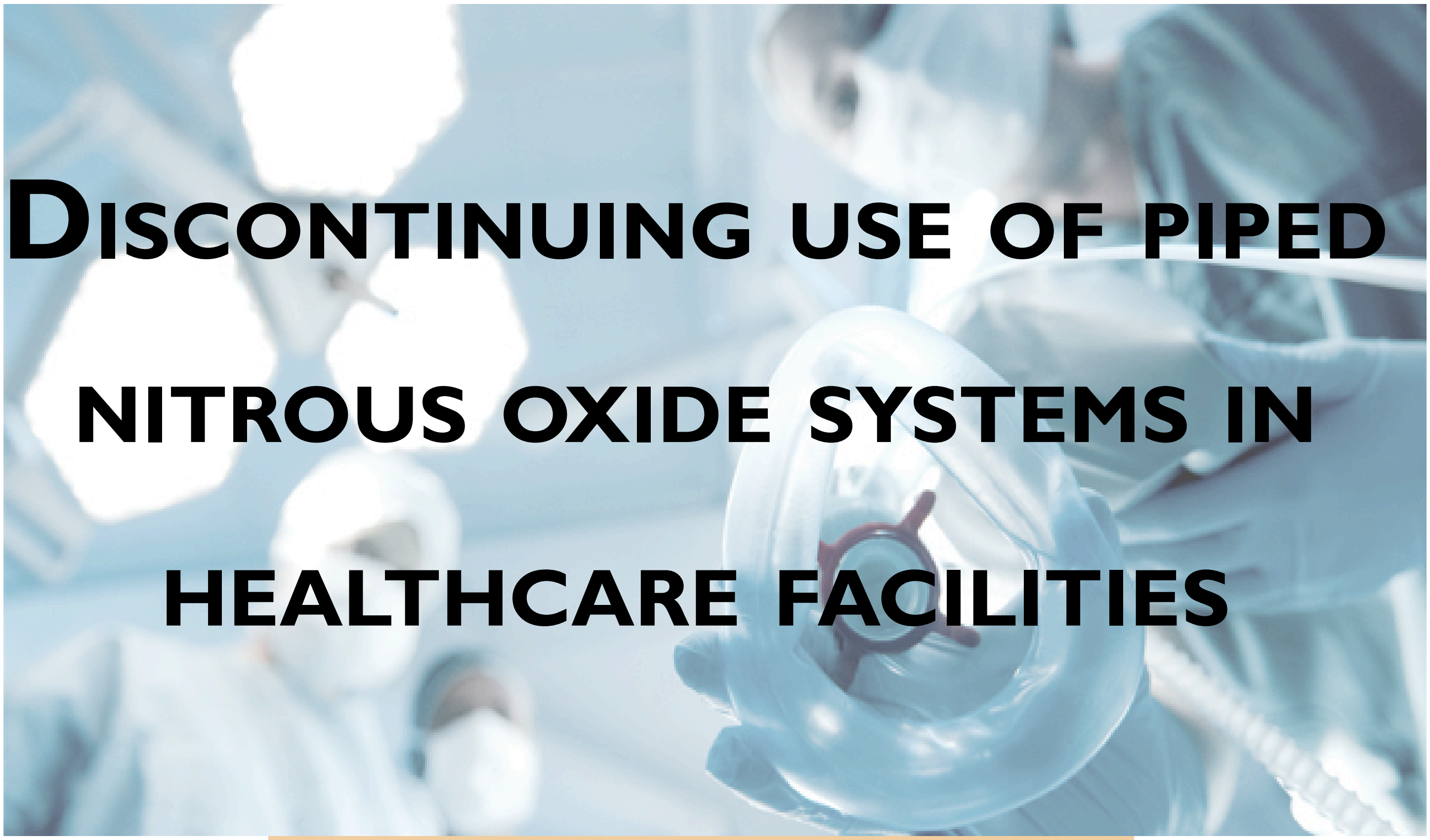
DISCONTINUING USE OF PIPED NITROUS OXIDE SYSTEMS IN HEALTHCARE FACILITIES



A playbook on how to reduce waste and emissions while improving efficiency and safety

Created by the Cascadia Collaborative

A group of healthcare leaders in the Pacific Northwest working together to educate and advocate for the adoption of environmentally sustainable healthcare practices.

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Introduction

The U.S. healthcare sector is responsible for an estimated 8.5% of U.S. greenhouse gas emissions.[1] To mitigate climate change and its harms to human health, it is vital for the healthcare sector to reduce its emissions from all possible areas, including anesthetic gasses.

Hospitals in the United States have discovered shocking rates of nitrous oxide leakage and fugitive carbon emissions associated with many central, piped nitrous oxide systems. As a result of these findings and their environmental implications, this playbook was created to help hospitals and surgery centers across the country employ practical solutions to radically reduce nitrous oxide waste.

Created in collaboration with anesthesiologists, healthcare facility managers and other experts in the field, this document describes the surprising inefficiency of tank rooms and central supply lines, as well as the ease and benefits of switching to a decentralized approach, with no impact on patient care. It will also outline, step by step, how to discontinue the use of a piped nitrous oxide medical gas system in favor of far more efficient "E-cylinders" at the point of care.

1. Executive Summary

Hospitals and surgery centers that investigate their usage of nitrous oxide (N_2O) compared to the amount they purchase discover that only a small percentage of the gas they purchase is used for direct clinical application. The remainder is lost to leakage from many points throughout the piped distribution system within their facility – tanks, manifolds, pipeline fittings, valves, wall outlets, and anesthesia machines – and to supplier disposal of the remaining gas in returned tanks.

Fortunately, an easy workaround exists to bypass the central nitrous oxide supply system and rely exclusively on portable E-cylinder use, without impacting patient care. With a bit of planning and coordination, healthcare facilities can shut off their central supply system and instruct anesthesia providers to use the E-cylinders directly at the point of care, already located on most anesthesia machines. When common practice is established for clinicians to open the E-cylinder valve when using the gas and close it at the end of any case, organizations reduce their N_2O purchases and the associated greenhouse gas emissions by 87-99%.

Discontinuing the use of centrally stored and piped nitrous oxide systems also modestly reduces costs, improves occupational and operational safety, and makes the supply chain more resilient to shortages or natural disasters.

The transition logistics are straightforward. The E-cylinders are already in place on most anesthesia carts, as a backup system. Replenishing the empty tanks is not a laborious or time consuming task for staff and will become even less onerous as more efficient flow rates are adopted and overall use decreases, as recommended by the American Society of Anesthesiologists.[2]

In some specialty care areas such as burn units or oral and maxillofacial clinics, the change out frequency will be higher. Discontinuing piped nitrous oxide systems in existing facilities and avoiding them in new construction has become best practice.[3,4] The safety, resiliency, environmental, and efficiency benefits of doing so are substantial. This change ties directly into the growing understanding of the health impacts from a changing climate, of healthcare's unintended yet large contribution to this problem, and of the industry's ethical obligation to decarbonize as rapidly as possible.

The scope of this playbook does not include any recommended changes to how or when providers should use nitrous oxide, which is already utilized at very low rates. The recommendation is to quickly transition to using E-cylinders at the point of care rather than a highly inefficient piped system.

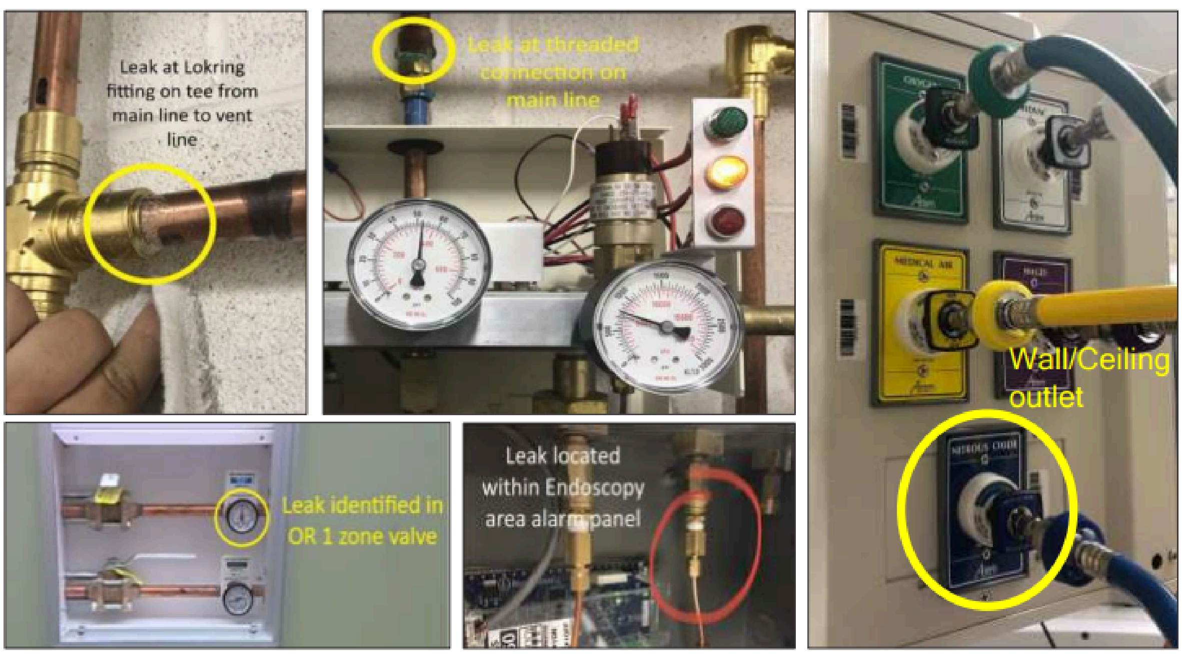
Left to right: Cryogenic tanks in tank room, H-cylinders in tank room, and E-cylinder on anesthesia cart.

2. Nitrous Oxide Use in Healthcare Facilities

Nitrous oxide (N_2O) is an anesthetic gas that is used in combination with other anesthesia agents to provide anesthesia in the operating room as well as pain relief during childbirth, dental procedures, and burn care procedures. Hospital gas delivery systems were designed at a time when a higher percentage of patients needed N_2O and higher flow rates were needed due to inefficient anesthetic machines and management. Now, at a typical acute care hospital in the United States, N_2O is less commonly used on surgical patients. A growing number of anesthesiologists have never administered N_2O and many who were accustomed to using it no longer do.

Hospitals and surgery centers purchase and centrally store N_2O either in liquid form in 380 pound cryogenic tanks, or in the form of regularly replaced 50-65 pound high pressure gas cylinders (“H-cylinders”). The gas is distributed under pressure through a vast circuit of pipes to each operating room and in some cases, to other treatment areas. It is standard practice to also purchase portable, 7-pound “E-cylinders” for backup availability and place them on every anesthesia cart in the OR.

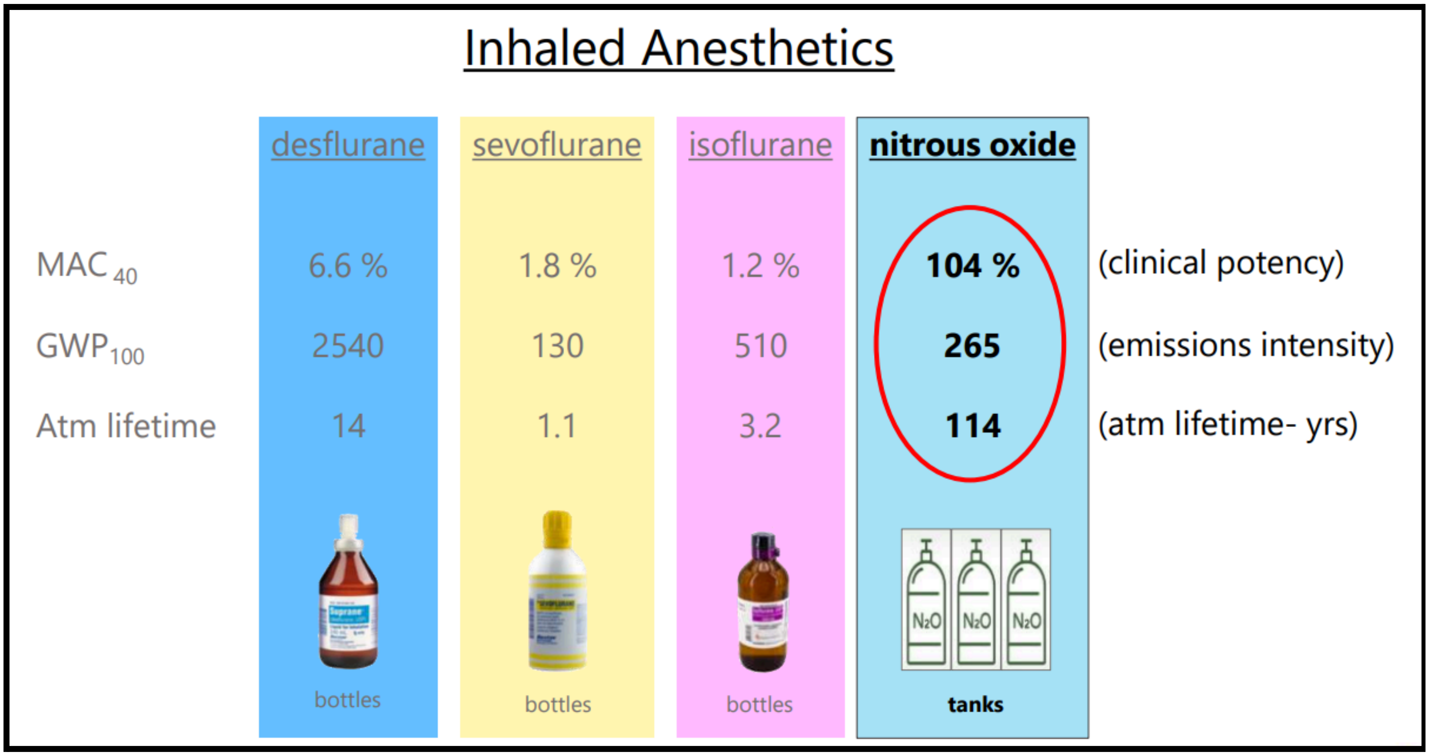
Cryogenic tank and H-cylinder central supply systems are both inherently inefficient when it comes to N_2O delivery. Cryogenic tanks are worse, because they release pressure by venting to the atmosphere. In either storage system type, leakage is inescapable and impractical to remedy downstream. Even in facilities using high pressure tanks instead of cryogenics, the loss rate at some hospitals has reached 97%.[5]



Leaks can occur throughout the delivery system.

The leakage occurs inside the healthcare facility, potentially exposing staff, patients, and visitors to the fugitive gas at some undetermined amount. Exploring the facility to identify and repair all leaks in a hospital or surgery center would be highly cost and labor intensive and would not address the ongoing leakage at the cryogenic tanks.

In addition to being an inefficient material use, N_2O delivered through a piped system is a significant contributor to a healthcare facility’s carbon footprint. Despite its nominal clinical value, nitrous oxide typically makes up around 80% of a facility’s greenhouse gas emissions from anesthetic gas use. This is due to N_2O's high global warming potential (273x CO_2) and 114-year lifespan in the atmosphere. All medical gasses combined typically contribute up to 40% of hospitals' direct (or "Scope 1") greenhouse gas emissions.



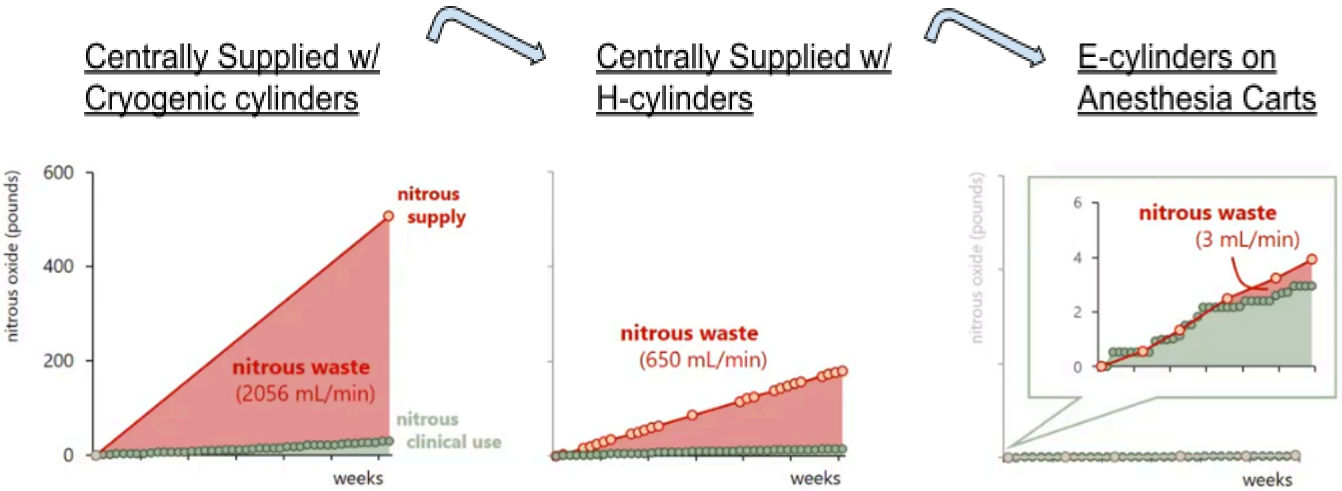
The diagram above illustrates the different types of inhaled anesthetics that are typically used in healthcare facilities.

3. Assessing the Opportunity

When assessing the opportunity to help your hospital or surgery center implement this change, you may ask yourself, "How much wasted gas can we avoid?" You may choose to measure that amount by collecting and analyzing your facility's data, or you may choose to rely upon the past work of others and be satisfied for the time being with an estimate.

Healthcare organizations pioneering this work first discovered alarming rates of nitrous oxide waste simply by comparing the amount they were purchasing to the amount they were using for patient care. Facilities with cryogenic tanks have found their clinical use rate to be as little as one percent of what they purchased, meaning their leakage/loss rate can be as much as 99%. Facilities using H-cylinders saw a ~3-12% clinical use rate, wasting 88-97% of what they purchased.[5]

Once organizations have converted from a piped system to the exclusive use of E-cylinders, those percentages are borne out in reduced purchases. The authors of this Playbook are aware of no exceptions to these percentages.



The diagram above shows one 539-bed tertiary care facility's nitrous oxide clinical use (in green) and losses to leakage (in pink) as it progressed from using cryogenic tanks to H-cylinders to E-cylinders.

For those looking for organization-specific data to support this change, you can collect purchasing data from your supplier and collect clinical use data through your electronic health record system. Some of your organization's key stakeholders may even steer you down this path, wanting to prove the waste occurring within your facility. You can find detailed instructions for data collection and analysis in the Appendix.

The easier estimation approach is to simply determine if your facility uses cryogenic tanks or H-cylinders and quote the respective percentages offered above as a general expectation of your facility's future waste prevention results. In time you will see exactly how much less gas you purchase following your facility's discontinuation of its piped system. This is the measurement that will ultimately matter the most.

4. Engaging the Stakeholders

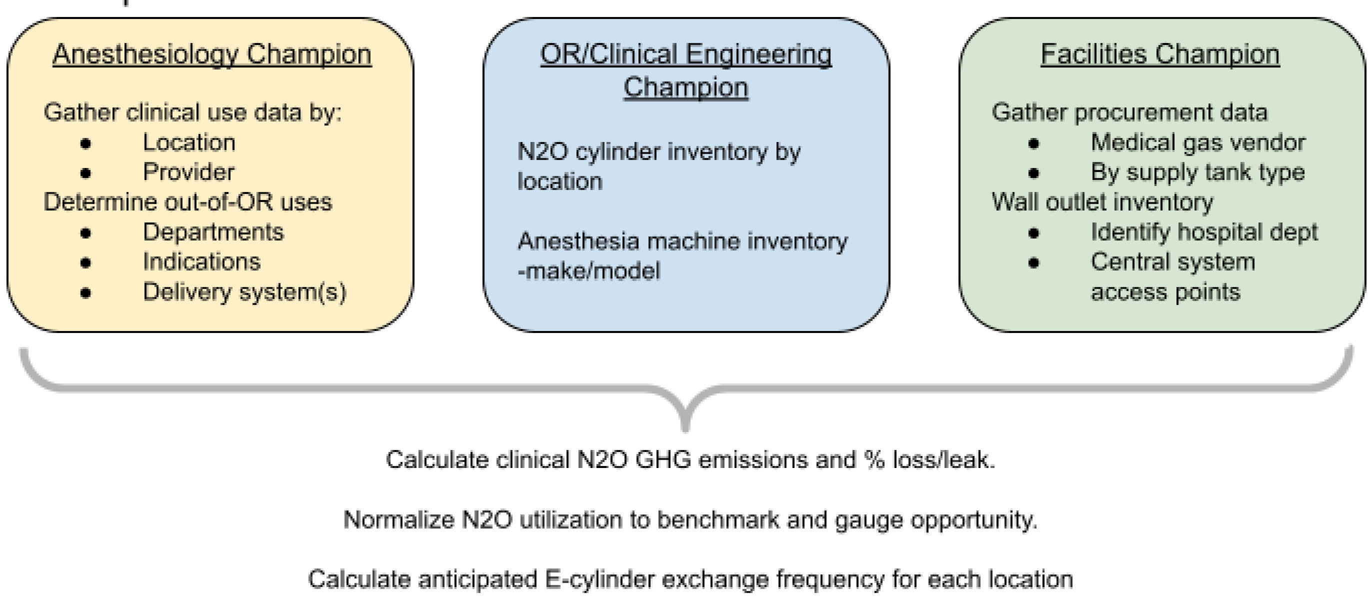
Engaging key stakeholders is necessary to ensure that discontinuing the use of a centrally stored and piped nitrous oxide medical gas system is carried out thoughtfully and appropriately, while minimizing disruption to patient care. While each health system/hospital may have unique stakeholders, the typical and most influential ones in moving forward with this project will come from the following:

- **Project manager** – Someone who can keep the team on track and coordinate the stakeholders needed to make this transition successful. This doesn't need to be a formal project manager but having someone in this role is crucial to ensuring proper engagement and collaboration. Whoever coordinates new construction projects at your organization may be a good fit for this role as they are used to managing many of the required stakeholder groups.
- **Clinical champion(s)** – A clinical champion, typically an anesthesiologist, will need to lead the efforts with the Clinical Teams up through the Chief Medical Officer. This person(s) will serve as the primary partner on the care side to ensure all processes and questions related to the environment of care are updated and answered. The Perioperative Services leader can also play a very helpful role in managing this change.
- **Facilities team** – The person or group responsible for maintaining the central supply system.
- **Sustainability leader** – If this role exists at your organization, this person can be a very helpful project manager and champion for the greenhouse gas emission reductions this project will create.
- **Clinical Engineering or Anesthesia Tech leader** – The person or group responsible for internally managing, moving and checking medical gas cylinders. In small hospitals and surgery centers, this could be the facility manager.
- **Clinical teams** – This includes the anesthesiology team, the perioperative team, nurses and other care providers in the settings that use nitrous oxide. Some areas include operating rooms, dental, Emergency Department, labor & delivery, mobile sedation team, cardiac cath lab, imaging, burn units, etc. The full list of departments and key clinical stakeholders will vary depending on the hospital services.
- **Supply Chain team** – The person or group responsible for the purchasing of nitrous oxide tanks used in the central supply and the portable E-cylinders.
- **Medical gas vendor** – The vendor that supplies nitrous oxide. They will need to supply some additional E-cylinders to make the transition away from the central supply.
- **Regulatory lead** – The person or team that is responsible for relations with the state Department of Health.
- **Hospital senior leaders** – The ultimate approvers for proceeding with shutting off the central supply of gas. Typically, this will include asking the Chief Medical Officer if there are objections or concerns on the clinical side and asking the Chief Operating Officer if there are objections or concerns on the administrative or operational side.

It is important to engage and collaborate with each stakeholder directly and at the appropriate time to gain support, move the process forward, and reduce the potential for misunderstanding or opposition. As an example, a provider that is reliant on the walled supply of nitrous could derail the project if they are not fully informed about the reasons for the change.

The support gathering and decision making processes will be different in every organization. Generally speaking, the anesthesiologists must first agree as a group to at least try exclusively using E-cylinders. Once their support is secured, the facilities team will typically also be supportive, and then approaching other clinical and administrative staff will have the best chance of success. The clinical champion(s) should eventually bring the message to the senior medical leadership in conjunction with the facilities leader and supply data.

Example of Roles and Tasks in Assessment Phase



5. COMMUNICATING THE VALUE PROPOSITION

There are financial gains to be had from purchasing up to 99% less nitrous oxide, but these are modest, since N_2O's cost is relatively low (~$3.00-$4.00/pound in 2023). It is the safety, resiliency, environmental, and efficiency benefits that are quite substantial. When building support for this project, you will want to communicate these advantages to the key stakeholders and decision makers in your organization. One format for doing this is a succinct, educational SBAR (situation, background, assessment, recommendation) document, which can easily be shared as an attachment to email messages and meeting invitations. (See the SBAR example in the Appendix.) Regardless of the communication style or format you choose, you may want to emphasize that discontinuing piped systems has been done successfully at a growing number of facilities across the continent, to the point where it is now considered best practice, for a number of the following reasons.

- **Safety** – Studies of workers exposed to N_2O have reported adverse health effects such as reduced fertility, spontaneous abortion, and neurological, renal, and liver disease.[6] Although the level of chronic exposure to individuals or groups inside healthcare facilities is unknown, the leakage rates from central supply systems are so alarming that the health and safety concerns alone should be persuasive to every decision maker. Using portable tanks at the bedside is clearly the better choice in regards to both occupational safety and patient safety.
- **Resiliency** – In the event of a lengthy supply disruption or a natural disaster such as a flood or earthquake, the central supply system could be compromised. Relying on the E-cylinders at every care location and in storage, each using a small fraction of the gas required of a piped system, provides the facility with resiliency advantages. Hospitals and surgery centers often have years' worth of gas stored and available for use in the form of E-cylinders already in place.
- **Environmental** – As an industry, healthcare faces particularly difficult challenges for cutting its operational carbon footprint in half by 2030 and reaching net zero by 2050 – as called for in the Paris Agreement [7] and the voluntary HHS Health Sector Climate Pledge [8] to avert the worst impacts of climate change and preserve a livable planet. Turning off N_2O central supply systems is probably the fastest and simplest single step hospitals can take to substantially reduce their direct greenhouse gas emissions. It is a proven intervention that requires very low or no investment, no change in clinical practice, and very little time to implement once the decision is made to proceed. In healthcare's battle to mitigate the health impacts of climate change, this is very low hanging fruit.
- **Efficiency** – Process improvement enthusiasts will applaud the following efficiencies gained from converting to E-cylinders.
    - Material efficiency: Your organization will actually use for patient care nearly every bit of nitrous oxide it purchases, rather than losing 87-99% of its purchased gas to the atmosphere.
    - Labor efficiency: Your facilities team will no longer need to monitor the piped nitrous system or manage the cylinders in your tank rooms. Facility managers will appreciate taking these responsibilities off their list. There will also be fewer wall or ceiling hoses in every one of your OR's to clean, maintain, and track in inventory.
    - Space efficiency: Sometime after your organization has committed to the change, your supplier can remove all of the large N_2O cylinders in your tank room, freeing up space for other uses.
- **Financial** – Because E-cylinders are already in place on the vast majority of anesthesia carts, the cost of converting to the exclusive use of portable tanks typically is relatively low or nonexistent. Those healthcare organizations that need to purchase a few additional carts, such

as for their birth center, will recoup that cost within two years in the form of dramatically reduced gas purchases.

6. Transitioning to E-cylinder Supply

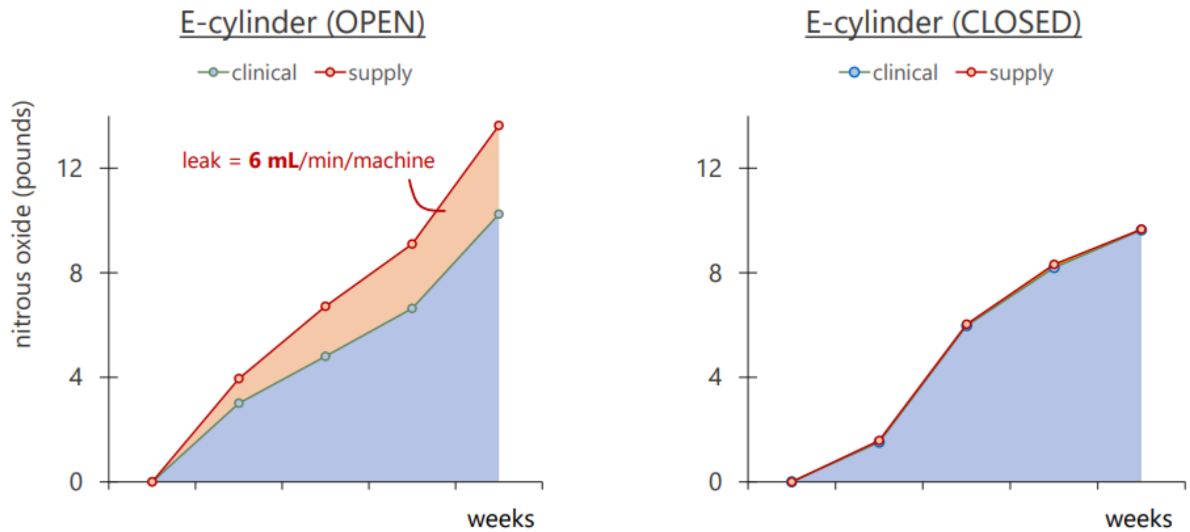
If your organization is already utilizing E-cylinders for redundancy on anesthesia carts in operating rooms, establishing a portable supply as part of the transition can be a relatively straightforward endeavor. Leveraging existing infrastructure and protocols for E-cylinder use provides a solid foundation for transitioning away from piped nitrous oxide systems while maintaining a reliable and efficient supply of nitrous oxide for patient care.

To begin, check each anesthesia machine to see if they have nitrous oxide E-cylinders available for use. Make note of any machines that need an additional holder for an E-cylinder. Storage in clinical areas should be evaluated to assure that there is adequate rack space and that the limit of 300 cubic feet of compressed gas per smoke compartment outside of a rated enclosure[5] will not be exceeded with additional cylinders. Clinical use volumes should guide the interdisciplinary team in determining the volume of gas to keep on the unit in reserve as well as the number of additional tanks to keep in the central supply and any increase in the cadence of their replacement by the supplier. Note that evaluations in a number of facilities have found that a majority of adult operating rooms will need less than one E-cylinder exchange per year, but that varies by clinical use.

> If end users are resistant to discontinuing the use of piped nitrous oxide, consider a hybrid approach where point-of-use supply is established but the central system is left active and available for a period of time. Once the validity of the local supply model has been proven, the central supply system can then be discontinued.

The team will need to establish any modifications to workflows and responsibilities prior to transitioning to local supply to assure that roles are understood and sufficient labor resources are available for tank management. Best practice is to keep the pin valve on the cylinder closed except when in use; the anesthesiologist opens it at the beginning of a case where it is to be used and closes it again at the end of that case. An individual should be assigned to do a final check at the end of the day to catch any valves that may have been left open.

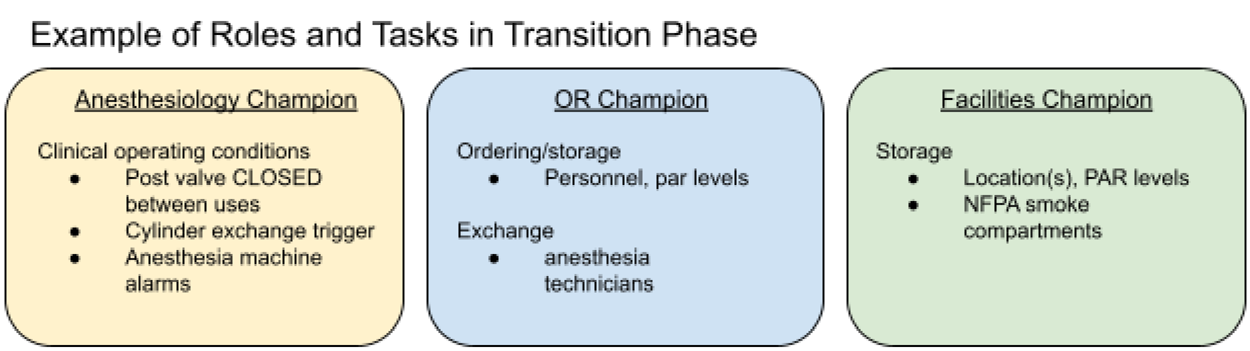
Evaluation of anesthesia machines have shown miniscule leaks when connected to pressurized N_2O E-cylinders (6mL/min was observed at one facility[5]). By closing the pin valve when nitrous oxide is not in use, efficiencies of up to 99% are achievable.



Closing the E-cylinder post-valve between clinical uses improves efficiency. (Data from Providence Portland Medical Center in Portland, OR; GE Aisys C2 anesthesia machines)

After making the transition to local supply, the cylinders on anesthesia machines may need to be replaced a bit more often. The individuals responsible for replacing the tanks should be aware that the rubber O-rings that seal the cylinder valve to the yoke can become brittle in the presence of an oxidizer and may crack when the yoke is removed, so a supply of O-rings should be kept on hand for ready replacement.[9]

Note that the low N_2O pressure alarm on many anesthesia machines will trigger when there is approximately 95 liters of gas remaining in the cylinder, and there is no low pressure cutoff that would stop flow before the tank is completely empty. It is at the discretion of the anesthesiologist to wait until the end of the case or the end of the day or even the complete emptying of the tank before having it swapped out.



Define N_2O E-cylinder management process, protocols, education. If needed, procure N_2O E-cylinders and retrofit anesthesia machines.

7. DISCONTINUING USE OF CENTRAL SUPPLY

Once the portable supply has been established and all key stakeholders are comfortable with the new process, the central supply may be discontinued.

Prior to transitioning away from central supply:

- Order any needed supplies such as blank plates or durable labeling materials.
- Select a target date and time that will minimize the impact on OR operations. Consider when case types or providers are scheduled that are more likely to use N_2O.
- Communicate to the relevant clinical teams and senior leaders what, when, and why this is happening.
- Follow internal processes/procedures for projects impacting the environment of care and allow for available staff to respond to unexpected issues.
- Determine how to disable the low pressure alarms at all central and local medical gas alarm panels and anesthesia machines. Consider contacting your med gas certifier or the distributor of the area med gas alarm panels about how to best do this. Note that on most newer touchscreen-based alarm panels, the N_2O alarm can simply be removed from the program.
- Some jurisdictions may have additional requirements when discontinuing a centrally piped medical gas system. Check with your state department of health or other authority having jurisdiction (AHJ) to determine if any additional work or documentation would be required. See the risk assessment documentation example in the Appendix.

On the selected date of transition:

- At the outlets, remove any hoses and label each outlet “not in use.” Better yet, replace each outlet with a blank plate to eliminate any confusion over whether nitrous oxide is available at the location.
- Disable the nitrous oxide low pressure alarms at all central and local medical gas alarm panels. Clearly label the nitrous oxide channel on each alarm panel as “not in use.”
- Close the source valve and label it “not in use.” If your system has a number of losses, the system pressure may drop off quickly. If not, it is a good idea to relieve the pressure in the system in a controlled manner. This will both validate that all low pressure alarms have been disabled at a time when facilities and clinical staff are prepared and prevent trapping a volume of gas under pressure in a section of piping that might be released unexpectedly at a later time.
- Once the pressure is relieved, shut all zone valves, remove the handles, and label the valves “not in use.”

Once your organization has embraced the conversion:

- Return central system tanks to the vendor and assure that they will not be automatically replenished. Consider removing the central N_20 manifold.
- If your facility uses a computerized maintenance management system, retire any nitrous oxide system assets to prevent them from being included in auto-generating preventative maintenance work orders in the future.
- For health systems planning future renovation, the central supply system could be removed at that time. Otherwise, it's extremely cost prohibitive and unnecessary, from a maintenance/regulatory standpoint, to remove the old system. In most jurisdictions, clearly noting that it has been discontinued will suffice.

"NOT IN USE" or "NOT IN SERVICE" label example.

Appendix

1. Citations

1. Eckelman, M. J., et al. 2020. Health care pollution and public health damage in the United States: An update. Health Affairs 39(12).
2. Inhaled Anesthetic 2023 Challenge
3. Sustainable Health Care Resource Center: Anesthetic Gases | The Joint Commission
4. Devlin-Hegedus, J.A., McGain, F., Harris, R.D. and Sherman, J.D. (2022), Action guidance for addressing pollution from inhalational anesthetics. Anaesthesia, 77: 1023-1029.
5. Recording of a CleanMed 2022 conference presentation on the findings at many Providence Health facilities
6. Controlling Exposures to Nitrous Oxide During Anesthetic Administration | NIOSH | CDC
7. Rogelj, J. D. et al. in Global Warming of 1.5 °C - An IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (eds. Masson-Delmotte, V. et al.) 93–174 (Cambridge Univ. Press, 2018).
8. Health Sector Commitments to Emissions Reduction and Resilience | HHS.gov
9. 2018 International Fire Code, Chapter 50, Hazardous Materials. 5003 is the relevant section; specifically Table 5003.1.1 - Maximum Allowable Quantity per Control Area of Hazardous Materials; and Table 5003.8.3.2 - Design and Number of Control Areas
10. NFPA 99 (2012) 5.1.14.2.3.1 (11)(d)

2. Conversion Source

For liters-to-pounds conversion, the gas density (g/L) at standard temperature & pressure (0 C & 1 atm) was used. Granted, gas volume changes with temperature as per Charles Law (V1/T1 = V2/T2), but the "standard" physical conditions were used in these calculations.

Based on gas density of 1.967 g/liter (Merck Index) and converting grams to pounds (0.002205 pounds/gram), this results in: **230.6 liters / pound**

3. Cryogenic and H-cylinder Waste Reference

Consider that a standard high-pressure H-cylinder contains approximately 16,000L of N_2O gas, whereas a 180L cryogen tank contains 119,000L of gas, a greater than 7-1 ratio. However, the cryogenic tank can be expected to vent 500L - 3,500L per day; industry standard evaporation rate from a cryogenic cylinder is 0.4 - 3.0% of the volume of a full tank per day, therefore a pair of cryogenic tanks in a typical primary/alternate setup could vent up to 7,000L per day. A general approximation is that a full tank connected to the alternate source and unused for a month before being placed on-line will be half empty when it begins supplying the system. Some high-efficiency cryogenic manifolds are able to scavenge gas from a tank that is not currently the primary source in order to relieve pressure and reduce these losses, but the facility usage needs to exceed the evaporation rate 24/7 for this system to be fully effective. Note that a cryogenic manifold may not be able to support high pressure (745 psi) tanks and would have to be replaced in order to perform this conversion.

When considering whether to maintain or discontinue a centrally piped system, also take into account that even a perfectly leak-free system has inherent losses. In addition to the losses from cryogenic tanks already described, a high pressure manifold will switch from the primary to alternate bank of H-cylinders when there is still about 8% of the nominal volume remaining in the cylinder. When these cylinders are returned to the vendor to be refilled, this residual is vented and the tank is pulled to a vacuum to assure that when the tank is refilled it contains only the intended gas, so a leak-free system using high pressure H-cylinders can achieve no better than 92% efficiency.

4. Evaluating System Losses

Even if your organization fully supports discontinuing use of the existing piped system, it may take several months to begin this process due to a variety of organizational strengths and/or conflicting priorities. Conversely, your organization may not yet support discontinuing your central supply of nitrous oxide. The following is offered for either of these situations.

If your centrally piped nitrous oxide system is supplied from cryogenic liquid cylinders, consider whether these could be replaced with high-pressure cylinders to reduce evaporative losses. Once the clinical use rate for your facility has been determined or estimated, that volume can be used to evaluate whether switching to high-pressure cylinders would put an undue strain on the department responsible for maintaining the system and replacing empty tanks.

Even a properly maintained piping system is likely not leak-free. While leak testing of a new piping installation is required at the time of installation,. only the outlets and inlets require periodic testing (NFPA 99 (2012) 5.1.14.2.3.1 (11)(d)). Consider shutting the source valve at a time when there is no N_2O use in the facility and recording the rate of pressure drop to determine if significant leaks are present. If the manifold room and system configuration allow it, placing an active cylinder on a large scale to record the weight before and after the source valve is re-opened can provide a reasonably accurate volume of any leakage.

Evaluations of piped systems have found leaks at gauges, pressure sensor wells, zone valves, pressure regulators, manifold valves, etc., which may not be routinely evaluated for leaks; all of these locations should be checked in addition to outlets and inlets and repaired as necessary to make the system as leak-free as reasonably possible.

Once leaks have been identified and repaired, a process should be put into place to assure that new leaks will be detected in a reasonable timeframe. Comparing purchase data with clinical usage may not be accurate or timely enough to catch new leaks; installing a flow meter that feeds data to the building management system where it can be logged and trended would allow a sudden increase in use or flow at a time of no clinical use to be discovered quickly. Placing an active tank on a scale and regularly recording the change in weight can also be a less granular but also less expensive alternative. Establishing an ongoing relationship between clinicians and facilities will greatly ease the gathering and analysis of clinical use versus supply volume.

However, as emphasized in this playbook, continuing to use a centrally supplied system for nitrous oxide will result in significantly higher inefficiencies and waste then switching to E-cylinders.

5. State Department of Health Guidance

In navigating the landscape of discontinuing the use of piped nitrous oxide systems, organizations often find themselves in a situation where direct guidance from state departments of health (DOH) is not readily available. The novelty of discontinuing such systems and its evolving nature pose challenges for regulatory frameworks to keep pace. In such circumstances, it becomes imperative for each organization to understand their own risk tolerance in the context of transitioning away from piped nitrous oxide. Striking a balance between risk evaluation and the imperative to implement necessary changes becomes crucial, particularly when waiting for formal regulations to catch up might impede progress.

This is the current understanding of state level guidance from the Playbook authors but it's important that you/your organization connects with your state's DOH. Even with imperfect guidance, one should expect to submit supporting documentation such as: floor plans with location of all wall outlets, risk assessment, functional narrative describing how nitrous oxide is administered, and a plan that denotes how the pipes will be tagged as discontinued.

6. Data Collection and Analysis in Detail

Before beginning data collection, determine if this is necessary for your organization. Some hospitals know how little nitrous oxide is used, have seen the waste data from other health systems, and decide to skip this exercise altogether.

If this is necessary, it is vital to understand if a nitrous oxide medical gas system supplied through larger, centrally stored tanks is being used. If E-cylinders are already in use as the primary supply source, then you may already be part of a low-emission, efficient organization! If that is not the case, confirming the types of tanks used (cryogenic, compressed gas or both) is an important first step.

To evaluate your organization's current nitrous oxide waste/leakage, you'll want to start with learning more about your current nitrous oxide environment. For this, you can generally work with your facilities group to learn the gas room(s) locations, the types and sizes of canisters and/or tanks in use, and to which departments nitrous oxide is being supplied. While this will give you an initial understanding of your leakage potential, additional details from your facilities group will be potentially useful later in the process: wall outlet inventory, clinical locations, locations of pressure alarms and isolation valves, details for the workflow for central tank exchanges and the ordering of new gas.

Most important for determining whether there is N_2O waste/leakage in your facility is a straight-forward calculation based on the difference between how much you are PURCHASING and how much you are USING clinically.

Purchase Data: This information can either be pulled from purchase orders (usually obtained from either your supply chain or accounts payable groups) or potentially more easily (and quickly) from direct contact with your gas vendor supplying your gases. Tip: try to obtain the monthly purchases for all N_2O for the same 12-month period that overlays the clinical usage period being examined.

To calculate the purchased volume, this example data was obtained by requesting a full calendar years' worth of N2O purchases for an acute care hospital:

Material		Total Billed Revenue	Quantity (Base UoM)	Volume (Base UoM)	Product Revenue
NS CC10ACT50C	NITROUS OXIDE CRYOCATH 10LB ALUM C/O	[illegible]	14 CL	140 LBS	[illegible]
NS USP20	NITROUS OXIDE USP 20 LBS	[illegible]	1 CL	20 LBS	[illegible]
NS USP56	NITROUS OXIDE USP SIZE 56LBS	[illegible]	37 CL	2,072 LBS	[illegible]
NS USPE	NITROUS OXIDE USP E CGA 910	[illegible]	6 CL	42 LBS	[illegible]
NS USPEAC	NITROUS OXIDE USP EA CGA 910 C/O	[illegible]	1 CL	7 LBS	[illegible]

Be on the lookout for cryogenic containers as initial targets for discontinuing, but be sure you understand their use. Many cardiac cath labs use cryogenic nitrous oxide tanks for procedures; these should be considered out of scope for this effort. From this list of purchased N_2O, you can determine that there are 56-LB tanks in use – a typical source of leakage.

You may have to normalize your data to properly compare usage to purchase quantities. Nitrous oxide is often purchased in pounds whereas usage is recorded in liters. In other words, because Epic provides N_2O usage in gas phase liters, you will need to convert the pounds provided in your purchase data using the formula:

1 lb N2O = 230.6 gas phase liters

see appendix for conversion

So, in this example, you can determine that this hospital used:

477,803 gas phase liters (2,072 lbs * 230.6)

Next, determine your clinical usage:

Clinical Usage Data: The answer for how much nitrous oxide is being used for clinical purposes can likely be obtained through your Electronic Health Record (EHR) – instructions for Epic are provided below (Cerner reporting for anesthetic gas consumption is not available to the best of our knowledge).

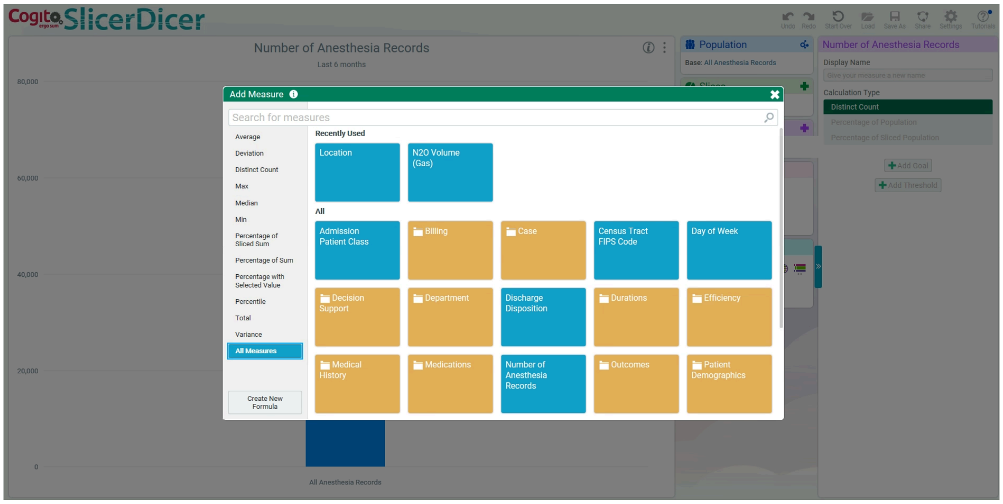
Some OR anesthesia groups do not document in an EHR while other departments that don't use anesthesia machines will not have usage data captured in the EHR. For these departments, annual use can be estimated by interviewing department leaders about cases per week, average case duration, flow rate, and the percent mix of nitrous oxide and oxygen.

Steps for obtaining clinical usage by operating room through Epic:

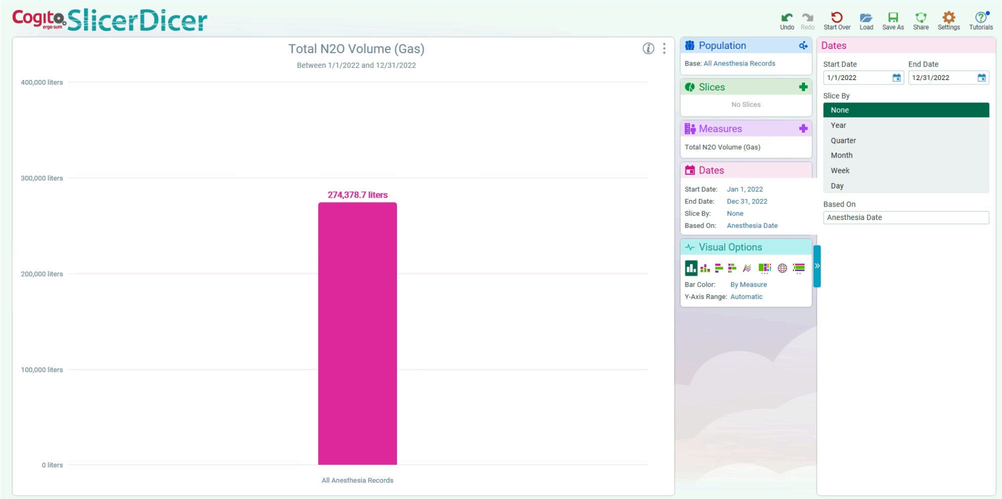
Reports → SlicerDicer …or search for "SlicerDicer" (top right).

When prompted to select a Data Model, search for/select "Anesthesia Records".

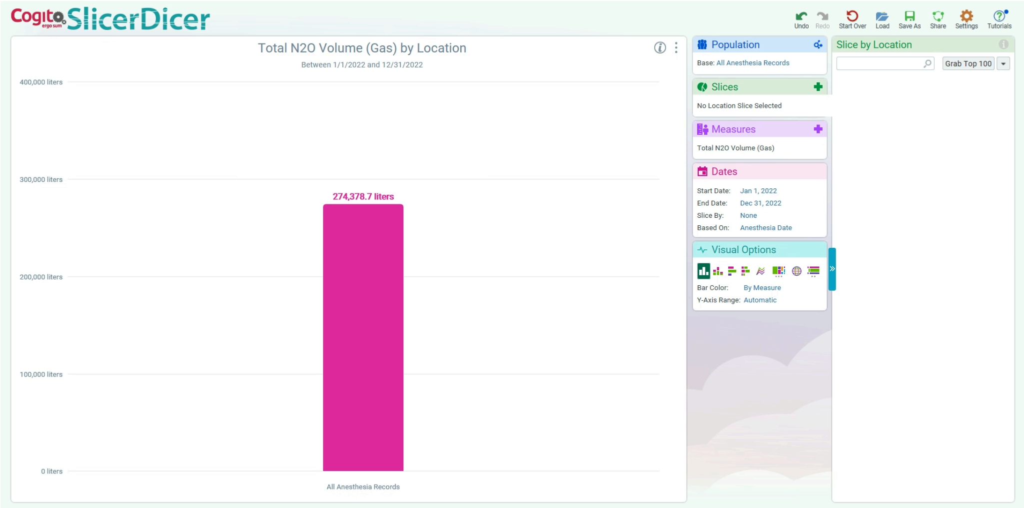
Default measure is often "Number of Anesthesia Records". You will want to "Add a Measure" of "N2O Volume (Gas)".



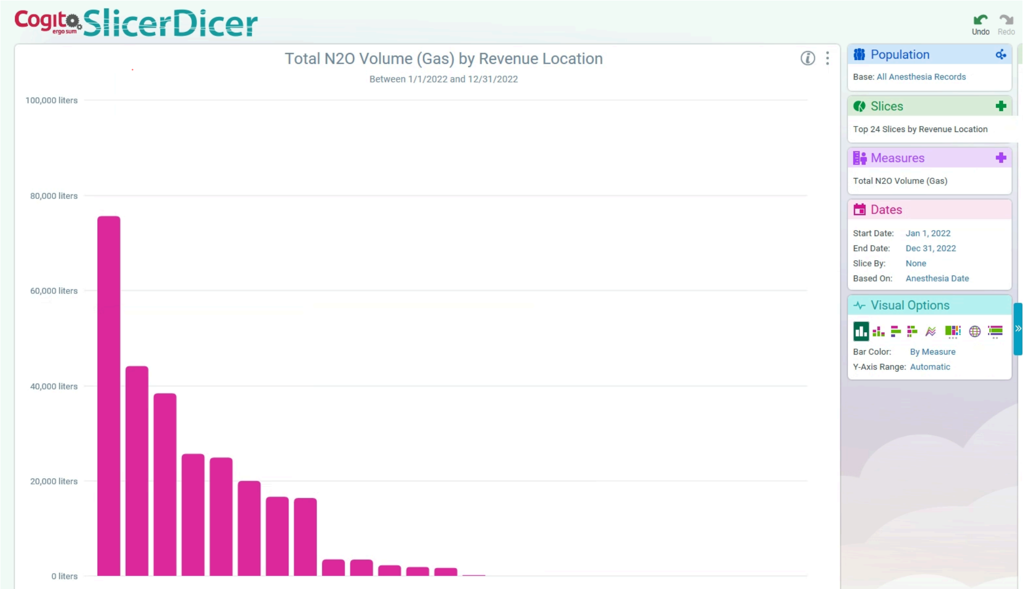
Choose the Date range you wish to review. At this point, the data being displayed is a total for your entire "Service Area" in Epic (often your entire health system).



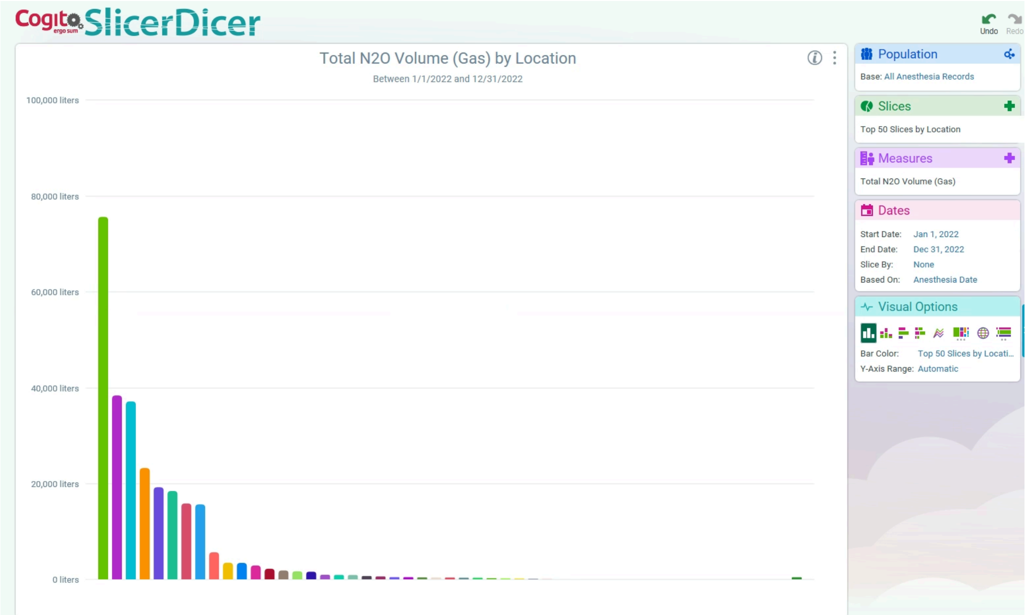
To get to location-specific data, you will need to "Add a Slice". Search for the record you'd like to slice by - note that slicing by "Location" or "Revenue Location" may yield different results (both of which may be useful in your analysis).



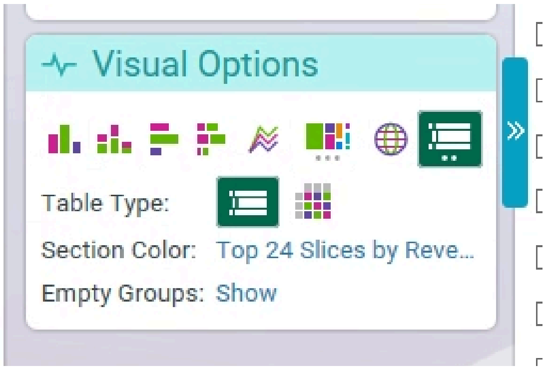
Once you've chosen which record to slice the data by, on the right-hand side, click "Grab Top ##". The number of location records you want to grab will depend on your organization. In the example below, while the top 100 "Revenue Locations" were pulled, this health system only has 24, so it shows them all.



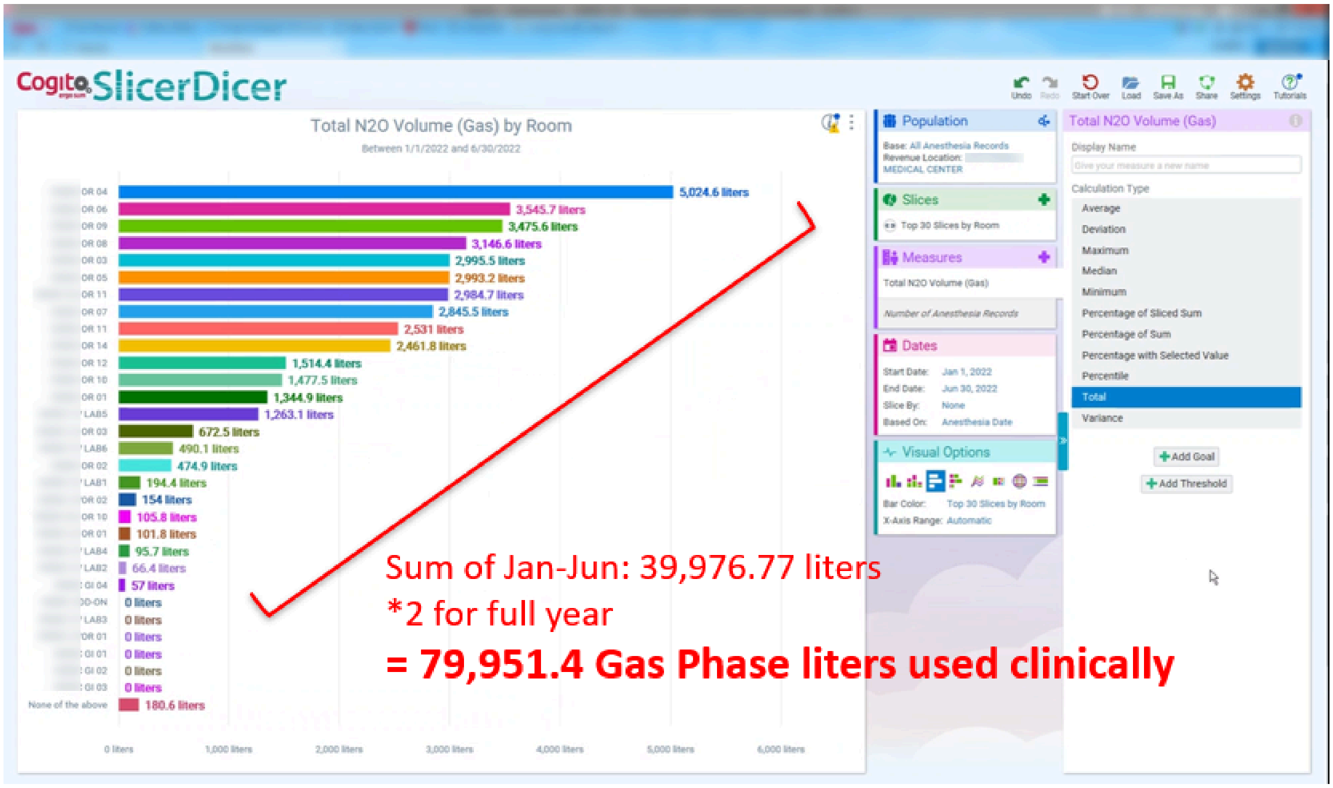
By changing your "Slice" you can show the amount of nitrous oxide used spread across different location types (ex. revenue location, location, operating room, etc.).



You can also change the view of your data using the visual options. The option on the far right will show data in table form which should allow you to export the data to excel.



In this example, data was queried for Jan-Jun and then simply doubled to get the approximate annual usage of 79,951 gas phase liters used for all rooms in which N_2O was used.



Note: *Anesthesia usage data pulled from Epic over the last few years may have erroneously high by-case usage. Epic corrected this in the November 2022 update, but some organizations are still seeing issues. It's recommended you check with your Epic OpTime Technical Support contact and do a brief audit of a few cases. If you find timeframes with errors, you can modify your date ranges to avoid this data issue (e.g.: a query for "1 January 2023 through 30 June 2023" will provide a dataset that can simply be doubled to get a good estimate of your annual usage). For this analysis example, the hospital did a record-by-record review of actual anesthesia usage to compare to the Epic-reported amount. From the analysis, they determined that Epic was over reporting by about 30%. So, from above, they multiplied the 79,951 by 70% to get the adjusted 55,966 gas phase liters used figure.*

From here, it's an easy calculation to determine how much of your purchase was actually used:

(55,966 gas phase liters used / 477,803 purchased) * 100 = 11.7%

From this analysis, the conclusion from this example can be read as:

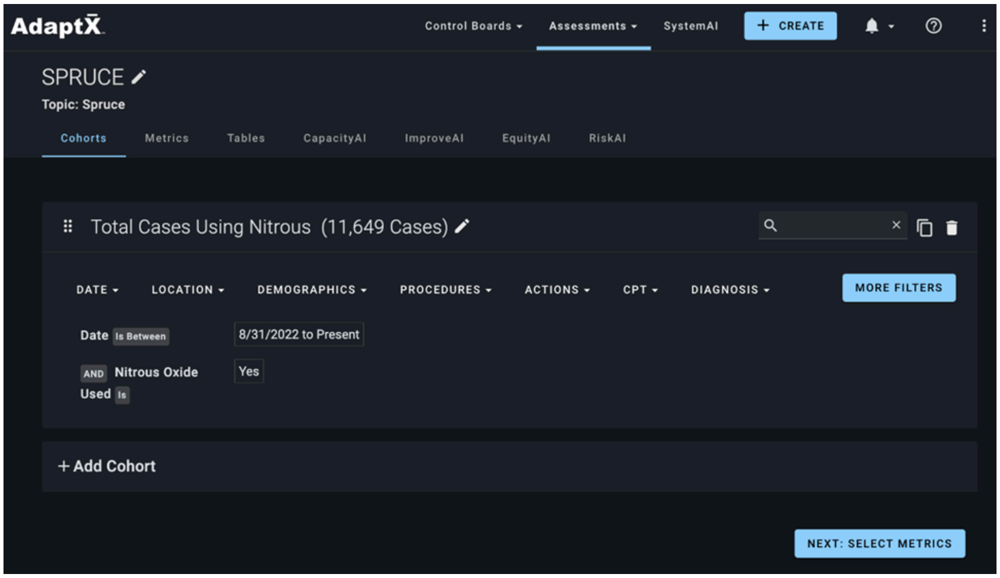
"This hospital's clinical usage was 11.7% of their total N_2O purchase."

or, read another way: "This hospital leaked or wasted more than 88% of their N2O."

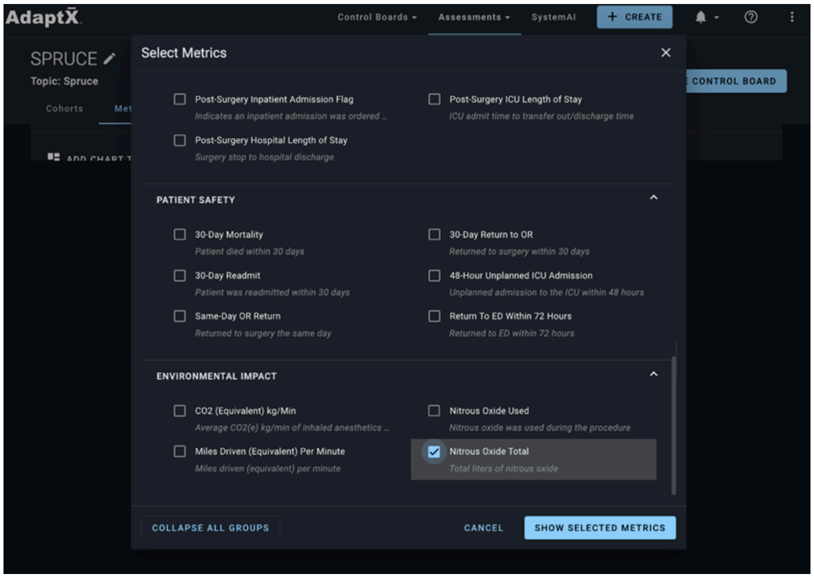
Provided below also are instructions determining clinical usage for AdaptX users. AdaptX is an application that helps clinical leaders analyze data from their EHRs to detect patterns and trends that might indicate ways to improve care or reveal inefficiencies in how care is delivered.

Steps for obtaining clinical usage through AdaptX

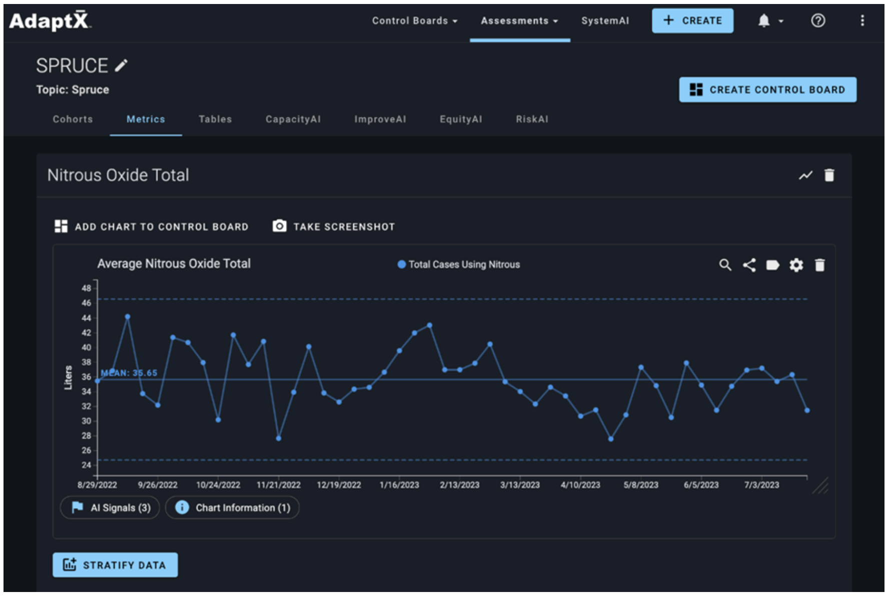
The first step is to create a cohort of patients identifying nitrous was used (11,649 cases here).



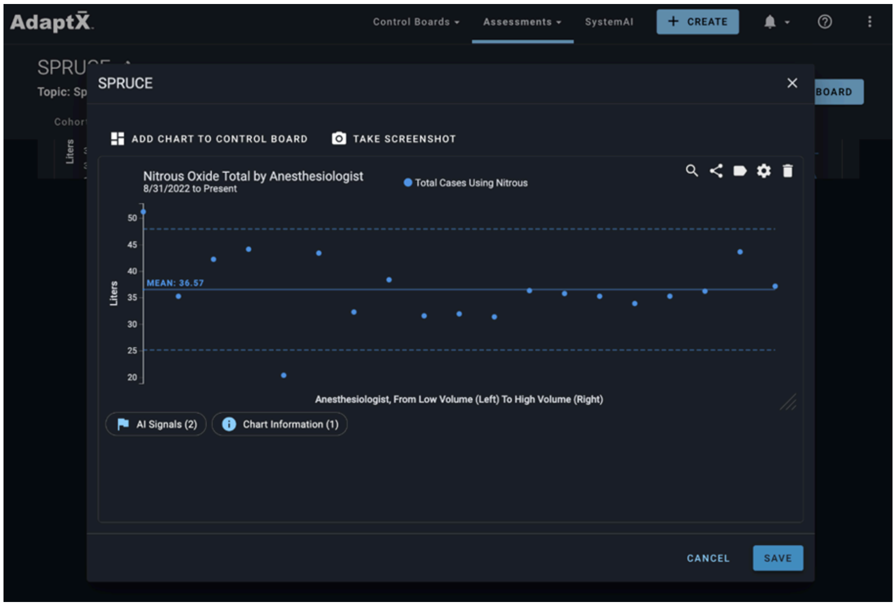
Select what you want to know about this cohort - in this case total nitrous (liters) used per case.



You can see average liters of nitrous oxide used per case is 35.65 liters (just multiply by your total cases 11,649) to get total for your hospital = **415,286 liters**



Tip: Now, the real power is showing who is doing what! Stratify the data by anesthesiologist, CRNA, resident, fellow etc. - this helps create the personal accountability needed to change practices.



7. Generic SBAR Language for Raising Awareness Among Stakeholders or Decision Makers

Feel free to use any of the following language, editing it for your circumstances, when communicating the issues to stakeholders and decision makers in your organization.

Discontinuing the Use of a Piped System for Nitrous Oxide

Situation

Less than 10% of the nitrous oxide (N_2O) that our hospital purchases is used for direct clinical application. The remainder is lost to leakage from many points throughout the distribution system within the medical center – cryogenic tanks, manifold, pipeline fittings, valves, wall outlets, and anesthesia machines – and to supplier disposal of the remaining gas in returned tanks. This very high rate of N_2O waste is not unique to our hospital.

Background

Nitrous oxide is an anesthetic gas that is used in combination with other agents to provide both anesthesia in the operating room, pain relief from labor, and as moderate sedation for minor procedures in the emergency department and dental clinics. Currently at our hospital, between five and 10 percent of surgical patients receive nitrous oxide for a portion of their care. Historically, the percentage of patients receiving nitrous oxide was much larger. Hospitals purchase and centrally store N_2O either in liquid form for refilling stationary 380-pound cryogenic tanks, or in the form of replaced 50-65 pound high pressure gas tanks (H-cylinders). It is standard practice to also purchase small, 7-pound E-cylinders for backup availability and place them on every anesthesia cart in the OR. Our hospital uses [*either* cryogenic *or* high pressure] tanks for bulk N_2O storage and pressurized gas distribution to the operating rooms and many treatment areas, including labor and delivery.

Cryogenic and high-pressure gas tank central supply systems are both inherently inefficient when it comes to N_2O. But cryogenic tanks are significantly worse, since they release pressure (or leak) by their very design. These systems have been found to leak more than 95% of their contents. In either storage system type, leakage is inescapable and impractical to remedy downstream. Even in hospitals using high pressure tanks instead of cryogenics, the loss rate is typically over 60%. The leakage occurs inside our buildings, exposing staff, patients, and visitors to the fugitive gas at some undetermined amount. Nitrous oxide is not entirely benign. Studies of workers exposed to N2O have reported adverse health effects such as reduced fertility, spontaneous abortion, and neurological, renal, and liver disease.

In addition to being an inefficient material use, nitrous oxide delivered through a central supply is a significant contributor to our hospital's carbon footprint. Despite its nominal clinical value, nitrous oxide makes up XX% of the greenhouse gas emissions from all anesthetic gas use at our hospital. This is due to N_2O's high global warming potential and 114-year lifespan in the atmosphere.

Assessment

The opportunity exists to bypass the central N_2O supply system and rely exclusively on portable E-cylinder use, without impacting patient care. Without much difficulty, our hospital can discontinue its central supply system and train its anesthesiologists to use the E-cylinders directly at the point of care. If clinicians open the E-cylinder valve when using the gas and close it at the end of any case when it is used, we can expect to reduce our N_2O purchases, and their greenhouse gas emissions, by over 87%.

Discontinuing N_2O central supply would save about $XX,000 per year, improve operational safety, and make our supply chain more resilient to shortages or emergencies, including earthquakes.

The transition logistics should be easy. The E-cylinders are already in place on nearly every anesthesia cart. This analysis shows that at the locations where N_2O is used most frequently, they would need to exchange E-cylinders about twice per year.

Recommendation

We recommend transitioning from central supply to E-cylinder for nitrous oxide. The safety, resiliency, environmental, and occupational exposure benefits of doing so are substantial. This change ties directly into our hospital's desire to decrease our operational greenhouse gas emissions.

Note that this is not a recommendation to our anesthesiologists to use less nitrous oxide, which is already utilized at very low rates; only a message to use the E-cylinders at the point of care rather than through a highly inefficient central supply.

8. Risk Assessment Template

Name: Hospital / Facility Click to Enter Facility Name

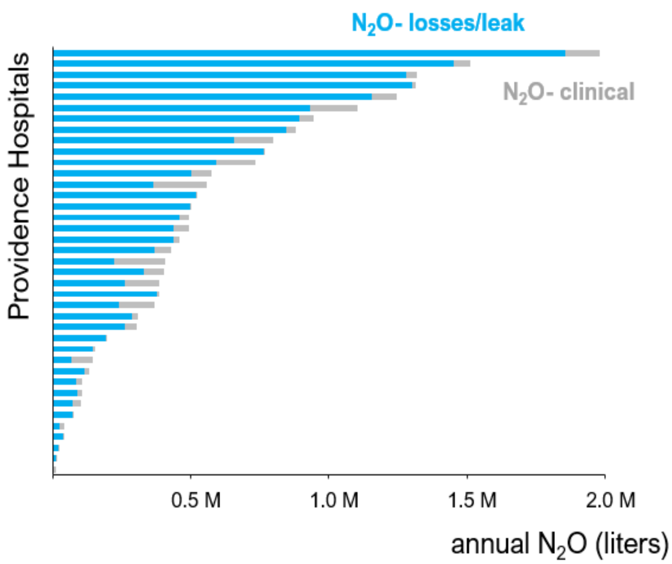
Proposed Change: transition supply of NITROUS OXIDE (N_2O) to portable E-cylinders and deactivate the central N_2O supply system.

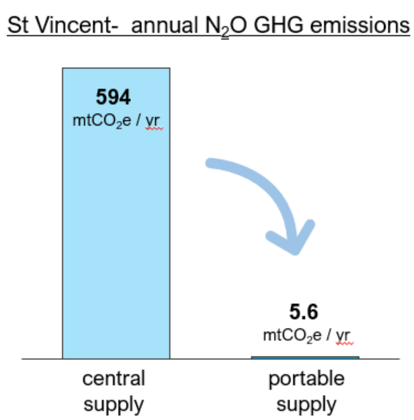
DESCRIBE THE ISSUE:

In alignment with the Providence goal of working toward becoming carbon negative by 2030, the direct greenhouse gas (GHG) emissions associated with nitrous oxide (N_2O) must be addressed. Nitrous oxide is a potent greenhouse gas, persisting in the atmosphere for 114 years with a global warming potential 298-times higher than carbon dioxide.

The largest source of medical N_2O consumption occurs via the central supply systems piped throughout hospital facilities. Work pioneered at Providence hospitals in Montana and Oregon compared clinical N_2O utilization to the total N_2O volume supplied and discovered that these central supply systems are inefficient, commonly wasting 70-95% of the N_2O purchased. These losses can occur at multiple points- from the supply tanks to the complex system of valves, gauges, outlets, couplings, and anesthesia machines.

Nevertheless, these excessive losses can be reduced to < 1% by shifting the primary supply of N_2O to portable compressed gas E-cylinders and deactivating the central N_2O supply system.





At Providence St Vincent Medical Center, the successful transition (Jan 2022) to a portable N_2O supply system reduced the overall consumption of N_2O and the associated GHG emissions ($mtCO_2e$) by 99%, while also maintaining the immediate, reliable clinical availability of N_2O.
Other hospitals within and beyond Providence have achieved similar results by transitioning the supply of N_2O to portable E-cylinders and deactivating central N_2O supply systems.

At enter facility name, the current central N_2O supply system **wastes** ## **%** of N_2O purchased.

Hospital / Facility Name: Click to Enter Facility Name

Analysis

SUPPORTING ARGUMENTS (why should the issue be changed?)	**OPPOSING ARGUMENTS** (why should the issue remain the same?)
ENVIRONMENTAL At enter facility name, the proposed change is projected to reduce annual N_2O GHG emissions by ## **$mtCO_2e$** (## **%** reduction).	
SAFETY At enter facility name, ## **liters** of N_2O are lost from the central supply system each year, creating potential workplace exposures that could exceed OHSA thresholds and increase associated health risks, including spontaneous abortion. Using portable N_2O E-cylinders confines the supply and clinical use within the highly controlled OR environment and eliminates the risk of exposure throughout the facility, while the E-cylinders themselves are relatively light and easy to handle, potentially reducing risk of physical injury associated with exchanging large central N_2O cylinders.	
EFFICIENCY Optimizing the efficiency of a central supply system is difficult, time-consuming, and potentially expensive. Some losses are unavoidable, such as residual N_2O volumes (~6-8%) in central containers and persistent, low-level losses from pressurized anesthesia machines.	Ordering, storage, and exchange of portable E-cylinders could present an additional workload that diverts labor from other critical and necessary tasks.
RESILIENCE As a parallel system, portable E-cylinders can be shifted to locations of high clinical utilization to extend the facility's supply in the event of an unanticipated disruption in N_2O market availability.	At present, the central supply system meets clinical demand.

COST The proposed change will reduce purchase costs by ## **%**, saving **$ ## /year**. The Facilities department would also be relieved of the labor required to maintain the central supply system.	For locations without pre-existing N_2O E-cylinders, there *may* be a cost associated with retrofitting anesthesia machines (in accordance with NFPA99-11.3.9).

Hospital / Facility — Click to Enter Facility Name

Other Considerations

Applicable performance improvement data, risk reports and/or Sentinel Event alerts?

Within the enter health system, enter facility name ranks **#** ## in highest overall N_2O consumption and is the ## **th** most efficient in its use of N_2O.

Clinically, nitrous oxide use is not widespread, with only **6.4%** of cases across the system receiving N_2O in 2023. Similarly, the **highest 10%** of clinicians (n = 140) using N_2O account for **72%** of system-wide clinical use, while 49% of clinicians (n = 682) did not use any N_2O in 2023.

Individual anesthesia clinicians' practices at enter facility name are highlighted in Figure 1 (attached).

Strategies to ensure adequate supply of nitrous oxide.

THIS PROJECT DOES NOT RESTRICT OR ELIMINATE CLINICAL ACCESS TO NITROUS OXIDE.

Establishing safe, consistent processes for the ordering, storage and use of portable E-cylinders is critical to ensure reliable clinical availability of N_2O. Location-specific N_2O utilization at enter facility name is presented in Figure 2 (attached).

Taken across the entire facility, ## cylinder exchanges per month are projected at enter facility name.

Applicable guidelines or regulations.

Facilities Guidelines Institute (FGI) releases guidelines on the design and construction of healthcare facilities.

○ The FGI guidelines (all versions) do NOT require a central nitrous oxide supply system.

○ Most states use FGI guidelines or FGI "equivalency" as their regulatory standard, although a small number of states have established independent regulatory standards (HI, IL, MN, SD, TX, WI).

- *Texas Administrative Codes do not require central N_2O supply systems (Table 6-133.169(f)).*

National Fire Protection Association Health Care Facilities Code (NFPA 99) provides criteria for the "installation, inspection, maintenance, and testing of all healthcare facilities." Applicable NFPA 99-2024 codes listed below (see attachment for details).

○ Portable medical gas cylinders
- storage- (11.3.1 – 11.3.10)
- handling & use- (11.5.2 – 11.5.3, 11.6.1, 11.6.3 – 11.6.5)

○ Central medical gas supply systems
- labeling- central system components must be labeled appropriately (5.1.11.1 – 5.1.11.5)
- deactivation- (A.5.1.14.3.5)

Hospital / Facility Name: Click to Enter Facility Name

Recommendation

Conclusion and Recommendation: PROCEED WITH THE PROPOSED CHANGE.

Based upon this local practice assessment and following the experience of other Providence hospitals, the transition to portable E-cylinder supply of N_2O is expected to result in significant benefits in environmental impact, institutional safety, system efficiency, resilience, and cost. The operational logistics of a safe, reliable portable E-cylinder supply system are easily manageable, while the Facilities team will be relieved of the responsibility of the central N_2O supply system.

See attached Implementation Checklist and Description Sheet for action items, responsibilities, and timelines.

Assessment completed by: enter name, role — enter date

Approval

Role / Name		Signature	Date
Facility Director:	enter name		enter date
Anesthesiology Dept Chair:	enter name		enter date
Operating Room Director:	enter name		enter date
Envir of Care / Safety Manager:	enter name		enter date
Chief Executive / Operating Officer:	enter name		enter date