White Paper on Anesthesia and Greenhouse Gases

Association for Climate Health

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Defining the problem

When you think of climate change and its causes, you may imagine polluting factories, automobiles or even people making easy, lazy decisions about how to live their lives. You don't usually think of highly skilled doctors in operating rooms working to make their patients better.

And yet a significant source of greenhouse gas is the anesthesia used in surgical settings. Less of these gases are released, but they are significantly more harmful than the better-known pollutants that drive global warming. Waste anesthesia gas traps as much as 2500 times more heat per molecule than carbon dioxide (CO_2), and lasts much longer in the atmosphere. Yet it has been left out of international climate accords and government regulation, even though there are easy substitutes with similar medical effect that do less harm to the atmosphere.

Anesthesia is often given to patients in gaseous form. Most of that inhaled gas is exhaled back into the air, unchanged, then vented outside where it lives long and destructively for years, trapping heat in the atmosphere. Though the amounts can be small, the fluorinated ethers especially can be 2,000 times more destructive than CO_2. And nitrous oxide (N_2O), while a somewhat less destructive molecule, is used in high quantities as a carrier gas for delivering the more potent ethers. Its cumulative emissions represent another poorly monitored but powerful source of harm to climates around the world.

Multiply these impacts by the number of operations taking place every day (over 50 million per year in the US alone)[i], and the harm becomes significant. Worthy of notice, worthy of considering efforts to mitigate it.

> *"Pollution is the largest environmental cause of disease and death in the world today … That makes pollution prevention part of the doctor's duty to "first, do no harm.""* [ii]

Add in other sites which use anesthesia – ambulances, birthing rooms, dentists' offices, veterinarians, scientists working on human or animal subjects in labs – and the cumulative impact grows even larger. One researcher estimates it as 3% of the total greenhouse gas emissions from the US; researchers in the UK estimated it at 2.5% of their country's carbon footprint[iii]. Emissions from anesthesia are a small percentage of the greenhouse gases, but they last decades, even centuries longer than molecules of carbon dioxide. Their volume is small but their impact much worse.

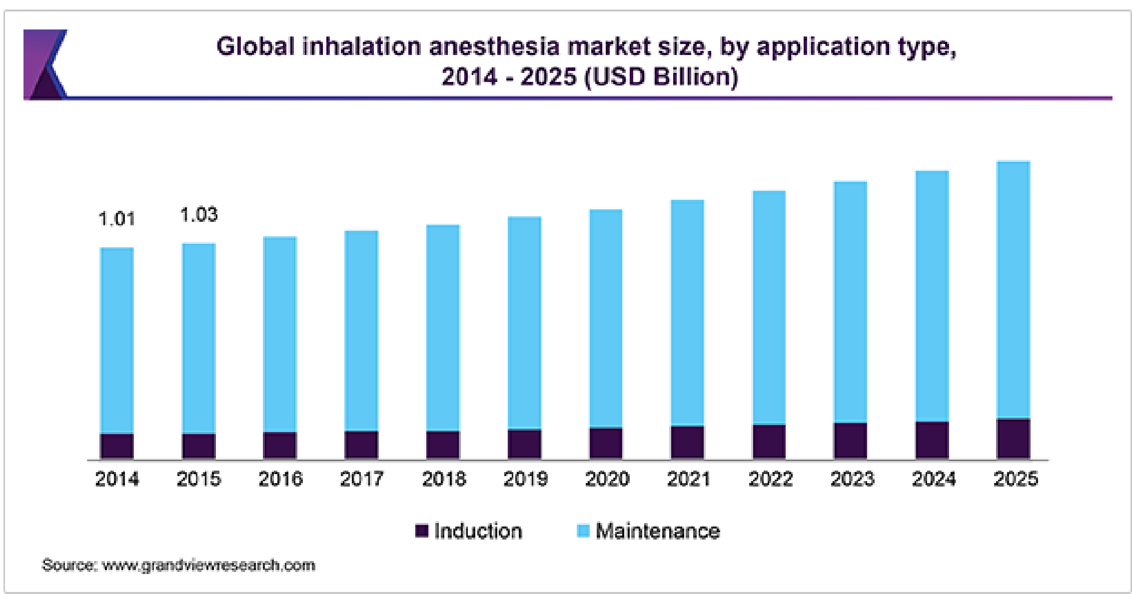
Additionally, these gases deplete the ozone layer, a hazard which receives less attention these days given the even more catastrophic risks of greenhouse gases, but a thinning ozone layer still threatens humans and other living creatures.

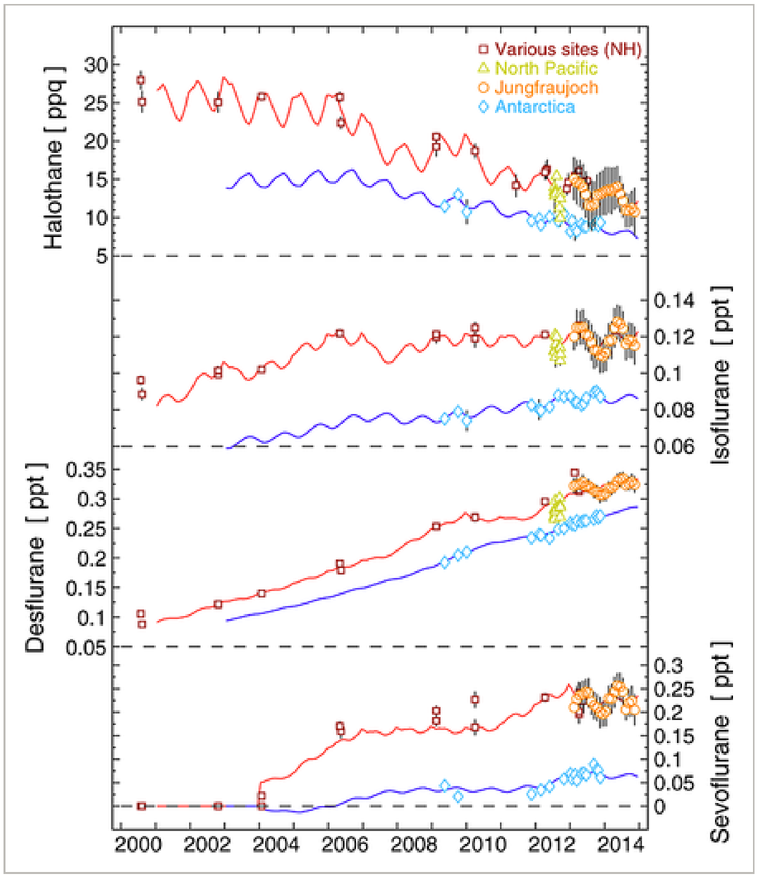
Some background on frequently used anesthesia medications

Sevoflurane and desflurane (both fluorinated ethers) are the most commonly used anesthesia gases, along with nitrous oxide (N_2O), sometimes known as laughing gas.

Patients are given gas through a mask; they breathe it in and it puts them to sleep, fast and effectively. Yet only 5% or less of the gas is broken down in the body. The rest is exhaled, unchanged. For patients, the risk of this limited exposure is small, and the benefits of pain management are huge. For doctors and nurses who are repeatedly exposed in the operating room, the risks can be significant. In many operating rooms pregnant doctors and nurses are excluded, or the patient is given anesthesia through injection instead. These gases, after all, endanger the fetus, as well as potentially mutating the DNA of anyone exposed.

Operating room personnel are somewhat protected because typically, most of the gas is sucked into a ventilating system and vented outside as medical waste gas. The result: waste anesthetic gases (WAGs) rise into the air where they become long-lasting greenhouse gases (GHGs). This represents a new threat for climate change, which is expected to continue to keep growing as the market for surgery and therefore anesthesia keeps increasing.





Previous: Financial analysts estimate a growing market for anesthesia, especially as the bulge of baby boomers enters the years of more frequent medical interventions. Induction gas brings the patient to a sedated state; maintenance gas keeps them there through the procedure. Source: Green View Research.

Left: Atmospheric records of halogenated anesthetics indicate growing use and accumulation in the atmosphere. Halothane use has been declining, and so is its concentration in the atmosphere. The three fluranes, which are more destructive to the atmosphere, have been increasingly adopted in anesthesia. Desflurane's steeper slope is due not only to increased use but to its longer life in the atmosphere. Data collected and reported in Volmer, et. al., "Modern inhalation anesthetics: Potent greenhouse gases in the global atmosphere," AGU Pubs, February 15, 2015

Sevoflurane and desflurane are similar in effect, and often chosen interchangeably for operations. Desflurane has a slightly faster onset and offset. Sevoflurane is less irritating to the patient's mucous membranes. Sevoflurane may need more careful monitoring but is also significantly cheaper. And it creates less of a hazard to the outside atmosphere.

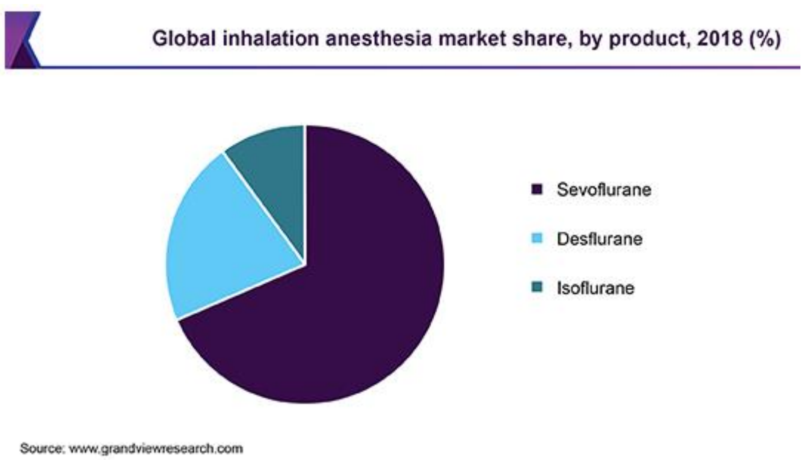
	Year introduced	Lifetime in the atmosphere	Global Warming Potential of a Molecule (over 100 yrs) compared to CO_2	Est emissions (t yr^{-1}), 2014
Halothane	1956	1	50	250
Isoflurane	1981	3.2	510	880
Desflurane	1992	14	2540	960
Sevoflurane	1993-5	1.1	130	1200
Nitrous oxide	1840s	114	298	5,300,000

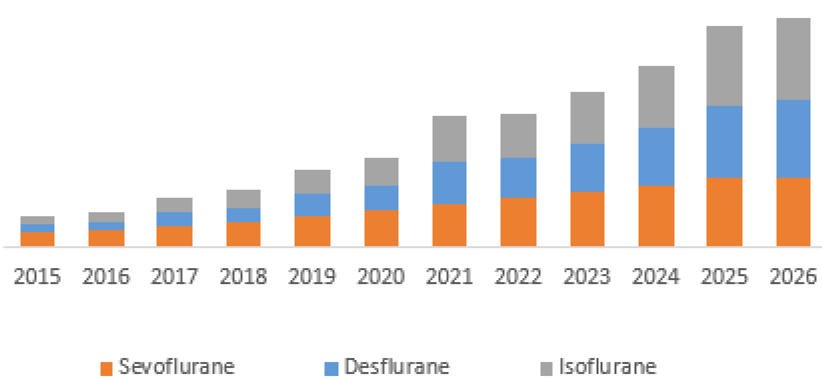
Data on widely used WAGs from Vollmer, et al, "Modern inhalation anesthetics: Potent greenhouse gases in the global atmosphere," *AGU Pubs.* Data on N_20 from Chestney, Nina, *Scientific American,* 2013 and includes emissions from agricultural fertilizers and natural decay of plant material in forests, etc.

Estimates of harm vary somewhat, depending on how you measure it. Desflurane lasts 14 years and is 20 times more powerful in trapping heat than sevoflurane, which is less durable and breaks down in a year. Given differences in flow rates needed for a particular operation, one NIH publication estimated desflurane has 26 times the global warming potential of sevoflurane and 13 times the impact of isoflurane. To put the hazard of these gases in perspective, they suggest the average US hospital has "an environmental impact comparable to that of 100 to 1,200 cars per year. Using desflurane for one hour is equivalent to 235 to 470 miles of driving."[iv]

Desflurane is manufactured by Baxter Healthcare and is also licensed as a generic by Sandoz, a division of Novartis. US Brand name: Suprane. Baxter also makes sevoflurane and isoflurane, as do AbbVie and Piramal Healthcare.

Isoflurane (another fluorinated ether gas), nitrous oxide, and propofol are also used as anesthetics. Isoflurane is less commonly used as it has been replaced by the newer desflurane and sevoflurane. It is still in common use in veterinary practice, and with weaker and geriatric patients as it is easier on the cardiovascular system.



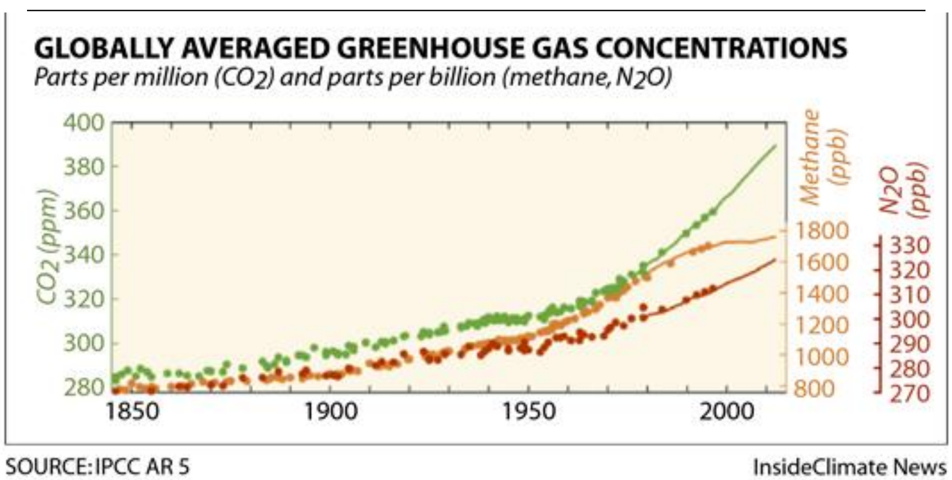


Global Inhalation Anesthesia Markets by Product, 2015-2026 (in million USD) – 3% compounded annual growth to $2.1 billion as estimated by market researcher firm Ameriresearch.

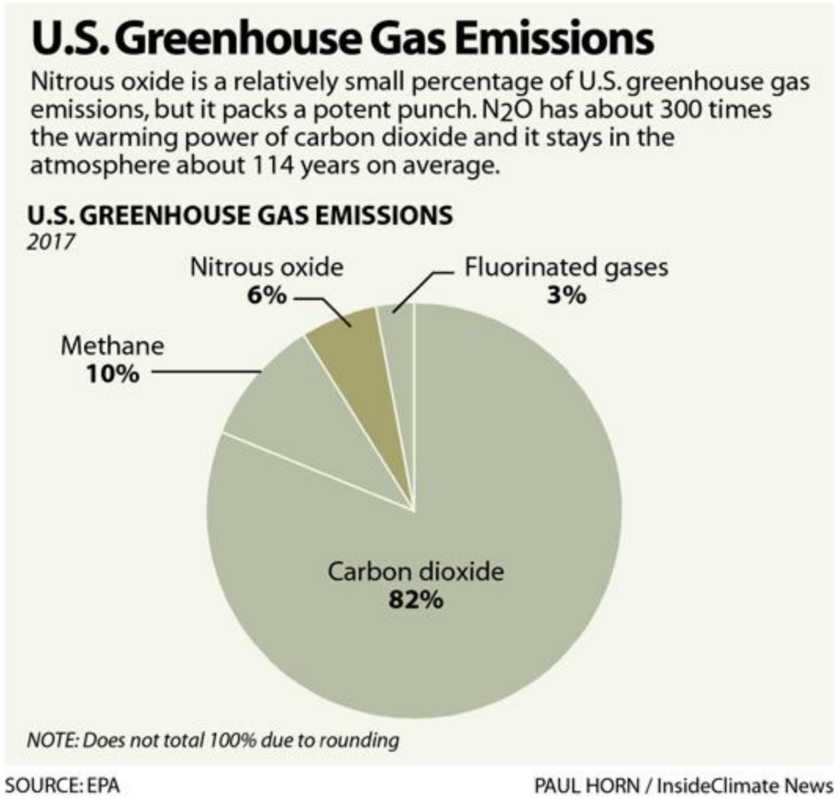
Propofol is a short-acting anesthesia used to induce sedation or for shorter procedures. It is given in liquid form, injected through IV. Its climate impact is much smaller than the gases described here.

Nitrous oxide (N_2O) has been used as an anesthetic since the 1840s. It has advantages – a faster onset and offset compared with the fluorinated ethers, no annoying odor, with a calming effect on the patient and the ability to help maintain a stable blood flow and pressure. It is more often used in minor procedures where the higher potency of the volatile ethers is not needed for pain management. But it is also used as a carrier gas, mixed with one of the more potent gases for transporting into the body, or in combination for its stabilizing properties. N_2O is used extensively outside the US in a 50/50 mixture with oxygen (Entonox) for pain management during labor and delivery.

The global market for nitrous oxide was valued at $805 million USD in 2016, and this is expected to increase. 85-90% of this market is for medical anesthesia.[v] Some of the manufacturers include Air Products and Praxair.



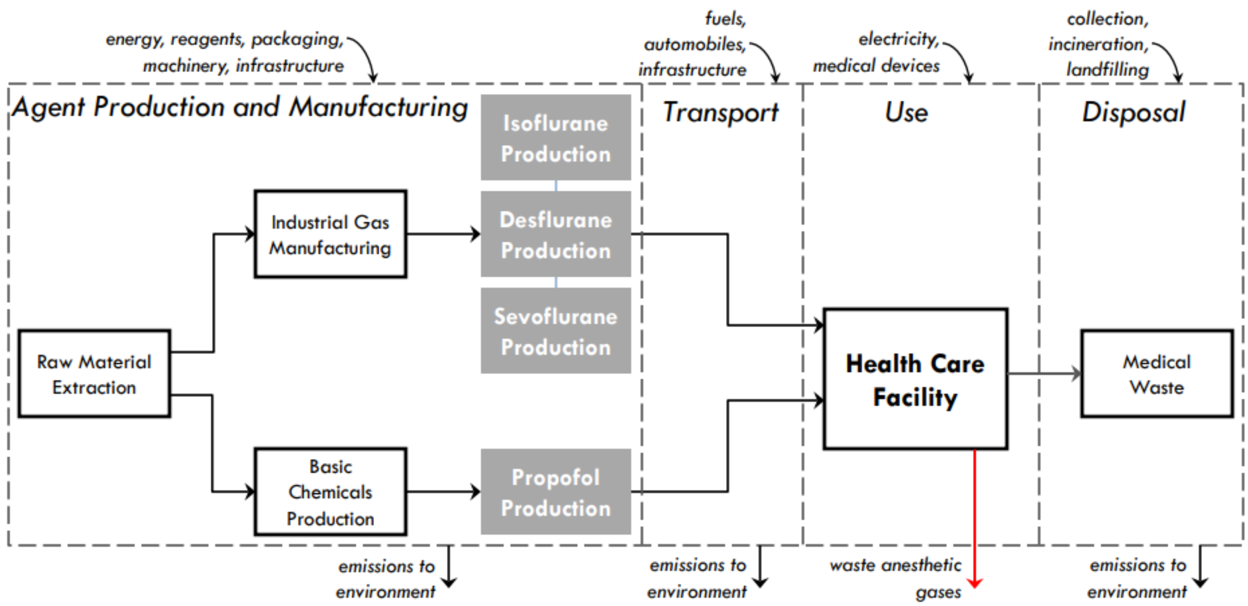
Comparing nitrous oxide with CO_2, one researcher estimates it is 300 times more harmful, partly due to its longer lifespan, and contributes about 7% to human-induced climate change.[vi] Additionally it is a significant threat to the ozone layer.



Sometimes oxygen in combination with room air is used as a carrier for the more potent ether gases, an alternative to an N_2O/room air mixture but without the other benefits of the nitrous oxide. Still, this carrier mixture has the benefit of no greenhouse gas effect.

Gaseous anesthetics given with a nitrous oxide/air mixture will greatly increase the harmful contribution to greenhouse gases. When combined with other anesthetics, N_2O is even more destructive with an impact roughly 900% higher for sevoflurane and 65% for isoflurane.

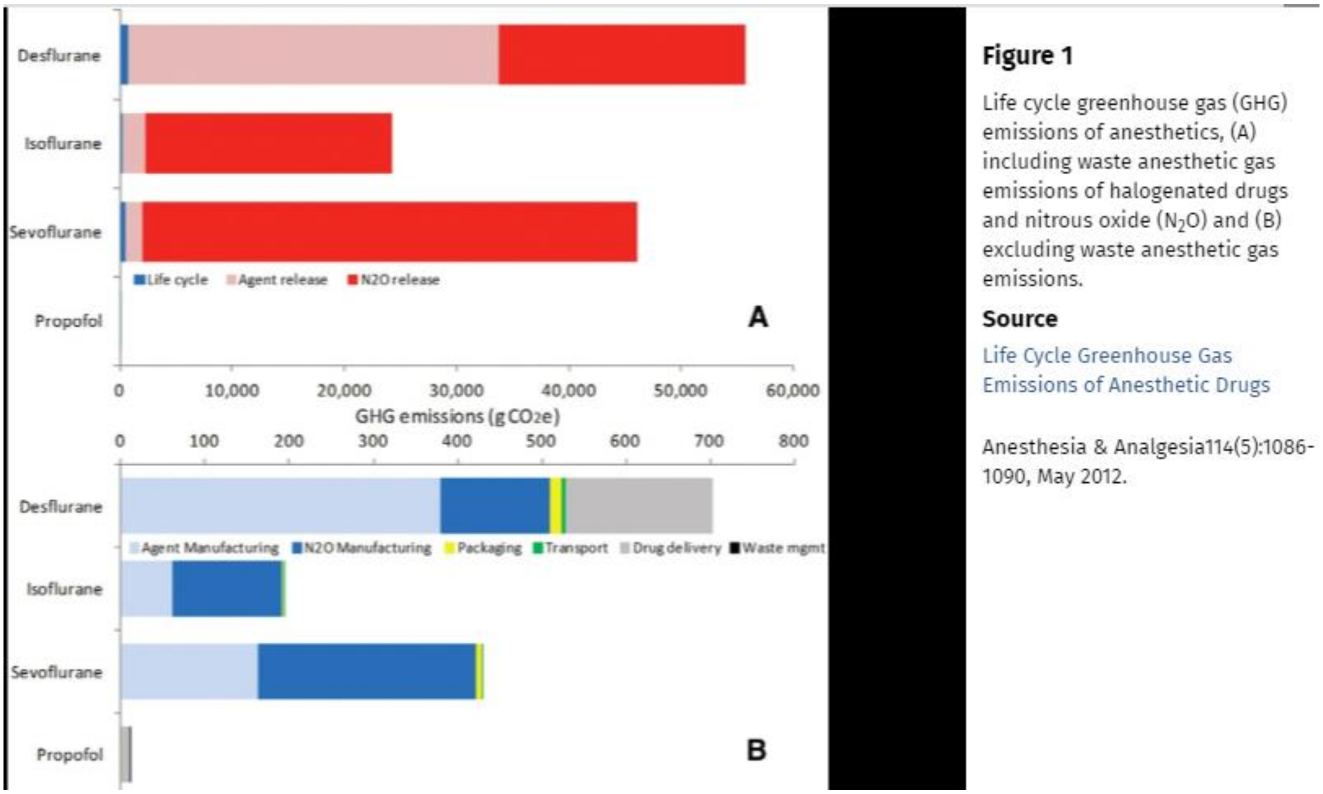
Understanding the effects on the atmosphere of these various anesthetic gases is complicated. On a cradle to grave comparison (which includes the greenhouse gas impacts created during mining, manufacturing, transportation to use sites, use and then disposing of the remains), Desflurane creates an estimated 15 times more harm than isoflurane and 20 times more harm than sevoflurane. Propofol, given by injection instead of as a gas, creates minimal harm in comparison. [vii]



Cradle to grave – the life cycle of anesthetics. From "Life Cycle Greenhouse Gas Emissions of Anesthetic Drugs," *Anesthesia & Analgesia*, May 2012.

Liquid anesthetics such as propofol, regional blocks, etc., generally create few greenhouse gas emissions. Their production and transport will cause some impact, and there may be waste disposal impacts too, but overall this is a tiny fraction of the damage done by, say, desflurane delivered by a nitrous oxide/air mixture.

They may have other environmental impacts, however. Take Propofol which is generally delivered by syringe. Researchers estimate that 30-50% of it is left in the syringe, tubing or container, then thrown away or incinerated. The air polluting results are likely small but unknown. Yet any waste sent to landfills can leak into the ground and enter the water table. Passing into rivers, lakes or oceans, it can have a toxic effect on fish and shellfish.[viii]



A comparison of total estimated life cycle greenhouse gas emissions of anesthetics. In red, estimates assume no capture of waste gas; in blue, estimates assume complete capture. Please note the two charts have different scales. From "Life Cycle Greenhouse Gas Emissions of Anesthetic Drugs," *Anesthesia & Analgesia*, May 2012.

Options for reducing the carbon footprint of pain management during operations

Anesthesiologists can often choose from several less environmentally harmful options:

- Sevoflurane instead of isoflurane
- Sevoflurane or isoflurane instead of desflurane
- The use of O_2/air mixture instead of N_2O/air mixture
- Lower flow rates for anesthesia may work sufficiently well for patients while reducing harmful gases vented to the atmosphere.
- In childbirth, increased use of natural birth techniques or epidurals would reduce N_2O gas emissions.
- Propofol or other liquid anesthetics work for some operations: IV anesthesia, neuraxial, regional or peripheral nerve blocks.
- Xenon, used mostly in Europe as an anesthetic. Xenon is extracted from air, and so when it returns to the atmosphere it does no damage. Xenon does not cause mutations or damage embryos or fetuses, nor is it considered dangerous for occupational safety.[ix]

Anesthesiologists can check on the greenhouse gas impacts of a particular procedure with a free smartphone app – Gassing Greener, from Yale University Department of Anesthesiology – by entering the amounts and flow rates of the gases they intend to use. Operating sites can calculate their facility's likely emissions given the type and amount of inhaled anesthetics purchased. This one app alone can help inform doctors and administrators about the climate footprint of their choices. https://downloads.zdnet.com/product/2129-78391433/

If we could choose two steps to prioritize, we suggest that surgeons and anesthesiologists

- Limit the use of desflurane in every case where it will not significantly compromise patient care, since that one gas has the highest heat-trapping effect of the anesthesia gases studied, and
- Shift from N_2O/air mixtures to O_2/air mixtures in every case possible as N_2O damages the atmosphere and is the anesthesia gas with the largest volume of emissions.

These two steps alone would greatly reduce the carbon footprint of medicine. And they can be taken with little cost impact, even create savings for cost centers.

Another climate-saving approach would continue to allow clinicians free choice, but install technologies in operating rooms to capture gas emissions even if you don't switch to less harmful anesthetics. At the present time there are no regulatory requirements for WAG reduction, capture or remediation, so the options are limited. Yet the technology may not be difficult to develop; there are gas capture and remediation systems in many chemistry labs, manufacturing facilities, coal and nuclear power plants, and other sites where harmful chemicals need to be managed. If governments decide this is important, more technology options would quickly follow.

In contrast to choosing different gases, which costs little or even saves money, new equipment represents added cost. Yet such improvements would preserve physician choice while cutting back on greenhouse gas emissions. Some options:

- Employ low fresh gas flow techniques with a circle breathing system. This is a closed loop with absorbent material picking up excess carbon dioxide and returning air and unconsumed anesthesia gas back to the patient. Thus less gas is required and less sent into the atmosphere.
- Nair, et al, developed a system alert to warn providers during a procedure if the flow rate exceeds a pre-set limit. They found that this technique could reduce use of sevoflurane by over 30% and save money at the same time.[x]
- Current **scavenging** systems remove WAGs from the operating room but generally only vent them outside without reducing their GHG impact. Thus they reduce workplace risk but continue contributing to global warming.

- Photochemical air purification system using UV light have been proposed to destroy waste anesthetic gases. These could be effective with the ethers and for nitrous oxide.
- **Capturing** systems can reclaim volatile gases for reuse. However current capture technology does not work for nitrous oxide.[xi]
- Catalytic converters added onto the system can help **eliminate** waste nitrous oxide. Labor and delivery rooms in Sweden commonly use WAG destruction systems to split N_2O into N_2 and O_2. They report a 95% collection rate which then feeds into a scavenging system for venting outside.[xii]
- Activated charcoal can be used to capture or absorb gases, but the result is temporary as it then off-gases over several days. However, we can envision a method of capture, containment and shipment to a central facility which then processes the gases for reuse.
- If gases can be recaptured, perhaps they can be reused within the surgical site or returned to manufacturers for refining and resale.
- Anesthesia recycling systems are being developed by at least 2 companies, including Anesthesia Reclamation LLC, and Deltasorb Technologies (Blue Zone Technology). Anesthesia Reclamation LLC offers the Anesthetic Recapture System, a cryogenic condensing system which collects waste anesthetics from the operating rooms.[xiii]
- Existing anesthesia equipment can be **retrofitted** with energy-efficient supplemental waste gas trapping (for volatiles) or waste anesthetic gas destroying (both volatiles and nitrous oxide), scavenging (volatiles only), and sequestering equipment.

Costs for Reducing Waste Anesthesia Gases

Cost frequently affects decisions, sometimes preventing a change or at least slowing it down. In the case of reducing or eliminating waste anesthesia gas, the cost may be minor or even result in savings for the centers making the change.

Take a simple decision to use sevoflurane instead of desflurane. Often both gases are readily available for use – may even be available at the same time on the anesthesia cart brought into the operating room, allowing the anesthesiologist to make an on-the-spot decision. Switching to the lower emissions choice can be made right there. Will that save money? The answer is complicated, but most likely, yes.

On a per-unit comparison, desflurane is noticeably more expensive than sevoflurane. But on a per-operation comparison it is harder to say what that cost savings would be, as procedures can require different amounts of gas depending on a variety of factors include length of the operation, type of operation and patient characteristics. Still, hospitals that have switched from using desflurane claim significant savings:

- The eight hospitals in Oregon’s Providence Health Systems save about $500,000 per year by eliminating desflurane[xiv]
- Virginia Mason Hospital (Seattle) reports saving $30,000 a year since switching from desflurane[xv]
- The University of Wisconsin Hospital saved about $120,000 per year by reducing desflurane use even though they did not eliminate it.[xvi]
- University of Utah Hospital stopped using desflurane when the late Dr. Michael Calahan, chair of the department, noticed it cost about $14 per hour to use it while isoflurane cost only $0.53.[xvii] Doing this one switch also reduced the hospital’s greenhouse gas emissions by 25%.

These cost savings can be used for other purposes, including investments in equipment, training or software which further reduce the remaining clinician exposure and greenhouse gas emissions.

Social and Policy Considerations

Environmental considerations are beginning to creep into hospitals, clinics and operating rooms, just as they are in other professional environments. Increasingly these sites consider reducing their carbon footprint through energy conservation measures, buying renewable power, recycling and other measures. But the subject of waste anesthesia gases is only beginning to be noticed.

Anesthetic gases were not included in the Paris Climate Accords, or the Kyoto or Montreal protocols, and have mostly slipped under the radar. People may have excluded them out of a sense that patient care is of more immediate importance, and since there was little research on their climate impact, they’ve been easier to ignore. Yet increasingly, research is beginning to show these gases are significantly harmful to the atmosphere, and there may be easy substitutes which do less damage. Additionally, switching can save money; desflurane is particularly costly compared to its alternatives. As Khan and Hauck argue, “Modern day anesthesia practice should actually be driven by environmental, patient and economic-related benefits to encourage the use of low-flow anesthesia. In fact, hospitals could save up to $500,000 per year with the use of low-flow anesthesia.”[xviii]

So, if these medical gases are so harmful, with cheap and available substitutes, why are clinicians still using them? As Hayanga and Hubbard report, “a recent survey of ASA members found a striking lack of knowledge of, and engagement with, environmentally conscious anesthetic practice. Though 80 percent of respondents reported an interest in O.R. recycling, less than 30 percent worked in institutions where anesthesia-related waste was recycled. Even for anesthesiologists endeavoring to reduce their environmental impact, which methods would prove most beneficial have not been well-defined, and how to actually implement a change is not always straightforward." Of the 30% working in institutions which do some recycling, how many are recycling of the solid and liquid waste (syringes and tubing with medicine stuck inside them) and how many also recycle waste gas? We do not know, but would guess: very few.

Yet leadership does not have to come from the institutions; it could come from the anesthesiologists and surgeons themselves. Is that happening? Very slowly, though there have been a handful of discussions in such thought-leader publications as *Anesthesia and Analgesia* and the *ASA (*American Society of Anesthesiologists) *Monitor.* Historically medicine has been slow to embrace new ideas. As one former hospital administrator described it, "The common theme I have gleaned when studying change in medical practice is the great resistance to change. It matters not the field. Cholera, yellow fever, poliomyelitis, smallpox and more had the medical establishment block change."[xix]

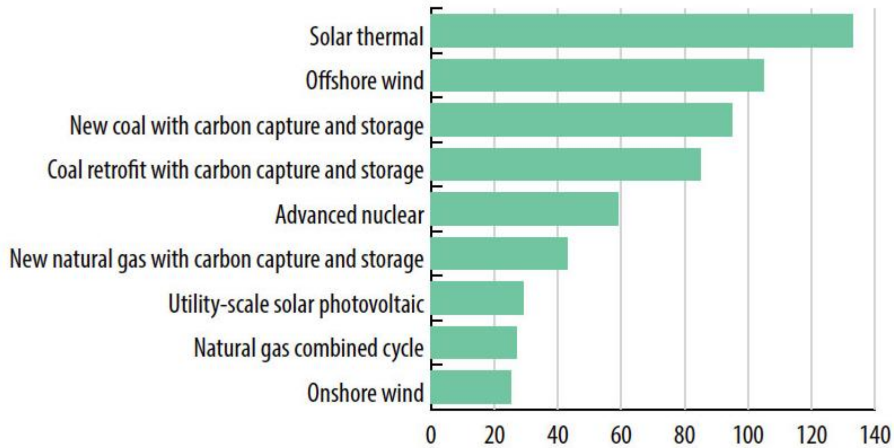
Thus, part of the problem is lack of knowledge, education or focus on the problem. This could be remedied through public outreach campaigns and voluntary adoption of cleaner methods, or by governmental regulation. We suspect most medical providers would prefer the former to the latter. Still, another part of the problem may be inertia, an innate conservatism in medicine, or even the constant pressure of marketing from drug companies who make their money selling the very products which cause the harm. But if education and voluntary compliance do not work, eventually it is likely that regulation will follow.

In terms of overall cost to society, reducing WAG emissions is less costly than reducing or recapturing CO_2 emissions. One study estimates the costs for removing a ton of carbon dioxide equivalents using UV light would be below half a cent for desflurane, about $0.11 for sevoflurane, and less than $50 per ton for nitrous oxide.[xx] This is in contrast to costs in the tens to hundreds of dollars per ton for removal (or avoidance) of carbon from the atmosphere. For comparison, some of the most cost-effective CO_2 reduction strategies are charted below. These significantly cheaper WAG reduction strategies are compelling as they are not only less costly but more effective in mitigating climate change because of the greater harm and durability of WAGs compared to CO_2. Additionally, if potent anesthetics are captured for reuse and/or resale, the savings may largely or wholly offset the costs of mitigation.

Comparing costs

Renewable-energy technologies are among the least costly relative to existing coal generation.

(Dollars per ton of carbon dioxide, in 2017 dollars)



Source: Kenneth Gillingham and James H. Stock, "The Cost of Reducing Greenhouse Gas Emissions," *Journal of Economic Perspectives* 32, no. 4 (Fall 2018): 53–72.
Note: Estimates are derived from the US Energy Information Administration's *Annual Energy Outlook* 2018. Costs are projected for facilities that come online in 2022. Costs do not include federal renewable-energy tax credits or other subsidies.

Clearly, reducing waste anesthesia gas emissions would be a cost-effective strategy for mitigating climate change. Yet such an effort is not currently being pursued by governments in the US or abroad. Legislation, most likely stemming from an increase in public awareness and political activism, would probably have to come first.

Alternatively, we can encourage voluntary change by clinicians and health care institutions who have come to understand:

- The importance of climate change mitigation
- Their responsibility for harm caused by anesthesia gas emissions and the moral obligation to right it
- Their potential role as leaders for a better future
- Or even the cost-saving and/or public relations benefits of reducing waste anesthesia emissions.

Creating the change

Switching or reducing particular anesthetics on a voluntary basis is within the power of thousands of sites right now. It can happen with no capital investment and may even save money. For greater emission reductions, or to preserve physician choice, adding abatement equipment could also be undertaken. Introducing new equipment may even pay for itself if expensive gas flows are reduced, if waste gases can be recaptured and reused, or captured and sent back to the manufacturers for credit towards future gas purchases.

Indeed, some forward-thinking health care systems in the US have already begun to change their practices, with excellent clinical results:[xxi]

- Providence Health & Services in Oregon reduced WAG emissions at eight hospitals by 85% when they eliminated desflurane, and found that patients did not need more time in the OR or the recovery room. This measure also cut costs for inhaled gases by more than half.
- Kaiser Permanente on the West Coast has been progressively eliminating desflurane since 2014.
- Yale-New Haven Health System removed desflurane from its formulary in 2013.
- Cleveland Clinic, Boston Medical Center, Rochester Regional Health and 65 other medical centers in the US are reportedly on track to eliminating desflurane[xxii]

So roughly 70 surgical centers have been identified which are in the process of reducing desflurane. To put this in perspective, there are roughly 9200 surgical centers in the US alone[xxiii] so the change is beginning, but slowly.

Change is often not easy. So how do you get people and institutions to make this kind of switch? Dr. Jodi Sherman, a key researcher on the subject of waste anesthesia gas, suggests that simply giving anesthesiologists the information may not be enough. Several hospitals around the country tried this simple approach and saw little change. Other systems took a more forceful approach, removing desflurane altogether or removing the vaporizers needed to convert the gas for use. Unfortunately, since the choice of anesthesia has traditionally been made by the clinicians themselves, this approach more often made clinicians angry and resistant to change.[xxiv] Strategies which invite involvement instead of forcing it may be more fruitful, for example:

- Create a committee or working group to look into methods for reducing waste anesthesia gas. Make sure the group includes clinicians and is led by a clinician.
- Begin a program to monitor gas use or emissions. Make the data available, including baseline and ongoing use. Provide anesthesiologists with regular reports so they can see the impact of their own choices.

- Create recognition and/or rewards for progress made reducing anesthesia gas emissions. These can be internal within the health care system itself or publicized by local news for wider recognition.

Adding gas scavenging and destroying equipment can reduce the climate impact of the operating room even further. Some options are currently available but many of these technologies are in their infancy stage, some existing only on paper or in prototype form, some available in other countries but not yet in the US. Costs and availability are beyond the scope of this paper, though we encourage surgical centers to investigate and consider such options.

In the longer term, voluntary change may not be enough. Should hospitals and other sites be slow to reduce their emissions, governments may begin to step in. Given the lower cost of WAG abatement technologies compared to other greenhouse gas abatement technologies, there are a variety of possible pathways to consider, including:

- Monitoring and regulation of use or emissions
- Licenses to use anesthesia gases with limits, inspections and audits
- Creating a tax on anesthesia gases
- Including sustainability equipment and techniques in the review process for hospitals done by the Joint Commission
- Including measures of sustainability in reimbursement programs such as Medicare and Medicaid
- Allowing hospital and other anesthesia centers to enter regional carbon offset markets after establishing a method comparing WAGs with carbon dioxide emissions

A few countries are beginning to consider WAG restrictions and regulations. In England, their National Health Service' Long Term Plan requires halving inhaled anesthesia emissions within 10 years. In Australia and New Zealand, their professional society asked members to reduce their carbon footprint.[xxv]

A pleasing side effect of reducing waste gas is that operating room personnel – doctors, nurses, janitorial staff, etc. – would face less occupational safety risk. WAGs are known to be mutagenic (capable of causing mutations in your own DNA) and teratogenic (capable of causing birth defects in any embryo or fetus exposed to the substance). Developing embryos are particularly vulnerable in the first trimester. Pregnant women exposed to WAGs, especially nitrous oxide, are at higher risk for spontaneous abortions.[xxvi] These effects are magnified If your site is not well-ventilated, or if the HVAC system is poorly maintained. This danger alone may help enlist support for adopting change.

Few climate strategists are yet discussing waste anesthetic gases as a target for public policy. These and other medical uses have in the past been given a free pass. Yet where there are easy substitutes or mitigation techniques, why not encourage adopting choices which create fewer side effects for the air we all breathe? After all, isn't that the path they pledge to follow in the oath they take as doctors? Physician, first do no harm!

Additional Resources for Hospitals and Clinics

The American Society of Anesthesiologists' Subcommittee on Environmental Health has issued the Inhaled Anesthetic 2020 Challenge – to reduce inhaled anesthetic emissions by 50%. They offer a free benchmarking report to begin with at www.asahq.org/about-asa/ governance-and-committees/asa-committees/committee-on-equipment-and-facilities/environmental-sustainability/inhaled-anesthetic-2020-challenge.

The Medical Society Consortia on Climate and Health – composed of member state medical societies, most of the specialist societies and additional groups such as the American Heart Association, has a report on health care's climate footprint, including a page on WAGs https://medsocietiesforclimatehealth.org/reports/health-cares-climate-footprint/

Practice Greenhealth offers training, webinars and toolkits for sustainability in medicine including such topics as energy efficiency, medical waste and waste anesthetic gases. https://practicegreenhealth.org/topics/greening-operating-room/greening-or

Health Care Without Harm offers a variety of information and a network of environmentally aware physicians though little on the topic of waste anesthesia https://noharm-uscanada.org/ as well as other green measures for hospitals and clinics

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