Reducing the carbon footprint of anaesthetic gasses

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Overview

- Review of anaesthesia
- Atmospheric science
- Review of the agents used for inhalational anaesthesia
- Tools that might help reduce the CO_2e
- Administrative components

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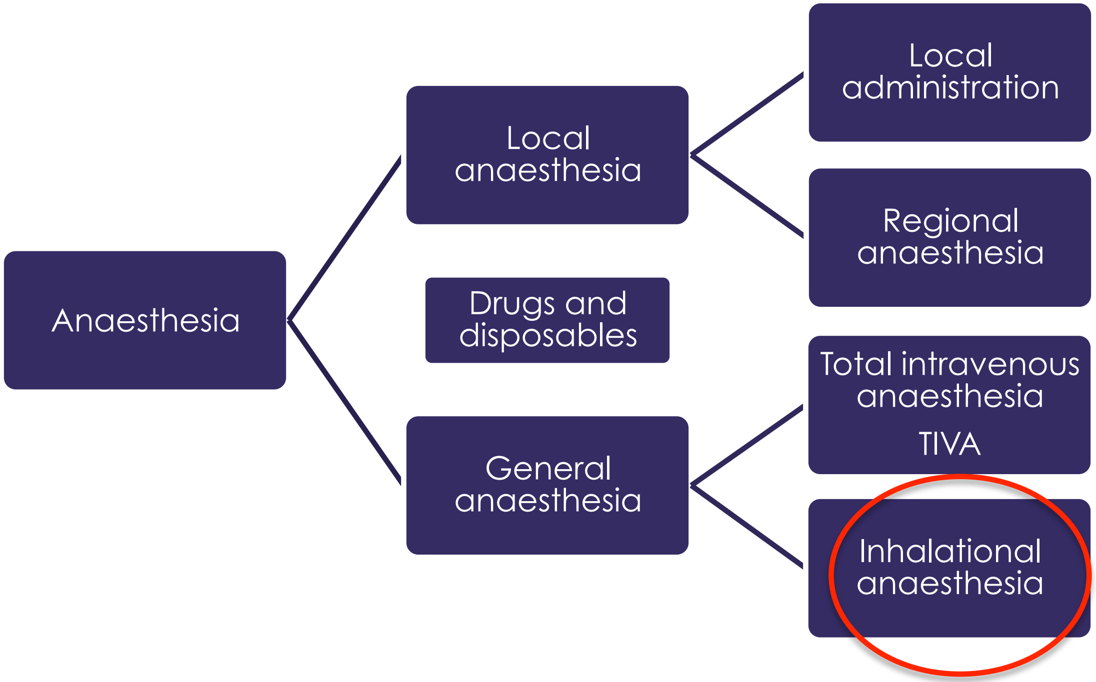
Overview of anaesthesia



Practical components of anaesthesia

Sedation analgesia and relaxation

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Practical components of anaesthesia

Maintenance of homeostasis

Vascular access

Monitoring

Cardiovascular and respiratory control

Temperature control

Fate of all of these components

- Disposables
  - Combustion
- Intravenous drugs
  - Metabolised
  - Unused residue combusted
- Packaging
  - Recycled
- Inhalational agents
  - Exhaled into the atmosphere unchanged

Combustion of1kg PVC produces 3kg CO_2

Combustion of 1kg paper 2.1-2.6 kg CO_2

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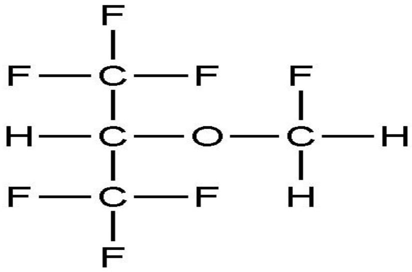
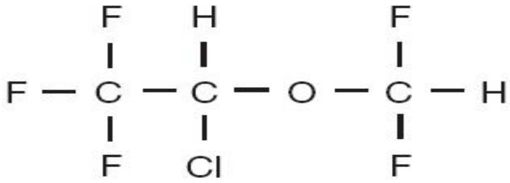
Inhalational anaesthetic agents



Sevoflurane

GWP 130

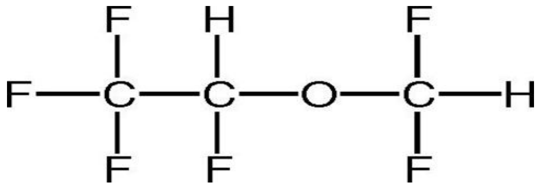
Bottle (250ml) 44kg CO_2e



Isoflurane

GWP 510

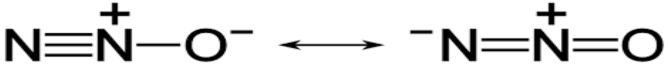
Bottle (250 ml)190 kg CO_2e



Desflurane

GWP 2540

Bottle (240 ml) 886 kg CO_2e



Nitrous oxide

GWP 310

Cylinder (3.4 kg) 1054 kg CO_2e

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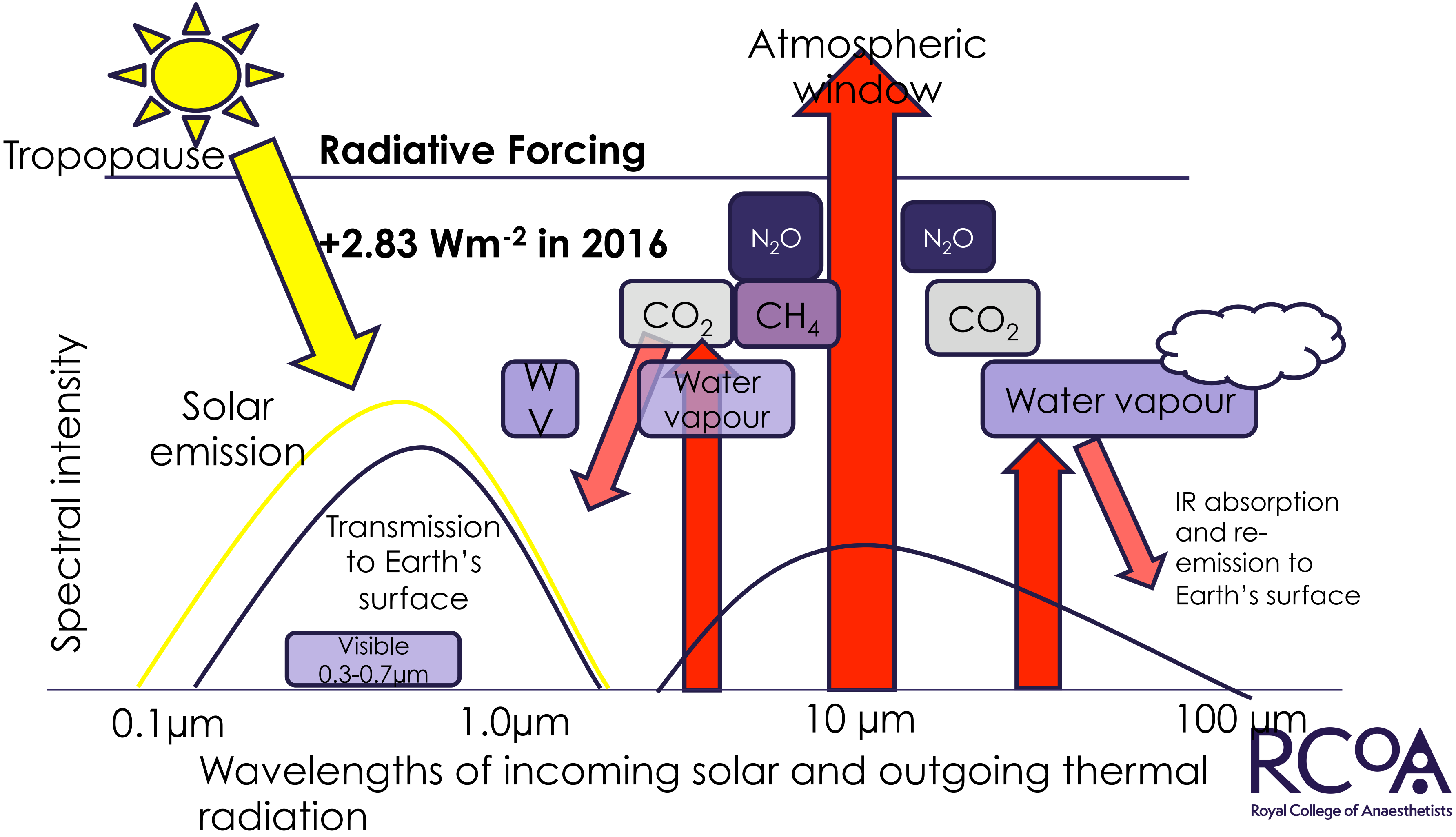

Atmospheric window
Tropopause
Radiative Forcing
+2.83 Wm-2 in 2016
N2O
N2O
CO2
CH4
CO2
W V
Water vapour
Water vapour
Solar emission
Spectral intensity
Transmission to Earth's surface
Visible 0.3-0.7µm
IR absorption and re-emission to Earth's surface
0.1µm
1.0µm
10 µm
100 µm
Wavelengths of incoming solar and outgoing thermal radiation
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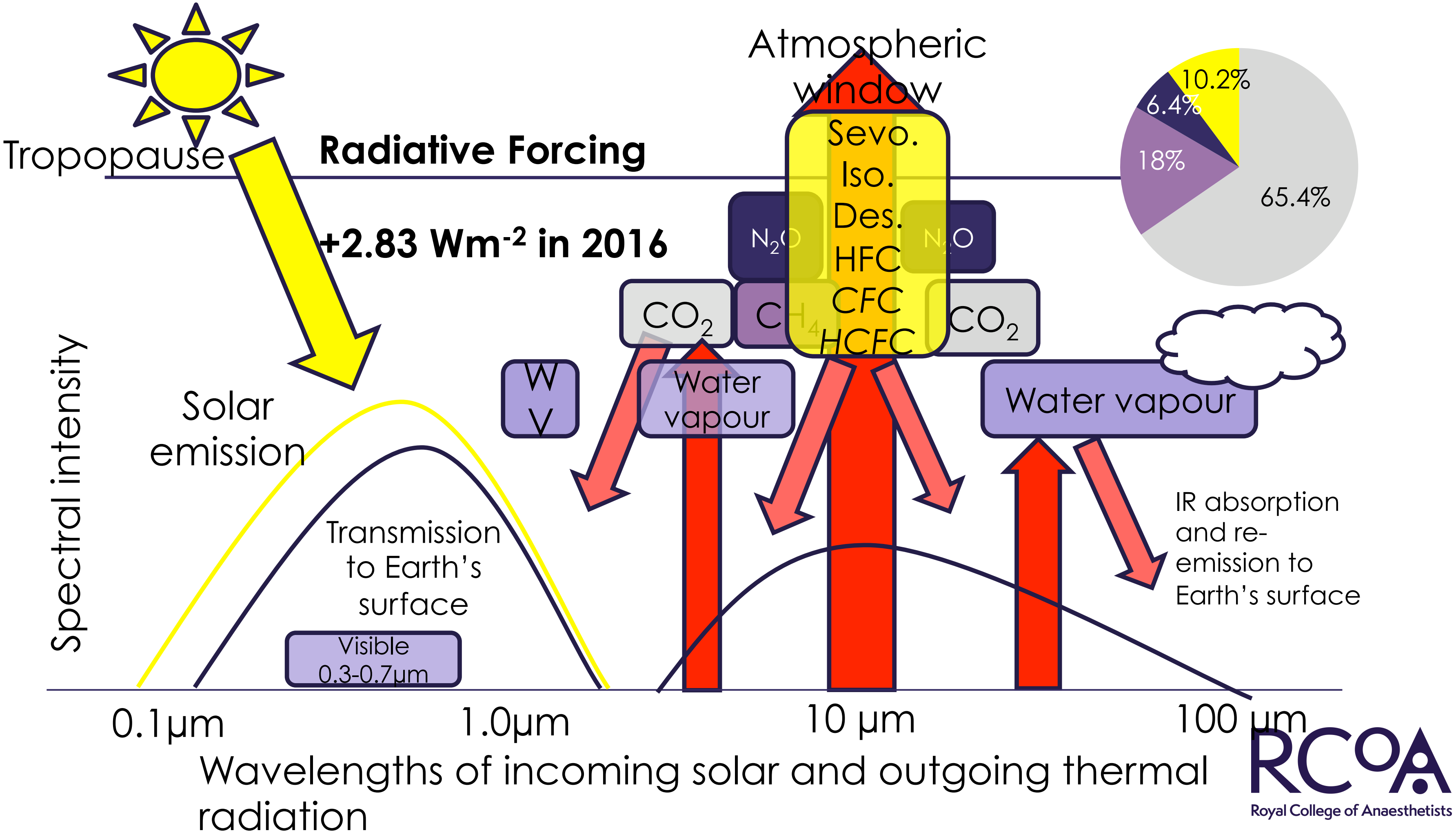
Atmospheric window
Tropopause
Radiative Forcing
+2.83 Wm-2 in 2016
Sevo.
Iso.
Des.
HFC
CFC
HCFC
N2O
N2O
CO2
CH4
CO2
10.2%
6.4%
18%
65.4%
W
V
Water vapour
Water vapour
Spectral intensity
Solar emission
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Visible 0.3-0.7µm
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Wavelengths of incoming solar and outgoing thermal radiation
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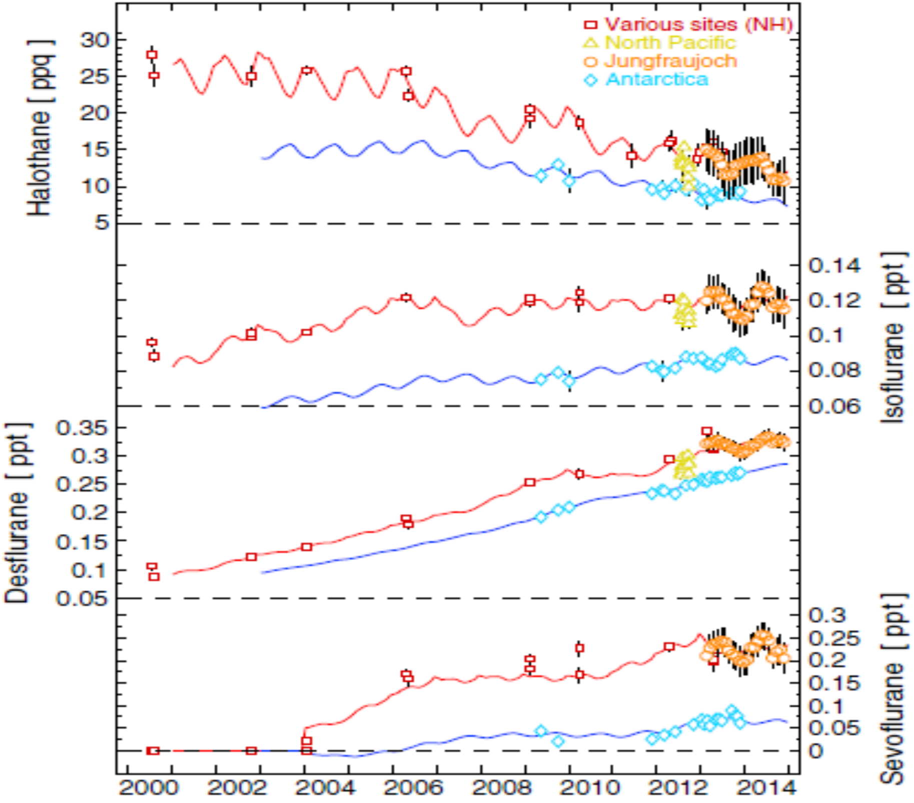
Atmospheric concentration of inhalational anaesthetic agents



Vollmer et al 2015

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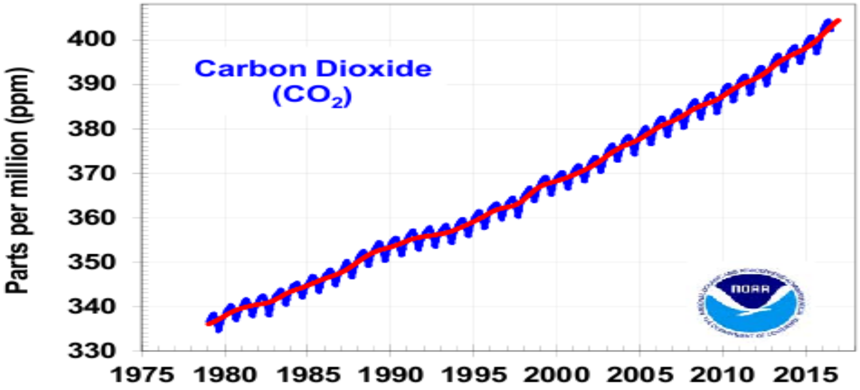
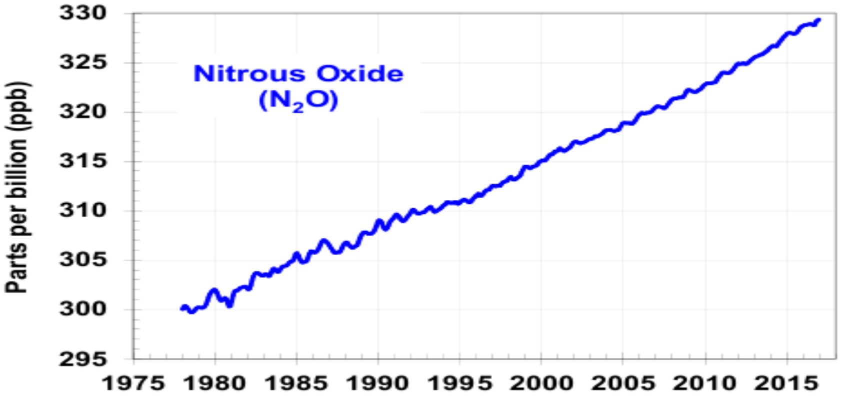
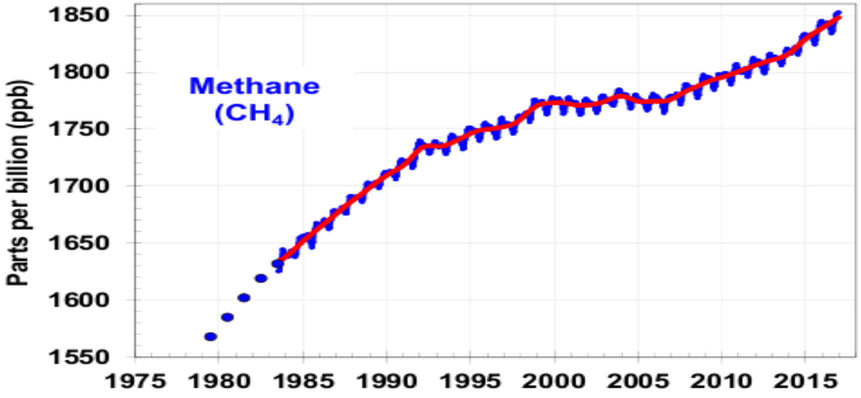
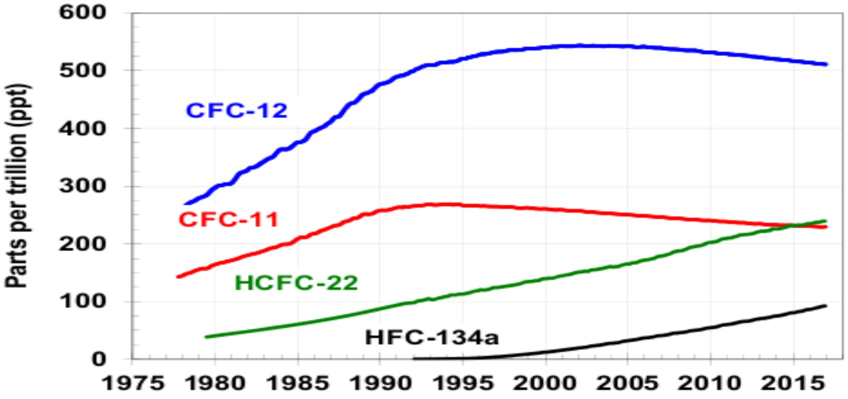
Atmospheric concentrations of major GHGs









Inhalational anaesthetic agents

	IR absorption range (µm)	Tropospheric lifetime (yr)	GWP $_{100}$	CO_2e Kg (container)	MAC_{40}
Sevoflurane	7-10 µm	1.1	130	44 (250ml)	1.8
Isoflurane	7.5-9.5µm	3.2	510	190 (250ml)	1.2
Desflurane	7.5-9.5 µm	14	2540	886 (240ml)	6.6
Nitrous oxide	4.5, 7.6, 12.5 µm	110	310	1054 (size E)	104

Sulbaek Andersen et al Anesth and Analg 2012; 114: 1081-5 Br J Anaesth 2010; 105: 760-6

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Peculiar aspects of inhalational anaesthesia

Volatile substituted ethers

Liquids at room temperature

Vapourised and added to the anaesthetic breathing circuit in a concentration from 1-8%

Carrier gas mixture is oxygen/air or oxygen/N_2O 30%/70%

Depth of anaesthesia depends on the exhaled partial pressure (concentration)

Exhaled unchanged recycled via CO_2 absorber and/or scavenged into the atmosphere

Most of the CO_2e of procurement is in disposal of the agent

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ET Isoflurane

Fresh gas flow

Patient gas supply

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Scope for choice in anaesthesia

- General anaesthesia vs regional anaesthesia
- Carrier gas oxygen enriched air or O_2/N_2O
- Inhalational agents
  - The type
  - The fresh gas flow "low flow anaesthesia"
  - Added intravenous analgesics or sedatives

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Sustainable Development Unit
Working across the NHS, Public Health and Social Care system

Carbon Footprint update for NHS in England 2012

Appendix 1 – Overview of major changes for the 2012 update

To maintain alignment with the latest methods and information available a number of changes have been included in the 2012 update:

Update	2012 ($MtCO_2e$)	%
Healthcare services commissioned from outside the NHS are now included	2.3	9%
Carbon intensity factors for goods and services updated	0.9	4%
Meter Dose Inhalers (MDIs) now included	1.4	6%
Anaesthetic gases now included	0.6	2%
Total	5.2	21%

Carbon footprint update 2013 Sustainable Development Unit NHS

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Sustainable Development Unit
Working across the NHS, Public Health and Social Care system

Carbon Footprint from Anaesthetic gas use

Conclusion

These results give total emissions for anaesthetic gases including Nitrous Oxide of an additional 2.5% (0.56 $MtCO_2e$) of NHS carbon footprint for England.

The majority of anaesthesia is in an acute setting. This is 5% of organisation footprint of acute organisations[18] (0.56 $MtCO_2e$ of 10.4 $MtCO_2e$). For acute organisations this is comparable with half the emissions from gas used for building energy use[19] (1.17 $MtCO_2e$) and would add around 15% to 25% on the building energy use carbon footprint (2.47 $MtCO_2e$)

Measuring, monitoring and reporting carbon dioxide equivalent emissions, from inhaled anaesthetics, is crucial for reducing emissions.

http://www.sduhealth.org.uk/documents/publications/Anaesthetic_gases_research_v1.pdf

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EUROPEAN COMMISSION
ENTERPRISE AND INDUSTRY DIRECTORATE-GENERAL

Consumer goods
Pharmaceuticals

EudraLex
The Rules Governing Medicinal Products in the European Union

Volume 4

Good Manufacturing Practice

Medicinal Products for Human and Veterinary Use

Annex 6

Manufacture of Medicinal Gases

32. Cylinders that have been returned for refilling should be prepared with care in order to minimise the risks of contamination, in line with the procedures defined in the Marketing Authorisation. These procedures, which should include evacuation and/or purging operations, should be validated.

Calculating the CO_2e of anaesthetics

Nitrous oxide cylinders

- Cylinder return data
- Cylinder volumes and temperature
  - Cylinders expressed in terms of numbers of litres of uncompressed gas at 15C
- Universal gas equation number of moles (PV=nRT)
- MWt N_20 44; calculate the mass of nitrous oxide
- GWP = 310

Entonox®

- 50:50 nitrous oxide : oxygen

Inhalational agents

- Number of bottles x volume x density x GWP

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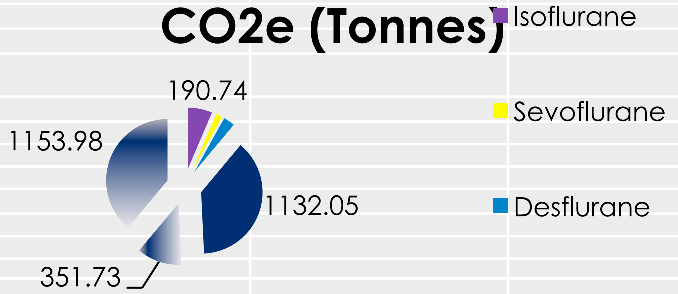
Anaesthetic agent CO_2e calculator

Usage	
Agent	Number of bottles issued from pharmacy
Isoflurane	1000
Sevoflurane	1000
Desflurane	100
Anaesthetic Nitrous oxide	Number of returned cylinders
Size E	30
Size F	30
Size G	200
Size J	0
Mobile Entnox Nitrous oxide	
Entonox EA	0
ENTONOX SIZE CD	10
ENTONOX SIZE D	2
ENTONOX SIZE ED	150
ENTONOX SIZE EX	200
ENTONOX SIZE F	200
ENTONOX SIZE HX	4
Maternity Manifold N2O	
ENTONOX SIZE G	800

CO2e		
	CO_2e (Tonnes)	Percent of total CO_2e
Isoflurane	191	6
Sevoflurane	49	2
Desflurane	89	3
Anaesthetic N_2O	1132	38
Portable Equanox N_2O	352	12
Maternity Manifold Entonox N_2O	1154	39
TOTAL	2967	100



http://www.sduhealth.org.uk/resources/default.aspx?q=anaesthetic+

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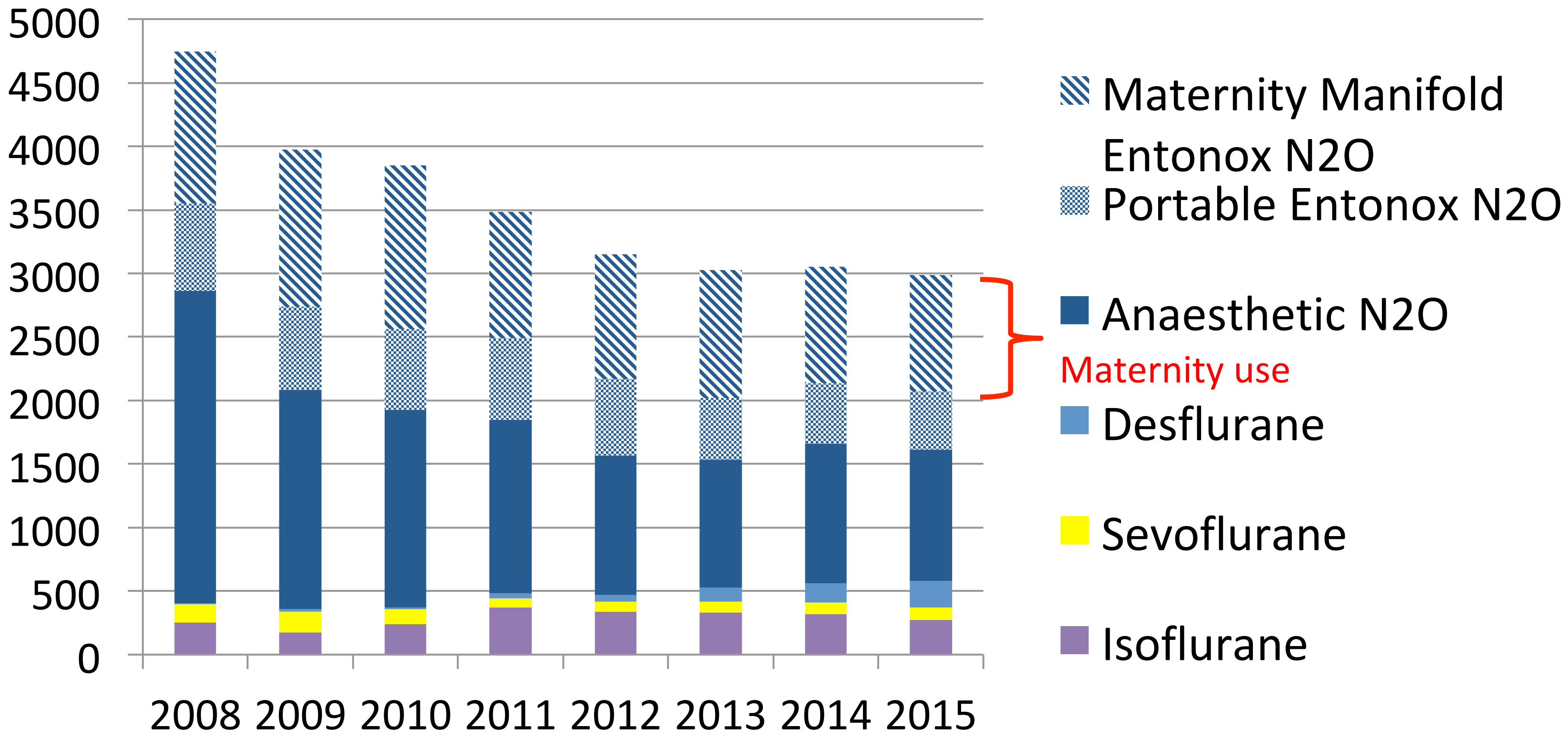
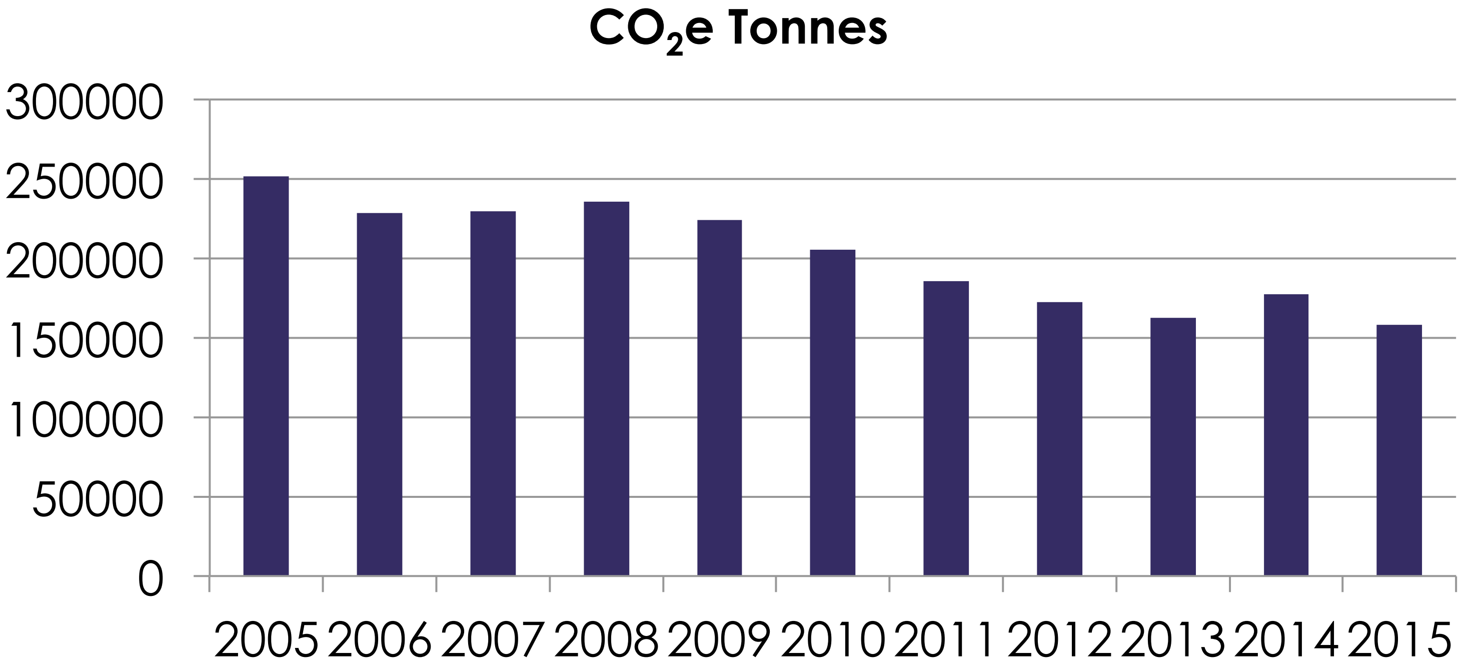
UHS CO_2e (T) of anaesthetic vapour use



http://bja.oxfordjournals.org/forum/topic/brjana_el%3B13932

UK medical gas supplier N_2O CO_2e



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Accounting for the change of CO_2e

Less general anaesthesia and more regional and local anaesthesia

Move away from nitrous oxide/oxygen to oxygen enriched air

Low flow anaesthesia

- Lower fresh gas flow
- Greater intraoperative recycling of exhaled agents
- Less wastage

Still a residual use of nitrous oxide

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Annual data

- Way of plotting trends
- Historical data
- Not contemporaneous
- Unlikely that it will change behaviour

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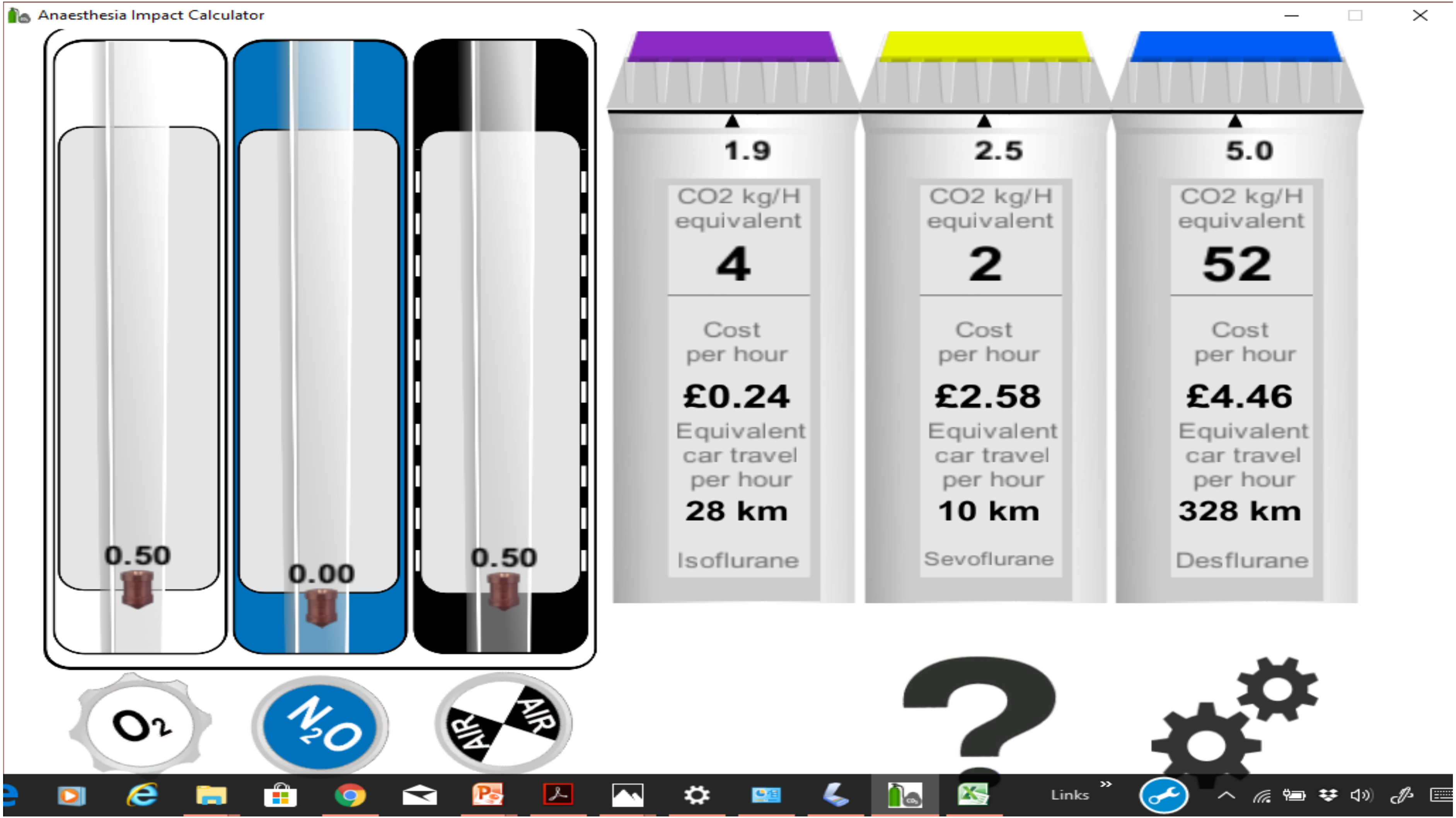
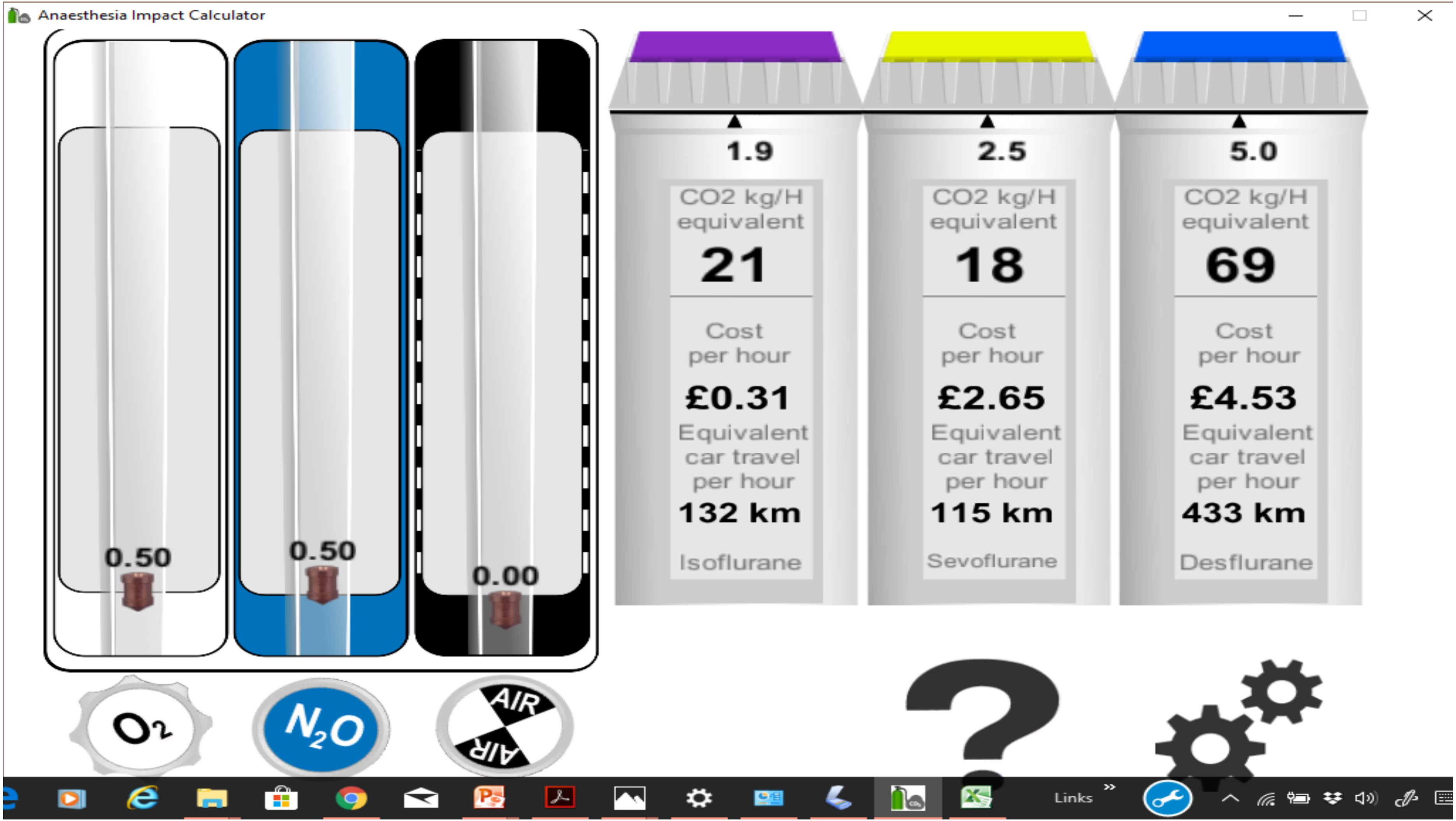
Real time CO_2e calculator

- Know the fresh gas flow (litres per min) and the vapouriser setting (%)
- Assume that inhaled agent behaves as ideal gas
- Know the temperature and the GWP of each agent
- Calculate the mass of agent used from the volume
- Mass used x GWP = CO_2e
- Know the unit cost then calculate the cost per hour of the inhalational component of anaesthesia

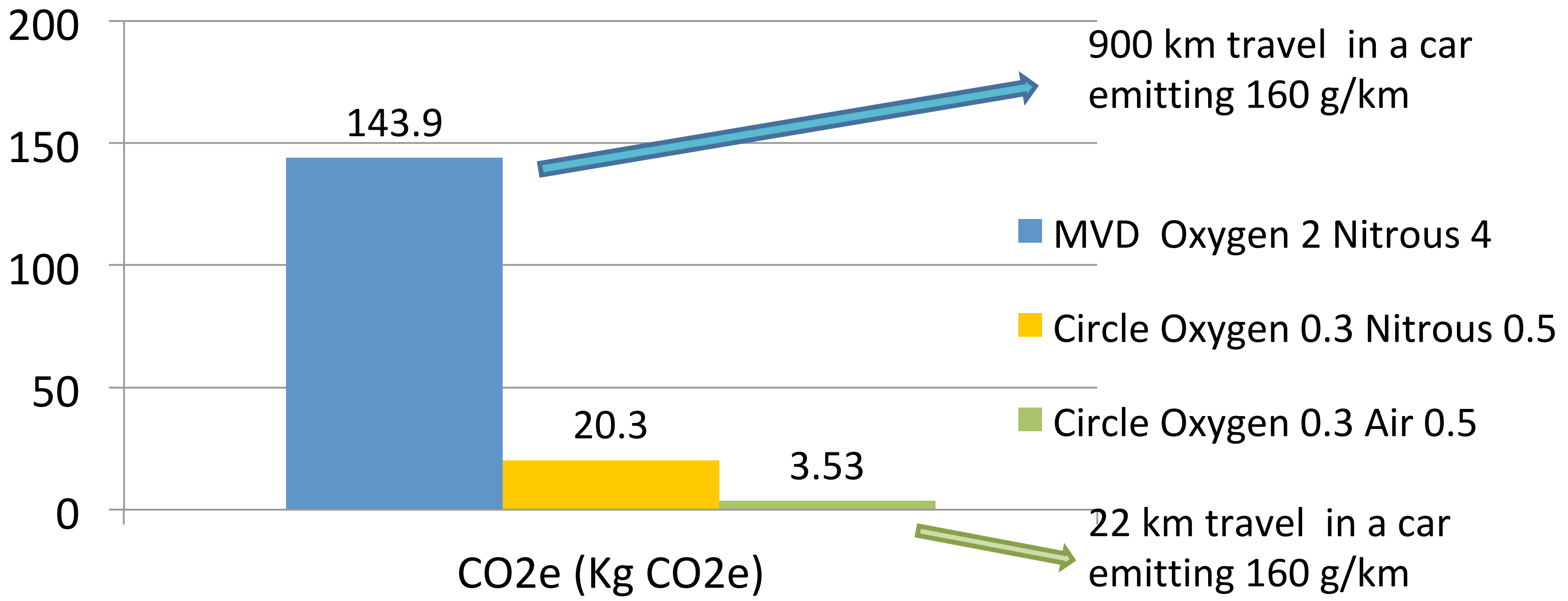

Anaesthesia Impact Calculator
0.50
0.00
0.50
O2
N2O
AIR
AIR
1.9
CO2 kg/H equivalent
4
Cost per hour
£0.24
Equivalent car travel per hour
28 km
Isoflurane
2.5
CO2 kg/H equivalent
2
Cost per hour
£2.58
Equivalent car travel per hour
10 km
Sevoflurane
5.0
CO2 kg/H equivalent
52
Cost per hour
£4.46
Equivalent car travel per hour
328 km
Desflurane
Links



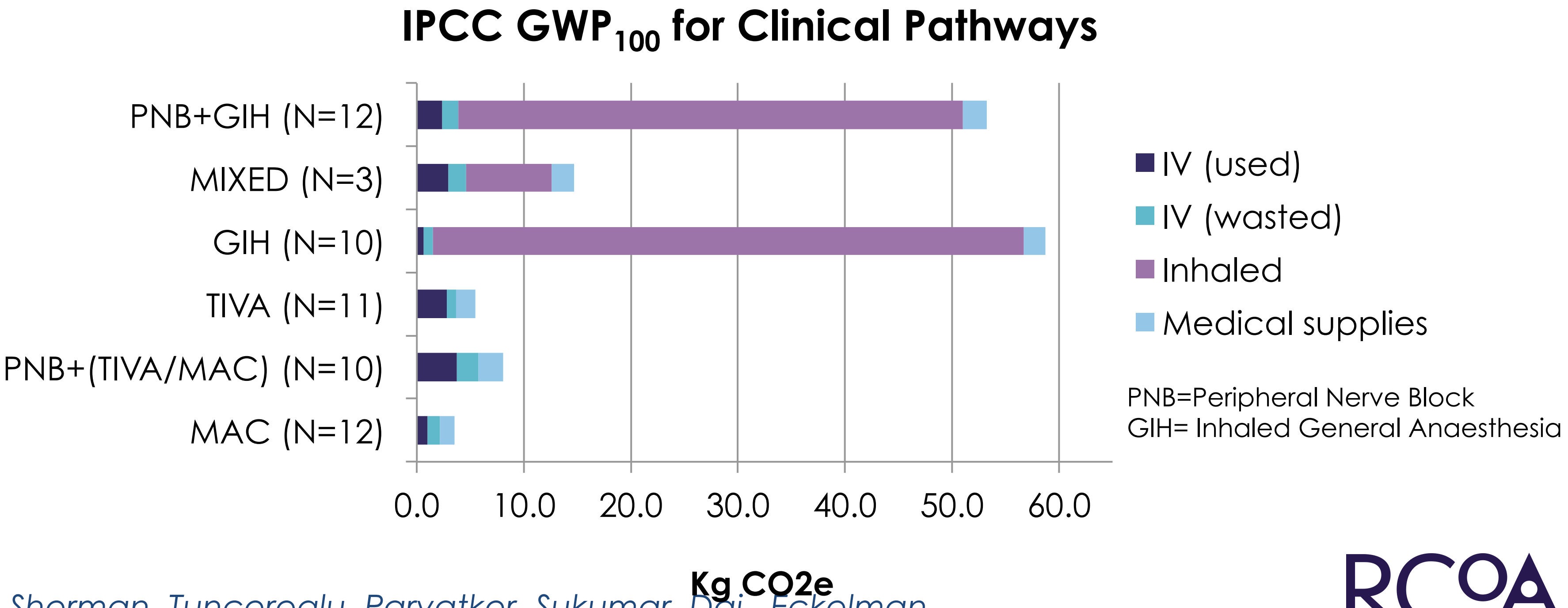
Anaesthesia Impact Calculator
0.50
0.50
0.00
O2
N2O
AIR
AIR
1.9
CO2 kg/H equivalent
21
Cost per hour
£0.31
Equivalent car travel per hour
132 km
Isoflurane
2.5
CO2 kg/H equivalent
18
Cost per hour
£2.65
Equivalent car travel per hour
115 km
Sevoflurane
5.0
CO2 kg/H equivalent
69
Cost per hour
£4.53
Equivalent car travel per hour
433 km
Desflurane
Links

An hour's CO_2e

Minute volume divider in1985 to circle with absorber 2017



CO_2e of different forms of anaesthesia



Sherman, Tunceroglu, Parvatker, Sukumar, Dai , Eckelman

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The bigger picture

- Travel for staff and patients
- Devices; single use or reusable?
- Use of energy and electricity
- Keeping patients warm in the operating room
- Recycling

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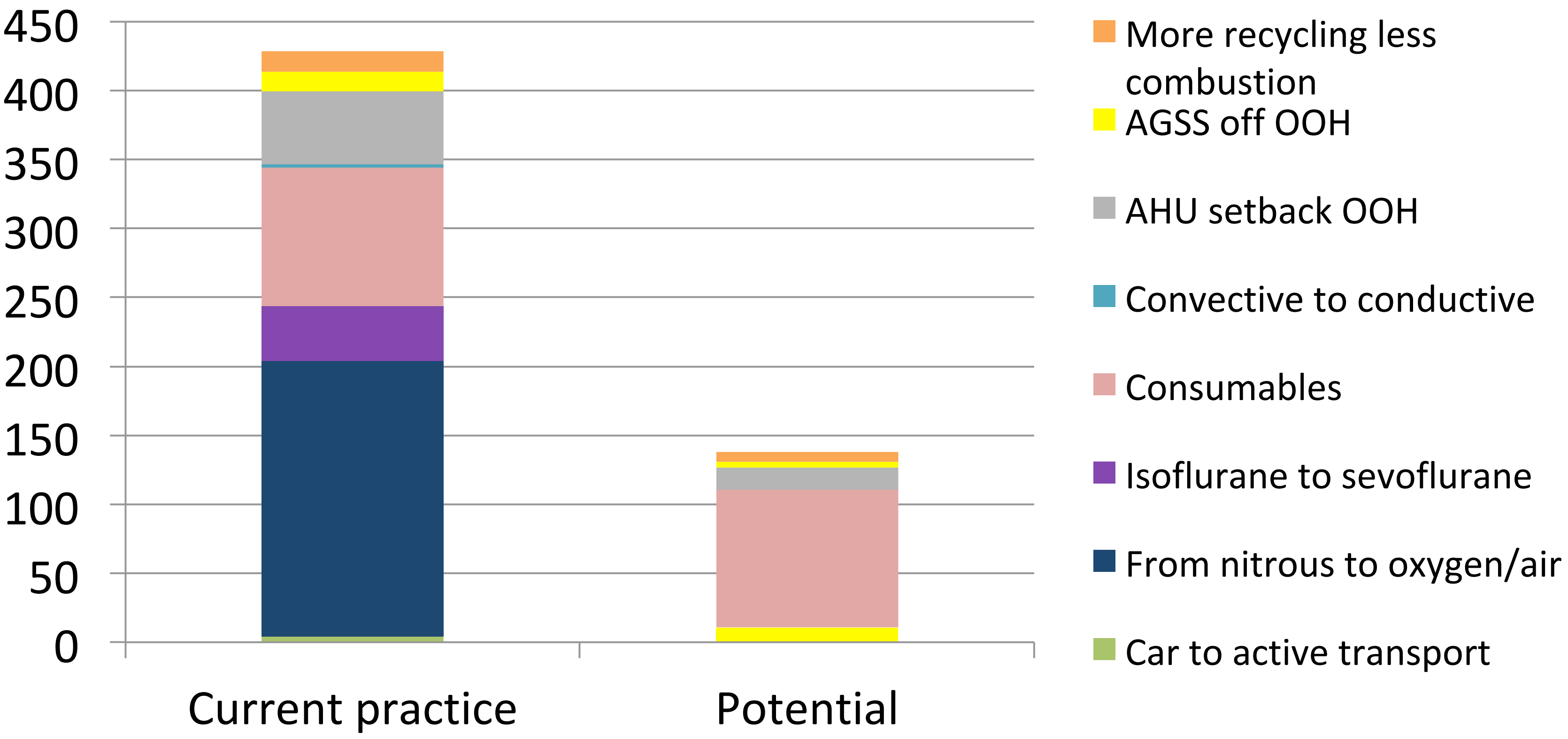
A day's anaesthesia related CO_2e (kg)



End tidal control

GE Aisys CS²

- Vapour use adjusted to achieve the desired Et_{agent}
- Reduces vapour use
- Displays the cost
- Reduces cost; £51k pa
  - Benefit at 3-4 years
- Values for cost are very similar to those obtained from the free app
- App provides CO_2e

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Administrative components

Protecting resources, promoting value:
a doctor's guide to cutting waste in clinical care

November 2014

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Guidelines for the Provision of Anaesthesia Services (GPAS)

ACSA
Anaesthesia Clinical Services Accreditation
Royal College of Anaesthetists
ACCREDITATION

ChoosingWisely UK

PQIP
Perioperative Quality Improvement Programme

GIRFT
GETTING IT RIGHT FIRST TIME

NHS
Improvement

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Guidelines for the Provision of Anaesthesia Services

- Work with estates to minimise energy use
  - Including AGSS and OR ventilation and lighting
- Reduce resource use
  - Low flow anaesthesia
    - Avoid nitrous oxide within reason
    - Desflurane low flow as a matter of course
    - TIVA
  - Minimise drug and disposable wastage
- Recycling to avoid combustion of waste or landfill

GPAS 2016 Further steps

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Choosing Wisely

1. **Day surgery** should be considered the default for most surgical procedures (except complex procedures)

2. Patients do **not need to come into hospital the day before surgery** if they have had the appropriate preoperative assessment and preparation

3. Most patients **do not need routine preoperative tests** before minor or intermediate surgery.

4. For many patients the chance of harm after an operation may be reduced if they **improve fitness, stop smoking, reduce alcohol intake** and in some cases **reduce weight** in the weeks or months before their surgery.

http://www.choosingwisely.co.uk/i-am-a-clinician/recommendations/#1476651640539-f279ec69-9e40

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Summary

- The overall impact of anaesthesia is small on a global scale compared with other GHGs
- The proportion of the CO_2e health care delivery attributable to anaesthesia is significant
- There is scope for informed choices of practice
- Reducing or eliminating the use of nitrous oxide is the largest single contribution one can make
- The Impact Calculator can help with those choices
- Need systems and processes in place

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Measurement tools

Annual carbon footprint of anaesthetic agents and nitrous oxide

http://www.sduhealth.org.uk/documents/publications/_carbon_hotspot_anaesthetic_gases_Feb_2014.xlsx

Smart phone app to calculate the real-time CO_2e of inhalational anaesthesia

- iOS search Anesthetic Impact Calculator
  - Sleekwater Software / Kevin Scott
- Android search Anaesthetic Impact Calculator
  - Sleekwater Software / Kevin Scott

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