# Techniques and tools for reducing the $CO_2e$ of inhalational anaesthesia

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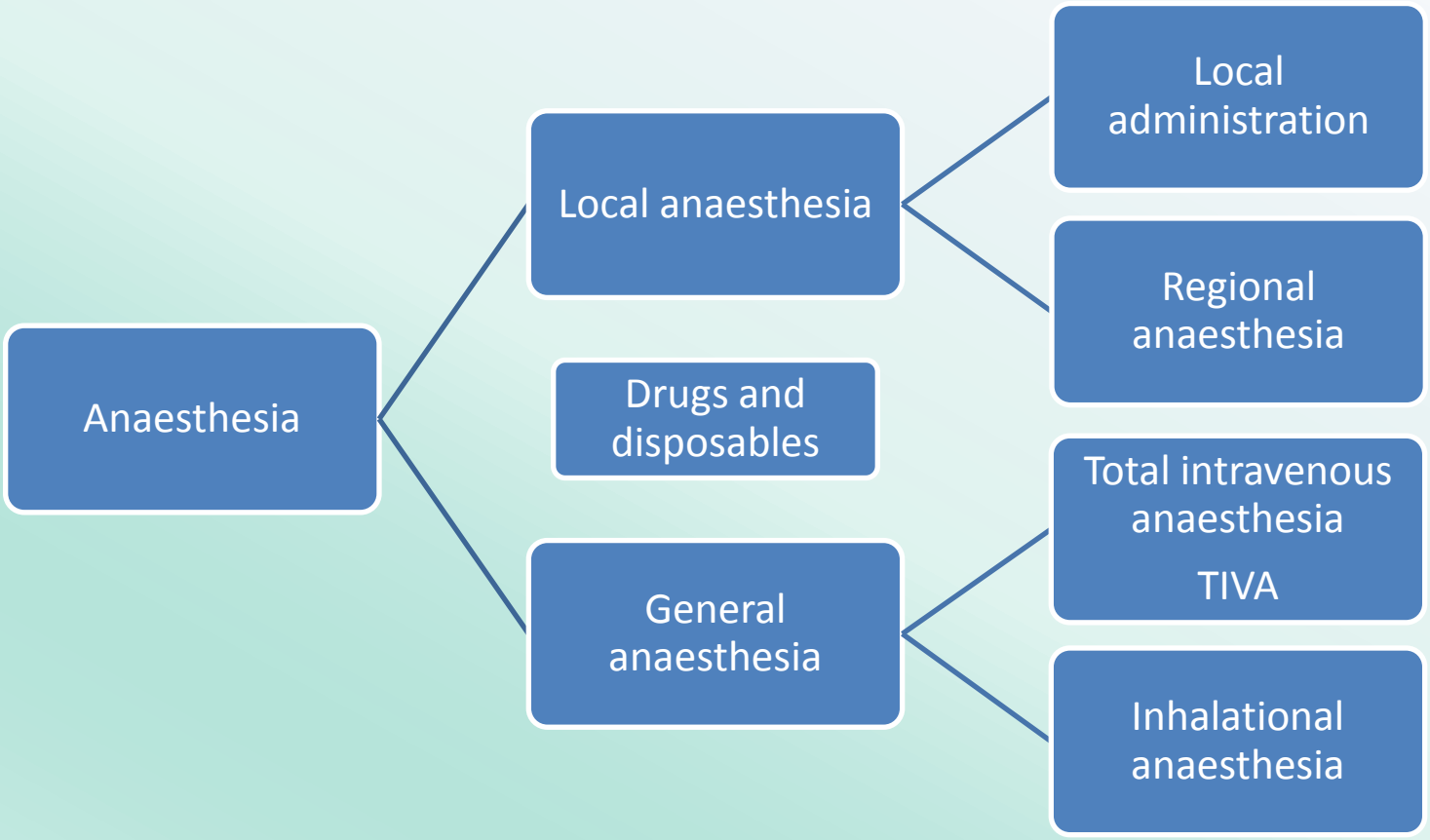
# Overview of this presentation

# Overview of anaesthesia



# Practical components of anaesthesia

*Sedation analgesia and relaxation*


# 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
  - 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 $CO_2$

# Conference of the Parties COP

COP 3 Kyoto protocol

$CO_2$ $N_2O$ $CH_4$ $SF_6$ perflurocarbons and HCFCs

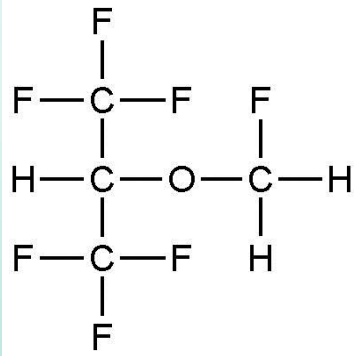
COP 7 adopted the Kyoto protocol

COP 21 Paris agreement no net $CO_2$ emission 2030-2050

COP 22 Marrakesh

Kigali agreement 2016 limiting hydroflurocarbons (HFC)

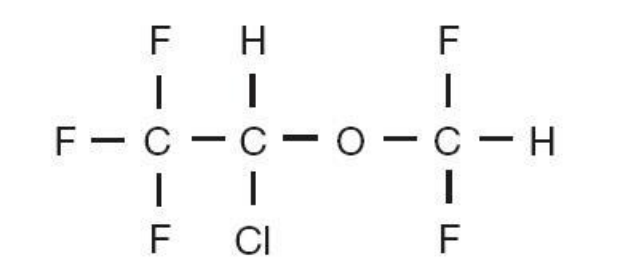
# Inhalational anaesthetic agents



*Sevoflurane*

GWP 130

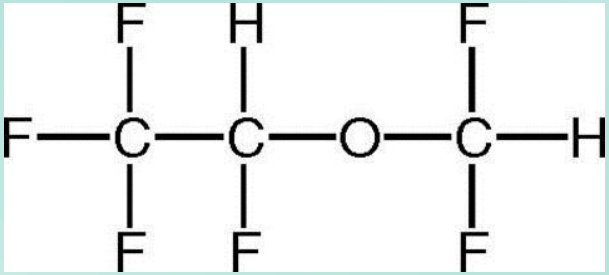
Bottle (250ml) 44kg $CO_2e$



*Isoflurane*

GWP 510

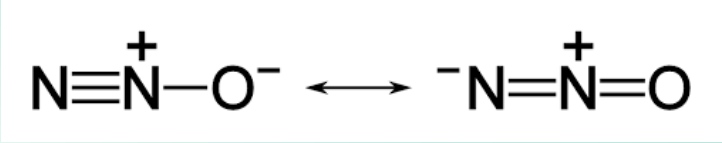
Bottle (250 ml)190 kg $CO_2e$



*Desflurane*

GWP 2540

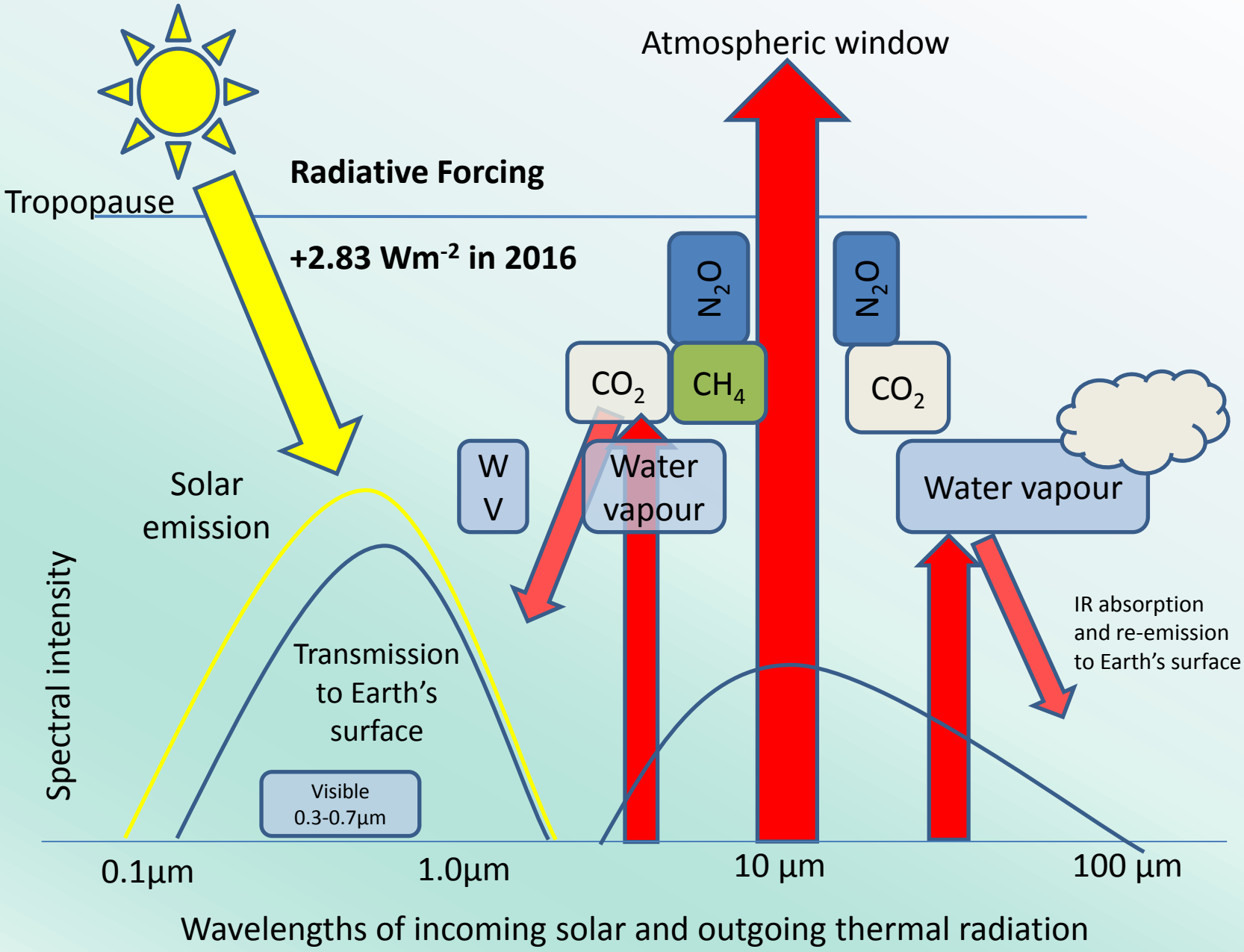
Bottle (240 ml) 886 kg $CO_2e$

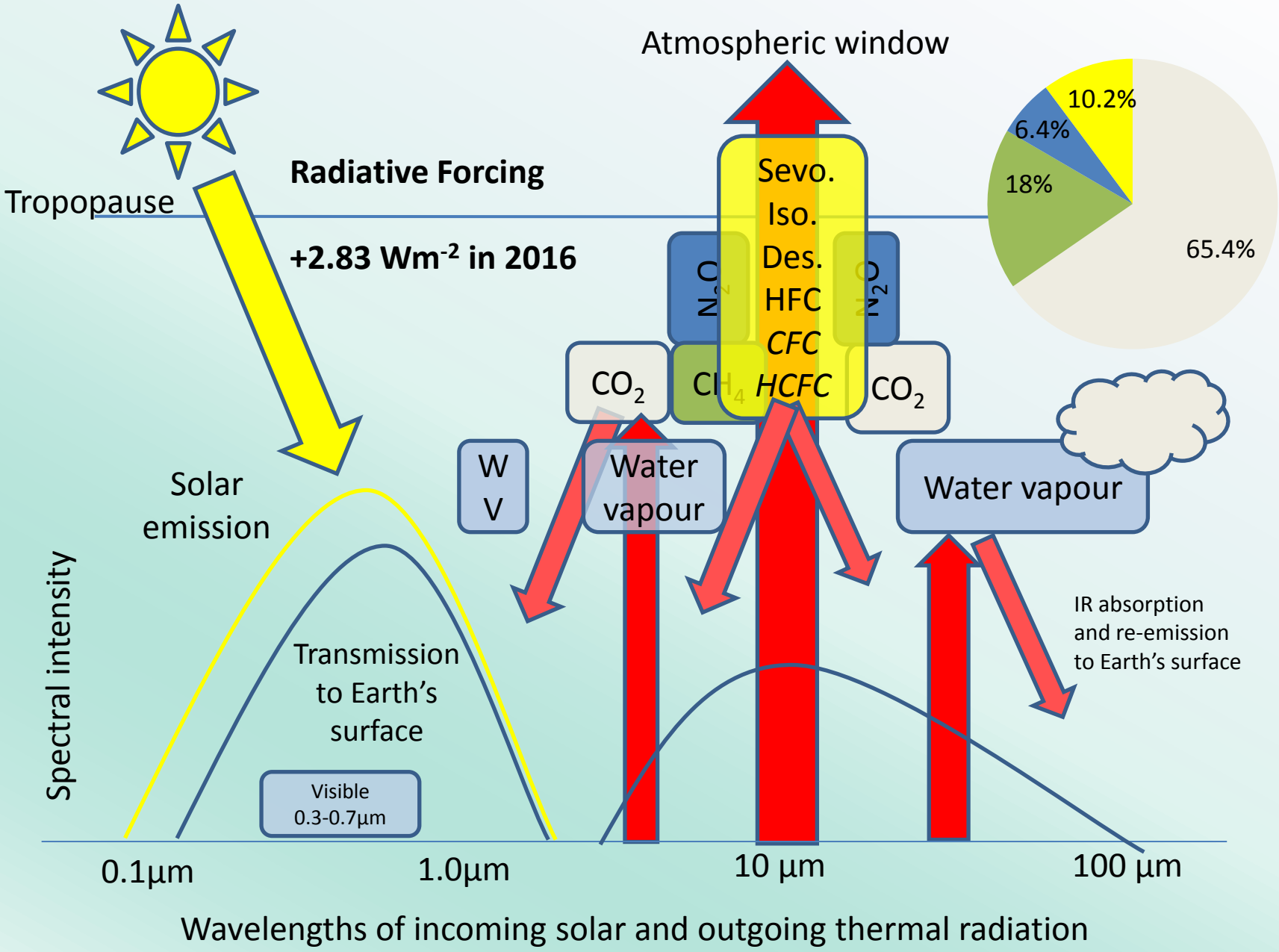


*Nitrous oxide*

GWP 310

Cylinder (3.4 kg) 1054 kg $CO_2e$


Atmospheric window
Radiative Forcing
Tropopause
+2.83 Wm-2 in 2016
N2O
N2O
CO2
CH4
CO2
W
V
Water vapour
Water vapour
Solar emission
IR absorption and re-emission to Earth's surface
Spectral intensity
Transmission to Earth's surface
Visible 0.3-0.7µm
0.1µm
1.0µm
10 µm
100 µm
Wavelengths of incoming solar and outgoing thermal radiation


Atmospheric window
Radiative Forcing
+2.83 Wm-2 in 2016
Tropopause
Sevo.
Iso.
Des.
HFC
CFC
HCFC
CO2
CH4
N2O
CO2
W
V
Water vapour
Water vapour
10.2%
6.4%
18%
65.4%
Solar emission
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Visible 0.3-0.7µm
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Spectral intensity
0.1µm
1.0µm
10 µm
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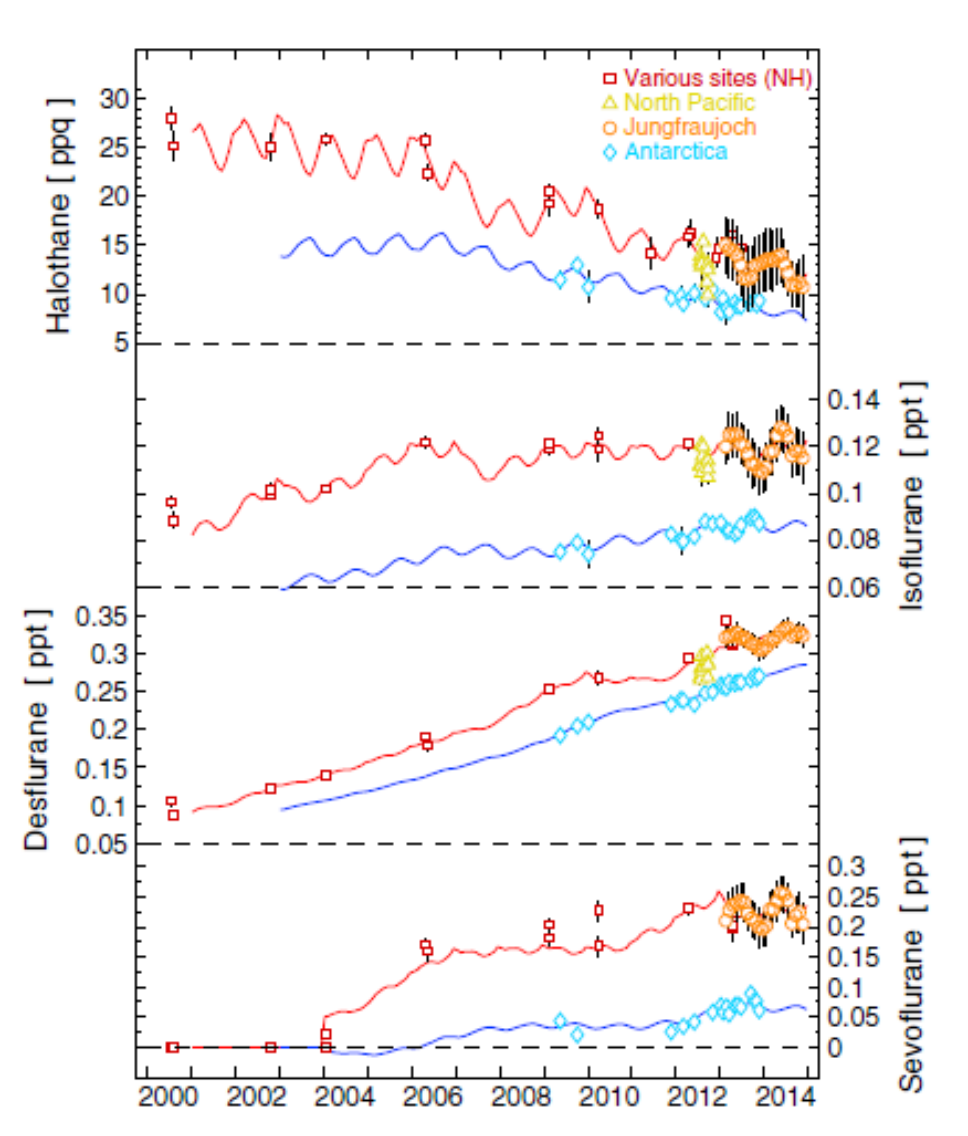
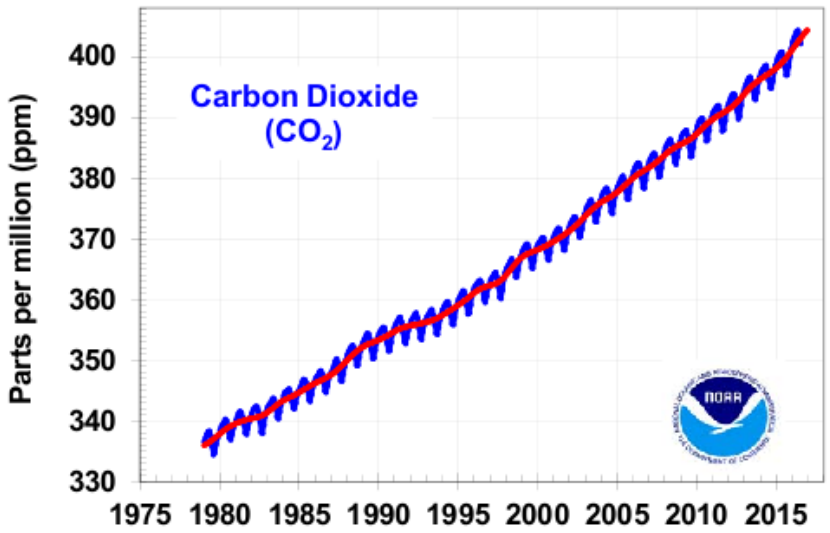
Wavelengths of incoming solar and outgoing thermal radiation

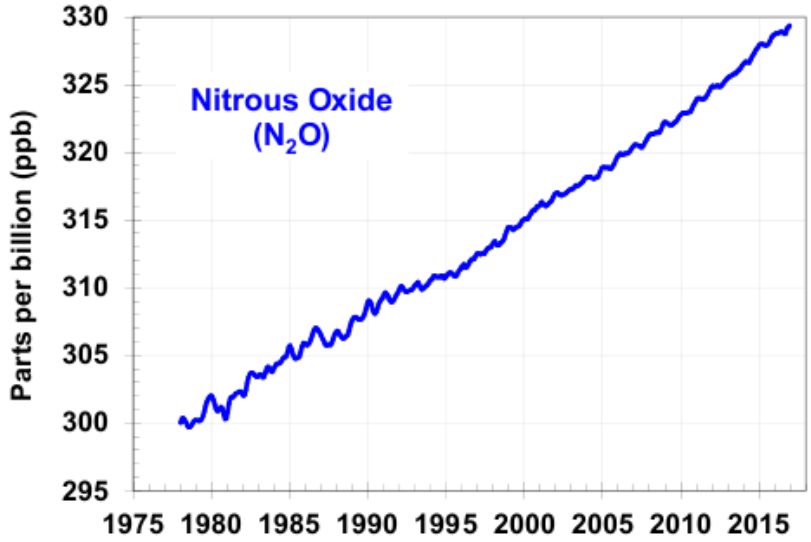
# Atmospheric concentration of inhalational anaesthetic agents

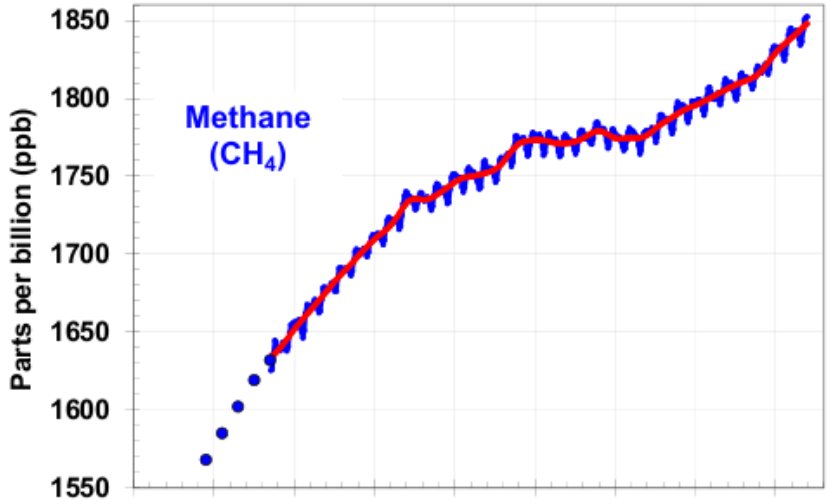


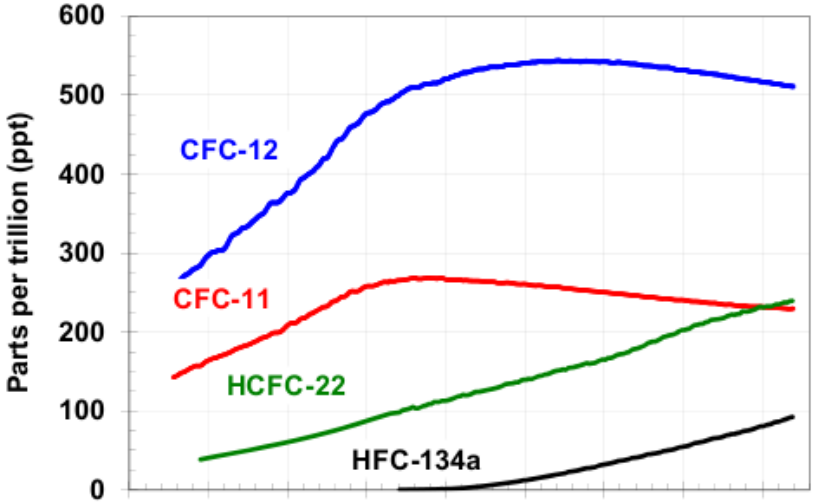

Vollmer et al 2015

# Atmospheric concentrations of major GHGs

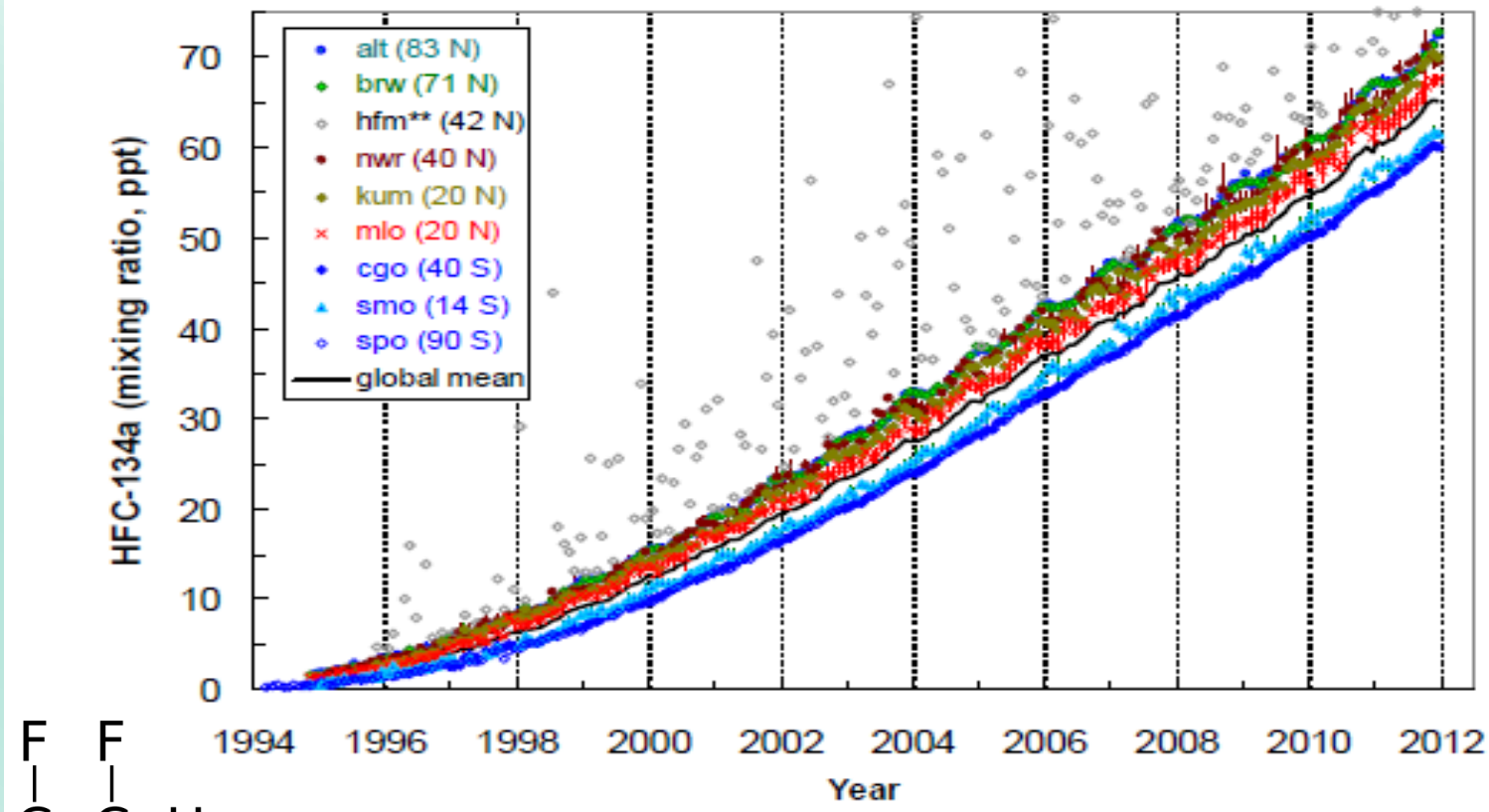


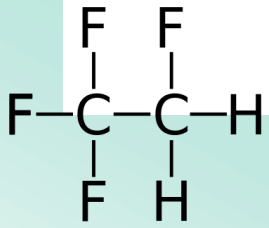



# Atmospheric concentration HFC-134a




HFCs in the atmosphere, concentrations emissions and impacts. Montzka SA

# 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 |

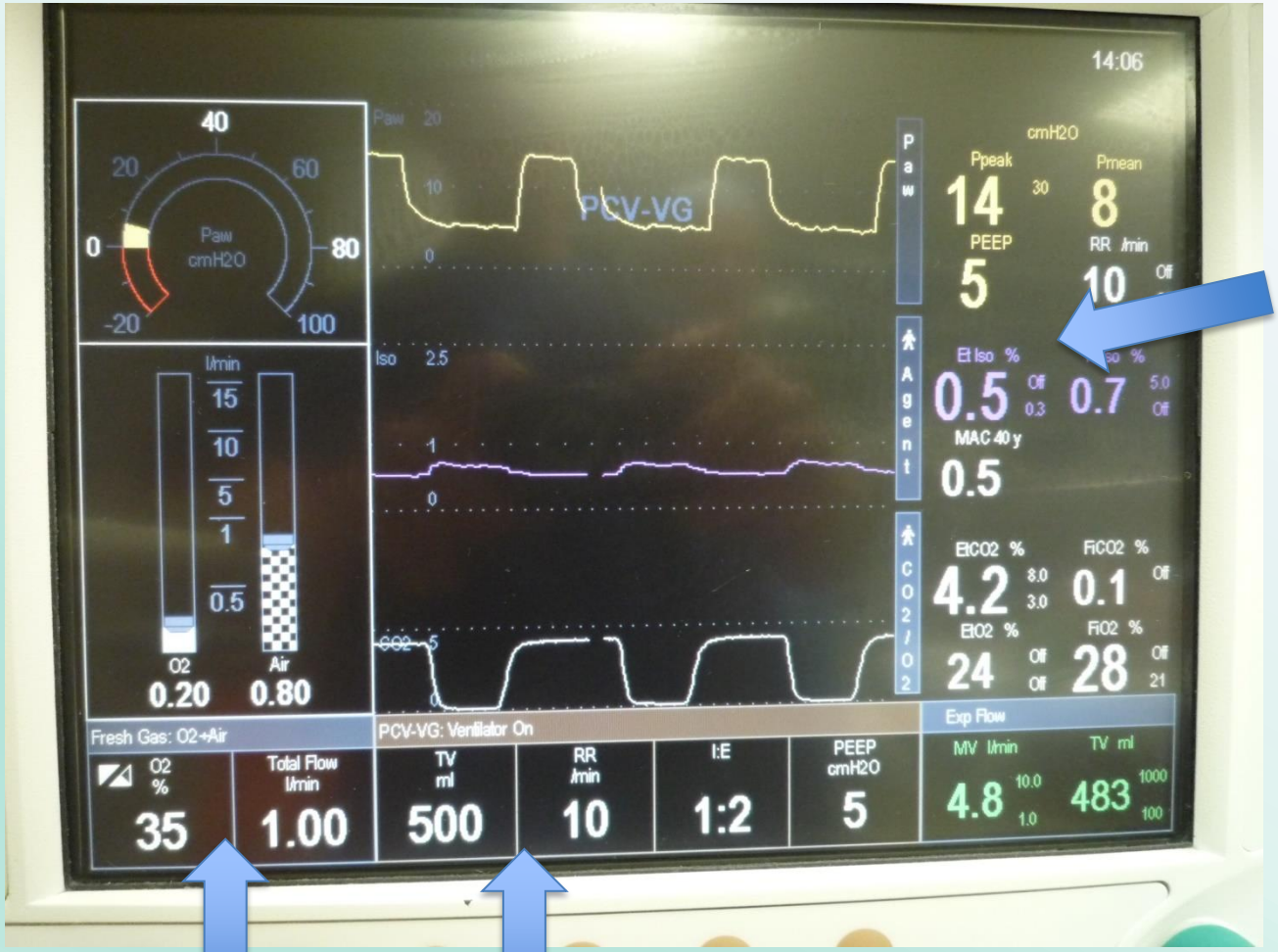
*Sulbaek Andersen et al Anesth and Analg 2012; 114: 1081-5  Br J Anaesth 2010; 105: 760-6*

# 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


Datex-Ohmeda
Aisys CS²
ISO
SEV


Vol.%
Baxter
Sevoflurane
Isotec 5
Use Only Isoflurane




ET Isoflurane

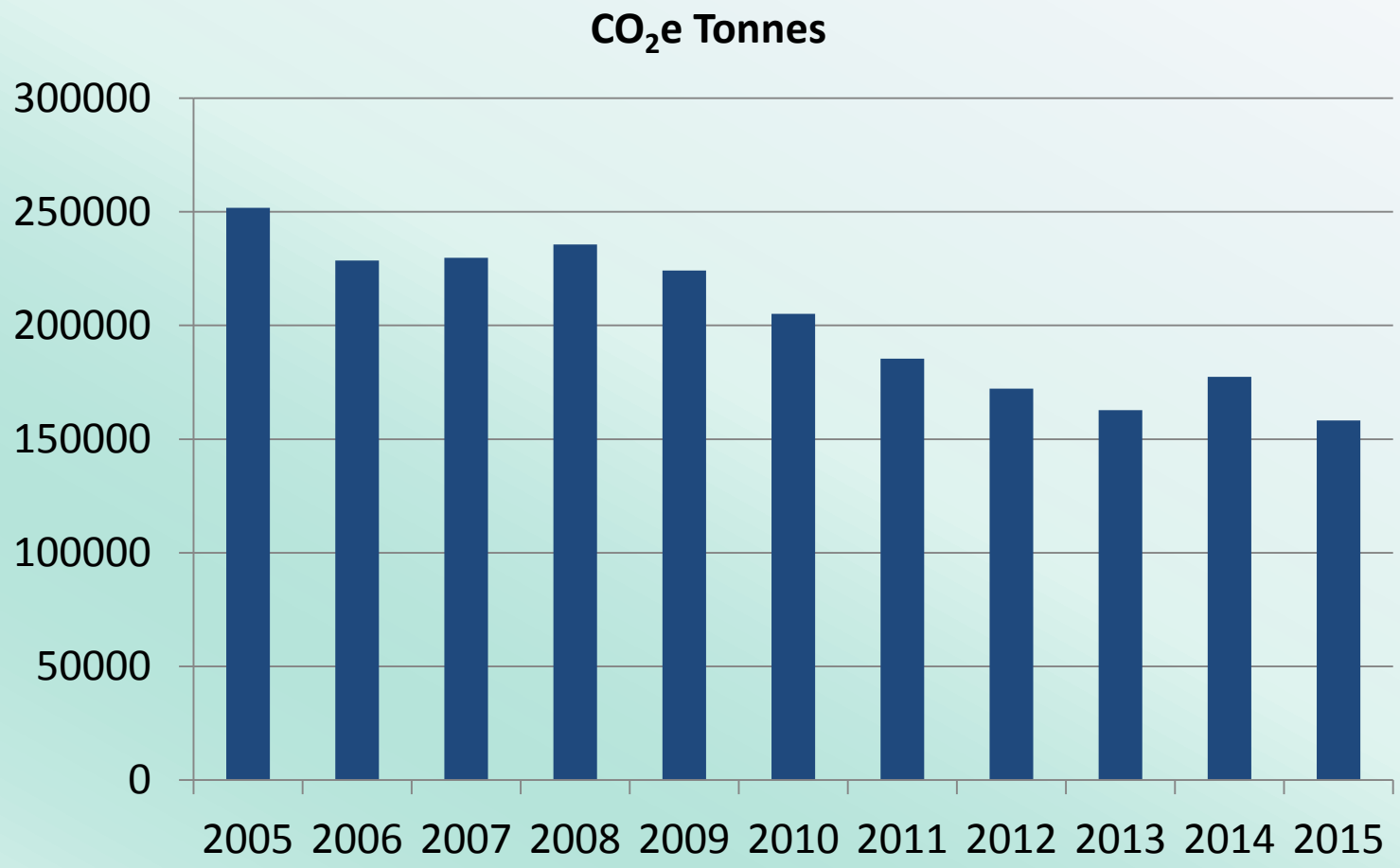
Fresh gas flow

Patient gas supply

# 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

# UK medical gas supplier $N_2O$ $CO_2e$



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

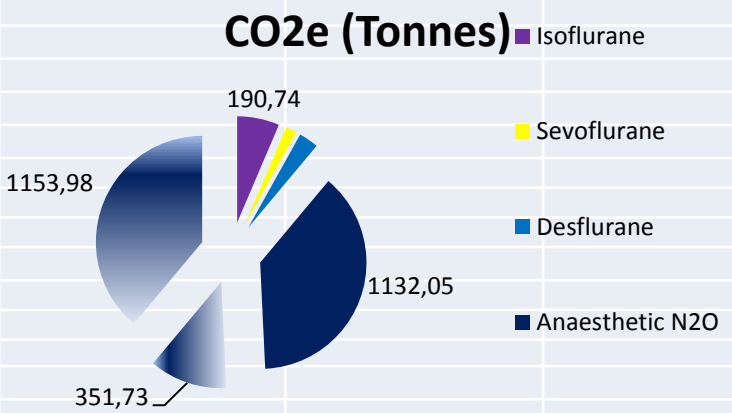
32. Cylinders that have been returned for refilling should be prepared with care in order to minimise the risks of contamination, in line with the procedures defined in the Marketing Authorisation. These procedures, which should include evacuation and/or purging operations, should be validated.

# Mathematics

- Fate of a cylinder
  - Cylinder return data
  - Cylinder volumes and temperature
    - Cylinders expressed in terms of numbers of litres
  - Universal gas equation number of moles
  - 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

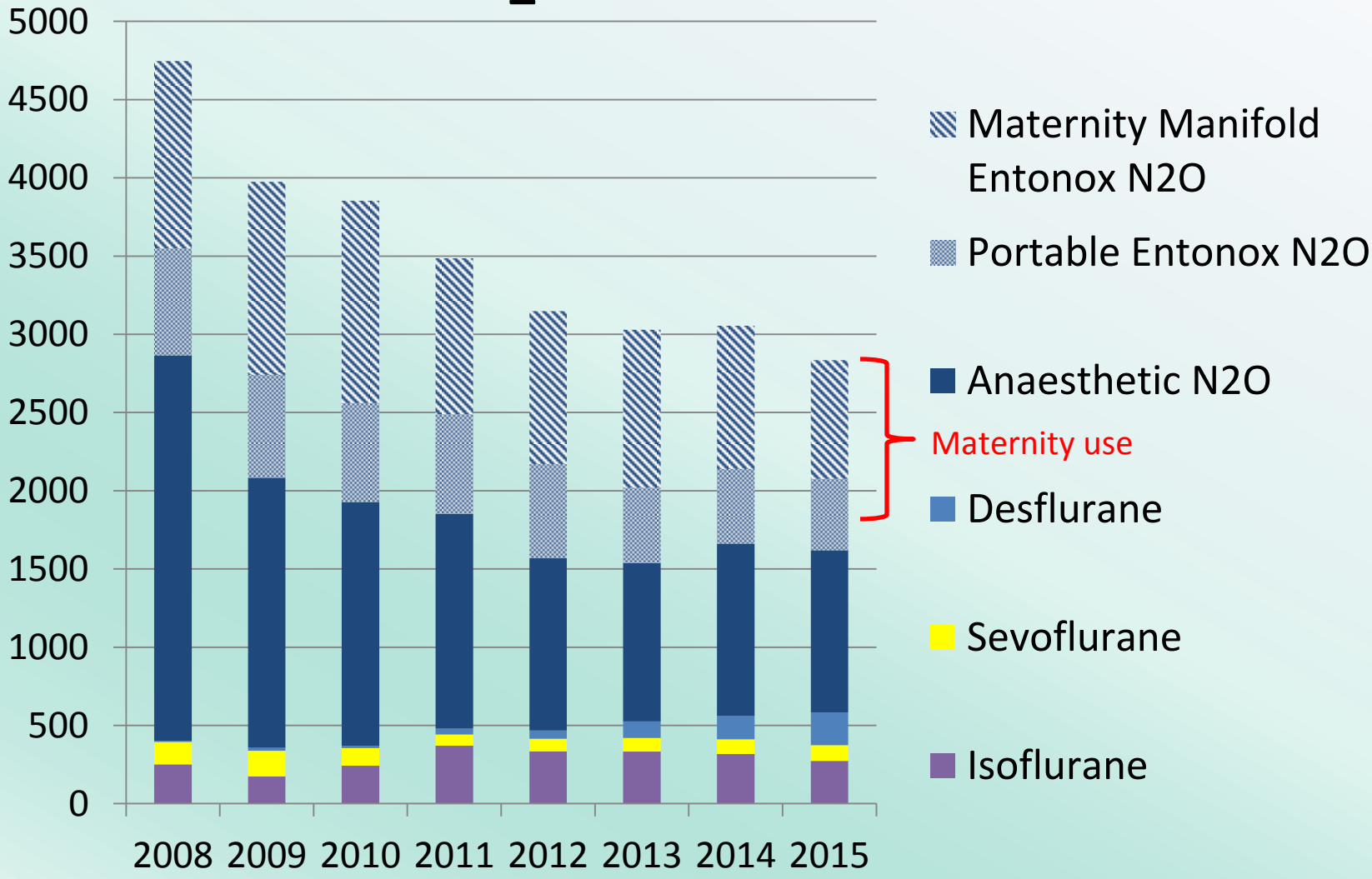
# Anaesthetic agent $CO_2e$ calculator

| Usage | | | CO2e | | |
|---|---|---|---|---|---|
| Agent | Number of bottles issued from pharmacy | | | $CO_2e$ (Tonnes) | Percent of total $CO_2e$ |
| Isoflurane | 1000 | | Isoflurane | 191 | 6 |
| Sevoflurane | 1000 | | Sevoflurane | 49 | 2 |
| Desflurane | 100 | | Desflurane | 89 | 3 |
| | | | Anaesthetic $N_2O$ | 1132 | 38 |
| | | | Portable Equanox $N_2O$ | 352 | 12 |
| Anaesthetic Nitrous oxide | Number of returned cylinders | | Maternity Manifold Entonox $N_2O$ | 1154 | 39 |
| Size E | 30 | | TOTAL | 2967 | 100 |
| 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 | | | | |




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

# UHS $CO_2e$ (T) of vapour use




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

# How has the practice of anaesthesia changed?

*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

# Annual data

- Way of plotting trends
- Supports the view that the use of nitrous oxide fallen
- Historical data
- Not contemporaneous
- Not much use for changing behaviour
- Sustainable Development Unit

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

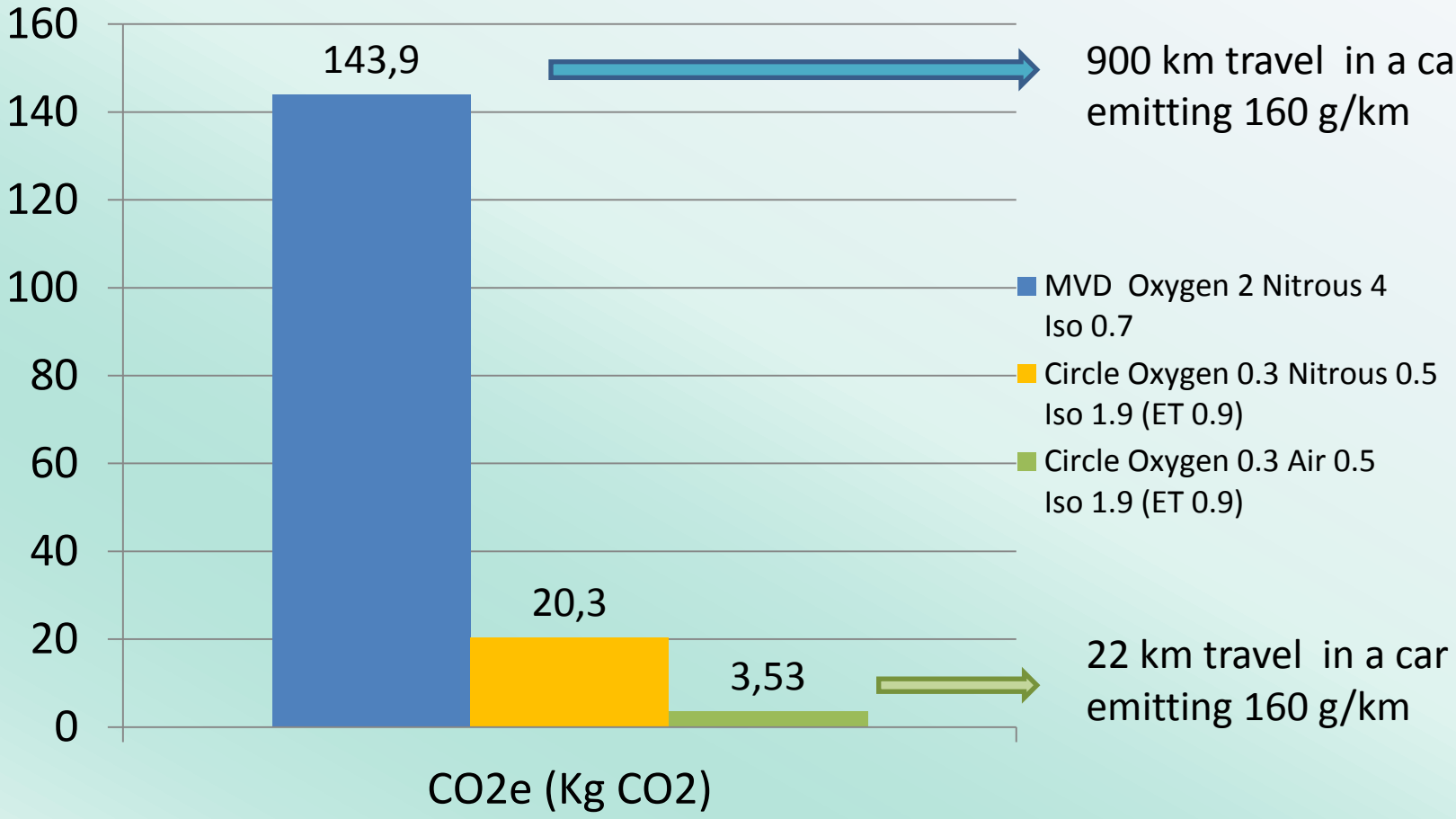
# Real time $CO_2e$ calculator

- 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

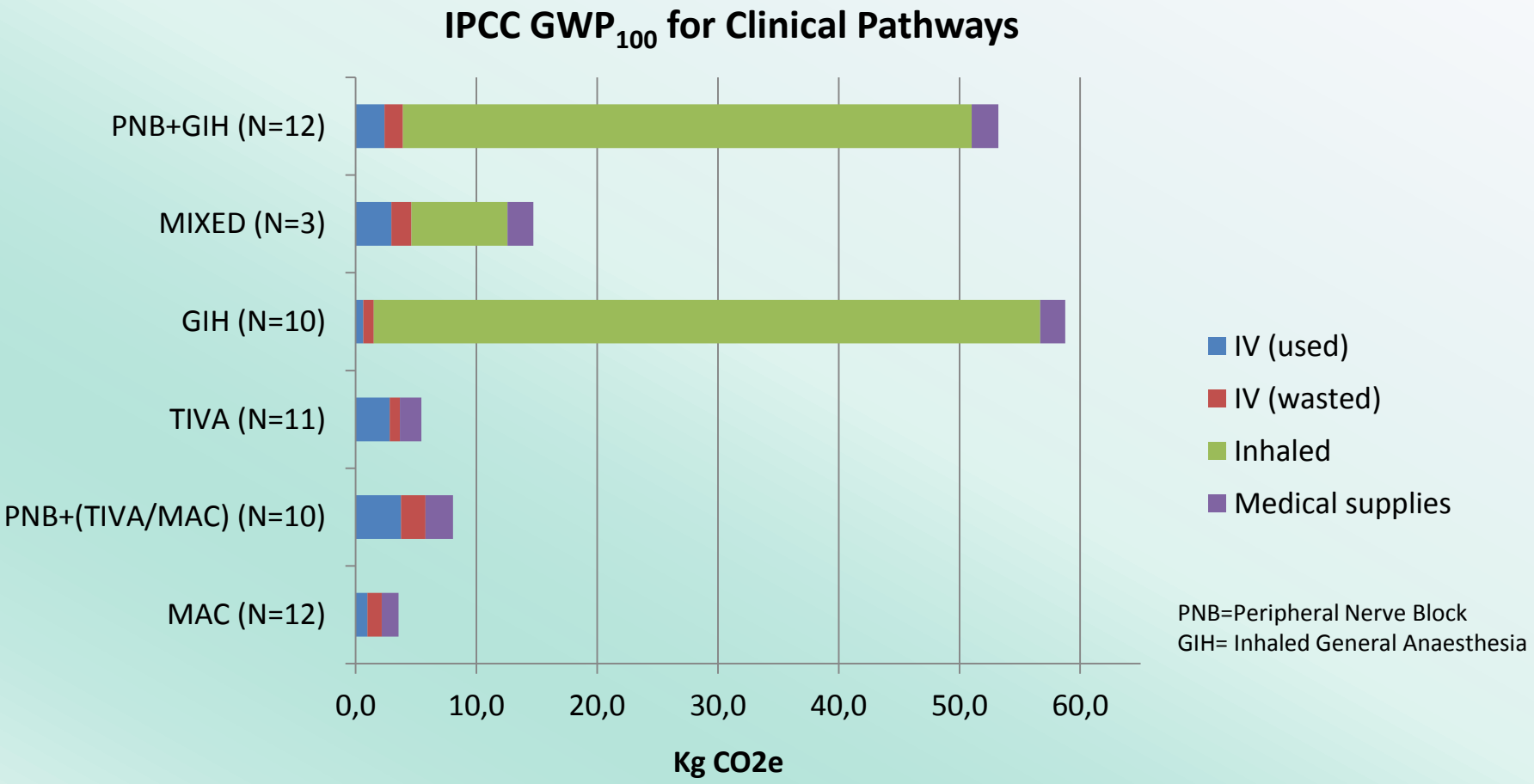
# Anaesthetic impact calculator

# An hour's $CO_2e$

## Minute volume divider 1985 to circle with absorber 2017



# $CO_2e$ of different forms of anaesthesia

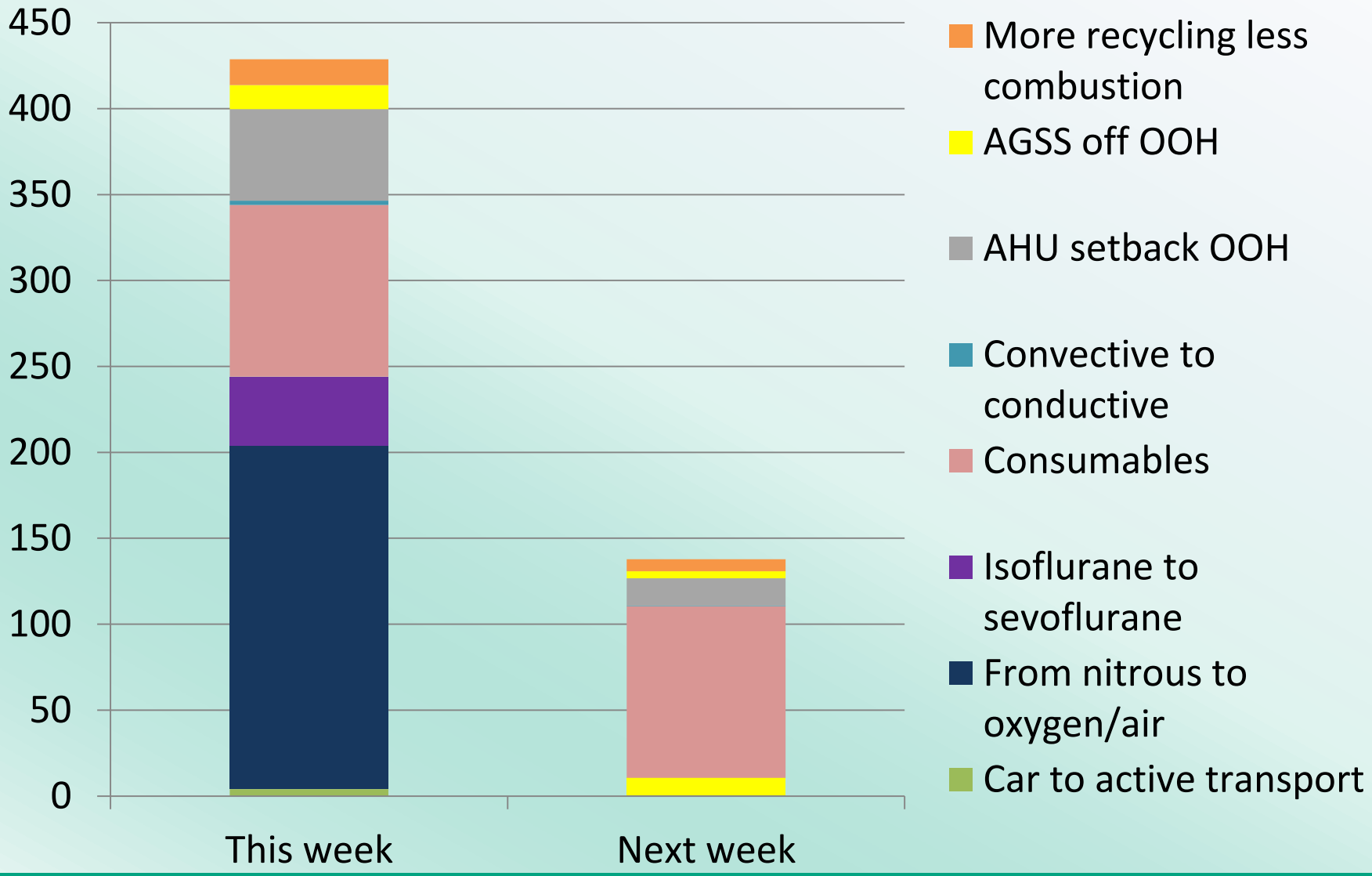



*Sherman, Tunceroglu, Parvatker, Sukumar, Dai , Eckelman*

# 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
- How much we recycle

# 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 $CO_2e$

# 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

# Key points

- All forms of anaesthesia require both drugs and disposables
- For general anaesthesia inhalational anaesthesia has a larger $CO_2e$ than total intravenous anaesthesia TIVA
- The inhalational agents with the highest $CO_2e$ are nitrous oxide and desflurane
- Low flow anaesthesia should be the standard of practice financially and environmentally
- Changing the inhalational agent is the single biggest contribution one can make to the reducing the $CO_2e$ of the anaesthesia care pathway

# 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