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

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.

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%.