

Nitrous Oxide Toolkit

Central Supply System Deactivation Guideline



CHEMICALS

 Providence



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TRANSPORTATION

TM

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Introduction



At Providence, we are inspired by a vision of good health creating a better world. We understand that the Earth, our common home, is a fundamental component of good health, and that we all must take responsibility for our contributions to environmental degradation. Our commitment to environmental stewardship is rooted in our core value of Justice, we strive to care wisely for our people, our resources, and our earth while focusing on finding solutions that are equitable for all.

We are proud to partner with other leading organizations and agencies to transform the health care sector. To show our leadership, we are doing all we can to work toward becoming carbon negative by 2030. To meet this aspirational goal, we are guided by our mitigation framework WE ACT, our resiliency framework We REACH and our advocacy framework We SHARE.

Providence caregivers are critical to this work. This toolkit outlines Providence's formal recommendation and suggested steps to transition to a portable nitrous oxide (N₂O) supply system with subsequent deactivation of the central supply system. The data are clear: central supply systems for nitrous oxide are inefficient, often wasting 70-99% of the nitrous oxide via infrastructure losses/leaks. Alternatively, a portable nitrous oxide supply system (using e-cylinders) is nearly 100% efficient—bypassing the central supply system while maintaining the immediate clinical availability of nitrous oxide. Several Providence hospitals have successfully transitioned to portable nitrous oxide supply systems, at little to no expense as these portable e-cylinders are often already in place as a redundant, reserve supply. As a result, following this transition, Providence St Vincent reduced this source of nitrous oxide GHG emissions by 99%.

OUR COMMITMENT

We are dedicated to caring for the poor and vulnerable by reducing environmental harm and injustice.

To show our dedication, we are doing all we can to work toward becoming carbon negative by 2030.





Nitrous Oxide (N₂O) Mitigation via Transition to Portable Supply Systems

Situation

In alignment with the Providence commitment to work toward carbon negative by 2030, the organization has initiated a systemwide transition of the nitrous oxide (N₂O) supply from the central pipeline system to a more efficient delivery system utilizing portable E-cylinders at the point of care.

Background

Nitrous oxide is a potent greenhouse gas (GHG), persisting in the atmosphere for 114 years with a global warming potential 298 (IPCC AR5) times higher than CO₂. The central pipeline systems supplying N₂O throughout hospitals are inefficient with potential for losses at multiple components. These losses resulted in the waste of 70-95% of purchased volumes. For example before transitioning to a portable supply system, N₂O waste at Providence Portland was 79%, resulting in excessive and unnecessary GHG emissions.

By measuring the amount of N₂O supplied to the central system vs the volumes used during clinical care, Providence was able to identify that avoidable losses of N₂O were occurring and developed solutions to significantly reduce their total N₂O GHG emissions. Providence's motivation for implementing these changes is to improve the value of these systems by reducing GHG emissions and financial costs, improving efficiency and resilience, and mitigating the potential health and safety risks associated with ongoing N₂O leaks/losses.

Assessment

Work pioneered at Providence hospitals in Montana and Oregon found that this wastage can be reduced to < 1% by deactivating the central supply system and instead utilizing portable E-cylinders on each anesthesia machine, or delivery unit, as the primary source of nitrous oxide.

Recommendations

Transition to portable supply systems for nitrous oxide and deactivate the central supply system.

Assemble Your Team

PROJECT TEAM MEMBERS

●	Project Coordinator- coordinates team members, action items and guides the project through all three phases of implementation.
●	Facilities Lead- ideally, the Facilities Lead role is filled by the staff member accountable for the central medical gas supply systems in the Facility. The Facilities Lead is a critical subject matter expert with action items throughout the project, with an emphasis on Phase 3- Deactivation.
●	OR Director- the OR Director has operational, educational, and leadership responsibility for the Operating Rooms and Perioperative departments, often including managerial oversight of Anesthesia Technicians. Involvement of the OR Director is most critical in Phase 2- Establish Portable Supply, as this involves logistic and workflow considerations within (& beyond) the department, as well as facilitating appropriate staff training and education.
●	Anesthesia Lead- in most facilities, the Anesthesiology department represents the sole, or majority, clinical utilizer of nitrous oxide. The engaged support of the Anesthesiology department is paramount to success. The Anesthesia Lead serves as a representative of the department in gathering data, soliciting feedback, providing education, and clinical leadership- particularly in Phase 1 and Phase 2.
Hospital Leadership- should be engaged and informed throughout implementation to support the project through leadership, accountability, and communication support.	

PHASE 1: ASSESSMENT

NITROUS OXIDE UTILIZATION

Gather central N2O supply system data (annualize).

Request at least 12 months of itemized N2O invoice data directly from the medical gas vendor (Airgas, Linde, etc). Normalize the data to a 12-month period. If possible, request the following data elements:

- invoice number
- delivery date
- facility name
- ship-to address
- item description (type of cylinder)
- number of each cylinder type per order
- amount N2O (pounds) per cylinder
- cost (\$) per cylinder

Not all medical N2O cylinders are used to supply the central system. When determining the total amount of centrally supplied N2O, be sure to include ONLY the large (≥ 50 lbs) central cylinders/containers. Nitrous oxide cylinders containing < 50 pounds are considered portable and used in clinical settings (cryoablation, sedation, analgesia, etc) not supplied by the central system.

Gather clinical N2O use data (annualize).

Clinical use volume data (N2O liters) should be gathered from the electronic medical record (EMR). Align the clinical report to the central supply system data interval (delivery dates) and normalize the data to a 12-month period. Some EMR products have clinical N2O volume reports pre-built (i.e.- Epic SlicerDicer), while others may require an analyst to build a custom report to query the N2O fresh gas flow data from anesthesia records. If possible, collect the following data elements:

- facility name
- date of surgery
- anesthesiologist / CRNA (name)
- operating room
- total N2O volume (liters) per surgery
- total N2O duration (minutes) per surgery

For facilities using pneumatic anesthesia machines &/or without an EMR, these clinical use data (N2O liters) will not be available. In this case, use the Nitrous Oxide Use Efficiency calculation (see below) to estimate the overall N2O consumption (clinical use + losses) in the facility. Alternatively, survey anesthesiologists and CRNAs to assess individual and group practices to estimate volume(s) of clinical N2O use.

PHASE 1 continued

Convert clinical N2O use data (liters) to pounds.

Clinical use data will be provided in LITERS. This can be converted to pounds as follows:

- 247.5 liters (N2O) = 1 pound (N2O)
- N2O gas density at STP (1.967 kg/m³- Merck Index Online, 2023) is corrected to 20°C and 760 mmHg using Charles's Law.

Calculate the % N2O use vs loss.

- The % of N2O CLINICAL USE = (clinical N2O lbs / central supply N2O lbs) x 100.
- The % of N2O LOSS/LEAK = ((central supply N2O lbs - clinical N2O lbs) / central supply N2O lbs) x 100.

Calculate greenhouse gas (GHG) emissions.

The global warming potential (GWP100) of nitrous oxide is 298 (IPCC AR5, 2014); meaning that every pound of N2O is the greenhouse gas (GHG) equivalent to 298 pounds of CO2. As such, GHG emissions are often measured in units of metric tons of CO2 equivalents (mtCO2e). The conversion for N2O pounds to mtCO2e is as follows:

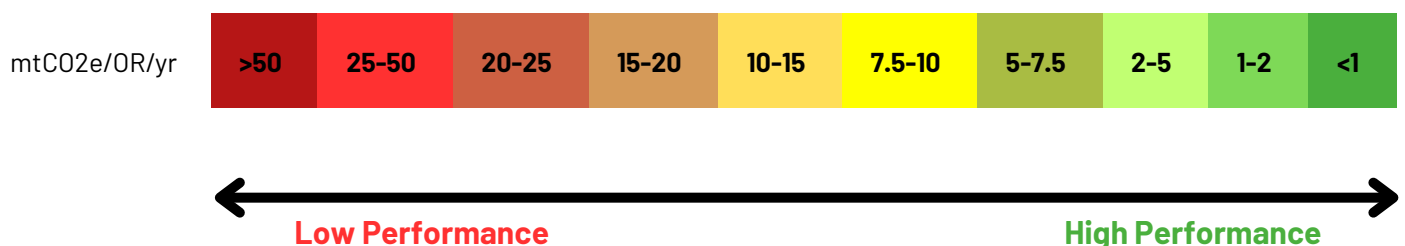
- 1 pound (N2O) = 0.135 mtCO2e

Calculate Nitrous Oxide Use Efficiency.

The complexity of the central supply system roughly mirrors the number of operating rooms in each facility. To provide a comparative measure of a facility's overall N2O consumption (clinical use + losses), the total annual N2O GHG emissions can be normalized by the number of operating rooms.

- Nitrous Oxide Use Efficiency = (annual central supply N2O emissions) / (# operating rooms)

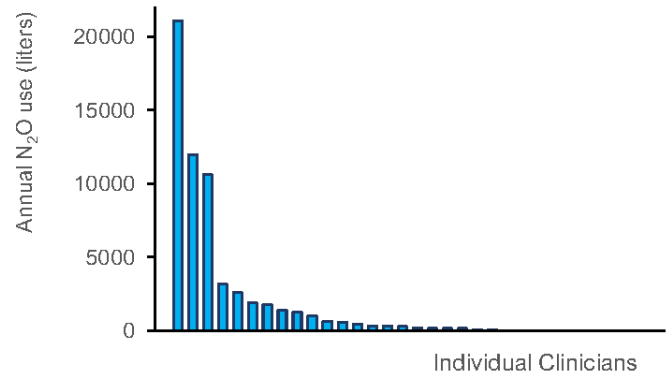
In Providence, the following table is used to track this measure across 52 acute care hospitals with a goal Nitrous Oxide Use Efficiency of < 1 mtCO2e/OR/year.



PHASE 1 continued

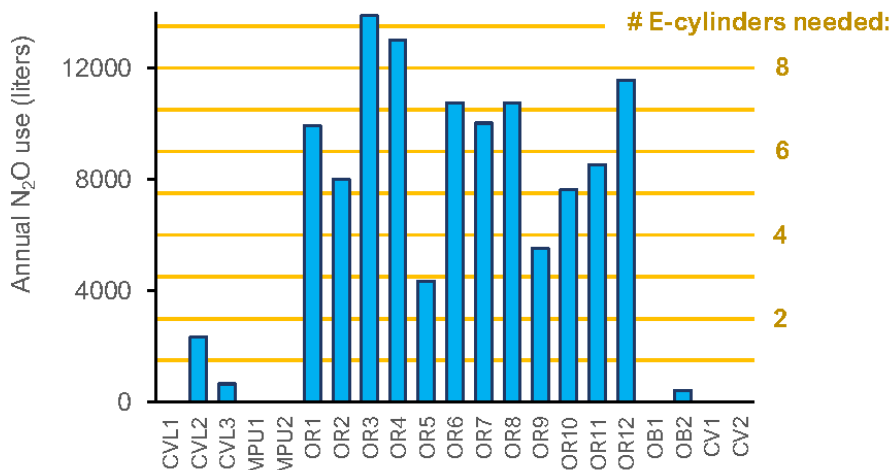
Consider: assess individual clinician N₂O utilization.

Clinical use of N₂O can vary dramatically between individuals and departments according to practice habits, with some people using N₂O every day, while others rarely or never use N₂O. Assessing individual practices can provide useful measures to engage clinicians on the variance in practice and encourage the judicious use of N₂O.



Consider: estimate E-cylinder exchange frequency for each clinical location.

Concerns often arise regarding the logistics needed to store, transport, and exchange the portable N₂O E-cylinders. Dividing the annual clinical use N₂O volume (liters) at each location by the volume of a N₂O E-cylinder (1590 liters- NFPA 99-2024: Table A.11.3.5) provides an estimate of the number of E-cylinders needed in each specific location and across the entire facility. This information is helpful to determine the PAR level for N₂O E-cylinders in the hospital, as well as identifying locations with higher clinical use, such as pediatric or neurosurgical operating suites. Clinical use of N₂O can vary dramatically between institutions, with implications for E-cylinder exchange frequency. For example, within Providence, the single clinical location with highest N₂O use requires approximately 22 N₂O E-cylinders per year (exchanging a cylinder roughly every 17 days), while most other locations throughout the health system might exchange a cylinder less than once per year, quarter or month.



PHASE 1 continued

FACILITY INFRASTRUCTURE

Gather inventory of N2O delivery units (anesthesia machines).

In preparation for Phase 2- Establish Portable Supply System, an inventory of anesthesia machines and other N2O delivery units (N2O sedation/analgesia machines) is needed. Different machine makes/models have different requirements and interfaces to receive portable N2O E-cylinders. Many machines have an integrated N2O yoke with attached cylinders, while some machines may require a retrofit yoke kit to receive a N2O E-cylinder (see photos below- Phase 2: Clinical Use). In addition, the different machines' low-pressure alarm thresholds and displays must be understood prior to the transition to portable N2O E-cylinders. If possible, collect the following elements for the machine inventory:

- make
- model
- use (anesthesia, sedation, analgesia)
- physical location
- is a N2O E-cylinder already in place?
- is a machine retrofit required?
- low-pressure threshold for N2O E-cylinder
- residual volume (liters) at time of alarm (estimate)

The low-pressure threshold for each machine make/model can be found in the technical specifications or by contacting the manufacturer. For example, the GE Aisys C2 anesthesia machine triggers an alarm when the N2O E-cylinder pressure reaches 381 psig, at which point the machine will continue to deliver an additional 95-100 liters before the N2O flow is discontinued. This residual E-cylinder volume was determined empirically at Providence Portland Medical Center and helps provide a rough estimate for consideration in other systems and alarm thresholds. Pneumatic anesthesia machines may require operator vigilance to determine timing of E-cylinder exchange, as they may not have a low-pressure alarm.

Gather central N2O supply system component inventory.

Prior to Phase 3- Deactivation of Central System, an inventory of the central N2O supply system is needed to prepare for appropriate removal, disabling and/or labeling of system components (outlets, valves, alarms). In addition, the outlet inventory helps identify each clinical department/location with potential access to the central N2O supply system. These departments must be engaged throughout the transition to ensure clinical care is uninterrupted. If possible, collect the following elements for the central system inventory:

- component (outlet, valve, alarm)
- physical location
- area(s) served
- clinical department(s) served

PHASE 2: ESTABLISH PORTABLE SUPPLY SYSTEM

STORAGE

Confirm location & logistics of primary portable medical gas storage room.

Most facilities have a primary portable medical gas storage room, which is often located in a central location to receive and store a variety of portable compressed gas cylinders (oxygen, CO₂, medical air, N₂O, argon, NO, etc) for subsequent use throughout the facility. The design and operation of these primary storage rooms are subject to NFPA 99 regulations, which vary depending on the total volume of compressed gases stored in the room (NFPA 99-2024: 11.3.5 – 11.3.7). If the facility's primary storage room is NOT approved to store volumes >85m³ (3000 ft³), any additional N₂O E-cylinders (56 ft³ / cylinder) must be carefully accounted to keep the overall storage volume(s) compliant (NFPA 99-2024: 11.3.6 – 11.3.7).

Determine department responsible for ordering & management of portable cylinders.

Most commonly, the Respiratory Therapy department is responsible for the ordering and initial management of portable medical gas cylinders, although other departments could include- Facilities, Safety Manager, or specific clinical managers. Regardless, the responsible department(s) and personnel should be engaged to coordinate the processes to order, receive, and store full (for use) and empty (for return) N₂O E-cylinders (NFPA 99-2024: 11.6.5.1 – 11.6.5.5).

Determine facility N₂O E-cylinder PAR level for primary storage room.

Facility PAR (periodic automatic replenishment) level for the primary storage room should be set appropriately to ensure adequate on-site supply of N₂O and in collaboration with Facilities, Respiratory Therapy, and the OR Director. The PAR level will depend, in part, on the capacity and logistics of the primary storage room, as well as the frequency of potential delivery from the medical gas vendor. A reasonable initial PAR level could be 4-5 N₂O E-cylinders in the primary storage room. Ideally, the determination can be further informed by clinical use data gathered earlier. For example, an initial suggested PAR level could provide storage for one month's facility-wide N₂O utilization as follows:

- facility N₂O E-cylinder PAR level = ((mean clinical N₂O use / month) / 1500)

Of note, if needed, aluminum N₂O E-cylinders to be used in the Magnetic Resonance Imaging (MRI) department should be accounted for separately.

Do additional N₂O E-cylinders need to be stored in clinical department(s)?

If deemed necessary, additional N₂O E-cylinders can be stored in clinical departments, but such storage must be NFPA-99 compliant. Outside of the primary storage room, the total volume of stored gases must not exceed 8.5m³ (300ft³) within a given smoke compartment (NFPA 99-2024: 11.3.7.1). Of note, NFPA 99-2024: 11.3.10 states, "individual small-size (A, B, D, E) cylinders available for immediate use in patient care spaces shall NOT be considered to be in storage."

PHASE 2 continued

HANDLING & EXCHANGE

Determine department responsible for N2O E-cylinder handling and exchange.

Usually, anesthesia technicians are the best-suited personnel to assume responsibility for the handling, transport, and exchange of N2O E-cylinders at the point of care. Anesthesia technicians are accustomed to fielding calls from clinicians to assist in anesthesia support and are in the best position to respond to clinicians' requests to exchange N2O E-cylinders. Anesthesia technicians commonly fall within the managerial oversight of the OR Director, whose leadership is required to facilitate this operational transition.

Define N2O E-cylinder handling & exchange protocols.

E-cylinder handling and exchange protocols should be created in collaboration with the Lead Anesthesia Technician, OR Director, Anesthesia Lead and Clinical Engineering department. These practices should also be in accordance with NFPA 99 regulations. Key components include:

- Storage & Handling (NFPA 99-2024: 11.6.5)
- Cylinder Exchange Procedures (NFPA 99-2024: 11.6.3)

Additional issues to consider:

- Certain types of O-rings between the N2O E-cylinder and the yoke connection can corrode following prolonged exposure to N2O. These O-rings should be inspected and replaced as needed during cylinder exchange.
- The N2O E-cylinder post valve should remain CLOSED when not in clinical use to eliminate low-level leaks within the anesthesia machine. Clinicians should open the post-valve immediately prior to use, while the anesthesia technicians should confirm post-valve closure on the N2O E-cylinder(s) during the end-of-day anesthesia machine shutdown protocol.



E-cylinder post
valve stem



Design & deliver N2O E-cylinder management competency program.

As E-cylinder management may represent a skillset beyond what is considered a core competency of anesthesia technicians, it is recommended that a clinical competency program be established to ensure consistent knowledge and skill. This program should be designed and administered in collaboration with the Clinical Engineering and Anesthesiology departments and compliant (NFPA 99-2024: 11.5.2.1, 11.6.1.2).

PHASE 2 continued

CLINICAL USE

Identify & engage department(s) utilizing centrally supplied N₂O.

Use the central supply system outlet inventory to identify each location and clinical department with access to the central supply system. The department/unit managers for each department should be engaged to determine the extent to which N₂O is clinically used and whether barriers exist to the transition to a portable supply system.

Confirm compatibility of N₂O delivery units with portable N₂O E-cylinders.

Typically, the most common and relevant N₂O delivery units are anesthesia machines, but could also include portable sedation/analgesia units occasionally used in Labor/Delivery, ICU, or Emergency Dept. Compatibility with N₂O E-cylinders with all relevant delivery units should be confirmed. Some anesthesia machines, for instance, must be retrofitted to accept a N₂O E-cylinder, while others have integrated N₂O cylinder yoke attachments.



Integrated N₂O
E-cylinder
attachment.



Retrofitted N₂O
E-cylinder
attachment.

Establish criteria to trigger exchange of a N₂O E-cylinder.

The Anesthesia Lead, in collaboration with the project team, should define the conditions at which a N₂O E-cylinder is considered “empty” and in need of exchange. For some, “empty” could be defined as the low-pressure alarm threshold on the anesthesia machine, while others might prefer to use each E-cylinder until it is completely empty with no residual N₂O gas/pressure. Ultimately, the timing of E-cylinder exchange should be at the discretion of the anesthesia clinician at the point of care.

Define Anesthesiology Department education module.

The Anesthesia Lead should assist with designing and delivering an educational module for the impacted department(s) to ensure that all clinicians are informed and prepared. Specific issues for emphasis could include: 1) the N₂O E-cylinder post-valve should remain closed when not in use, 2) individual clinicians are responsible for opening the valve prior to clinical use, 3) the anesthesia technicians will confirm closure of the valve during end-of-day machine shutdown procedures, 4) low pressure alarm thresholds and interfaces (machine checkout & real-time alarms) should be presented for each anesthesia machine make/model in the facility, 5) the residual N₂O volume in the E-cylinders at the low-pressure threshold should also be communicated, and finally, 6) clinicians should receive instruction on the safe handling and exchange of N₂O E-cylinders.

PHASE 3: DEACTIVATION OF CENTRAL SYSTEM

Confirm with Responsible Facility Authority (RFA) and Authority Having Jurisdiction (AHJ).

Ultimately, the person accountable for the medical gas central supply systems is the hospital's Responsible Facility Authority (RFA), or designated equivalent. The RFA is often the Facilities Director or designate with responsibilities outlined in NFPA 99-2024: 5.1.14.1. Beyond the hospital or health system, the perspective of the Authority Having Jurisdiction (AHJ) should be considered, as some AHJ may not consider the operational change of this mitigation project to fall within their purview, while others may want more direct involvement. The AHJ varies from facility to facility and state to state. Examples of AHJ could include: a federal, state, or local agency such as a Department of Health, a fire marshal, building official, or other(s) having statutory authority.

Conduct a risk assessment to consider operational and value implications.

A risk assessment should be completed to identify and address potential local risks, challenges, and benefits associated with this transition to portable N2O supply systems. (see attached example)

DISCONNECT

Many sites choose to conduct a Disconnection Trial to test the process logistics of the portable supply system established in Phase 2. Anesthesia machines and other clinical delivery units (sedation/analgesia units, etc) can be easily disconnected from the central supply system hose couplings or wall outlets. This disconnection does not disrupt the central supply system "behind the walls" and the anesthesia machines can be reattached to the central supply system within seconds if needed.

Disconnect all delivery units from central supply system outlets or couplings.

Anesthesia machines and other clinical N2O delivery units (sedation, analgesia, etc) should be disconnected from the central N2O supply system at the wall outlet or hose coupling.

N2O
Wall Outlet



Label each outlet.

During the disconnection trial, the point of disconnection should be clearly labelled indicating the nature of the trial and instructing staff to NOT reattach to the central system.

PHASE 3 continued

Trial period.

Start and end dates for the disconnection trial should be determined and communicated to relevant departments. A common and reasonable disconnection trial period is 1-2 months. Once the portable supply system processes are in place, there should be no delay in starting the disconnection trial while preparing for the subsequent Depressurization and Deactivation steps.

Solicit feedback from stakeholders & address concerns prior to depressurization.

At the conclusion of the disconnection trial, feedback from stakeholders should be solicited. Any concerns or challenges should be addressed prior to proceeding to Depressurization Trial.

DEPRESSURIZE

Draft & distribute hospital-wide communication (SBAR).

Prior to depressurization of the central supply system, a hospital-wide communication (SBAR) should be distributed. All clinical departments with access points (i.e.- wall outlets) to the central system should already be engaged and well-prepared following Phase 2 and the Phase 3-Disconnection Trial. However, staff must be aware that the central system will be depressurized and any attempt to reconnect machines will NOT result in the clinical delivery of N2O via the central supply system.

Confirm all central system alarms are disabled prior to closure of the central valve.

Prior to depressurization, the Facilities Team must identify and disable all low-pressure alarms in the central N2O supply system. Alarms and alarm panels should be labelled as "DISABLED" or "INACTIVATED." As part of the SBAR communication, contact information should be included to field any alarm-related questions and concerns which may arise immediately following depressurization.

Trial period.

Start and end dates of Depressurization Trial should be determined. A common and reasonable trial period is 1-2 months, during which time the Facilities Team can be preparing for deactivation.

Close central valve (immediately downstream from central manifold).

To start the trial, the central valve should be closed to depressurize the central N2O supply system.

Solicit feedback from stakeholders & address concerns prior to deactivation.

Prior to final deactivation, another round of stakeholder feedback should be solicited with concerns addressed.

PHASE 3 continued

DEACTIVATE

Remove components.

Upon deactivation of the central system, the following components should be REMOVED:

- Central N2O supply compressed gas cylinders and/or cryogenic containers.
- Drop hoses, if applicable.

Disable components.

Upon deactivation, the following components should be DISABLED:

- Alarms: disabling procedure is specific to alarm make/model. Refer to manufacturer for details.
- Valves: all central N2O system valves should be CLOSED, with valve handles either removed or fixed in place.
- Outlets: outlets can be addressed via options listed in NFPA 99-2024: A.5.1.14.3.5.
 - Outlets removed and tubing capped.
 - Outlets plugged, provided with a blank-off plate.
 - Outlets remain accessible for maintenance and testing.
 - Other means deemed appropriate by the AHJ.
- Central manifold



Label components.

All central N2O supply system components should be clearly labeled as INACTIVE or DISCONTINUED in accordance with NFPA 99 system labeling regulations. Specifically, components should be labeled according to the following:

- Alarms and Alarm Panels (NFPA 99-2024: 5.1.11.4)
- Valves (NFPA 99-2024: 5.1.11.2)
- Outlets (NFPA 99-2024: 5.1.11.3)

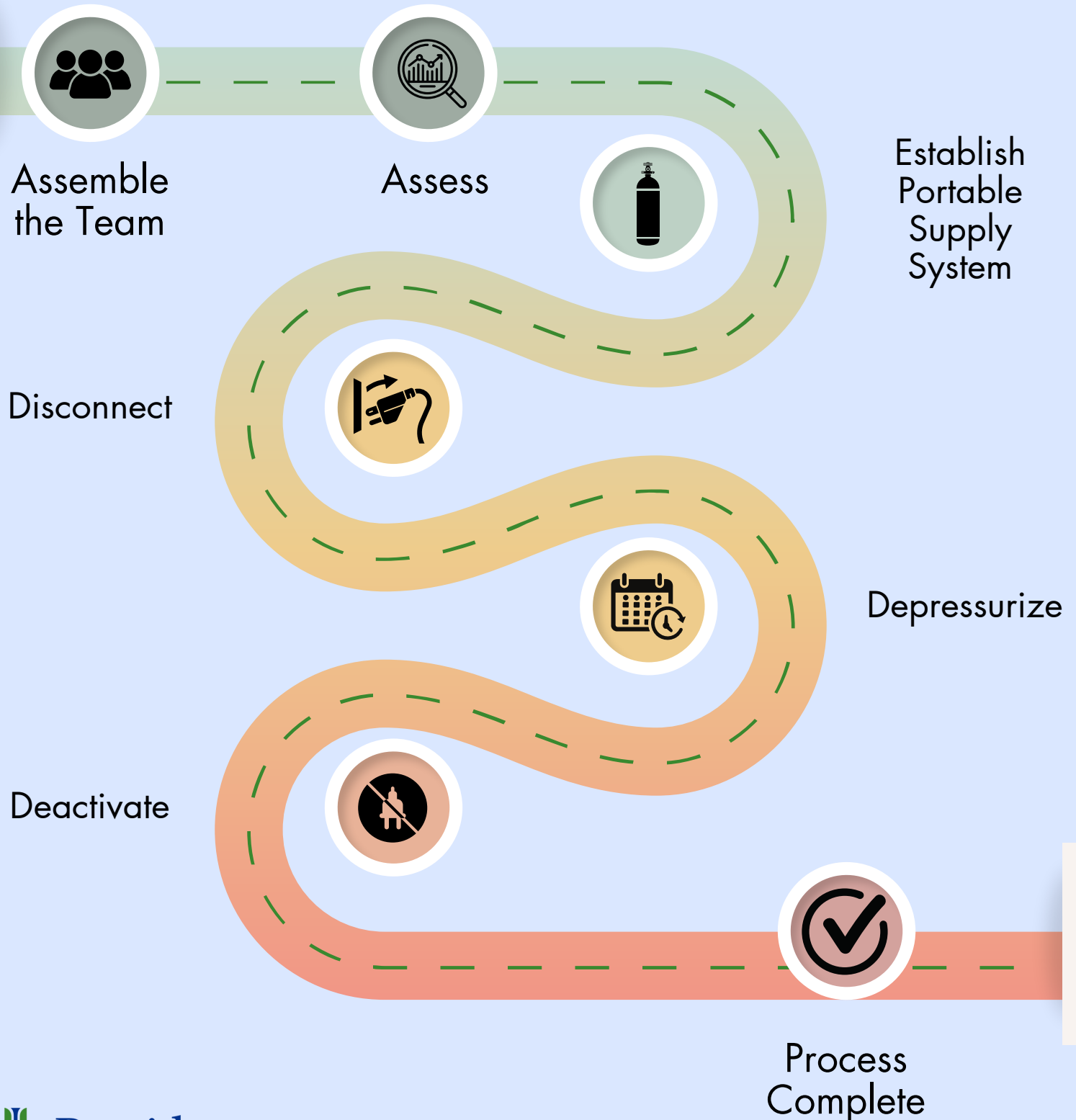
Consider consultation with medical gas system certifier.

Local or Regional medical gas system certifiers may be helpful as subject matter experts with operational/technical support and applicable regulatory requirements.

Appendix

NITROUS OXIDE CENTRAL SUPPLY SYSTEM DEACTIVATION

A STEP-BY-STEP GUIDE



NITROUS OXIDE (N₂O) MITIGATION PROJECT CHECKLIST

Anesthesia Lead
OR Director
Facilities Lead
Project Coordinator

FACILITY NAME

PHASE 1: ASSESSMENT

NITROUS OXIDE UTILIZATION

- | | | | | | | | |
|-----------------------|-----------------------|-----------------------|-----------------------|---|----------------|--------------------------|------|
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Gather central N ₂ O supply system data (<i>annualize</i>). | ### (lbs) | <input type="checkbox"/> | date |
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Gather clinical N ₂ O use data (<i>annualize</i>). | ### (liters) | <input type="checkbox"/> | date |
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Convert clinical N ₂ O use data (liters) to pounds. | ### (lbs) | <input type="checkbox"/> | date |
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Calculate % N ₂ O use vs loss: CLINICAL USE- ### (%) LOSS/LEAK- ### (%) | | <input type="checkbox"/> | date |
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Calculate GHG emissions: CLINICAL N ₂ O- ### (mtCO ₂ e) TOTAL N ₂ O- ### (mtCO ₂ e) | | <input type="checkbox"/> | date |
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Calculate Nitrous Oxide Use efficiency. | ### | <input type="checkbox"/> | date |
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Consider- assess individual clinician N ₂ O utilization. | choose an item | <input type="checkbox"/> | date |
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Consider- estimate E-cylinder exchange frequency per location. | choose an item | <input type="checkbox"/> | date |

FACILITY INFRASTRUCTURE

- | | | | | | | | |
|-----------------------|-----------------------|-----------------------|-----------------------|--|----------------|--------------------------|------|
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Gather inventory of N ₂ O delivery units (anesthesia machines). | choose an item | <input type="checkbox"/> | date |
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Gather central N ₂ O supply system component inventory. | choose an item | <input type="checkbox"/> | date |

PHASE 2: ESTABLISH PORTABLE SUPPLY SYSTEM

STORAGE

- | | | | | | | | |
|-----------------------|-----------------------|-----------------------|-----------------------|--|----------------|--------------------------|------|
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Confirm location & logistics of primary portable medical gas storage room. | | <input type="checkbox"/> | date |
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Determine dept responsible for <u>ordering</u> & mgmt of portable cylinders. | choose an item | <input type="checkbox"/> | date |
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Determine facility N ₂ O E-cylinder PAR level for primary storage room. | ### | <input type="checkbox"/> | date |
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Do additional N ₂ O E-cylinders need to be stored in clinical dept(s)? | choose an item | <input type="checkbox"/> | date |

HANDLING & EXCHANGE

- | | | | | | | | |
|-----------------------|-----------------------|-----------------------|-----------------------|---|----------------|--------------------------|------|
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Determine dept responsible for N ₂ O E-cylinder handling & exchange. | choose an item | <input type="checkbox"/> | date |
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Define N ₂ O E-cylinder handling & exchange protocols. | | <input type="checkbox"/> | date |
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Design & deliver N ₂ O E-cylinder management competency program. | | <input type="checkbox"/> | date |

CLINICAL USE

- | | | | | | | | |
|-----------------------|-----------------------|-----------------------|-----------------------|---|----------------|--------------------------|------|
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Identify & engage department(s) utilizing centrally supplied N ₂ O: | | | |
| | | | | <input type="checkbox"/> -MainOR <input type="checkbox"/> -PedsOR <input type="checkbox"/> -CVOR <input type="checkbox"/> -Endoscopy <input type="checkbox"/> -Cath Lab <input type="checkbox"/> -Radiology <input type="checkbox"/> -MRI | | | |
| | | | | <input type="checkbox"/> -Labor/Delivery <input type="checkbox"/> -Outpatient Surgery <input type="checkbox"/> -Emerg. Dept <input type="checkbox"/> -ICU <input type="checkbox"/> -Other: dept name | | | |
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Confirm compatibility of N ₂ O delivery units with portable N ₂ O E-cylinders. | | <input type="checkbox"/> | date |
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Establish criteria to trigger exchange of N ₂ O E-cylinder. | choose an item | <input type="checkbox"/> | date |
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Define Anesthesiology Dept education module. | | <input type="checkbox"/> | date |

NITROUS OXIDE (N₂O) MITIGATION PROJECT CHECKLIST

Anesthesia Lead	OR Director	Facilities Lead	Project Coordinator	
				FACILITY NAME
				PHASE 3: DEACTIVATE CENTRAL SUPPLY SYSTEM
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Confirm with Responsible Facility Authority (RFA) and Authority Having Jurisdiction (AHJ). RFA (or equivalent): <u>Name, Role</u> AHJ: <u>Department Name</u> <input type="checkbox"/> <u>date</u>
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Conduct a risk assessment to consider operational and value implications. <input type="checkbox"/> <u>date</u>
				DISCONNECT
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Disconnect all delivery units from central supply system outlets or couplings. <input type="checkbox"/> <u>date</u>
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Label each outlet: "Portable N ₂ O supply trial underway. Do NOT reconnect." <input type="checkbox"/> <u>date</u>
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Trial period: (<u>start date</u> to <u>end date</u>) <input type="checkbox"/> <u>date</u>
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Solicit feedback from stakeholders & address concerns prior to depressurization. <input type="checkbox"/> <u>date</u>
				DEPRESSURIZE
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Draft & distribute hospital-wide communication (SBAR) <input type="checkbox"/> <u>date</u>
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Confirm all central system alarms are disabled prior to closure of central valve. <input type="checkbox"/> <u>date</u>
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Trial period: (<u>start date</u> to <u>end date</u>) <input type="checkbox"/> <u>date</u>
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Close central valve (immediately downstream from central manifold). <input type="checkbox"/> <u>date</u>
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Solicit feedback from stakeholders & address concerns prior to deactivation. <input type="checkbox"/> <u>date</u>
				DEACTIVATE
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Remove components: <input type="checkbox"/> <u>date</u> <input type="checkbox"/> - central N ₂ O supply tanks, <input type="checkbox"/> - central N ₂ O manifold, <input type="checkbox"/> - drop hoses
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Disable components: <input type="checkbox"/> <u>date</u> <input type="checkbox"/> - alarms, <input type="checkbox"/> - valves, <input type="checkbox"/> - outlets
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Label components: "INACTIVE" or "DISCONTINUED" <input type="checkbox"/> <u>date</u> <input type="checkbox"/> - alarms, <input type="checkbox"/> - valves, <input type="checkbox"/> - outlets
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Consider consultation with medical gas system certifier. <input type="checkbox"/> <u>date</u>

<input type="radio"/>	Project Coordinator	<u>NAME</u>	<u>E-MAIL ADDRESS</u>	<u>PHONE</u>
<input type="radio"/>	Facilities Lead	<u>NAME</u>	<u>E-MAIL ADDRESS</u>	<u>PHONE</u>
<input type="radio"/>	OR Director	<u>NAME</u>	<u>E-MAIL ADDRESS</u>	<u>PHONE</u>
<input type="radio"/>	Anesthesia Lead	<u>NAME</u>	<u>E-MAIL ADDRESS</u>	<u>PHONE</u>
	Hospital Leadership	<u>NAME</u>	<u>E-MAIL ADDRESS</u>	<u>PHONE</u>

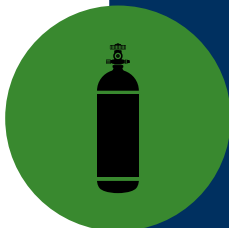
Tips and Tricks



Stratify clinical N₂O use data by location to predict cylinder exchange frequencies and facilitate logistical planning.



Contact the medical gas vendor directly to request supply reports.



Go on a tour! See the system elements in person to better understand the reports, infrastructure, and processes.

FAQ

Q: Our systems are regularly tested without finding leaks. How do we know we are losing these large amounts of nitrous oxide?

- A: We test the overall efficiency of the system by comparing the amount supplied to the amount clinically delivered (via anesthesia machines) rather than trying to find isolated physical leaks. When viewed as a whole system rather than as individual components, we find a large degree of waste and inefficiency. **We know how much nitrous we put into the system vs the amount used clinically, and we see a huge discrepancy.**

Q: Are we required to have centrally supplied nitrous oxide?

- A: No. The Facilities Guidelines Institute (FGI) provides the guidelines for the design and construction of medical facilities. These guidelines do NOT require central nitrous oxide supply systems.

Q: Does this mean we are losing clinical access to nitrous oxide?

- A: No. The portable nitrous oxide supply cylinders will provide immediate, reliable access at all relevant clinical locations. This initiative is aimed at reducing waste, not availability.

Q: Are these portable e-cylinders big enough? Will we have to change them frequently? Will this be a logistical challenge?

- A: The frequency of portable E-cylinder exchanges will vary depending on the amount of clinical use at a particular location within a particular facility. Within Providence, the single location with the highest clinical use should exchange an E-cylinder approximately once every 2.5 weeks. Most locations will need to exchange E-cylinders far less frequently.

Q: What are the expenses related to this program?

- A: Some anesthesia machines may require a simple retrofit in order to accept a N2O e-cylinder. If you already have e-cylinders in place there is little to no investment.

Q: This sounds complicated. Is this hard to do?

- A: In essence, the data clearly show the extent of the problem (phase 1), the portable supply system is reliable and efficient (phase 2) and deactivating the central supply system (phase 3) is straightforward- disconnect, depressurize and label the components appropriately.

Environment of Care Risk Assessment

(adapted from Fig 1-6, Joint Commission Resources, 2nd edition)

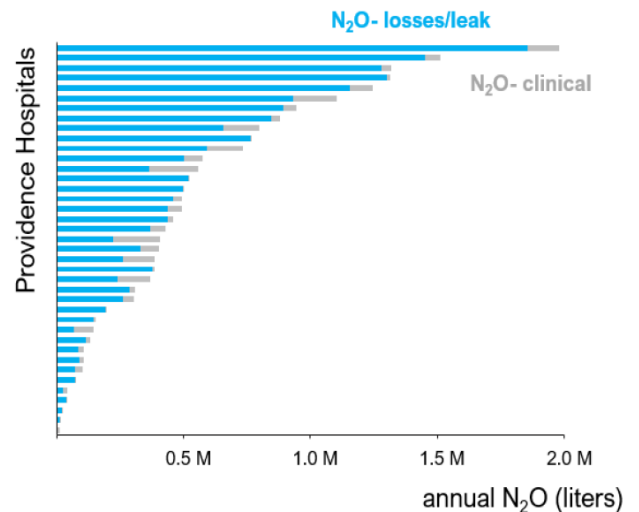
Hospital/Facility Name:

Proposed Change: Transition supply of NITROUS OXIDE (N₂O) to portable E-cylinders and deactivate the central N₂O supply system.

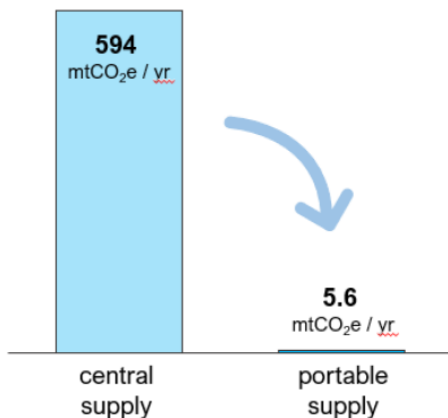
DESCRIBE THE ISSUE:

In alignment with the Providence goal of working toward becoming carbon negative by 2030, the direct greenhouse gas (GHG) emissions associated with nitrous oxide (N₂O) 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 N₂O consumption occurs via the central supply systems piped throughout hospital facilities. Work pioneered at Providence hospitals in Montana and Oregon compared clinical N₂O utilization to the total N₂O volume supplied and discovered that these central supply systems are inefficient, commonly wasting 70-95% of the N₂O purchased. These losses can occur at multiple points- from the supply tanks to the complex system of valves, gauges, outlets, couplings, and anesthesia machines.



St Vincent- annual N₂O GHG emissions



Nevertheless, these excessive losses can be reduced to < 1% by shifting the primary supply of N₂O to portable compressed gas E-cylinders and deactivating the central N₂O supply system.

At Providence St Vincent Medical Center, the successful transition (Jan 2022) to a portable N₂O supply system reduced the overall consumption of N₂O and the associated GHG emissions (mtCO₂e) by 99%, while also maintaining the immediate, reliable clinical availability of N₂O. Other hospitals within and beyond Providence have achieved similar results by transitioning the supply of N₂O to portable E-cylinders and deactivating central N₂O supply systems.

Environment of Care Risk Assessment

Hospital/Facility Name:

Analysis	
SUPPORTING ARGUMENTS (Why should the issue be changed?)	OPPOSING ARGUMENTS (Why should the issue remain the same?)
ENVIRONMENTAL: At _____ (facility), the proposed change is projected to reduce annual N2O GHG emissions by ____mtCO2e (____% reduction).	
SAFETY: At _____ (facility), _____ liters of N2O are lost from the central supply system each year, creating potential workplace exposures that could exceed OSHA thresholds and increase associated health risks, including spontaneous abortion. Using portable N2O 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 N2O cylinders.	
EFFICIENCY: Optimizing the efficiency of a central supply system is difficult, time-consuming, and potentially expensive. Some losses are unavoidable, such as residual N2O 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 N2O 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 N2O E-cylinders, there may be a cost associated with retrofitting anesthesia machines (in accordance with NFPA99-11.3.9).

Environment of Care Risk Assessment

Hospital/Facility Name:

Other Considerations

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

Within your health system, _____ ranks # _____ in overall N2O consumption and is the # _____th most efficient in its use of N2O.

Clinically, nitrous oxide use is not widespread amongst anesthesia clinicians.

- Over the past 12 months, the top-5 clinicians used _____ % of the department's total, while the top-10 used _____%.
- Simultaneously, _____ (#) clinicians did not use any N2O.

Strategies to insure 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 N2O.

Taken across the entire facility, _____ (#) cylinder exchanges per month are projected at _____ (facility).

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 N2O 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 health care facilities." Applicable NFPA 99-2024 codes listed below.

- 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)

Environment of Care Risk Assessment

Hospital/Facility Name:

Recommendation		
Conclusion and Recommendation: <u>PROCEED WITH THE PROPOSED CHANGE</u>		
<p>Based upon this local practice assessment and following the experience of other Providence hospitals, the transition to portable E-cylinder supply of N2O 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 N2O supply system.</p> <p>See attached Implementation Checklist and Description Sheet for action items, responsibilities, and timelines.</p>		
Assessment completed by:	Name(s):	Date:
Approval Signatures		
Facility Director (name):		Date:
Anesthesiology Department Chair (name):		Date:
Operating Room / Perioperative Director (name):		Date:
Environment of Care Safety Manager (name):		Date:
Chief Executive / Operating Officer (name):		Date:

Competency Statement and Evaluation

Anesthesia Machine Nitrous Oxide (N2O) E-Cylinder Tank Replacement

This competency is supplemental and is not required by regulation or policy.

☐ New Hire

☐ Ongoing

Employee Name: _____

Facility: _____

Department Name: _____

Employee #: _____

Regarding the competencies below: I understand the key points necessary to provide safe and appropriate care, can demonstrate safe performance, and agree to follow approved guidelines.

Signature: _____ Initials: _____

Date of Validation: _____

Competency Statement: The caregiver will demonstrate knowledge of E-cylinder handling and safety precautions when exchanging and validating connection on anesthesia machine.

Criteria: The caregiver will correctly complete the following:	Verification Method*	Date	Validator Initials**
<p>Attends Clinical Engineering/Biomed in-service on how to maintain safety with E-cylinders to include:</p> <ul style="list-style-type: none">• Hazards associated with compressed medical gas.• Review types of nitrous oxide E-cylinders (color) and how to identify which are MRI safe.• Safe, appropriate transport and handling of E-cylinders.• Pin-index safety system.• Review manufacturers' instructions for use related to E-cylinder exchange procedures for relevant anesthesia machine makes/models.<ul style="list-style-type: none">◦ Including inspection & replacement of the O-ring gasket between the E-cylinder and the yoke attachment.	Didactic		
<p>Tour the primary portable medical gas storage room to observe the proper storage & retrieval of full N2O E-cylinders and return of empty E-cylinders.</p> <p>Location:</p>	Direct Observation		



Competency Statement and Evaluation

Criteria: The caregiver will correctly complete the following:	Verification Method*	Date	Validator Initials**
<p>Demonstrate process for exchanging a N2O E-cylinder (removal, connection, verification, labelling).</p> <p>Exchange protocol:</p> <ol style="list-style-type: none"> 1. use wrench to close post-valve on E-cylinder to be replaced/exchanged. 2. loosen tee-handle on the yoke assembly to release the E-cylinder. 3. remove used/empty cylinder. 4. inspect the used O-ring gasket and replace it as needed. 5. align full E-cylinder with yoke pin-index safety system. 6. tighten tee-handle on yoke assembly to secure cylinder connection. 7. test connection <ol style="list-style-type: none"> a. open the E-cylinder post-valve. b. listen for leak if present reattach/tighten the yoke assembly &/or replace the O-ring gasket. c. label E-cylinder: date/initial cylinder pressure. 	Return Demonstration		
<p>Describes identification of aluminum, MRI-compatible E-cylinders.</p> <p>Gas cylinders for use in MRI (magnetic resonance imaging) suites must be made of aluminum and are silver with the associated medical gas color on the top portion.</p>	Verbal Response		



Competency Statement and Evaluation

Criteria: The caregiver will correctly complete the following:			Verification Method*	Date	Validator Initials**
Recognize and interpret the following scenarios: <ul style="list-style-type: none"> The post-valve should be closed following clinical use to prevent any loss/leak. The N2O E-cylinder pressure gauge is located on the anesthesia machine. Most makes/models require the anesthesia machine to be turned on to display the pressure. 			Verbal Response		
Scenario	Is the E-cylinder post-valve open?	Is the anesthesia machine pressurized?	Interpretation & Actions		
1	No. (closed)	No.	With a closed post-valve, the N2O E-cylinder does not actively pressurize the anesthesia machine. No action needed.		
2	Yes. (open)	Yes.	Indicates one of the following: 1) if pressure is above the low-pressure alarm threshold, the E-cylinder has adequate volume remaining. Close the E-cylinder post-valve. 2) if pressure is below the low-pressure alarm threshold, the E-cylinder is approaching empty. Exchange with a full E-cylinder.		
3	Yes. (open)	No.	Indicates one of the following: 1) the E-cylinder is empty. Exchange with a full E-cylinder. 2) the anesthesia machine is not registering pressure. Call Clinical Engineering.		
4	No. (closed)	Yes.	Indicates that the E-cylinder post-valve was closed following recent clinical use. The residual line pressure in the anesthesia machine will slowly bleed off. No action needed.		

* See Verification Methods list below

** Complete signature section below

Competency Statement and Evaluation

Signature of Competency Validator (AKA: preceptor, super trainer, unit champion, expert practitioner, educator)		
Name (print)	Signature	Title

VERIFICATION METHODS

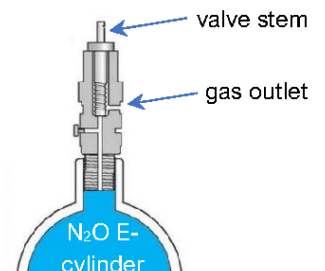
- Didactic (i.e., HealthStream Module; Classroom Teaching; Journal Article; Other Online Presentation)
- Written Exam
- Simulation
- Return Demonstration
- Verbal Response
- Direct Observation
- Chart Review
- Other: _____

Appendix:

- Standard designation colors for medical gas systems (NFPA 99-2024: table 5.1.11):
 - Nitrous oxide (BLUE)
 - Oxygen (GREEN)
 - Medical air (YELLOW)
 - Carbon dioxide (GREY)



- The Pin-Index safety system uses a precise and specific pattern of pins and holes to facilitate the connection of specific gas cylinders to the correct, corresponding yoke assembly.



- Each E-cylinder has a post-valve which can be easily opened and closed with the appropriate wrench. These wrenches are usually attached to the back of each anesthesia machine.

Providence Environmental Stewardship Goals

Working Toward Carbon Negative by 2030

WE ACT: Mitigation

WASTE	ENERGY/WATER	AGRICULTURE/ FOOD	CHEMICALS	TRANSPORTATION
Divert >50% of waste from landfill and hazardous streams by 2030	By 2030, at all sites: • Electricity EUI < 85 • Thermal EUI < 110 • Water use <30 gal/sf	• Decrease carbon intensity of meals • Decrease waste • Healthy, sustainable foods	• Reduce GHGs from Nitrous oxide by 90% • Reduce GHGs from volatile anesthetics by 70%	• GHG emissions from business travel 50% less than 2019
Data	Caregiver Engagement		Procurement	
• Expand industry leading WE ACT Scorecard for effective data tracking and action planning	• Communications reach 50% of caregivers • Active green teams and affinity groups at all sites/regions • ES Anchored in our core value of justice		• Reduce GHGs from purchases by 30% • Reduce single-use disposable device purchases by 30%	

We REACH: Adaptation

Develop climate resilient care delivery, helping our communities adapt to changes in our environment through:
• Operations • Clinical • Community

We SHARE: Advocacy/Leadership

- Advocacy for healthy climate
- National leadership groups (NAM, HCWH, IHI, AHRQ, TJC, etc.)
- Share our knowledge with other health systems to model sound practices in Environmental Stewardship



REFERENCES

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2. IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland.
3. National Fire Protection Association. (2024). NFPA 99- Health Care Facilities Code. Retrieved from: <http://www.nfpa.org/codes-and-standards/9/9/99>

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OUR MISSION

As expressions of God's healing love, witnessed through the ministry of Jesus, we are steadfast in serving all, especially those who are poor and vulnerable.

OUR VALUES

Compassion, Dignity, Justice, Excellence, Integrity