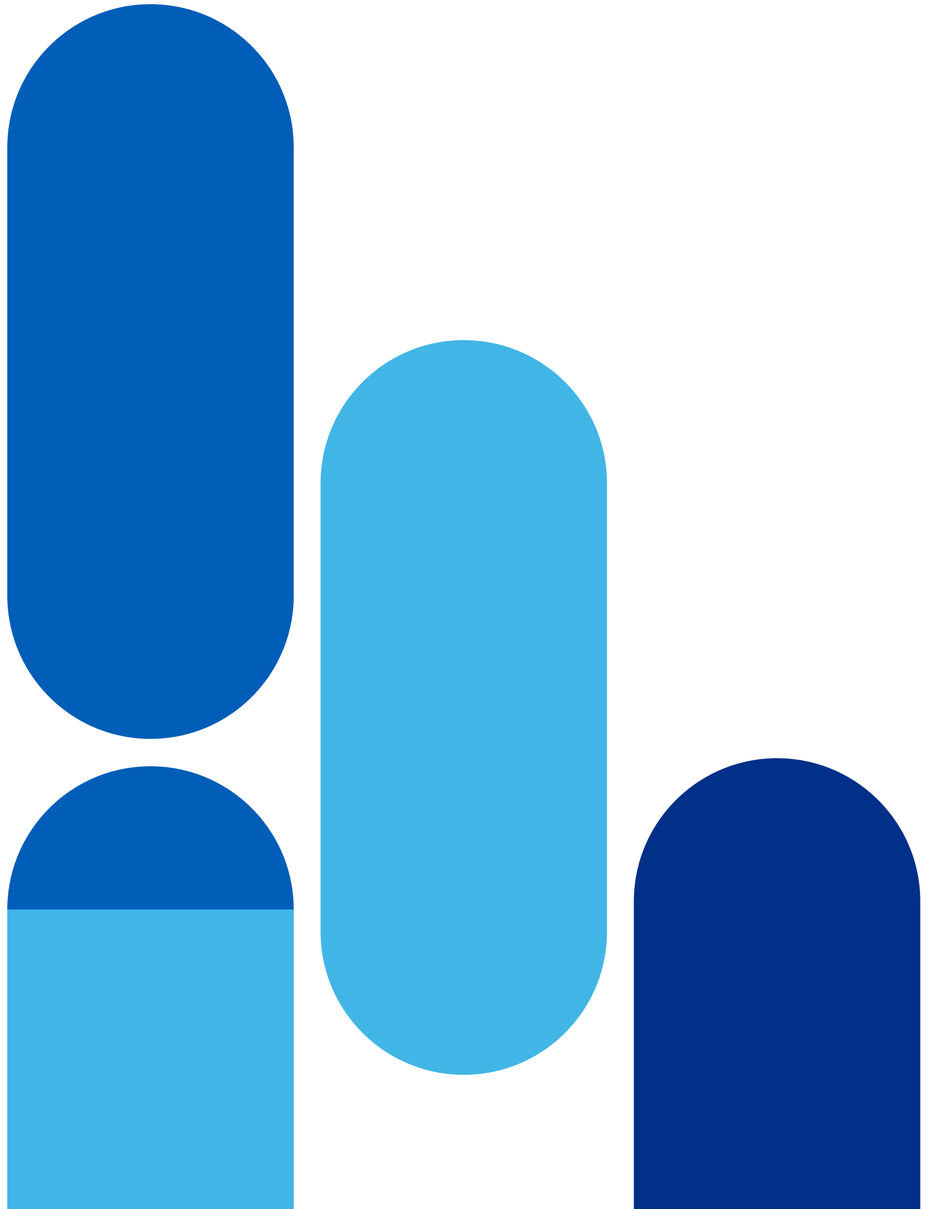
# Nitrous oxide toolkit: Reducing waste in NHS trusts

# Contents

# About this toolkit

**This toolkit helps NHS trusts to minimise nitrous oxide waste from piped medical gas systems and to make significant cost savings. It provides technical guidance on safely decommissioning systems. Using best practice examples, it explains how to reduce waste, costs and emissions to support our commitment to become a net zero health service.**

This toolkit is designed for NHS staff within trusts who are involved in the procurement, management or use of nitrous oxide including but not limited to: sustainability teams, pharmacy, maternity, dental, anaesthetists and theatre staff, emergency department staff, and estates and facilitates teams.



# The case for change

**Climate change poses a major threat to our health and has direct and immediate consequences for patients, the public and the NHS. Carbon emissions are the primary driver of climate change and 4% of England's carbon emissions are caused by the NHS.**

In October 2020, the NHS became the world's first health system to commit to reaching net zero to improve patient care, cut costs and reduce emissions.

Multiple NHS trusts in England have lowered carbon emissions and saved money by understanding – and then reducing – the waste that occurs when buying and supplying nitrous oxide. Importantly, they achieved this without disrupting care or hindering clinical access to nitrous oxide as required. Much of the work across the NHS to reduce nitrous oxide waste has been inspired by the work led by pharmacist Alifia Chakera.

Decommissioning piped medical gas systems is supported by leading anaesthetic organisations in the UK and Ireland.

4%

of England's carbon emissions are currently caused by the NHS.

80%

of anaesthetic gas emissions are caused by nitrous oxide and nitrous oxide/oxygen mixture

## Nitrous oxide

Nitrous oxide is a potent greenhouse gas that makes up at least 80% of the total emissions from ozone-depleting medical gases in the NHS (NHS, 2022). It has significant global warming potential, around 300 times that of carbon dioxide, and is an ozone depleting substance. Efforts to reduce waste from the use and procurement of nitrous oxide represent a significant carbon saving opportunity and support the NHS's commitment to become a net zero health service.

## Financial

The ongoing maintenance and investment costs for complex medical gas pipeline supply systems can be unnecessarily high if the size of a supply is larger than it needs to be for the clinical areas it serves. This also leads to excessive costs for gas, especially if the system leaks.

## Efficiency and staff time

Medical gas pipeline systems often have large manifold rooms with extensive piping networks that are complex and easily damaged. This means they need frequent maintenance. In addition, oversized systems demand more frequent cylinder changes than would be required under a system better matched to clinical needs. Addressing this misalignment can support operational efficiencies, such as freeing up staff time for other critical tasks.

## Occupational exposure

Nitrous oxide leaks can occur in staffed areas. Preventing leaks from medical gas pipeline systems helps protect staff by limiting their occupational exposure to nitrous oxide. NHS England has published guidance which outlines the mitigations that NHS trusts should consider to protect staff.

## Estimated annual impact of transition from medical gas pipeline system to a portable cylinder supply of nitrous oxide in anaesthetics

### Manchester University NHS Foundation Trust

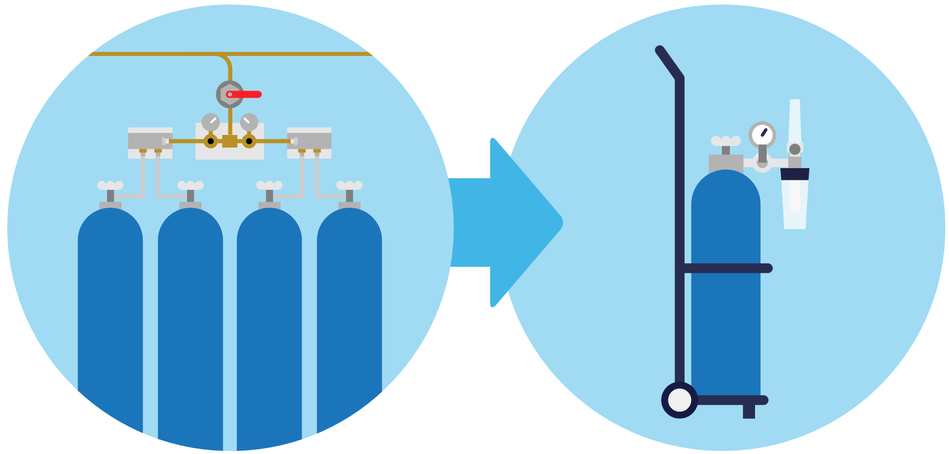
Emissions avoided
**2,000t$CO_2e$**

Nitrous oxide saved
**4,200,000L**

### Cambridge University Hospitals NHS Foundation Trust

Emissions avoided
**1,800t$CO_2e$**

Nitrous oxide saved
**3,000,000L**



### Gloucestershire Hospitals NHS Foundation Trust

Total saved
**£11,800**

Emissions avoided
**770t$CO_2e$**

Nitrous oxide saved
**1,400,000L**

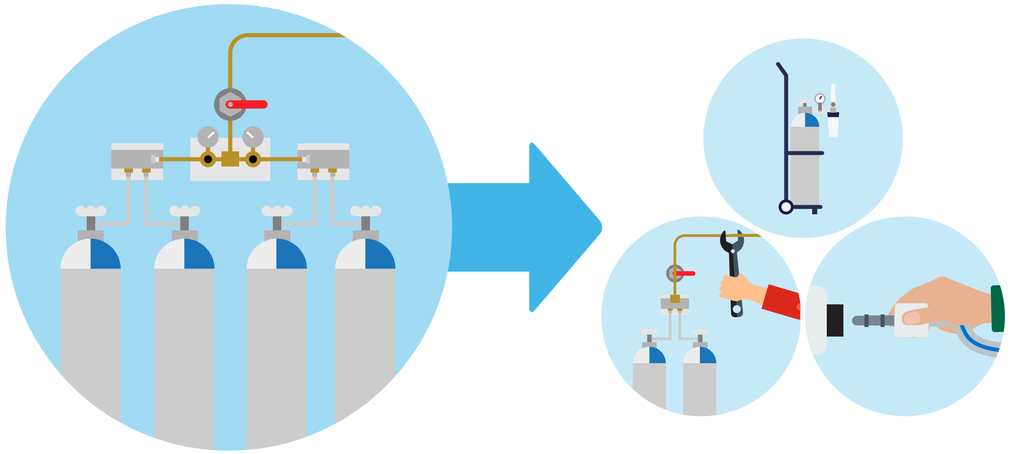
## Estimated impact of waste reduction activities for nitrous oxide/oxygen mixture

### Kings College Hospital NHS Foundation Trust

Emissions avoided
**1,500t$CO_2e$**

Nitrous oxide/Oxygen saved
**6,000,000L**

By using a portable cylinder system in maternity over 12 months compared to the previous 12 months



### Hull University Teaching Hospitals NHS Trust

Emissions avoided
**2,600t$CO_2e$**
over a year

Nitrous oxide/Oxygen saved
**10,300,000L**
over a year

From fixing leaks and removing demand valves

**Units:** t$CO_2e$ – tonnes of carbon dioxide equivalent, L – litres, cost savings include gas and maintenance

# Using this toolkit

Users can focus on sections most relevant to their role or stage of implementation. The toolkit includes practical tools, case studies and advice from trusts.

**The toolkit has four main sections:**

| Section | Understand nitrous oxide and nitrous oxide/oxygen mixture in the NHS | Get started on reducing waste | Ensure supply of nitrous oxide and nitrous oxide/oxygen mixture is aligned to clinical use | Continue to optimise systems |
|---|---|---|---|---|
| What's included | ▶ how nitrous oxide is used and supplied in clinical settings<br>▶ where waste occurs in gas supply systems | ▶ practical advice on initiating waste reduction efforts including setting up governance and project teams<br>▶ key stakeholders and their roles | ▶ action plan for aligning supply systems to clinical use<br>▶ guidance on assessing and mapping current usage | ▶ optimisation strategies for both pipeline and portable supply systems |
| Who is it for | This section is relevant for those who are new to understanding the supply and use of nitrous oxide in the NHS. | Project team<br>Decision makers | Project team<br>Estates, facilities and technical staff<br>Clinical staff | Project team<br>Estates, facilities and technical staff<br>Clinical staff |

03

# Understand nitrous oxide and nitrous oxide/oxygen mixture in the NHS

**In this section**

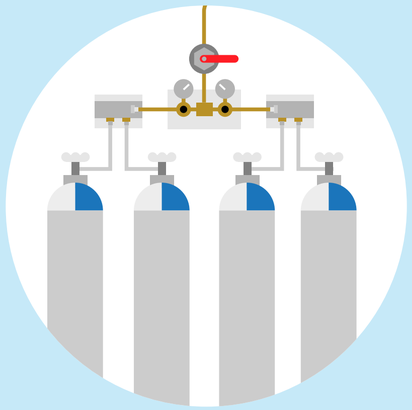
# The essentials of nitrous oxide management in medical settings

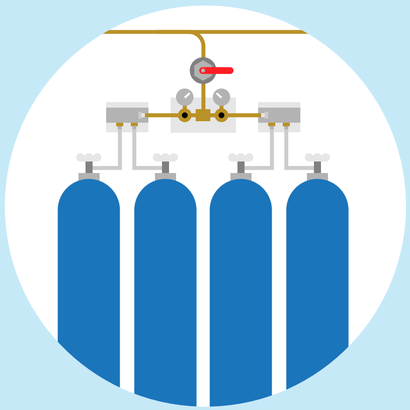
## What is nitrous oxide

Nitrous oxide is a colourless medical gas that is commonly administered to patients for anaesthesia and analgesia (pain relief). The gas is available for patients in two ways.

**1. Nitrous oxide / oxygen mixture**
A mixture of 50% nitrous oxide and 50% oxygen used in maternity, emergency departments, endoscopy and other settings. This is often called 'gas and air' and is also known by brand names like Entonox® and Equanox®. In this toolkit, it is called 'nitrous oxide/oxygen mixture'.

**2. Nitrous oxide**
Pure nitrous oxide mixed with oxygen by healthcare professionals, used in anaesthetics and dentistry. Healthcare professionals can adjust the amount of nitrous oxide and oxygen to suit each patient. In this toolkit, it is called 'nitrous oxide'.





## Properties of nitrous oxide

Pure nitrous oxide is stored as a liquid/gas combination in cylinders but is used as a gas. Nitrous oxide/oxygen mixture is stored as a gas. These properties and characteristics can have implications for reading cylinder pressure gauges, understanding of volume of gas in cylinders, cylinder management, storage and clinical use.

Staff should seek the latest guidance and advice from relevant professional bodies and health technical guidelines to ensure safe management of gases according to their properties.

## How is nitrous oxide supplied to hospitals?

Nitrous oxide and nitrous oxide/oxygen mixture gas cylinders are typically purchased by pharmacy services, delivered by medical gas suppliers and managed by facilities teams.

Depending on the gas and the supplier, they come in blue or blue and white cylinders. Cylinders come in a variety of sizes to suit different types of supply.

**Supporting resource 1: nitrous oxide and nitrous oxide/oxygen mixture use and supply in the NHS** describes how nitrous oxide and nitrous oxide/oxygen mixture are used across various clinical settings. It outlines the specific clinical purposes, delivery methods and usage patterns in each. It also includes tables listing common cylinder sizes and names used in nitrous oxide supply systems.

## How is it supplied to healthcare professionals?

The type of supply system used differs depending on multiple factors such as historical practice, physical infrastructure, contractual agreements and clinical needs.

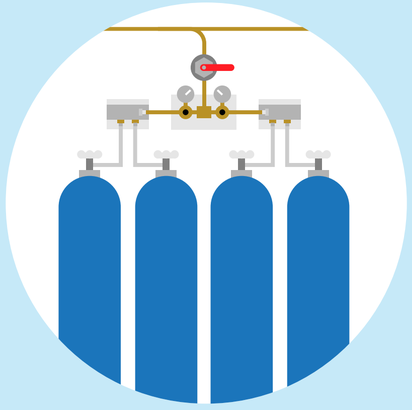
Nitrous oxide and nitrous oxide/oxygen mixture can be accessed by health professionals for clinical use in two ways:

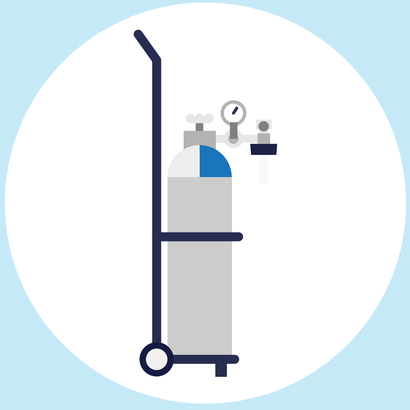
### 1. Medical gas pipeline system

Medical gas pipeline systems are primarily managed by estates and facilities services in trusts following health technical memorandum (HTM) guidelines. Staff involved in handling medical nitrous oxide gas cylinders are specially trained to understand the gas properties, the correct operating procedures and what to do in an emergency.

### 2. Portable cylinder systems

These systems use smaller, portable gas cylinders suitable for point-of-care use. There are several types of portable cylinder systems. The best option will depend on the specific requirements of a department and trust policies. Portering staff, operating department practitioners and healthcare assistants usually manage the storage, delivery and maintenance of portable cylinder systems.





### Health Technical Memorandum 02-01

Health Technical Memorandum 02-01 (HTM 02-01) provides guidance on the design, installation and operational management of medical gas pipeline systems in healthcare premises. It supports estates and facilities services to ensure medical gas pipeline systems are managed effectively and safely, are reliable and comply with regulations.

HTM 02-01 Part A provides guidance on terminal unit provision, location of AVSUs, local alarm indicator panels and LVAs by department in table 11. It is not necessary to have all the gases and terminal units listed in this table to comply with the memorandum. It provides a starting point for clinical teams to look at requirements based on current and future patient need. Project teams should continually review requirements for individual schemes.

A new HTM 02-01 is in development. This will point to the need for risk assessments and a By Informed Design Process (BIDP) methodology when designing medical gas systems. Current and future guidance allows for the removal of piped nitrous oxide systems. This must be done as part of a joint process of risk assessment between estates and clinical teams and should be overseen and agreed by the trust medical gas committee (MGC).

A list of the different types of portable cylinder system is in **supporting resource 2: different types of portable cylinder system.**

# A nitrous oxide gas supply system in the NHS

This image shows how a typical NHS hospital might manage and distribute nitrous oxide gases across different departments

### Portable cylinder system

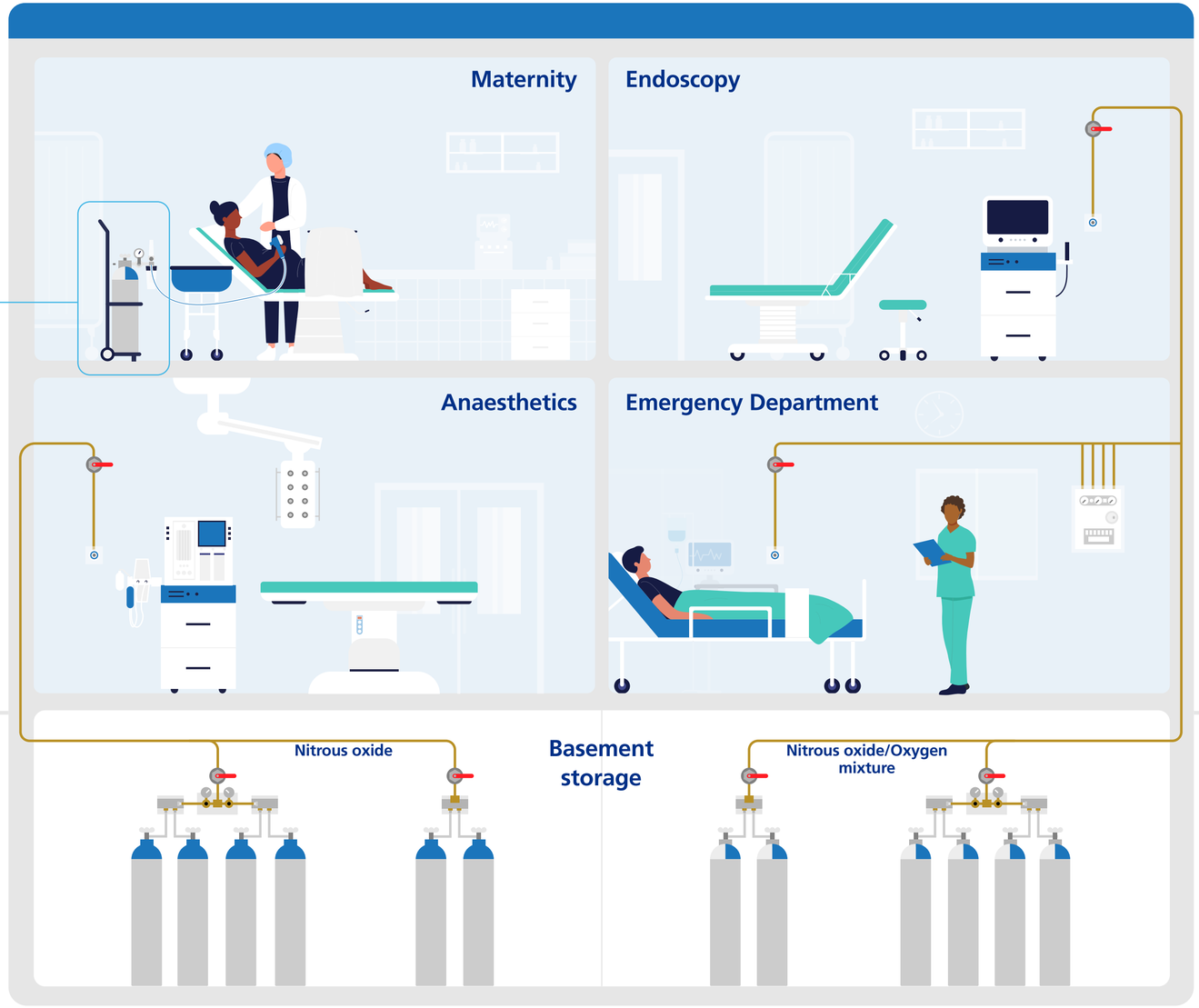
- **Gas cylinder:** a small, portable size cylinder used for portable supply.
- **Trolleys:** a trolley especially designed to safely store and transport gas cylinders.
- **Regulator or pressure gauge:** a device placed on the top of a cylinder to control pressure and flow of gas from cylinder to medical equipment.

### Medical equipment

- **Demand valves:** typically used in maternity settings, these connect to the terminal unit plug via a hose and opens to allow gas flow when a patient inhales, and closes when the patient exhales, ensuring gas is delivered only when needed.
- **Therapeutic equipment:** anaesthetic machines, regulators, analgesic delivery systems and sedation equipment used to deliver care.

### Connection and flow control

- **Schrader valve:** a valve used to connect anaesthetic machines or other medical devices to the gas supply. It allows gas to flow into the device at the desired pressure.
- **Medical gas tubing:** Flexible, color-coded tubing that connects terminal units or cylinders to medical equipment or directly to the patient. Each gas has a specific color and connector type to prevent misconnections.
- **Flow meter:** a device that can measure and control the flow rate of gas delivered to patients through therapeutic equipment.




**Key:**

Portable cylinder system | Both systems | Medical gas pipeline system

### Delivery points

- **Terminal unit:** a wall-mounted outlet that provides access to gas supply in patient care areas. Medical devices can be connected to it.
- **Operating room pendant:** a ceiling-mounted arm containing terminal units for medical gases and electrical outlets.

### Control and safety

- **Area valve service unit (AVSU):** a control unit installed in each patient care area that can shut off local gas supply in case of an emergency or for maintenance.
- **Isolating valve:** a valve along the pipeline that enables sections of it to be isolated without interrupting the gas supply to other areas.

### Gas source and distribution system

- **Copper pipeline:** piping that contains the gas, made of high-quality, medical-grade copper.
- **Manifold:** a device that connects the cylinder bank to the pipeline. It automatically switches from one cylinder bank to the other when the active one runs low. The term ‘manifold’ is often used to refer to the room where the cylinder bank is stored and connected.
- **Manifold connection:** a connection between the manifold and the pipeline system, made using rigid copper piping.
- **Cylinder bank:** a row of cylinders connected to a manifold to provide a continuous gas supply to the pipeline system.
- **Emergency reserve manifold:** a separate manifold with a smaller cylinder bank supply that automatically activates in case the main manifold fails.

# What are the sources of waste?

Nitrous oxide waste commonly occurs in:

- **Medical gas pipeline systems, due to leaks:** The pressurised delivery system increases the risk of damage to pipeline components, making leaks inevitable over time. Leaks occur at terminal units, operating room pendants, deteriorated isolating valves, therapeutic equipment and manifold connections.
- **Oversized systems in areas like operating theatres, emergency departments and endoscopy suites:** These provide an unnecessarily large supply to areas of low clinical use. The larger and more complex the system, and the further the manifold room is from the clinical area, the more gas you will waste. This is due to the increased number of potential leak points and the difficulty in detecting and repairing leaks in large, complex pipeline networks.
- **Cylinder management:** In both medical gas pipeline and portable cylinder systems, scheduled 'milk round' deliveries, where medical gas suppliers routinely swap empty cylinders with full ones can lead to oversupply of cylinders in hospitals. Tailoring cylinder delivery more closely with clinical needs would result in a less wasteful procurement and delivery process, avoiding cylinders expiring before they can be used. Waste can also occur when medical gas devices and flow meters are not turned off after use.

Cylinders sent back with nitrous oxide or nitrous oxide/oxygen mixture in them are vented into the atmosphere as per Medicines and Healthcare products Regulatory Agency batch control regulatory requirements.
Medical gas suppliers are working with regulators on a solution to this waste.

### Medicines and Healthcare products Regulatory Agency batch control requirements

The Medicines and Healthcare products Regulatory Agency (MHRA) enforces batch control requirements for nitrous oxide cylinders to ensure each batch meets safety and quality standards before distribution to healthcare providers. These requirements include:

- all returned cylinders must be vented to remove any residual gas before refilling. This prevents contamination and ensures the integrity of the gas supply.
- cylinders cannot be "topped up" with additional gas. Each cylinder must be completely emptied and inspected before being refilled. This practice helps maintain consistent gas purity and prevents potential safety hazards.
- each batch undergoes rigorous testing for contaminants and compliance with quality standards.
- detailed records are kept for each batch, tracking its production, testing and distribution. These records ensure traceability and accountability throughout the supply chain.

# How does waste occur?

This image shows the areas where waste can occur in either a medical gas pipeline, or portable cylinder supply system.

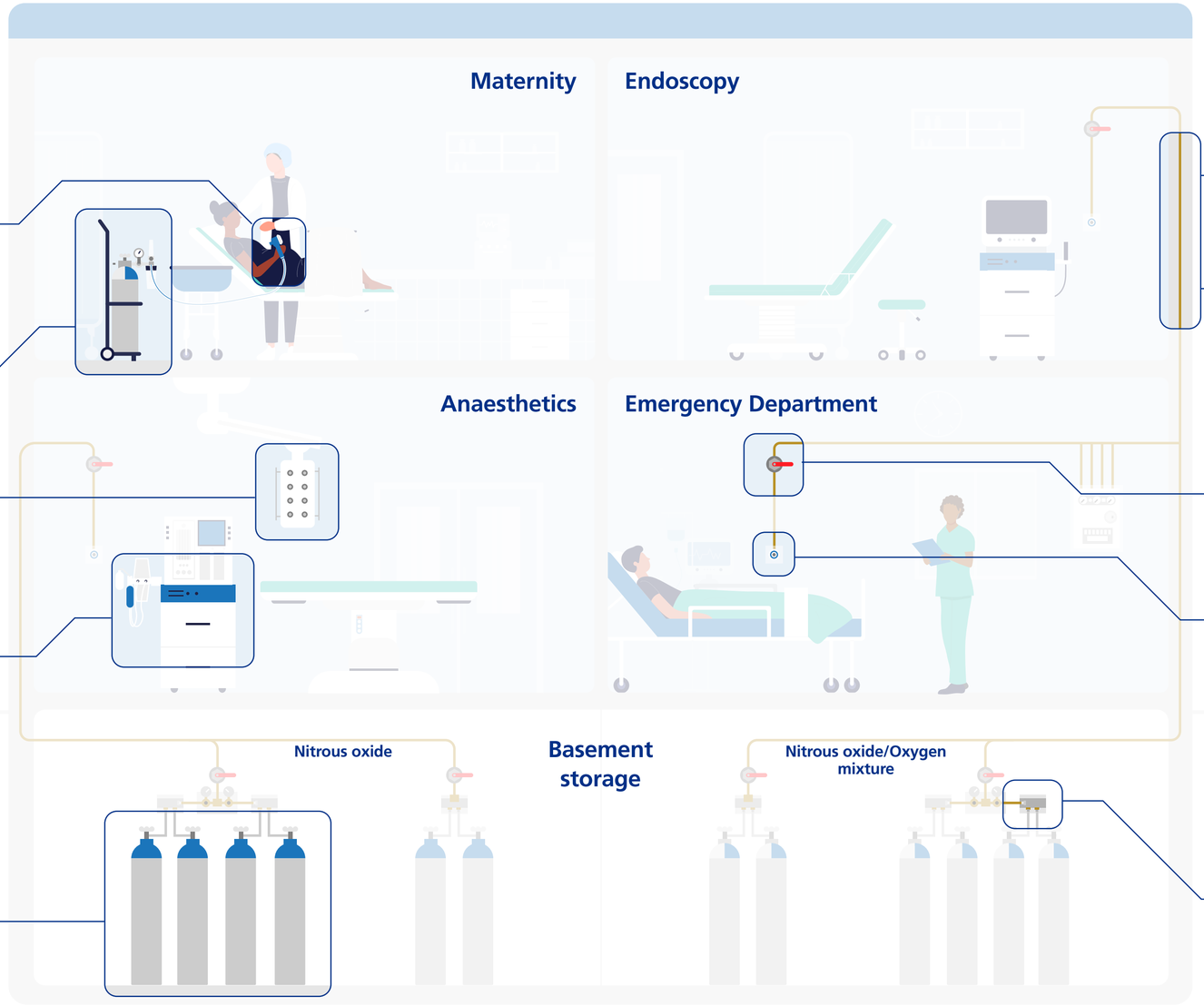
**Mouthpiece and demand valves:** at point-of-use leaks can occur when patients inhale and exhale the gas.

**Returning partially used cylinders:** cylinders (often smaller, portable ones) can be returned to the medical gas supplier before all the gas in the bottle is consumed.

**Operating room pendants connections:** leaks in these may be difficult to detect and repair due to often being hidden behind walls or ceiling.

**Delivery equipment:** medical devices such as anaesthetic machines or flow meters connected to the terminal units may be defective and can be a source of leaks as they age or are not maintained.

**Stock management:** in addition to leaks in the piped system, waste can also occur through the ordering of more than is clinically required.




**Complex pipeline:** long pipeline lengths and numbers of bends can increase opportunities for leaks.

**Pipeline damage:** although rare, the copper pipeline itself may sustain damage and develop leaks.

**Isolating valves:** leaks can occur from these in the pipeline, especially when they deteriorate over time or become damaged.

**Unused terminal units:** hospital rooms may have multiple wall outlets for nitrous oxide. When these rooms are converted for other uses or clinical uses of the product ceases, the pipework supply may not be properly decommissioned, leading to leaks.

**Manifold connections:** leaks at connection points can occur due to frequent cylinder changes and high gas pressure. Rapid cylinder activation by staff can cause sudden pressure surges, damaging connections.

# Get started on reducing waste

04

Reducing nitrous oxide waste in NHS trusts requires collaboration across multiple departments and stakeholders. This section provides practical advice to help you navigate common challenges and set your trust up for success from the start. It provides key steps to establish effective governance, engage stakeholders and implement successful waste reduction initiatives.

**In this section**

# Key actions to get started

## Establish governance and a project team

1. Set up a governance structure including executive leadership, medical gas committee and a multidisciplinary project team.
2. Engage key stakeholders early and often, including healthcare professionals, estates and facilities, and procurement teams.
3. Bring these stakeholders together regularly to build relationships and enable work to progress.
4. Use governance structures to gain approval for actions required.

## Use project management tools

1. Use specific project management tools to support the work.

Below are two resources that could help you from the start to manage the project effectively.

**Supporting resource 3: project management templates** is an editable Excel workbook for managing and tracking project progress.

**Supporting resource 4: action list** is an editable Excel workbook with actions for all stages of nitrous oxide waste reduction work.

## Understand the current picture

1. Review available data on nitrous oxide supply in your hospital.
2. Meet in-person and visit a manifold to understand how gas is supplied in a medical gas pipeline system and the work involved.
3. Visit wards and other clinical areas to understand how nitrous oxide is used and address any concerns directly.

# Establish governance and a project team

**Reducing nitrous oxide and nitrous oxide/oxygen mixture waste requires a governance structure that promotes ongoing ownership, accountability and effective change management. Each trust will have pre-existing governance structures that will help but it may be useful to establish a project team.**

## Executive leadership

Trust leaders are instrumental in integrating sustainability into strategic and operational practices. The Health and Care Act 2022 requires NHS trusts to contribute towards statutory emissions and environmental targets. Every trust and integrated care board (ICB) must have a board-level net zero lead to oversee or delegate responsibility for the local green plan and for nitrous oxide waste reduction projects. Current green plan guidance is available from NHS England.

CASE STUDY

## King's College Hospital NHS Foundation Trust: Establishing a dedicated project team

### The issue

King's College Hospital investigated the hospital's nitrous oxide waste and built a project team including pharmacy, theatres and anaesthetics, and estates and facilities colleagues, with support from a corporate project management function within the trust to tackle the issue.

### The approach

Due to limited resources, the project team started small and scaled up. To start, the levels of nitrous oxide were investigated at a single hospital. The required changes were decided on a case-by-case basis and rolled out sequentially. This enabled the team to examine the results of their initial approach before focusing on another area. Some initial successes in decommissioning nitrous oxide supply in areas of low and no clinical use helped buoy the team and demonstrated early progress. The early successes have expanded the project's scope to reducing the waste of nitrous oxide/oxygen mixture.

### Learning points

Colleagues met regularly as a multidisciplinary project team. Using a project management approach and framework already in place at the trust, they included further colleagues in decision-making where necessary. Updates were sent to all stakeholders informing them of improvements made to the nitrous oxide supply.

The project team relied on support from:

- the trust's executive lead for net zero and the chief financial officer who agreed to sponsor the project. Risks, issues and concerns were reported at regular intervals to the senior responsible officer who escalated and resolved blockers at pace.
- staff and clinical leads, who were provided with detailed updates of any planned work
- the trust's medical gas committee (MGC), which was kept informed and was a source of support.
- the trust's sustainability committee, which helped ensure the project was aligned to the trust's green plan.

### Outcomes

The team has successfully decommissioned 4 surplus nitrous oxide manifolds, aligning the supply more suitably with the needs of 8 clinical areas. They have also downsized one medical gas pipeline system, thereby reducing waste, costs and related carbon emissions.

## Medical gas committee

The medical gas committee (MGC) oversees the safe and efficient supply of medical gases within NHS trusts, ensuring medical gases are handled safely and comply with regulatory requirements. The committee can support the trust to reduce its environmental impact and promote the sustainable use of medical gases, including reducing waste from nitrous oxide and nitrous oxide/oxygen mixture and optimising its supply where it is needed, by:

- implementing, supporting and monitoring waste reduction work
- having a standing item on nitrous oxide waste reduction on its agenda
- regularly reviewing the trust's nitrous oxide consumption and emissions
- supporting the activities to ensure a supply aligns to clinical needs and supporting the continued optimisation of these supplies
- driving improvements in waste management practices

### Medical gas committee membership

The medical gas committee should include representatives from professions involved in the handling and use of nitrous oxide and nitrous oxide/oxygen mixture. Members should include:

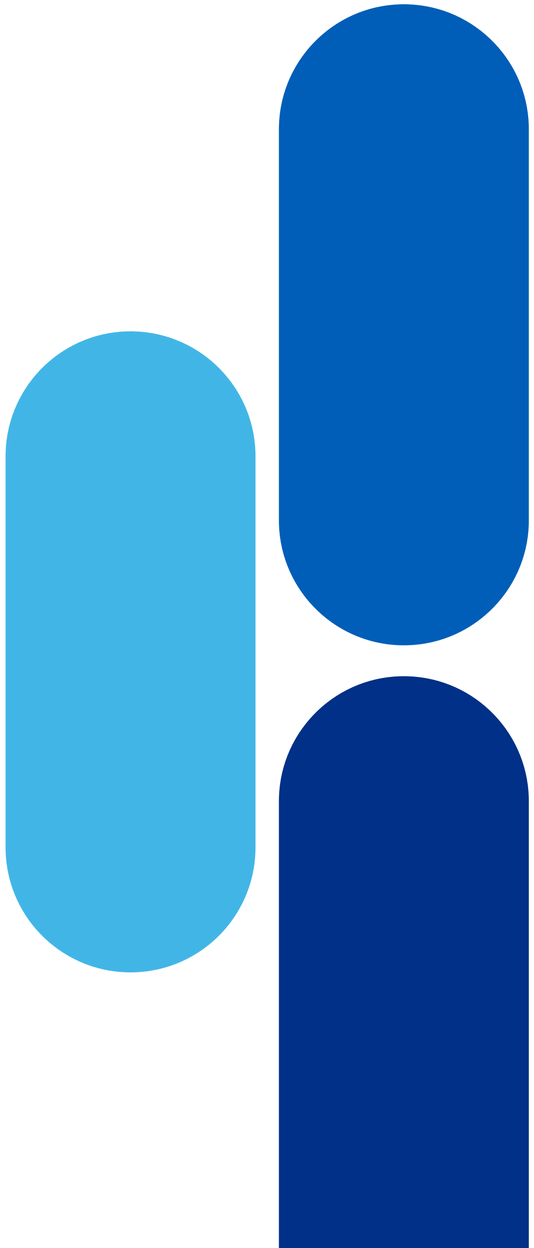
- chair - for example, a chief pharmacist with appropriate knowledge and decision-making authority
- authorised person for medical gas pipeline systems (MGPS) - this may be from an NHS trust or private finance initiative (PFI)
- authorising engineer (MGPS, co-ordinating)
- head or director of estates, or senior deputy
- other relevant pharmacy manager, for example procurement
- quality control (QC) for MGPS
- medical physics or electro-biomedical engineer (EBME)
- facilities or portering staff
- clinical representation including senior nursing staff, anaesthetists or other clinicians
- primary medical gas supplier representative

## Multidisciplinary project teams

A multidisciplinary team should be responsible for progressing the activities to align existing nitrous oxide and nitrous oxide/oxygen mixture supplies to clinical need.

This team should include:

- clinical representation from areas using nitrous oxide and nitrous oxide and oxygen mixture
- professionals involved in procurement, delivery and supply of nitrous oxide
- those with an interest in nitrous oxide waste reduction in the trust



## Key stakeholders to engage

Healthcare professionals who use the gases may not be aware of the systems that supply them, while estates and facilities and procurement staff may not understand clinical applications. Including stakeholders from different disciplines helps to:

- maintain clinical and patient choice
- reduce the management and maintenance of medical gas pipeline supply systems
- increase the efficiency of cylinder management tasks for portering staff
- reduce costs associated with procurement, management and maintenance
- reduce carbon emissions
- reduce the potential for occupational exposure to nitrous oxide

Table 1 identifies each stakeholder's usual contribution to projects and some of the factors that may motivate and enable them to take part in nitrous oxide waste reduction activities.

## Common challenges and opportunities when getting started

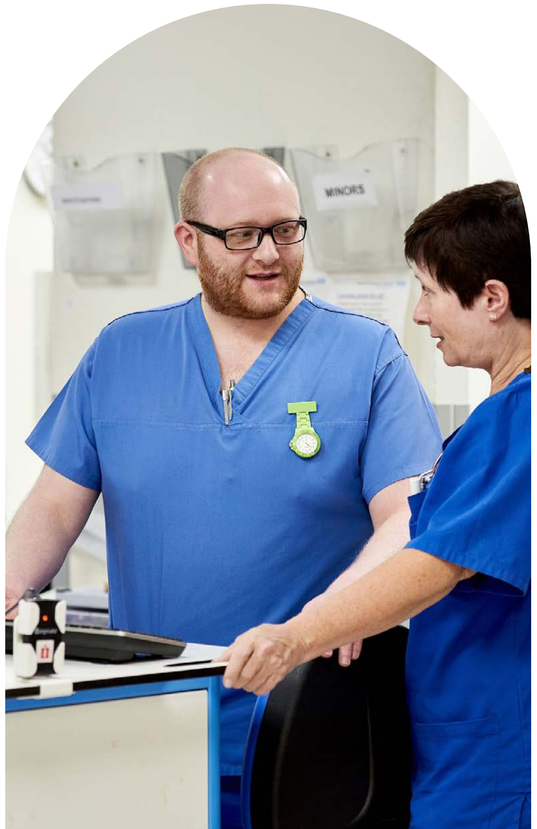
### Challenges

- limited staff capacity to manage nitrous oxide projects in addition to existing workloads
- lengthy approvals to undertake waste mitigation activities
- lack of dedicated budget can affect the likelihood and pace of project delivery
- complex organisational structures require stakeholder mapping, engagement, and alignment to implement cross-cutting nitrous oxide reduction interventions
- ensuring multidisciplinary committees and project meetings find ways to engage with high-use areas of nitrous oxide like emergency and maternity, anaesthetists, estates and pharmacists
- co-ordinating projects across multiple hospitals with different medical gas infrastructure designs, ages and maintenance requirements can complicate stakeholder engagement and co-ordination efforts

### Opportunities

- concentrating on clinical areas with appetite for sustainability projects
- starting with the removal of supply systems from clinical areas that do not use nitrous oxide or nitrous oxide/oxygen mixture can require very little budget
- developing strategies to engage with project stakeholders can help address potential delays in the business case approval process
- running projects concurrently or phasing them by hospital or department can improve co-ordination
- supporting with specific working groups or stakeholder meetings where needed
- providing communications tailored to different audiences and preferences ensures all stakeholders are equipped to contribute to waste reduction efforts

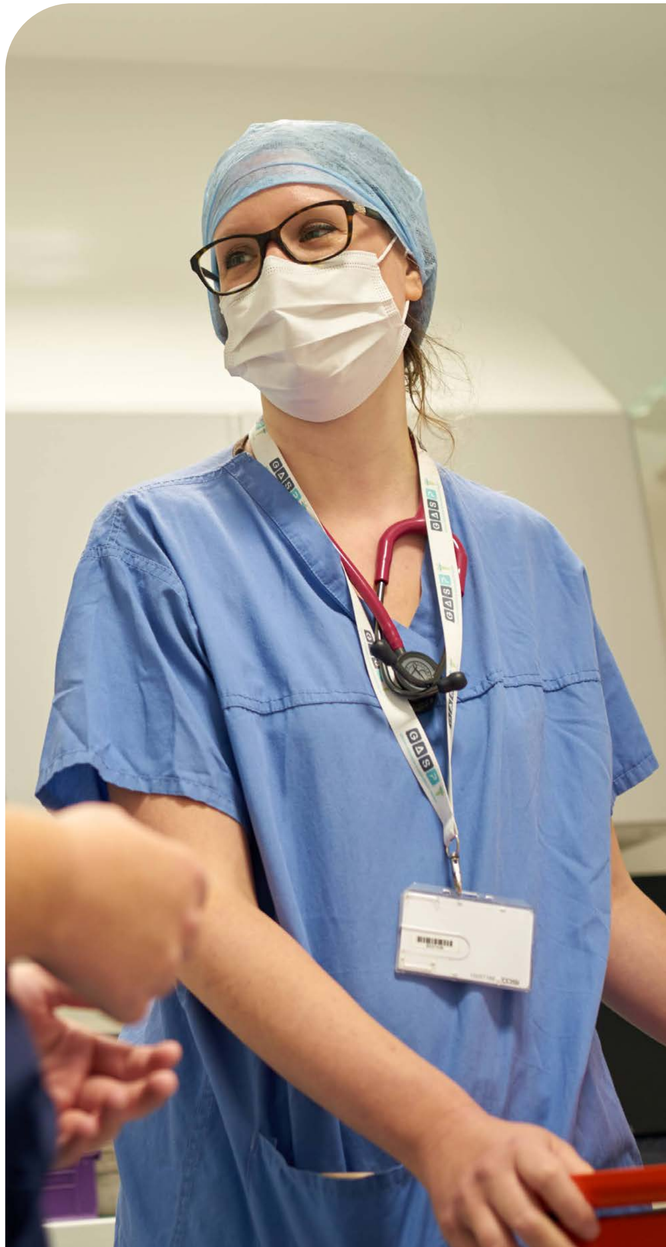
**Supporting resource 5: project communications templates** contain useful information such as a project on a page, FAQs, template emails and posters to help keep work on track and ensure internal stakeholders are informed and engaged.



## Table 1: Stakeholders to engage in waste reduction

| Stakeholder | Contribution to projects | Interest(s) | Enabler(s) |
|---|---|---|---|
| **Executive sponsor** | • Provides high-level support and ensures alignment with the trust's strategic objectives | • Reducing waste and the cost associated with maintaining inefficient systems<br>• Achieving organisational sustainability targets | • Strong leadership<br>• Dedication to sustainability |
| **Clinical leaders** | • Direct clinical aspects of the project and make evidence-based decisions<br>• Ensure adherence to clinical guidelines<br>• Support changes and role model new approaches | • Enhancing patient care<br>• Improving clinical efficiency<br>• Innovating and using best practices to improve | • Clinical expertise<br>• Peer influence<br>• Budgetary responsibilities |
| **Anaesthetists and theatre staff** | • Administer nitrous oxide in theatres<br>• Provide insights on practical challenges and solutions | • Enhancing patient outcomes<br>• Innovating and using best practices to improve<br>• Ensuring access to required anaesthetic techniques | • Hands-on experience<br>• Direct use of nitrous oxide and nitrous oxide/oxygen mixture gases |
| **Operating department practitioners (ODPs)** | • Support in surgeries and patient care<br>• Ensure effective use and management of nitrous oxide | • Ensuring safe and efficient surgeries<br>• Minimising waste<br>• Ensuring effective use or theatre resources | • Collaboration with anaesthetists |
| **Other healthcare staff across clinical areas (this could include nurses, midwives, dentists and others)** | • Collaborate with clinical leaders on strategies for reducing nitrous oxide waste | • Improving patient care<br>• Contributing to sustainability initiatives | • Clinical knowledge<br>• Teamwork |
| **Estates and facilities/ security staff** | • Oversee hospital infrastructure and equipment<br>• Manage the medical gas pipeline system | • Enhancing facility efficiency<br>• Cutting maintenance costs<br>• Adhering to guidelines | • Technical expertise<br>• Implementation capabilities |
| **Facilities management/portering staff** | • Manage logistics and movement of gas cylinders<br>• Ensure correct storage and handling of nitrous oxide | • Ensuring operational efficiency<br>• Enhancing safety | • Familiarity with hospital logistics<br>• Support a wide range of clinical areas |

| | | | |
|---|---|---|---|
| **Medical equipment technicians** | • Ensure medical equipment operates correctly<br>• Oversee modifications to nitrous oxide supply systems | • Upgrading equipment<br>• Reducing operational downtime | • Technical proficiency<br>• Troubleshooting skills |
| **Pharmacy and pharmacy procurement** | • Accountable for safe and effective use of medicines, including nitrous oxide | • Optimising inventory management<br>• Reducing costs | • Inventory management systems<br>• Expertise in gas procurement processes |
| **Project manager** | • Manages project structure and progress<br>• Co-ordinate activities and timelines | • Improving hospital efficiencies<br>• Reducing waste<br>• Contributing to sustainability | • Effective project planning<br>• Stakeholder analysis |
| **Quality improvement and transformation teams** | • Support project teams to understand processes and quantify waste | • Achieving quality standards<br>• Continuous improvement | • Quality improvement and transformation frameworks<br>• Data-driven strategies |
| **Sustainability team** | • Align the project with sustainability objectives<br>• Monitor progress and outcomes | • Reducing carbon emissions<br>• Meeting sustainability goals | • Robust commitment to environmental objectives<br>• Advocacy |



**Supporting resource 5: project communications templates** contain useful information such as a project on a page, FAQs, template emails and posters to help keep work on track and ensure internal stakeholders are informed and engaged.

# Ensure supply of gas is aligned to clinical use

05

This section provides you with guidance and tools to assess and improve your nitrous oxide and nitrous oxide/oxygen mixture supply and significantly reduce waste by aligning supply to clinical use.

The clinical use of nitrous oxide and nitrous oxide/oxygen mixture differs across specialties and departments including maternity, endoscopy, dentistry, emergency departments and anaesthetics.

**In this section**

# Tailor your approach

**Think about your unique circumstances to best manage and optimise your supply of nitrous oxide and nitrous oxide/oxygen mixture. Consider the complexity of your hospitals, volume of gas supplied, clinical specialties, operational practices and contractual arrangements to make informed decisions about adapting supply to meet clinical needs and reduce waste.**

Each nitrous oxide and nitrous oxide/oxygen mixture supply system should be aligned to clinical use. Supply systems should be optimised across all areas. Action plans based on clinical use demonstrates how to categorise different clinical areas into no/low/high use and the recommended decision for each area.

Specific actions for implementing supply system alignment can be found in **supporting resource 4: action list**.

CASE STUDY

## Different approaches to reducing nitrous oxide and nitrous oxide/oxygen mixture waste

This case study highlights different methods used by trusts, demonstrating there is no one-size-fits-all solution.

**King's College Hospital NHS Foundation Trust** adopted a phased strategy, starting with reducing waste from nitrous oxide, then moving to nitrous oxide/oxygen mixture. While decommissioning most nitrous oxide manifolds, they retained their dentistry manifold implementing more robust ongoing testing and planned and preventative maintenance. They optimised this system by shutting off branches to areas no longer requiring nitrous oxide outlets, using a portable cylinder system there instead. For anaesthetics, they retrofitted machines to accommodate E-sized cylinders. In their large maternity department, they are currently using portable cylinders for nitrous oxide/oxygen mixture, and they have shut off the medical gas pipeline system to the accident and emergency department.

**Great Ormond Street Hospital** completely decommissioned their manifolds and switched to a small, portable cylinder system on their anaesthetic machines for all theatres. This solution suited their specific needs as a children's hospital and significantly reduced the nitrous oxide purchased.

**Leeds Teaching Hospitals NHS Trust** used a pilot and rollout approach. They initially trialled small trolleys in a limited area before expanding these to all their theatres. This phased implementation allowed them to refine their process before switching off their manifolds entirely.

**University College London Hospitals NHS Foundation Trust** opted for a data-driven approach. They conducted an extensive audit comparing clinical use data from their electronic medical records system against purchasing data. Additionally, they surveyed all manifolds and used this comprehensive data to systematically plan the shutdown of their manifolds.

**East Suffolk and North Essex NHS Foundation Trust** demonstrated that different approaches could be used within the same organisation to reduce nitrous oxide waste. They used existing evidence of waste at other hospitals to build the case for change and used a staff survey to understand clinical needs. At Colchester Hospital, they limited cylinder nitrous oxide to two anaesthetic machines in the maternity theatres and removed nitrous oxide from use in all other areas, including paediatrics. At Ipswich Hospital, they kept cylinders on all anaesthetic machines. This flexibility allowed them to cater to the specific needs of each hospital.

# Action plans based on clinical use

You can reduce waste, improve operational efficiency, generate cost savings and decrease the environmental impact of nitrous oxide and nitrous oxide/oxygen mixture by implementing these key recommendations based on clinical use:

## No clinical use

Nitrous oxide or nitrous oxide/oxygen mixture is not used

### Possible area

- Areas that no longer use nitrous oxide but still have terminal units
- Some anaesthetic
- Some emergency departments
- Some endoscopy

### Recommended actions

1. Decommission medical gas pipeline system and do not replace with alternative system

→ Click here

## Low clinical use

Nitrous oxide or nitrous oxide/oxygen mixture may be used occasionally due to clinical or patient preferences

### Possible area

- Anaesthetics
- Emergency departments
- Endoscopy
- Some dentistry
- Some maternity

### Recommended actions

1. Use a portable cylinder system and decommission any existing medical gas pipeline system

→ Click here

2. Enhance stock control of nitrous oxide cylinders
3. Identify supply system inefficiencies
4. Reduce waste through clinical practice

→ Click here

## High clinical use

Nitrous oxide or nitrous oxide/oxygen mixture is used in the delivery of care for a majority of patients

### Possible area

- Some paediatric and adult dentistry
- Some maternity

### Recommended actions

Options include:

1. Use a portable cylinder system and decommission any existing medical gas pipeline system
2. Reposition/redesign a manifold and medical gas pipeline system
3. Retain existing medical gas pipeline system and optimise it

→ Click here

4. Enhance stock control of nitrous oxide cylinders
5. Identify supply system inefficiencies
6. Optimise remaining medical gas pipeline systems
7. Reduce waste through clinical practice

→ Click here

# Assess supply and clinical use

**There are several approaches you can take to assess if the nitrous oxide or nitrous oxide/oxygen mixture supply system is aligned with clinical use. The key steps to assess this are to:**

- identify areas supplied with nitrous oxide and nitrous oxide/oxygen via medical gas pipeline systems and which manifold they are supplied from
- classify the clinical use (no/low/high) for each area using a method suitable for your trust
- decide what actions to take based on recommended decisions in Action plans based on clinical use

Trusts may approach this assessment differently. Some may identify immediate opportunities by locating unused medical gas pipeline systems and planning decommissioning. Others might identify and contact departments with likely low use (for example anaesthetics, endoscopy and emergency departments) to agree on portable cylinder systems. Some may prefer a detailed data-driven approach, mapping supply systems and comparing supply and usage data at manifolds and clinical outlets before deciding.

In some cases, trusts have taken immediate action without extensive data collection. They have implemented portable cylinder systems based on evidence from other trusts, colleague consultations, and departmental usage information collected from staff surveys. This approach allows for quicker implementation while relying on existing knowledge and best practices.

Table 2 outlines assessment methods and recommendations for understanding supply and usage patterns to align supply systems with clinical use.

The approach chosen should balance the need for accurate data with the opportunity to quickly implement waste reduction measures.

**Supporting resource 6: approaches and tools for understanding nitrous oxide supply and use** explains the process for each of the recommended methods

**Table 2: Steps to assess nitrous oxide and nitrous oxide/oxygen mixture supply, usage and waste**

| Step | Action | Recommended | Supplementary |
|---|---|---|---|
| **Work out which areas use each gas and how they are using it** | Identify clinical areas that have a medical gas pipeline supply system and its key contacts | ✓ | |
| | Map areas with terminal units to its medical gas pipeline supply system manifold/s | ✓ | |
| | Consult with departmental leaders to request their nitrous oxide use requirements | ✓ | |
| | Survey clinicians to understand clinical use requirements | | ✓ |
| | Collect data from anaesthetic machines or electronic medical record system to understand the clinical use of nitrous oxide | | ✓ |
| **Work out how much gas is being supplied** | Identify procurement patterns using the Greener NHS dashboard | ✓ | |
| | Request procurement data from pharmacy procurement team | ✓ | |
| | Review manifold logs or switchboard data for turnover rates | | ✓ |
| **Work out levels of waste** | Compare supply amount to usage amount to determine quantity of waste | | ✓ |
| | Measure leakage by weighing cylinders | | ✓ |

# Plan supply system improvements

**Once data is collected and reviewed using the chosen method, you can make informed decisions on the type of nitrous oxide supply that best suits each clinical area.**

Trusts will take different approaches to improve their nitrous oxide and nitrous oxide/oxygen supply system, based on clinical areas, operations and contracts.

**Table 3** provides an example of how a trust might capture their assessment and plan to take action to reduce waste and **supporting resource 8: supply system map and decision template** can be used to document the decisions for each clinical area.

| Considerations | Possible decision |
|---|---|
| **Private finance initiative (PFI) contracts:** PFI contracts may impose limitations or financial penalties for alterations to medical gas pipeline systems. Running a portable cylinder system will not be affected but decommissioning a medical gas pipeline system as part of the transition will be. | **Possible decision:** you could consider putting in a variation request to a PFI or timing the decommissioning of medical gas pipeline systems to align with contract renewals or renegotiation opportunities to avoid or minimise financial impacts. There could be an opportunity to share decommissioning costs with the PFI provider due to existing leakages and future reductions in maintenance costs. |
| **Medical gas pipeline system infrastructure:** often multiple gas pipeline systems are fed by one manifold. This means that clinical areas with differing levels of use may draw from the same manifold through different parts of the piping infrastructure. | **Possible decision:** you could identify which clinical areas are fed by the same manifold. If these are all areas of no or low use, you may decide to rollout changes in supply to these areas together and decommission a manifold more quickly. Branches of the medical gas pipeline system can also be isolated, enabling it to continue to flow to one area, while stopping it in another. |
| **Capacity of staff:** availability to enable or support the changes can be difficult due to other priorities. | **Possible decision:** rotational, trainee clinical staff are often required to undertake or support improvement projects in their chosen areas. It may be possible for these staff to support on the nitrous oxide waste mitigation projects, especially auditing, communications and benefits realisation. |
| **Number of hospitals:** trusts with multiple hospitals need to consider different needs and capabilities. | **Possible decision:** a phased rollout might be more practical, starting with hospitals that have a more urgent need for adjustment. |
| **Vary your engagement:** engaging clinical specialties and meeting their specific needs can influence project success. Engaged, aligned healthcare professionals can enable smooth implementation of changes. | **Possible decision:** you might prioritise making changes in areas where clinical teams are most supportive or enthusiastic. |
| **Availability of budget:** access to funding to make the changes can be challenging. | **Possible decision:** changes may need to be in stages according to available funds. Requesting funding for a small-scale pilot to demonstrate benefits that can be scaled and spread may be useful. |

## Table 3: example of a trust's nitrous oxide and nitrous oxide/oxygen mixture supply system plan based on assessment of supply and use

| Hospital | Clinical destination of pipeline supply | Manifold ID | Gas type | What is the level of clinical use? | Notes on clinical usage based on email, survey or quantiative data on waste | Trust decision |
|---|---|---|---|---|---|---|
| Hospital 1 | Main theatres | Manifold A | Nitrous oxide | No | Survey demonstrates that anaesthetists no longer use nitrous oxide in this department. | Decommission medical gas pipeline system and do not replace with alternative system. |
| Hospital 1 | Birthing unit | Manifold B | Nitrous oxide/ oxygen mixture | High | Clinicians are happy to transition to a portable cylinder system. | Ensure supply of gas is aligned to clinical use: Use a portable cylinder system and decommission any existing medical gas pipeline system.<br>Continue to optimise systems: Enhance stock control of nitrous oxide cylinders AND identify supply system inefficiencies AND reduce waste through clinical practice. |
| Hospital 2 | Main theatres | Manifold C | Nitrous oxide | Low | Survey demonstrates that anaesthetists occasionally use nitrous oxide in this department. | Ensure supply of gas is aligned to clinical use: Use a portable cylinder system and decommission any existing medical gas pipeline system.<br>Continue to optimise systems: Enhance stock control of nitrous oxide cylinders AND identify supply system inefficiencies AND reduce waste through clinical practice. |
| Hospital 2 | Birthing unit | Manifold D | Nitrous oxide/ oxygen mixture | High | Identified that the manifold is a far distance from the birthing unit, and there are branches of the medical gas pipeline system that go to places with low clinical use. | Ensure supply of gas is aligned to clinical use: Reposition/redesign a manifold and medical gas pipeline system<br>Continue to optimise systems: Enhance stock control of nitrous oxide cylinders AND identify supply system inefficiencies AND optimise remaining medical gas pipeline systems AND reduce waste through clinical practice. |
| Hospital 2 | Emergency department | Manifold D | Nitrous oxide/ oxygen mixture | Low | Part of same medical gas pipeline system as birthing unit. Requires decommissioning of branch. | Ensure supply of gas is aligned to clinical use: Use a portable cylinder system and decommission any existing medical gas pipeline system.<br>Continue to optimise systems: Enhance stock control of nitrous oxide cylinders AND identify supply system inefficiencies AND reduce waste through clinical practice. |

# No clinical use: Discontinue unused supply systems

**Trusts should decommission piped nitrous oxide and nitrous oxide/oxygen supplies in areas where there is no clinical need for it. This includes the following key actions:**

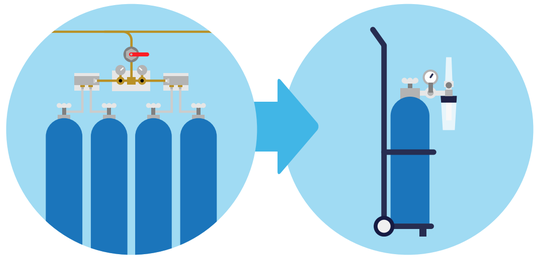
- **Cap the terminal units**: securely cap all terminal units in the clinical area to prevent accidental use of the old piped system.
- **Decommission the relevant medical gas pipeline**: decommission the entire piped system if appropriate for all other clinical areas supplied by that manifold, or the specific branch that connects to the clinical area.

See 'Decommission the medical gas supply system' for more details.

# Low clinical use: Transition to a portable cylinder supply and decommission the medical gas pipeline system

**In areas with low clinical use, switching from piped medical gas to portable cylinder systems for nitrous oxide significantly reduces waste. Trusts should switch to a portable cylinder system proportional to clinical use, and then decommission the piped supply.**

To support this change, you should emphasise to stakeholders that clinical choice is maintained: portable cylinders ensure availability of nitrous oxide and nitrous oxide/oxygen mixture when and where needed. You can opt for a phased introduction of portable systems with a pilot to start or implement the change across all areas at once.



## Transition to a portable cylinder system

### Choose the approach for each area

Decide which portable cylinder system should be used for each low-use clinical area.

Often the simplest option for a portable cylinder supply is for these to be set up on trolleys to be stored in a safe space and available for clinical use when needed. Cylinders on trolleys require pressure regulators and Schrader socket adaptors to connect to the delivery equipment through a gas supply hose.

### Manage system alterations

Some anaesthetic gas machines may sound a low-pressure alarm when attached to a portable cylinder supply, even if gas remains in the cylinder. To manage this, consult technical specifications or contact manufacturers to determine the low-pressure threshold for each machine make/model and how to safely manage swapping to a new cylinder.

Some trusts have included management of this in system checks run by clinical staff at the start of each day or in preparation for use. It is recommended that trusts agree an approach to alarm management that may work best for them and consult with technical experts if they have any questions or concerns.

### Purchase equipment and amend cylinder supply

Identify and purchase all necessary equipment including cylinders, trolleys, regulators and terminal unit caps to ensure a smooth transition in each new area.

Contact the medical gas supplier to ensure the existing supply is stopped and realigned with new requirements. More details about stock control can be found in ‘Enhance stock control of gas cylinders’.

### Set up secure storage

Trusts should establish secure storage facilities to safely store cylinders and other equipment. These should only be accessible to specific, authorised staff.

This and other options are outlined in **supporting resource 2: different options for portable cylinder systems**.

CASE STUDY

## Piloting portable cylinder system in anaesthetics

Implementing a portable cylinder system is an effective way to minimise nitrous oxide waste in anaesthetics. Piloting this means you can test the feasibility, effectiveness and impact of a portable cylinder system in a controlled environment before committing to a full-scale rollout. It also offers tangible proof of cost savings and reduced waste to gain support for trust-wide implementation.

### The issue

An anaesthetist at Gloucestershire Hospitals NHS Foundation Trust was inspired by The Nitrous Oxide Project to reduce the emissions and noticed high volumes of nitrous oxide procurement despite low use in their anaesthetic department.

### The approach

The trust initiated their pilot at Gloucester Royal Hospital where they:

- conducted a survey of nitrous oxide use in the anaesthetic department to engage staff and initiate the pilot
- implemented a 4-week trial by capping off the piped nitrous oxide supply to theatres and using a portable cylinder
- after the trial, met with the head of pharmacy, medical gas committee, estates and portering to switch off the manifold

### The results

The success at Gloucester in the pilot (which did not include obstetric and paediatric theatres) led to Cheltenham General Hospital following suit, where they are using 3 trolleys to supply 14 theatres.

The trial revealed no one was using nitrous oxide cylinders and there was no need for the trust to continue to maintain a medical gas pipeline system. This evidence built a strong case for change, and the trust engaged stakeholders and refined the implementation strategy. The trust has now decommissioned all their nitrous oxide medical gas pipeline supply, reducing their nitrous oxide purchases from 1.1 million litres and 568t$CO_2$e in financial year 2022/23 to 111,000 litres and 55.7t$CO_2$e in financial year 2023/24. This change represents a 90% reduction in emissions from nitrous oxide.

### Agree a process

The handling of small cylinders varies based on local guidance and the type of portable cylinder system used. Identify who is best suited for this task and determine the support needed for the safe transfer and movement of small cylinders. You should document the roles and responsibilities of different stakeholders when establishing the process.

### Deplete existing stock and amend deliveries

Before transitioning to portable cylinders, you should plan for the depletion and return of your existing nitrous oxide and nitrous oxide/oxygen mixture.

This ensures only empty cylinders are returned to the medical gas supplier and no new cylinders are ordered to replace them.

Stock management is an important part of waste reduction. Find additional guidance in 'Enhance stock control of nitrous oxide cylinders'.


## Safe storage area

Once you move to a supply that aligns to clinical need, the storage requirements for cylinders of nitrous oxide and nitrous oxide/oxygen mixture in NHS trusts are generally low and manageable. Every hospital is equipped with designated areas for medical gas cylinder storage and should adhere to established handling protocols. These protocols – that apply to all medical gas cylinders – ensure that all are stored safely and appropriately.

Trusts have adapted to these storage needs in various ways:

- repurposing former manifold spaces for portable cylinder storage
- installing new, purpose-built storage units
- utilising existing storage areas near relevant clinical areas

Guidance from the Specialist Pharmacy Service on all processes supporting secure storage of cylinders.

## Graphic: Process map

Charing Cross Hospital created a clear process map showing how portering staff, healthcare professionals, pharmacy staff and suppliers should manage nitrous oxide cylinders.

This visual guide helped the trust reduce waste by:

- only ordering new cylinders when needed
- keeping the right amount of stock for clinical use
- making sure cylinders are closed when not in use to stop leaks
- storing cylinders safely and securely to prevent theft

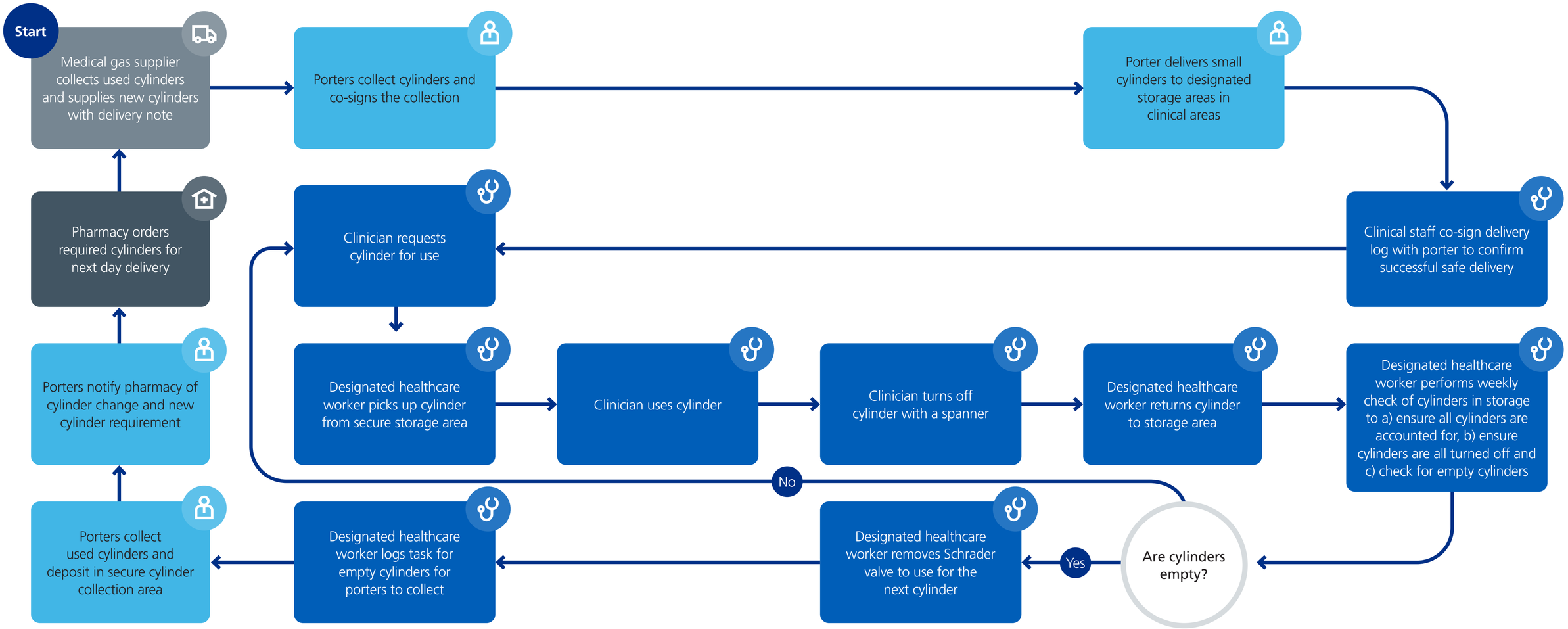
The process map also made sure staff handled cylinders safely and followed regulations.

An editable version of this process map is available in **supporting resource 10: cylinder management process map**.

# Portable supply cylinder management process

Medical gas supplier | Porter | Health care professional | Pharmacy

**Tip:** portable cylinders are likely to have an infrequent replacement rate once the supply system is matched to clinical use and the cylinders are turned off once used.



## Transition the supply system

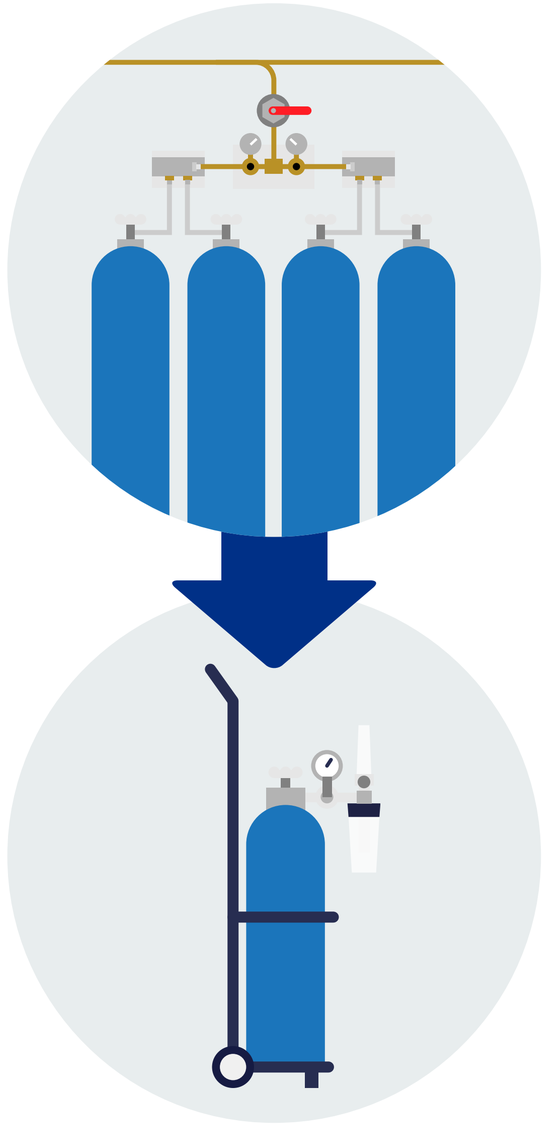
Ensure the following steps are completed when they are ready to switch to a portable cylinder system:

- **Receive sign-off from relevant leadership:** once it has been established that a supply is no longer required to a clinical area, an appropriate medical or clinical lead should confirm this in writing to the project team, including the head of estates and appropriate pharmacy staff.
- **Communicate with staff**: inform all relevant staff, including medical, clinical and portering teams, about the transition using template emails and meetings to ensure everyone is aware of the new procedures and timelines.
- **Set up the system**: work with your medical engineers and other relevant colleagues to set up the portable cylinder system and install the small cylinders.
- **Put up posters at terminal units**: display informative posters near the old valves and in key areas to educate staff about the new cylinder setup and the reasons for the switch, reinforcing the new procedures and safety measures.
- **Cap the terminal units**: securely cap all terminal units in the clinical area to prevent accidental use of the old piped system.
- **Decommission the relevant medical gas pipeline**: decommission the entire piped system if appropriate for all other clinical areas supplied by that manifold, or the specific branch that connects to the clinical area. The physical decommissioning should not hinder the transition in clinical practice and can follow as soon as practically possible.

See the ‘Decommission the medical gas supply system’ for more details.

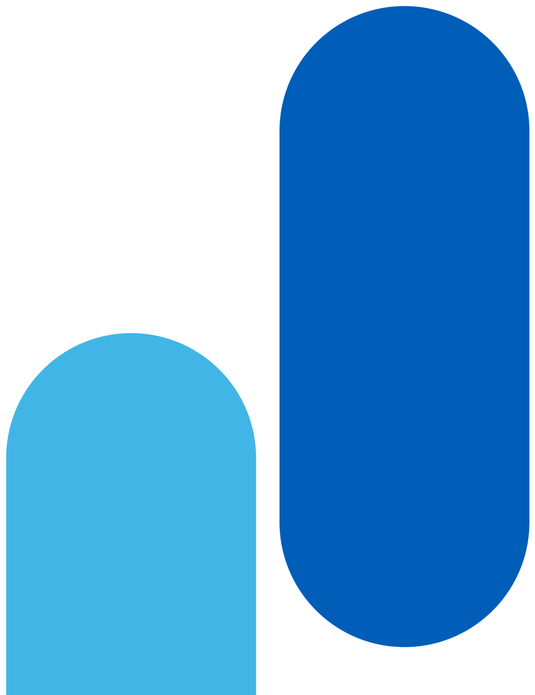
Specific actions for transitioning to a portable cylinder system are in **supporting resource 4: action list**

**Supporting resource 3: project communication templates** provides information and resources for when a team is ready to transition to a portable cylinder system. It contains emails and posters to help communicate the change.



# High clinical use: Optimise supply systems

**In all areas where nitrous oxide or nitrous oxide/oxygen mixture use is 'high', significant opportunities exist to reduce waste. While most waste reduction efforts to date have focused on areas with no or low clinical use, dedicated teams across the NHS are now trialling innovative approaches to tackle waste in high-use clinical settings such as maternity units and paediatric dentistry.**



Options for waste reduction in high-use areas include:

- **Replace the pipeline with a portable cylinder system:** in high-use areas, portable systems can offer greater flexibility and efficiency. Follow the guidance under 'Low clinical use' for implementation steps.
- **Redesigning pipeline systems:** repositioning and resizing manifolds can reduce waste by minimising pipeline length and optimising supply. For guidance on improving medical gas pipeline design, refer to 'Improve design of existing systems and evaluate new gas supply needs.'
- **Optimising existing medical gas pipeline systems:** ensuring the existing medical gas piped supply system is operating at peak efficiency. Refer to the next chapter 'Continue to optimise systems' for detailed information on optimising existing medical gas pipeline systems.

In all cases, work with medical gas suppliers to enhance the existing supply to reduce waste. More details about stock control can be found in 'Enhance stock control of gas cylinders.'

CASE STUDY

## Using a portable cylinder system in a busy maternity unit

### The issue

King's College Hospital, part of King's College Hospital NHS Foundation Trust, has one of the largest maternity units in London, with on average 7,000 births per year. Nitrous oxide/oxygen mixture was supplied to the unit by a large 14-cylinder manifold connected to a medical gas pipeline system.

The team knew their nitrous oxide/oxygen mixture usage was much higher compared to similar size units. They also understood cylinders were changed on the manifold far more regularly at King's than at these similar locations. They suspected leaks were present in the system but it was not possible to predict or anticipate when usage of the busy unit would be low to run a pressure test to identify leaks.

### The approach

Over the course of a few weeks, the team prepared the unit with sufficient smaller cylinders that could be used in a portable cylinder supply. They planned and disseminated a cylinder ordering and replacement process to ensure small cylinders would always be available on the unit. Midwives and nursing staff were integral to the planning and execution of the process and dissemination of information before and during this period.

### The results

King's College Hospital continues to use a portable cylinder system in maternity. It uses an average of 105,000 litres a month (compared to a previous average of 406,875). This is a monthly carbon emission saving of 113t$CO_2$e and roughly £9,560 (gas refill cost and cylinder rental). Staff have noticed patient benefits in the portable cylinder system, meaning they can use the nitrous oxide/oxygen mixture in different locations. This gives the option of pain relief to patients who may prefer to be mobile or away from the bedside.

# Decommission the medical gas pipeline system

**You may choose to decommission either entire manifolds or just parts of a medical gas pipeline system, based on their clinical use assessment. The decision will align with the transition to portable systems, or the elimination of nitrous oxide use in certain areas.**

The decommissioning process should be aligned as closely as possible with the clinical changes in nitrous oxide supply. However, perfect alignment may not always be achievable due to various logistical factors. The physical decommissioning should not hinder the transition in clinical practice and can follow as soon as practically possible.

The decommissioning should be carried out by an authorised person. An authorised person is likely to be a member of the estates team, and they will have sufficient technical knowledge, training and experience to understand fully the workings of a medical gas pipeline system. Authorised persons are responsible for the day-to-day management of the medical gas pipeline system (including maintenance of manifolds, pipe work, valves, terminal units and alarm systems). As standard practice, they are aware of and follow safety guidelines (including international standards and health technical memorandum) to manage medical gas pipeline systems.

Steps for decommissioning an entire medical gas pipeline system or specific branches that do not require a supply due to no/low clinical use are available in the action lists in **supporting resource 4: action list**.

While it is not always necessary to completely remove the physical infrastructure, such as pipes and manifolds, they must be securely deactivated. This process requires ensuring that all components of the system are fully shut off, a task that can be complex, especially if the system is extensive or intricately connected throughout various parts of the hospital.

**International Standards and Health Technical Memorandum for switching off piped supply**

Both Health Technical Memorandum 02-01 and ISO 7396 provide critical guidelines that ensure the safe and effective operation of medical gas pipeline systems. When switching off the piped supply of nitrous oxide, adherence to these standards is essential to ensure safety, maintain compliance and optimise medical gas pipeline system performance.


## Hospital infrastructure variability

Depending on the hospital's infrastructure, such as Private Finance Initiative (PFI) agreements or specific contractual agreements, the approach to decommissioning the medical gas pipeline system may differ.

Some hospitals may need to deactivate the entire system at the same time, while others might require a phased approach, shutting down each manifold sequentially according to a rollout plan. Assess the specific contractual and infrastructural constraints of a hospital to determine the most feasible approach for decommissioning, allowing for either a total or staged shutdown.

This plan should be reviewed and approved by the authorised person and should comply with all relevant regulations to ensure safety and minimise disruption.

## Managing alarms and control panels

The decommissioning process also involves managing the medical gas pipeline system's alarms and control panels. Schedule dedicated time to address the alarms and control panels as part of a decommissioning plan.

These systems are designed to alert staff to problems like low pressure or leaks and must be adjusted to prevent false alarms during and after the decommissioning process. The estates and facilities teams should support the project team to methodically manage each section, ensuring all valves are closed, the system is depressurised, and all terminal units are capped to prevent accidental use or leaks.

Technical staff, such as clinical engineers, should be tasked with adjusting the alarms to ensure they do not activate unnecessarily once the gas supply has been turned off. This might involve reprogramming or temporarily disabling alarms until the decommissioning is confirmed to be complete and safe.

Anaesthetic machines and other clinical equipment may also need adjustments by clinical engineers or equipment representatives to avoid alarms due to the removal of piped nitrous oxide supply.

# Continue to optimise systems

06

Alongside improving gas supply systems, ensure these systems perform as efficiently as possible. This section outlines how you can optimise nitrous oxide and nitrous/oxide gas supply systems to further reduce waste and save costs.

Optimising a system to work to maximum efficiency is an ongoing process and is important for portable and medical gas pipeline supply systems and includes stock management, identifying system inefficiencies, ongoing maintenance and reducing waste through clinical practice.

**In this section**

# Enhance stock control of nitrous oxide cylinders

**Effective management of portable cylinder system and medical gas pipeline system cylinder stock reduces waste and costs. Once each clinical area has a supply system aligned to clinical use then ensure the existing supply is realigned with what is required.**

It is common for hospitals to rely on a 'milk-round' system for their cylinder procurement, where a fixed number of cylinders are delivered on a regular schedule regardless of actual usage. This approach often leads to inefficiencies such as overstocking and significant waste.

Ensuring the amount and size of cylinders are appropriate and that these are handled, stored, transported and installed correctly can minimise the risk of over-stocking.

To address these issues, transition to a demand-driven delivery system. This system bases cylinder orders on usage data rather than fixed schedules, ensuring the inventory of cylinders meets needs.


### Who is involved?

**1. Pharmacy procurement team:** collaborate with suppliers to ensure cylinder orders are based on usage rather than estimates. They negotiate supply contracts to support a demand-driven model.

**2. Portering staff:** responsible for the distribution and collection of cylinders. They maintain the flow of supplies and ensure that used cylinders are returned promptly for refilling.

**3. Suppliers:** work closely with the trust to adapt the supply chain to a system where cylinders are replaced based on returns. This partnership supports the implementation of a demand-driven system.

**4. Clinical staff:** provide usage data and feedback to ensure that the cylinder stock aligns to clinical demand. Following best practice for use of small cylinders.

**5. Switchboard team:** communicate issues. Alarms often placed in switchboard sound when issues occur – such as banks on a manifold running low – and switchboard staff notify portering staff to rectify.

### Why implement a demand-driven cylinder management system?

- With fewer unnecessary cylinders on hand, the time spent on handling, storing, and maintaining excess inventory is significantly reduced. This allows portering and estates and facilities staff to focus on other critical tasks.
- By ordering based on usage, hospitals can avoid the accumulation of unused cylinders, reducing cylinder rental costs and environmental impact associated with wasted gases.
- Appropriate stock levels free up valuable storage space within medical facilities.

Some trusts have implemented the following strategies to ensure their management systems are efficient:

- **Transition from routine 'milk-round' deliveries** to a tailored delivery system that aligns to clinical needs, enhancing efficiency and reducing waste.
- **Establish clear roles and responsibilities** and foster collaboration among all stakeholders in the cylinder management process, drawing on the medical gas committee members whose teams are involved in the process.
- **Implement proactive monitoring** to identify and fix maintenance issues including leaks across the cylinder management system.
- **Enable portering staff** and other stakeholders to communicate risks, issues and concerns directly to the medical gas committee.
- **Develop inventory and stock management systems** to ensure optimal supply levels and track cylinder usage effectively. This may include electronic tagging systems (such as Radio-Frequency Identification or RFID), sign-in/out processes, or app-based cylinder management tools. These technologies help to automatically track the location and status of gas cylinders, improving efficiency and reducing waste.
- **Maintain secure and safe storage areas** to comply with health and safety regulations, preventing potential hazards. As with larger cylinders used for a medical gas pipeline system, secure storage where access can be tracked or traced is imperative to reduce the risks of theft or misuse.
- **Provide ongoing training** to estates, facilities and clinical staff to ensure they are competent in inspecting and managing medical gas equipment. This training should include routine checks for damage and the timely replacement of equipment.
- **Ensure mandatory training**, usually provided by medical gas suppliers, is completed for estates and facilities staff to handle gas cylinders and piped systems safely, covering emergency procedures and the correct use of safety equipment to minimise risks and enhance preparedness for any situation.

CASE STUDY

## Redesigning a nitrous oxide cylinder management system

Hull University Teaching Hospitals NHS Trust has redesigned its nitrous oxide cylinder management system, improving environmental sustainability, reducing costs and enhancing safety.

### The issue

In 2023, the trust identified inefficiencies in its nitrous oxide supply, where 'milk bottle rounds' led to excessive purchasing of the gas. Recognising those with the most experience of the system were the best placed to improve it, management of the supply transferred from the pharmacy department to the portering team overseen by the medical gas committee, to streamline processes and reduce waste.

### The approach

The portering team used their digital task management system for real-time monitoring and proactive stock management to make sure it aligned to clinical demand. The team completed daily inspections and weekly reviews to ensure cylinders were available and stock levels appropriate. The team notified the estates team if they identified any leaks and raised tasks for them to fix the system. They documented any leaks or fixes required via their incident reporting system for continuous improvement.

Monthly audits and reports to the medical gas committee helped resolve issues. The portering team also collaborated closely with clinical and estates staff in multidisciplinary meetings to refine their processes.

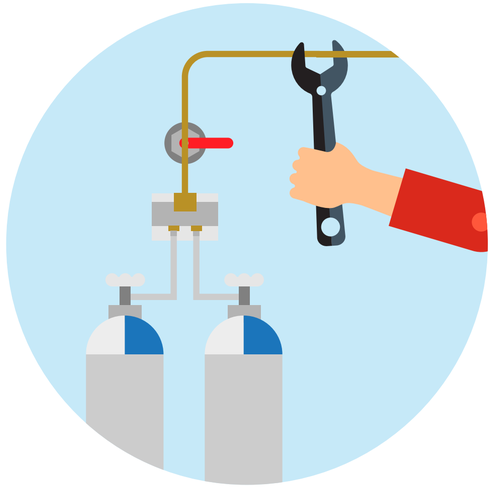
### The results

The Hull portering team's process enabled them to better understand and effectively manage appropriate stock levels, ordering fewer cylinders to better meet clinical needs. Leak checks and fixes have also led to a reduction in the waste of nitrous oxide, which, in turn, has meant fewer cylinders are needed. These improvements have saved time for the portering team who now manage a smaller supply.

Incident reporting and collaborative working have fostered a culture of safety and accountability, to continue eliminating further wastes in the system.

# Optimise remaining medical gas pipeline systems

**When it has been decided that a portable cylinder system is not appropriate and a medical gas pipeline system will remain in place, avoid waste by proactively detecting and maintaining leaks. You do not need to perform leak tests or repairs on piped systems or parts of piped systems that are not clinically necessary. Instead, decommission the system to avoid unnecessary maintenance and costs.**



## Annual scheduled system pressure tests

Annual system pressure tests ensure that systems are sealed and functioning at the required pressure. These tests should be scheduled annually, overseen by an Authorised Person from the estates and facilities team, during periods of low demand – such as nights, weekends or staff training days – to minimise disruption. This timing is important because it allows for a thorough assessment without compromising the availability of medical gases for patient care.

Some areas have unpredictable clinical demand making it difficult to schedule system pressure tests. To support these tests, especially in areas like maternity units, hospitals often arrange for portable gas cylinders to ensure that gas supply is uninterrupted.

Ensure your hospital has a portable cylinder system available for deployment during system pressure tests so they can be scheduled in. This planning ensures that patients continued to be cared for while necessary maintenance is carried out. It also provides a contingency plan in case of unplanned piped system outages.

### Standards and assurance for estates and facilities teams

NHS trusts must follow structured maintenance and optimisation protocols for medical gas pipeline systems, in line with international standards (such as ISO 7396) and national guidelines (including Health Technical Memorandum HTM 02-01). These protocols are designed to maintain medical gas pipeline systems at a high level of safety and efficiency, in accordance with patient care requirements and regulatory expectations. Adherence to these standards helps trusts meet their obligations for patient safety and high-quality healthcare facility management.

Medical gas committees should oversee the integration of ongoing maintenance schedules into standard operating procedures including annual testing of the efficacy of the equipment, environment, clinical practices, training of staff and all other mitigations. These schedules must be included in the trust's monitoring and assurance processes (see Health Technical Memorandum 02-01 Part B). Routine maintenance schedules also support compliance with Control of Substances Hazardous to Health (COSHH) Regulations 2002 and EH40/2005 Workplace exposure limits.

# Identification of leaks

Regular inspections of the medical gas pipeline system can identify and address leaks before they lead to system-wide issues, contributing to long-term savings by preventing gas waste.

Leak detection methods can be categorised into two main types:

**System-wide leak identification:** assess the entire medical gas pipeline system to determine if leaks are present and quantify overall system waste. This provides assurance about the system's integrity.

**Location-specific leak detection:** once a leak is suspected or confirmed through system-wide methods, these techniques are used to pinpoint the exact location of leaks. While they cannot provide assurance about overall system integrity, they can help to target repairs.

Table 4 outlines the available methods and recommendations for their use.

### How the pressure tests work

During a system pressure test, the system is isolated and then pressurised to a specific level (usually four bar) and monitored to see if the pressure remains stable. If the pressure drops, it indicates a leak, leading to further investigations to locate and fix the issue.  HTM02-01 (paragraphs 15.12-15.16) provides detailed guidance on the pressure testing procedure, which involves isolating the pipeline system, connecting a pressure gauge, and pressurising the system to 1.5 times the nominal pipeline distribution pressure (or a maximum of 1000 kPa) for at least 30 minutes. The system passes the test if the pressure drop is less than 0.2% of the test pressure per hour.

Sometimes, pressure tests are conducted without isolating the system, which can lead to false indications of zero leaks in the medical gas pipeline.

## Table 4: Available methods and recommendations for their use

| Method | Tool | Description | Advantages | Disadvantages |
|---|---|---|---|---|
| **Methods to understand the extent of system leaks – only these methods can give confidence that no leaks are present.** | | | | |
| **Gold standard method for system-wide leak identification** | System pressure test with system isolated | This is outlined in the annual scheduled system maintenance section and complies with Health Technical Memorandum guidelines. | | |
| **Alternative method for system-wide leak identification** | Measuring leakage by weighing cylinders (Gaff et al., 2023; Green Theatres, 2023) | Uses digital scales to measure depletion of cylinders at the manifold providing an accurate assessment of potential gas losses. | • Detects small leaks with high sensitivity<br>• Helps to correct leaks in a timely way<br>• Reduces waste and improves supply system efficiency<br>• Less disruption to operations<br>• Can help to quantify total system waste by comparing leak volume to clinical use data | • Requires precise scales and technology<br>• Novel approach to system wide leak detection |
| **Methods to support the identification of leak locations. These can identify leaks but cannot be used to confirm the absence of leaks.** | | | | |
| **Recommended method for location-specific leak detection** | Portable nitrous oxide detectors/ analysers - in accessible locations | Measure nitrous oxide concentrations from 0 to 1000 ppm and can store up to 1000 readings. These devices allow for the calculation of time-weighted averages of exposure to gas. | • Accurate and portable<br>• Useful for both leak detection and monitoring occupational exposure | • Cost may be a consideration<br>• Requires regular calibration to maintain accuracy |
| **Supplementary method for location-specific leak detection** | Bubble tests using soapy water | A solution is applied to pipes, and the formation of bubbles indicates a leak. | • Inexpensive and easy to perform | • Only viable on exposed and accessible sections of piping<br>• Ineffective for detecting leaks in concealed areas |
| | Ultrasonic acoustic signal tests | Uses acoustic sensors to detect ultrasound frequencies indicating gas leaks. Features an automated recording function to create an electronic audit trail for increased accuracy and accountability in leak detection. | • Can be used for all medical gases<br>• Provides early warning by ‘hearing’ leaks before they become more significant issues | • Expensive<br>• Requires expert interpretation |

## Replace damaged or outdated equipment

For medical gas pipeline systems, trusts should thoroughly maintain damaged or leaking points, with worn parts replaced quickly to maintain system integrity. This proactive maintenance approach extends the equipment's life and ensures consistent delivery of medical gases to clinical areas, contributing to long-term savings by preventing gas waste.

Estates and facilities teams should ensure they embed scheduled replacement into their processes for managing pipeline equipment. Regular inspections and maintenance of pipeline components, including valves, connections, and seals, help to prevent leaks and ensure system efficiency.

For managing portable cylinder supplies, trusts should ensure there are processes to replace components that are prone to wear and tear, particularly the connection points between cylinders and equipment. The rubber O-rings can become brittle when exposed to oxidisers like nitrous oxide and may crack when the yoke is removed during cylinder changes. Ensure staff responsible for replacing cylinders are aware of this potential issue.

## Improve design of existing systems and evaluate new gas supply needs

Assess if a medical gas pipeline for nitrous oxide is necessary, either in its entirety or for specific areas. If new medical gas pipeline systems are required, they should be designed to optimise space, efficiency and aligned to clinical need.

Only consider new piped supply systems for nitrous oxide gas products if a portable cylinder system or repositioning of the manifold is not possible and in areas of high clinical demand, where a needs assessment has been completed. Installing unnecessary medical gas pipeline systems can lead to increased nitrous oxide waste, added costs, and a higher workload for estates and facilities staff in the long term.

The following steps have been considered in trusts building new clinical areas:

- conduct a thorough assessment to determine the clinical necessity for a piped nitrous oxide supply system
- ensure the manifold space is appropriately sized and located based on clinical requirements
- avoid oversized manifold spaces with excess connections and cylinders, as they can lead to higher gas waste and increased pressure requirements to drive gas through the components
- design manifolds with shorter pipe distances to the point of care to reduce the likelihood of leaks

If a medical gas pipeline system for nitrous oxide is necessary, maintenance and monitoring should be implemented as per the relevant guidelines and best practices in ISO 7396-1:2016 Medical gas pipeline systems and Health Technical Memorandum 02-01: Medical gas pipeline systems (Part A and B) to ensure efficiency and minimise waste.

### Who is involved?

Medical gas committees should play a central role in hospital design decisions related to piped medical gas supplies, ensuring these decisions are grounded in evidence specific to the hospital and supported by clinical insights. These decisions should prioritise practical benefits and operational efficiency. The Health Technical Memorandum 02-01 (HTM) provides guidance which trusts should follow. It is not prescriptive, for example table 11 - Provision of terminal units, AVSUs and local alarms outlines options trusts could utilise when designing systems to meet local requirements.

Healthcare professionals and other NHS staff should be consulted to understand the consequence of any change on delivery of care and the impact on work practices. Insights should be shared with medical gas committees to inform decision making relating to new piped medical gas supplies.

# Reduce waste through clinical practice

**This section aims to support the effective management of clinical equipment to mitigate environmental impact while maintaining patient care standards. Distribute guidance to clinical staff and organise learning events focused on reducing nitrous oxide waste in clinical settings.**

## Manage clinical equipment

Healthcare professionals can help to reduce nitrous oxide waste by:

- turning off equipment when not in use
- disconnecting equipment from the supply when not needed
- regularly checking for damage and arranging repairs or replacements

In maternity settings, demand valves should be disconnected from the gas supply when not in use. While these valves conserve nitrous oxide/oxygen mixture by releasing it only upon patient inhalation, they can leak if left connected.

In other clinical settings, it is important for healthcare professionals to ensure that all devices are turned off and portable cylinder valves are closed fully after use to avoid minor leaks that can occur if the cylinder remains connected.

Effective strategies implemented in trusts that have done this work:

- **Visual cues:** place posters, signs or labels near nitrous oxide equipment to remind healthcare professionals to turn off devices and flow meters when not in use.
- **Champions:** assign a team member to manage nitrous oxide equipment and to support colleagues to follow visual cues and best practices.
- **Protocols:** establish a checklist or protocol for setting up and shutting down equipment. This might include incorporating equipment checks into post-procedure routines to confirm that demand valves are removed, and all nitrous oxide devices and equipment are turned off after being used.

The poster in the **supporting resource 5: project communications templates** can be used to run a campaign to remind maternity teams to disconnect demand valves.

CASE STUDY

## Reducing gas emissions at Hull Women and Children's Hospital

### The issue

Hull University Teaching Hospitals NHS Trust identified that almost one fifth (around 17% or 5,000 tonnes) of their total carbon emissions were generated by anaesthetic gases. Of these, approximately 4,000 tonnes came from the use of nitrous oxide/oxygen mixture as a pain-relieving gas for women giving birth in Hull Women and Children's Hospital. The trust set a target to halve gas emissions by 2025 as part of its Zero30 ambitions.

### The approach

A multidisciplinary team including midwives, pharmacy and estates staff, and colleagues from the PFI company investigated possible leaks throughout the system, from gas cylinders to the point of use. They identified small leaks at both the bedhead panels and demand valves. In response, they changed the bedhead seals and implemented a new practice of only plugging demand valves into the nitrous oxide/oxygen mixture supply when in use, rather than keeping them connected constantly. They also launched a campaign to remind staff about the new practices.

### The results

This approach led to an 80% annual reduction in emissions related to the nitrous oxide/oxygen mixture and annual savings projected to be about £40,000. The changes did not affect the high-quality care offered to women in labour.

In this case study, carbon and cost savings were initially estimated in January/February 2022, around four months after improvement work commenced, using the available data at that time. The infographic on page 4 presents the total actual carbon savings achieved over the 12 months following the start of the improvement work.

Read the full article on the trust's website.

## Completely deplete small cylinders

While portable cylinder supply of nitrous oxide or nitrous oxide/oxygen mixture produces less waste, some still occurs when used (but not empty) cylinders are vented into the atmosphere upon return to medical gas suppliers, as per MHRA regulations. To mitigate the environmental impact of this, healthcare professionals should use cylinders until they are empty.

Accurately monitoring the remaining gas in a cylinder can be challenging due to nitrous oxide's properties. The pressure gauge on small cylinders indicates internal pressure, not volume, which can be misleading. Additionally, anaesthetic machines may sound low-pressure alarms before the cylinder is fully depleted. These factors can lead to difficulties in estimating supply duration and determining when replacements are necessary.

Healthcare professionals might replace cylinders prematurely based on these indicators, despite significant gas remaining. Healthcare professionals should feel confident in using cylinders until they are fully depleted.

To support this practice, some trusts have implemented the following steps in their nitrous oxide waste reduction training:

- ensure there is a backup cylinder readily available to switch to if required
- before using a cylinder, check the pressure gauge to determine the amount of gas remaining in the current cylinder
- regularly check the pressure gauge during the procedure to ensure that the cylinder is being depleted effectively
- once the pressure gauge indicates that the cylinder is nearly empty, prepare to switch to a new cylinder
- when the cylinder is completely depleted, turn off the nitrous oxide supply and disconnect the empty cylinder from the patient circuit, replacing it with the full backup cylinder following the manufacturer's instructions and trust protocols

Ultimately, it is at the discretion of the healthcare professional to decide when best to swap out the portable cylinder to a new one.

CASE STUDY

## Safely depleting nitrous oxide cylinders

### The issue

Gloucestershire Hospitals NHS Foundation Trust transitioned to a portable supply of nitrous oxide. Their focus is now on reducing waste from the remaining nitrous oxide used.

### The approach

Cylinders can be changed when they are empty with minimal risks as due to low flow rates - even if nitrous oxide stops being added to the circuit, the existing nitrous in the system can last for up to 15 minutes. This provides ample time to change cylinders if needed.

The only exception might be during a gas induction, where high flows are used. In this case, staff can wait for a new cylinder or proceed without nitrous oxide.

- staff are advised to change cylinders only when they are empty, minimising waste
- back-up cylinders are made readily available to switch to once the first cylinder is completely depleted
- staff are educated about the low risk of running cylinders to depletion, given the extended period that nitrous oxide remains in the system even after the supply is stopped

Similarly, Yorkshire Ambulance Service (YAS) uses a portable supply of nitrous oxide/oxygen mixture. They identified significant waste levels from sending back cylinders with 25% of gas remaining and have implemented a process to ensure cylinders are completely depleted on return to the supplier. Like Gloucestershire, YAS ensures staff have back up cylinders available to switch to once they have completely depleted the first cylinder.

### The results

By depleting cylinders completely before returning them, both organisations reduced residual nitrous oxide waste and associated emissions.

# Catalytic destruction units

**The main contributor to emissions is nitrous oxide waste released before clinical usage. Catalytic destruction technologies do not address this pre-clinical waste, which can account for a significant portion of supplied gas.**

Catalytic destruction technology captures nitrous oxide and breaks it down into nitrogen and oxygen before it enters the atmosphere. There are 2 main types: Mobile Destruction Units (MDUs) for single rooms and Central Destruction Units (CDUs) that connect to multiple rooms via the hospital's ventilation system. Both require patients to exhale into devices to capture the gas.

This toolkit does not address the effectiveness of this technology. Prioritise aligning supply systems to clinical need and ongoing optimisation of systems before considering the technology.

Some trusts have also looked into catalytic destruction to reduce staff exposure to nitrous oxide. Read the guidance on NHS England's website on how to protect staff.

If trusts do consider implementing catalytic destruction technology, they should carefully assess the costs, practicality and potential benefits within their specific clinical context.

07

# References

# References

Much of the information in this toolkit has been captured from stakeholder engagement with trusts who have completed the work.

The following resources have also contributed to the material in this toolkit.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