Anesthetic gas how-to guide

A guide to climate-smart anesthesia care

Table of contents

Acknowledgements

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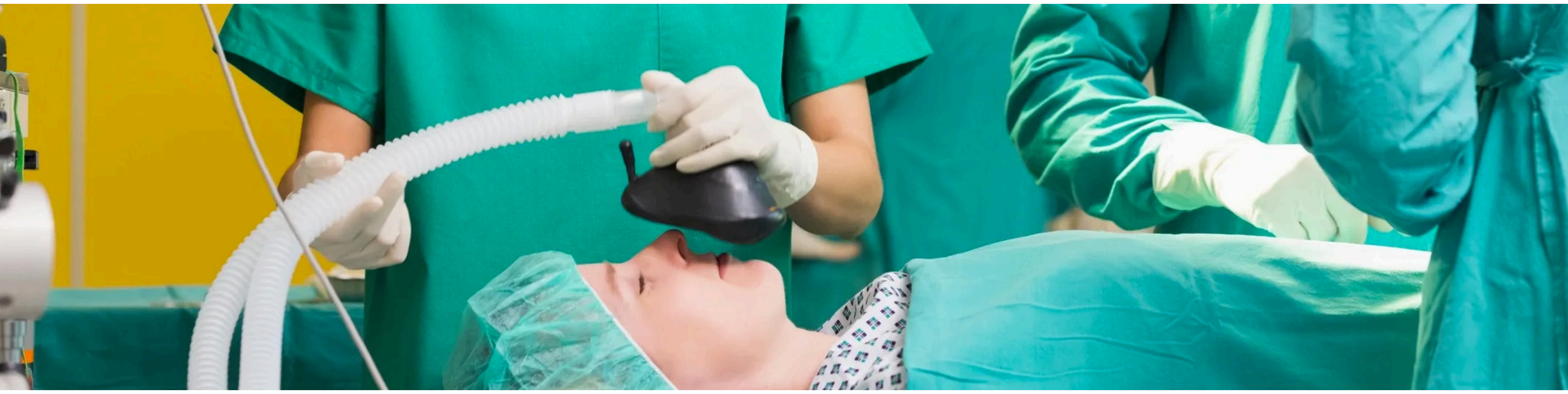
- American Association of Nurse Anesthetists

This document does not provide clinical guidance or dictate patient care. These resources were developed to support sustainability professionals and health care organizations in their efforts to reduce the environmental impact of their operations and supplement the resources developed for clinical audiences by the American Society of Anesthesiologists.



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Introduction

As respected leaders, clinicians and health care professionals have an important role to play in reducing health care's environmental impact and greenhouse gas emissions (GHG).

One major focus for anesthesia providers is the use of anesthetic agents due to their global warming potential. Anesthesia and analgesia are essential for patient safety and quality care. While typically associated with inpatient and ambulatory surgical settings, anesthesia can be used in cardiac catheterization labs, GI endoscopy, and diagnostic imaging procedures, as well as labor and delivery, pediatric, emergency, and other departments.

The Lancet Commission on Health and Climate identified climate change as the greatest threat and opportunity for public health in the 21st century. Health care is responsible for 10 percent of U.S. emissions, with hospitals representing more than one third of those emissions. Of that, a conservative estimate representing only acute care and inpatient hospitals suggests anesthesia is responsible for 5 percent of a facility's GHG emissions.

According to the 2018 Greening the OR benchmark report, Practice Greenhealth members who reported purchasing volumes of anesthetic gases had an average 2,027 metric tons of carbon dioxide equivalents ($MTCO_2e$) per facility, or 152 $MTCO_2e$ per OR annually, from purchased inhaled anesthetic agents. That's the same as annual emissions from more than 434 passenger vehicles or 219 homes.

Although it may be a small piece of the bigger picture, anesthetic gases directly contribute to a health care facility's GHG emissions. As more health care organizations are establishing greenhouse gas reduction goals, reducing the footprint of anesthetic gases can help. Clinicians need to take an active leadership role in their facility's environmental impact and bottom line.

Greenhouse gas emissions are defined as gases that trap heat in the atmosphere. The most prominent is carbon dioxide (CO_2), but methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), nitrogen trifluoride (NF_3), and sulphur hexafluoride (SF_6) also contribute to climate change. GHGs are measured in carbon dioxide equivalents (CO_2e), the amount of CO_2 that has the equivalent global warming impact. Source: Practice Greenhealth's greenhouse gas reduction toolkit.

The most common inhaled anesthetic gases used for patient care in the United States – desflurane, sevoflurane, isoflurane, and nitrous oxide – persist in the atmosphere for up to 114 years. Isoflurane, sevoflurane, and desflurane are volatile halogenated ethers; nitrous oxide, commonly used as a carrier drug or analgesic, is also a potent greenhouse gas. Desflurane has the highest global warming potential (GWP) – more than five times higher than isoflurane. Nitrous oxide persists in the atmosphere for 114 years, making its impact second worst after desflurane.

A study in The Lancet found anesthetic gases make up 51 percent of an average U.S. operating room's GHG emissions, whereas anesthetic gases represent 4 percent of an OR's greenhouse gas emissions in U.K. hospitals. This variation is related to providers' anesthetic gas selections – specifically, higher use of desflurane in the United States. Another study in the American Journal of Public Health found that eliminating desflurane from laparoscopic hysterectomies reduced greenhouse gas emissions by 25 percent per case.

During a procedure using inhaled anesthetics, only about 5 percent of administered anesthesia is metabolized by the patient. The remaining 95 percent is exhaled as waste anesthetic gas (WAG) by the patient during respiration. A scavenging system draws WAG out of the surgical field to minimize staff exposure, instead venting these agents into the atmosphere and outside air of local communities.

Since waste anesthetic gases are vented directly from the hospital, they are considered direct emissions and are reported as scope 1 GHG emissions.

Direct emissions are from sources owned or controlled by the reporting organization. All direct emissions are reported under scope 1.

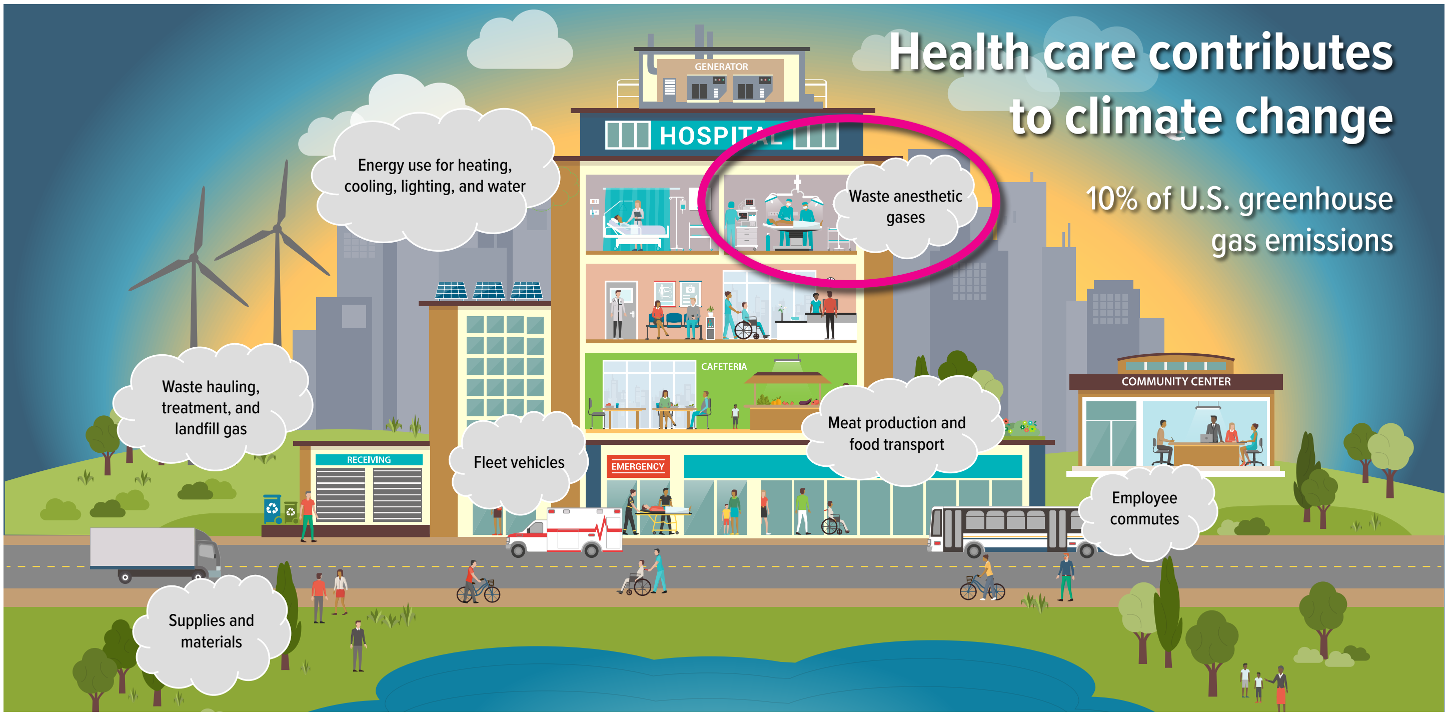
Scope 1 emissions can include on-site stationary combustion of fossil fuels, mobile combustion of fossil fuels by vehicle fleets, and fugitive emissions, as well as those caused by intentional or unintentional GHGs released, such as waste anesthetic gas or refrigerant leakage.

For more information, see Practice Greenhealth's greenhouse gas reduction toolkit.

Global warming potential of inhaled anesthetic agents

Inhaled anesthetic agent	100-year global warming potential (per kg, in comparison with CO_2 where CO_2 = 1)	Atmospheric lifetime (years)
Desflurane	2,540	14
Isoflurane	510	3.2
Sevoflurane	130	1.1
Nitrous oxide	298	114

https://journals.lww.com/anesthesia-analgesia/fulltext/2012/05000/Assessing_the_Impact_on_Global_Climate_from.24.aspx. This table is a subset of the data provided in Table 1. Summary of Radiative Properties, Atmospheric Lifetimes, and Global Warming Potentials for Nitrous Oxide and the Halogenated Anesthetic Gases from Andersen, M., et al. Assessing the Impact on Global Climate from General Anesthetic Gases. Anesthesia & Analgesia 114(5):1081-1085, May 2012. At time of publication, nitrous oxide values are in alignment with IPCC 4th Assessment Report and current EPA GHG reporting guidelines and the ASA.



Source: Health Care Without Harm Climate Action Playbook

Choices in anesthesia delivery have financial implications for health care institutions. Anesthetics are costly. Desflurane, the worst environmental offender due to its high global warming potential, is often the most expensive. Some organizations began eliminating desflurane from a cost-containment perspective, with the added benefit of reducing GHG emissions.

Health care organizations that have educated clinicians on the impacts of anesthesia and worked on strategies to reduce those impacts have achieved considerable cost savings. A study in the Journal of Clinical Anesthesiology highlighted an intervention at Wake Forest Baptist Health that resulted in more than $1.8 million in savings. At a time when health care professionals are tasked with cutting costs while still providing quality care, this can be an easy win.

Beyond the environmental and financial implications of anesthesia, adverse health impacts from exposure to waste anesthetic gases raise concerns for health care staff – especially perioperative and PACU staff – and their surrounding communities. Potential adverse health risks from exposure range from dizziness and nausea to sterility, miscarriage, birth defects, cancer, and liver and kidney disease.

Anesthetic gas goal

The Practice Greenhealth anesthetic gas goal has a dual purpose:

1. to help hospitals establish a baseline, set targets, and identify strategies to reduce the greenhouse gas emissions of anesthetic gases and measure progress.
2. to strengthen data integrity, and help establish a median range for the health care sustainability community.

The goals focus on establishing a baseline and working toward absolute reduction in greenhouse gas emissions from purchased inhaled anesthetic gases. These goals and strategies are based on recommendations from the American Society of Anesthesiologists' Environmental Task Force and the EUKI Anesthetic Gases Project on fostering low-carbon health care in Europe, in alignment with the Inhaled Anesthesia Climate Initiative's global Project Drawdown campaign, as well as reductions achieved by member hospitals.

The Practice Greenhealth anesthetic gas goal is branched, since desflurane can account for such a large percentage of a facility's anesthesia-related GHG emissions. If a facility eliminated desflurane prior to establishing a baseline and tracking this work, the opportunity to reduce emissions may be significantly less than for facilities just getting started. Since total elimination of anesthetic gases is not possible in acute care hospitals, there's a limit to GHG emission reductions health care organizations can achieve.

Goal: to reduce the direct (scope 1) greenhouse gas emissions from the use of anesthetic gases

Baseline	Conduct baseline assessment of total anesthetic gases purchased per year (12 consecutive months)	
	Has the facility eliminated desflurane?	
	No, desflurane is still on formulary.	**Yes,** desflurane has been eliminated from formulary.
Level 1	Reduce GHG emissions specific to anesthetic gases by 20 percent from baseline.	Reduce GHG emissions specific to anesthetic gases by 5 percent from baseline.
Level 2	Reduce GHG emissions specific to anesthetic gases by 50 percent from baseline.	Maintain 5 percent reduction from baseline.

For more information on the measure, data, calculations, and definitions, see the anesthetic gas data addendum.

Getting started

Step 1: Identify an anesthesia champion

Due to the clinical nature and direct impact on patient care, it is imperative that an anesthesia provider leads and supports this work. Perioperative staff may help identify one or more anesthesia providers interested in educating their peers, which will go much further than non-clinician led efforts. The American Society of Anesthesiologists' Environmental Task Force offers a wealth of peer-reviewed literature and resources for anesthesiologists.

Use the clinical champion checklist and worksheet from the employee engagement toolkit for help identifying an anesthesia champion. Connect with the Health Care Without Harm Physician Network.

Step 2. Identify additional key stakeholders and create a project team

The steering committee needs representatives from anesthesia, as well as key stakeholders from nursing, surgery, supply chain, pharmacy, clinical engineering, administration, and facilities/operations, among other departments. Residents, students, and researchers may also be valuable assets to the team. Medical gas vendors may be able to support data reporting and purchasing records needs.

Align anesthetic gas reduction strategies with organizational priorities around GHG reduction and greening the OR goals, employee health and wellness, and cost reduction efforts.

Step 3: Establish a baseline

"You can't manage what you don't measure" is not a new saying, but it holds true. An important step is establishing baseline GHG emissions from inhaled anesthetic gases in order to identify next steps.

To do this, 12 consecutive months of anesthetic gas (isoflurane, sevoflurane, desflurane, and nitrous oxide) use or purchasing data will be needed. Team up with the anesthesia champion and supply chain, pharmacy, clinical engineering, medical gas vendor, or EMR management system to pull this information.

Step 4: Conduct an assessment

Once a baseline waste anesthetic gas footprint is determined, the team should use the anesthetic gas checklist or anesthetic gas data collection tool to assess current practices, identify opportunities, and set goals.

Tip: Use the anesthetic gas data collection tool for help converting purchasing data into $MTCO_2e$ for anesthetic gases. The GHG Reduction Toolkit tracks scopes 1, 2, and limited scope 3 emissions. Enter purchasing data in the inventory tool to convert into scope 1 emissions from waste anesthetic gases and track along with other sources of emissions. For more on the terms and step-by-step guidance on calculating emissions from purchasing data by hand, use the anesthetic gas data addendum.

Step 5: Set a goal

After completing the checklist, determine a goal for your organization. Work with the project team to select an appropriate anesthetic gas reduction goal, which may depend on whether the facility has eliminated desflurane from its formulary. Consider adding facility-specific measures, such as a timeline for completion. Example: "Hospital commits to level 3 and will reduce GHG emissions from anesthetic gases by 50 percent from baseline by 2022."

Review the Practice Greenhealth anesthetic gas toolkit for supporting resources, including hospital highlights, webinars, slide decks, exemplary documents, and additional resources to inspire, educate, and inform various stakeholders within the organization.

Step 6: Identify and implement target strategies

Review the anesthetic gas checklist for strategies and opportunities that align with organizational strengths and work already underway, such as GHG reduction, carbon neutral, or Greening the OR goals.

Strategies for success

Education and communication

If the organization is just getting started, work on educating and engaging clinician stakeholders first. In a survey of more than 780 anesthesia providers from the United Kingdom, Australia, and New Zealand, 95 percent supported increasing recycling and sustainability efforts. A similar U.S. survey with more than 2,000 responses indicated 91 percent of anesthesia providers were interested in recycling and sustainability programs. The common takeaway: despite interest, clinicians believed they lacked adequate education around these practices.

According to the 2018 Greening the OR benchmark report, 48 percent of hospitals have taken the initial step of educating providers on the environmental impacts of anesthesia, a 42 percent increase from three years ago.

Use the making the case worksheet from the engaged leadership and anesthetic gas toolkits for ideas on framing the issue and gaining buy-in.

Focus on high-impact opportunities

When working to reduce greenhouse gas emissions from anesthesia, if the facility is still using desflurane, this may be an ideal place to focus first. Desflurane has the highest GWP of commonly used anesthetic gases and is often the most expensive. Removing desflurane vaporizers from the OR and making it available only by clinician request is a strategy 22 percent of Practice Greenhealth hospitals reported using to reduce desflurane use. Another 27 percent eliminated desflurane from the formulary altogether.

Johns Hopkins Hospital provided education and reduced inhalational anesthetics purchasing costs from $12,500 to $8,500 per OR annually, a savings of more than $226,000 per year.

Lower fresh gas flow rates

Per ASA and FDA recommendations, lowering fresh gas flow rates can reduce anesthetic gas usage. Anesthesia providers can reduce their impact by using less anesthetic gas to begin with, while closely monitoring the patient. Many new anesthesia machines help monitor fresh gas flow rates and support anesthesia providers using this strategy.

The University of Wisconsin's University Hospital and American Family Children's Hospital saved around $20,000 per month – or nearly $240,000 annually – by educating anesthesia providers about the environmental impact of anesthetic gases and providing reminders on FDA-recommended fresh gas flow rates.

Consider newer CO_2 absorber technologies

During general anesthesia, the patient exhales carbon dioxide, which travels through a breathing circuit and is absorbed by one of several technologies to reduce the risk of toxic byproducts. An article in the ASA Monitor reviews newer CO_2 absorbers that allow for lower fresh gas flow rates while also reducing risk to the patient.

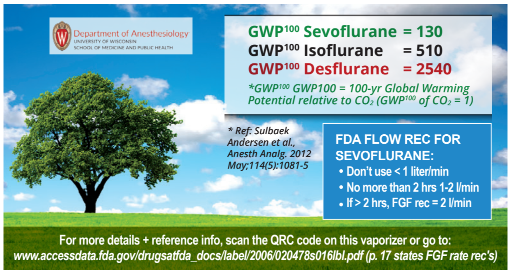
Evaluate the environmental attributes of new anesthesia machines

Work with anesthesia providers, supply chain, clinical engineering, and the value analysis team to purchase new anesthesia machines and equipment. Some new models are more energy efficient, monitor anesthetic gas consumption and provide fresh gas flow rate alerts, scavenge and sequester waste anesthetic gases rather than venting outside.

Reduce nitrous oxide use

Nitrous oxide is typically used as a carrier gas and has the second-highest GHG impact after desflurane because it persists in the environment for 114 years, much longer than other anesthetic gases. Although primarily used in the OR, nitrous oxide can be found throughout the hospital, typically in dental, labor and delivery units, and emergency departments. These units are not equipped with scavenging systems, so staff and visitors can be exposed to leaks and waste anesthetic gases, posing a potential health risk.

Encourage clinical staff to look for opportunities to reduce nitrous oxide use and consider alternatives when safe and reasonable for patient care.



The University of Wisconsin - University Hospital and American Family Children's Hospital created posters and visuals to educate providers

Harborview Medical Center's surgical services staff is committed to greening the OR, consistently looking for ways to expand and support environmental stewardship. When it was time to upgrade equipment, staff looked for features that would reduce their impact.

Between 2014 and 2017, Harborview Medical Center purchased 37 new anesthesia machines. The old machines required a minimum gas flow even when not in use. The team selected machines that require no gas until the start of use and notify staff of high gas flow rates. The new machines and a different carbon dioxide absorbent allow providers to consistently maintain low anesthetic gas flow rates.

As a result, between 2014 and 2017, Harborview Medical Center

- decreased purchase of volatile anesthetic agents by 30.4 percent
- decreased purchase of nitrous oxide by 45.5 percent
- reduced $MTCO_2e$ from anesthetic gases by 47.4 percent, from 1,835.04 metric tons in 2014 to 999.62 metric tons in 2017, while simultaneously performing 1,363 more OR procedures in 2017 compared to 2014
- reduced spending on anesthetic gases by almost $50,000, or 27.3 percent

Check anesthesia machine and medical gas vacuum for leaks

Hospitals are always working to optimize building and energy performance, and a routine part of anesthesia setup is checking the machine for leaks. Completing this step is essential to reducing staff exposure to waste anesthetic gas in the operating room and decreasing the amount of gas wasted overall.

Install medical gas vacuum or scavenging valves to reduce energy consumption

The medical gas vacuum scavenges vented waste anesthetic gases out of the immediate surgical environment to reduce exposure. The Joint Commission requires scavenging, and the National Institute for Occupational Safety and Health and a number of clinical associations recommend scavenging for worker safety. Many facilities have an active scavenging system constantly running even when a patient is not in the room.

Work with clinical engineering and facilities departments to determine if medical gas vacuum valves would be appropriate. These valves attach to the anesthesia machine and reduce energy consumption by ensuring the vacuum is only scavenging when the pressure switch is on. This can help the facility reduce energy consumption and increase the lifespan of the equipment, as well as require less maintenance.

Install supplemental anesthetic gas sequestration systems

Facilities can retrofit existing anesthesia machines with supplemental anesthetic gas scavenging and capture systems. These systems capture and contain WAGs rather than venting outside.

The American Society of Anesthesiologists provides additional guidance on opportunities for anesthesia providers to use their position as clinical leaders to reduce the environmental impact in the OR. These strategies are supported by peer-reviewed literature and based on recommendations from the American Society of Anesthesiologists but are not intended as clinical guidance; medical professionals need to determine appropriate care for their patients.

Cleveland Clinic installed more than 120 medical gas vacuum valves across its main campus. The combined energy savings, reduced maintenance, and prolonged lifespans of its systems yielded a savings of more than $110,000. Along with energy rebates, the organization saw a return on its investment in two years or less and reduced GHG emissions.

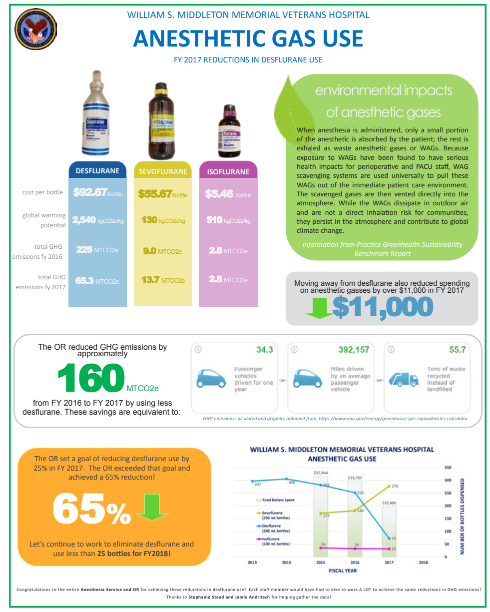
Step 7: Track cost savings

In addition to creating a baseline for greenhouse gas emissions from inhaled anesthetic gases, monitoring financial impact can support the business case with senior leadership. Use the anesthetic gas data collection tool to track purchased volume and aggregate annual costs per anesthetic agent. Highlighting the difference between use, cost center, and $MTCO_2e$ per agent can help identify savings opportunities.

Consider tracking other benefits that go hand-in-hand with this work, such as measuring employee engagement scores, health and wellness data, green team participation, and more.

Step 8: Develop a communications plan

It is important to maintain consistent messaging about environmentally responsible anesthesia initiatives and offer support to providers leading this work. Use teaching opportunities like grand rounds to share the program's goals and progress. Consider using attention-grabbing methods, such as UW Health's stickers or William S. Middleton Memorial VA Hospital's poster. Use the EPA's greenhouse gas equivalencies calculator to translate the organization's $MTCO_2e$ into concrete and relatable visuals. Consider the audience when developing talking points; for instance, financial savings might be relevant to the CFO, but highlights from peer-reviewed literature might resonate more with anesthesia providers. Consider regular updates in the organization's newsletter, green team meetings, and Earth Day or World Environment Day activities as public relations opportunities.



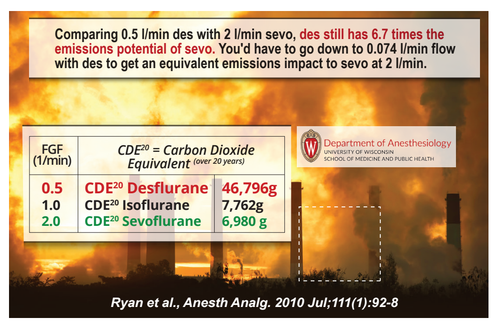
William S. Middleton Memorial Veteran's Hospital developed a poster to highlight the progress of their anesthetic gas reduction efforts.

Step 9: Track progress and celebrate success

It is critical to track anesthetic gas metrics before, during, and after implementation of reduction strategies. Tracking progress toward waste anesthetic gas reduction goals helps make the case to senior leadership for the program's continuation and validates the efforts of the clinicians leading this work. Effective strategies include regular reporting to executive leadership, clinical staff, supply chain, and operational managers on anesthetic gas purchasing data, including any changes in spend or greenhouse gas emissions.

Use the anesthetic gas data collection and tracking tool to capture annual purchasing data and monitor progress. Be consistent with the reporting period, and consider including notes on where/how data was pulled for future reference. Some facilities may wish to report data on a monthly or quarterly basis, track demographic data, or review by provider or case type for closer analysis.

Celebrate the individual and collective efforts that extend health care beyond the four walls of the hospital with recognition, awards, and appreciation at meetings, events, and celebrations.



Step 10: Make the program sustainable

Work with anesthesia providers, supply chain, pharmacy, and others to develop education and embed environmental considerations into anesthetic choices. Continue to track anesthetic gas purchases and consider committing to a maintenance goal to ensure the program remains sustainable in the long term.

LEARN MORE

The University of Wisconsin- University Hospital and American Family Children's Hospital developed visual reminders, like this poster and QR code, to engage and educate providers.

References

Below is a sampling of the literature and resources that support environmental stewardship in anesthesia care.

- American Society of Anesthesiologists' Greening the operating room and perioperative arena: environmental sustainability for anesthesia practice
- A simple intervention to reduce the anesthetic pharmacy budget: the effect of price list stickers placed on vaporizers
- Managing fresh gas flow to reduce environmental contamination
- The impact of surgery on global climate: a carbon footprinting study of operating theatres in three health systems
- Financial and environmental costs of reusable and single-use anaesthetic equipment
- $1.8 million and counting: how volatile agent education has decreased our spending $1,000 per day
- Global warming potential of inhaled anesthetics: application to clinical use
- Sustainable anesthesia
- Life cycle greenhouse gas emissions of anesthetic drugs
- Assessing the impact on global climate from general anesthetic gases
- Inhalation anaesthetics and climate change
- Cataract surgery and environmental sustainability: waste and lifecycle assessment of phacoemulsification at a private healthcare facility
- Strategies to reduce greenhouse gas emissions from laparoscopic surgery
- WAG treatment and CO2 absorbers: new technologies for pollution and waste prevention
- The value of environmental sustainability in anesthesia
- Pre-filled syringes: reducing waste and improving patient safety
- Disposal and treatment of controlled substances from the OR
- Hospitals are scrambling to solve their air pollution issue
- Leadership in OR environmental sustainability: methods and metrics for engagement
- Environmental impact of inhaled anesthetics: a literature review
- American Society of Regional Anesthesia and Pain Medicine's Green anesthesia SIG
- European Climate Initiative's Fostering low-carbon health care in Europe – EUKI anesthetic gases project
- United Kingdom's National Health Services Sustainable Development Unit's Anesthetic gases carbon calculator

View additional resources, research, literature, and associations in the anesthetic gas toolkit.

Anesthetic gas reduction how-to guide: Data addendum

Anesthetic gases are greenhouse gases (GHG) representing 5 percent of a facility's GHG footprint or 51 percent of an OR's emissions. As more health care organizations are setting GHG reduction and carbon neutral goals, focusing on anesthesia is one strategy that can support reduction of scope 1 emissions and engage clinicians.

Use the addendum to support the anesthetic gas goal, review structure, terms, and rationale, and work through a step-by-step example calculating GHG emissions from anesthetic gas purchasing data.

Goal structure: Absolute vs. normalized

An absolute reduction aligns with the overarching global imperative to reduce greenhouse gas emissions, regardless of patient census; however, it poses some limitations on comparing facilities and setting a benchmark. For example, a 20 percent reduction from baseline is an absolute reduction goal, while achieving X metric tons of carbon dioxide equivalent ($MTCO_2e$) per anesthesia hour would be a normalized goal.

The Practice Greenhealth anesthetic gas goal focuses on an absolute reduction. As more data becomes available, future work will focus on establishing a normalized target range for facilities to work toward and maintain.

A normalized range will help compare health care organizations, while an absolute reduction aligns with GHG reduction and carbon neutral goals of reducing emissions regardless of patient census.

Goal		Measure	Calculation details
Baseline	Conduct baseline assessment of total anesthetic gases purchased per year / 12 consecutive months	Total metric tons of carbon dioxide equivalent ($MTCO_2e$) for isoflurane, sevoflurane, desflurane, nitrous oxide per year Total dollars spent on anesthetic agents per year	Calculate $MTCO_2e$ for each anesthetic agent to get total footprint Add dollars spent for each anesthetic agent to get total spent on anesthetic gases
If desflurane has NOT been eliminated from hospital formulary			
Level 1	Reduce GHG emissions specific to anesthetic gases by 20 percent from baseline	Percent change in total $MTCO_2e$ of purchased anesthetic gases	Subtract baseline year footprint from current year footprint Divide by current year footprint Multiply by 100 This is the percent reduction from baseline *Consider also tracking dollars spent per anesthetic agent and percent change from baseline
Level 2	Reduce GHG emissions specific to anesthetic gases by 50 percent from baseline	Percent change in total $MTCO_2e$ of purchased anesthetic gases	Subtract baseline year footprint from current year footprint Divide by current year footprint Multiply by 100 This is the percent reduction from baseline *Consider also tracking dollars spent per anesthetic agent and percent change from baseline
If desflurane has been eliminated from hospital formulary			
Level 1	Reduce GHG emissions specific to anesthetic gases by 5 percent from baseline	Percent change in total $MTCO_2e$ of purchased anesthetic gases	Subtract baseline year footprint from current year footprint Divide by current year footprint Multiply by 100 This is the percent reduction from baseline *Consider also tracking dollars spent per anesthetic agent and percent change from baseline
Level 2	Maintain 5 percent reduction from baseline	Percent change in total $MTCO_2e$ of purchased anesthetic gases	Subtract baseline year footprint from current year footprint Divide by current year footprint Multiply by 100 This is the percent reduction from baseline *Consider also tracking dollars spent per anesthetic agent and percent change from baseline

Demographic information

Gathering basic demographic information will help with comparison and benchmarking. The scope of operations, providers, and other factors may vary year to year within a facility, as well as across facilities. By normalizing data, performance can be more accurately gauged.

At this time, based on recommendations from an expert reviewer panel, Practice Greenhealth suggests tracking:

- **Total number of general anesthesia hours** (this is the preferred normalizer)
- **Total number of general anesthesia cases performed** (including adults, pediatrics, OB/GYN, interventional radiology, ambulatory, off-floor, other)
- **Number of operating rooms** (including inpatient and outpatient/ambulatory operating rooms)

Other possible normalizers include staffed beds, number of surgeries/OR cases, number of babies delivered (correlates with higher nitrous oxide consumption), and total ER visits (also correlates with nitrous oxide consumption).

Units of measure

Typically, isoflurane and sevoflurane are purchased in 100 or 250 mL units, while desflurane is generally purchased in 240 mL units.

Purchasing reports from medical gas vendors often indicate the total pounds of nitrous oxide delivered. Nitrous oxide can be used throughout the facility; in addition to the OR, it's often used in labor and delivery, ER, interventional radiology, dentistry, and other departments. When gathering data, work with the facility's medical gas vendor to ensure all departments are included.

Global warming potential

Anesthetic gases commonly used in the United States are considered scope I greenhouse gases, which persist in the environment for years. To calculate the footprint of each gas, or GHG emissions measured in metric tons of carbon dioxide equivalents ($MTCO_2e$), Practice Greenhealth uses the 100-year global warming potential (GWP) values based on a study assessing the impact on global climate from general anesthetic gases, in alignment with the American Society of Anesthesiologists (ASA). At the time of publication, for nitrous oxide Practice Greenhealth used the value in the Intergovernmental Panel on Climate Change's 4th Assessment Report, which is in alignment with EPA reporting guidelines and the ASA.

Calculating the footprint of anesthetic gases

A few available tools calculate the $MTCO_2e$ of anesthetic gases automatically using purchasing data.

- The anesthetic gas data collection tool automatically calculates the footprint using purchasing data.
- The Practice Greenhealth awards application has a calculator built into the Greening the OR section.
- The formula is built into the Practice Greenhealth GHG inventory tool.

Other available resources:

- Yale School of Public Health facility inhaled anesthetic survey
- National Health Service England and Public Health Sustainable Development Unit anaesthetic gases carbon calculator

Calculating the footprint of anesthetic gases by hand

To calculate GHG emissions from anesthetic gas purchasing data by hand, follow the steps below. Use the reference table below for GWP of the anesthetic gases and density values.

Calculate footprint: Use the formula to calculate the $MTCO_2e$ for anesthetic agents used.

For sevoflurane, isoflurane, and desflurane, the equation is:

Number of bottles x bottle volume x density x GWP*0.001 = total $MTCO_2e$ of particular anesthetic

*Note: 0.001 allows the conversion from grams to metric tons

For nitrous oxide, the equation is:

Pounds of gas to kg x density x GWP*0.001=$MTCO_2e$ of nitrous oxide

Global warming potential of inhaled anesthetic agents

Inhaled anesthetic agent	100-year global warming potential (per kg, in comparison with CO_2 where CO_2 = 1)	Atmospheric lifetime (years)	Gas density
Desflurane	2,540	14	1.46
Isoflurane	510	3.2	1.5
Sevoflurane	130	1.1	1.52
Nitrous oxide	298	114	2.2046

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Example: Establishing a baseline

The table below uses sample purchasing data for sevoflurane, isoflurane, desflurane, and nitrous oxide to calculate the MTCO_2e of each.

Anesthetic agent	Number of bottles purchased Baseline year	Size*	Footprint (MTCO_2e) Baseline year
Sevoflurane	7068	250 mL	1. Multiply the number of bottles purchased by the size to get the number of milliliters (mL) 7068 * 250 mL = 1,767,000 mL 2. Divide by 1000 to convert to liters (L) 1,767,000 mL /1000 = 1,767 L 3. Multiply the liters purchased by the density of the gas 1,767 x 1.522 = 2,689.374 4. Multiply by the 100 year GWP of the gas 2,689.374 x 130 = 349,159.2 5. Multiply by 0.001 to get MTCO_2e 349,159.2 x 0.001 = 349.61862 The facility generated 349.62 MTCO_2e from sevoflurane in 2017.
Isoflurane	71 2631	100 mL 250 mL	1. Multiply the number of bottles purchased by the size to get the number of milliliters (mL) Since the facility purchased two bottle sizes of Isoflurane, multiply the number of bottles purchased by the size, and then add the two sums together to get the total mL of isoflurane purchased. 71 x 100 mL= 7,100 2631 x 250 mL = 657,750 7,100 + 657,750 = 664,850 mL 2. Divide by 1000 to convert to liters (L) 664,850 mL /1000 = 664.85 L 3. Multiply the liters purchased by the density of the gas 664.85 x 1.5 = 997.275 4. Multiply by the 100 year GWP of the gas 997.275 x 510 = 508,610.25 5. Multiply by 0.001 to get MTCO_2e 508,610.25 x 0.001 = 508.61025 The facility generated 508.61 MTCO_2e from isoflurane in 2017
Desflurane	1513	240 mL	1. Multiply the number of bottles purchased by the size to get the number of milliliters (mL) 1513 x 240 mL = 363,120 mL 2. Divide by 1000 to convert to liters (L) 363.120 mL /1000 = 363.12 L 3. Multiply the liters purchased by the density of the gas 363.12 x 1.46 = 530.1552 4. Multiply by the 100 year GWP of the gas 540.1552 x 2540 =1,346,594.208 5. Multiply by 0.001 to get MTCO_2e 1,346,594.208 x 0.001 = 1346.59421 The facility generated 1,346.59 MTCO_2e from desflurane in 2017

Anesthetic agent	Number of bottles purchased Baseline year	Size*	Footprint ($MTCO_2e$) Baseline year
Nitrous oxide	27,712	lbs	1. Multiply the total number of pounds (lbs) purchased by the density of one kg of nitrous oxide 27,712 lbs x (1kg/2.2046) (or 27,712 x 0.4536) = 12,570.1632 2. Multiply by the 100 year GWP of the gas* 12,570.1632 x 298 = 3,748,590.6336 3. Multiply by 0.001 to get $MTCO_2e$ 3,748,590.6336 x 0.001 = 3748.5906336 The facility generated 3,748.59 $MTCO_2e$ from nitrous oxide in 2017
			Add the totals for each gas to derive the total $MTCO_2e$ from inhaled anesthetic gases. Sevoflurane: 349.62 Isoflurane: 508.61 Desflurane: 1,346.59 + Nitrous oxide: 3,748.59 Total = 5,953.41 $MTCO_2e$

Example: Calculating percent change and tracking progress

Once a baseline for anesthetic gas emissions has been established, it's important to track the program. Some facilities choose to track purchasing or usage data weekly or monthly, while others assess progress quarterly or on an annual basis. Determine what works best for the team at your organization. Regular progress reports and communication can keep engagement high.

To calculate percent change from baseline, the equation is:
[(current year $MTCO_2e$ minus baseline year $MTCO_2e$) / baseline year $MTCO_2e$] x 100

The anesthetic gas data collection tool can help track your facility's progress with built-in formulas to calculate percent change from baseline each year, as well as graphs that illustrate changes in anesthetic agent use and dollars spent.

Example: Calculating percent change from baseline

Follow the example in the table below calculating percent change from baseline for sevoflurane, isoflurane, desflurane, nitrous oxide, and overall. A negative number indicates a reduction from baseline, whereas a positive number indicates an increase from baseline.

Anesthetic agent	Baseline year footprint ($MTCO_2e$)	Current year footprint ($MTCO_2e$)	Calculated percent change from baseline
Sevoflurane	349.62	204.54	1. Take the current year, subtract the baseline year 204.53778 – 349.62 = -145.62 2. Divide by the baseline year. (-145.62) / 349.62 = -0.41 A negative number means a decrease from baseline. 3. Multiply by 100 to get % (-0.41)*100 = -41% The facility reduced its $MTCO_2e$ from sevoflurane by 41%.
Isoflurane	508.61	851.77	1. Take the current year, subtract the baseline year 851.77 – 508.61 = 343.16 2. Divide by the baseline year. (343.16) / 508.61 = 0.67 A positive number means an increase from baseline. The facility increased its $MTCO_2e$ from isoflurane by 67%.
Desflurane	1,346.59	705.52	1. Take the current year, subtract the baseline year 705.51 – 1346.59 = -641.08 2. Divide by the baseline year. (-641.08) / 1346.59 = -0.48 A negative number means a decrease from baseline. The facility decreased its $MTCO_2e$ from desflurane by 48%.
Nitrous oxide	3,748.59	2847.69	1. Take the current year, subtract the baseline year 2847.69 – 3748.59 = -900.9 2. Divide by the baseline year. (-900.9)/ 3748.59 = -0.24 A negative number means a decrease from baseline. The facility decreased its $MTCO_2e$ from nitrous oxide by 24%.
Total $MTCO_2e$	5,953.41	4609.51	1. Take the current year, subtract the baseline year 4609.51 – 5953.41 = -1344.41 2. Divide by the baseline year. (-1344.41)/ 5953.411 = -0.22582 A negative number means a decrease from baseline. The facility decreased its total $MTCO_2e$ from anesthetic gases by 23%.