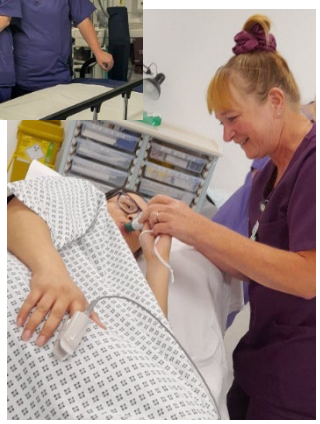
SUSQI PROJECT REPORT

Introducing Penthrox for patients undergoing colonoscopy as a greener alternative to Intravenous analgesia or Entonox





Start date of Project:
April 2026
Date of Report:
August 2026

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Background:

The NHS is responsible for around 4-5 % of the UK's total carbon footprint and has committed to achieving Net Zero emissions by 2040, extending to suppliers by 2045. Achieving this ambition requires action across all specialties, including gastroenterology.

Practice Plus Group (PPG) Hospitals plan to reduce their carbon footprint by 80% by 2032 and achieve net zero by 2040. PPG plan to achieve 10% net biodiversity gain by 2030, across the PPG Estate. PPG plan to adopt the Clean Air Hospital Framework to achieve an 'Excellent' score of 70% by 2028. PPG plan to have a Climate Change Adaption Plan and ensure that we have reduced the risk our hospital premises have on this by 20% by the end of 2025. PPG plan to adopt a sustainable model of care for each clinical pathway by 2028.

Endoscopy is the third highest emitting hospital department generating about 3.09kg of waste per bed day which is equivalent to burning 39 million pounds of coal or 13,500 tonnes of plastic. Each endoscopic procedure generates approximately 2kg of disposable waste and routine endoscopy can generate significant emission with individual procedures estimated at around 28kg CO_2 in some settings — travel and equipment contribute substantially.

PPG Endoscopy services are JAG (Joint Advisory Group) accredited, performing over 22,000 endoscopies a year over 9 sites. In 2021 a new standard was introduced to the accreditation standards- GRS standard 1.9. *The service has a green endoscopy working group to reduce the environmental impact of the service and initiates at least one environmental initiative*. JAG Green Endoscopy is an

initiative to make gastrointestinal endoscopy more eco-friendly by reducing carbon footprints, improving waste segregation, and embedding sustainability into the JAG accreditation process.



In response to the new JAG standard our Endoscopy Services added 'Greener Endoscopy' as a standing agenda item to its endoscopy quarterly forums (EQF) and started to explore initiatives and ways to understand and reduce environmental impact of its services. Working alongside PPG's central 'Greener Hospitals' Group we identified that offering the use of Entonox as an option of analgesia for endoscopy procedures, whilst benefiting our patients was also contributing to the greenhouse gases impacting on the environment. The costs of Installing an Anaesthetic Gas Scavenging System (AGSS) across our sites with destruction technology to reduce Entonox emissions is likely to be space and cost prohibitive. We started to explore alternatives and looked at UK studies and ambulance service evaluations comparing Penthrox (methoxyflurane) and Entonox (nitrous oxide/oxygen) which showed that Penthrox provides faster moderate-to-severe trauma pain relief, offers a significantly lower carbon footprint, and avoids heavy gas cylinders.

Penthrox (see image to right) and Entonox are both fast-acting, inhaled pain relief options used in emergency and healthcare settings, differing primarily in active ingredients, delivery, and environmental impact. Penthrox uses methoxyflurane in a small pocket-sized device, while Entonox uses a 50% nitrous oxide, 50% oxygen from a large gas cylinder or piping.



Entonox is a fast-acting, self-administered inhaled gas via tubing and a demand valve mouthpiece and has been widely used in endoscopy for many years. It is a safe alternative to sedation, allowing for rapid recovery and no requirement for an escort home. The gas is exhaled directly into the air by patients after use, carrying the greenhouse effect straight into the atmosphere. When used in healthcare, up to 60% of nitrous oxide escapes into the atmosphere. Nitrous Oxide (N_2O) is a potent greenhouse gas and ozone depleting substance which persists in the environment for over 121 years.

Nitrous Oxide emissions account for 2% of the total NHS emissions and Entonox represents approximately 2/3rds of all N_2O emissions. Entonox emits potent greenhouse gases and suffers from leakage, causing significant environmental harm and has been linked to harm related to occupational exposure. Most nitrous oxide emissions arise from infrastructure leaks, reducing sustainability even in efficient clinical programs. Entonox is contraindicated in conditions involving trapped body air, increased intracranial pressure, or impaired consciousness. Key absolute exclusions include pneumothorax, bowel obstruction, and recent intraocular gas injection. These are managed through Entonox safety checklists.

Penthrox (Methoxyflurane) delivers analgesia with a climate impact over 100 times lower than Entonox, using single-use handheld inhalers. Adopting Penthrox reduces greenhouse gas emissions without compromising patient care, aiding decarbonisation strategies. Penthrox provides rapid-onset analgesia, is easy to self-administer, and reduces staff exposure to nitrous oxide, improving occupational safety. Penthrox provides fast-acting pain relief, ideal for timely control during endoscopic procedures. Patients self-administer Penthrox via handheld inhaler, allowing customized dosing and increased comfort. Penthrox simplifies procedures by reducing IV needs and offers superior environmental performance compared to alternatives. Contraindications in renal or hepatic impairment are managed through screening protocols ensuring patient safety.

Specific Aims:

The aim of this project was to introduce and pilot Penthrox for patients undergoing colonoscopy as a greener and effective alternative to Intravenous sedation and analgesia or Entonox, still ensuring that their comfort and safety remain a priority throughout their procedure and recovery. To compare auditable outcomes with a view to a long-term change in practice within PPG Endoscopy Services.

Methods:

Pilots have taken place at two PPG sites Gillingham and Portsmouth. Both are independent providers for the NHS and self-pay patients, both with different demographics.

Gillingham is a day case surgical centre providing diagnostic investigations for the population of Kent, with Medway and Swale serving a population of 2 million. The endoscopy service has 1 endoscopy suite and performs approximately 3000 endoscopy procedures annually. Data collated from May 2025 -May 2026 showed 434 Colonoscopies were performed of which 58% were unsedated with 186 patients choosing Entonox. 175 Flexible sigmoidoscopies were performed of which 98% were unsedated with 137 patients choosing Entonox.

Portsmouth is also a day case surgical centre providing diagnostic investigations for the population of Hampshire and the Isle of Wight serving a population of 1.9 million. The endoscopy service is busier and larger and has two endoscopy suites, performing approximately 7000 endoscopy procedures annually. Data collated from May 2025 -May 2026 showed 1293 Colonoscopies were performed of which 42.2% were unsedated with 545 patients choosing Entonox, 1026 Flexible sigmoidoscopies were performed of which 93% were unsedated with 954 patients choosing Entonox.

To introduce and implement Penthrox at site level, as an alternative option to IV sedation or Entonox each team had a nominated project clinical lead to work alongside and engage the endoscopy leads, endoscopists and their teams and to collate the data required both pre and post pathway change.

Studying the System

The project originated from an awareness of the significant environmental impact associated with the use of nitrous oxide (Entonox) within endoscopy services. Nitrous oxide is recognised as a potent greenhouse gas with a long atmospheric lifespan, and reducing its use aligns with national healthcare sustainability ambitions. While staff understood the environmental implications, a detailed review was required to identify a clinically appropriate and sustainable alternative that could be used within endoscopy settings without compromising patient care or experience.

To better understand the available options, a review of current practice and alternative analgesic agents was undertaken. This involved researching literature, reviewing examples of innovation from other healthcare organisations, and conducting internet searches to identify solutions already being used successfully within healthcare settings. Through this process, Penthrox (methoxyflurane) was identified as a potential alternative to Entonox. Evidence from other organisations demonstrated that Penthrox was being used effectively for procedural pain management and could offer substantial environmental benefits when compared with Entonox.

Following identification of a potential alternative, baseline data were gathered to understand the extent of Entonox usage across the organisation. A retrospective review of consumption data was undertaken using information obtained from the procurement and supplies department. Weekly ordering records for Entonox cylinders were analysed to establish patterns of use and determine the volume of gas consumed by endoscopy services. This baseline information enabled the project team to quantify current usage, estimate the environmental impact of Entonox use, and provide a benchmark against which any future reduction could be measured.

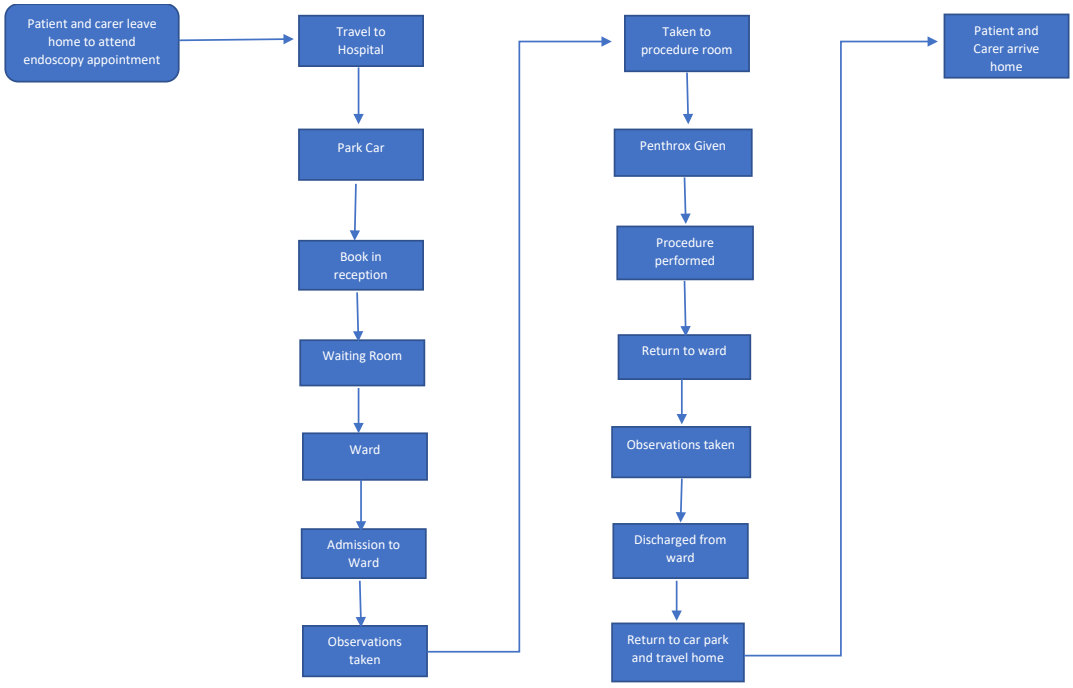
Engagement with key stakeholders was identified as a critical component of the project from the outset. A multidisciplinary approach was adopted to ensure that all individuals involved in the prescribing, supply, administration, governance, and operational management of analgesia within endoscopy services had the opportunity to contribute. Stakeholders included pharmacists, endoscopy managers, heads of nursing, endoscopy nursing and clinical staff, stores and procurement teams, and hospital directors.

A series of meetings were held with each stakeholder group to explain the rationale for the project, discuss the evidence supporting Penthrox as an alternative, outline the proposed trial, and answer any questions or concerns. These discussions proved invaluable in identifying potential barriers early, understanding operational requirements, and securing organisational support. Stakeholder engagement also helped build confidence in the proposed change and ensured that there was a shared understanding of both the environmental benefits and patient safety considerations associated with the transition.

To support project planning, process mapping was undertaken to understand the existing patient pathway involving Entonox (see figure 1.). This enabled the team to identify all stages involved in

prescribing, supply, administration, patient consent, monitoring, documentation, and stock management. The mapped process highlighted where changes would be required to accommodate the introduction of Penthrox. In addition, a driver diagram was produced to identify the primary and secondary factors required to achieve successful implementation. Key drivers included clinical effectiveness, staff confidence, patient acceptance, governance approval, education, and sustainable procurement processes. These tools helped prioritise actions and ensured that implementation planning was comprehensive and systematic.

Figure 1. Process map for Entonox pathway.



Implementing Change

Once Penthrox had been identified as a suitable alternative and stakeholder engagement completed, a structured implementation programme was established. The initial phase focused on ensuring that all governance and regulatory requirements were addressed before introducing the product into clinical practice.

Several new documents were required to support the safe administration of Penthrox. A Standard Operating Procedure (SOP) was developed detailing appropriate patient selection, contraindications, administration processes, monitoring requirements, and documentation standards. A patient consent form was also created to ensure that patients received sufficient information and agreed to the use of Penthrox as part of their procedure. In addition, a Patient Group Directive (PGD) was developed, allowing appropriately trained staff to administer Penthrox within an agreed clinical framework. These documents were developed collaboratively with pharmacy colleagues, endoscopy clinicians, and governance teams to ensure compliance with organisational and regulatory requirements.

Formal approval was required before implementation could proceed. The proposal underwent review by multiple governance groups to ensure that both clinical and environmental considerations had been adequately assessed. Initial review and approval were sought through the Drugs and Therapeutics Committee, which evaluated the clinical appropriateness and safety profile of Penthrox. The proposal was also presented to the Greener Hospitals Group due to the sustainability benefits associated with reducing nitrous oxide use. Final organisational approval was granted through the Quality Governance and Assurance Committee, which reports directly to the Company Board. This robust governance process ensured that all risks and benefits were fully considered before implementation commenced.

Staff engagement and education were recognised as essential components of successful change management. Given that Penthrox represented a new product for many endoscopy team members, a comprehensive training programme was developed. Face-to-face training sessions were delivered to all staff who would be involved in administering or supporting the use of Penthrox. These sessions covered the pharmacology of methoxyflurane, indications and contraindications, administration techniques, patient counselling, documentation requirements, and management of potential adverse effects.

To reinforce learning and provide evidence of competence, staff were also required to complete an online training module. Successful completion of the programme resulted in certification of proficiency, ensuring that only appropriately trained staff could administer Penthrox. This combination of practical and online education helped build confidence among staff and supported consistent practice across all participating sites.

Implementation also required procurement and supply chain changes. Penthrox supplies were sourced and ordered through approved suppliers, while educational materials and training resources were obtained from the manufacturer. Pharmacy and stores teams worked closely together to ensure adequate stock availability ahead of implementation dates and to minimise the risk of supply disruption during the transition period.

Financial considerations formed an important aspect of the project. Although the environmental advantages of reducing nitrous oxide use were clear, Penthrox represented a different cost profile compared with Entonox. To secure organisational approval, a detailed business case was developed and presented to senior leadership. The business case included a financial analysis comparing current Entonox expenditure with projected Penthrox costs, alongside consideration of environmental sustainability benefits, operational impacts, and anticipated patient outcomes. By presenting both the financial and environmental case for change, approval was successfully obtained from the Board.

A phased implementation approach was considered; however, the project team determined that introducing a clear swap-over date at each participating site would provide greater consistency and reduce confusion for staff. Each site included within the trial therefore transitioned from Entonox to Penthrox on an agreed implementation date. Sites did not commence simultaneously. Instead, implementation was staggered, allowing lessons learned from the first site to be reviewed and incorporated before subsequent sites adopted the new process.

This approach provided an opportunity to refine educational materials, address operational issues, and share positive experiences between teams. Continuous feedback was sought from clinical staff throughout the implementation period to identify any concerns or areas for improvement. To date, no significant changes have proven unsuccessful, and no major barriers to implementation have been encountered. Early and ongoing engagement with pharmacists, endoscopy staff, and clinical leadership has contributed significantly to the smooth transition and acceptance of the new process.

Through careful planning, robust governance, comprehensive staff training, and strong stakeholder engagement, the organisation successfully implemented Penthrox as an alternative to Entonox within endoscopy services. The structured methodology ensured that patient safety remained paramount while supporting the wider objective of reducing the environmental impact of healthcare delivery.

Implementation Phases

Phase 1 – Preparation

- Write PGD and send for approval
- Write SOP and send for approval
- Procurement and Logistics – confirm supply chain and ordering processes
- Establish stock levels for pilot sites
- Ensure safe storage and disposal arrangements
- Collect Entonox Usage

Phase 2 – Pre- trial Surveys

- Undertake staff surveys at trial sites
- Undertake patient surveys at trial sites

Phase 3 - Training and Competency

- Staff to commence on-line training and produce certificate
- Arrange face to face training to support online training

Phase 4 – Pilot Deployment

- Ensure staff are trained
- Ensure feedback forms (patients and staff)

Phase 5 – First Evaluation

- Compare pilot data with historical Entonox performance
- Stakeholder Review
- Recommendations
- Environmental impact

Measurement and results:

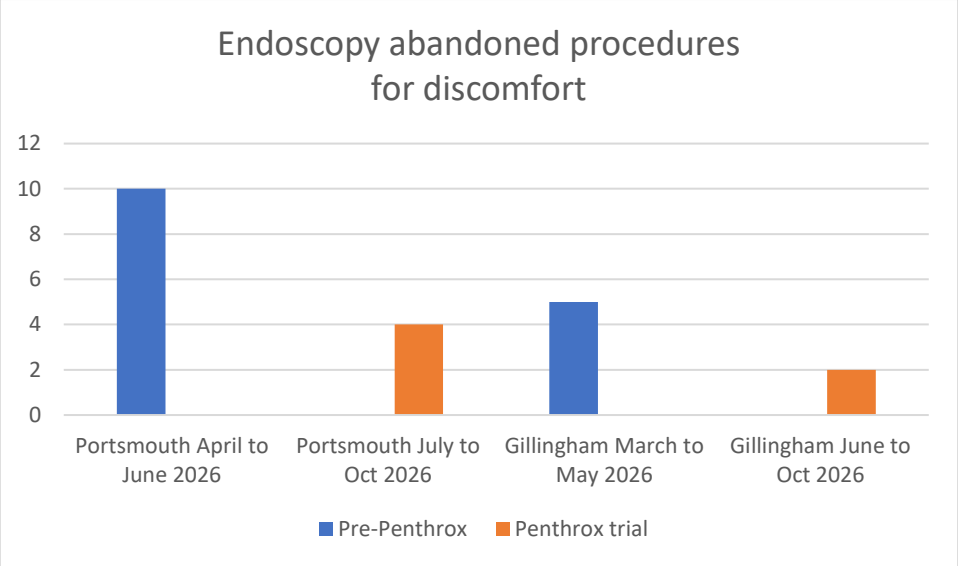
Patient outcomes

Direct measurement of clinical outcomes was beyond the scope and timeframe of the project, as changes in outcomes such as complication rates, long-term patient recovery, or disease progression would require larger patient numbers and longer follow-up periods. Instead, the project monitored clinical incidents and adverse events as a pragmatic safety measure to identify any unintended consequences associated with the introduction of Penthrox. No evidence of reduced safety was identified during the evaluation period.

Datix Gillingham**:** In March 2026, two Datix incidents were reported that two patients who were unable tolerate colonoscopy. Since the introduction of Penthrox on 5 June 2026, no Datix incidents related to patients being unable to tolerate colonoscopy or flexible sigmoidoscopy have been reported at the Gillingham endoscopy unit.

Datix Portsmouth. No incidents or adverse effects were reported with the use of Penthrox, 1 patient displayed some inappropriate behaviour but this was quickly and easily reversed by withholding the device for a few minutes, with no impact on comfort. 1 patient would have had an abandoned procedure with IV sedation if Penthrox had not been available.

An unexpected impact identified during the project was a reduction in abandoned and incomplete procedures, negating the need for a repeat procedure, repeated bowel cleansing and preparation, both on the patient and organisation but also reducing clinical time to complete incident reports(datixes). This improves effectiveness and timeliness of care.



The reduction in abandoned procedures suggests that improved symptom control may have enabled more patients to successfully complete their procedure. In addition, staff reported a number of operational and patient experience benefits associated with the introduction of Penthrox. Unlike nitrous oxide, which may require equipment preparation and recovery periods, Penthrox can be administered quickly and allows patients to self-regulate inhalation according to their pain levels.

Staff reported that this may contribute to improved procedural efficiency and reduced delays associated with analgesia delivery. Staff also perceived that patients were mobilising and recovering more rapidly following procedures, potentially reducing the need for post-procedure observation and supporting more efficient patient flow. Whilst these outcomes were not formally measured, the team felt that the streamlined pathway could improve patient experience, release clinical capacity, reduce pressure on treatment areas, and enable staff to focus on delivering care to other patients.

Environmental sustainability

Methodology

A cradle-to-grave carbon footprint analysis was used to estimate the items greenhouse gas (GHG) emissions. The analysis included GHG emissions associated with primary materials production, transport, and disposal.

Data was provided on the equipment used to deliver Entonox and Penthrox and were carbon footprinted using a process-based carbon footprint analysis. Items were weighed by the team and materials identified.

Data was obtained from previous studies by the Centre for Sustainable Healthcare and other references. Where data was not available, calculations were made based on the weight and material of the product. Material weights were converted into GHG emissions using emission conversion factors taken from the Department of Energy Security and Net Zero (DESNZ)'s Greenhouse Gas Reporting Conversion Factors 2026 database, ICE V4.0 database and primary research papers and LCAs. Transport emissions per journey are calculated by weight of product, distance travelled and emissions per tonne.km travelled. The emission factor for average laden, non-refrigerated HGV of 0.127 $kgCO_2e$ per tonne.km was used, taken from the department of Energy Security and Net Zero (DESNZ)'s Greenhouse Gas Reporting Conversion Factors 2026 database. Waste emissions were calculated by amount of waste (tonnes) using emission factors for clinical waste (1074 $kgCO_2e$), dry mixed recycling (172 $kgCO_2e$) and domestic waste (172 $kgCO_2e$) taken from Rizan et al 2021.

For a detailed summary of the carbon foot printing methodology, see Appendix 1.

The yearly activity data for both sites is shown in Table 1.

Table 1. Number of procedures performed at Portsmouth and Gillingham, and the number of patients receiving Entonox or IV sedation.

Procedure	Patients per year	Method of sedation	Patients per year
Portsmouth			
Colonoscopy	1293	Had Entonox	545
		IV sedation	748
Flexible sigmoidoscopy	1026	Had Entonox	954
		IV sedation	72
Gillingham			
Colonoscopy	434	Had Entonox	186
		IV sedation	248
Flexible sigmoidoscopy	175	Had Entonox	137
		IV sedation	38

Results

Based on current patient numbers, and assuming the numbers of colonoscopy and flexible sigmoidoscopy patients are accurate, Table 5 presents the estimated emissions for each location and procedure type according to sedation method. It also shows the calculated maximum achievable reduction in emissions that could be realised if 100% of patients currently receiving Entonox were switched to Penthrox.

Table 2. Emissions by location, procedure type and method of sedation.

Procedure	Patients per year	Method of sedation	Patients per year	Current yearly emissions (kgCO2e)	Yearly emissions If 100% moved to Penthrox (kgCO2e)	Yearly emissions saving (kgCO2e)
Portsmouth						

Colonoscopy	1293	Had Entonox	545	5,869.7	458.1	**5,411.6**
		IV sedation	748	495.2		
Flexible sigmoidoscopy	1026	Had Entonox	954	10,274.6	849.1	**9,425.5**
		IV sedation	72	45.7		
Gillingham						
Colonoscopy	434	Had Entonox	186	2,003.2	165.5	**1,837.7**
		IV sedation	248	164.2		
Flexible sigmoidoscopy	175	Had Entonox	137	1,475.5	121.9	**1,353.6**
		IV sedation	38	25.2		

(* if same equipment was used for canulation and delivery of IV medication as Gillingham).

The total avoidable emissions with 100% move from Entonox to Penthrox is 18,028 kgCO_2e per year. A 50% swap to Penthrox would deliver yearly avoided emissions of 9,014 kgCO_2e and a 25% swap would deliver 4,507 kgCO_2e of avoided emissions – the 25% reduction is the equivalent of driving **13,414 miles** in an average size petrol car.

Economic sustainability:
The cost of the Penthrox inhalation device was collated and measured against the cost of the consumables required for the set up and delivery of Entonox inhalation or IV sedation and analgesia. All financial data was obtained locally from either PPG procurement teams, NHS supply chain or directly from consumable suppliers.

Cost of Penthrox inhaler per patient per procedure £17.99
Cost of Entonox per patient per procedure £12.17
Cost of Entonox plus IV sedation per patient per procedure £16.66

The projected additional consumable cost associated with a 100% switch from Entonox to Penthrox is £10,604 per year. A 50% switch would result in an additional annual cost of £5,302, while a 25% switch would result in an additional annual cost of £2,651.

Pharmaceutical Waste Bins were sourced for the disposal of the Penthrox inhaler (100g) as per manufacturer recommendations and costs measured against the disposal costs of the Entonox mouth pieces (20g) in clinical waste. Cost was comparable and not included in calculations. Packaging for both methods continue to be disposed of in the general waste with no additional costs.

Training was sourced free of charge from the Penthrox suppliers and delivered to the teams face to face on site and also available as an online module with CPD time and certificate. SOP, PGD, Consent forms, Patient information leaflets and pre and post procedure and project questionnaires were written and produced by the project team in printable versions for the duration of the pilot with the implementation cost of time and paper. No other consumable costs were required to set up this pilot.

These estimates include only the direct consumable costs of analgesia delivery and do not account for potential cost efficiency savings associated with clinical time gained back from reduced abandoned or repeat procedures, reduced recovery requirements and discharge times, incident reporting and improved service efficiency.

Social sustainability:
There are several anticipated benefits from this project for patients and staff, which were captured via a patient and staff survey.

Patient experience:

From the 5 June to 5 August, Gillingham performed 46 colonoscopies and 3 Flexible sigmoidoscopies where Penthrox was used. A patient satisfaction questionnaire was completed by 19 patients between June and July 2026 to evaluate the use of Penthrox during endoscopy. The questionnaire demonstrated that:

- Patients found Penthrox easy to use
- The majority reported that Penthrox provided effective pain relief.
- Most patients said they would recommend Penthrox to other patients.
- A small number of patients required additional analgesia during the procedure.
- Most patients were unaware Penthrox is a more environmentally sustainable analgesic option.

In addition, an audit of 8 colonoscopy patients between 06/07/2026 and 31/07/2026 found that:

- 5 patients completed their procedure without sedation and reported a comfort score of 1.
- 3 patients initially received sedation and then Penthrox. Their comfort scores improved from 3 to 1, demonstrating improved pain control.

The implementation of the pilot at Portsmouth started a month later due to procuring Penthrox supplies and some initial staff nervousness. Portsmouth Endoscopy team is much larger than Gillingham's due to the size of the service, so initial engagement was more difficult but with additional support and encouragement is now growing in momentum and confidence with outstanding results. During July 85 colonoscopies were performed. A patient satisfaction questionnaire was completed by 41 patients during this period to evaluate the use of Penthrox during endoscopy. The results are as follows:

Post Penthrox (pain relief) Questionnaire for Endoscopy Patients - Results

	Very Easy	**Easy**	**Not Easy**	**Hard to use**	**Don't Know**
How easy was the use of Penthrox (pain relief medication) for your procedure?	38	3			
	Yes	**Some**	**No**	**Don't know**	
Did Penthrox (pain relief medication) give the required level of pain relief?	37	2		1	
	Yes	**Maybe**	**No**	**Not at all**	**Don't know**
Would you recommend the use of Penthrox (pain relief medication) for other patients?	38	2			
	Yes	**No**	**Don't know**		
Did you require any other pain relief during the procedure	5	34	1		
	Yes	**Maybe**	**No**	**Don't know**	
Did you know that Penthrox (pain relief medication) is a sustainable alternative to other medications that can be used?	26	2	11	2	

The questionnaire demonstrated that:

- All Patients found Penthrox easy to use
- The majority reported that Penthrox provided effective pain relief.
- Most patients said they would recommend Penthrox to other patients.
- 5 patients chose IV sedation initially but required additional analgesia during the procedure and Penthrox was given with good effect enabling the procedures to be completed.
- Most patients were aware that Penthrox is a more environmentally sustainable analgesic option due to the patient information fact sheet provided with their bowel preparation and procedure information.

Initially at the start of the pilot, patients were given the Penthrox fact sheet on admission to the department and prior to consent. Initial patient feedback was that they would have liked more time to digest to make an informed choice, so we adjusted the pathway so that the information was given at the pre-assessment stage improving the take up of Penthrox and patient outcomes.

Staff experience:
The Gillingham endoscopy team, including consultant's and nurse endoscopists, reported a positive experience using Penthrox. They found it was easy to assemble and administer and provided effective pain relief, helping patients tolerate the procedure more comfortably.

No significant negative feedback was reported by the endoscopy team. Staff did not identify any issues with the odour of Penthrox, and it was considered easy to assemble, administrate and incorporate into routine practice. Since 5 June 2026, when Penthrox was introduced at Gillingham endoscopy unit, Entonox has not been used for colonoscopies and flexible sigmoidoscopies.

The endoscopy team at Portsmouth also reported a positive experience. A questionnaire was completed by 12 out of 16 nursing team members. The results are as follows:

Post Penthrox Questionnaire for Endoscopy Staff

	Very Easy	**Easy**	**Not Easy**	**Hard to use**	**Don't Know**
How easy was it to use Penthrox?	10	2			
	Very Easy	**Easy**	**Hard**	**Very Hard**	**Don't know**
How difficult was it to explain the use of Penthrox to the patients?	5	7			
	Very Easy	**Easy**	**Hard**	**Very Hard**	**Don't know**
How difficult was it to set up the Penthrox device?	12				
	Yes	**Maybe**	**No**	**Don't know**	
Do you feel that Penthrox gave the require pain relief to patients?	9	3			

	Yes	Maybe	No	Don't know	
Would you recommend the use of Penthrox as an alternative to Entonox	11	1			
	Yes	**Maybe**	**No**	**Don't know**	
Did you know that Penthrox is a more sustainable medicine than using Entonox?	10	1	1		

The questionnaire demonstrated that:

- All nurses found Penthrox easy to use
- All nurses found it easy to explain the use of Penthrox to the patients
- All nurses found it easy to set up the Penthrox device
- Most nurses felt that Penthrox gave the required pain relief to patients
- Most nurses felt that they would recommend the use of Penthrox as an alternative to Entonox
- Most nurses were aware that Penthrox is a more environmentally sustainable analgesic

Like Gillingham's feedback it was considered easy to assemble, administrate and incorporate into routine practice.

Challenges: 1 consultant has been reluctant to use Penthrox on patients without a Liver function test and 1 consultant and some nursing staff have reported odour and questioned potential staff exposure and the financial cost for use on shorter flexible sigmoidoscopy procedures. This has enabled us to target further training.

Additional anticipated benefits

By giving patients a choice, we aim to empower them and support a greater sense of control over their health and medical interventions. Both gases offer patient-controlled self-administration, giving individuals a psychological sense of empowerment during a potentially uncomfortable procedure and faster self-administered analgesia onset can improve patient compliance. Both Penthrox and Entonox allow patients to remain conscious throughout the endoscopy and wears off quickly enough so that patients generally do not require a 24-hour companion or heavy sedation recovery, meaning patients can often independently travel home or return to light daily routines shortly after the procedure.

By demographics, a large proportion of our patient cohort are elderly, and using inhalation analgesia not only eliminates the risks of sedation but also reduces unnecessary travel and alleviates pressures on their relatives, carers and escorts. For the rest of the cohort offering inhalation analgesia minimises the need for the patient and family members to take time off work, arrange childcare, and provide transport for appointments. We were unable to quantify this benefit during the project phase.

Using Penthrox instead of Entonox in endoscopy impacts healthcare staff through improved workflow efficiency, a dramatically reduced physical footprint, improved comfort score, see ***appendix 2 a***nd reflected in endoscopist KPI's and distinct occupational exposure profiles. Nurses and clinicians experience easier room setups and manoeuvrability around the procedure table without restrictive hosing or large equipment. Patient co-operation with a faster self-administered analgesia onset can

improve patient compliance, leading to smoother procedural teamwork and reduced staff stress during difficult moments.

For the recovery teams, the increased use of inhalation analgesics improves the efficiency of recovery times and contributes to the smoother running of endoscopy lists, reducing waiting area crowding and shortening waiting times, which indirectly benefits the health workflow reducing pressure and stress. The ability for patients to travel independently also reduces disruption to daily life and increases flexibility when arranging appointments. This has the potential to improve attendance rates and reduce cancellations resulting from transport or supervision difficulties. In addition, reduced recovery requirements mean that patients spend less time within healthcare settings, improving convenience and reducing demand on waiting and treatment areas.

Discussion:

Summary, Interpretation and Limitations

Overall, this project demonstrated that the introduction of Penthrox (methoxyflurane) as an alternative analgesic option to nitrous oxide was both successful and well received by patients and clinical staff. The implementation process was delivered effectively, with clear governance arrangements, staff education, stakeholder engagement and clinical oversight supporting a smooth transition to the new pathway. The project achieved its intended objectives of reducing reliance on nitrous oxide whilst maintaining a high standard of patient care and clinical safety.

The findings indicate that Penthrox offers several advantages over nitrous oxide in the procedural setting. Patients experienced effective pain relief that could be administered rapidly and independently, contributing to a more efficient patient journey. Staff reported confidence in the use of the device following training and found the administration process straightforward within routine clinical practice. Patient feedback was particularly positive, with many patients appreciating the ability to remain independent before and after treatment and the improved convenience associated with the procedure.

From an environmental perspective, the project has delivered significant benefits through the reduction of nitrous oxide use. Nitrous oxide is recognised as a potent greenhouse gas with a substantial environmental footprint. By replacing nitrous oxide with Penthrox where clinically appropriate, the organisation has reduced emissions associated with procedural analgesia while simultaneously decreasing consumable usage and waste generation. This demonstrates that environmental sustainability can be successfully integrated into clinical decision-making without compromising patient outcomes.

No significant limitations were identified during the implementation period. While ongoing monitoring will be required to assess long-term sustainability and identify any emerging issues, no concerns have been identified to date regarding safety, acceptability or operational delivery. The project demonstrates that sustainable healthcare interventions can deliver environmental benefits alongside positive clinical, financial and social impacts.

Barriers and Challenges Encountered, Risk management

The primary health and safety consideration relates to the correct use of the Penthrox inhaler. Patients must be appropriately instructed to inhale and exhale through the device as intended. Although the likelihood of significant exposure was considered low, if used incorrectly, there is a potential risk that staff may be exposed to methoxyflurane vapour.

To manage this risk, staff were trained to provide clear instructions to patients, procedures were undertaken in well-ventilated clinical areas and surgical masks could be used where appropriate. Ongoing monitoring and compliance with the Standard Operating Procedure further reduced the probability of this risk occurring. Consequently, no safety incidents or concerns have been reported.

Clinical education proved to be one of the most important factors in the success of the project. Staff needed to understand both the clinical benefits and environmental rationale for the change in practice. Providing this information early in the implementation process generated enthusiasm and supported positive engagement.

Encouragingly, both patients and staff adapted quickly to the new approach. Feedback has consistently indicated a preference for Penthrox over nitrous oxide in many procedural settings. No significant logistical challenges were encountered, and no additional space requirements were identified. Existing clinical environments were able to accommodate the new process without modification.

From a governance perspective, the development of a robust SOP and approval through the relevant organisational processes ensured safe and consistent implementation. No policy barriers were encountered during the project.

Potential for Spread and Wider Application

There are several settings where nitrous oxide is currently used and where Penthrox may provide a suitable alternative. One notable opportunity is within outpatient hysteroscopy services, other gynaecological procedures and wound dressings where effective procedural analgesia is required and patient independence is particularly beneficial. Similar advantages may also be realised in urgent treatment centres, emergency care settings and minor injury units, where rapid pain relief can support efficient patient management.

The organisation is actively exploring opportunities to expand implementation into these areas. Wider adoption could deliver substantial environmental benefits through further reductions in nitrous oxide use, while simultaneously improving patient experience and operational efficiency. The successful implementation model developed through this project provides a strong framework that can be replicated across other services.

Conclusions:

This project has demonstrated that Penthrox is a valuable and effective alternative to nitrous oxide within selected procedural settings. The initiative has delivered measurable environmental benefits while improving patient experience, maintaining safe and effective pain management and supporting service efficiency. While there is a cost increase associated with the medication and consumables, there is potential for this to be offset by streamlined service delivery and reductions in repeat procedures. Further work is planned to evaluate these impacts and better understand the overall cost benefit of the intervention.

Several key factors contributed to the success of the project. Firstly, the development of a clear project and implementation plan established a strong foundation for change. Secondly, staff education and competency-based training ensured clinical teams were confident in using the new analgesic pathway. Thirdly, early engagement of stakeholders and clear communication of project aims was essential to ensure alignment and engagement across the team. By involving clinical staff, governance leads, sustainability teams and operational managers from the outset, the project gained broad support and shared ownership. Presentations, educational materials and stakeholder discussions ensured that all parties understood why the change was being introduced and how success would be measured.

To ensure lasting change, the project has been embedded within organisational governance structures and continues to be reported through relevant committees, including the Greener Hospitals Committee. Regular updates maintain visibility of the project and ensure sustainability objectives remain aligned with operational priorities.

Ongoing patient and staff feedback also plays an important role in sustaining improvement. Regular evaluation allows the organisation to monitor satisfaction levels, identify opportunities for optimisation and respond to any emerging challenges. Staff engagement will remain critical because long-term success ultimately depends on continued support from frontline clinical teams.

The involvement of the communications and marketing teams has also contributed to wider awareness of the initiative both internally and externally. Increased visibility has encouraged discussions regarding alternative analgesia pathways and has supported the spread of learning across the organisation.

The project has already generated interest from other departments wishing to adopt similar approaches and the organisation intends to expand the initiative into additional areas, including outpatient procedures, endoscopy and urgent treatment centres across our 11 sites. Potentially running this across the sites would see potential carbon saving of 99,154 kgCO2e per year (roughly 99.2 tonnesCO2e), equal to driving an average petrol car about 294,000 miles (468,000 km) (DESNZ Greenhouse Gas Reporting Conversion Factors 2026; National Travel Survey 2025).

Looking forward, the organisation will continue to collect data relating to patient satisfaction, staff experience and wider cultural change. Ongoing evaluation will ensure that the benefits observed to date are maintained and that future opportunities for improvement are identified. Through continued engagement, governance oversight and expansion into additional clinical specialties, the project has the potential to deliver lasting and meaningful improvements to sustainable healthcare delivery.

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Appendix 1: Detailed carbon footprinting methodology

Entonox

Emissions due to delivering Entonox consist of three elements. Firstly, raw materials, production and waste management of disposable equipment, secondly, from Entonox itself and thirdly, the transport of Entonox.

Disposable equipment

A mouthpiece is used by patients to use to inhale the Entonox. Weights and material composition were identified and supplied by the team and are shown in Table 2 along with the emissions for the raw materials and production and waste disposal.

Table 1. Inventory for equipment, weights, emissions factors, and the carbon footprint for the mouthpiece.

	Type of material	Weight /item (g)	Carbon emission factor for raw materials ($kgCO_2e$ /tonne)	Carbon emissions for raw material ($kgCO_2e$)	Waste disposal method	Carbon emission factor for waste ($kgCO_2e$ /tonne)	Carbon emissions for disposal ($kgCO_2e$)	Carbon emissions per item ($kgCO_2e$)
Mouthpiece	Plastics: PP (incl. forming)	18	2575.3	0.046	Clinical waste	1074	0.0193	0.0657
Packaging plastic bag	Plastics: LDPE and LLDPE (incl. forming)	2	2963.6	0.006	Domestic waste	172	0.0003	0.0063

The total emissions for raw materials, production and waste disposal of the mouthpiece is 0.0720 $kgCO_2e$.

Entonox gas

The data from the amount of Entonox used in Portsmouth per month is shown in Table 3a. 1,499 procedures were undertaken annually using Entonox, equating to approximately 125 per month. There were 2,400 gastroscopies per year which used Entonox. Assuming all three procedures (gastroscopy, colonoscopy and flexible sigmoidoscopy) use the same volume of Entonox, volume per procedure is total volume (14,000l = 4 * 3,500l cylinders) divided by number of procedures per month (125 colonoscopies and flexible sigmoidoscopies and 200 gastroscopies) resulting in 43.09 l per procedure.

Table 2a. Entonox use at Portsmouth hospital per month and per procedure.

Number of cylinders used per month	4
Size of cylinder (l)	3500
Total volume used in 1month (l)	14,000
Number of gastroscopies	200
Combined number of colonoscopies and flex sigmoidoscopies	125
Number of procedures per month	325
Volume used per procedure (l)	43.1

The data from the amount of Entonox used in Gillingham between May 2025 and May 2026 is shown in Table 3b. During this period, 2 Entonox cylinders were used. Each cylinder contained 3,500L, giving

a total volume of 7,000 L. a total of 323 procedures used Entonox, comprising 186 colonoscopies and 137 flexible sigmoidoscopies. No gastroscopies used Entonox during the study period.

Table 2b. Entonox use at Gillingham surgical centre per month and per procedure.

Number of Cylinders used per month	2
Size of cylinder (l)	3500
Total volume used (l)	7,000
Numbers of gastroscopies	0
Combine number of colonoscopies and flexible sigmoidoscopies	323
Number of procedures per month	27
Volume used per procedure (l)	21.7

Entonox is 50% Nitrous oxide, 50% oxygen. Emissions factors from the Greener NHS are 0.248 $kgCO_2e$ per litre. Approximately four 3,500 litre cylinders of Entonox are used monthly, totalling 14,000 litres. It has been assumed the cylinder is emptied prior to sending for refilling or is vented to the atmosphere on return to BOC.

For a procedure using 43.1 litres of Entonox, the carbon footprint is 10.69 $kgCO_2e$ per procedure.

Transport of Entonox

Transport emissions per journey are calculated by weight of product, distance travelled and emissions per tonne.km travelled.

*Total emissions = Weight in tonnes per delivery*distance in km*emission factor*

Weight

- 3500l cylinder weighs 19.8kg when full.
- Weighs 15.4kg when empty.

Distance

- Distance from BOC, Southampton SO45 3NX to Portsmouth Hospital PO6 3LY is 36 miles/59 km.

Emission factor

- The emission factor for average laden, non-refrigerated HGV is 0.127 $kgCO_2e$ per tonne.km.

Transport to hospital

- 0.0198*59*0.127 = 0.148 $kgCO_2e$.

Transport returning for refilling

- 0.0154*50*0.127 = 0.1156 $kgCO_2e$.

Assuming the cylinders are delivered and refilled once a month, total monthly emissions due to transport 0.148+0.1156 = 0.264 $kgCO_2e$ per cylinder or 1.056 $kgCO_2e$ for 4 cylinders.

Annual emissions (based on 12 deliveries per year) = **12.67 $kgCO_2e$ from transporting Entonox.**

Emissions per procedure from Entonox transport is **12.67/1499 = 0.008 $kgCO_2e$ to Portsmouth**.

Summary of Entonox emissions per procedure

- Consumable equipment 0.072 $kgCO_2e$
- Entonox 10.69 $kgCO_2e$

- Transport of Entonox 0.008 $kgCO_2e$

Total emissions are 10.77 $kgCO_2e$ per procedure using Entonox.

Penthrox device

The carbon footprint has been calculated via LCA (Environmental impact of low-dose methoxyflurane versus nitrous oxide for analgesia: how green is the 'green whistle'? | Emergency Medicine Journal)

Emissions per device are 0.83965 $kgCO_2e$ which included transport to University Hospital Southampton, UK. Additional transport from Southampton to Portsmouth Hospital via HGV was calculated and added.

Transport

- For 100g weight, the additional 59km equates to emissions of 0.0007 $kgCO_2e$ or 0.7 gCO_2e.

Waste disposal

- Disposal of 50g via the clinical waste stream generates emissions of 0.050 $kgCO_2e$.

Summary for Penthrox device

Total emissions per Penthrox device, including additional transport and waste is 0.890 $kgCO_2e$.

IV sedation

To deliver IV sedation a variety of clinical consumables are required. An inventory was supplied by both Gillingham and Portsmouth. As Gillingham hospital routinely canulates patients, the carbon emissions associated with their equipment was used. Weights and material composition were identified and supplied by the team and are shown in Table 4 along with the emissions for the raw materials and production and waste disposal.

Table 3. Inventory for equipment, weights, emissions factors and the carbon footprint for canulation and IV sedation.

Canulation and IV sedation	Number of items used	Carbon emission factor per item (kgCO2e /item use)	Carbon emissions for item (kgCO2e)	Waste disposal method	Carbon emission factor for waste (kgCO2e /tonne)	Carbon emissions for disposal (kgCO2e)	Carbon emissions per item (kgCO2e)
For canulation							
2% chlorhexidine alcohol skin wipes	1	0.003	0.003	*Clinical waste*	1074.0	0.0048	0.0081
IV300 dressing (10cm X 12cm)	1	0.009	0.009	*Clinical waste*	1074.0	0.0048	0.0135
22G IV Cannula	1	0.046	0.046	*Medicinal sharps*	1074.0	0.0032	0.0493
Prefilled 0.9%NaCl – 10 ml	1	0.047	0.047	*Clinical waste*	1074.0	0.0107	0.0573

Single-use Tourniquet	1	0.074	0.074	*Clinical waste*	1074.0	0.0075	0.0816
2 x Clinell wipes for cleaning the reusable tray	2	0.021	0.041	*Clinical waste*	1074.0	0.0043	0.0455
Blue gloves	2	0.026	0.052	*Clinical waste*	1074.0	0.0430	0.0950
For sedation							
2 x 2 ml syringes	2	0.024	0.048	*Clinical waste*	1074.0	0.0069	0.0549
2 x filter needle	2	0.003	0.006	*Medicinal sharps*	1074.0	0.0021	0.0080
NaCl, 10 ml	1	0.047	0.047	*Clinical waste*	1074.0	0.0107	0.0573
2 x Clinell wipes	2	0.021	0.041	*Clinical waste*	1074.0	0.0043	0.0455
Blue gloves	2	0.026	0.052	*Clinical waste*	1074.0	0.0430	0.0950

The total emissions for raw materials, production and waste disposal for canulation is 0.350 $kgCO_2e$. The total emissions for raw materials, production and waste disposal for equipment used during IV sedation is 0.261 $kgCO_2e$. The total emissions are 0.611 $kgCO_2e$ for the equipment used to canulate a patient and deliver IV medication.

Emissions from medication

The medication used for sedation is:

- 5ml vial Midazolam 5mg/5ml 35.95 gCO2e per vial (0.036 $kgCO_2e$).
- 2ml vial Fentanyl 100mcg/2ml is 25.28gCO2e per vial (0.025 $kgCO_2e$).

Data taken from MCF Formulary (https://formulary.yewmaker.com/)

Summary for IV sedation

In total, to deliver IV medication, emissions are

- Consumable equipment 0.611 $kgCO_2e$.
- Medication 0.061 $kgCO_2e$.
- Total 0.662 $kgCO_2e$.

Summary for all sedation per procedure

Total emissions are

- 10.77 $kgCO_2e$ per procedure using Entonox.
- 0.890 $kgCO_2e$ per procedure using the Penthrox device
- 0.662 $kgCO_2e$ per procedure for IV sedation

Annual emissions

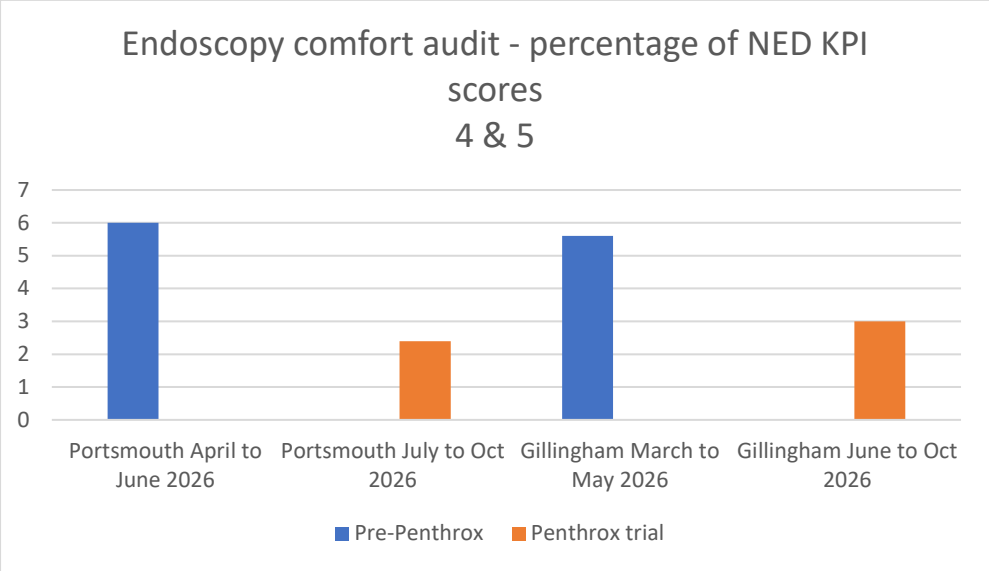
Based on current patient numbers, and assuming the numbers of colonoscopy and flexible sigmoidoscopy patients are accurate, Table 5 presents the estimated emissions for each location and procedure type according to sedation method. It also shows the calculated maximum achievable reduction in emissions that could be realised if 100% of patients currently receiving Entonox were switched to Penthrox.

Table 4. Emissions by location, procedure type and method of sedation.

Procedure	Patients per year	Method of sedation	Patients per year	Current yearly emissions (kgCO2e)	Yearly emissions If 100% moved to Penthrox (kgCO2e)	Yearly emissions saving (kgCO2e)
Portsmouth						
Colonoscopy	1293	Had Entonox	545	5,869.7	458.1	**5,411.6**
		IV sedation	748	495.2		
Flexible sigmoidoscopy	1026	Had Entonox	954	10,274.6	849.1	**9,425.5**
		IV sedation	72	45.7		
Gillingham						
Colonoscopy	434	Had Entonox	186	2,003.2	165.5	**1,837.7**
		IV sedation	248	164.2		
Flexible sigmoidoscopy	175	Had Entonox	137	1,475.5	121.9	**1,353.6**
		IV sedation	38	25.2		

(* if same equipment was used for canulation and delivery of IV medication as Gillingham).

Appendix 2



• The Gloucester Comfort Scale (1–5): This is the default, validated observational scale used within Solus for gastrointestinal (GI) endoscopy.

• Target Benchmark: To comply with standard audits, the platform calculates performance metrics against the national standard: 90% or more of procedures should achieve a score of 3 or less (indicating the patient remained comfortable or experienced only mild/transient distress). Scores of 4 or 5 denote significant patient discomfort

Appendix 3

PPG General Exclusion Criteria:

• Systemic disease with functional limits ASA 4-5
• Patients requiring an overnight stay in hospital for medical reasons
• Cancer pathway unless that centre is set up for this work (i.e. receipt of a specific direct 2 week wait proforma by Fax or eReferral).
• Under 16 years of age (under 18 years in some hospitals/ surgical centres).
• Emergency referrals e.g., acute bleeding.
• Pregnancy.
• Weight >160 kg (maximum weight for trolley.
• Suspected diverticulitis within the last 6 weeks (exclusion flexible sigmoidoscopy/ colonoscopy).
• Patients receiving chemotherapy or radiotherapy treatment for another active cancer.

• **Cardiovascular**
o Uncontrolled hypertension with systolic >180 and Diastolic >110 mmHg
o Myocardial infarction/ angioplasty +/- coronary stenting in last 3 months
o Uncontrolled or poorly controlled angina
o Uncontrolled tachyarrhythmia
o Pacemaker with implantable cardioverter defibrillator (ICD)
o Heart failure (NYA III and IV)
o Enlarging abdominal aortic aneurysm

• **Respiratory**
o Severe COPD or asthma FEV < 50% predicted
o home oxygen therapy
o Oxygen saturations < 92% on room air

• **Renal**
o eGFR < 45 ml/min/1.73m2 (exclusion for colonoscopy only)

• **Endocrine**
o Poorly controlled diabetes with hypoglycaemia/ diabetic ketoacidosis.
o Please note that HbA1C is not

• **Hepatic**
o End stage liver disease
o Variceal surveillance or investigation for suspected varices

• **Neurological**
o Uncontrolled movement disorders
o Myasthenia gravis (consider individually)

• **Blood disorders**
o Thrombocytopenia < 50 x 109/litre
o Bleeding disorders including von Willebrand's/ haemophilia

• **General**
o BMI >45 kg/m2
Other restrictions may apply (e.g. restrictions on the use of intravenous sedation, intravenous opiates, and inhaled drugs [e.g. Entonox]. There are PPG and BSG guidelines around managing

anticoagulation and diabetes in endoscopy procedures, and these and other conditions should be considered on an individual basis.

Endoscopy- Criteria specific Exclusion

Gastroscopy
- Suspected acute GI bleeding
- Variceal surveillance
- Gastric polypectomy

Colonoscopy
- Severe acute colitis. An unprepared flexible Sigmoidoscopy is acceptable
- Acute diverticulitis (should be carried out at least 6 weeks after an acute episode)
- Suspected or confirmed perforated bowel
- Colonic obstruction.
- eGFR < 40

Sigmoidoscopy
- Suspected or confirmed perforated bowel
- Acute diverticulitis
- Colonic obstruction
- Whenever a colonoscopy is indicated

Other restrictions may apply (e.g. restrictions on the use of intravenous sedation, intravenous opiates, and inhaled drugs [e.g. Entonox]. These are considered on an individual basis.

Penthrox- Criteria specific Exclusion

Penthrox should not be given to patients with a history of
- Significant kidney disease
- Liver damage,
- Arrhythmia
- Symptomatic heart failure
- Hypersensitivity to Methoxyflurane or anaesthetic gases.
- Penthrox should not be given if you have had antibiotics within the last 2 weeks (except amoxicillin).

Critical success factors

Please select **one or two** of the below factors that you believe were most essential to ensure the success of your project changes.

People	Process	Resources	Context
☐ Patient involvement and/or appropriate information for patients - to raise awareness and understanding of intervention ✓Staff engagement ☐ MDT / Cross-department communication ☐ Skills and capability of staff ☐ Team/service agreement that there is a problem and changes are suitable to trial (Knowledge and understanding of the issue) ☐ Support from senior organisational or system leaders	✓clear guidance / evidence / policy to support the intervention. ☐ Incentivisation of the strategy – e.g., QOF in general practice ☐ systematic and coordinated approach ☐ clear, measurable targets ☐ long-term strategy for sustaining and embedding change developed in planning phase ☐ integrating the intervention into the natural workflow, team functions, technology systems, and incentive structures of the team/service/organisation	☐ Dedicated time ☐ QI training / information resources and organisation process / support ☐ Infrastructure capable of providing teams with information, data and equipment needed Research / evidence of change successfully implemented elsewhere ☐ Financial investment	☐ aims aligned with wider service, organisational or system goals. ✓Links to patient benefits / clinical outcomes ☐ Links to staff benefits ☐ 'Permission' given through the organisational context, capacity and positive change culture.