–80</sup> An analysis by Vozzola and colleagues, based on 1000 gown uses, found that utilizing reusable gowns reduced energy use (64%), greenhouse gas emissions (66%), water consumption (83%), and solid waste (84%), compared with using disposable alternatives.<sup>80</sup> Literature suggests that reusable surgical linens are more durable and have better water resistance, and are therefore more likely to be effective at preventing infection.<sup>75,81,82</sup> The available data on the comfort of reusable gowns are mixed, with some quality-improvement and survey studies showing a preference for reusable gowns<sup>75,82</sup> and others not.<sup>81</sup>

A life-cycle analysis provides support for switching to reusable sharps containers, finding a 65% reduction in carbon footprint and more than 50 tonnes of plastic waste avoided while also yielding cost savings on waste disposal and procurement.<sup>83</sup> In terms of safety, Grimmond and colleagues conducted a microbiological study to assess the decontamination process for reusable sharps containers in the US and found that all traces of *Clostridioides difficile* were removed after decontamination.<sup>84</sup>

Remanufacturing single-use medical devices is another intervention that provides environmental and financial benefits, while maintaining high-quality care. In terms of safety, a 2024 review by Canada’s Drug Agency (previously Canadian Agency for Drugs and Technologies in Health) found no difference in patient outcomes between new and remanufactured devices.<sup>85</sup> Despite this, survey studies have noted the concerns of health care professionals regarding the potential safety and efficacy of using these remanufactured devices.<sup>86,87</sup> In Canada, regulatory standards enforced by Health Canada, and provincial policies, state that remanufactured devices must meet the same standards as new devices.<sup>86,87</sup> In terms of environmental and financial impacts, a life-cycle analysis noted savings of US\$182 000 to US\$520 000 per year from remanufactured single-use medical devices.<sup>71</sup> A narrative review found that hospitals participating in remanufacturing of single-use medical devices diverted 7000 tons of waste and saved US\$471 billion per year.<sup>88</sup>

## Recycle

Considerable evidence supports the 2 “recycle” recommendations, as numerous waste audits and quality-improvement studies have consistently shown that recycling of plastics and paper in ORs needs to be improved.<sup>21,22,42,53,89–91</sup> One audit noted that 40% of OR waste was recyclable,<sup>53</sup> and a Canadian audit reported that nearly 90% of preoperative waste could be recycled.<sup>91</sup> Although cost savings will depend on each institution, recycling has the potential to yield notable savings, as the disposal cost of recycling is nearly half that of general waste.<sup>42</sup> Environmental benefits are also noteworthy: a waste audit by Sullivan and colleagues estimated that an OR recycling program in a children’s hospital could prevent 58 500 to 91 500 kg of carbon dioxide-equivalent emissions annually.<sup>90</sup> In addition to traditional recycling programs, specialized recycling programs for polyvinyl chloride, batteries, single-use medical devices, copper wire, and blue wrap, have been implemented in some centres, some of which have been considered in several quality-improvement studies.<sup>6,92,93</sup> Despite these advantages, establishing and maintaining traditional and specialized recycling programs requires sustained effort and coordination, and often the leadership of a dedicated local champion.<sup>8,94</sup>

## Rethink

Two of the 4 “rethink” interventions have limited evidence to support a recommendation, yet are often suggested in the literature and considered to be an important element of greening ORs.<sup>11,12,49</sup> Several review articles note that creating and sustaining policies for donations of unused supplies or older machines and devices, as well as environmentally preferable purchasing policies, could have a large positive, lasting impact on reducing the environmental footprint of ORs.<sup>11,41,95</sup> Many organizations and hospitals provide guidance for hospitals seeking to create these policies, including the World Health Organization’s guidelines for appropriate donations.<sup>37,38,96–98</sup> The other 2 “rethink” interventions — consideration of alcohol hand rub for surgical scrubs<sup>99,100</sup> and use of anesthetic techniques other than inhalational anesthesia<sup>10–12,49–52</sup> — both have some supporting evidence, but not enough to provide a recommendation for or against their use. Thus, we suggest considering these interventions as options.

## Methods

This is an update to a guideline that was developed in 2020 by Best Practice in Surgery, Department of Surgery, University of Toronto.<sup>7</sup> The development of the guideline was funded by the Department of Surgery and Collaborative Centre for Climate, Health and Sustainable Care, University of Toronto. We used the Appraisal of Guidelines for Research and Evaluation Health Services (AGREE-HS) tool for the methodologic framework, as it provides guidance on developing, reporting, and implementing health services challenges based on best evidence.<sup>48,101</sup> The Guidelines International Network (GIN)–McMaster Checklist was also used.<sup>102</sup> We used ADAPTE to create the recommendations for inhalational anesthesia.<sup>103</sup> Lastly, we undertook a modified Delphi approach to gain expert agreement on the recommendations.<sup>104</sup>

## Composition of participating groups

This guideline was developed by a multidisciplinary team of 17 clinicians, administrators, environmental specialists, and patients ( $n=2$ ). We invited known experts in environment sustainability, surgery, and hospital management from across Canada; members of the Patient Advisors Network ([www.patientadvisors.ca](http://www.patientadvisors.ca)); and authors of the 2020 guideline<sup>7</sup> to participate in this guideline panel. The panel took part in all aspects of the guideline development, including determining priority topics, developing the grading matrix, reviewing summaries of evidence, and voting on recommendations. The steering committee consisted of the leads (S.E.W., E.A.P.) for Best Practice in Surgery at the University of Toronto, and a medical student (J.G.). This committee was tasked with conducting the literature reviews, summarizing the evidence, drafting and revising the recommendations and supporting evidence summaries, administering the surveys, liaising with the panel, and writing most of the guideline. To ensure broad applicability, an end-user group was formed for external review with participants from the Ontario Surgical Quality Improvement Network (ONSQIN; [www.hqontario.ca/quality-improvement/quality-improvement-in-action/ontario-surgical-quality-improvement-network](http://www.hqontario.ca/quality-improvement/quality-improvement-in-action/ontario-surgical-quality-improvement-network)), CASCADES ([www.cascadescanada.ca](http://www.cascadescanada.ca)), and the Patient Advisors Network.

## Selection of priority topics

To determine all possible interventions on increasing the environmental sustainability of ORs, a librarian (C.D.C.) undertook a scoping review in PubMed, MEDLINE, and Embase, and 2 authors carried out a search of the grey literature (J.G., E.A.P.) in Google Advanced in summer 2023 (search strategy included in Appendix 2, available at [www.cmaj.ca/lookup/doi/10.1503/cmaj.251192/tab-related-content](http://www.cmaj.ca/lookup/doi/10.1503/cmaj.251192/tab-related-content)). Three authors (J.G., K.L., E.A.P.) independently reviewed titles, abstracts, and full-text articles to generate a comprehensive list of reported possible interventions. The guideline panel then voted on whether to include the intervention for further review, based on predetermined inclusion criteria (e.g., specific to the OR, relatable to the Canadian context, implementable). Anonymous voting took place during an online meeting in November 2023. An 80% threshold for agreement was selected a priori, as there is no gold standard for Delphi studies, but 80% is noted as the most rigorous.<sup>105</sup> Of the 39 interventions presented, we selected 24 to undergo further review.

## Literature review and quality assessment

We conducted 24 rapid reviews using the *Rapid Review Guidebook*.<sup>106</sup> Searches for each intervention, framed by the triple bottom line, were performed by a librarian (C.D.C.) in PubMed ([www.pubmed.ncbi.nlm.nih.gov](http://www.pubmed.ncbi.nlm.nih.gov)), MEDLINE ([www.nlm.nih.gov](http://www.nlm.nih.gov)), and Cochrane ([www.cochrane.org](http://www.cochrane.org)) in August 2023 and February 2024, using the Peer Review of Electronic Search Strategies (PRESS) checklist to ensure rigour.<sup>107</sup> We conducted grey literature searches in summer 2024 in Google Advanced, supplemented by the HealthcareLCA database (<https://healthcarelca.com/>) and reference list screening (Appendix 2).

Two authors independently screened titles and abstracts in Covidence (J.G., K.L.), with discrepancies resolved by a third

author (E.A.P.) (screening criteria included in Appendix 3, available at [www.cmaj.ca/lookup/doi/10.1503/cmaj.251192/tab-related-content](http://www.cmaj.ca/lookup/doi/10.1503/cmaj.251192/tab-related-content)). We screened a total of 7768 titles and abstracts, yielding 344 full-text articles; 405 documents were added from grey literature and hand-searching, for a total of 749 data sources. Full-text articles and grey literature sources were imported into Zotero. We extracted data using a standardized form addressing the triple bottom line and implementation strategies and synthesized the results narratively.

We searched PubMed and Google Advanced for relevant guidelines, using terms such as “inhalational anesthesia,” “guidelines,” and “environmental sustainability,” in August 2023. During this process, we identified several recent anesthesia guidelines from reputable organizations,<sup>9–12,50,51,108,109</sup> most of which recommended similar interventions. Thus, we opted to summarize these guidelines using ADAPTE methodology,<sup>103</sup> rather than undertake new reviews for each intervention related to inhalational anesthesia.

We updated our searches in October 2025, to ensure there were no major additions to the literature that might affect the guideline recommendations.

Traditional quality assessments were not possible given the types of studies included in this review (e.g., quality-improvement studies, life-cycle analyses, carbon footprint analyses, cost analyses, guidance documents, narrative and scoping reviews). Although several quality-assessment tools exist for various types of study designs,<sup>46,110–114</sup> only 30% of the included studies allowed for quality assessment, and we determined that assessing the quality of those studies would not add value to the recommendations. Currently, no validated way exists to include quality assessment of environmental studies into health care-related guidelines.<sup>115</sup>

## Development of recommendations

The steering committee developed a unique grading matrix for the evidence we considered, as there is no known framework or quality assessment relevant to the triple bottom line (people, planet, and profit) and the types of studies referenced in this article (Box 1).<sup>46,116,117</sup> The triple bottom line is increasingly used in health care to provide a more comprehensive, holistic assessment of the impact of an intervention or activity.<sup>47,118</sup> As the objective of this guideline is to increase environmental sustainability, the summary of evidence supporting each recommendation needed to include sustainability studies, in addition to studies reporting traditional outcomes (i.e., profits and people). We did not undertake formal quality assessments (as noted above), but we wanted the type of supporting evidence to be transparent. Therefore, we adapted the traditional hierarchy of evidence to map where the types of studies used for each component of the triple bottom line fit.<sup>43,45</sup> For example, life-cycle analyses and carbon-footprint audits are the most robust types of environmental studies, similar to the robustness of a randomized controlled trial for a clinical intervention (high quality). Similarly, many quality-improvement studies are like traditional observational studies (moderate quality). The guideline panel approved the matrix.

After data extraction, we reviewed each included reference to determine the type of study and assigned each study to a ranking (high, moderate, low) (Box 1).

The steering committee prepared summaries of evidence based on the triple bottom line and drafted recommendations using these summaries, noting recommendations from the 2020 version,<sup>7</sup> and in accordance with AGREE-HS and GIN-McMaster guidance documents.<sup>48,102</sup>

For developing draft recommendations related to inhalational anesthesia, we used a modified approach to the ADAPTE process.<sup>103</sup> We omitted the set-up and finalization phases of the ADAPTE process for these recommendations, as all recommendations underwent the same review process (i.e., Delphi voting and external review). We followed the adaptation phase, which included determining the health questions; searching and screening guidelines; assessing the quality, currency, content, consistency, and applicability and acceptability of the recommendations; and reviewing assessments and selections for adapted recommendations. Two authors (E.A.P., S.E.W.) independently reviewed the guidelines we found, using the AGREE instrument and ADAPTE evaluation sheets (completed tables included in Appendix 4, available at [www.cmaj.ca/lookup/doi/10.1503/cmaj.251192/tab-related-content](http://www.cmaj.ca/lookup/doi/10.1503/cmaj.251192/tab-related-content)). Overall, most of the included guidelines lacked transparency regarding the methods for creating the recommendations and for searching and summarizing the related evidence. Additionally, quality assessments were omitted. Despite this, the recommendations and summaries of evidence were similar across the guidelines we assessed.

The draft recommendations, including those developed using the ADAPTE process, and summaries of evidence were sent to the guideline panellists as part of the Delphi process for a round of anonymous voting in September 2024. Panellists had the opportunity to vote on whether they agreed or disagreed with the recommendation, provide suggestions for wording, or indicate whether a recommendation required further discussion. The guideline panellists discussed the results in an online meeting in October 2024. The threshold for agreement was 80%.<sup>105</sup>

### External review

The updated recommendations and evidence summaries underwent external review (November to December 2024). An online, anonymous national survey was distributed via ONSQIN and CASCADES mailing lists. Respondents ( $n = 102$ ) represented a range of participants: surgeons (27%), anesthesiologists (14%), nurses, trainees, administrators, managers, patients, and researchers from academic (41%), community (34%), and mixed settings (21%) across rural (10%) and urban (85%) areas in 7 provinces and territories.

The steering committee reviewed the feedback, which led to further refinements in wording and categorization of some of the recommendations (e.g., the alcohol hand-rub recommendation moved from “reduce” to “rethink”). The recommendations were circulated to the guideline panel as part of the Delphi process for a final round of voting. More than 80% agreement was achieved for all recommendations, with most exceeding 90%.

### Management of competing interests

We adhered to the GIN Principles for Conflicts of Interest in Guidelines.<sup>119</sup> Each member of the guideline panel was asked to indicate whether they had any financial and nonfinancial competing interests at the beginning of the project and again at the end. As no members had any conflicts to declare, no further action was required. Funding was received from the Collaborative Centre for Climate, Health and Sustainable Care, and the Department of Surgery at the University of Toronto, to assist with the preparation of this guideline; the funders had no direct role in its development.

### Implementation

Successful implementation will require tailored strategies, and not all recommendations will be feasible for every hospital. Barriers to implementation of these recommendations exist, including limited resources (financial, time, and personnel), staff buy-in, site-specific restrictions (e.g., access to reusable sharps containers, portable nitrous oxide canisters) and administrative restrictions (e.g., OR occupancy sensors, current purchase agreements, space restrictions).<sup>120,121</sup> Given these and other barriers, we strongly suggest that the first step in implementation should be the development of a multidisciplinary green OR team to determine which recommendations may be feasible for a particular site, as well as having interdisciplinary champions to lead and oversee the changes to be made.

CASCADES (<https://cascadescanada.ca/resources/perioperative-scorecard-dashboard/>) has modified its Perioperative Scorecard to align with these recommendations to assist with national implementation via its dashboard. The Canadian Coalition for Green Health Care ([www.greenhealthcare.ca](http://www.greenhealthcare.ca)) also offers tools to support tracking and progress. Additional resources, such as webinars and toolkits, are available through Choosing Wisely Canada ([www.choosingwiselycanada.org](http://www.choosingwiselycanada.org)) and international groups like Practice Greenhealth ([www.practicegreenhealth.org](http://www.practicegreenhealth.org)). Many studies also highlight effective implementation strategies (Table 1).

Best Practice in Surgery intends to update this guideline every 5 years, incorporating emerging evidence and best practices.

### Other guidelines

Since the first version of this guideline,<sup>7</sup> several reviews and guidance documents aimed at greening ORs have been published.<sup>2,8,9,13,49,90,122,123</sup> As noted earlier, many anesthesia societies have guidelines that include recommendations on environmental sustainability; however, these pertain only to the practice of anesthesiology.<sup>9–11,13,30,50,108,109</sup> In 2024, several European organizations jointly released a comprehensive practice guide that provides similar recommendations to ours, although in the European context.<sup>12,49</sup>

Our recommendations align with other guidance documents but are based on a rigorous evidence review and are tailored for the Canadian context.

## Gaps in knowledge

Several topics emerged during our literature review that require further research before recommendations can be made for or against their use (e.g., anesthetic gas capture systems, environmental impact of surgical techniques). More life-cycle analyses are required to characterize the environmental impact of activities fully. Emerging evidence will be incorporated into future versions of this guideline.

Another major gap in knowledge is the lack of suitable quality-assessment tools to facilitate the inclusion of evidence from environmental studies and quality-improvement studies in health care guidelines.<sup>115</sup> New tools should be created or existing tools modified to ensure that a broader evidence base can be used in development of recommendations, without affecting the guideline quality or transparency. As well, we consider creating a framework for implementing the triple bottom line in guideline development to be of benefit for future guidelines.

## Limitations

Because of the extensive scope of reviews undertaken, our literature reviews were completed in 2024. We are not aware of any new studies or guidelines that have been published subsequently that would alter the recommendations presented here. Because traditional quality assessments (e.g., using Grading of Recommendations Assessment, Development and Evaluation<sup>46</sup>) were not applicable, we had to develop a new grading matrix, which was not validated. Our recommendations related to anesthesia were adapted from existing guidelines rather than through new reviews; although this may have reduced methodological rigour, the consistency of existing sources rendered duplication unnecessary. The guideline focused exclusively on ORs, excluding perioperative practices that could also affect environmental sustainability. Finally, although we attempted to have broad national input, we did not achieve representation from all provinces and territories.

## Conclusion

Operating rooms are major contributors to the environmental impact of health care. We developed 21 evidence-based recommendations that health care providers and organizations can follow to increase the environmental sustainability of ORs, within the Canadian context. Adopting these recommendations will generally confer both environmental and financial benefits, and will often also benefit the people providing and receiving care. Given the large environmental impact of ORs and the danger to human health represented by climate change and other global ecological challenges, we urge those involved in providing surgical care to review this guideline carefully and adopt as many recommendations as are feasible within their own organizations.

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