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Environmental Sustainability in Anesthesia Practice: Strategies to Reduce Carbon Emissions and Waste

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Abstract:

Background: The healthcare sector is a significant contributor to environmental degradation, accounting for a substantial portion of national greenhouse gas emissions. Within hospitals, operating rooms (ORs) and anesthesia practice are identified as major sources of carbon emissions and waste due to energy-intensive ventilation, single-use consumables, and the use of potent inhaled anesthetic agents. **Aim:** This article aims to outline pragmatic, high-yield strategies for anesthesiologists to reduce the environmental footprint of perioperative care, thereby aligning clinical practice with planetary health. **Methods:** The proposed strategies are grounded in life-cycle assessment (LCA) methodology, which evaluates the environmental impact of products and processes from manufacture to disposal. The recommendations are structured around the "Reduce, Reuse, Recycle" hierarchy. Key methods include reducing the use of high-global warming potential anesthetic agents like desflurane and nitrous oxide, adopting low fresh gas flows, and transitioning to total intravenous or regional anesthesia where clinically appropriate. Reuse strategies focus on implementing reusable medical devices (e.g., laryngeal mask airways, textiles) where validated by LCA and infection control standards. Recycling initiatives emphasize proper waste segregation to divert uncontaminated materials from costly, polluting incineration. **Results:** Evidence indicates that these strategies can dramatically reduce the carbon footprint of anesthesia. For instance, substituting sevoflurane for desflurane and optimizing gas flows

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has led to emission reductions equivalent to taking thousands of cars off the road. Furthermore, proper waste segregation can cut disposal costs by up to 80%.

Conclusion: Anesthesiologists are uniquely positioned to lead healthcare's response to the climate crisis. By adopting evidence-based, sustainable practices, the specialty can significantly mitigate its environmental impact without compromising patient safety, turning a critical challenge into an opportunity for professional leadership.

Keywords: Environmental Sustainability, Anesthesia, Carbon Emissions, Life-Cycle Assessment, Operating Room, Green Healthcare, Waste Reduction.

Introduction:

Climate change and environmental degradation constitute urgent and well-documented threats to population health, as emphasized by The Lancet Commission on Climate Change [1,2]. Paradoxically, the health sector itself is a major driver of these harms: healthcare-related activities account for approximately 4.6% and 10% of total national greenhouse gas emissions in Canada and the United States, respectively, and this proportional impact is rising as other sectors decarbonize more rapidly [3,4]. Beyond carbon, healthcare supply chains and facility operations contribute substantially to acid rain precursors, photochemical smog formation, criteria air pollutants, stratospheric ozone depletion, and air toxics, thereby amplifying downstream morbidity and mortality burdens [3]. When translated into health outcomes, the environmental footprint of healthcare is estimated to correspond to 23,000 and 405,000 disability-adjusted life years lost annually in Canada and the United States, respectively—figures that strikingly mirror the magnitude of mortality attributed to medical errors in the Institute of Medicine's "To Err is Human," which catalyzed the modern patient safety movement [3,4]. In light of these convergent health imperatives, the Intergovernmental Panel on Climate Change has underscored that immediate and substantive actions are necessary to avert the most severe impacts of climate change, thereby placing a compelling ethical and practical mandate on healthcare systems to mitigate their own emissions and environmental harms [5].

Hospitals and Operating Rooms:

Within healthcare, hospitals are disproportionately resource-intensive, and operating rooms (ORs) are especially carbon- and energy-heavy due to ventilation, sterilization, single-use consumables, and anesthetic gas use [6]. Marked inter-institutional variability in per-case emissions demonstrates substantial opportunities to reduce footprint without compromising safety or outcomes, particularly through standardized measurement, targeted quality improvement, and procurement reform [6]. Anesthesiologists, who influence anesthetic selection, scavenging, fresh gas flows, equipment choices, and perioperative pathways, have shown strong interest in the environmental consequences of their practice and are uniquely positioned to lead evidence-based decarbonization initiatives [7]. Evidence-informed strategies include preferential use of low–global warming potential agents, minimizing fresh gas flows, avoiding routine desflurane and nitrous oxide where clinically appropriate, optimizing OR energy management, and shifting toward reusables with robust life-cycle assessments and infection control validation [6,8]. Embedding these practices within perioperative governance, aligning incentives with sustainability metrics, and transparently reporting environmental key performance indicators can help surgical services advance patient care while shrinking environmental externalities [6]. Accordingly, this article highlights pragmatic, high-yield strategies for Canadian anesthesiologists to enhance the environmental sustainability of perioperative care and, by extension, strengthen the health system's response to the climate crisis [6,8].

Sustainability

Sustainability in healthcare is defined as the principle that healthcare services must be designed, funded, and delivered in a manner that meets the needs of current populations without compromising the ability of future generations to meet their own health needs [9]. While financial sustainability—maintaining economic viability and efficiency—has long been a focus of health system planning, there is a growing recognition that environmental sustainability is equally critical. Environmental sustainability extends beyond reducing pollution or greenhouse gas emissions; it encompasses building resilient systems capable of adapting to climate-related challenges, such as the rising prevalence of vector-borne diseases, extreme weather events, and the depletion of essential natural resources, including clean water and energy sources [9,10]. Although some policymakers perceive environmental sustainability as being at odds with fiscal responsibility or patient safety, evidence increasingly demonstrates that this is not necessarily the case when healthcare is examined through a systems lens [9]. Initiatives that reduce waste, improve energy efficiency, and prevent disease through upstream interventions often yield multiple co-benefits—enhancing health outcomes, reducing operational costs, and improving overall quality of care. For instance, investments in disease prevention and sustainable technologies can reduce long-term expenditures associated with chronic illnesses and environmental damage. Therefore, integrating sustainability into healthcare is not only an ecological or ethical imperative but also a strategic approach to achieving lasting health, economic stability, and system resilience [9,11].

Life-Cycle Assessment (LCA):

Life-cycle assessment (LCA) represents one of the most rigorous and widely recognized methodologies for evaluating the environmental sustainability of products, processes, and services across their entire lifespan—from raw material extraction to end-of-life disposal [12,13]. Within healthcare, this approach is particularly valuable given the sector's substantial reliance on manufactured goods, disposable materials, and energy-intensive technologies. The LCA framework systematically quantifies the cumulative inputs and outputs associated with a product's "cradle-to-grave" trajectory, encompassing the acquisition of raw resources, manufacturing, packaging, distribution, use, reuse or reprocessing, and eventual disposal. By summing these stages, the LCA provides a holistic understanding of environmental burdens, including resource consumption, energy expenditure, and pollutant generation. Such comprehensive analysis enables the identification of environmental "hotspots," or stages of the product life-cycle that contribute disproportionately to environmental harm, which can then be targeted for improvement [12,13]. The environmental endpoints evaluated in an LCA can include, but are not limited to, greenhouse gas (GHG) emissions, photochemical smog formation, ozone layer depletion, eutrophication, acidification, and contamination of air, water, and soil with carcinogenic or non-carcinogenic substances [12]. These diverse indicators provide a multidimensional view of a product's ecological footprint. In healthcare, where procurement decisions often emphasize clinical efficacy and cost-effectiveness, incorporating such environmental dimensions adds a vital layer of ethical and operational accountability. By tabulating these outcomes, LCAs allow institutions to compare the environmental profiles of competing products or treatment modalities, thereby empowering purchasing departments and clinicians to make more sustainable, evidence-informed choices [13]. Moreover, LCAs can uncover opportunities for design innovation—such as selecting lower-impact raw materials, optimizing manufacturing processes, or introducing more efficient waste management systems—that collectively reduce the environmental footprint of healthcare delivery.

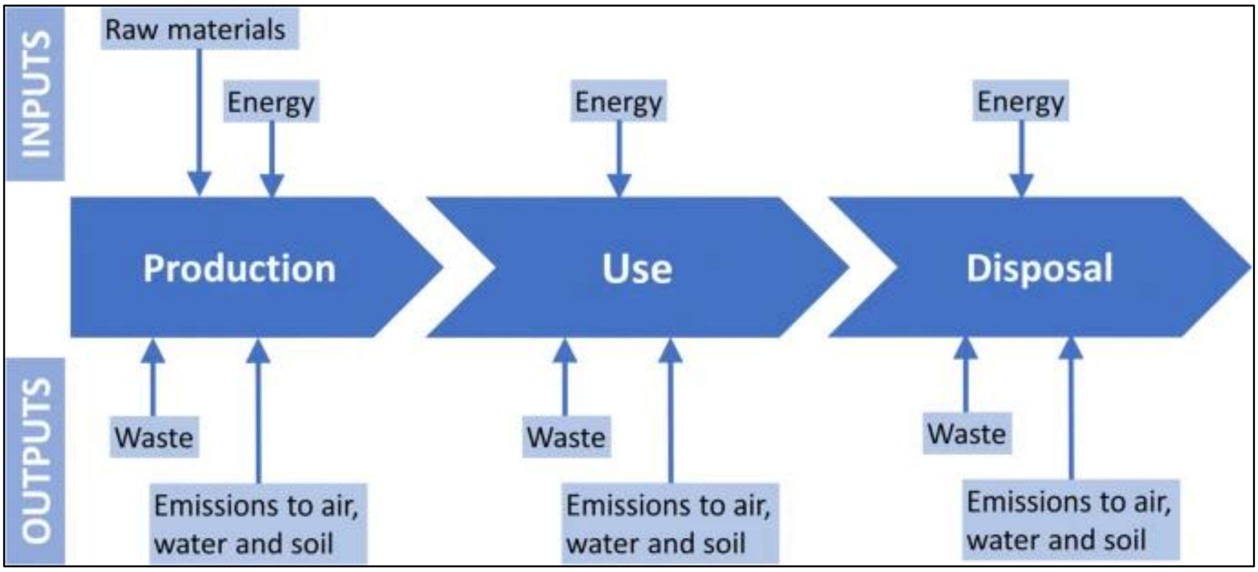

Figure 1: Life-cycle assessment methodology aims to summate raw resources, energy, emissions, and wastes resulting from the production, use, reuse, and ultimate disposal of a product.

Applications of LCA within healthcare have been diverse and impactful. The methodology has been used to evaluate the environmental implications of different approaches to performing the same surgical procedure, revealing how variations in technique, device selection, and anesthetic agents influence overall emissions [8]. Similarly, LCAs have been instrumental in quantifying the relative impacts of different anesthesia modalities, such as volatile anesthetics versus total intravenous anesthesia (TIVA), by measuring their contributions to global warming potential and ozone depletion [14]. Another significant area of application involves the comparison between reusable and single-use medical devices. Studies have shown that reusable items—such as surgical instruments, laryngeal mask airways (LMAs), and laryngoscopes—often result in lower cumulative environmental burdens when sterilization, transportation, and disposal are appropriately managed [15]. These findings challenge the conventional assumption that disposability always enhances safety and convenience, emphasizing instead the importance of evidence-based assessments that consider the full environmental and economic costs of product use. Beyond environmental impacts, life-cycle assessment has a natural extension in economic analysis known as life-cycle costing (LCC). LCC evaluates the total cost associated with a product over its entire life-cycle, including not only the initial purchase price but also downstream costs such as waste disposal, sterilization, maintenance, and potential repackaging for multi-use items [15]. This broader economic perspective strengthens the business case for sustainability by revealing that environmentally friendly products are often financially advantageous in the long term. For instance, analyses have demonstrated that pre-filled syringes can reduce medication waste and disposal costs while improving safety and workflow efficiency [16]. Similarly, reusable LMAs and laryngoscopes have been shown to be both more sustainable and more cost-effective than their single-use counterparts when assessed through comprehensive LCC models [15,17]. In these examples, aligning environmental performance with economic efficiency supports a compelling argument for transitioning toward greener procurement practices within hospitals.

However, while LCAs and LCCs are powerful tools, their utility is not without limitations. They are inherently product- and context-specific, meaning that results can vary widely depending on regional conditions, production methods, and supply chain characteristics [15]. For example, if a large proportion of a product's environmental burden arises from electricity consumption, the final LCA outcome will differ substantially depending on whether the electricity originates from coal, nuclear, or renewable energy sources. Likewise, variations in waste management infrastructure, sterilization technology, and transportation logistics can significantly alter environmental performance metrics. Moreover, LCAs frequently depend on estimated data, particularly for proprietary manufacturing processes that companies may be unwilling to disclose in detail [15]. This lack of transparency can introduce uncertainty into assessments, making it difficult to draw universally applicable conclusions. Conducting LCAs also requires specialized expertise and substantial financial investment, limiting their feasibility for routine use in procurement decision-making. Given these challenges, a pragmatic approach involves leveraging and adapting data from previously published LCAs to local contexts, rather than commissioning new analyses for each procurement decision [15]. By applying standardized frameworks and using validated reference data, healthcare institutions can make informed sustainability choices that balance environmental integrity with clinical and economic priorities. Ultimately, integrating LCA and LCC methodologies into healthcare decision-making fosters a culture of accountability, innovation, and stewardship—one that aligns patient care with planetary health and ensures that healthcare systems remain both resilient and responsible in the face of global environmental challenges.

General strategies for improved environmental sustainability in healthcare

Recent analyses from the United Kingdom underscore the scale and distribution of healthcare's carbon liabilities, attributing approximately 65% of the National Health Service's total emissions to procurement, 19% to energy use, and 16% to the travel of patients and staff [9]. These proportions clarify where targeted interventions can deliver the greatest environmental gains and reveal that decarbonization must extend beyond facilities management to encompass supply chains, care pathways, and organizational culture. While numerous interventions can contribute to mitigation across each sector, sustained progress relies on embedding evidence-based practices into purchasing, infrastructure planning, and clinical operations, while aligning incentives and governance with sustainability outcomes [18]. In this context, a strategic blend of procurement reform, energy stewardship, and mobility redesign emerges as the backbone of comprehensive healthcare decarbonization [9,18]. Procurement, which accounts for roughly two-thirds of institutional emissions, is the linchpin of healthcare sustainability because it concentrates the "subsumed" or embodied carbon in pharmaceuticals, medical devices, food services, and ancillary supplies [9]. Evidence-based purchasing centered on life-cycle assessment (LCA) enables decision-makers to compare products on greenhouse gas intensity, toxicity, water use, and end-of-life impacts, complementing traditional metrics of efficacy and cost [18]. Although clinicians are not always directly responsible for contracting, they are influential in specifying clinical requirements and therefore in shaping demand. Deliberate engagement with pharmaceutical and device manufacturers—and with hospital purchasing committees—signals that environmental performance is a decisive dimension of value, catalyzing suppliers to disclose LCA data, redesign packaging, optimize logistics, and reduce process emissions to remain competitive [9,18]. Because pharmaceuticals are among the most carbon-intensive categories on a per-kilogram basis, with footprints that can exceed those of other chemicals, drug lifecycles present high-yield opportunities for optimization through greener synthesis routes, concentration and dosing formats that reduce waste, and end-of-life stewardship programs [9,19].

Energy consumption remains the second major contributor to the health sector's carbon profile and is driven by heating, ventilation, and air conditioning (HVAC), sterilization, laundry, lighting, clinical equipment, information technology, and food preparation [20]. Building and equipment investments should prioritize the highest efficiency standards, including advanced HVAC controls, heat recovery, variable air volume systems in non-sterile areas, and high-performance building envelopes that lower base loads [20]. Yet capital projects alone are insufficient; low-cost operational measures—such as scheduled shutdowns of idle imaging suites, de-energizing nonessential equipment after hours, and dynamic setbacks of air changes in unoccupied rooms—can capture significant savings quickly without compromising infection control or safety [20]. Energy dashboards that provide transparent, real-time feedback to clinical units can further align behavior with institutional targets and sustain improvements through continuous quality cycles [18,20]. The third pillar of emissions, travel by patients and staff, is especially amenable to service redesign and digital transformation. Telemedicine, when integrated thoughtfully with clinical triage and perioperative pathways, can replace a substantial fraction of in-person consultations, reducing emissions and time costs associated with transportation while preserving quality and patient satisfaction [21,22]. Its impact is amplified when interoperable, province- or nation-wide electronic medical records facilitate shared access to diagnostics and prior histories, thereby preventing duplicative testing and unnecessary visits that generate avoidable travel and resource use [23]. Complementary investments in active and public transportation infrastructure—secure bicycle storage, showers and lockers, subsidized transit passes, optimized bus routing to hospital campuses—can sustainably shift commuter behavior and simultaneously improve cardiometabolic health among staff and patients [24]. Institutions can reinforce these shifts through equitable scheduling, remote work policies where clinically appropriate, and location-aware clinic templates that cluster visits to minimize travel burdens [21,24].

Because these interventions traverse departmental boundaries and implicate procurement, infection control, facilities, perioperative services, and clinical leadership, stewardship structures are essential. Hospital-wide "green teams," with representation from nursing, surgery, anesthesiology, pharmacy, sterile processing, environmental services, infection prevention, and supply chain, have proven effective in scanning for opportunities, coordinating pilots, and normalizing environmental performance as a shared quality metric [25,26]. Such teams elevate sustainability within governance by establishing measurable objectives—e.g., reductions in volatile anesthetic use, increases in reprocessed device utilization where validated, or defined energy intensity targets—and by integrating these metrics into routine performance reviews and accreditation processes [25]. Importantly, green teams also function as change-management engines: they disseminate education, curate best practices, and steward multidisciplinary initiatives from concept to scale, ensuring compliance with safety standards and regulatory requirements [26]. Within this overarching strategy, procurement reform merits continued emphasis. Clinically equivalent options with lower life-cycle burdens should be preferentially selected, with purchasing contracts that require suppliers to disclose standardized environmental data and to participate in take-back and recycling programs where feasible [18]. Pharmacologic stewardship can prioritize agents and formulations with smaller footprints, reduce waste through unit-dose and prefilled options when evidence supports safety and cost-effectiveness, and employ inventory management that minimizes expired stock [9,19]. In parallel, device pathways should be re-evaluated using LCA evidence to support durable, reusable solutions where infection prevention standards are met, leveraging central sterile services modernization to optimize water and energy use [18]. Collectively, these actions translate environmental intent into procurement practice and unlock the largest source of carbon reductions in healthcare systems [9,18,19].

On the facilities side, hospitals should pair energy-efficiency retrofits with strategic electrification and long-term power purchase agreements that decarbonize supply while enhancing resilience to grid disruptions and extreme weather [20]. Operational policies—such as nighttime OR hibernation protocols, vacancy-driven lighting and ventilation controls, and preventive maintenance cycles that sustain peak performance—can yield rapid returns and demonstrate the feasibility of integrating sustainability into clinical operations [20]. Data transparency further accelerates progress: metering at the service-line level enables targeted interventions, while periodic reporting fosters accountability and shared learning across units [18]. Travel-related emissions can be curbed by redesigning patient journeys and workforce mobility. Virtual preoperative assessments and remote monitoring reduce repeated onsite visits, while streamlined digital scheduling consolidates care episodes to minimize round-trip [21-23]. For staff, secure bicycle access, cash-out options for parking, and reliable last-mile transit partnerships shift commuting patterns, especially when combined with flexible shift times to avoid transit bottlenecks [24]. By measuring avoided miles and associated emissions, institutions can reinvest savings into telehealth infrastructure and community access programs, reinforcing a virtuous cycle of decarbonization and equity [21,24]. Ultimately, durable change requires an institutional architecture that assigns responsibility, measures outcomes, and aligns incentives. Green teams serve as the hub for this architecture, translating executive commitments into operational playbooks, ensuring that sustainability initiatives are clinically sound, cost-effective, and consistent with patient safety [25,26]. As these structures mature, sustainability becomes a routine dimension of quality, comparable to infection prevention or medication safety, rather than a standalone project. The remainder of this article adopts the “Reduce, reuse, recycle” hierarchy to delineate pragmatic, evidence-based methods tailored to anesthesia practice, illustrating how perioperative services can achieve meaningful emissions reductions while safeguarding clinical excellence and fiscal stewardship [18,25,26].

Reduce

Inhaled anesthetic agents and nitrous oxide (N2O)

Inhaled anesthetics and nitrous oxide (N2O) represent a distinctive and disproportionately potent source of greenhouse gas (GHG) emissions within perioperative care because, once vented as waste gases, they persist in the atmosphere for years to decades and exert radiative forcing many orders of magnitude greater than carbon dioxide over comparable time horizons [27,28]. The global warming potential (GWP) framework provides a standardized means to compare these agents’ heat-trapping potency against carbon dioxide over 20-year (GWP20) and 100-year (GWP100) intervals, enabling clinicians and administrators to interpret the climate consequences of routine anesthetic choices in clinically meaningful terms [27,28]. Translating agent-specific GWPs and clinically used concentrations into carbon dioxide equivalents over 20 years (CDE20) further contextualizes emissions by relating an anesthetic episode to familiar activities such as personal vehicle travel, thereby making visible the hidden climate externalities of everyday practice decisions [27,28]. Among volatile agents, desflurane carries exceptionally high GWPs, sevoflurane the lowest, and isoflurane an intermediate profile, a hierarchy that, when integrated with minimum alveolar concentration requirements, leads to wide variation in per-case climate impact even before fresh gas flow (FGF) is considered [27,28]. Because the volatile anesthetics and N2O constitute one of the largest contributors to operating room (OR) emissions, targeted mitigation of inhalational techniques is the single highest-yield opportunity for anesthesia providers to reduce their environmental footprint without compromising patient safety [6].

Choice of anesthetic technique is foundational. Total intravenous anesthesia (TIVA) with propofol demonstrates orders-of-magnitude lower cradle-to-grave GHG emissions than volatile anesthetics in comparative life-cycle assessment (LCA), reflecting the absence of atmospheric venting and the generally smaller energy inputs of the intravenous supply chain when scaled per anesthetic hour [14]. Nevertheless, anesthesiologists must be mindful that environmental stewardship is not merely a binary substitution; unused propofol is frequently discarded, and unmetabolized propofol exhibits environmental persistence and aquatic ecotoxicity, underscoring the need for dosing precision, closed-loop infusion technologies, and pharmacy-level waste minimization to realize the full sustainability advantage of TIVA [29,30]. Regional and neuraxial techniques constitute a parallel pathway to mitigation by obviating volatile anesthetic use and thereby eliminating a major GHG source at its origin [31]. While local anesthetics and sedatives carry their own ecotoxicity profiles, their quantities in regional anesthesia are typically far smaller than those of volatile agents in general anesthesia, hinting at favorable environmental trade-offs even as the field awaits LCAs directly comparing regional techniques to TIVA and inhalational approaches across standardized clinical scenarios [32]. Until such studies are available, pragmatic selection should integrate clinical indication, patient preference, and environmental externalities, prioritizing non-volatile strategies when they are clinically equivalent or superior [14,31,32]. When inhalational anesthesia is indicated, agent selection can dramatically differentiate the climate impact of otherwise similar anesthetics. Foregoing desflurane and N2O in favor of sevoflurane or isoflurane with air-based FGF can reduce GHG emissions per minimum alveolar concentration hour by an order of magnitude or more, a finding consistently reinforced by LCA modeling and operational case studies [14]. Real-world implementation at multiple hospitals in Vancouver demonstrated the scale of achievable change: a coordinated initiative to substitute sevoflurane for desflurane and use lower FGFs yielded a 66% reduction in anesthetic-related GHG emissions over five years, equivalent to removing approximately 1,700 personal vehicles each driving 22,000 km annually from the road—an easily communicable comparison that galvanized multidisciplinary support and sustained practice change [33]. This experience illustrates the importance of combining evidence on agent potency with institutional policies, clinician education, and feedback mechanisms that translate climate science into everyday clinical routines [14,33].

Fresh gas flow management is the second core strategy for reducing emissions from inhalational techniques, influencing both agent consumption and the total volume of waste gases vented to scavenging systems [34]. Principles of low-flow and closed-circuit anesthesia are long-established, yet their environmental implications are newly salient: by aligning FGF more closely with the patient's oxygen consumption and anesthetic uptake, clinicians can maintain adequate anesthetic depth while markedly reducing agent throughput and atmospheric release [34]. During inhalational induction—especially common in pediatric practice—traditional teaching has favored high FGF for speed, followed by turning off the vaporizer during intubation. A more environmentally sound approach is to briefly cease

FGF while leaving the vaporizer on, preserving circuit concentrations without continuous agent flushing to the scavenger [34]. If maintenance will proceed via TIVA even in pediatric cases, an initial intravenous induction can be both clinically appropriate and environmentally preferable by avoiding the additional burden of a high-flow volatile induction altogether [35]. For volatile maintenance following intravenous induction, the concept of "overpressure" helps balance the initial high uptake phase: rather than resort to very high FGFs, clinicians can transiently increase vaporizer concentration at modest flows to achieve target end-tidal levels, then transition promptly to low flows once a steady state is established [34]. During emergence, emissions are minimized by postponing any FGF increase until the vaporizer is off, avoiding a late surge of agent-rich gases to the scavenging system [34]. Although low-FGF strategies increase the consumption of carbon dioxide absorbent, the life-cycle burden of absorbent use is unlikely to outweigh the benefits of substantially reduced volatile agent emissions, a hypothesis that invites future LCA to quantify trade-offs with greater precision [34].

A third pillar of mitigation addresses the fate of scavenged gases. Even with meticulous low-flow practices, substantial volumes of volatile agents enter the scavenging system and would otherwise be exhausted directly to the atmosphere. Anesthetic gas capture technologies now offer a practical interception point: silica zeolite–based filters installed in the scavenging line can adsorb and retain halogenated anesthetics with reported efficiencies around 75%, concentrating these agents in replaceable canisters for off-site processing [36]. The captured mixture can be desorbed, purified, and readied for potential reintroduction into the pharmaceutical supply chain, closing a portion of the loop from use to reuse and accelerating circularity in anesthetic delivery [36]. In Canada, the regulatory pathway for recycling and reselling recovered volatiles remains in progress, with Health Canada approval pending for end-to-end commercialization, but capture itself already prevents a substantial fraction of emissions from entering the atmosphere and complements source reduction efforts at the bedside [37]. It is important to recognize that current capture systems do not remove N2O, which neither adsorbs effectively to the zeolite matrix nor lends itself to straightforward on-site abatement in existing configurations, leaving a large and long-lived GHG untouched by this intervention [38]. Consequently, the most effective N2O strategy is avoidance at the source whenever clinically feasible, supported by pipeline decommissioning, leak surveillance, and the adoption of alternatives for analgesia and anesthesia that do not carry N2O's atmospheric persistence [14,38].

Clinical implementation depends on more than technical adjustments; it requires a system design that makes the sustainable choice the easy choice. Agent formularies can be redesigned to default to lower-GWP volatiles, reserving desflurane to narrow indications justified by documented clinical benefit rather than habit or perceived convenience [14]. Vaporizer inventories can be rationalized, with desflurane vaporizers removed from routine carts and housed centrally to introduce a deliberate step for exceptional use, thereby nudging behavior without eliminating clinician autonomy [33]. Anesthesia information management systems can be configured to display real-time FGF, cumulative agent consumption, and estimated CDE20 for the ongoing case, translating abstract climate metrics into actionable feedback that supports low-flow practice and agent selection in the moment [27,28,34]. Similarly, post-case dashboards that benchmark clinicians and services against local peers on volatile consumption per case-mix–adjusted anesthetic hour can anchor quality-improvement cycles that normalize sustainability as a dimension of clinical excellence, analogous to infection prevention or medication safety [33,34].

Education and culture change intersect with these tools to sustain progress. Resident curricula should integrate climate science fundamentals, GWPs, CDE metrics, and practical low-flow techniques alongside traditional pharmacology and physiology, ensuring that new graduates view environmental stewardship as integral to safe, high-quality anesthesia [27,28,35]. Continuing professional development can disseminate emerging evidence on comparative LCAs of techniques and agents, updates on capture technology performance, and pragmatic tips for waste reduction across varied clinical contexts, from pediatric inhalational inductions to long adult cases requiring deep anesthesia [14,36]. Pharmacy and supply chain partners can collaborate with anesthesia services to right-size propofol vial availability, expand prefilled syringe programs where compatible with safety and cost-effectiveness, and optimize inventory to minimize expiries, thereby reducing ecotoxic waste and strengthening the environmental advantage of TIVA [30]. Environmental services and facilities engineering can coordinate with OR leadership to ensure scavenging systems are properly maintained, capture canisters are replaced at the correct adsorption thresholds, and monitoring identifies leaks or bypasses that would nullify upstream efforts [36].

N2O merits focused attention because its historical ubiquity can obscure its outsized climate impact and limited contemporary indications. Many labor and dental suites retain legacy infrastructure that delivers N2O through pipelines prone to chronic leakage, creating continuous emissions regardless of clinical use [38]. Systematic audits frequently reveal that decommissioning or isolating N2O pipelines, substituting portable systems deployed only when clinically required, and replacing N2O-based regimens with multimodal alternatives can rapidly curtail a significant, previously invisible GHG source [38]. In the perioperative setting, analgesic and anesthetic strategies that rely on short-acting opioids, ketamine, dexmedetomidine, and regional blocks can often eliminate the need for N2O without degrading recovery profiles, provided decisions are individualized and embedded in evidence-based protocols [31,32,38]. Where N2O remains necessary, metering, leak detection, and staff training on proper cylinder handling reduce fugitive emissions, but the most sustainable path remains selective avoidance consistent with modern clinical practice [38]. Measurement underpins management. Incorporating anesthetic gas consumption into institutional sustainability reporting, ideally as service-line–specific indicators, makes emissions visible and actionable for clinical leaders and executive sponsors alike [18,33,34]. Targets—for example, year-over-year reductions in volatile agent CDE20 per anesthetic hour, elimination timelines for routine desflurane use, and progressive deimplementation of N2O—can be codified in departmental plans, with feedback loops that celebrate milestones and troubleshoot barriers [33,37,38]. Importantly, environmental metrics should be interpreted alongside patient-centered outcomes and operational indicators to reassure clinicians that stewardship coexists with safety, efficacy, and efficiency, echoing the broader lesson that environmental and fiscal sustainability frequently align when examined from a systems perspective [9,18].

The maturation of capture and recycling technologies may eventually extend beyond halogenated agents to more comprehensive abatement strategies, but even partial capture offers meaningful climate benefit when layered atop source reduction through technique choice, agent selection, and low-flow practice [36,37]. Pending regulatory approvals for reclaimed-agent reintroduction will determine the feasibility of a circular supply, potentially lowering costs and further shrinking the life-cycle emissions of anesthetic delivery, though ongoing vigilance will be required to ensure quality, purity, and pharmacopoeial compliance [37]. Until then, the hierarchy of action remains clear: avoid where possible, minimize flows where necessary, and capture where available, with N2O avoidance occupying a special priority due to its persistence and current non-capture status [14,34,38]. In sum, anesthesiology stands at a high-leverage intersection of clinical care and climate stewardship. Through judicious technique selection that privileges TIVA and regional anesthesia when clinically appropriate, deliberate avoidance of desflurane and N2O in routine practice, rigorous low-flow application supported by real-time feedback, and adoption of zeolite-based capture to intercept remaining volatiles, anesthesia providers can deliver immediate and substantial reductions in OR emissions [14,27,28,33,34,36,38]. These actions, grounded in LCA evidence and operational experience, carry co-benefits for cost containment, supply resilience, and professional leadership in sustainability. As institutions normalize such practices through policy, education, and measurement, the environmental externalities of perioperative care can be markedly reduced, aligning the specialty's commitment to patient safety with a parallel duty of care to planetary health [6,14,33,34,37].

Drug waste

Anesthesiology's pharmaceutical footprint is both environmentally consequential and financially material, with estimates suggesting that 25–30% of the anesthesia drug budget is routinely discarded rather than administered to patients [39]. Within this wastage profile, propofol stands out as the most frequently dispensed and most frequently wasted agent, with studies reporting that 32–49% of supplied volume is ultimately discarded—often because of conservative preparation habits, vial sizes misaligned with clinical needs, and strict beyond-use dating once a vial is opened [30,39]. Similar dynamics apply to routinely prepared emergency medications—such as ephedrine, atropine, and phenylephrine—as well as neuromuscular blocking agents, which are prepared preemptively for safety but go unused as much as half the time and are then wasted at case end [16,30,40]. Given that anesthesiologists are already adept at rapid drug preparation under pressure, a pragmatic, less wasteful practice is to stock unopened ampoules and sterile syringes immediately at hand, drawing up only when clinically indicated rather than pre-filling by routine [16,30,40]. A complementary, system-level solution is pharmacy-prepared, bar-coded prefilled syringes for commonly used agents, which can reduce partial-vial discard, standardize concentrations, and improve medication safety while delivering meaningful cost savings through lower aggregate waste [41]. These operational changes, when paired with inventory right-sizing and case-type–specific drug preparation standards, directly address the principal drivers of avoidable disposal and translate quickly into reduced purchasing volumes and environmental releases [39,41].

The ecological urgency of drug waste reduction is sharpened by the growing body of evidence on the persistence and toxicity of pharmaceuticals in the environment. Propofol again serves as a salient example: unmetabolized propofol does not readily degrade, exhibits high toxicity to aquatic organisms, is mobile in soils, and accumulates in fatty tissues—an unfavorable profile that magnifies the consequences of routine discard into waste streams [30]. For this reason, best practice prohibits disposal via sinks or municipal trash and instead requires high-temperature incineration compliant with manufacturer guidance and pharmaceutical waste regulations, ensuring destruction of the compound and preventing downstream contamination of water and ecosystems [30]. Establishing clear OR workflows for segregating pharmaceutical waste, providing appropriately labeled receptacles, and training staff on the legal and environmental rationale for incineration-based disposal can substantially reduce inadvertent environmental release [30]. At the same time, feedback loops—such as monthly reports on rates of opened-but-unused vials by drug and service line—help clinicians see the tangible effects of practice changes and reinforce stewardship culture [39]. Ultimately, anesthesia providers should remain mindful of what they draw up, recognizing that each prefilled, unused syringe carries both an environmental and financial cost that is often avoidable through modest process redesign and adherence to evidence-based waste minimization strategies [37].

Other opportunities for waste reduction

Beyond pharmaceuticals, several anesthesia-specific practices present underappreciated avenues to reduce waste at the source. One promising area is kit optimization. Many prepared procedural bundles—central venous catheter sets, spinal and epidural kits, and even standard airway packs—contain components, instructions, and packaging that are rarely used but must be discarded once the sterile wrap is opened. Collaborating with regulators, manufacturers, and hospital supply chain leaders to create modular, right-sized kits tailored to local practice patterns can meaningfully reduce single-use plastics, paper inserts, and redundant disposables without compromising sterility or safety. Such efforts benefit from formal life-cycle thinking, whereby each component is scrutinized for clinical utility and environmental burden, and from iterative pilot testing that ensures clinical equivalence while trimming unnecessary materials [18]. Even small reductions in pack contents scale into sizable waste and cost savings across high-volume perioperative services, particularly when combined with packaging redesign that minimizes mixed-material laminates and favors recyclability where compatible with infection-prevention requirements. Another often overlooked source of disposable consumption is anesthesia suction. Routine use of dedicated anesthesia suction systems throughout a case can generate additional plastic waste and tubing disposal, especially when a separate surgical suction remains available. In many circumstances, particularly at extubation, the airway can be effectively suctioned using the existing surgical suction with a freshly opened Yankauer tip, thereby eliminating redundant anesthesia-side suction setups while preserving safety and sterility. Embedding this practice into extubation checklists and providing clear criteria for exceptions (e.g., anticipated copious secretions or high aspiration risk) can standardize adoption and ensure that waste reduction never compromises patient care. Complementary steps include auditing default room setups to remove rarely used disposable items from automatic opening, revising preference cards to trigger supplies "on demand," and aligning case-end cleanup protocols to segregate clean, unopened items for return to stock. Sustained improvement across these domains hinges on measurement and multidisciplinary governance. Tracking per-case drug discard rates, unopened-item returns, and kit-component use informs targeted interventions and allows departments to celebrate progress credibly. Pharmacy-anesthesia partnerships are integral to expanding prefilled syringe programs where evidence supports safety and cost-effectiveness, optimizing vial sizes to match common dosing ranges, and revising par levels to curb expiries [41]. Education remains essential: trainees and staff benefit from concise guidance on environmentally responsible drug preparation, regulatory disposal pathways for hazardous pharmaceuticals, and the clinical rationale for kit modularization and suction rationalization. When these clinical micro-practices are coupled with institutional policies that prize waste prevention, anesthesia services can shrink their environmental footprint while enhancing medication safety and fiscal stewardship—demonstrating, once again, how systems-minded efficiency yields convergent benefits for patients, providers, and the planet [30,39,41].

Reuse

The rapid expansion of single-use medical devices over recent decades has been driven largely by legitimate concerns about infection prevention and patient safety; however, this shift has also produced a substantial escalation in healthcare-related waste with consequential pollution and public health burdens that must be considered alongside the benefits of disposability [42]. In this context, the systematic application of life-cycle assessment (LCA) offers a robust, comparative framework to evaluate the environmental footprints of reusable versus single-use alternatives for common anesthesia products. By quantifying resource inputs, energy consumption, emissions, and waste across production, use, reprocessing, and end-of-life, LCA enables clinicians, infection prevention teams, and supply chain leaders to reconcile safety imperatives with environmental stewardship and to identify circumstances in which reuse can responsibly reduce harm without compromising clinical outcomes [42]. The emerging body of evidence across supraglottic airways, textiles, breathing circuits, and selected ancillary products demonstrates that, in many cases, well-designed reusable options deliver both environmental and economic advantages, provided that rigorous reprocessing standards and validated barrier protections are maintained [15,43,44]. At the same time, product- and context-specificity remains paramount, and institutions must remain attentive to items for which disposability still confers net benefit or for which evidence is incomplete, necessitating careful local evaluation and ongoing research [45,46].

Table 1: Recyclable Anesthetics Materials.

Plastics*	Paper	Glass
Surgical instrument wraps (including blue wrap) Forced-air warming blankets Saline and water ampoules and bottles Uncontaminated intravenous fluid bags and tubing Oxygen masks and tubing Suction tubing Uncontaminated syringes Hard plastic packaging (procedure equipment trays, ex., central line trays)	Boxboard Paper package inserts Rippable paper packaging	Glass vials

Supraglottic airways

Reusable and single-use supraglottic airway devices—exemplified by the Classic™ and Unique™ LMA® families—have comparable clinical performance profiles with respect to effectiveness and ease of use, making them ideal candidates for LCA comparison focused on environmental and cost dimensions [15]. In a seminal analysis, Eckelman and colleagues contrasted the impacts of forty uses of a single reusable Classic™ LMA with forty one-time uses of disposable Unique™ LMAs across multiple environmental and human health categories [15]. Despite the repeated demands of cleaning, packaging, and re-sterilization inherent to reusable workflow, the LCA strongly favored the reusable device on most impact indicators, highlighting that the embedded burdens of manufacturing and disposing of forty single-use items outweigh the marginal burdens of reprocessing a durable device across its service life [15]. Notably, the per-use financial costs also favored the reusable option, underscoring that environmental and economic stewardship can align when procurement and reprocessing systems are competently designed and executed. These findings support a default institutional preference for reusable supraglottic airways where validated reprocessing protocols are in place and where clinical indications do not mandate disposability for specific infection control reasons [15].

Reusable textiles

A parallel evidence base has accumulated for surgical textiles, with multiple studies demonstrating that reusable gowns and drapes outperform disposable counterparts on resource energy use, water consumption, carbon footprint, volatile organic emissions, and solid waste generation, while maintaining comparable levels of barrier protection, comfort, and clinical acceptability [43,44]. The advantages emerge from both the amortization of manufacturing impacts over many launder-sterilize cycles and from advances in high-performance textile engineering and reprocessing technologies that optimize water and energy efficiency without compromising sterility assurance levels [43,44]. Hospitals that adopt robust reusable textile programs frequently report downstream operational benefits, including reduced waste handling and storage demands and improved reliability of supply during disruptions, which can further strengthen the case for reuse as a dimension of resilience as well as sustainability. As with airway devices, realization of these benefits depends on well-validated laundering, packaging, and sterilization processes, along with disciplined quality assurance to monitor integrity over the textile life cycle [43,44].

Breathing circuits

The reuse of anesthesia breathing circuits has generated spirited debate because it sits at the intersection of infection prevention, occupational safety, and material waste reduction. Practice patterns vary: some departments replace circuits for every patient, while others reuse circuits with a high-efficiency filter at the circuit Y-piece changed between cases [45,46]. International professional guidance provides pragmatic, risk-stratified direction. The German Anesthesiology Society supports circuit reuse for up to seven days under appropriate filtration and change-out criteria, whereas the Association of Anesthetists of Great Britain and Ireland endorses reuse across an entire operating day, provided an appropriate filter with > 99% airborne particle retention efficiency is changed between patients. In both frameworks, circuits are changed immediately if visibly contaminated or following use in highly infectious cases such as pulmonary tuberculosis, aligning infection control prudence with resource stewardship [45,46]. Evidence indicates that disposable bacterial filters can prevent transmission of airborne bacteria and protect circuits from contamination for up to one week, lending microbiological support to these time-limited reuse protocols when applied judiciously and monitored by infection control teams [47,48]. While comprehensive LCAs comparing filtered circuit reuse against per-patient disposability are still needed, the current infection prevention literature and consensus guidance suggest that, with high-efficiency filtration and clear exception criteria, circuit reuse can be compatible with safety while curbing waste, and anesthesiologists should collaborate closely with local infection control committees to develop and maintain evidence-based policies [45–48].

Other products

Beyond airway devices and textiles, LCA studies have evaluated a variety of anesthesia-relevant products with heterogeneous findings that reinforce the necessity of item-specific appraisal. Reusable laryngoscope handles and blades, as well as reusable sharps containers, have demonstrated decreased environmental impacts compared with their single-use alternatives, reflecting the same principle that durable devices can amortize manufacturing burdens across many uses and avoid the repeated production and disposal inherent to disposables [17,49]. By contrast, central line kits have not shown a sustainability advantage for reusable options, likely due to the complexity of components, stringent sterility requirements, and reprocessing burdens that can overshadow benefits in certain configurations [50]. When viewed collectively, these results caution against universal conclusions: while reusable options appear preferable in many categories, the balance of environmental, clinical, and economic considerations remains product- and context-specific, and institutions should seek LCA-grade evidence where available or commission targeted analyses when high-volume products lack comparative data [51]. Priority gaps deserving rigorous comparison include reusable versus disposable videolaryngoscope blades and reusable circulating water blankets versus single-use air-warming systems, where clinical performance nuances, infection control logistics, and energy profiles can interact in complex ways [51].

Reprocessing single-use devices (SUDs)

The "single-use" designation often reflects manufacturer strategy as much as evidence-based infection risk assessment, and experience has shown that many labeled SUDs can be safely and effectively reprocessed under validated protocols, reducing waste and generating significant cost savings without compromising patient safety [52]. Reprocessing may be conducted within the hospital's sterile processing department or outsourced to third-party reprocessors that operate under regulatory oversight and quality systems, allowing hospitals to "buy back" reprocessed devices at a fraction of the new-device cost [52]. The Association of Medical Device Reprocessors catalogs commonly reprocessed SUDs that are amenable to validated cleaning, functional testing, and sterilization, including blood pressure cuffs, tourniquet cuffs, pulse oximetry sensors, and anesthesia masks, among others [52,53]. For anesthesia services, partnering with reputable reprocessors and establishing transparent criteria for device selection, cycle limits, and functional verification can embed reprocessing into routine practice, thereby diverting substantial waste from landfill and conserving procurement budgets [52,53]. Clear labeling, staff education, and traceability systems are critical to ensure end-user confidence and regulatory compliance while enabling post-market surveillance to rapidly detect and correct any performance deviations [52].

Infection risk

Any program that expands reuse or reprocessing must foreground infection prevention and patient safety. The literature indicates that documented infection transmissions associated with reuse typically arise not from the concept of reuse per se, but from failures in cleaning, disinfection, or sterilization of complex devices—such as flexible bronchoscopes—or from reuse of equipment that is structurally compromised and therefore not amenable to effective reprocessing [54–56]. These events are rare but can be devastating, emphasizing that the ethical calculus for sustainability must incorporate rigorous risk management, conservative device selection, and relentless attention to process quality [54–56]. Systematic audits—encompassing process observation, biological and chemical indicator performance, device integrity inspection, and post-use microbiological surveillance—are essential to quantify both global and device-specific risks, ensuring that the small individual risk to a given patient remains acceptably low when weighed against the broader public health risks posed by escalating medical waste and pollution [42,54–56]. Institutions should formalize governance structures that integrate infection control, sterile processing leadership, anesthesia and surgical representatives, biomedical engineering, and supply chain, enabling shared accountability for policy development, staff training, and continuous improvement [42]. Across all these domains, successful reuse strategies depend on disciplined implementation. First, device selection should privilege designs engineered for reusability, with materials and geometries that withstand repeated cleaning and sterilization while preserving performance. Second, reprocessing workflows must be validated end-to-end, including pre-cleaning at the point of use, transport under conditions that prevent bioburden fixation, mechanical cleaning with detergents verified for material compatibility, standardized visual inspection augmented by borescopic evaluation for lumened devices, and sterilization cycles matched to device tolerances and microbial lethality targets [54–56]. Third, lifecycle limits should be empirically derived and enforced to retire devices before microdamage undermines cleanability or structural integrity. Fourth, data systems should capture device identity, cycle counts, process parameters, and quality indicators to enable traceability and root-cause analysis when anomalies arise. Finally, education for clinicians and sterile processing teams should be ongoing, emphasizing the clinical rationale, environmental benefits, and safety guardrails that justify reuse, thereby cultivating a culture in which sustainability is perceived not as a trade-off against safety but as integral to high-quality care [42,54–56].

The policy environment can either accelerate or impede the uptake of safe reuse. Where reimbursement structures and procurement contracts undervalue reprocessed options or fail to recognize avoided waste handling costs, financial signals may inadvertently favor disposability despite inferior environmental performance [49,52]. Conversely, contracts that require suppliers to disclose LCA data, participate in take-back and refurbishing programs, and support reusable alternatives where clinically appropriate can shift markets toward lower-impact solutions [51,52]. Accreditation and regulatory bodies can further catalyze progress by recognizing validated reprocessing pathways, harmonizing guidance across jurisdictions, and promoting standardized metrics for environmental performance that allow benchmarking and accountability without diluting infection prevention standards [45,46,52]. In sum, the transition from a default disposable paradigm to a rigorously governed reuse model in anesthesiology is both feasible and desirable when guided by sound evidence and implemented with uncompromising attention to safety. LCAs of supraglottic airways and textiles already justify routine preference for reusable options, while consensus guidance on breathing circuit reuse—anchored by high-efficiency filtration and clear exception criteria—provides a prudent path to reduce waste without elevating infection risk [15,43–48]. Additional product-specific LCAs and field studies should resolve remaining uncertainties for complex categories such as central line kits, videolaryngoscope blades, and patient warming systems, ensuring that context-specific recommendations reflect true life-cycle burdens and clinical realities [50,51]. Meanwhile, structured programs for reprocessing selected SUDs, executed under validated protocols and reinforced by strong governance, can materially reduce environmental footprints and operating costs, provided vigilance is maintained against the rare but serious risks associated with reprocessing failures [52–56]. By embedding these practices within institutional policy, quality management, and culture, anesthesia services can advance patient safety and planetary health together—affirming that responsible reuse, done right, is a hallmark of modern, sustainable perioperative care [15,42,43–48,49–53,54–56].

Recycle and Segregate

Operating rooms (ORs) are among the most resource-intensive areas of healthcare facilities, generating between 20% and 33% of total hospital waste, with anesthesia-related activities accounting for up to one-quarter of all surgical trash [57,58]. The magnitude of this waste underscores the need for targeted interventions in waste segregation and recycling, particularly within anesthetic practice. Medical waste is typically divided into two main categories: biomedical (hazardous) and general (non-hazardous) waste. Biomedical waste includes materials contaminated with blood or other bodily fluids that carry a risk of infection, requiring specialized treatment such as incineration or autoclaving before disposal. This process significantly increases disposal costs and contributes disproportionately to environmental degradation. In contrast, general waste—comprising packaging materials, paper, plastics, and non-contaminated disposables—can often be safely recycled or sent to standard landfill streams with far less environmental burden [57]. Expert consensus suggests that biomedical waste should constitute no more than 15% of an institution's total waste output; however, observational audits across multiple hospitals reveal that this threshold is often exceeded, primarily due to improper segregation practices. More than 70% of general OR waste that could be recycled is incorrectly disposed of as biomedical waste, resulting in higher disposal costs and avoidable environmental harm [59]. Effective segregation of waste at the point of generation is therefore both an environmental and economic priority. The study by Wyssusek et al. demonstrated the tangible benefits of implementing a structured OR waste segregation program: after its introduction, the proportion of biomedical waste fell to just 18% of total OR waste, producing an 80% reduction in overall waste management costs [59]. This outcome illustrates how education, infrastructure, and compliance can directly translate to measurable financial and environmental benefits.

A key example relevant to anesthesia is the use of sharps containers, which are typically autoclaved prior to final disposal—a costly and energy-intensive process. Often, these containers are misused, with non-sharp items such as syringe barrels being disposed of alongside actual sharps. Such misuse unnecessarily inflates the volume of regulated biomedical waste. To adhere to best practice, the contents of sharps containers should be restricted strictly to items capable of cutting or puncturing the skin—needles, scalpels, and broken ampoules—while the associated syringes or non-piercing components should be placed in the general or recycling waste stream [59]. Staff education and clearly labeled receptacles can ensure consistent adherence to this policy, preventing contamination of recyclable materials and minimizing costly overclassification of waste. The economic rationale for proper segregation and recycling is equally compelling. The cost of recycling is typically lower than that of solid waste disposal, and estimates suggest that 60–70% of general anesthesia-related waste is recyclable [59,60]. Many hospitals operate under contractual arrangements where they must pay waste management companies for the removal of general and biomedical waste, but can sell recyclable materials to recycling firms. This inverse cost structure means that rigorous segregation and recycling can produce substantial savings, potentially augmented by negotiated rebates from industrial recyclers [59,60]. Moreover, improved recycling compliance reduces the volume of waste requiring incineration—an energy-intensive process that releases harmful pollutants and greenhouse gases—further amplifying environmental benefits.

Despite these clear advantages, recycling remains underutilized in clinical settings. Recent surveys reveal that fewer than one-third of Canadian anesthesiologists actively recycle at work, despite expressing strong support for environmental sustainability initiatives [7]. This discrepancy between intent and practice points to a series of institutional barriers, including inadequate leadership support, insufficient infrastructure (such as appropriately labeled bins in ORs), and limited education on what can and cannot be recycled [7]. Furthermore, many clinicians cite uncertainty regarding contamination protocols and concerns that recycling facilities may reject medical plastics perceived as biohazardous. These perceptions highlight the need for greater communication between hospitals and recycling partners to establish transparent, mutually acceptable criteria for waste acceptance and decontamination [39]. One practical strategy to address contamination concerns is temporal segregation—collecting recyclable materials during the setup phase of a surgical case, before the patient enters the OR. At this stage, packaging and wrapping materials are not contaminated with bodily fluids and can therefore be safely diverted to the recycling stream without risk to waste-handling personnel [37]. Implementing this approach requires coordination among anesthesia providers, circulating nurses, and environmental services staff to ensure that recycling receptacles are easily accessible and that workflows facilitate separation without disrupting clinical efficiency. For instance, separate bins labeled for plastics, paper, and metals can be positioned adjacent to the anesthesia workstation for collecting uncontaminated packaging from syringes, airway devices, and IV tubing. The types of recyclable materials associated with anesthesia practice vary by institution and jurisdiction, depending on regional recycling infrastructure and regulations. Examples commonly cited in the literature include uncontaminated polypropylene and polyethylene plastics (e.g., IV fluid bags, syringe wrappers, and tubing), aluminum cans, clean paper packaging, and certain rigid plastics used in anesthesia circuit components [61,62]. However, recyclability is not universal: composite materials combining plastic and foil or multilayer films are often non-recyclable due to their complex composition. As such, anesthesiologists and OR teams should consult their hospital's environmental services department or local recycling representative to clarify which materials are accepted by regional facilities and to receive updated lists as recycling technologies evolve [61,62].

In addition to material-specific efforts, institutional education and feedback mechanisms are central to sustained success. Staff should receive regular briefings on waste segregation protocols, environmental performance indicators, and progress toward departmental goals. Visible feedback—such as monthly dashboards showing the proportion of waste correctly segregated and corresponding cost savings—can reinforce compliance and cultivate a culture of accountability. Hospitals can further incentivize participation through recognition programs, sustainability champions, or by integrating environmental metrics into quality improvement frameworks. Ultimately, improving recycling and segregation in anesthetic and surgical practice requires a multi-tiered approach: education to close the knowledge gap, infrastructure to facilitate easy separation of waste streams, leadership commitment to embed sustainability within organizational priorities, and collaboration with external waste and recycling partners to ensure downstream processing integrity. When executed cohesively, these strategies can transform waste management from a reactive, compliance-driven process into a proactive component of environmental stewardship. As evidence demonstrates, meticulous segregation not only minimizes environmental impact but also yields financial savings, freeing resources that can be reinvested in patient care and sustainability innovation. In the broader context of healthcare's contribution to environmental degradation, such initiatives represent tangible, achievable steps toward aligning clinical excellence with planetary responsibility [57–62].

Future Steps

Future initiatives must prioritize uniting the Canadian anesthesia community around a shared mission to reduce the environmental footprint of the specialty. Achieving meaningful progress requires both institutional commitment and professional collaboration, integrating sustainability into the fabric of clinical practice, research, and policy development. Establishing consensus on measurable sustainability targets—such as anesthetic gas reduction, waste minimization, and procurement reform—will help standardize progress across the country and encourage accountability within departments. To this end, participation in dedicated professional bodies such as the Canadian Anesthesiologists' Society (CAS) Section for Environmental Sustainability can be instrumental in fostering coordination, data sharing, and advocacy [63]. These platforms serve as focal points for collective learning and innovation, enabling clinicians, researchers, and administrators to exchange practical insights and generate high-quality data to inform evidence-based policy. Collaborative research efforts under the auspices of national and international organizations can further strengthen the knowledge base supporting sustainable anesthetic practice. By pooling data across institutions, the Canadian anesthesia community can conduct multicentre life-cycle assessments (LCAs) and cost-benefit analyses of emerging technologies, helping to refine local policies based on robust national evidence. Additionally, these organizations can take leadership in developing guidelines and toolkits that translate research into clinical practice, ensuring that sustainability principles become embedded within hospital protocols, procurement standards, and residency curricula. The inclusion of environmental sustainability metrics within hospital accreditation and quality assessment frameworks would reinforce the principle that environmental responsibility is inseparable from patient safety and quality care [63]. Political and professional advocacy through these bodies can also influence health policy, urging regulators and funding agencies to prioritize sustainable infrastructure investment and to incentivize green innovations in healthcare delivery.

Beyond research and policy, the individual clinician has an equally vital role as both practitioner and educator. Clinicians should embrace their responsibility to model environmentally sustainable practice—whether by choosing low–global warming potential anesthetics, minimizing waste, or promoting efficient resource use—and by mentoring the next generation of anesthesiologists to internalize these values [63]. Environmental stewardship can be integrated into medical education through lectures, case discussions, and simulation training that emphasize the health and ethical dimensions of sustainability. Such inclusion would ensure that trainees understand the broader implications of their clinical decisions, equipping them to become advocates for sustainable practice throughout their careers. Moreover, interprofessional collaboration should be strengthened, bringing together anesthesiologists, nurses, surgeons, infection control specialists, and hospital administrators to co-design sustainable workflows that protect both patients and the planet. Institutional "green teams," supported by professional societies, can operationalize sustainability goals by coordinating initiatives, monitoring outcomes, and disseminating success stories across departments. These teams serve as local champions for environmental quality improvement, fostering a culture where sustainability is viewed as a shared professional duty rather than an optional add-on. In sum, the future of environmentally sustainable anesthesia in Canada depends on collective action at multiple levels—national leadership through professional organizations, institutional commitment through accreditation and policy, and individual engagement through education and example. By aligning these efforts, the Canadian anesthesia community can position itself as a global leader in sustainable perioperative care, ensuring that environmental responsibility becomes an enduring pillar of medical professionalism and patient safety [63].

Conclusion:

This article addresses the critical need for environmental sustainability within anesthesia practice, a significant source of healthcare's carbon emissions and waste. It proposes a practical framework for anesthesiologists to mitigate their specialty's environmental impact, focusing on the "Reduce, Reuse, Recycle" hierarchy. The most impactful strategy is to reduce the use of potent greenhouse gases, specifically by avoiding desflurane and nitrous oxide in favor of sevoflurane or total intravenous and regional techniques. Minimizing fresh gas flows and drug waste are also essential. For reuse, the article advocates for a shift towards reusable devices like laryngeal mask airways and surgical textiles, supported by life-cycle assessments showing lower environmental burdens and costs compared to single-use alternatives, provided rigorous reprocessing protocols are maintained. Finally, effective recycling requires proper waste segregation at the source to prevent recyclable materials from being incorrectly sent for expensive, polluting incineration. The conclusion emphasizes that anesthesiologists have an ethical and professional imperative to lead these efforts. By implementing these evidence-based strategies, the specialty can achieve substantial reductions in its carbon footprint and waste generation, advancing patient care while safeguarding planetary health.

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